FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

C U R S O S   A B I E R T O S

ILUMINACION EXTERIOR:

PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

EVALUACION INICIAL

PALACIO DE MINERIA

"ILUMINACION EXTERIOR: PRINCIPIOS
DISEÑO Y APLICACIONES"
PALACIO DE MINERIA.
MARZO 1992

EVALUACION INICIAL

1.- ¿Cuàl es la unidad de flujo luminoso?

a) Lux b) Lòmen c) Lambert d) Candela

2.- ¿Cuàl es la unidad de potencia luminosa?

a) Lux b) Lòmen c) Lambert d) Candela

3.- ¿Cuàl es la unidad de iluminancia?

a) Lux b) Lòmen c) Lambert d) Candela

4.- ¿Con què aparato se mide la iluminancia?

a) Vòltmetro b) Luxòmetro c) Osciloscopio d) Galvanòmetro

5.- ¿Con què equipo se trazan las curvas fotomètricas?

a) Rayos Làser b) Goniòmetro c) Espectròmetro d) Radiòmetro

6.- ¿Por què se deben usar luxòmetros con factor de coseno corregido?

a) Son los ùnicos que se fabrican b) Son màs baratos

c) Son màs exactos d) Son màs ligeros

7.- ¿En què unidades se presenta una curva de distribuciòn?

a) Luxes b) Lòmenes c) Candelas d) Lamberts

8.- ¿Què parte del ojo determina la sensibilidad para la visiòn escotòpica?

a) Iris b) Còrnea c) Bastones d) Retina

9.- ¿En què unidades se mide el C.R.I.?

a) Grados Kelvin b) Nanòmetros c) Adimensionalmente d) Angstroms

10.- ¿En què unidades se mide la Temperatura de Color?

a) Grados Celsius b) Grados RanKin c) Grados Kelvin c) Grados ASA

11.- ¿Còmo varía la emisiòn lumínica de una làmpara incandescente cuando disminuye el voltaje?

a) Aumenta b) Disminuye c) No varía d) Oscila

12.- ¿Cuàl de las siguientes làmparas es la màs eficaz?

a) V.S.A.P b) V.M.A.P. c) V.S.B.P d) V.A.M.

13.- ¿Cuàl es el tiempo aproximado de reencendido de una làmpara de aditivos metàlicos?

a) 2 minutos b) 5 minutos c) 12-15 minutos d) 30-50 minutos

14.- ¿Cuàl es la funciòn principal de un balastro?

a) Ahorrar energía b) Proteger la làmpara c) Controlar la potencia d) Limitar la corriente

15.- ¿Què tipo de balastro es un balastro tipo reactor serie?

a) El que regula +/- 5% b) El màs pesado c) El de mayores pèrdidas d) El que se usa sòlo para V.S.B.P.

16.- Un balastro con ignitor es para operar làmparas de:

a) V.S.A.P. b) V.S.B.P. c) Fluorescente d) Tungsteno Halògeno

17.- Antes de medir iluminancia se debe dejar estabilizar las làmparas de alta intensidad de descarga durante mínimo:

a) 5 minutos b) 1 hora c) 5 horas d) 8 horas

18.- Para què sirve el reflector de un luminario?
a) Para proteger la làmpara b) Para enfriar la làmpara
c) Para formar la curva de distribución d) Para dar apariencia

19.- ¿Còmo se clasifican los luminarios?
a) Directos e indirectos b) Directos, Semidirectos, Directos-Indirectos, Semi-indirectos, Indirectos c) Directos Indirectos Difusos d) Semi-directos, semi-indirectos.

20.- ¿Què representa el Coeficiente de Utilizaciòn?
a) Porciento de luz que sale del luminario b) Porciento de luz que llega a las paredes c) Porciento de luz que llega al plano de trabajo.

21.- Entre què distancias se encuentra el punto de màxima emisiòn luminica de un luminario clasificado como corto?
a) 0 y 1 AM b) 1 y 2.25 AM c) 1.75 y 2.25 AM d) o y 1.75 AM

22.- Un luminario con distribuciòn luminosa simètrica es tipo:
a) Larga b) V c) Isocandela d) Sin clasificaciòn

23.- Un luminario No Cutoff es un luminario:
a) Ventilado b) Abierto c) Hermètico a prueba de polvo
d) Sin control del flujo luminoso

24.- Una de las principales caracteristicas que se deben tomar en cuenta para una eficiente iluminaciòn deportiva es:
a) Area de juego b) Nùmero de làmparas c) Brillantez
d) Nùmero de espectadores

25.- El tipo de iluminación más recomendable para en un diseño deportivo es:

a) Concentrada   b) Difusa   c) Directa   d) Indirecta

26.- En què mètodo de càlculo se basa la iluminación de àreas exteriores?

a) Lúmen   b) Cavidad Zonal   c) Punto por punto   d) Computadora

27.- Cuando se tiene un luminario con distribución lumínica asimètrica, cuàl carta o curva representa en forma màs pràctica esta distribución?

a) Curva de distribución   b) Carta Isolux   c) Carta isocandela   d) Curva de Flujo

28.- Cuàl es la fòrmula bàsica para el càlculo punto por punto?

a) $E = \frac{\text{Lum} \times \text{Area}}{CU}$ b) $E = \frac{I}{d2} \text{Cos } O$ c) $E = I \text{ d2 Cos } O$

d) $E = I \text{ d2 sen } O$

29.- Mencione 5 elementos de un sistema de alumbrado público.

30.- Comente cuàl es el principal propòsito de la iluminación exterior.

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CURSOS ABIERTOS

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1. Definition of Light

a. Light is a part of an energy group called radiant energy.

b. The Illuminating Engineering Society defines light as radiant energy evaluated according to its capacity to produce visual sensation.

c. Light is measured in a unit called lumen-hours (lm-h); the symbol is Q.

(1) Illumination is the result of light falling on a surface and is measured in footcandles.

(2) Luminance (Photometric Brightness) (L) is the luminous flux per unit of projected area and unit solid angle either leaving a surface at a given point from a given direction or arriving at a given point from a given direction. Luminance is also defined as the luminous intensity of a surface in a given area of the surface as viewed from that direction.

d. Light can be represented diagrammatically as shown in Fig. 1-1.

e. Light exhibits properties of wavelength (λ) and frequency (f). In many applications these characteristics are not necessary and light can be represented simply by an arrow indicating its direction.

f. The velocity of light (c) is approximately 186,000 miles per second in air or vacuum.

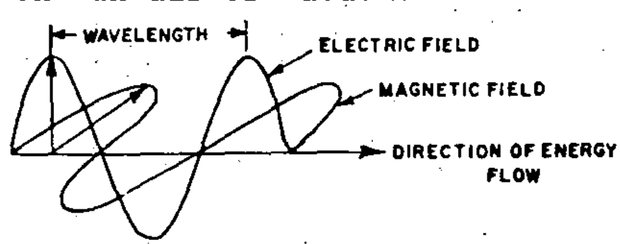


Fig. 1-1. Simplified graphic interpretation of electromagnetic energy. Oscillations perpendicular to direction of energy flow.

g. Scientists today use two concepts in explaining the nature of light. These are the "electromagnetic wave theory" and the "quantum theory." The electromagnetic theory conceives that luminous bodies emit light in the form of radiant energy, that this energy is transmitted in the form of electromagnetic waves (Fig. 1-1) and that these waves act upon the eyes to produce the sensation of light. The quantum theory conceives that luminous bodies emit radiant energy in discrete "bundles," that these are ejected in straight lines, and act upon the eyes to produce the sensation of light. The movement of light through space may be explained best by the electromagnetic theory.

The effect of light on matter (a barrier layer cell light meter, for example) is best explained by the quantum theory.

2. Picture of the Radiant Energy Spectrum

a. In addition to light there are other forms of radiant energy. The entire energy group is called the electromagnetic spectrum, or the radiant energy spectrum. See Fig. 1-2.

b. Radiant energy travels at a constant velocity of approximately 186,000 miles per second in air or vacuum.

c. Wavelength represents the distance between the crests of adjacent waves. See Fig. 1-1.

d. Frequency represents the number of waves (wavelengths) that pass a given point in a second.

e. Wavelength is expressed in several units, depending upon the part of the spectrum referred to or unit system used; i.e., picometers for the short cosmic rays to miles for the long power transmission waves. The wavelength of light is measured in a unit called nanometers (mn).

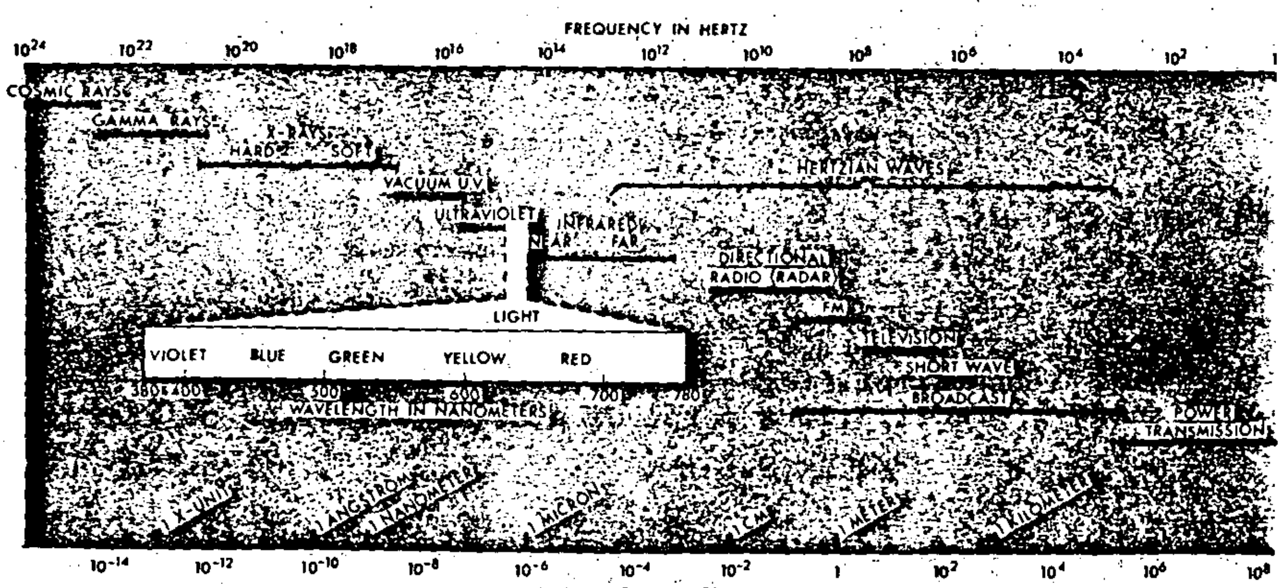


Fig. 1-2. The radiant energy (electromagnetic) spectrum.

f. Radiant energy is measured in units called watt-hours (Wh).

g. Radiant flux is measured in units called watts (W). Radiant flux is also called radiant power.

3. Visible Light Spectrum

a. In 1666, Sir Isaac Newton passed a beam of light through a prism and discovered that it contained all colors of the rainbow.

b. Though the colors of the visible spectrum blend continuously, each color is arbitrarily divided in bands. See Fig. 1-3.

c. The primary colors of light according to the Young-Helmholz color theory are red, blue and green.

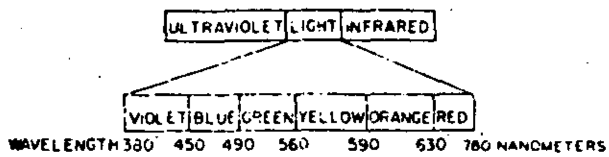


Fig. 1-3. The visible spectrum; white light is composed of all the colors of the rainbow.

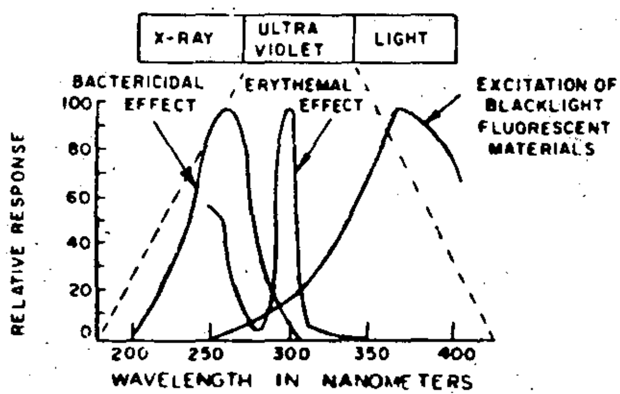


Fig. 1-4. The ultraviolet spectrum.

4. Ultraviolet Spectrum

a. Ultraviolet energy is invisible to the eye.

b. Though the sun is a source of the near ultraviolet, man-made sources are available for producing the entire ultraviolet spectrum.

c. Three effects are produced in this band; these are indicated in Fig. 1-4.

5. Infrared Spectrum

a. Infrared energy is invisible to the eye.

b. The sun is a natural source. Generally speaking, incandescent lamps radiate up to 5,000 nm. The region from 780 nanometers and up is known as the infrared spectrum.

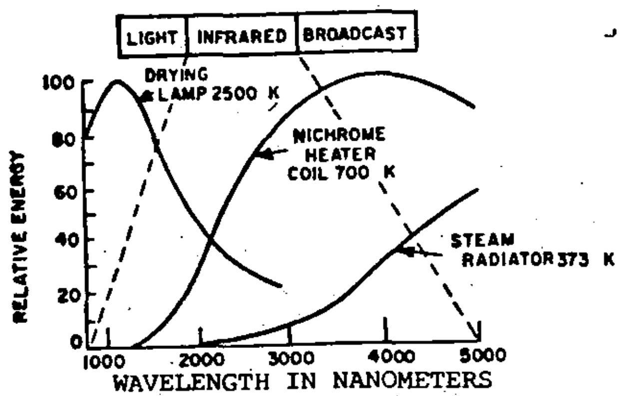


Fig. 1-5. The near infrared spectrum.

c. Special lamps are available for therapeutic and industrial applications of the near infrared region. See Fig. 1-5.

6. Structure of the Eye

a. The eye is a fine precision instrument; in many ways it can be compared to a camera.

b. Following is a comparison of the eye and the camera:

Eye	Camera
Sclera	Covering or housing
Choroid	Middle Lining
Retina	Film
Iris	Diaphragm
Pupil	Aperture
Lid	Shutter
Lens	Lens

c. **A description of parts of the eye:**

(1) The sclera is the outer coat or covering; it is tough, white and opaque; it holds the eyeball in shape. Toward the front it becomes transparent and is here called the cornea.

(2) The choroid is the middle lining; it consists of a layer of blood vessels, and serves as the nourishing and feeding coat of the eyeball. In front it becomes the iris; this is a colored diaphragm which serves the same purpose as the diaphragm in the camera. It automatically controls the amount of light which enters the eye; for example, by expanding the pupil under low levels of light. The pupil is the hole in the center of the iris and corresponds to the aperture in the shutter of the camera.

(3) The Retina and Its Parts. The retina is the inner lining; it is the seeing part of the eye and corresponds to the film in the camera. It consists of a delicate layer of nerve tissue, in which there are nerve fiber endings called cones and rods. In addition, there are two spots in the retina: one for most distinct vision, called the fovea or yellow spot; and the other called the blind spot, where the optic nerves enter the eyeball.

(a) Cones. There are approximately 7 million cones. They are packed most closely in the fovea or yellow spot. Cones do the seeing in daylight. They are also responsible for seeing colors. Color blindness is due to improper functioning of the cones.

(b) Rods. There are also approximately 135 million rods. They fan out and are located all the way from the fovea or yellow spot to the periphery of the retina. They come into predominance during early darkness and are used for night vision. They cannot detect color. Rods are many times as sensitive to blue light as cones at low levels of illumination. For this reason blue was ruled out and the red light preferred during the war blackouts.

(4) The aqueous humor is a watery solution between the cornea and the iris.

(5) The lens is suspended and held in place by muscles immediately behind the pupil. It is a flexible, multiple layer body formed in the shape of a lens and corresponds to the lens in a camera; however, it is an automatic focusing device, whereas in a camera focusing is accomplished by moving the lens. Eye focus

accomplished with muscles which actually change the shape of the lens. The eye is at rest and normal when viewing objects at distances of 20 feet or more. At close distance, such as work or reading at the usual 14 inches, the eyes accommodate and converge. Continued convergent activity for long periods may result in a sense of fatigue.

(6) The vitreous humor is found behind the lens and fills the remaining space in the eyeball. It is a jellylike mass. Its purpose is to work in conjunction with the lens to refract or bend light rays into the fovea (or near fovea) region for night vision).

(7) Visual purple is the photochemical substance found in rods. Under the action of light it bleaches and decomposes into a succession of products.

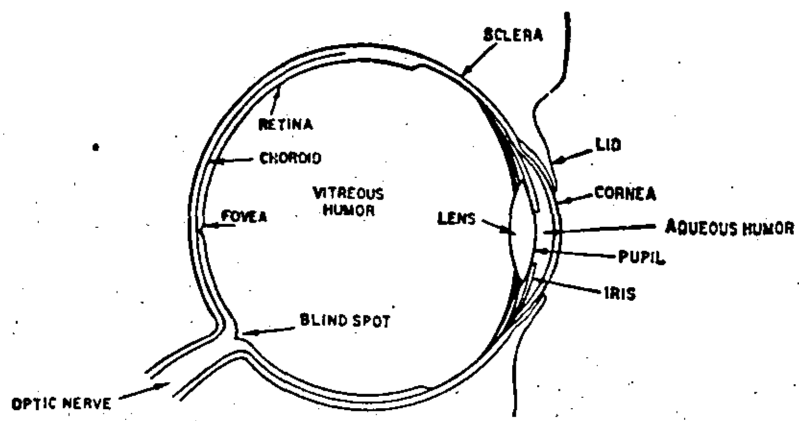


Fig. 1-6 Cross section of the eye.

7. How We See

Let us follow a beam of light. When electromagnetic radiations between 380 nm and 780 nm pass through the transparent protective outer layers of the eye, the cornea, they are bent or refracted; from the cornea they pass through the aqueous humor and through the pupil. The amount of light coming through is controlled automatically by the contraction or expansion of the pupil. Light passes through the pupil and through the lens, which focuses the rays through the vitreous humor and on to the retina. Here the cones and rods come into action. From this point on the process is electro-chemical. Pulsations are set up and are carried from the cones and rods to the optic nerve, which transmit them to the brain where they are interpreted as light, or where they cause the sensation of vision. The brain and the eye cooperate in transforming radiant energy into the sensation of sight.

8. Seeing Characteristics of the Eye

a. Accommodation refers to the focusing activity of the lens.

b. Adaptation refers to photochemical changes in the light sensitivity in the retina. It is this ability that is responsible for the tremendous range (1,000,000 to 1) of luminance levels to which it is sensitive.

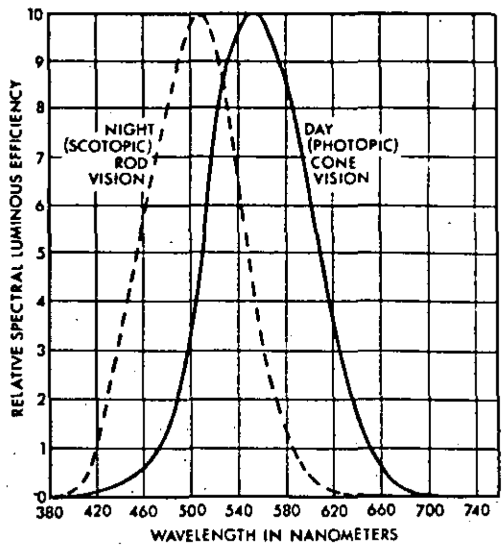


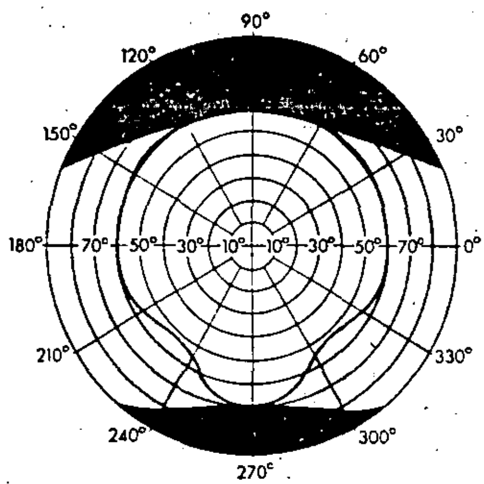
Fig. 1-7. Relative spectral sensitivity curves for photopic (cone) and scotopic (rod) vision showing the Purkinje Effect on the wavelength of maximum sensitivity. (Values beyond 700 nanometers are very low.)

c. The function of the iris is to control the amount of light that enters the eye to a limited degree. This degree of control is in the range of 16 to 1.

d. The standard spectral luminous efficiency curve graphically indicates the relative ability of the eye to evaluate radiant energy at the various wavelengths in the visible spectrum. This curve is also called the eye sensitivity curve. The eye has maximum sensitivity at 555 nanometers which is in the yellow-green portion of the visible spectrum. The sensitivity of the eye decreases as the wavelengths get shorter or longer. When radiant flux (watts) is weighed according to the spectral luminous efficiency curve and multiplied by a constant, the result is luminous flux (lumens).

e. Purkinje Effect. The standard (photopic) eye sensitivity curve is based on "cone and rod vision." At very low levels of illumination, where the luminances are of the order of 0.01 to 0.001 footlambert, the cones no longer function and the rods take over the entire seeing process. In rod or scotopic vision a new sensitivity curve becomes effective, of the same shape as the photopic curve, but displaced 50 nm toward the blue end of the spectrum. This is called the Purkinje Effect.

f. Visual Field. The normal visual field extends approximately 180 degrees in the horizontal plane and 130 degrees in the vertical plane, 60 degrees above the horizontal and 70 degrees below. The fovea subtends an angle of about two degrees. This is the central field. The surroundings which are most effective are usually considered as extending from the outer limit of the central field to a circle approximately 30 degrees from the optical axis.



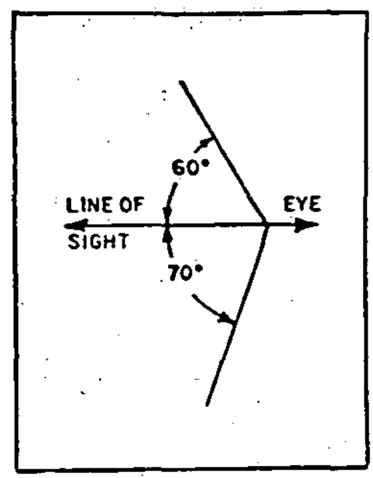


Fig. 1-8. Normal field of view of a pair of human eyes. The central white portion represents the region seen by both eyes. The gray portions, right and left, represent the regions seen by the right and left eyes, respectively. The cutoff by the eyebrows, cheeks, and nose is shown by the dark areas.

9. Light and Sight are Interdependent.
A perfect eye in darkness is no more effective than a blind eye. In order to properly recommend and apply light, both light and sight must be considered.

a. Distant vs. Near Vision. The normal distance for seeing at which the eye is practically at rest is 20 feet or more. Most seeing tasks are performed approximately 14 inches away from the eyes.

b. Large vs. Small Objects. Tasks such as many in agriculture, trapping, lumbering and the like are simple eye tasks as compared to bookkeeping, watch repairing, proofreading, sewing or reading.

c. Daylight Hours vs. Day and Night Hours. Sunrise to sunset was a normal day for man living in a simple age. Today, after a normal day's work, usually under artificial light, man continues to use his eyes far into the night, reading at home, viewing movies and television, driving his car at high speeds, as well as performing other seeing tasks.

d. Natural Illumination Levels vs. Artificial Illumination Levels. The illumination levels of daylight are many hundreds and even thousands of times as great as those encountered under artificial illumination. The following are representative values that may be checked with the aid of a footcandle meter:

	Approximate Footcandles
(1) Natural light	
(a) Open field-noontime in summer	7,000 to 10,000
(b) Shade of tree-noontime	1,000
(c) On porch-noontime in summer	300
(d) Cloudy day-any season	200
(e) Threshold of darkness-midway between Civil Twilight	3 to 5
(f) Nighttime-full moon	0.01
(2) Artificial illumination not necessarily recommended	
(a) Offices, factories, stores, schools and homes	5--200
(b) Average well lighted roadways	
1. Freeways	0.6 to 3
2. Major and Expressway	1 to 3
3. Collector	0.5 to 3
4. Local	0.4 to 1
5. Alleys	0.2 to 1

10. Changing of Eyes with Age

a. Physical changes (presbyopia). At the age of 40 or more there is often a gradual lessening of elasticity of the lens so that the muscles cannot readily reshape the lens for close vision. Glasses can correct this condition and high-level lighting is a big help to older people.

b. Per cent defect vision (see Fig. 1-9).

11. Elements of Seeing (See Fig. 1-10).

a. The eye. Little can be done with our eyes except to sharpen vision by using glasses.

b. Light.

c. Object (task).

12. Factors Relating to Visibility as used for Lighting Roadways.

a. The size of an object and its critical detail. See Fig. 1-11.

b. The luminance of an object on or near the roadway. See Fig. 1-13.

c. The luminance of the background of the roadway.

d. The time available for seeing the object. See Fig. 1-14.

e. The contrast between an object and its surroundings. Fig. 1-15 shows a relationship between contrast and luminance that was determined by Dr. Blackwell.

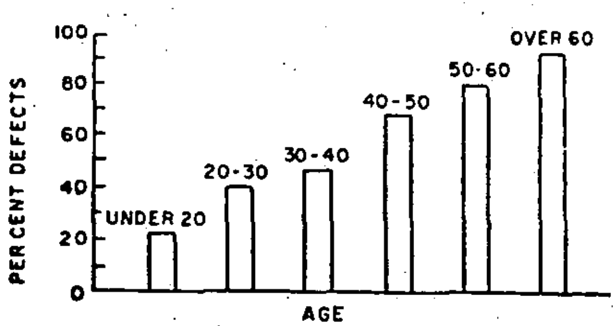


Fig.1-9. Prevalence of defective vision by ages.

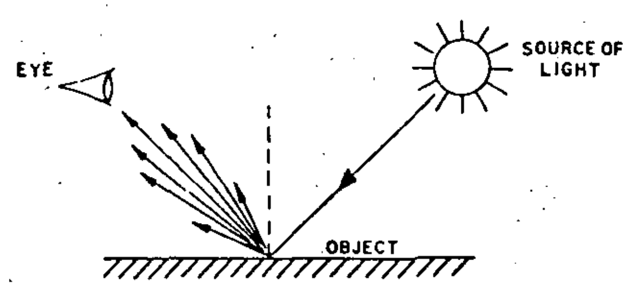


Fig. 1-10. Factors in seeing.

f. The ratio of pavement luminance to the surroundings as seen by the observer.

g. Glare - This term as it affects human vision is divided into 2 components.

(1) Disability Glare (which usually is not apparent to the observer). It acts to reduce contrast or ones ability to see or spot an object. It is sometimes also referred to as "blinding glare" or "veiling glare."

(2) Discomfort Glare - It produces a sensation of ocular discomfort but does not necessarily affect the visual acuity or the ability to discern an object.

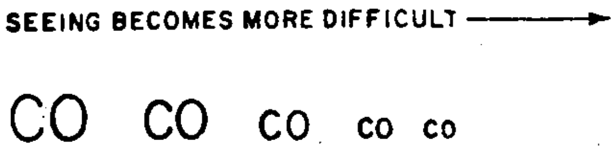


Fig. 1-11. Gap in the letter c is the critical detail.

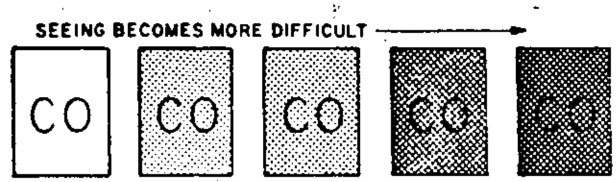


Fig. 1-12. Illumination constant, surfaces reflecting differing amounts of light.

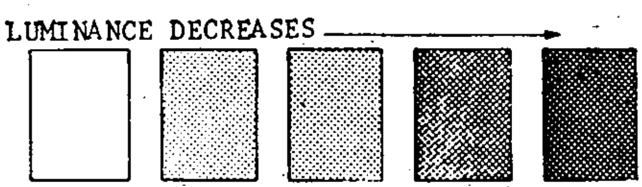


Fig. 1-13. Illumination constant surfaces reflecting differing amounts of light.

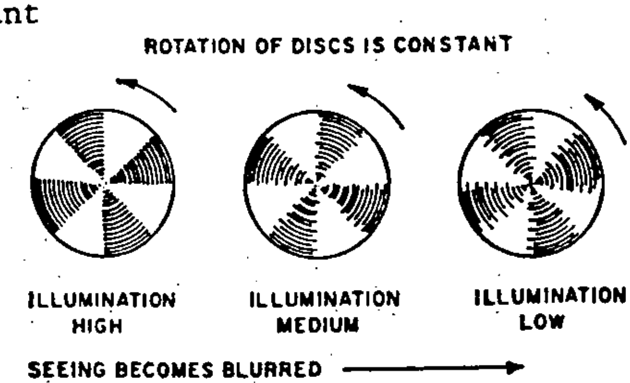


Fig. 1-14. The time factor in seeing.

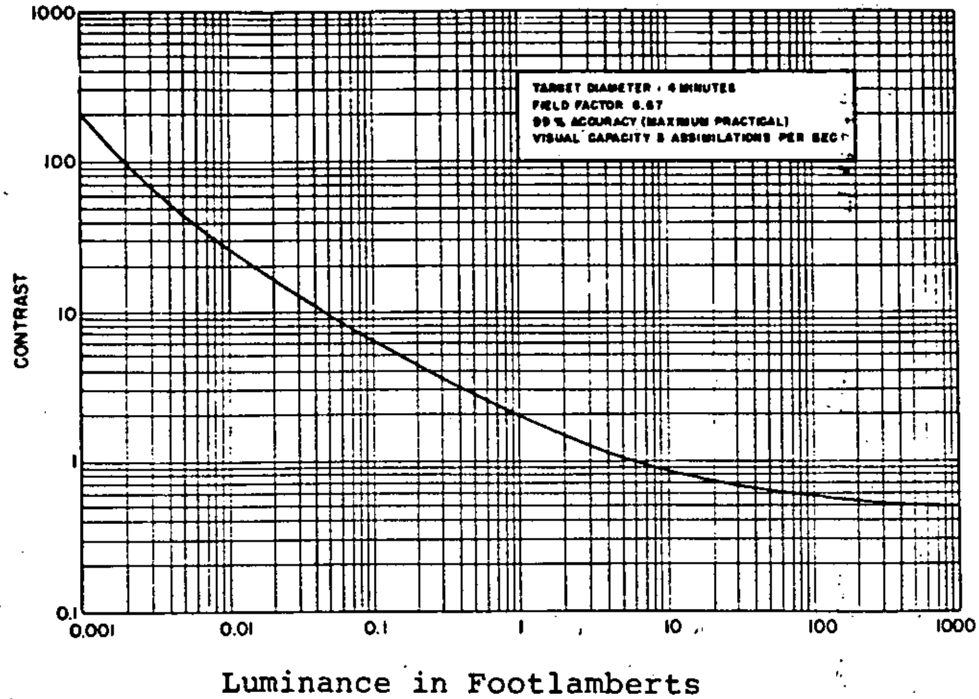


Fig. 1-15. Field Use Curve. All unknown field tasks may be related by the Visual Task Evaluator to this curve of a four-minute circular disc which has been weighted to represent "moving-eyes" field conditions and maximum field accuracy.

13. Method of Discernment

a. Discernment by Silhouette. An object is discerned by silhouette when the general luminance level of all or a substantial part of the object is lower than the luminance of its background. This method of discernment predominates in the observation of distant objects on lighted roadways. Silhouette discernment depends upon the pavement surface reflectance.

b. Discernment by reverse silhouette. An object is discerned by reverse silhouette when the general luminance level of all or a substantial part of the object is higher than the luminance of its background.

c. Discernment by Surface Detail. When an object is seen by virtue of variations in brightness or color over its own surface, without regard to its contrast with its background, it is discerned by surface detail.

TEST YOURSELF (QUESTIONS)

1. Explain the nature of light.
2. Name two effects that occur when there is a change of light on the retina.
3. What is the difference between scotopic and photopic vision?
4. What are the four fundamental factors that affect visibility?
5. What is the eye sensitivity curve?
6. What is the relationship between colored light and white light?
7. How does the illumination level of moonlight compare with the minimum level of alleys?

TEST YOURSELF (ANSWERS)

1. According to the best information available, light appears to be dualistic in nature; propagation is best explained by considering light as a form of electro-magnetic energy, whereas interaction with matter can be best explained with a corpuscular theory.

2. When a change of light occurs on the retina, adaptation and adjustment of the iris take place.

3. Photopic vision refers to the normal or day vision when the luminance in the visual field is in the order of one footlambert or greater. This condition is also called the light-adapted eye. Scotopic vision refers to night vision when the luminance in the visual field is less than 0.01 footlambert. This condition is also called the dark-adapted eye.

4. The four fundamental factors of visibility are size, contrast, luminance, and time.

5. The eye sensitivity curve shows the relative visual effect of the various wavelengths in the visible spectrum.

6. White color represents all colors of the visible spectrum in proper proportions.

7. Moonlight at .01 footcandles is about one-fourtieth of the illumination recommended for residential alleys.

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TERMINOLOGIA

PALACIO DE MINERIA

LANGUAGE OF ROADWAY LIGHTING 2

A. Fundamental Lighting Terms and Units

1. Solid angle (ω) is defined as the ratio of spherical areas (A_s) to the square of the radius (R). Solid angle is measured in a unit called the steradian (sr). See Fig. 2-1.

   $\omega = A_s/R^2$ (Equation 2-1)

2. Luminous Flux (ϕ) is the time rate of flow of light. The unit of luminous flux is the lumen (lm). This is a concept of a rate and may be considered similar to the rate at which other quantities flow; for example, gallons per minute, cubic feet per hour, etc. Although time is not indicated in the unit of luminous flux (lumen), it is implied.

   Example: Light is emitted from a 100-watt incandescent lamp at the rate of 1750 lumens, while the flow of light from a 40-watt fluorescent lamp is about 3200 lumens.

   Note: It is possible to make use of the idea of a lumen without being concerned with the time concept. In popular usage the rate of flow concept is not necessary for normally encountered lighting calculations.

3. Luminous intensity (I) is defined as the solid-angular luminous flux density in a given direction. The unit used to measure luminous intensity is the candela (cd).

   $I = \phi/\omega$ (Equation 2-2)

   Candlepower and luminous intensity are descriptive terms and are used in the same sense. From an operational standpoint, candlepower or luminous intensity indicates the ability of a light source to produce illumination in a given direction.

4. Illumination (E) is incident luminous flux density. When the unit of luminous flux is the lumen and the area is in square feet, the unit of illumination is the footcandle (fc). When the area is in square meters, the unit of illumination is the lux (lx). See Table 2-1.

   $E = \phi/A$ (Equation 2-3)

Table 2-1-Multiplying Factors for Conversion from Customary Units to SI* Units

Values in Customary Units	X	Multiplying Factors	=	Values in SI Units
fc	x	10.76	=	lx
fL	x	3.426	=	cd/m^2
cd/in^2	x	1.55	=	kcd/m^2
ft	x	0.3048	=	m
in	x	2.54	=	cm

*Systeme International d'Unites (International System of Units)

5. Luminance (Photometric Brightness) (L) is the luminous flux per unit of projected area per unit solid angle either leaving a surface at a given point from a given direction or arriving at a given point from a given direction. When the unit of luminous flux is the lumen and the area is in square feet, the unit of luminance is the footlambert (fL). Luminance is also defined as the luminous intensity of a surface in a given direction per unit of projected area of the surface as viewed from that direction. When the luminous intensity is in candelas and the area is expressed in square inches, the unit is in candelas per square inch cd/in^2. The relationship between footlamberts and candelas per square inch is:

$$1\ cd/in^2 = 452\ fL \qquad \text{(Equation 2-4)}$$

a. Subjective brightness is the subjective attribute of any light sensation giving rise to the percept of luminous intensity, including the whole scale of qualities of being bright, light, brilliant, dim or dark.

Note: The term brightness often is used when referring to the measurable "photometric brightness." While the context usually makes it clear as to which meaning is intended, the preferable term for the photometric quantity is luminance, thus reserving brightness for the subjective sensation.

b. Reflectance. The illuminating engineer is particularly interested in the total reflected light so that he defines reflectance as:

$$\rho = \frac{\text{Total reflected light}}{\text{Total incident light}}$$

$$\rho \quad \text{for diffuse surfaces} = \frac{L}{E}$$

Note: Refer to the IES Lighting Handbook

Note: Reflected light is luminance in footlamberts, incident light is illumination in footcandles. Since footlamberts are reflected lumens per square foot, the footcandle meter can be used to approximately measure the reflected light when the surface is perfectly diffuse. Incident light is measured in footcandles with a footcandle meter.

c. Transmittance

$$\tau = \frac{\text{Total transmitted light}}{\text{Total incident light}}$$

$$\tau \quad \text{for diffusing media} = \frac{L}{E}$$

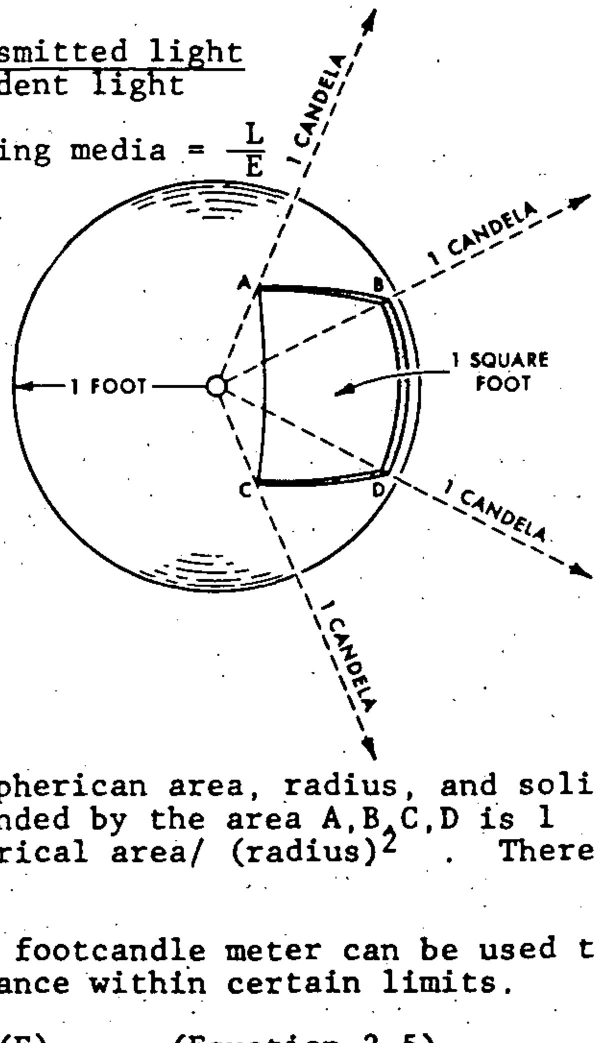


Fig. 2-1. Relationship of a spherican area, radius, and solid angle. The solid angle subtended by the area A,B,C,D is 1 steradian solid angle = spherical area/ $(\text{radius})^2$. There are 4π steradians in a sphere.

Note: Again, the footcandle meter can be used to measure transmittance within certain limits.

Also: $L = (\rho)\ (E)$ (Equation 2-5)
$L = (\tau)\ (E)$ (Equation 2-6)

6. Luminous efficacy of a light source is the ratio of the total luminous flux emitted by the source to the total power input to the source. In the case of an electric lamp, efficacy is expressed in lumens per watt (lm/W).

7. Color Temperature. The color temperature of a light source is the temperature at which a blackbody radiator must be operated to have the same color appearance as that of the light source. Color temperature is a specification of the color appearance only and has no concern with the energy distribution of the light source. Most incandescent filament lamps, however, in addition to having the same color appearance as a blackbody, approach the energy distribution of a blackbody quite closely.

   Although the energy distributions or fluorescent lamps do not approach that of a blackbody, a color temperature designation is given when the color appearance is similar. The blackbody radiator serves as the laboratory standard in kelvins.

Table 2-2 - Color Temperature of Various Sources

Noon sun	5500 K
100-watt tungsten inside frosted	2800 K
100-watt tungsten daylight	3500 K - 4000 K

B. Terms Used in Roadway Lighting*

1. Candela, cd. The unit of luminous intensity; one lumen per unit solid angle (steradian) see Fig. 2-1. 1 candela per square inch = 452 footlamberts.

2. Candlepower. Luminous intensity in a specified direction expressed in candelas. It is no indication of the total light output.

3. Candlepower Distribution Curve. A curve showing the variation of luminous intensity of a lamp or luminaire with angle of emission. A Vertical Candlepower Distribution Curve is obtained by taking measurements at various angles of elevation in a vertical plane through the light center; unless the angle of azimuth is specified, a vertical curve is assumed to represent an average such as would be obtained by rotating the unit about its vertical axis. A Horizontal Candlepower Distribution Curve represents measurements made at various angles of azimuth in a horizontal plane through the light center.

*American National Standard Practice for Roadway Lighting

4. Coefficient of Utilization. The percentage of rated lamp lumens which fall on either of two striplike areas of infinite length, one stopping in front of the luminaire, the other behind the luminaire, when the luminaire is level and oriented over the roadway in a manner equivalent to that in which it was tested. Since the roadway width is expressed in terms of a ratio of luminaire mounting height to roadway width, the term has no dimensions.

5. Cutoff Light Distribution. A classification with prescribed limits of control of candlepower distribution above the maximum candlepower.

6. Footcandle, fc. The unit of illumination when the foot is the unit of length; the illumination on a surface one square foot in area on which is uniformly distributed a flux of one lumen. It equals one lumen per square foot.

7. Footlamberts, fL. The unit of photometric brightness (luminance) equal to $1/\pi$ candela per square foot. A theoretical perfectly diffusing surface emitting or reflecting flux at the rate of one lumen per square foot would have a photometric brightness of one footlambert in all directions. No actual surface completely fulfills this condition.

8. Glare. The effect of brightness or brightness differences within the visual field sufficiently high to cause annoyance, discomfort, or loss in visual performance.

    a. Direct Glare. Glare resulting from high brightness or insufficiently shielded light sources in the field of view, or reflecting areas of high brightness and large area.

    b. Reflected Glare. Glare resulting from specular reflections of high-brightness sources in polished surfaces in the field of view.

    c. Discomfort Glare. The sensation experienced by an observer when brightness relationships in the field of view cause discomfort but do not necessarily interfere with seeing.

    d. Veiling Glare. The effect produced by candlepower emitted in the direction of the eye which has a veiling effect within the eye that reduces the ability to see.

9. Glint. The reflection of light from a specular surface.

10. Isocandela Line or Trace. A line or trace plotted on any appropriate coordinates to show all the direction in space, about a source of light in which the candlepower is the same.

For a complete exploration the line is a closed curve. A series of such curves usually for equal increments of candlepower is called an isocandela diagram.

11. Isolux (Isofootcandle) Line. A line or trace plotted on any appropriate coordinates to show all the points on a surface where the illumination is the same. For a complete exploration the line is a closed curve. A series of such lines for various illumination values is an isolux (isofootcandle) diagram.

12. Lateral Width of a Light Distribution. The lateral angle between the reference line and the width line, measured in the cone of maximum candlepower. This angular width includes the line of maximum candlepower. See Fig. 2-2.

13. Light Distribution Pattern. A diagramed description of the behavior of the light from a luminaire.

    a. Lateral Distribution Pattern. A candlepower curve plotted in a specified cone with the luminaire at the vertex. See Fig. 2-2.

    b. Vertical Distribution Pattern. A candlepower curve plotted in a specified plane perpendicular to the roadway and containing the luminaire. See Fig. 2-3.

14. Light Loss Factors. Factors based on physical conditions causing a reduction or depreciation of the lumens received on surfaces in the vicinity of a luminaire, usually due to other than ideal operating conditions. Such factors are:

    a. Luminaire Ambient Temperature. With some luminaires, the effect of temperature is considerable. Important considerations are: lamp ambient temperature, mounting position, and the effect of introduced air.

    b. Voltage. Voltage to the luminaire, when varies from equipment design, may affect ballasts adversely, and may also have an indirect adverse effect on lamp life and light output.

    c. Ballast Efficiency. All ballasts, other than standard laboratory reactors, will vary lamp light output by some small amount, which increases with poor electrical supply values.

    d. Luminaire Component Depreciation. Luminaire surface depreciation results from adverse changes in aluminum, paint, and plastic components, which reduce light output. Clearly this is an important consideration in design calculations.

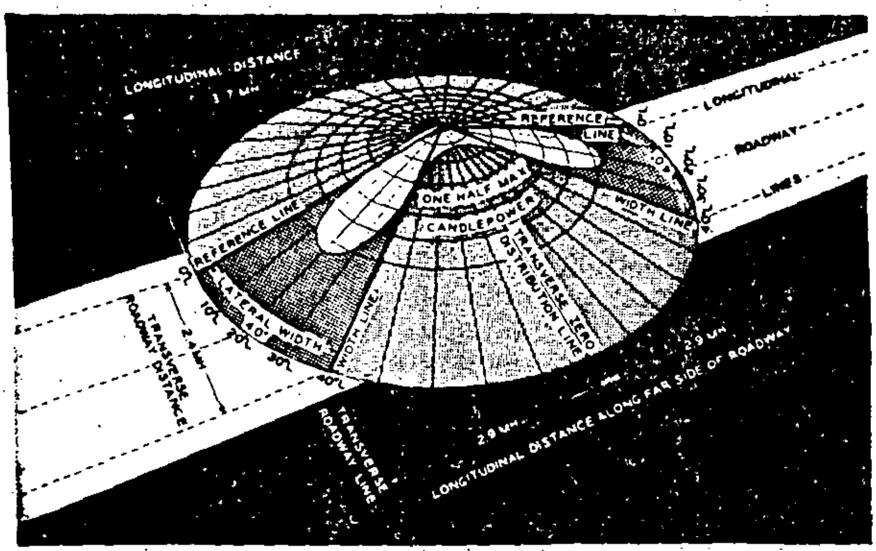
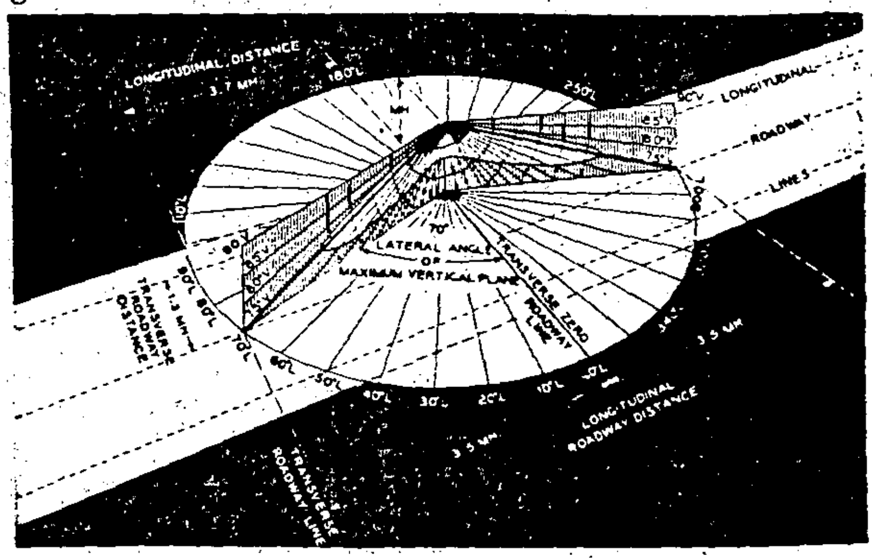


Fig. 2-2. An example of a cone of maximum candlepower showing lateral distribution of light.

Fig. 2-3. An example of a vertical plane through maximum candlepower showing a vertical light distribution.



e. <u>Change in Physical Surround</u>. New construction or demolition within or adjacent to the roadway that was not considered at the time of design of the lighting system.

f. <u>Burnouts</u>. As a practical matter, the number of lamp outages is determined by the quality of the lighting servicing program incorporated in the initial design procedure and by the quality of the physical performance of that program.

g. <u>Lamp Lumen Depreciation</u>. The loss in light output resulting from lamp aging. Its amount should be determined by reference to manufacturers statistics for the performance of each particular type.

h. <u>Luminaire Dirt Depreciation</u>. The loss in light output resulting from the accumulation of dirt on the luminaire. This factor is determined from the relationship between light output of a clean luminaire and that of the same luminaire immediately prior to the next planned cleaning.

15. <u>Longitudinal Roadway Line. (LRL)</u>. May be any line along the roadway parallel to the curb line.

16. <u>Luminaire</u>. A complete lighting device consisting of a light source together with its direct appurtenances such as globe, reflector, refractor, housing and such support as is integral with the housing. The pole, post or bracket is not considered a part of the luminaire.

17. <u>Maintenance Factor</u>. A value to be used in calculation formula, that is less than a whole number, and is to be known as the Light Loss Factor. It is the product of all the separate factors listed in section 14, each of which has been determined after careful consideration of those conditions that will cause a depreciation. This depreciation point is at the end of a time period immediately prior to any recovery procedure.

18. <u>Mounting Height</u>. The vertical distance between the roadway surface and the center of the apparent light source of the luminaire.

19. <u>Noncutoff Light Distribution</u>. A classification with no prescribed limits of control of candlepower distribution above maximum candlepower.

20. <u>Overhang</u>. The distance between a vertical line passing through the luminaire and the curb or edge of the roadway.

21. Reference Line. Radial lines where the surface of the cone of maximum candlepower or of the roadway is intersected by a vertical plane parallel to the curbline and passing through the light center of the luminaire.

22. Semicutoff Light Distribution. A classification with prescribed limits of control of candlepower distribution above maximum candlepower.

23. Spacing. The distance between successive lighting units measured along the center line of a roadway.

24. Spacing-to-Mounting Height Ratio. Ratio of the distance between luminaires to the mounting height.

25. Transverse Roadway Line. (TRL). May be any line across the roadway that is perpendicular to the curb line.

26. Uniformity of Illumination. The ratio of average illumination level on the roadway to the minimum illumination at any point on the roadway.

27. Utilization Curves. A plot of the quantity of light falling on horizontal plane both in front of and behind the luminaire. It shows only the percent of bare lamp lumens which fall on the horizontal surface and is plotted as a ratio of width of area to mounting height of the luminaire.

28. Visual Angle. The angle subtended by an object or detail at a point of observation. It usually is measured in minutes of arc. It is determined by the size of an object and its distance from the viewer.

C. Lighting Laws

1. The inverse square law states that the illumination (E) on a surface varies directly with the candlepower (I) of the source and inversely with the square of the distance (D) between the source and the surface. The inverse square law refers to point sources.

$E_{normal} = I/D^2$ (Equation 2-7) In Fig. 2-4.

$E_1 = I/(D_1)^2 = 100/1 = 100$ fc

$E_2 = I/(D_2)^2 = 100/4 = 25$ fc

$E_3 = I/(D_3)^2 = 100/9 = 11.1$ fc

Table 2-3 - Most Often Used Lighting Terms

DESCRIPTIVE TERM	SYMBOL	UNIT	ABBREVIATION	DEFINITION
Light	Q	Lumen-Hour	lm-h	Radiant energy the eye can evaluate
Luminous Flux	ϕ	Lumen	lm	Time rate of flow of light
Luminous Intensity - Candlepower	I	Candela	cd	The solid-angular flux density in the direction in question
Illumination	E	Footcandle Lux	fc lx	The density of the luminous flux incident on a surface
Luminance	L	Footlambert (candelas per square meter	fL (cd/m^2)	The luminous intensity on any surface in a given direction per unit of projected area of the surface

a. Lumen Concept. The inverse square law can also be derived from a luminous flux viewpoint. Assume spherical surfaces being subtended by a unit solid angle. If these areas are one, two, and three feet from the center, the areas will be one, four, and nine square feet. Now, assume the center contains a uniform emitting point source of 100 candelas. Since luminous flux is defined as = (I) ( ), the lumens contained in the unit solid angle are I or (100) (1) = 100. Illumination is also defined as incident luminous flux per square foot. When is in lumens and A is in square feet, illumination is in footcandles.

$$E = \phi/A$$

Then: $E_1 = \phi/A_1 = 100/1 = 100$ fc

$E_2 = \phi/A_2 = 100/4 = 25$ fc

$E_3 = \phi/A_3 = 100/9 = 11.1$ fc

These agree with the results obtained using the candlepower concept. The candlepower concept is therefore used to determine illumination at a very small area (on a point). The lumen concept is used when the area becomes large..

Note: Average illumination. When the luminous flux is not uniformly distributed on an area, the illumination is said to be average.

b. Conclusions and Assumptions

(1) Any point on a spherical surface equidistant from a source of uniform candlepower will have the same illumination value. The work point is used in the sense that it has a small finite area.

(2) Any spherical area equidistant from a source of uniform candlepower will have the same illumination value.

(3) In any case, whether the lumen or the candlepower concept is assumed, the illumination at the same distance on a point or area is the same.

(4) The inverse square law applies to point sources and from a practical standpoint this is true only if the distance is more than five times the maximum dimension of the source.

(5) This law measures only direct illumination from the source.

(6) Illumination from more than one source is added arithmetically:

$$E_{total} = E_1 + E_2 + E_3 \qquad \text{(Equation 2-8)}$$

2. The cosine law states that the illumination on any surface varies as the cosine of the angle of incidence (between the normal to the surface and the direction of the incident light). See Fig. 2-4.

$$E_\phi = (I/D^2)(\cos\phi) = (E_{normal})(\cos\phi) \qquad \text{(Equation 2-9)}$$

Table 2-4 - Basic Lighting Equations

$\omega = A_s/R^2$	Equation 2-1
$I = \phi/\omega$	Equation 2-2
$E = \phi/A$	Equation 2-3
$1\ cd/in^2 = 452\ fL$	Equation 2-4
$L = (\rho)(E)$	Equation 2-5
$L = (\tau)(E)$	Equation 2-6
$E_{normal} = 1/D^2$	Equation 2-7
$E_{total} = E_1 + E_2 + E_3$	Equation 2-8
$E_\theta = (1/D^2)(\cos\theta)$	Equation 2-9

WHERE:

ϕ = luminous flux in lumens

I = luminous intensity in candelas

E = illumination in footcandles

L = luminance in footlamberts or candelas per square inch

ω = solid angle in steradians

θ = angle in degrees which the illuminated plane must be rotated to be normal to the projected ray from the source

D = distance in feet from source to point in question

A = area of illuminated surface in square feet

A = spherical area

R = radius

ρ = reflectance

τ = transmittance

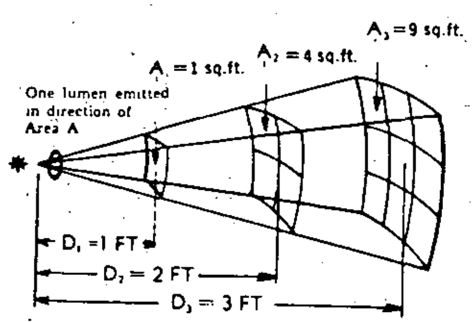


Fig. 2-4. Inverse square law. Normal illuminations on a point (small finite area); surfaces of all points are perpendicular to the direction of candlepower. When these areas become very small they may be assumed to be flat with little sacrifice in accuracy.

a. Lumen Concept. The cosine law can be derived from a luminous flux viewpoint. It may be easily visualized by considering a right pyramid whose apex solid angle is one steradian and with a base one square foot (see Fig. 2-5, p. 2-15). The altitude of the pyramid is the normal to the base. If the apex is assumed to contain a point source of uniform candlepower of 100 candelas, the solid angle contains ($\Phi = I \cdot \omega$) = 100 lumens; the illumination on the base ($E = \Phi/A$) is 100 fc. When the plane containing the base is rotated through some angle θ, as indicated in Fig. 2-5, the solid angle will intercept an area (A') equal to the area (A) of the base divided by the cosine of the angle rotated through ($A' = A/\cos\theta$). Therefore: $E = \Phi/A' = (\Phi/A)(\cos\theta)$

TEST YOURSELF (QUESTIONS

Lighting Terms

Place the letter in the parenthesis that corresponds to the term defined.

a. luminous flux	g. light
b. illumination	h. wavelength
c. luminous intensity	i. adaptation
d. luminance	j. accommodation
e. reflectance	k. brightness
f. transmittance	

( ) 1. The ratio of the light reflected by a body to the incident light.
( ) 2. Radiant energy evaluated by its capacity to produce a visual sensation.
( ) 3. Solid angular flux density in the direction considered.
( ) 4. Density of luminous flux incident upon a surface.
( ) 5. Time rate of flow of light.
( ) 6. The luminous intensity of any surface in a given direction per unit of projected area of the surface viewed from that direction.
( ) 7. The focusing activity of the lens of the eye.
( ) 8. Adjustment of the iris and change in response of the cells on the retina.
( ) 9. Sensation

Units

Place the letter in the ( ) corresponding to the units used to measure the term indicated.

( ) 1. luminous flux	a. candela
( ) 2. luminous intensity	b. footcandle
( ) 3. illumination	c. footlambert
( ) 4. wavelength	d. nanometer
( ) 5. luminance	e. lumens/watt
( ) 6. light	f. per cent

( ) 7.	light source efficacy	g.	lumen
( ) 8.	reflectance	h.	watt
( ) 9.	solid angle	i.	lumen-hour
( )10.	electric power	j.	steradian

Abbreviations

Place the letter in the ( ) corresponding to the units used to measure the term indicated.

( ) 1.	Candela	a.	fL
( ) 2.	Footcandle	b.	lm/W
( ) 3.	Footlambert	c.	cd
( ) 4.	Wavelength	d.	lm
( ) 5.	Efficacy	e.	fc
( ) 6.	Lumens	f.	nm

TEST YOURSELF (ANSWERS)

Lighting Terms	Units	Abbreviations
1. e	1. g	1. c
2. g	2. a	2. e
3. c	3. b	3. a
4. b	4. d	4. f
5. a	5. c	5. b
6. d	6. i	6. d
7. j	7. e	
8. i	8. f	
9. k	9. j	
	10. h	

TEST YOURSELF (PROBLEMS)

Place the number and unit in the space provided which will complete the statement correctly.

1. A surface subtends two unit solid angles and one lumen of flux; the source illuminating the surface has a luminous intensity of ______________________.

2. A surface two square feet is ten feet from a point source; if it receives four lumens it is illuminated to ______________.

3. A point source of 100 candela is five feet from a point; the normal illumination at the point is ______________.

4. A surface (reflectance ten per cent) has an area of five square feet; if it receives 20 lumens, it has an average illumination of ______________________________.

5. A source of ten candelas has a total lumen output of ______________________________.

6. One square foot of a surface is normal to a light beam of two lumens; if the surface is rotated through an angle of 60 degrees, the average illumination would be ______________________________.

7. A surface has an average luminance of 100 footlamberts and a reflectance of ten per cent; it has an average illumination of ______________________________.

8. A point source of 100 candelas is six feet above and eight feet to the left of a point; the horizontal illumination at the point is ______________________________.

9. A point source of 100 candelas is five feet from a point P; if the source is moved to a distance of ten feet from P, the luminous intensity of the source would be ______________________________.

10. A square foot surface (reflectance 20 per cent) receives 100 lumens; it has luminance of ______________________________.

TEST YOURSELF (ANSWERS)

Problems

1. $I = \phi/\omega = 1/2$ cd
2. $E = \phi/A = 4/2 = 2$ fc
3. $E = I/D^2 = 100/25 = 4$ fc
4. $E = \phi/A = 20/5 = 4$ fc
5. $F = I.\omega = (10)(4\pi) = 125.7$
6. $E_{60} = (\phi/A)(\cos 60) = (2/1)(0.5) = 1$ fc
7. $E = L/\rho = 100/0.1 = 1000$ fc
8. $E_H = (I/D^2)(\cos\theta) = (100/100)(6/10) = 0.6$ fc
9. 100 cd (candlepower does not change with distance.)
10. $L = \rho E = (\rho)(\phi/A) = (0.20)(100/1) = 20$ fL

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IES Lighting Handbook, Fifth Edition, Illuminating Engineering Society, 345 E. 47th St., New York, NY 10017, 1972.

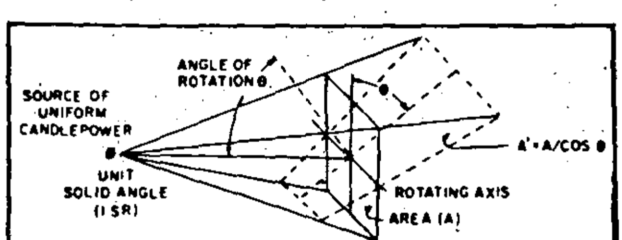


Fig. 2-5. Cosine law and average illumination. Note that the planes are flat rather than spherical and the illumination on every point on either flat plane varies; hence, the illumination is said to be average illumination. $E_{avg} = \phi/A$. $E'_{avg} = \phi/A' = (\phi/A)(\cos\theta)$.

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

CURSOS ABIERTOS

ILUMINACION EXTERIOR:
PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

PRINCIPIOS DE CONTROL DE LA LUZ

PALACIO DE MINERIA

Palacio de Minería Calle de Tacuba 5 Primer piso Deleg. Cuauhtémoc 06000 México, D.F. Tel.: 521-40-20 Apdo. Postal M-2285

PRINCIPLES OF LIGHT CONTROL 3

General

Light control may be provided in a number of ways, all of which are applications of one or more of the following phenomena: reflection, refraction, diffusion, and absorption.

Reflection

Reflection is the process by which a part of the light falling on a medium leaves that medium from the incident side. Reflection may be specular, spread, diffuse, or compound, and selective or nonselective. Reflection from the front of a glass plate is called "first-surface reflection," and that from the back, "second-surface reflection." Refraction, diffusion, and absorption by supporting media are avoided in first surface reflectors.

1. Specular Reflection. If a surface is polished, it reflects specularly; that is, the angle between the reflected ray and the normal to the surface will equal the angle between the incident ray and the normal as shown in Fig. 3-1. If two or more rays are reflected, these may form a virtual, erect, or inverted image of the source. A lateral reversal of the image occurs when an object is reflected in an odd number of plane mirrors.

2. Specular Reflectors. Examples of specular reflectors are:

   a. Polished and electroplated metals, such as gold or copper, and first-surface silvered glass or plastic mirrors. Inside-aluminized, sealed-beam lamps utilize first-surface reflectors in which the incident light strikes the thin metal reflecting surface without passing through the glass, as shown in Fig. 3-2b.

   Light reflected from the upper surface of a glass plate, as in Figs. 3-2a and 3-2c, also is an example of first-surface reflection. As shown in Fig. 3-3, less than 10 percent of the incident light is reflected at the first surface unless it strikes the surface at wide angles from the normal. The sheen of silk and the shine from smooth or coated paper are images of light sources reflected in the first surface.

b. <u>Rear-Surface Mirrors</u>. Some light, the quantity depending on the incident angle, is reflected by the first surface. The rest goes through to the silvered backing and is reflected back through the glass, as shown in Fig. 3-2c, parallel to the ray reflected by the first surface.

c. <u>Reflection from Regular Curved Surfaces</u>. Fig. 3-4 shows the reflection of a beam of light by a concave surface and by a convex surface. A ray of light striking the surface at "T" obeys the law of reflection, and by taking each ray separately, the paths of the reflected rays may be constructed.

In the case of parallel rays reflected from a concave surface, all the rays can be directed through a common point "F" by properly designing the curvature of the surface. This is called the <u>focal point</u>. The <u>focal length</u> is "f" (FA).

d. <u>Spread Reflection</u>. If a surface is figured in any way (corrugated, deeply etched, or hammered) it spreads any rays it reflects; that is, a pencil of incident rays is spread out into a cone of reflected rays, as shown in Fig. 3-5b.

e. <u>Spread Reflectors</u>. Depolished metals and similar surfaces reflect individual rays at slightly different angles but all in the same general direction. These are used where smooth beam and moderate control are required.

Corrugated, brushed, dimpled, etched, or pebbled surfaces consist of small specular surfaces in irregular planes. Brushing the surface spreads the image at right angles to the brushing. Pebbled, lightly hammered, or etched surfaces produce a random patch of highlights. These are used where beams free from striations and filament images are required; widely used for sparkling displays.

f. <u>Diffuse Reflection</u>. If a material has a rough surface or is composed of minute crystals or pigment particles, the reflection is diffuse. Each single ray falling on an infinitesimal particle obeys the law of reflection, but as the surfaces of the particle are in different planes, they reflect the light at many angles, as shown in Fig. 3-5c.

g. <u>Diffuse Reflectors</u>. Flat paints and other matte finishes and materials reflect at all angles and exhibit little directional control. These are used where wide distribution of light is desired.

h. Compound Reflection. Most common materials are compound reflectors and exhibit all three reflection components (specular, spread, and diffuse). In some, one or two components predominate, as shown in Fig. 3-8. Specular and narrowly spread reflection (usually surface reflection) cause the "sheep" on etched or embossed aluminum and semi-gloss paint.

i. Diffuse-Specular Reflectors. Porcelain enamel, glossy synthetic finishes, and other surfaces with a shiny transparent finish over a matte base exhibit no directional control except for the specularly reflected ray that is shown in Fig. 3-8a which usually amounts to from 5 to 15 percent of the incident light.

j. Circular Contour--Cylindrical and Spherical. These reflectors assume a focal point or line at a center of radius, with the reflector surface at equal distances from the focal point or line. Light emitted from a source located at the focal point or line will be reflected back through the same point. The cylindrical reflector has a flat dimension parallel to the axis of the focal line and a circular contour on a plan perpendicular to the axis. The spherical reflector has a circular contour in any plane intersecting the focal point.

k. Parabolic Contour. The parabolic reflector has the property that reflects light emitted from the focal point back along a direction parallel to the axis of the parabola. The parabolic reflector has a contour that is a parabola on a plane parallel to and intersecting its axis.

l. Other Reflectors--Combinations. When the contour of the reflecting surface follows the path of an ellipse of a hyperbolic reflector, respectively, both of these reflectors will produce a diverging beam of greater or lesser width, depending on position of the light source along the reflector axis.

Combinations of the above basic reflector shapes (which can be calculated mathematically) can be combined to produce a more complex, but predictable light-redirecting function to produce beams of different characteristics and lumen content. A complex contour, not easily calculated, can be determined by graphically working backwards from an approximate required candlepower distribution curve.

In all of these cases a true point source of light flux and a truly specular surface are assumed. Departures from true specularity, or an increase in the size of the light source, will have the effect of smoothing out or rounding off the final distribution curve. This will increase as the proportion of diffuse reflection component to the total increases or as the light source size increases in proportion to the size of the reflector.

m. Total Reflection. Total reflection of a light ray at a surface of a transmitting medium (see Fig. 3-9) occurs when the angle of incidence (i) exceeds a certain value such that its sine equals or exceeds n_2/n_1. If the index of refraction of the first medium (n_1) is greater than that of the second medium (n_2), sin "r" will become unity when sin "i" is equal to n_2/n_1. At angles of incidence greater than this critical angle (l_c), the incident rays are reflected totally, as in Fig. 3-9. In glass, total reflection occurs whenever sin "i" is greater than 0.66--that is, for all angles of incidence greater than 41.8 degrees (glass to air). Both edge lighting and efficient light transmission through rods and tubes are examples of total reflection.

When light, passing through air, strikes a piece of ordinary glass (n_2/n_1=1.5) normal to its surface, about 4 percent is reflected from the upper surface and about 3 or 4 percent from the lower surface. Approximately 85 to 90 percent of the light is transmitted and 2 to 8 percent absorbed. The proportion of reflected light increases as the angle of incidence is increased. See Fig. 3-3.

n. Reflection Factor--Reflectance--Coefficient of Reflection. A reflection factor is the number representing the ratio between reflected brightness (footlamberts) and incident illumination (footcandles). Practically all surfaces have both a specular reflectance component and a diffuse component. Therefore, the combined reflectance or reflection factor also depends on the direction of incident light and the direction at which the reflected flux is measured.

This is particularly important in roadway lighting applications where there is a relatively high specular component of pavement surfaces (this can be true with either asphalt or concrete pavements). When observed at the low grazing angles of the motorist's position on the roadway, a high pavement brightness condition is observed when illuminated by high emission angle light flux projected to the roadway at near grazing angles.

Because of this directional aspect, the reflectance characteristics of roadway surfaces must be represented by curves relating the reflection factor to the angle of emission and observation rather than by a single factor.

Every surface absorbs some of the light flux it receives. The overall percent reflected or coefficient of reflection varies greatly with different materials. The total reflectances or reflection coefficients of some common materials are shown in Table 3-1.

3. Refraction. When a light ray passes from a transparent medium of one density into a medium of another density, the light ray is bent. This is due to the change in velocity of light which varies as the optical density of the medium changes when, passing into a medium of greater density (such as glass, plastic, or water) the velocity is reduced and the light ray is bent towards the normal to the entering surface, as in Fig. 3-10a.

When the light ray enters a medium of lesser optical density (such as air), the velocity is increased and the light ray is bent away from the normal to the surface, as in Fig. 3-10b.

The law of refraction (Snell's law) states:

$$n_1 \sin i = n_2 \sin r$$

where

n_1 = the index of refraction of the first medium

i = the angle of the incident ray with the normal to the surface

n_2 = the index of refraction of the second medium

r = the angle the bent ray of light takes with the normal to the surface

If the first medium is air (usually the case with lighting equipment), the index of refraction is assumed to be 1.0. (Actually, this is the index of a vacuum with the index for air being in the neighborhood of 1.000293, depending on wave length of the light ray.) The formula then is:

$$\sin i = n_2 \sin r$$

If a ray of light is passed through a piece of clear glass with parallel faces, the light ray emerges from the glass in the same direction as the entering ray, as shown in Fig. 3-11.

a. Refraction by Prisms. If the two surfaces of the glass (or plastic) are not parallel, as in a typical prism, then the emerging ray of light is bent into a different direction than the entering ray, following the law of refraction stated before. Some typical examples of prismatic action on a light ray are illustrated in Fig. 3-12 a, b, and c.

b. Reflection by Prisms. As shown in Fig. 3-10b, when a light ray enters a rarefied medium, as when emerging from glass to air, the angle of refraction (r) is greater than the angle of incidence (i). If the incident angle increases, the refraction angle also increases until it reaches a maximum of 90 degrees. At this point the emerging ray lies in the surface of the medium; it does not escape into the rarefied medium. Beyond this angle the ray is reflected back into the denser medium, following the rule for surface reflection, angle "r" = angle "i". The angle at which internal reflection takes place is called the "critical angle," and its value depends upon the index of refraction (n) for the particular medium in which it occurs. Representative values are:

Water - Critical angle = 48.6 degrees (n = 1.33)

Crown glass - Critical angle = 42.1 degrees (n = 1.51)

Flint glass - Critical angle = 34.7 degrees (n = 1.75)

Figs. 3-13a and b show the bending of the incident ray by 90 and 180 degrees, respectively, by the process of internal reflection. In each case the incident ray within the glass right-angle prism strikes the inner surface at an angle of 45 degrees, and hence results in reflection. There are many practical applications of reflecting prisms in common use, in prism binoculars, for example, and in reflecting roadway marking signals, as well as in prismatic glassware for the control of roadway lighting.

4. Lenses. A type of refraction, known as lens action, uses curved surfaces to produce gradual bending of rays of light. Lenses as such are not generally used in roadway illuminating equipment, but often the lens action may be used on a prism face instead of a flat surface as described in the next paragraph. Some simple lens actions are illustrated in Fig. 3-14. A plano-convex lens is shown in Fig. 3-15. The convex surface is so chosen that light rays from the light source will be bent into parallel rays.

Without altering the light ray bending characteristics, the convex surface can be regressed into small prismatic steps, as shown in Fig. 3-16. Each prism consists of two surfaces, the active or refracting surface and the intermediate surface (sometimes called a "riser"), which connects the two adjacent refracting surfaces. The riser is made inactive by arranging it to be parallel to the light rays within the glass. This is known as a Fresnel lens. Lenses of this type, of similar design except on curved sections and in combination with other prismatic configurations, are used extensively for lighting equipment.

Another type of prismatic action using curved surface prisms is the diffusing Blondel prism of flute. The action of spreading incident light into very wide angles is shown in Fig. 3-17.

Control by Transmission

1. Materials which transmit no light are called "opaque." They cast shadows when held in a beam of light, attesting to the fact that light ordinarily travels in straight lines. Opaque materials reflect some light and absorb the rest.

   A transparent material, one which transmits light without scattering, can be either clear or colored.

   a. A clear transparent material will pass the highest possible percentage of the light flux directed to its surface. Approximately 4 percent of the light will be lost due to surface reflections when the light rays enter, an additional 4 percent will be lost when the light rays leave the opposite surface, with perhaps as much as 1 percent lost in absorption within the medium itself--the total loss being approximately 9 percent. (Special surface coatings can be applied that will reduce surface reflections and thereby increase the transmission. This type of coating is extensively used in precise optical instruments.)

   b. A colored transparent material, while having no scatter effect, does reduce transmission selectively in the spectrum, absorbing some wave lengths and passing others in varying percentages, producing what is known as a filter action. The color of light rays actually seen through a filter depends on both the nature of the filter and the spectral characteristic of the illuminant providing the light flux.

      An enclosing medium of more or less transparency is sometimes used in an outdoor lighting fixture, as a protection from the weather and from insects or dirt infiltration. No optical control of light is intended when the enclosure is transparent and colorless. Transparent and colorless material does exhibit control characteristics when one or both surfaces are roughened or configurated, as in the form of prisms or other contours which redirect and/or diffuse the light into desirable patterns. Wide use of refracting glassware and plastics in street lighting warrants special emphasis, as will be found elsewhere in this chapter under "Control by Refraction."

   c. A translucent material is one that transmits light so that it is emitted in a diffuse, scattered or non-image-forming condition. It can be produced by suspending a scattering or absorbing material within the transmitting medium or by treating the surface of the medium in some manner.

Translucent materials generally are considered to be those that contain a colored or white scattering and/or absorbing pigment or substance as part of the material. Depending on the nature of the mixture, more or less light is transmitted and a large portion of that not transmitted is reflected back from the material. The more diffusing the material, the more hiding power it has, but also the more light it will absorb or reflect. Different compositions of translucent materials will produce varying degrees of spread or diffuse transmission and/or reflection.

d. Surface-treated materials can be in the form of frosted, etched, sand-blasted, configurated, or prismatic types. While these generally are not as highly diffusing as the pigmented variety (except in the special case of prismatic diffusion), they do permit higher transmission. This surface treatment can be applied to colored materials as well as clear, although the latter is by far the most common.

As in the case of reflectance, transparent and translucent materials vary widely in the degree of light transmitted or absorbed, and in the resulting pattern of emission. Several types of transmission are generally recognized.

e. Regular transmission takes place in clear glass, or other transparent media. A ray of light entering the medium at right angles to the surface continues through the material with no change of direction, and no scattering or dispersion. If the ray enters the medium at an angle with the surface less than 90 degrees, it will be bent by the process of "refraction" while passing through the medium, but will be bent back to its original direction upon emergency, provided both surfaces of the medium are parallel. In regular transmission, as in regular reflection, emerging rays retain their relative position, making it possible to "see through" the material. See Fig. 3-18, "Regular transmission."

f. Diffuse transmission occurs in translucent material such as white or opal glass. Rays of light are scattered in all directions by particles or pigments dispersed throughout the medium. Total, "perfect" diffusion follows a particular pattern in accordance with "Lambert's Cosine Law of Emission." See Fig. 3-19 for a graphic representation of Lambert's Law.

g. Spread transmission occurs when the translucent medium is of a relatively light density white or opal glass, for example. The result is retention of some directivity of the incident ray, but with a spreading out of the pattern, the maximum candlepower of which is parallel to the incident ray. Frosted or acid-etched glass if sufficiently heavy, may produce spread transmission. See Fig. 3-20.

h. Mixed transmission occurs with still lighter density media, or with configurated surface material of high transparency. In this case the emerging pattern combines a diffuse or spread component with a component of regular transmission, a characteristic of certain types of pebbled, rippled, or configurated surfaces of otherwise clear glass or plastic. See Fig. 3-21.

2. Transmission Factors - Transmittance. A transmission factor is the ratio of transmitted light flux to the incident light flux. This generally is assumed to be total transmittance, although diffuse, regular, and spectral components can be measured. Some typical transmission factors are listed in Table 3-2.

Figures shown in Table 3-2 are based on the thickness of the material generally used for lighting purposes. The amount of light transmitted depends on thickness, particularly of the more opaque materials.

Control by Absorption

Because the process of absorption represents a loss of light, we do not think of it as a tool for "control" of light except in certain limited applications. For example, selective absorption of light finds practical application when it is desired to change the color of light from a particular source. Common examples are the use of colored lenses or filters for signal lights, and for theatrical or display lighting. A limited application in roadway lighting is the use of colored glass or plastic enclosures to produce a golden yellow "cautionary" color in the emitted light.

Practical Applications of Light Control in Roadway Lighting Equipment

1. Luminaire Optical Designs

a. Control by Reflector Only: Luminaires having control of light by reflector only, have been built both without any closure, and also with a transparent flat or contoured enclosure.

The problem with vertical source luminaires has been that, as shown by Figure 3-22, as the angle of beam maximum is increased the amount of light available from the reflector for beam direction drops off drastically. With a horizontal type luminaire it is possible to compensate for this by extending the luminaire in a horizontal plane as shown in Figure 3-24 to obtain satisfactory short and medium distributions.

As can also be seen from Figure 3-24, lateral control of light from a reflector-only optical system depends upon its lateral contour, specular or diffuse reflecting surface, and upon the lateral positioning of the light source within the reflector. In order to concentrate as much flux as possible in directions up and down the roadway, the reflector will have a generally parabolic section on either side. Theoretically these parabolic sections could extend and close at either end on each other in a point, but as a practical matter they are generally joined each end with some sort of curved sections. Offsecting the light source effects some control of the lateral emission angle as shown in 3-24. The main advantage of a reflector only and reflector with a flat lens or flat plate optical system is to permit very sharp cut-off above the main beam with very little light emitted above the beam and complete cut-off at horizontal.

b. Diffusers. Luminaires consisting of diffusers along have limited application in roadway lighting except for special areas where architectural style trends have been the dominant factor in ruling out conventional roadway luminaire designs. The function of the diffuser, from an engineering viewpoint, is to reduce the brightness or glare from today's light source. Its effectiveness is a function of optical density, or obscuring power, and of its physical size. A larger globe, for a given size of lamp, results in lower brightness per square inch of surface. With high quality diffusers, this can be accomplished with efficiencies as high as 80 percent. By their very nature, however, diffusers militate against concentration of light in asymmetric patterns; hence, they are ineffective in controlling vertical or lateral light distribution in the usual sense.

c. Refractors. Unlike the reflector-type luminaire, the refractor can be designed to entirely surround the lamps, thus making it possible to control a relatively high percentage of the available lamp lumens. Practical refractors, in glass or in plastic, rely upon refracting and reflecting prisms in the surface to collect a major portion of the light flux and redirect it vertically and laterally, as required to meet a preconceived distribution pattern.

As in the case of reflectors, the refractor is also sensitive to lamp type and size as well as to the position of the light source within the refractor. Phosphor-coated mercury lamps will produce a broad distribution as compared to a clear mercury lamp, and the maximum candlepower may be markedly reduced. Likewise, a shift in lamp position vertically will raise or lower the angle of emission; a shift laterally will cause a shift in the lateral angle of emission. These effects are utilized in practice to meet varying needs with a minimum of equipment types.

Figure 3-23 illustrates the effect of lamp position on vertical emission from a refracting globe. The use of refractors alone for roadway lighting has long been superseded by the reflector-refractor type, but a modern version with an open bottom has found wide acceptance for rural and residential areas as a replacement for the obsolete radial-wave reflector. Figure 3-25 shows a section of such a refractor. Vertical control prisms are formed in the exterior as shown in the elevation. The plan view shows lateral control prisms on the interior surface, producing an asymmetric, ANSI Type I distribution.

d. Reflector-Refractor Combinations. The luminaires in general use today combine the effective shielding of the reflector with the unique control features of the refractor. A most important feature of these luminaires is that the reflector and refractor are designed to work together as a complete optical system. Certain models of such systems have the reflector and refractor spun together to make a tight seal. See Figure 3-26, but generally the Refractor is held in a door.

In modern versions of the reflector-refractor type for mercury and other metallic vapor sources, the lamp is generally placed in a near horizontal position. Reflector contours are carefully shaped to redirect the upward light to the refractor bowl where the prisms take over the function of elevating or depressing the beam, and by shaping the lateral pattern of emission to meet a particular ANSI standard type. Figure 3-27 illustrates the control features of a typical oval-shaped reflector-refractor luminaire designed for mercury vapor lamps.

e. Influence of Light Source Dimensions. The degree of precise optical control attainable depends on the physical dimensions of the source, and the limiting dimensions of practical reflector-refractor combinations. All practical light sources have finite dimensions; they are not "point sources," which form the basis for many optical system designs. The effect of such practical sources is to broaden the distribution pattern as compared to that attainable with a point source. Such a broadening is advantageous to the extent that it may eliminate striations, or unevenness of the light which reaches the pavement.

The trend to gaseous sources, and particularly the use of phosphor-coated lamps, aggravates the control problem, and complicates the design of luminaires. By making the reflectors and refractors as large as possible, acceptable control can be achieved. As mentioned elsewhere, the distribution pattern from a particular luminaire depends upon the particular lamp used and upon its position in the optical system.

Questions:

1. Almost every street luminaire uses the principle of "reflection" of light. How?

2. What "type of reflection" or "degree of Specularity" is most generally used?

3. Mention is made in the chapter of "true point sources." Name one.

4. Refraction is the bending of light with prisms. How much can a light ray be bent?

Answers:

1. The most common luminaires of "ovates" employ a "reflector" above the lamp to: a) redirect the light to a generally downward direction, and b) to form a "beam" or concentration of parallel light to provide the "punch" to light remote areas on the street.

   Another use of "reflection" employed in most street luminaires is the house-side "shielding" section of the refractor which utilizes totally internally- reflecting prisms to redirect unwanted "house-side" light back to useful directions.

2. To concentrate light into a "beam" requires specular or near-specular material. This is generally obtained by using a "reflector-sheet grade of aluminum, then chemically or electrically brightening and anodizing. Occasionally non-compound curvature reflectors will be fabricated from pre-finished specular "lighting sheet."

3. There is really no such thing as a "true point source" for street and highway lighting. (Short-Arc Xenon lamps come closest such as those used in theatre projection and Solar simulators, but they are completely impractical for street-lighting.) The term usually means a short line source such as clear mercury or metal halide, or high pressure sodium where the arc stream is perhaps 1/8" to 1/4" in diameter and from say 1 1/2" to several inches long.

4. The limitation of how much a light ray can be bent by refraction is usually dictated by the "sharpness" or how small the miter of the prism can be in the molding equipment. As a practical matter light can be bent by straight refraction about 45° maximum. By manipulating the prismatic structure so one face reflects internally and the second face of the prism refracts, light can be bent as much as perhaps 90° but a greatly reduced efficiency.

FIGURES

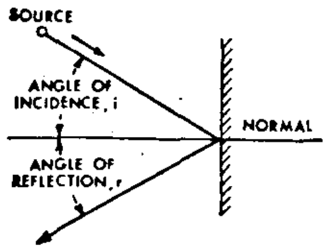


Fig. 3-1. The law of reflection states that the angle of incidence i = angle of reflection r.

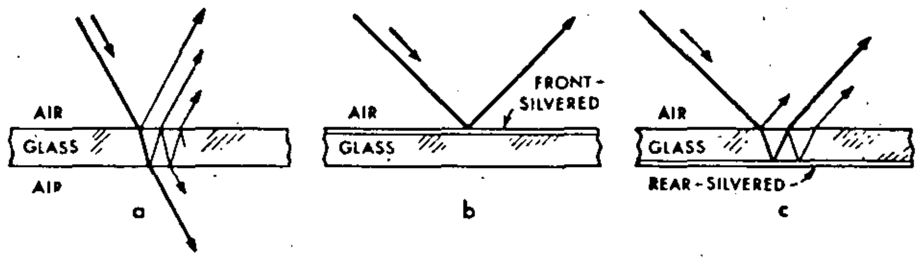


Fig. 3-2. Reflections from (a) clear plate glass and (b) from front and (c) rear silvered mirrors.

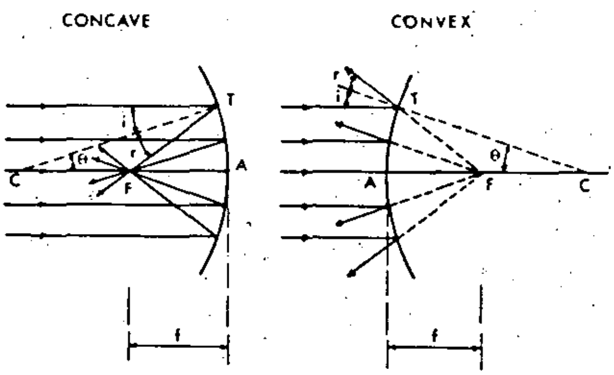


Fig. 3-4. Focal point and focal length of curved surfaces.

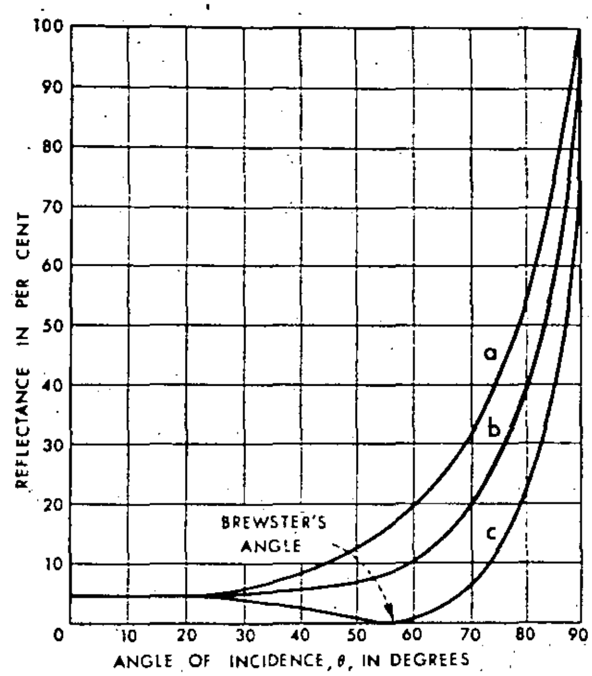


Fig. 3-3. Effect of angle of incidence and state of polarization on per cent of light reflected at an air-glass* surface: a. Light that is polarized in the plane of incidence. b. Nonpolarized light. c. Light that is polarized in plane perpendicular to plane of incidence.

*For spectacle crown glass, n = 1.523.

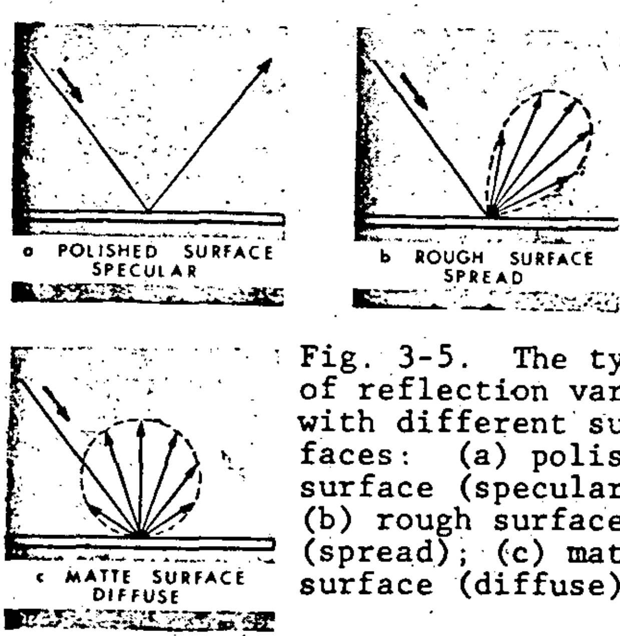


Fig. 3-5. The type of reflection varies with different surfaces: (a) polished surface (specular); (b) rough surface (spread); (c) matte surface (diffuse).

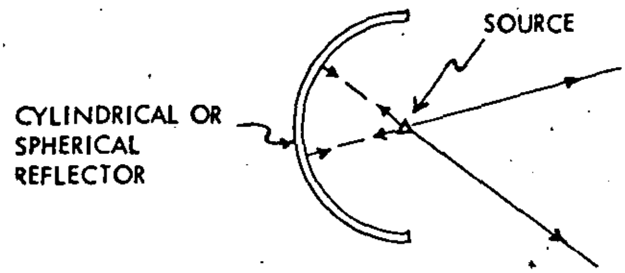


Fig. 3-6. Cylindrical or spherical reflector.

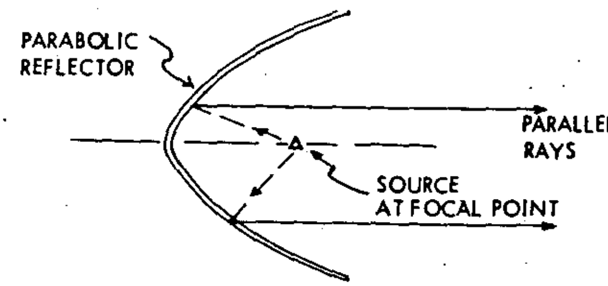
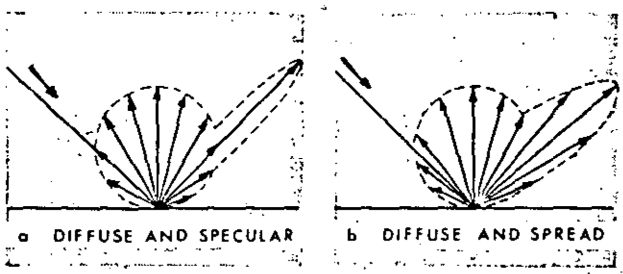


Fig. 3-7. Parabolic reflector.



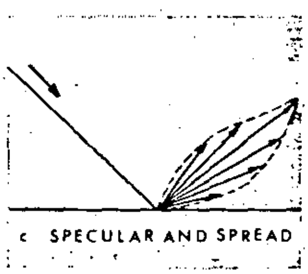


Fig. 3-8. Examples of compound reflection: (a) diffuse and specular; (b) diffuse and spread; (c) specular and spread.

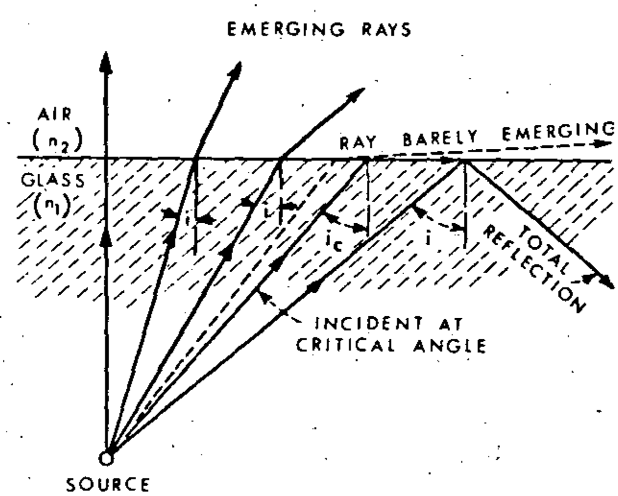


Fig. 3-9. Total reflection occurs when sin r = 1. The critical angle varies with the media.

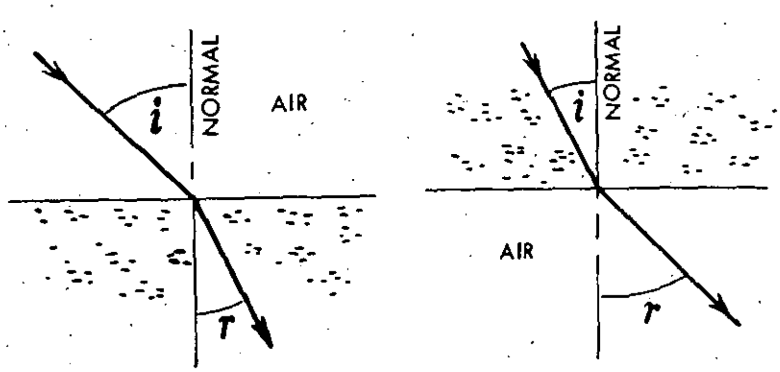


Fig. 3-10. (a and b) - Principles of refraction.

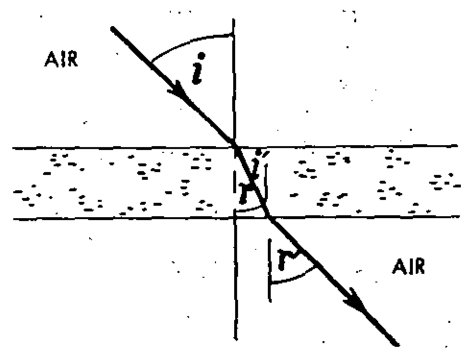


Fig. 3-11. Regular refraction

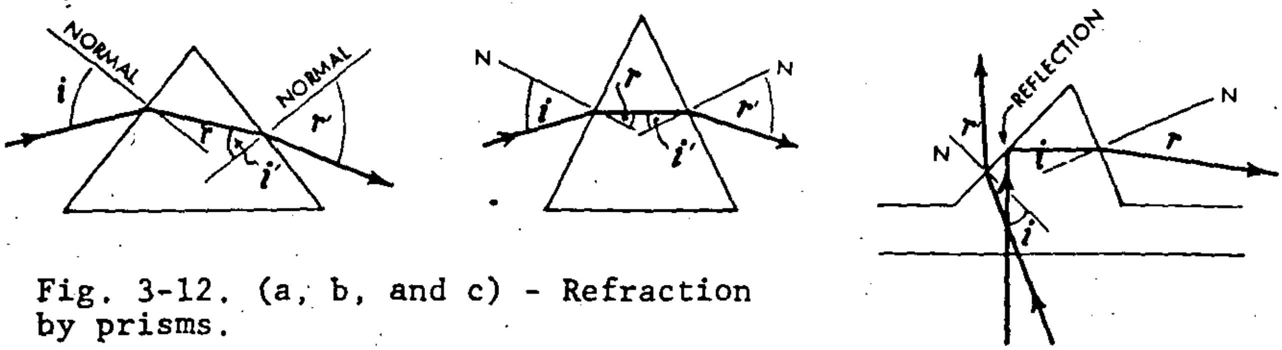


Fig. 3-12. (a, b, and c) - Refraction by prisms.

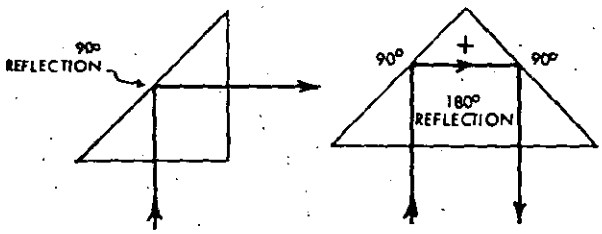


Fig. 3-13 (a and b) - Total reflection by prisms.

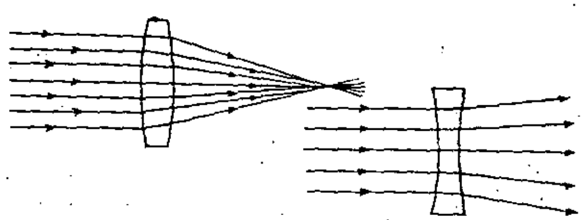


Fig. 3-14. Converging and diverging lens control.

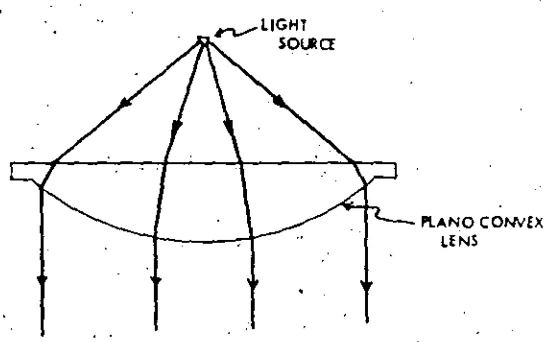


Fig. 3-15. Plane convex lens.

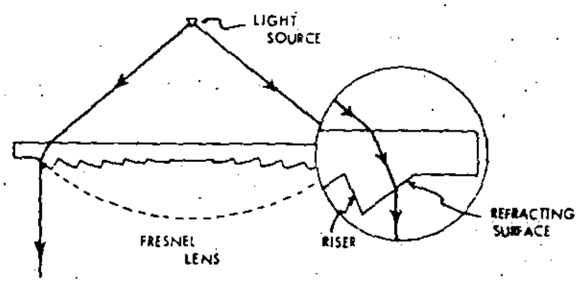


Fig. 3-16. Fresnel lens development

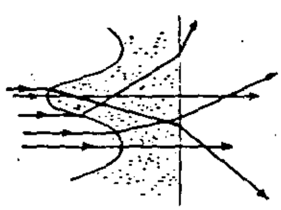


Fig. 3-17. Blondel diffusing prisms.

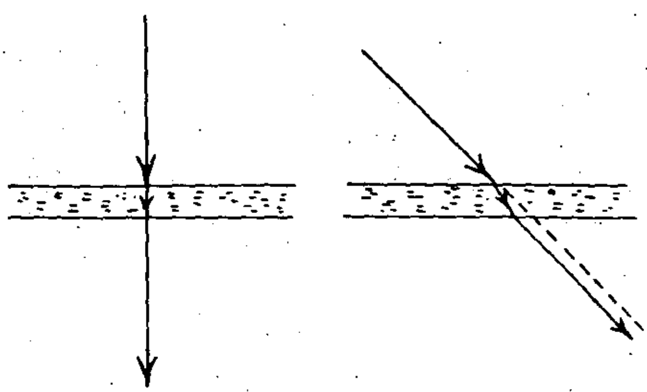


Fig. 3-18 (a and b) - Regular transmission.

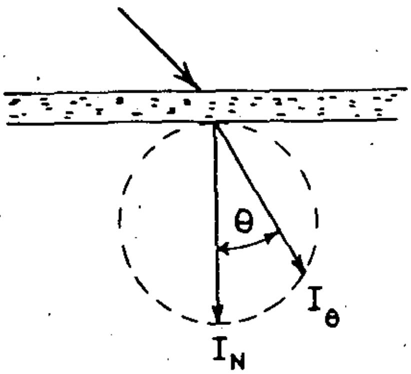


Fig. 3-19. Diffuse transmission.

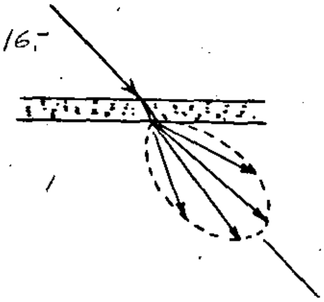


Fig. 3-20. Spread transmission.

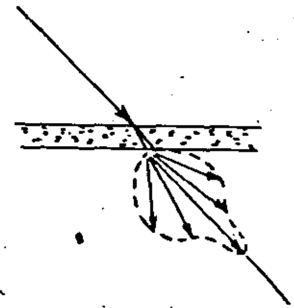


Fig. 3-21. Mixed transmission.

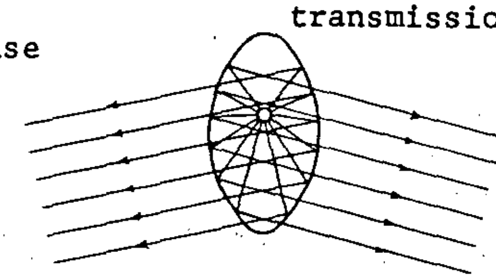


Fig. 3-24. Offset light center vs. lateral emission angle.

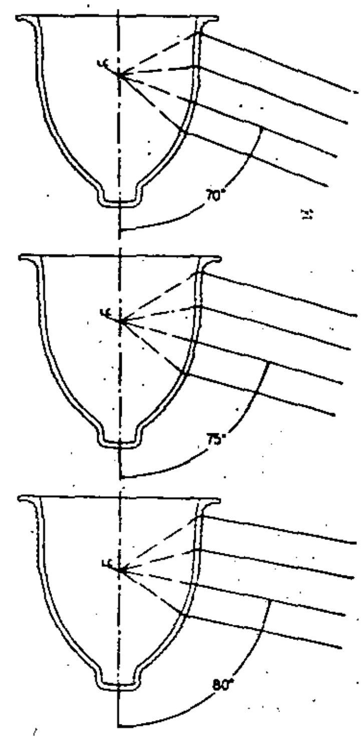


Fig. 3-23. Refractor light center vs. vertical emission angle.

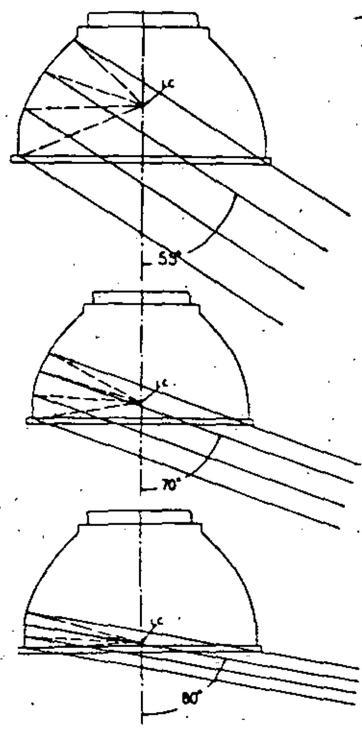


Fig. 3-22. Reflector light center vs. vertical emission angle.

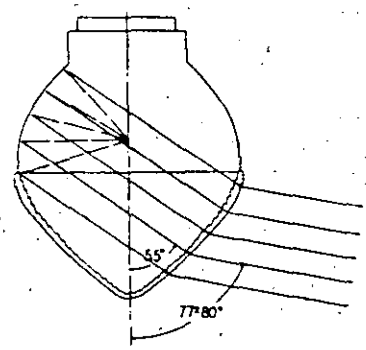


Fig. 3-26. Light control by modern relfector-refractor combination, vertical lamp position.

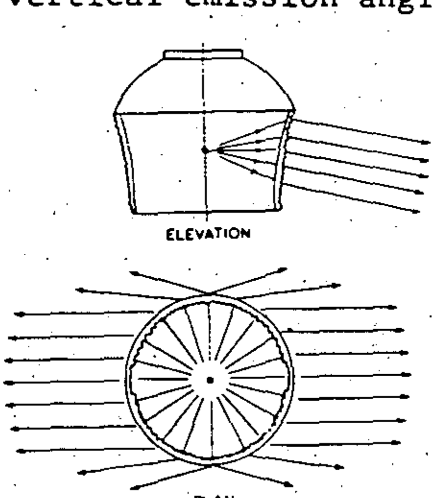


Fig. 3-25. Vertical and lateral control by street lighting refractor.

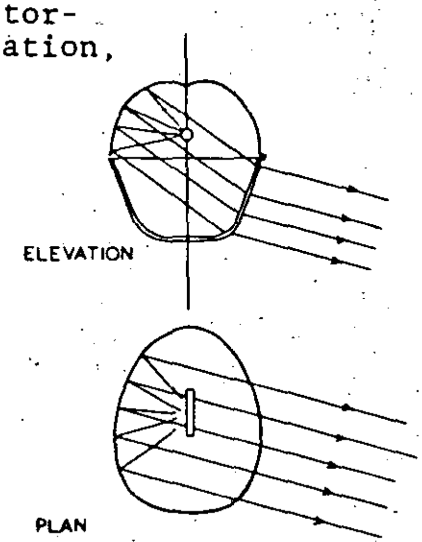


Fig. 3-27. Optical system for horizontal lamp position of gaseous discharge sources.

Tables

Table 3-1-Total Reflection Coefficients of Various Surfaces

Material	Reflectance
Highly polished silver	0.92
Glass lined mirrors	0.70 to 0.85
White blotting paper	0.82
Emerald green paper	0.18
Black paper	0.05
Dark blue suit	0.03
Dark blue overcoat	0.02
Light grey suit	0.11
Grey suit	0.07
Caucasian (male) face, front	0.30 to 0.50
Negroid (male) face, front	0.10 to 0.30
Roadway (total of specular and diffuse)	
Macadam	0.06 to 0.13
Concrete	0.08 to 0.15
Dirt and gravel	0.03 to 0.07
Black velvet	0.004

Table 3-2-Total Transmission Factors of Light-Transmitting Material

Material	Transmittance
Glass	
Clear transparent and prismatic	0.90–0.95
Configurated, etched, frosted and sandblasted	0.70–0.85
Opalescent and alabaster	0.55–0.80
Flashed (cased) opal	0.30–0.65
Solid opal	0.15–0.40
Plastics	
Depending on type	0–0.95

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

C U R S O S   A B I E R T O S

ILUMINACION EXTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

FOTOMETRIA

PALACIO DE MINERIA

PHOTOMETRY 4

OBJECTIVE

Photometry is the science of measuring light. Photometric data is the information needed to provide the engineer with the quality and quantity of light he requires to give the proper visibility and comfort in typical street lighting systems. Therefore, the objective of this lesson is to describe the general equipment and methods of reporting data that will promote the uniform evaluation of the optical performance of roadway luminaires.

EQUIPMENT

1. Luminaires. Luminaires selected for test should be representative of the manufacturer's typical product.

2. Lamps. Test lamps should be selected for close conformance to the manufacturer's design dimensions and construction, and seasoned in accordance with I.E.S. recommendations.

3. Gonio - Photometric Equipment

   a. Photometric equipment should be calibrated throughout the entire usable scale. Individual readings should be reproducible within a tolerance of plus or minus two percent. Angular settings or readings should be reproducible within plus or minus one degree. It should be noted that a tolerance of plus or minus two percent cannot be expected at a given angle without taking into account angular tolerance.

   b. Provision should be made for correct optical positioning of the luminaire in relation to the photometer axis, and for candlepower measurement at any angular setting in both horizontal and vertical directions. Provisions should be made for eliminating stray light and/or reflected light from the test setup.

4. Test Distance. For adequate accuracy in light measurements the test distance should be at least five times the largest dimension of the light emitting section of the luminaire.

5. Electrical Requirements

   a. Regulation of supply. Where luminaires are intended for multiple supply, supply voltage should not vary more than plus or minus one half of one percent during the test. For series supply, the current should be held within the same limits.

   b. Wave form of supply. The ac power should be such that the RMS summation of the harmonic component does not exceed three percent of the fundamental.

   c. Instruments. Instruments should have reproducibility of indication and large scale deflection for conditions under which they are used. Lamp current and wattage, depending upon type of light source, should be checked with a calibrated instrument with reproducibility of plus or minus one quarter of one percent. Instruments also should be free from frictional and/or heating errors. (See Section 6.1.1 of the "IES General Guide to Photometry.")

6. Temperature. A temperature of 25 °C ± 1 °C should be maintained in the laboratory during all tests. The air in the vicinity of the test luminaire should be free of drafts.

TEST PROCEDURE

1. Photometric Calibration. Calibration relates the light output of test lamps to an assigned lumen value.

2. Relative Method. From a practical standpoint the relative method is desirable because a calibrated photometric reference is not necessary. Final candlepower values are as if the test lamp is delivering designed lumens.

3. Direct Method.

   a. In the direct method both the test lamp and photometer should be calibrated against photometric standards. Lumen and candlepower standards are light sources which have been calibrated by a recognized standardizing laboratory. Lumen output or candlepower in a given direction is established.

   b. The test lamp should be calibrated in an integrating sphere (see fig. 4-1) for lumen output and on a bar photometer to establish directional candlepower.

   c. The photometer, photoelectric or visual type, should be calibrated against candlepower standard.

   d. The luminaire candlepower distribution should be read with a calibrated test lamp and a calibrated photometer.

4. Special Photometer Calibration.

   a. If it is desired to provide photometric data for optical performance of a luminaire using a specific ballast and lamp, the factor for the ballast must be obtained and entered into calibration. The report should include ballast information.

   b. Calibration of temperature sensitive lamps should be performed in still air at an ambient temperature of 25° C $\pm$ 1° C. The report should include ballast information and relative light output versus luminaire ambient temperature.

5. Positioning Luminaire. If the light center of the test lamp (If more than one lamp, the geometric center of the lamp light centers) is below the reflector opening, the luminaire should be mounted on the goniometer so that the light center of the lamp is at the goniometer center. If the lamp light center is above the reflector opening, the luminaire should be positioned so that the center of the reflector opening coincides with the goniometer center. It is also desired to keep the luminaire in a constant position during the test.

6. Light Source Positioning. If the lamp is not rotated inside the luminaire, the filament (or arc tube if mercury or sodium lamps) should be aligned and the position recorded in the test report. It is extremely important that arc discharge lamps be held in the same position throughout the test. A change in position will affect the lumen output of the lamp and therefore have a result on the lamp luminaire photometric data.

7. Cleaning. All glass, reflectors, and other optical parts should be thoroughly cleaned before any measurements are made unless the purpose of the test is to determine the effect of dirt on the luminaire.

8. Measurements. Sufficient candlepower values must be taken in each vertical plane or lateral plane to adequately describe the performance of a particular type of luminaire distribution. Many laboratories have incorporated the use of automatic recording equipment and data processing equipment to help speed up the preparation of photometric data.

LUMINAIRE CHARACTERISTICS

1. Luminous intensity distributions are taken along various surfaces. For the luninaire as an entity, an isocandela diagram is plotted and three methods of isocandela diagrams

are shown in figures 4-2a, 4-2b, and 4-2c. From this, all necessary information about a luminaire can be either read or calculated. The lines on the isocandela diagram are "curves traced on an imaginary sphere with the source at its center and joining all the points corresponding to those directions in which the luminous intensity is the same."

From this basic distribution of luminous intensity, several of the more commonly used distribution curves and tables are also plotted.

2. The vertical distribution of candlepower through the lateral angle of maximum candlepower is shown in figure 4-3.

3. The lateral distribution of candlepower through the cone of maximum candlepower is shown in figure 4-4.

4. Isolux curve is obtained by calculating the horizontal footcandle values from the candlepower values, by applying the inverse square law and the cosine law. Lines are then drawn thru points of equal footcandle values to produce the isofootcandle chart.

5. Luminous flux. Luminous flux measurements give a breakdown of light in quadrants: upward, downward, for both street and house sides of the luminaire, and the total. In addition to giving these values in lumens, they are also given in percent of bare lamp lumens. This represents the true efficiency of the luminaire in percent. (Figure 4-6)

6. Utilization curve. Utilization curves are available for various types of luminaires and afford a practical method for the determination of lumens per square foot (average footcandle) over the roadway surface where lamp size, mounting height, width of paved area and spacing between luminaires are known. Conversely, the desired spacing or any other unknown factor may readily be determined if the other factors are given. Figure 4-7 illustrates an example of a utilization curve of a typical luminaire. The utilization curve indicates how much light falls on the roadway in terms of "coefficient of utilization" reveals very little of the way in which the light is distributed.

7. Angles commonly used in roadway lighting are as follows:

   Vertically - 0 degrees at nadir
   90 degrees at horizontal
   180 degrees at Zenith

   Laterally - Measured clockwise viewing luminaire from above.
   0 degrees at right angle to curb toward street side.
   90 degrees parallel to curb.
   180 degrees at right angle to curb toward house side.
   270 degrees parallel to curb.

-5-

8. Mounting height correction factors (figure 4-16)

ROADWAY LIGHTING DISTRIBUTION CLASSIFICATIONS

1. General. Proper distribution of the light flux from the luminaires is one of the essential factors in efficient roadway lighting. In order to have a definite system of light distributions, the Illuminating Engineering Society Roadway Lighting Committee has established the following terminology to describe roadway lighting distributions. There are three general criteria used to describe distributions.

   a. Vertical light distributions.

   b. Lateral light distributions.

   c. Control of light distribution above the maximum candlepower.

2. Vertical Light Distribution

   a. Short distribution (figure 4-15)

   b. Medium distribution (figure 4-15)

   c. Long distribution (figure 4-15)

3. Lateral Light Distribution. The lateral light distributions are further clsssified into the following:

   a. Type I Distribution (figure 4-8)

   b. Type I way distribution (figure 4-9)

   c. Type II distribution (figure 4-10)

   d. Type II 4 way distribution (figure 4-11)

   e. Type III distribution (figure 4-12)

   f. Type IV distribution (figure 4-13)

   g. Type V distribution (figure 4-14)

4. Control of Light Distribution

   a. Cutoff distribution

   b. Semi-cutoff distribution

   c. No cutoff distribution

(Note: See the American Standard Practice for Roadway Lighting for specific limits for each light distribution.)

TEST REPORT

1. General. Test results should include the following. (A typical data sheet is shown in Figure 4-17).

2. Luminaire Description

   a. Manufacturer's name

   b. Catalog number and/or adequate description to identify.

   c. Dimensions to give a general idea of size.

   d. Light center location by dimensions, if necessary.

   e. Other essential information such as auxiliary reflecting devices.

   f. Goniometer center location with respect to luminaire.

   g. Test distance.

3. Lamp description. ANSI type service and designation rating in watts, volts, or amps and lumens.

   a. Bulb shape and base type.

   b. Filament construction and light center length lamp.

   c. Rotation speed.

   d. Location of support rods of lamp.

4. Photometer Data. Sufficient data to permit classifying light distribution in accordance with the latest ANSI/IES recommended practice.

   a. Isolux diagram (isofootcandles) (see Figure 4-4)

   b. Utilization efficiency (See Figure 4-6)

   c. Four quadrant efficiencies (See Figure 4-5)

   d. Curve or table of values for relative light output.

   e. Mounting height conversion factors (Figure 4-16)

5. Optional information

   a. A complete isocandela diagram.

b. Curve or table of relative light output when luminaire uses a lamp and ballast combination.

FIELD MEASUREMENTS

1. General. Field measurements are extremely useful in demonstrating the effectiveness of a good lighting design. The measurements will clearly indicate what the footcandles are on the roadway and whether the maximum to minimum light ratios have not been exceeded, etc. The field readings can be used for an effective before and after story or how dirt accumulation affects footcandle levels. The "IES Guide for Outdoor Illumination Tests"* should be followed for meaningful results. (Note: The observer should avoid wearing light colored clothing so that no light rays are reflected from the clothing and into the footcandle meter. Extreme care should be taken so that only direct light rays are recorded.)

2. Footcandle meters of various size are shown in figure 4-18.

3. Luminance meters are shown in figure 4-19.

4. Quantities measured. The illumination characteristics are described in terms of illumination in footcandles from luminaires at specified mounting heights and spacing arrangements. The illumination on a horizontal plane is always measured, and in some installations measurements on vertical planes may be needed in addition.

5. Conditions of test

   a. The test stations should be located so that the test results represent the effective illumination. Suggested test-station locations for typical street lighting illumination tests are given in Figs. 4-21 and 4-22.

   b. If the test is made for the purpose of checking the performance of the installation after depreciation in service, the condition of the luminaires and lamps should be noted; the number of hours the lamps have burned and the current, voltage or wattage supplied to the individual lamps should be determined or estimated. Otherwise, the luminaires should be cleaned, new lamps (preferably seasoned and rated) installed, and both lamps and luminaires properly adjusted. If improvement due to cleaning is to be determined, measurements should be made both before and after cleaning.

   c. Discharge lamps should be operated for at least a half-hour to reach normal operating temperature before measurements are made.

*Reprinted from August 1951, Illuminating Engineering.

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d. Test should be made when the atmosphere is clear, during the dark of the moon, and when extraneous light is at a minimum. Suggestions for making tests when these conditions can not be realized are contained in Appendix A.

6. Test Equipment

   a. Test Surface-Regardless of whether the photometer is of the visual or photoelectric type, the test surface should be accurately leveled. For accurate results a test plate or photoelectric cell compensated for departures from the cosine law must be used.

   b. Use of Filters- If a visual photometer is used, any existing color differences should be minimized by filters, and proper allowances made for their absorption. This is especially important where the illumination to be measured is from mercury and sodium vapor lamps. When possible it is best to calibrate visual photometers with neutral range-changing filters in place. Where photoelectric photometers are used, correction may be made with color filters so that the spectral response of the system follows the standard (CIE) spectral luminous efficiency curve within practicable limits. The proper multiplying factors for use with uncorrected cells may be obtained from the photometer manufacturer but for maximum accuracy should be determined by separate laboratory test on the particular cell employed.

   c. Electrical Instruments - All instruments should have good reproducibility of indication and large scale deflections for the values that are to be read.

   d. Photometers - Visual photometers with a split field are preferable to those with a concentric field. (See Appendix A.)

7. Test Procedure - Use a recently calibrated photometer and in the case of visual photometers check the comparison lamp current (or voltage) at each reading station throughout the test (see Appendix A). Several readings should be taken at each station and the average recorded. Repeat readings at the first test station at the middle and end of the test. Photoelectric photometer readings should be reproducible within 5 per cent; visual photometer readings within 10 per cent. Keep the electrical operating conditions of the lighting equipment as near to rated values as possible throughout the test.

8. Test Report. The test report should present the significant data in a manner that will permit further derivation of useful information. It is recommended that the items listed below be included.

a. Description of installation and conditions

(1) Location (city, street and section thereof, alley, pathway, bikeway, date, etc.).
(2) Description of lamps luminaires, floodlights or projectors.
(3) Mounting height, spacing and arrangement. (For street and highway lighting include overhang and in the case of steep hills or streets record the grade. If foliage interferes with the illumination at any test station, so note and give an estimate of the extent of such interference.)
(4) Diagram showing test stations.
(5) Electrical operating conditions.
(6) Condition of luminaires and other accessories.
(7) Describe environment, particularly any extraneous light sources which could not be controlled, weather and sky conditions, location and reflectance of buildings influencing lighting.
(8) Describe environment as to surrounding dirt. The adjacent atmosphere is the product of the effect of the contributions from the neighborhood, such as an asphalt plant, open dirt areas, heavy or light industry - in fact, any sources that can supply contamination to the air that will get to the luminaire. The second source of dirt is the surrounding atmosphere that comes from the roadway itself. This surrounding atmosphere, as well as the adjacent atmosphere, may be intermittent but being effected by the roadway, is more critical. Careful analysis of the roadway, what dirt that may be on it, and what vehicles use it, is very important. Inert, adhesive, and attracted dirt generated by small to large moving objects and other air movements can make it difficult to evaluate conditions under which the lighting system will operate.

b. Photometric Data

(1) Tabulation of test data.
(2) Tabulation of special measurements taken.
(3) For street lighting record the ratio of maximum and minimum to average horizontal illumination.
(4) Horizontal or vertical illumination. Record height of test plate above surface of street or field. For vertical illumination record orientation of test plate.
(5) Manufacturer's name and model of visual or photoelectric photometer used.

LOCATION OF TEST STATIONS FOR STREET AND HIGHWAYS

1. General.

   a. Test stations should be systematically chosen in such manner as to represent correctly the illumination pattern. The test span should be divided into an even number of equal rectangular test areas, the luminaires being over the intersection of boundary lines of such areas rather than over the centers of the areas. Footcandle readings are taken at centers of the test areas. The mean for the entire surface can be computed from the average horizontal illumination for test stations so disposed if sufficient number is selected. Enough stations should be chosen so that additional readings in similarly distributed locations will not change the average results significantly. The test plate should be not more than six inches above the street surface.

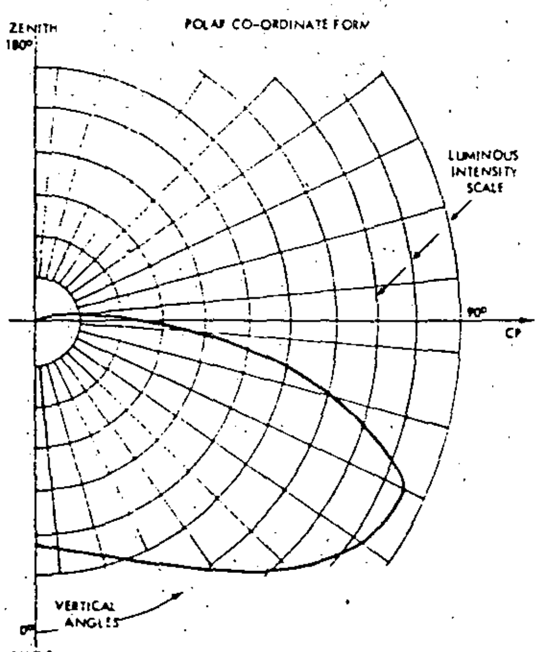
   b. Typical arrangements of street lighting luminaires and test stations are shown in Figs. 4-21 and 4-22. Fig. 4-22 shows typical survey charts. Fig. 4-21 is a photograph with test stations plotted on the surface.

   c. Only the readings taken at the basic test stations should be used in the calculation of the average values. However, other measurements may be taken at points of special significance, such as along the curb line and center line, half-way between or immediately under luminaires, or at points where a maximum or minimum intensity is anticipated. Where illumination on the sidewalks is important (as on residential streets) a row of test stations should be located along the sidewalk. Readings taken opposite each luminaire aid in plotting isolux curves and also give additional data where the illumination is changing most rapidly.

2. Crosswise. It is advisable to locate the stations in the centers of the traffic lanes. For this purpose, a traffic lane is considered to be approximately 10 feet wide. (For example, a 36-foot roadway is considered as 4 lanes.)

3. Lengthwise. Divide the distance between luminaires into an even number of divisions (approximately ten-foot intervals are suggested); take a reading in the middle of each rectangle thus formed.

Fig. 4-1. Three-meter-diameter spherical photometer in back of engineer holding 8-foot fluorescent lamp.



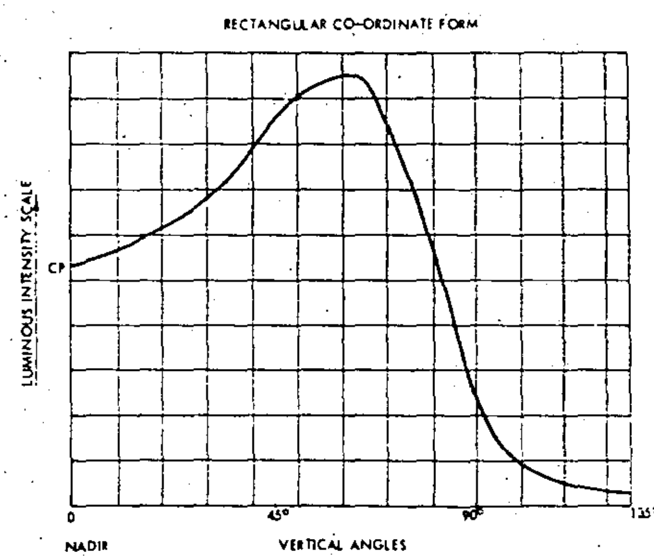


Fig. 4-3. (Left and above)-Two methods of presentation of candlepower distribution data in a vertical plane.

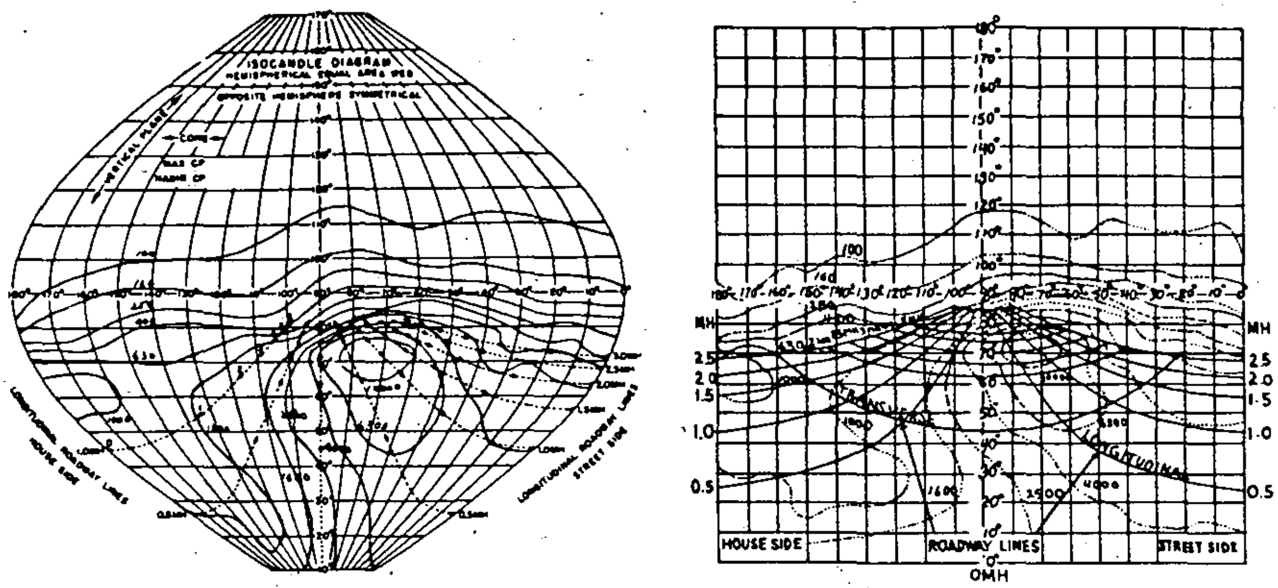


Fig. 4-2a. For symmetrical distributions-(1) left, sinusoidal equal-area web; (2) right, rectangular web.

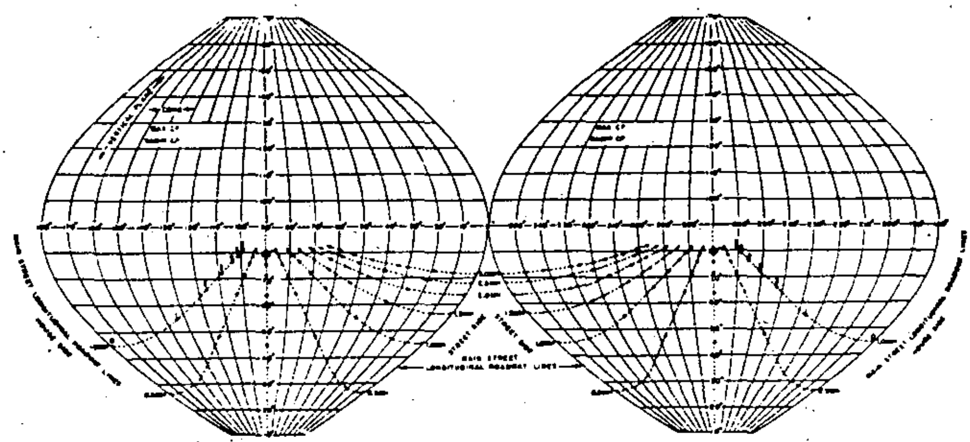


Fig. 4-2b. For asymmetrical distributions-sinusoidal equal-area web.

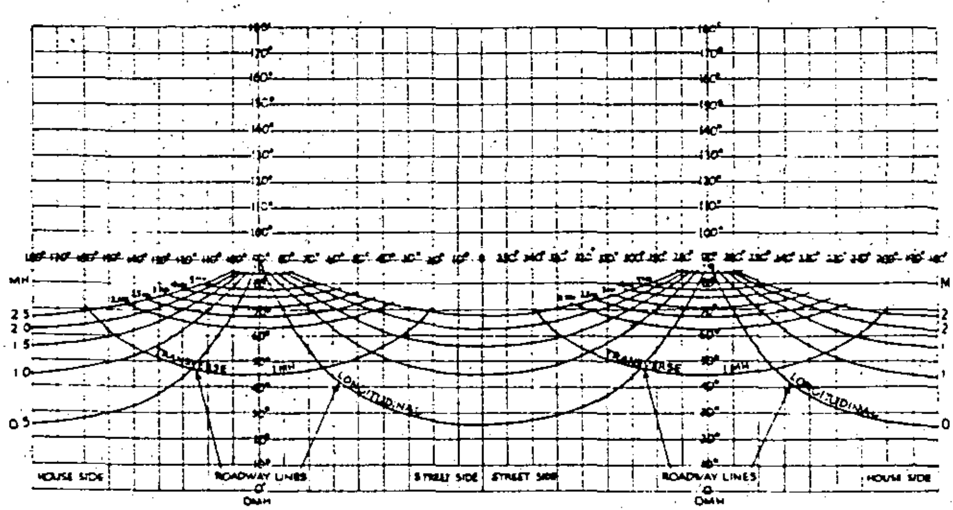
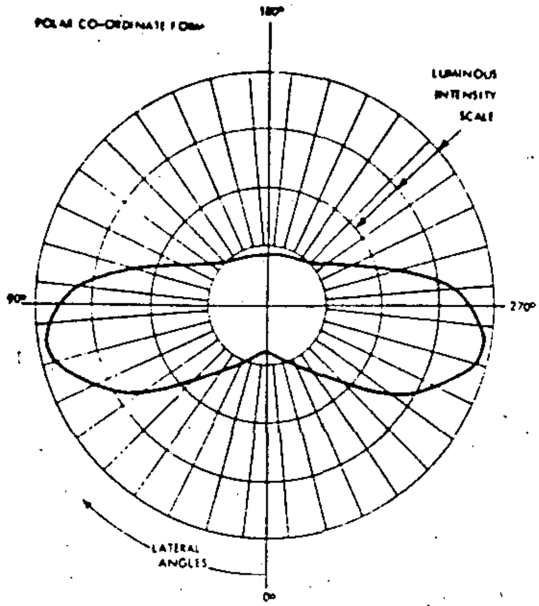


Fig. 4-2c. For asymmetrical distributions-rectangular web.

Fig. 4-2: Isocandela diagrams and associated methods of presentation. Principal reason for use of sinusoidal projection is the ease of using graphical analysis techniques while the rectangular format is adapted to automated mechanical plotting techniques.



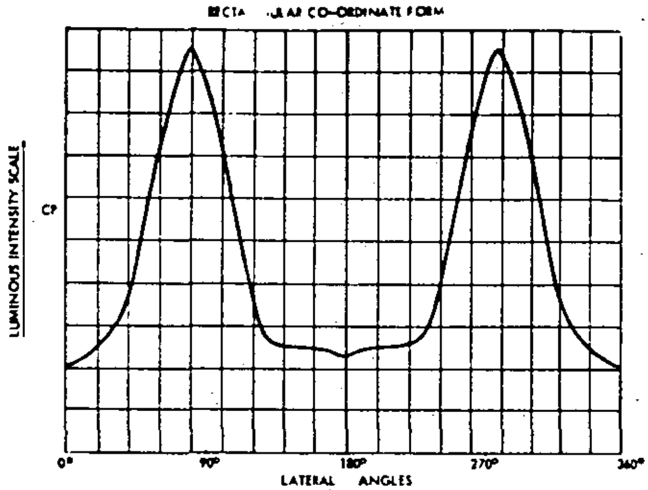


Fig. 4-4(Left and above)-Two methods of presentation of candlepower distribution data in a cone.

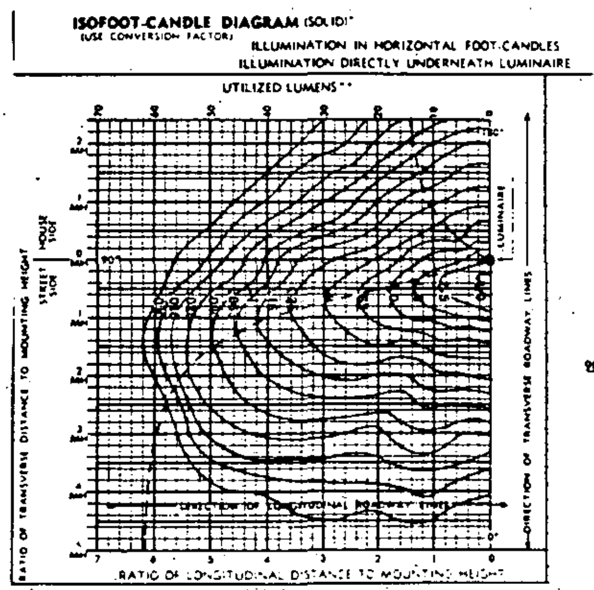
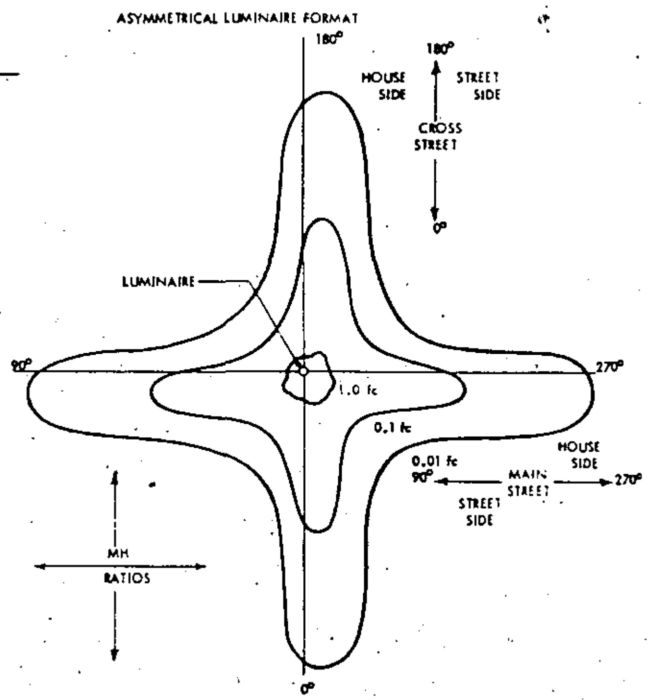


Fig. 4-5



RESULTS ARE TYPICAL ONLY WHEN ALL TEST CONDITIONS SUCH AS LC POSITION, LAMP LUMENS, ETC. ARE REPRODUCED		
LIGHT FLUX VALUES		
	LUMENS	PERCENT OF LAMP
DOWNWARD STREET SIDE	13200	62.8
UPWARD STREET SIDE	250	1.2
DOWNWARD HOUSE SIDE	3100	14.8
UPWARD HOUSE SIDE	150	0.7
TOTAL	16700	79.5

Fig. 4-6. Light Flux Values.

*Per Cent of Lamp Lumens.

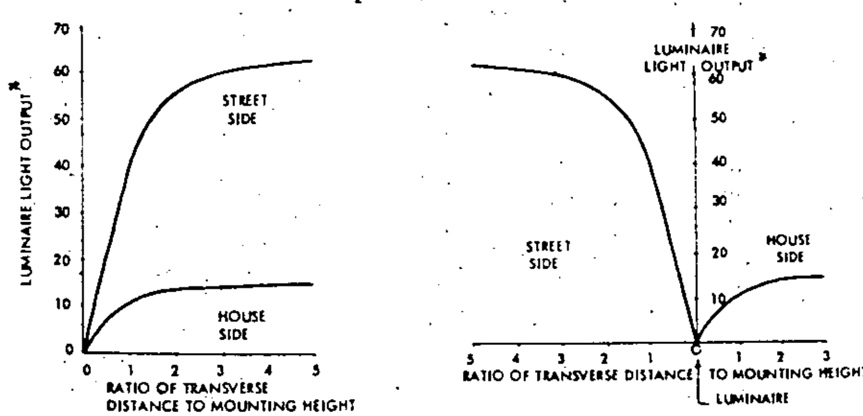


Fig. 4-7. Two popular methods of presentation of luminaire utilization curves.

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Fig. 4-8. Type I

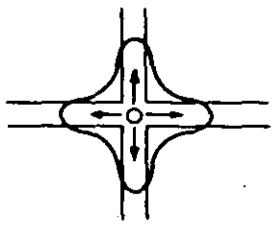

Fig. 4-9. Type I-4-way.

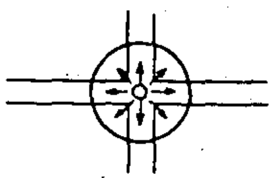

Fig. 4-14. Type V

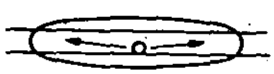

Fig. 4-10. Type II

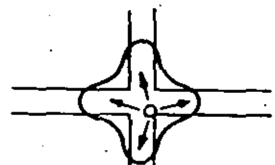

Fig. 4-11. Type II-4-way.

Fig. 4-12. Type III.

Fig. 4-13. Type IV.

Figs. 4-8 to 4-14. Plan view of roadway coverage for different types of luminaires.

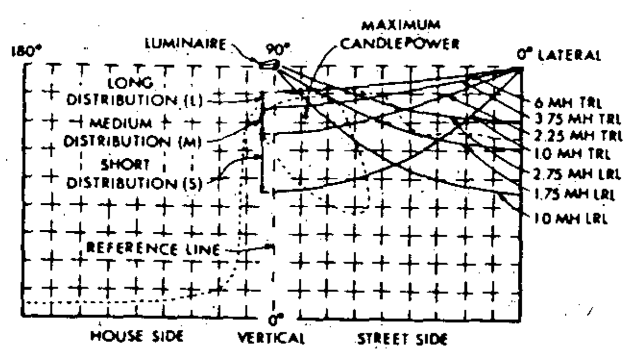

Fig. 4-15. Recommended vertical light distribution boundaries on a rectangular coordinate grid (representation of a sphere). Dashed lines are isocandela traces.

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Conversion Factors in Terms of 15, 20, 25, 30 and 35 Foot (4.6, 6.1, 7.6, 9.1 and 10.7 Meter) Mounting Heights

Mounting Height		Conversion Factors				
Feet	Meters	15 Feet (4.6 Meters)	20 Feet (6.1 Meters)	25 Feet (7.6 Meters)	30 Feet (9.1 Meters)	35 Feet (10.7 Meters)
10	3.1	2.25				
11	3.4	1.86				
12	3.7	1.56				
13	4.0	1.33				
14	4.3	1.15				
15	4.6	1.00	1.78			
16	4.9	0.879	1.56			
17	5.2	0.779	1.39			
18	5.5	0.694	1.23	1.93		
19	5.8	0.623	1.11	1.73		
20	6.1	0.562	1.00	1.56	2.25	
21	6.4		0.907	1.42	2.04	
22	6.7		0.826	1.29	1.86	
23	7.0		0.757	1.18	1.70	
24	7.3		0.694	1.09	1.56	
25	7.6		0.640	1.00	1.44	1.96
26	7.9			0.925	1.33	1.81
27	8.2			0.857	1.24	1.68
28	8.5			0.797	1.15	1.56
29	8.9			0.743	1.07	1.46
30	9.1			0.695	1.00	1.36
31	9.5				0.936	1.27
32	9.6				0.878	1.20
33	10.1				0.826	1.12
34	10.4				0.779	1.06
35	10.7				0.735	1.00
36	11.0					0.945
37	11.3					0.895
38	11.6					0.848
39	11.9					0.805
40	12.2					0.765

Note: Conversion factors are the square of the mounting height at which the isofootcandle (isolux) diagram is plotted divided by the square of the mounting height desired.

Fig. 4-16. Mounting Height Conversion Factors.

$$fc = \frac{\text{LAMP LUMENS X CU X EQUIPMENT FACTOR}}{\text{AREA}}$$

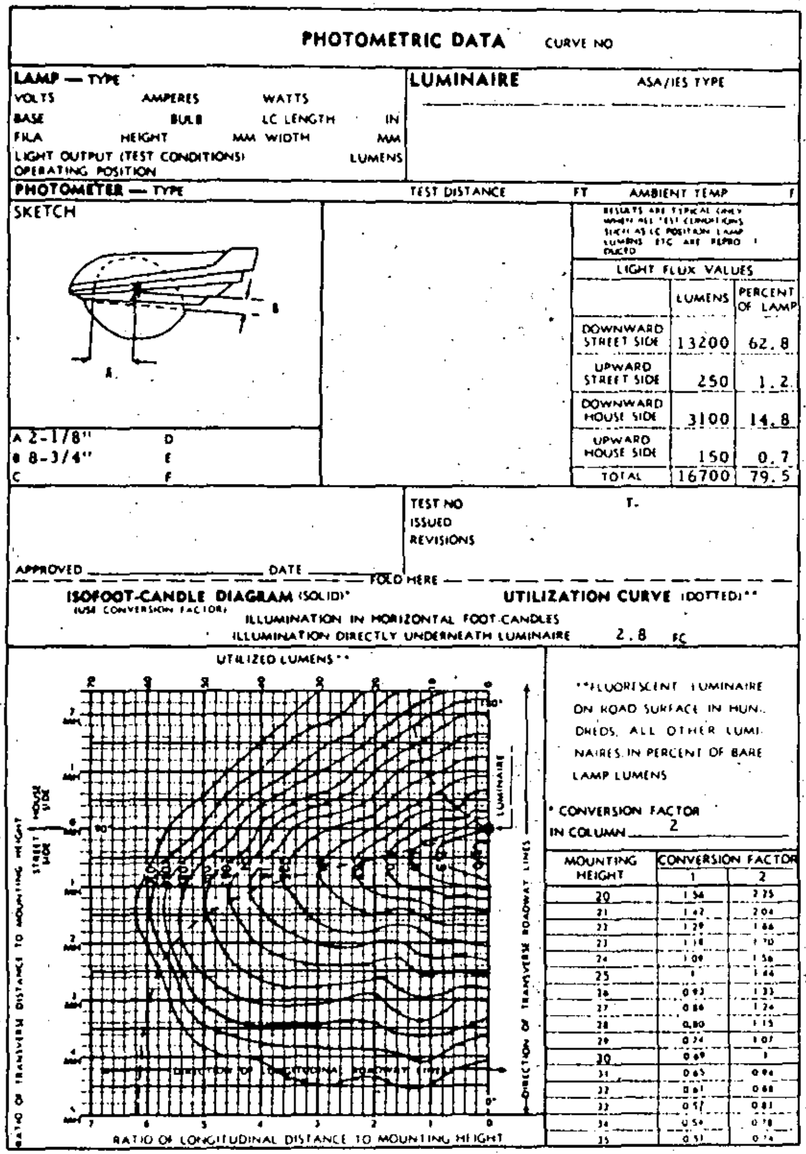


Fig. 17a.

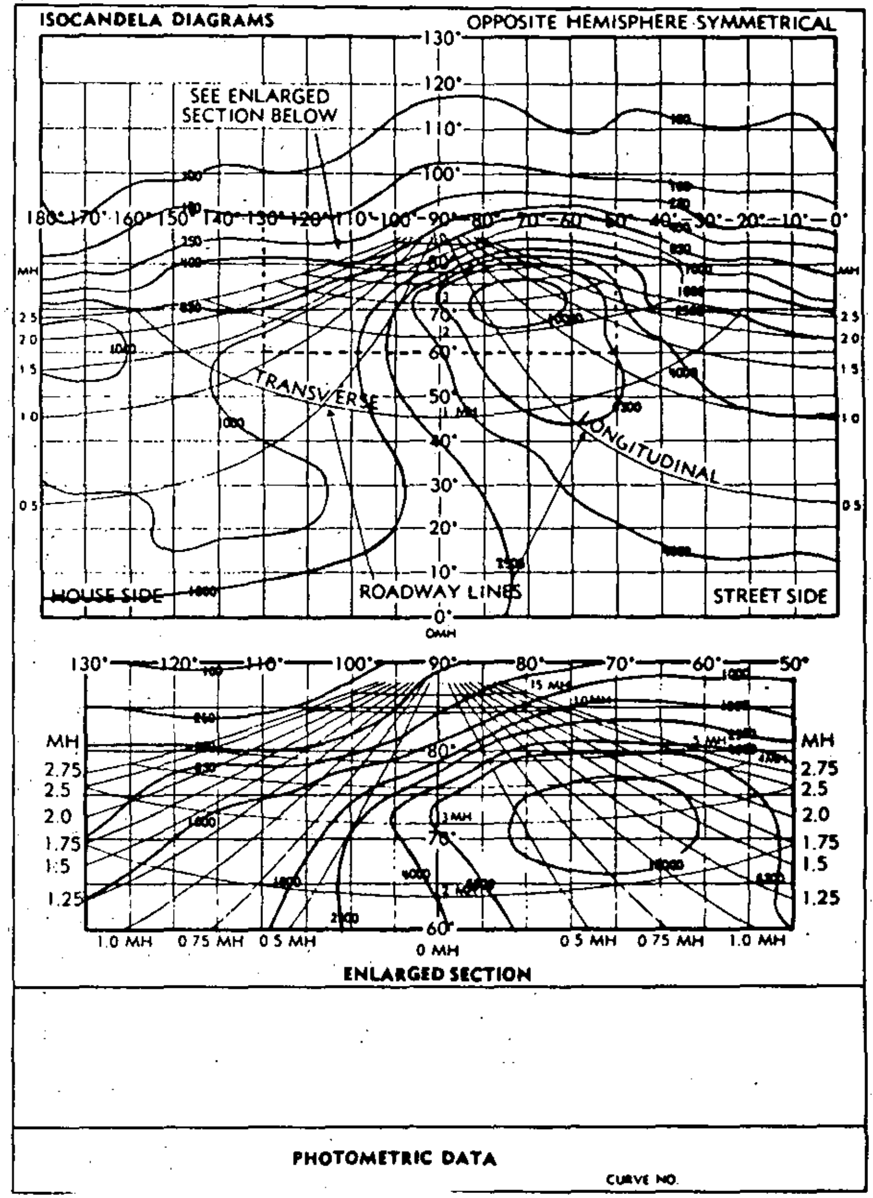


Fig. 17b.

Fig. 17. Typical photometric data sheet on a street lighting luminaire, without essential descriptive information on lamp and luminaire tested.
(Note 4-17a and 4-17b each to be blown up to fill an entire page.)

4-18a.
Low range portable illumination meter.

Fig. 4-18b.
Low range street lighting footcandle meter.

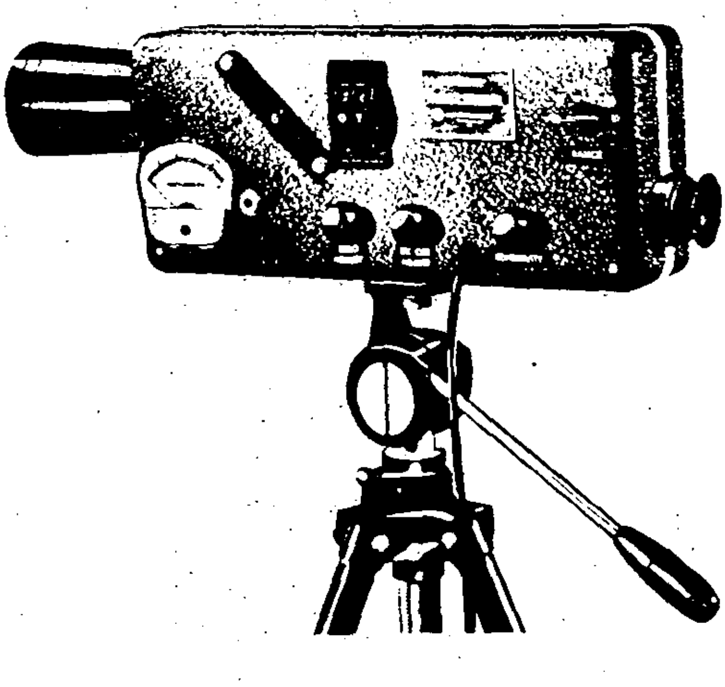
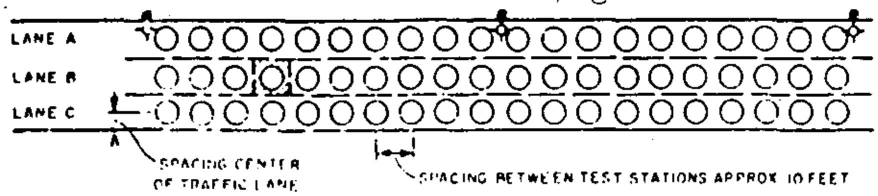


Fig. 4-19.
Pritchard Photoelectric Telephotometer.



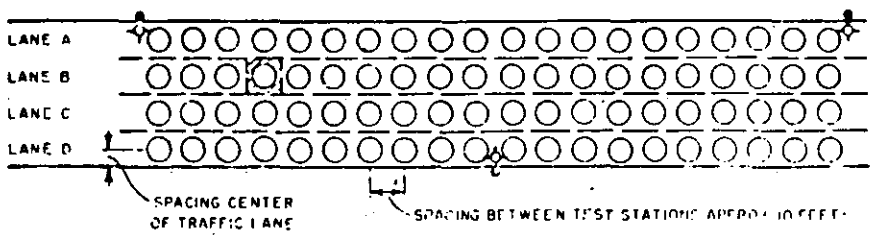
INSTALLATION DATA

Average of reading stations ....
Minimum value ....
Maximum value ....
Ratio of minimum to average ....
Ratio of maximum to average ....

Street classification ....
Type of pavement ....
Reflectance .... (optional)
Luminaire type ....
Light source ....
Electrical and operating conditions:

Mounting height ....
Spacing ....
Environment:

Test plate leveled at not more than 6 inches above the roadway surface.
Test plate compensated for departure from cosine law.



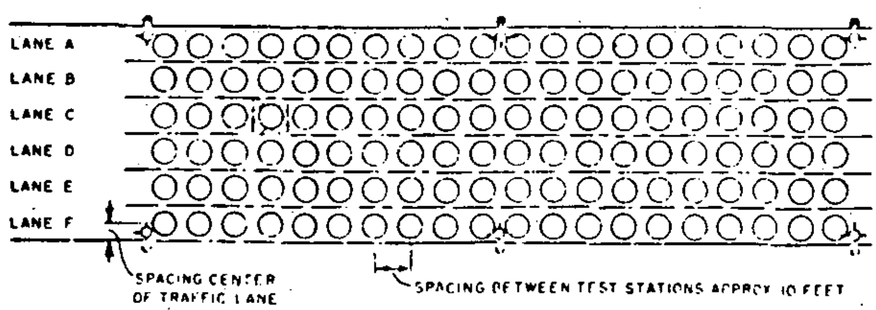
INSTALLATION DATA

Average of reading stations ....
Minimum value ....
Maximum value ....
Ratio of minimum to average ....
Ratio of maximum to average ....

Street classification ....
Type of pavement ....
Reflectance .... (optional)
Luminaire type ....
Light source ....
Electrical and operating conditions:

Mounting height ....
Spacing ....
Environment

Test plate leveled at not more than 6 inches above the roadway surface.
Test plate compensated for departure from cosine law.



INSTALLATION DATA

Average of reading stations ....
Minimum value ....
Maximum value ....
Ratio of minimum to average ....
Ratio of maximum to average ....

Street classification ....
Type of pavement ....
Reflectance .... (optional)
Luminaire type ....
Light source ....
Electrical and operating conditions:

Mounting height ....
Spacing ....
Environment

Test plate leveled at not more than 6 inches above the roadway surface.
Test plate compensated for departure from cosine law.

Fig. 4-22. Locations of test stations for illumination measurements on streets and highways: (a) luminaires located on one side of roadway; (b) luminaires located in staggered arrangement (on alternate sides of the roadway); (c) luminaires located in opposite arrangement (on both sides of roadway). Crosshatching indicates typical rectangular test area at the center of which illumination reading is taken.

Appendix A—Procedure for Computing Isofootcandle (Isolux) Curves

A1 The following is a suggested method where manual data taking is used.

(a) Calculate horizontal illumination values for vertical angles listed in Table A1 for each lateral angle through which a vertical candlepower distribution curve has been taken. Horizontal illumination values equal candlepower times the cosine cubed of the vertical angle divided by the mounting height squared.

(b) Plot horizontal illumination values versus the tangent of the vertical angle. This may be done on semilog paper or on rectangular coordinate paper if the ordinate (horizontal illumination values) scale is changed each time that value goes below one-tenth full scale value.

(c) The isofootcandle (isolux) diagram has as its scale a ratio of distance to mounting height which is the tangent of the vertical angle. Radial lines may be drawn on the chart representing the intersection of the vertical planes through which candlepower values were recorded. Then from the horizontal illumination values versus tangent curves, desired horizontal values may be selected, plotted and values of equal illumination joined by a smooth curve to form the isofootcandle (isolux) diagram. See references 2, 3 and 13.

A2 Suggested methods where automatic recording is used are:

(a) Transparencies with lines of equal illumination (isofootcandle (isolux) lines) can be made by plotting candlepower for an isofootcandle (isolux) line versus the vertical angle. A transparency is required for each mounting height and each full scale candlepower value. The equation from which values are calculated for plotting is: Candlepower equals Horizontal Footcandles (Lux) times Mounting Height Squared divided by the Cosine Cubed of the Vertical Angle.

(b) The photometer must be calibrated so that full scale deflection of recorder is the same as that of one of the transparencies.

(c) As distribution curves are taken from the recorder, the transparency overlay is used. Points of intersection locate the vertical angle at which that horizontal illumination value should be plotted on the Isofootcandle (Isolux) diagram. It is plotted on the line which represents the lateral angle through which the vertical distribution curve was taken at a distance from the luminaire location numerically equal to the

Table—Appendix A1

Constants for (Cosine Cubed Vertical Angle/Mounting Height Squared)

Vertical Angle	Tangent	15 Feet (4.6 Meters)	20 Feet (6.1 Meters)	25 Feet (7.6 Meters)	30 Feet (9.1 Meters)	35 Feet (10.7 Meters)
0	0.0	.004444	.002500	.001600	.001111	.0008163
5	.087	.004394	.002472	.001582	.001098	.0008070
10	.176	.004245	.002388	.001528	.001051	.0007797
15	.268	.004005	.002253	.001442	.001001	.0007357
20	.364	.003688	.002074	.001328	.0009220	.0006774
25	.466	.003309	.001851	.001191	.0008272	.0006077
30	.577	.002887	.001624	.001039	.0007217	.0005302
35	.700	.002443	.001374	.0008794	.0006107	.0004487
40	.839	.001998	.001124	.0007192	.0004995	.0003670
45	1.000	.001571	.0008839	.0005657	.0003929	.0002886
50	1.191	.001180	.0006640	.0004318	.0002951	.0002168
55	1.428	.0008387	.0004717	.0003019	.0002097	.0001540
60	1.732	.0005556	.0003125	.0002000	.0001389	.0001020
65	2.144	.0003347	.0001887	.0001208	.00008387	.00006162
67½	2.414	.0002491	.0001401	.00008967	.00006227	.00004575
70	2.747	.0001778	.0001000	.00006401	.00004445	.00003342
72½	3.172	.0001208	.00006798	.00004350	.00003021	.00002220
75	3.732	.00007706	.00004334	.00002774	.00001926	.00001415
77½	4.511	.00004506	.00002535	.00001622	.00001127	.000008277
80	5.671	.00002327	.00001309	.000008378	.000005818	.000004274
81	6.313	.00001701	.000009570	.000006125	.000004254	.000003125
82	7.115	.00001198	.000006739	.000004313	.000002995	.000002201
83	8.144	.000008044	.000004525	.000002895	.000002011	.000001478
84	9.514	.000005076	.000002855	.000001827	.000001269	.0000009323
85	11.430	.000002943	.000001655	.000001059	.0000007355	.0000005404
86	14.300	.000001509	.0000008486	.0000005431	.0000003771	.0000002771

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TEST QUESTIONS

1. What is the required laboratory temperature for testing street lighting luminaires?

2. Describe the directions of beams in a type I distribution.

3. What does the utilization efficiency chart do for us?

4. What are the three general criterias used to describe street lighting luminaire light distributions?

5. Why is it necessary for the meters to have the light sensitive cell match the eye sensitivity curve?

ANSWERS

1. $25^{\circ}C \pm 1^{\circ}C$

2. The light distribution beams are 180° apart.

3. The utilization curve affords a practical method for the determination of lumens per square foot (average foot-candles) over the roadway surface.

4. a. Vertical light distribution
   b. Lateral light distribution
   c. Control of light distribution above the maximum candlepower.

5. So that the photocell records the same amount of light that our eyes record.

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

CURSOS ABIERTOS

ILUMINACION EXTERIOR:
PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

FUENTES LUMINOSAS

ING. SERGIO GARCIA ANAYA

PALACIO DE MINERIA

Lámparas de sodio baja presión.- La lámpara de sodio baja presión ha sido usada extensamente en Europa desde 1940. En los Estados Unidos se inició una gran campaña de publicidad en 1972. La lámpara de sodio baja presión tiene la eficacia más alta de todas las fuentes, pero tiene un espectro monocromático amarillo.

Elemento productor de luz.- El elemento productor de luz es un tubo de arco. El tubo de arco tiene forma de U y esta construido de vidrio. El tubo tiene pequeñas burbujas para mantener una distribución uniforme del sodio a través de él. El tubo de arco contiene una pequeña cantidad de argón y neón para ayudar al encendido de la lámpara. La presión interna del tubo de arco es de aproximadamente 1×10^{-3} mm.

Tiempo de encendido = 9 min. (89%), 15 min. (100%)
Reencendido = 30 seg. (80%)

Bulbo.- El bulbo esta hecho de vidrio común. Este sirve - para mantener un ambiente constante para el tubo de arco. El espacio entre el bulbo y el tubo de arco esta bajo va-- cío. El tubo de arco opera a una temperatura de 260°C - -- (500°F).

Hay cinco potencias de lámparas:

POTENCIA NORMAL (WATTS)	LONGITUD MAXIMA (PULGADAS)	FORMA DEL BULBO	POSICION DE OPERACION
35	12 3/16	T17	HOR/ARRIBA
55	15 3/4	T17	HOR/ARRIBA
90	20 3/4	T21	SOLO HORIZONTAL
135	30 1/2	T21	SOLO HORIZONTAL
180	44 1/8	T21	SOLO HORIZONTAL

Conexión eléctrica.- La base es una base bayoneta (BAY-B1) la cual mantiene la U del tubo de arco en una posición --- horizontal.

Características de color.- La luz producida por una lámpara de sodio baja presión es un amarillo monocromático (ver -- figura 3-33). La distribución de potencia espectral consiste de dos líneas a 589 nm (aproximadamente 95% de la salida). Debido a la característica del amarillo monocromático, no existe rendimiento de color. Todos los colores aparecen como diferentes tonos de gris y café excepto los objetos -- amarillos.

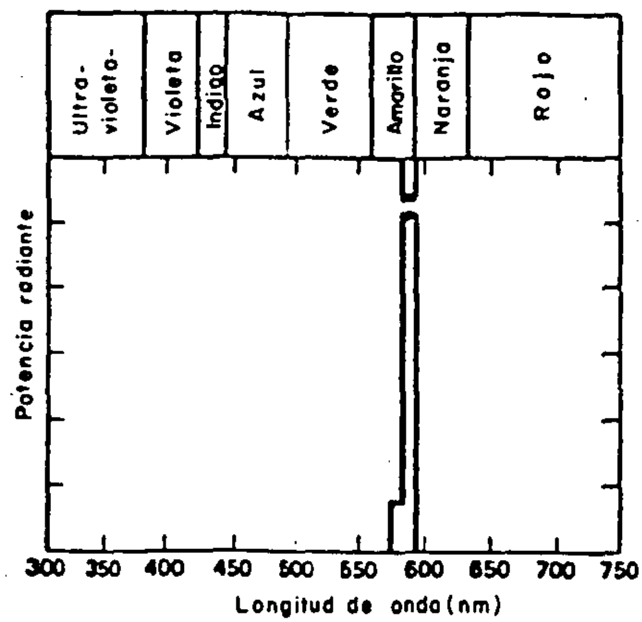

Figura 3-33 Distribución de Potencia Espectral para una Lámpara de Sodio Baja Presión.

Designación de la lámpara.- La designación de SOX se usa para indicar una lámpara de sodio de baja presión. La designación también incluye la potencia nominal de la lámpara, tal como SOX 180 (180W).

Características de funcionamiento.- Depreciación del flujo luminoso. El flujo luminoso aumenta ligeramente durante la vida de la lámpara. Se dice que el flujo luminoso es constante con un rango de temperatura de operación de - 10°C a + 40°C. El efecto en el flujo luminoso cuando la lámpara se opera fuera de este rango de temperatura no ha sido publicado.

Vida.- El tiempo de vida para todas las potencias es de 18,000 horas, basadas en un ciclo de encendido de 5 horas. La posición de encendido de la lámpara es crítica para la vida de esta, ya que ésta falla debido a la migración de sodio hacia los electrodos. Esta migración causa un aumento en los watts consumidos por la lámpara durante su vida, lo cual da como resultado que falle el electrodo.

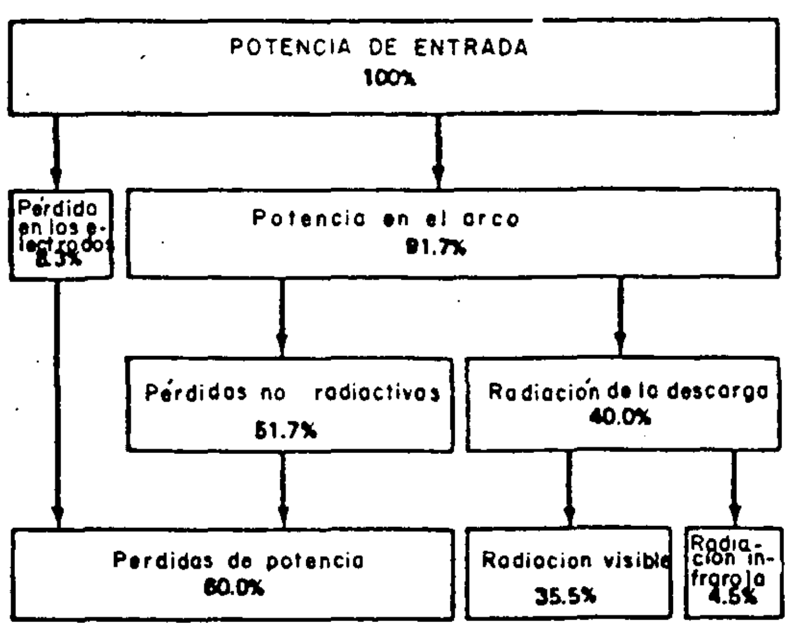

Figura 3-34 Distribución de Energía de una Lámpara de Sodio Baja Presión con 180 lm/watt y 35.5% de radiación Visible.

WATTS NOMINALES	LUMENES	WATTS DE LAMPARA (100 h)	EFICACIA LAMPARA (100 h)	WATTS DE LAMPARA (18000 h)	EFICACIA LAMPARA (18000 h)
35	4,640	36	129.2	44	105.7
55	7,700	53	145.3	62	124.2
90	12,500	90	138.9	122	102.5
135	21,500	130	165.4	178	120.8
180	33,000	176	187.5	241	136.9

3.3.2.2. FUENTES DE DESCARGA GASEOSA DE ALTA PRESION (FUENTES DE DESCARGA DE ALTA INTENSIDAD).

Lámpara de Vapor de Mercurio.

Elemento productor de luz.- El elemento productor de luz -- es un tubo de arco. El tubo de arco es construido de cuarzo, el cual permite transmitir la radiación ultravioleta (ver figura 3-35). El tubo de arco contiene mercurio y una --- pequeña cantidad de argón, neón y kryptón. Cuando la lámpara es energizada, se genera un arco entre el electrodo principal y el de encendido, en cuanto se ioniza el mercurio, -- la resistencia dentro del tubo de arco disminuye. Cuando la resistencia interna del tubo de arco es menor que la resistencia externa, el arco se establece entre los electrodos - principales. El mercurio continua ionizandose, incrementandose la emisión luminosa, la luz producida es típica de --

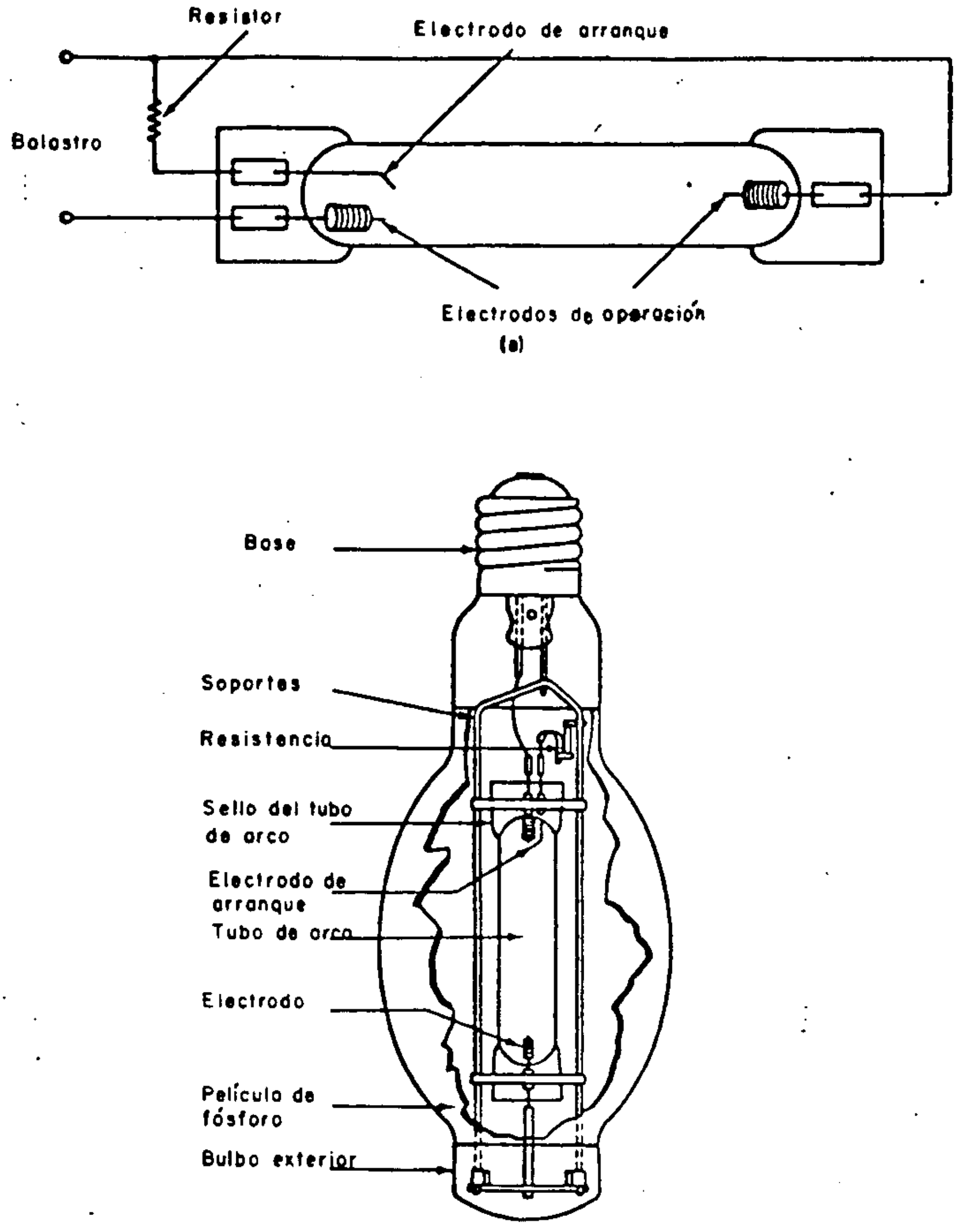

Figura 3-35 Lámpara de Vapor de Mercurio y Tubo de Arco.

las líneas de mercurio (404.7, 435.8, 546.1, 577.9), -- además genera energía ultra violeta.

El tubo de arco es operado desde 1 a 10 atmósferas de -- presión.

TIEMPO DE ARRANQUE = 5 min. (80%) 7-10 min. (100%)
TIEMPO DE REENCENDIDO = 7 min. (80%)

Bulbo exterior.- Las funciones principales del bulbo exterior son tres:

1.- El vidrio primario actua como un filtro de rayos ultravioleta, el cual previene contra quemaduras en la piel y ojos.

2.- Proporciona también un ambiente constante para el -- tubo de arco. La presión del tubo de arco es afectada por el rápido cambio de temperatura y el movimiento del aire.

3.- Este proporciona una superficie para el recubrimiento de fósforo, el cual es colocado en el interior -- del bulbo exterior para corregir el rendimiento de - color de la lámpara de vapor de mercurio: Una lámpara con recubrimiento de fósforo requerirá de un lumi nario muy grande para tener un buen control óptico ya que el bulbo exterior se convierte en el elemento productor de luz.

Conexión eléctrica.- Se utiliza una base tipo mogul para las lámparas con potencias mayores de 100 watts; las lámparas de 40, 50, 75 y 100 watts se fabrican con bases medianas.

Características de color.- La lámpara clara de vapor de mercurio tiene un color predominante azul-verde, característico de las líneas del espectro del mercurio. La figura 3-36 muestra las curvas DPE. Para corregir el color de la lámpara, se aplica un recubrimiento de fósforo en la pared interna del bulbo exterior. Los colores primarios adicionados por el fósforo son el rojo y naranja. Las lámparas de vapor de mercurio blancas o con recubrimiento de fósforo se recomiendan para todas las aplicaciones donde el color es importante. Existen comercialmente tres tipos de lámparas de vapor de mercurio blancas:

1.- Color mejorado: Muy pobre en color rojo, color marginal, no recomendada.

2.- Blanco de lujo, DX: Incrementa el color rojo, buen color, se recomienda.

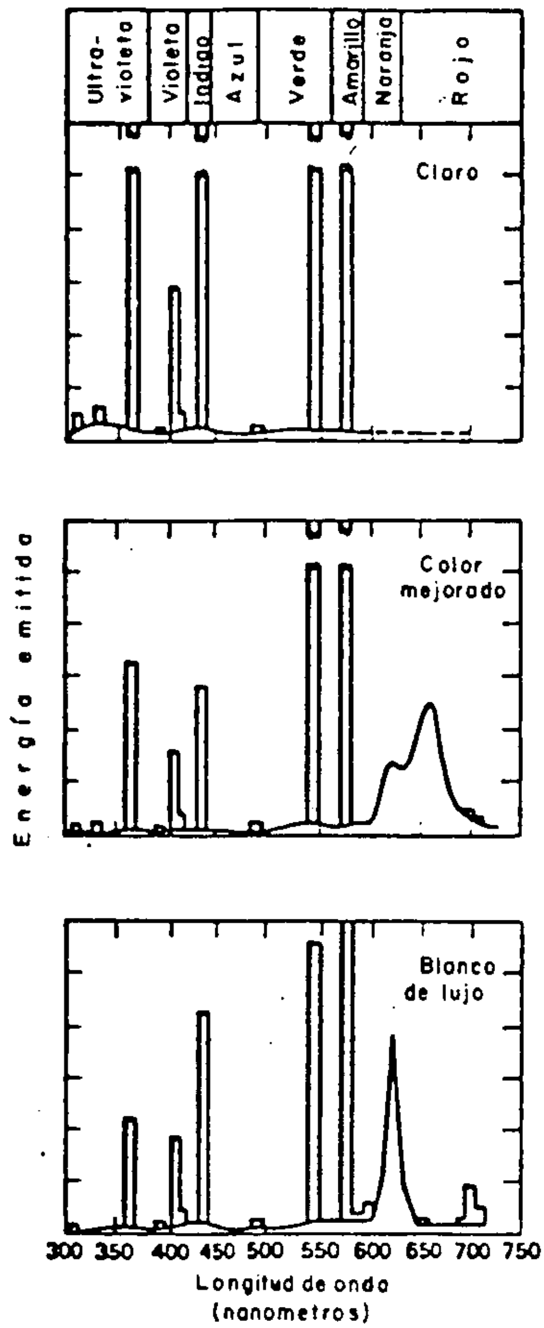

Figura 3-36 Curvas de Distribución de Potencia -- Espectral, para Lámparas de Vapor de Mercurio

3.- Blanco calido de lujo, WWX: Excelentes rojos, excelente color, altamente recomendado; menos lumenes.

Designación de las lámparas.- La designación para las lámparas de vapor de mercurio es muy diferente a las lámparas incandescentes y lámparas fluorescentes. Las unicas partes que tienen significado importante son la designación H, la cual identifica la lámpara como de vapor de mercurio (Hg mercurio), y la potencia. Los números y letras marcados son arbitrarios.

H 33 GL - 400/DX

H - Indica que es una lámpara de vapor de mercurio.

33 - Números que se usan para los balastros de 400 Watts.

GL - Son dos letras convencionales que describen las características físicas de la lámpara, tales como: tamaño-forma, material y acabado.

400 - Indica la potencia nominal de la lámpara.

DX - Indica el color de las lámparas; en el ejemplo: "Blanco de Lujo"

El bulbo se designa en términos de una letra y una combinación de números. La letra o letras son utilizadas para designar la forma del bulbo (ver fig. 3-37).

PAR: Parabolico

PS: Forma de pera

T: Tubular

B: Abultado

BT: Tubular abultado

R: Reflector

E: Eliptico

A: Estandar

Los números representan los diámetros máximos de la lámpara en octavos de pulgadas.

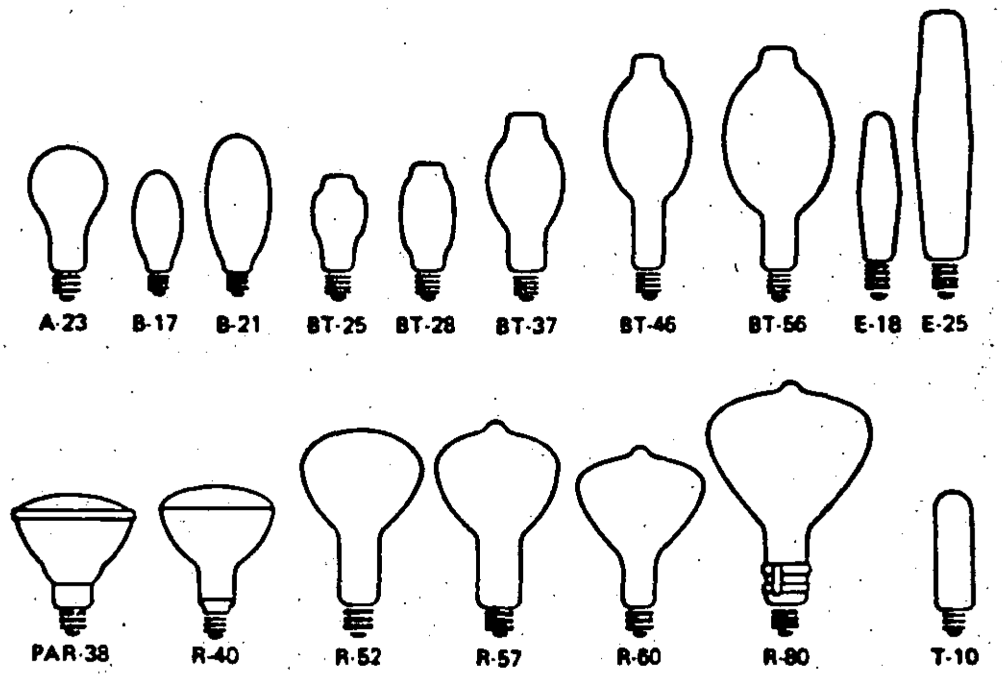

Figura 3-37 Designación de las Formas de Bulbos para Lámparas de Descarga de Alta Intensidad.

BT-37

$$\text{Diámetro} = \frac{37''}{8} = 4\ \frac{5''}{8}$$

Forma: tubular abultado

La posición de encendido es función de la posición del -- electrodo de arranque. El electrodo de arranque debe es-- tar siempre colocado en la parté superior de la lámpara - para evitar que el mercurio se deposite en el electrodo - de arranque.

Características de Funcionamiento.-

Depreciación lumínica. La gráfica de depreciación lumíni- ca para una lámpara de vapor de mercurio es algo drastica y es función del balastro y de la potencia. (ver figura -- 3-38). La lámpara de vapor de mercurio es la única lámpara que se publica su vida nominal y su vida útil.

La emisión lumínica también es función del suministro y re gulación del voltaje a la lámpara (ver fig. 3-39).

Vida.- La vida de la lámpara de vapor de mercurio puede - ser descrita en términos de su vida útil o de su vida no- minal, típicamente, la vida nominal de las lámparas se es- tablece en base al 50% de la curva, de mortandad. Debido- a su rápida depreciación de lumenes, la vida de la lámpa- ra de vapor de mercurio se establece cuando aún hay más - del 50% de lámparas encendidas, para mantener una salida- de lumenes más razonable (ver fig. 3-40) .

Distribución de energía.- La distribución de energía para las lámparas de vapor mercurio se muestra en la fig. 3-41

Eficacia de las lámparas.- La eficacia de la lámpara - -- varía con la potencia de esta. A mayor potencia de lámpara, mayor eficacia.

40/50 W : 25 a 30 Lm / W

75,100,175,250 W : 34 A 48.4 Lm / W

400 W : 55 A 60 Lm / W

1000 W : 57 A 63 Lm / W

H 33 GL - 400 / DX CON 22,500 Lm

$$\text{EFICACIA} = \frac{22,500}{400} = 56.3 \text{ Lm / W}$$

Lámparas de vapor de mercurio autobalastradas.- Las lámparas de vapor de mercurio autobalastradas contienen ya sea- un componente de estado sólido para arranque, o un filamen to incandescente que actua como balastro. La lámpara con - componente de estado sólido no debe utilizarse en un lúminario totalmente cerrado, debido al calor generado por este tipo de lámpara. En general, la lámpara de vapor de mercurio autobalastradas, son 50% menos eficaces en comparación con las lámparas normales de mercurio, pero 50% más eficaces que las lámparas incandescentes.

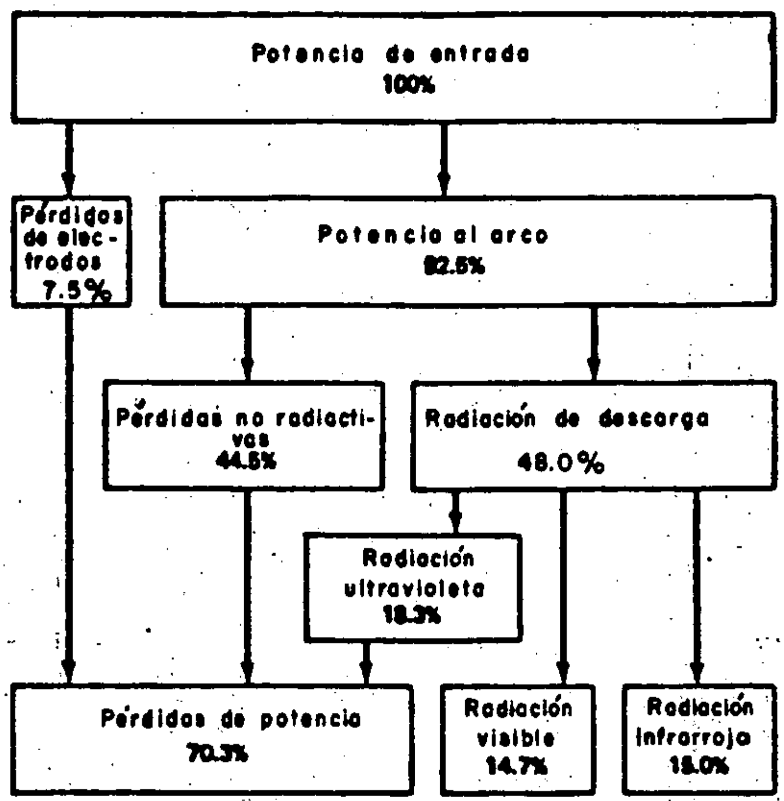

Figura 3-41 Distribución de Energía para Lámpara de Vapor de Mercurio con 56.3 lm/watt (400 w).

Estas lámparas debén limitarse a sustituir lámparas incandescentes, dónde el cambio de lámparas es difícil y el -- adicionar un balastro es impráctico.

Dispositivos ahorradores de energía.- Recientes desarro-- llos en los balastros electrónicos para lámparas de vapor de mercurio permiten atenuarlas actualmente. Los balas--- tros electrónicos han sido estudiados desde que apareció- la lámpara de vapor de mercurio. Existen todavía varios - problemas, entre ellos el alto costo; pero se sabe que -- con un balastro electrónico la eficacia de la lámpara y - la eficacia total del sistema aumentan considerablemente. Otras ventajas que se esperan del balastro electrónico -- son: el menor tamaño y peso, menor ruido, aumento de la - vida de la lámpara y mayor facilidad para atenuar.

Lámparas de Aditivos Metálicos.-

Elemento productor de luz.- El elemento productor de luz- es un tubo de arco. El tubo de arco tiene los mismos principios de operación y tipo de construcción del de la lámpara de vapor de mercurio (ver fig. 3-42). El tubo de arco contiene además del mercurio, argón, neón y kryptón; - yoduros de metales. (Los aditivos primarios son el mercurio, sodio y escandio; otros son el talio, indio y cesio). Estos aditivos proporcionan colores adicionales a las - - líneas típicas del mercurio, esto es, rojo, naranja y amarillo. El color de la lámpara de aditivos metálicos estabalanceado a través del espectro. Debido a que la lámpara de aditivos metálicos mejora el color sin necesidad de un recubrimiento de fósforo, la lámpara se aproxima a una fuente puntual, lo cual da como resultado que se facilite su control óptico. Para la posición horizontal de encendido, el tubo de arco es curveado ligeramente, para tener una temperatura más uniforme dentro del tubo de arco (ver fig. 3-42).

Tiempo de encendido = 9 minutos (80%)

Tiempo de reencendido =10 a 15 minutos (80%)

Cubierta.- La cubierta exterior (bulbo) sirve solo para dos funciones.

1.- Filtro de luz ultravioleta
2.- Ambiente constante para el tubo de arco (mantiene la temperatura constante y evita las corrientes de aire)

No se necesita un recubrimiento de fósforo para el buen rendimiento de color y además debe evitarse ya que afecta en forma negativa el control óptico; esto es la lámpara ya no se aproxima a una fuente puntual.

Conexión eléctrica.- La lámpara de aditivos metálicos usa una base mogul para todas las potencias. Las lámparas para posición de operación horizontal que contienen el tubo de arco curvo (ver fig. 3-42), tienen un pasador en la -- base para posicionarlas. Existe un portalámpara especial- que asegura el posicionamiento adecuado del tubo de arco- cuando la lámpara es asegurada en el portalámpara adecuadamente. El tubo de arco curvo siempre debe ser colocado- con la curva hacia arriba en un plano vertical.

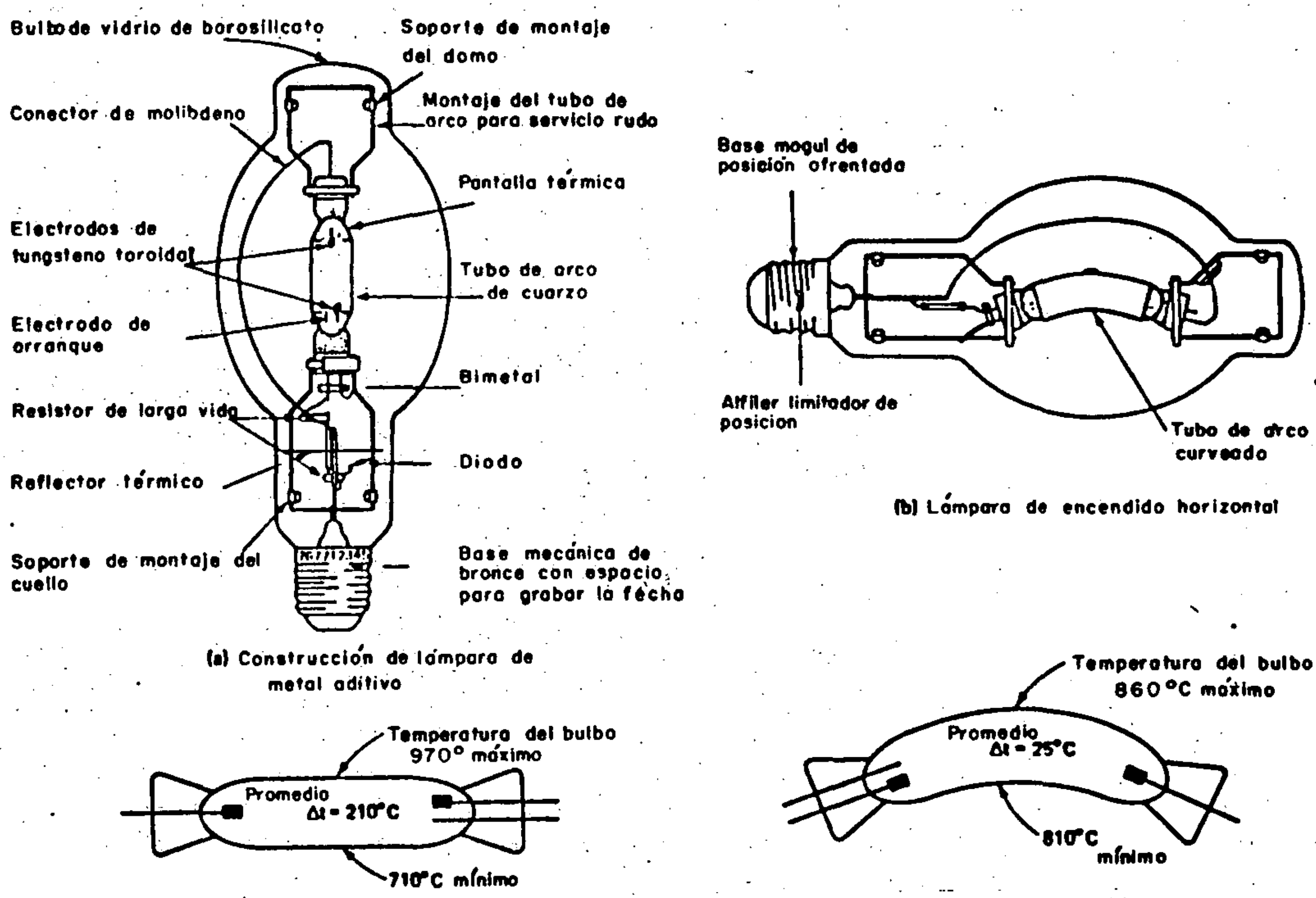

Figura 3-42 Variación de Temperatura Interna y Temperatura de la Pared, de una Lámpara de Aditivos Metálicos.

Características del color.- La lámpara de métales aditivos produce energía en todas las longitudes de onda a través - del espectro visible. Esto es, su distribución de energía- espectral esta bien balanceada, lo que significa que la -- lámpara produce un buen rendimiento del color sin la necesidad de una pantalla de fósforo (ver fig. 3-43). La apa-- riencia del color es una función del control de calidad -- de los aditivos dentro del tubo de arco. La consistencia - del color de una lámpara a otra es función del balastro, -- del voltaje aplicado y edad de la lámpara. Donde es una -- consideración importante de diseño el tener igualdad de -- color entre las lámparas, estas deben cambiarse en grupo,- debido al cambio de color con el tiempo.

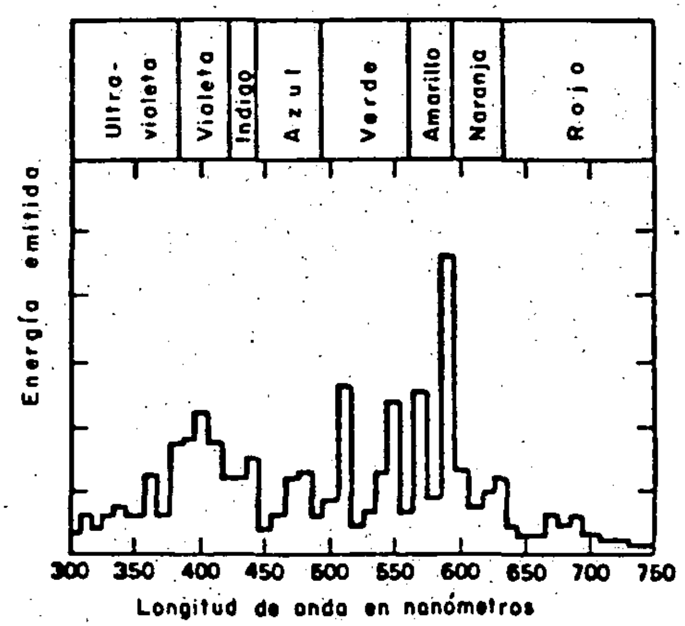

Figura 3-43 Distribución de Potencia Espectral de una Lámpara de Aditivos Metálicos.

Designación de la lámpara.- Las designaciones para lámparas de métales aditivos no han sido normalizadas. El ingeniero debe tener cuidado al especificar las lámparas con-designaciones no standar para evitar que algún fabricante sea descartado.

La designación de la letra M ó MH debe ser usada para - - identificar una lámpara de métales aditivos.

MH 400 / BU

Métal aditivo Watts Posición de operación - de la lámpara

Las lámparas de métales aditivos son especialmente sensibles a la posición de encendido. Los datos de los fabri-- cantes debén ser consultados para conocer los requerimientos de la posición de encendido.

El bulbo es designado por una letra y una combinación de-números. Las lámparas de métales aditivos se fabrican con bulbos BT y E (ver fig. 3-37). El número representa el -- diámetro exterior máximo del tubo, en octavos de pulgada.

$$BT - 37 \text{ Diámetro} = \frac{37''}{8} = 4\ 5/8''$$

Características de operación.-

Depreciación de lúmenes. La curva de depreciación de lúmenes para una lámpara de métales aditivos es sustancialmente mejor que la curva para una lámpara de vapor de mercurio. La salida de lúmenes al final de la vida de una lámpara de alta potencia es 75% (ver figura 3-44).

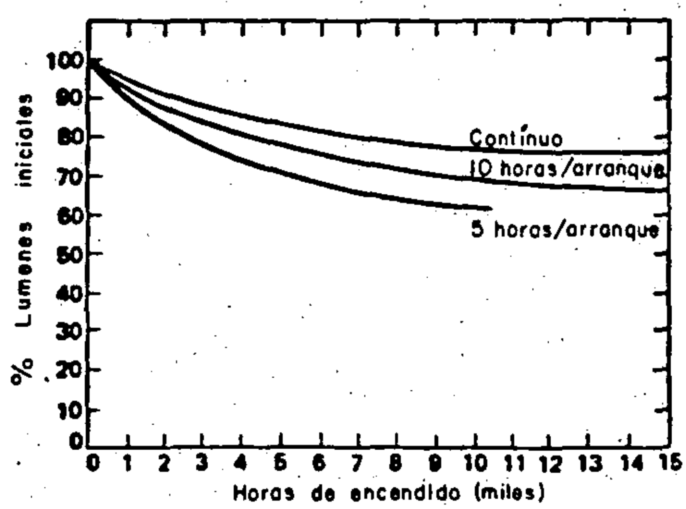

Figura 3-44 Depreciación de Lúmenes en la Lámpara de Aditivos Metálicos.

Vida.- La vida varía como una función de los watts de la lámpara y el lapso del tiempo que la lámpara ha estado en el mercado. Por ejemplo, la lámpara MH 175/Hor estaba comercialmente disponible en 1972.

La práctica normal en la industria de las lámparas es introducir todas las lámparas nuevas al mercado con un promedio de 7,500 hrs. Cuando los informes sobre mortandad y vida sean desarrollados, lo cual requiere pruebas a largo plazo, la vida de la lámpara se espera se incremente a un mínimo de 15,000 hrs. Los catálogos de lámparas usuales de todos los fabricantes, deben ser consultados para obtener el promedio de vida de las lámparas.

Distribución de energía.- La distribución de energía para una lámpara de aditivos metálicos se muestra en la figura 3-45.

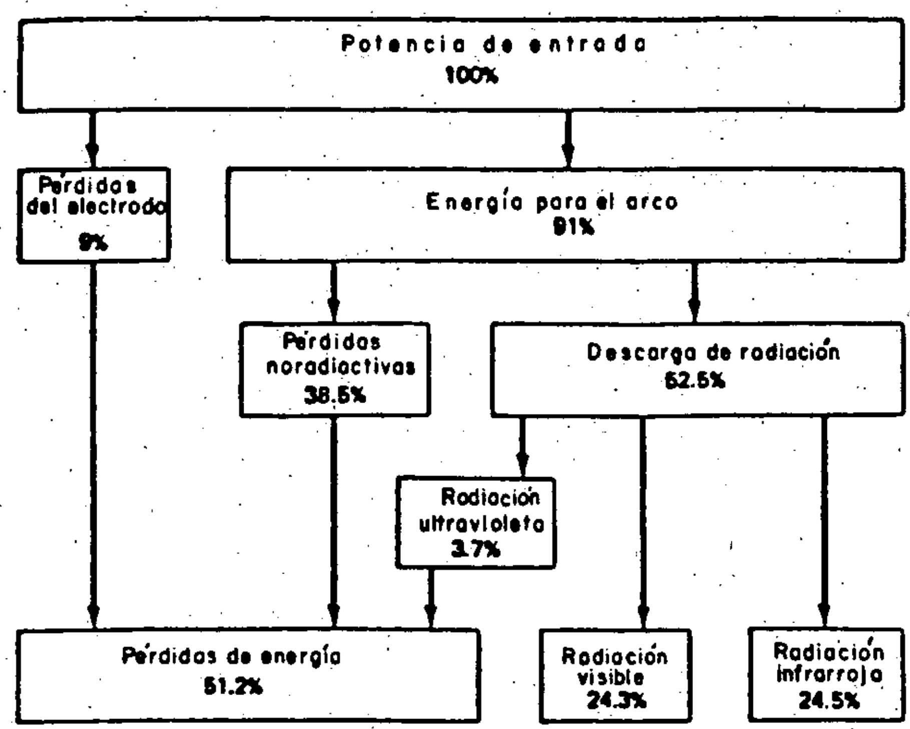

Figura 3-45 Distribución de Energía en una Lámpara de Aditivos Metálicos con 100 lm/watt y 24.3% de Radiación Visible.

Eficacia de las lámparas.- Las eficacias de las lámparas varian con la posición de operación y los Watts de la -- lámpara. Mientras mayor es la potencia, mayor es la eficacia.

175 W	:	80 a 85.7 Lm/W
250 W	:	82 Lm/W
400 W	:	85 a 100 Lm/W
1000 W	:	100 a 115 Lm/W
1500 W	:	96.7 a 10.33 Lm/W

NOTA: Los rangos de valores son debido a variaciones entre fabricantes.

Dispositivos de ahorro de energía.- El atenuado de lámparas de métales aditivos es un desarrollo reciente. La lámpara de 400 W puede ser atenuada (5 min.) en un 47% del - total de energía consumida, lo cual resulta en un 22% de- reducción en lúmenes. La lámpara de métales aditivos de - 1000 W puede ser atenuada (15 min.) en un 35% de su energía total consumida, o 14.6 de su rendimiento de lúmenes. Cuando ocurra un desarrollo tecnológico adicional, el --- costo de atenuación deberá disminuir y el rango incrementarse.

Lámparas de Sodio Alta Presión.

Elemento productor de luz.- El elemento productor de luz es un tubo de arco. El tubo de arco es pequeño en diámetro para mantener una temperatura de operación alta. Debido a que el diámetro es pequeño, no hay electrodo de arranque dentro del tubo de arco. El sodio operando a una presión alta y a alta temperatura tiene un efecto corrosivo sobre el vidrio ordinario o cuarzo. Por eso, el tubo de arco está hecho de cerámica de aluminio. El tubo de arco contiene Xenón, una amalgama de mercurio, y sodio operando a una presión de 200 mm., de mercurio.

Tiempo de encendido = 3 min. (80%)
reencendido = 1 min. (80%)

Envolvente (bulbo).- La envolvente ayuda a mantener el tubo de arco dentro de una temperatura ambiente constante y protege al tubo de arco de corrientes de aire.

Conexión eléctrica.- La conexión eléctrica es una base mogul. La lámpara requiere un pulso de energía de 2500 a 5000 V para el encendido de la lámpara. Esto se realiza por medio de un pequeño dispositivo de arranque electrónico, que suministra el pulso de alto voltaje para abatir la resistencia y encender la lámpara.

Características de color.- La lámpara de sodio de alta -- presión produce energía en todas las longitudes de onda - (fig. 3-46). Sin embargo la mayor porción de energía está concentrada en la parte amarillo-naranja del espectro. -- Las características de color de la lámpara cambian los -- objetos rojos a naranja y obscurece el color aparente de los objetos azul y verde, incrementando la presión en el tubo de arco parece mejorar la apariencia de color de --- rojos, azules y verdes. La consistencia del color de una - lámpara a otra es mejor que con las lámparas de métales - aditivos. Sin embargo, los cambios de color pueden ocu--- rrir debido a las variaciones de voltaje y diferencias -- en balastros.

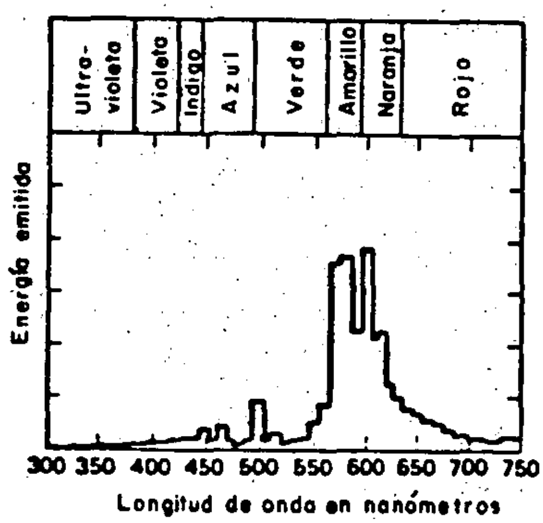

Figura 3-46 Distribución de Potencia Espectral para una Lámpara de Vapor de Sodío alta - Presión.

62.

Designación de las lámparas.- Las designaciones de las -- lámparas de sodio de alta presión no han sido normaliza-- das por la Industria de lámparas. El ingeniero debe tener precaución en no especificar o usar nombres comerciales - que provoquen que lámparas aceptables queden descartadas. Las lámparas de sodio de alta presión estan disponibles - en bulbos, E, BT, y T (ver fig. 3-37). Se utiliza una - - combinación de letras y números para designar la configuración del bulbo.

Características de operación.-

Depreciación de lumenes.- La curva de depreciación de --- lúmenes de la lámpara de sodio alta presión es una de las mejores de las lámparas del tipo de descarga de alta intensidad. El rendimiento lumínico al final de la vida de la-misma, para altas potencias es 80% (ver fig. 3-47).

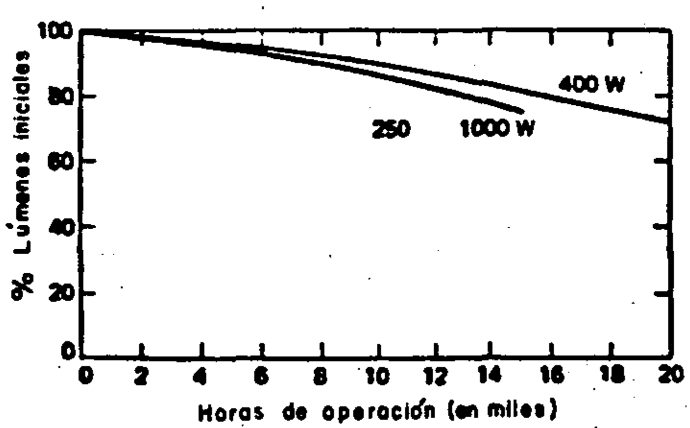

Figura 3-47 Depreciación de Lúmenes en una Lámpara de Sodio alta Presión.

Vida.- La vida varía en función de la potencia, el circuito del balastro y del fabricante. El rango es desde - --- 15,000 a 24000 hrs. para las lámparas de alta potencia -- más comunes.

Distribución de energía.- La distribución de energía para las lámparas de sodio alta presión es mostrada en la fig. 3-48

Eficacia de las lámparas.- La eficacia de las lámparas -- de sodio alta presión varía como función de la posición - de operación y de la potencia de la misma.

70 W : 77 a 82.9 Lm/W
100 W : 88 a 95 Lm/W
150 W : 100 a 106.7 Lm/W
250 W : 102 a 120 Lm/W
400 W : 118.8 a 125 Lm/W
1000 W : 140 Lm/W

Las lámparas de sodio alta presión también estan disponibles en potencias que pueden ser operadas con balastros- de mercurio. Las potencias disponibles son 150, 215, 310 y 360 W. Los informes de los fabricantes debén ser con-- sultados para una adecuada selección del balastro para - la lámpara.

Dispositivos de ahorro de energía.- Es posible atenuar -- algunas potencias de lámparas de sodio alta presión. La - lámpara de 1000 W puede ser reducida en un 38% de su po-- tencia total en aproximadamente 15 min., con una reducción en la salida de luz en un 20% de los lúmenes nominales.

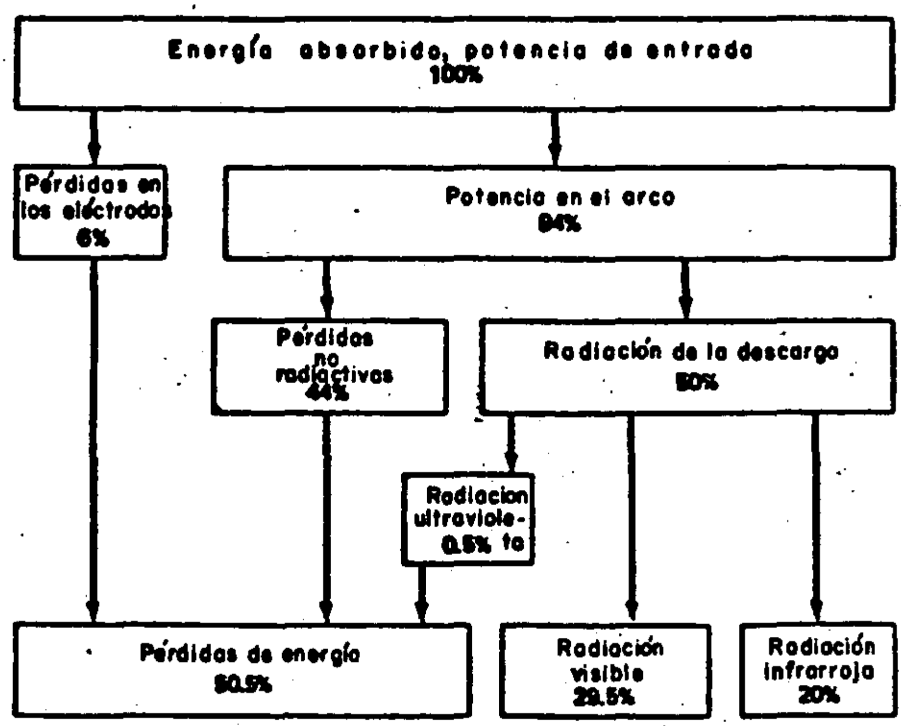

Figura 3-48 Distribución de Energía para la Lámpara de Sodio Alta Presión con 125 lm/watt y 29.5% de ra-- diación Visible.

3.3.3. BALASTROS.

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

C U R S O S   A B I E R T O S

ILUMINACION EXTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

LUMINARIOS PARA ALUMBRADO PUBLICO

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LUMINAIRES FOR ROADWAY LIGHTING 6

1. General Considerations

The Roadway Lighting Luminaire is a more specialized and sophisticated luminaire than most commercial luminaires. Its components may be broken down into three basic structures or systems. An optical system, consisting of a light source, reflector, and if it is a closed system, a transparent cover or a light controlling refractor.

They generally consist of a housing which supports the integral ballasting equipment, lamp socket and reflector and a slip fitter for the pole mount. The cover is hinged and latched and supports a plain transparent cover or a light controlling refractor. In some completely enclosed optical assembly designs, the gaskets are made of special air filtering material and in others air breathing is directed through separate air filters: More recently, open ventilated designs were introduced for very high mounting heights which utilize a reflector and in some designs an open bottom refractor for additional light control. Dirt buildup on the optical surfaces is prevented by a chimney effect of the heat from the lamp and wind currents which produce a continuous upward air movement through the optical assembly.

2. Light Distribution Requirements

We learned in Chapter 3 on the Principles of Light Control that optical systems can be designed which will redirect the light source towards a useful area, in the case of roadway luminaires onto the roadway area. This may be accomplished by means of a reflector alone or by a reflector and refractor integrated optical system.

Chapter 5 described the various light sources, such as, incandescent, fluorescent, and high intensity discharges, which may be employed in the roadway luminaire.

Chapter 4 described how the light emitted from a luminaire is measured and how its distribution is displayed in data form. Here we also learned that specific light distributions have been defined and classified by the IES - ANSI Standard Roadway Lighting Practice so that a luminaire purchased to meet a given ANSI classification can be expected to satisfactorily light the roadway area covered by that classification. Thus, the beam elevation of maximum candlepower can be specified as Short, Medium, or Long. The roadway width or area covered is covered by the classifications Type I, II, III, IV, V, I 4 way and II 4 way, etc. Last, a glare indication is represented by the classification of cutoff, semi-cutoff and non-cutoff.

In many luminaires, especially the HID types, the classification can be made to shift from one type to another within limits by an adjustable lamp socket holder.

Since all luminaires must conform optically to this classification system, it is more appropriate to discuss them by source types rather than by light distribution.

3. Luminaire Types and Component Parts

Luminaire design varies more with the type light source used than by differences in their optical systems. The incandescent types being the oldest in use evolved into a fairly standardized construction. The fluorescent by nature of the lamp size has a mechanical design completely different from existing luminaires and the HID luminaires tend toward the more modern streamline design. There are overlapping between the incandescent and HID designs simply because of the similarity of light source sizes.

a. Incandescent: The incandescent luminaire generally consists of a standardized hood assembly (Fig. 6-3) and a detachable optical assembly. The hood is supplied in two sizes, Medium and Mogul, and will accept optical assemblies interchangeably from a number of manufacturers. It consists of an outer housing with lugs for attaching the optical assembly, an adjustable slip fitter for attachment to the support arm, and an adjustable light socket support and light socket (Fig. 6-4). Electrically, provision is often made for high voltage insulators for series street light circuits, for a connector socket for a photoelectric light switch, and for enclosing small internally mounted High Intensity Discharge lamp ballasts.

   The optical system may consist, in addition to the incandescent lamp, of an open reflector a reflector with an open bottom refractor, (Fig. 6-6) or a reflector with a closed refractor (Fig. 6-3). Sometimes a small auxiliary reflector - light shield is provided to sufficiently reduce house-side light. The optical assemblies are fastened to the hood with toggle clamps and provided with a safety chain to prevent them from dropping to the street should the toggles come unsnapped, unintentionally.

b. Fluorescent: The fluorescent luminaire generally consists of an aluminum housing with an internal specular reflector and a clear plastic enclosing cover. The housing also contains the necessary electrical ballasts and control equipment for proper operation of the lamps.

Due to the fact that the fluorescent lamp is a long source, very little lateral optical control can be obtained. Thus these luminaires will not be found with narrow beam distributions. Vertical control can be obtained quite satisfactorily from the reflector alone, therefore, most plastic covers have little or no optical control formed in them. The covers usually are attached to the housing with a toggle clamp arrangement which allows it to swing open for servicing and replacement of the lamps.

They generally use the high output and super high output fluorescent lamps in various lengths and as many as twelve per luminaire. These lamps are quite temperature sensitive and often require heaters or special design for cold weather operation and cooling fans for summer hot weather operations.

One exception to the decline in the use of fluorescent luminaires has been its application to tunnel lighting. In this application, it seems to have advantages over other sources and continues to be used.

c. High Intensity Discharge Luminaires: The High Intensity Discharge Lamps in many cases made it necessary to redesign the optical systems of incandescent reflectors and or luminaires due to the differences in the source size and area. This led to Ovate and square styling changes in the luminaires which has occurred since the early sixties (Figure 6-11.)

The conventional luminaire is supplied in three sizes: a small luminaire which takes the 175-250 watt lamp, a medium size which accepts the 400-watt lamp and a large luminaire for the 700 and 1000-watt sizes. An adjustable socket is used in many luminaires which enables its lighting optical distribution to be altered. A second factor which affects the light classification is the use of a clear or phosphor-coated mercury lamp. When the fluorescent mercury lamp is used, light control is decreased because of the enlargement of the light source to the size of the bulb envelop. This leads to wider beam patterns and the loss of light cutoff at higher angles. In general, the improved color quality is preferred by the public in business and residential areas and the lamp is used in these applications in spite of the diminished beam control. On open highways where quantity and glare control are of more importance the clear mercury is used.

At the start of the 70s two new sources are being adapted for use in the conventional luminaire. The metal halide mercury lamp which has improved color over the clear mercury and many more lumens per watt is replacing both the clear mercury and phosphor mercury lamp. A second type known as the high pressure sodium source offers more than double the light of the comparable mercury source with a golden white color. In adapting these sources to the conventional luminaire care should be exercised in the application to avoid excessive glare since the sources are so much brighter. In general, lower beam angles and higher mounting heights should be employed.

d. Decorative Luminaires: In downtown, commercial areas, boulevards, parks, campuses, and residential areas where people are becoming more aware of day time esthetics something more than the conventional functional luminaire is being asked for. To fill the needs of this market, manufacturers have been able to incorporate the functional optical system in a decorative housing. Thus, night time lighting efficiencies have been preserved with an improved day time appearance. In the newer residential areas underground wiring is being used. This made the low mounted decorative post top luminaire practical (Fig. 6-14). In the lower wattage sizes and with a good optical design, brightness of these luminaires can be kept within acceptable limits.

For large area lighting such as parking and mall areas high mounted high wattage luminaires such as shown in (Fig. 6-15) are often used.

e. Underpass Luminaires: Wall mounted luminaires (Fig. 6-16) are available both with and without ballasts for use in lighting underpasses. These are usually supplied with the lower wattage lamps which combined with a well designed optical system will usually provide satisfactory distributions at fifteen foot mounting heights.

f. Luminaires for High Mounting Heights: A recent trend in large interchange lighting has been the use of high mounting height luminaire systems. Towers of 50, 100 and even 150 feet are used. At these heights, several luminaires are usually employed, mounted on a pole surrounding ring which can often be lowered to the ground by winch for servicing. The luminaires use vertical burning discharge lamps in reflectors and/or reflector-refractor optical assemblies. I.E.S. Type V symmetric distributions were first introduced to light the entire central area of the interchange. Later the asymmetric distributions were added to more effectively distribute the light at entrances, exits and tangent sections. No doubt as the future brings forth still newer and larger light sources, additional luminaire designs will be developed.

g. Standardization of Luminaires and Accessories: The utility and street light servicing organizations have long sought standardization of the components which comprise a street lighting luminaire.

One of the first successes was the so called NEMA hood used in incandescent round luminaires. These were standardized to a point that an optical assembly made by any of a number of manufacturers could be attached to them.

More recently the flange openings of the various size refractors has been standardized to a point that refractors of one manufacturer will fit in a luminaire of another manufacturer. This is fine from a replacement purchasing and inventory point of view, however, mechanical interchangeabilities do not always imply optical interchangeability. Optical systems are not standardized, therefore one manufacturer's refractor may not be compatible with another's optical system with the resulting effect of producing a light distribution pattern different than the original specification. If interchangeability is contemplated, photometric tests should be performed on each refractor to determine the compatibility of the light distributions before the refractors are certified as interchangeable.

Standardization in many instances does serve a useful function, especially for mechanical parts, electrical supply accessories, photoelectric light switches, etc. However, it should be emphasized again that care should be taken in interchanging optical parts lest the light distribution be something other than originally specified. A further limitation of standardization may be to stifle creativity and the development of new and better luminaires and competitive rivalry among manufacturers.

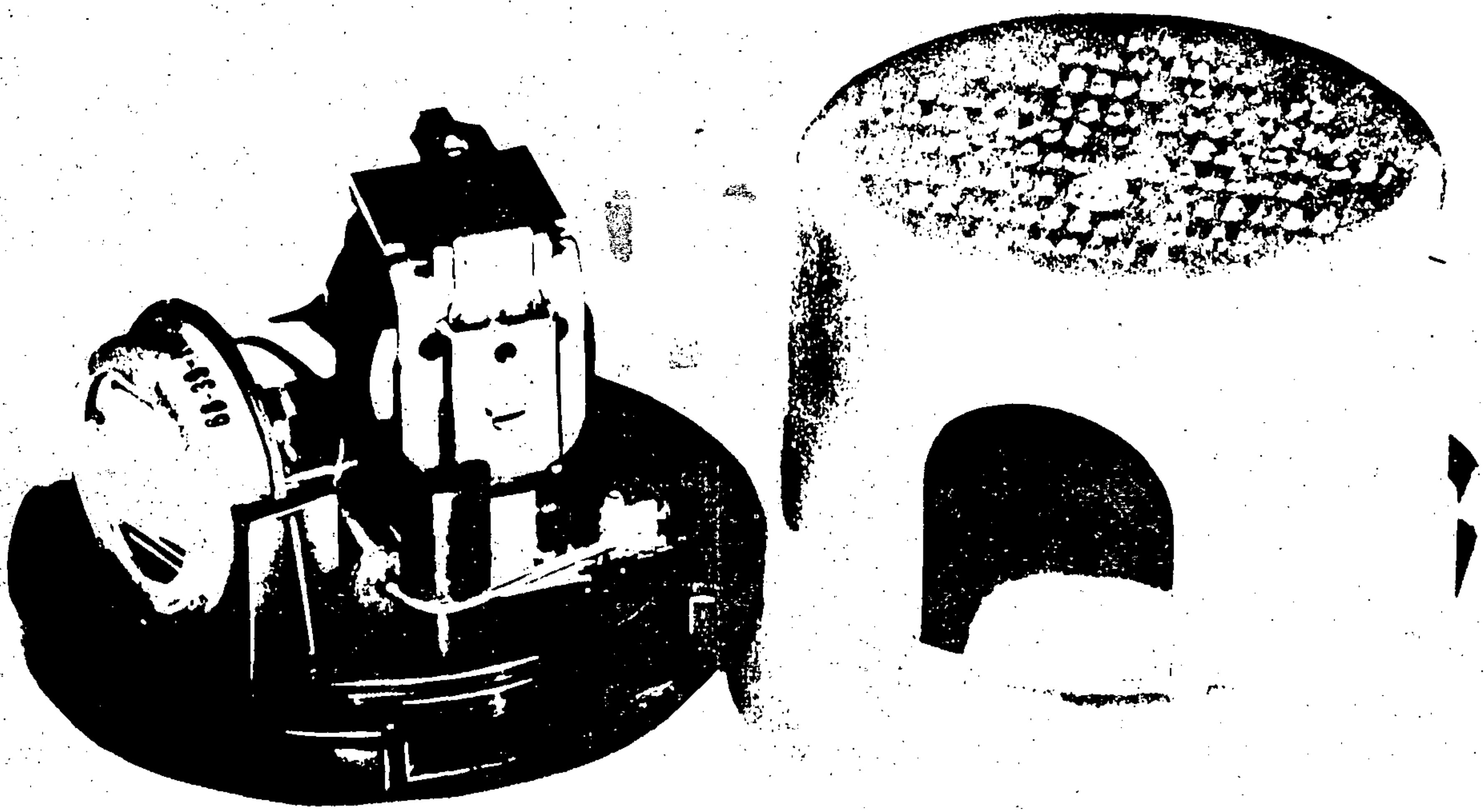


Fig. 6-2. AC Relay Photoelectric Control Element with Cover Removed.

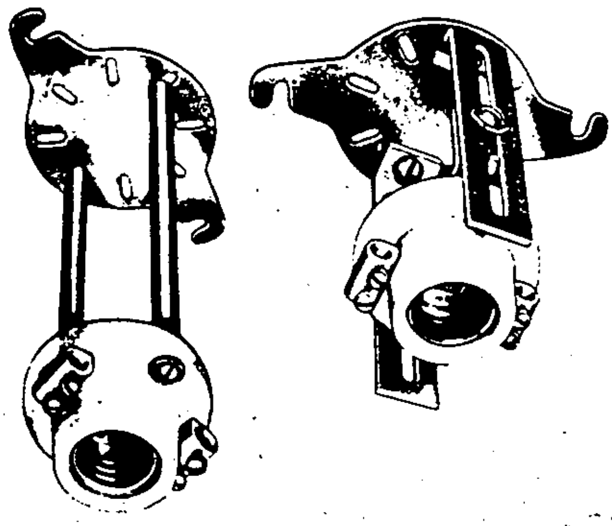


Fig. 6-4. Sockets-fixed (left) and adjustable (above).

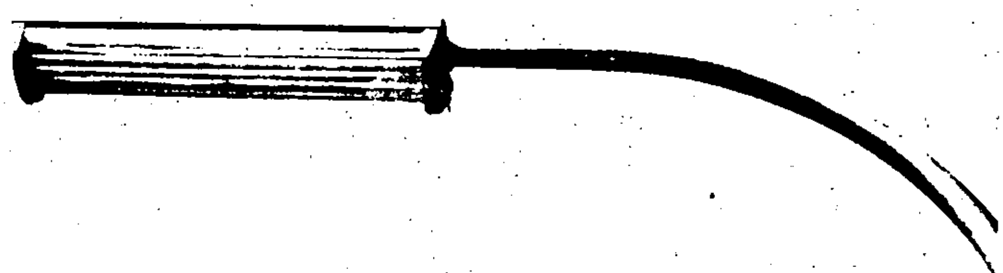


Fig. 6-3. Fluor   re.

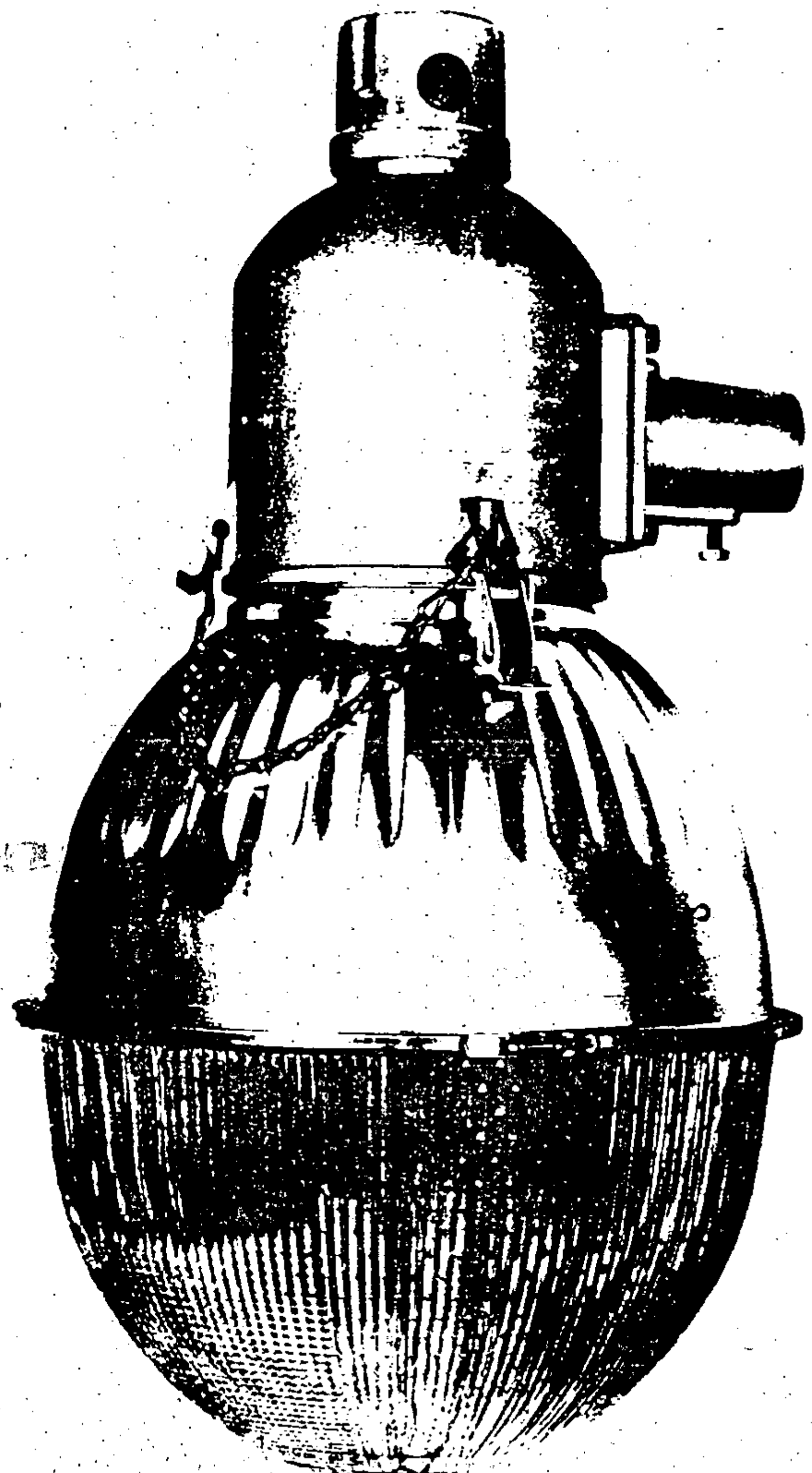


Fig. 6-8. Fluorescent luminaire.

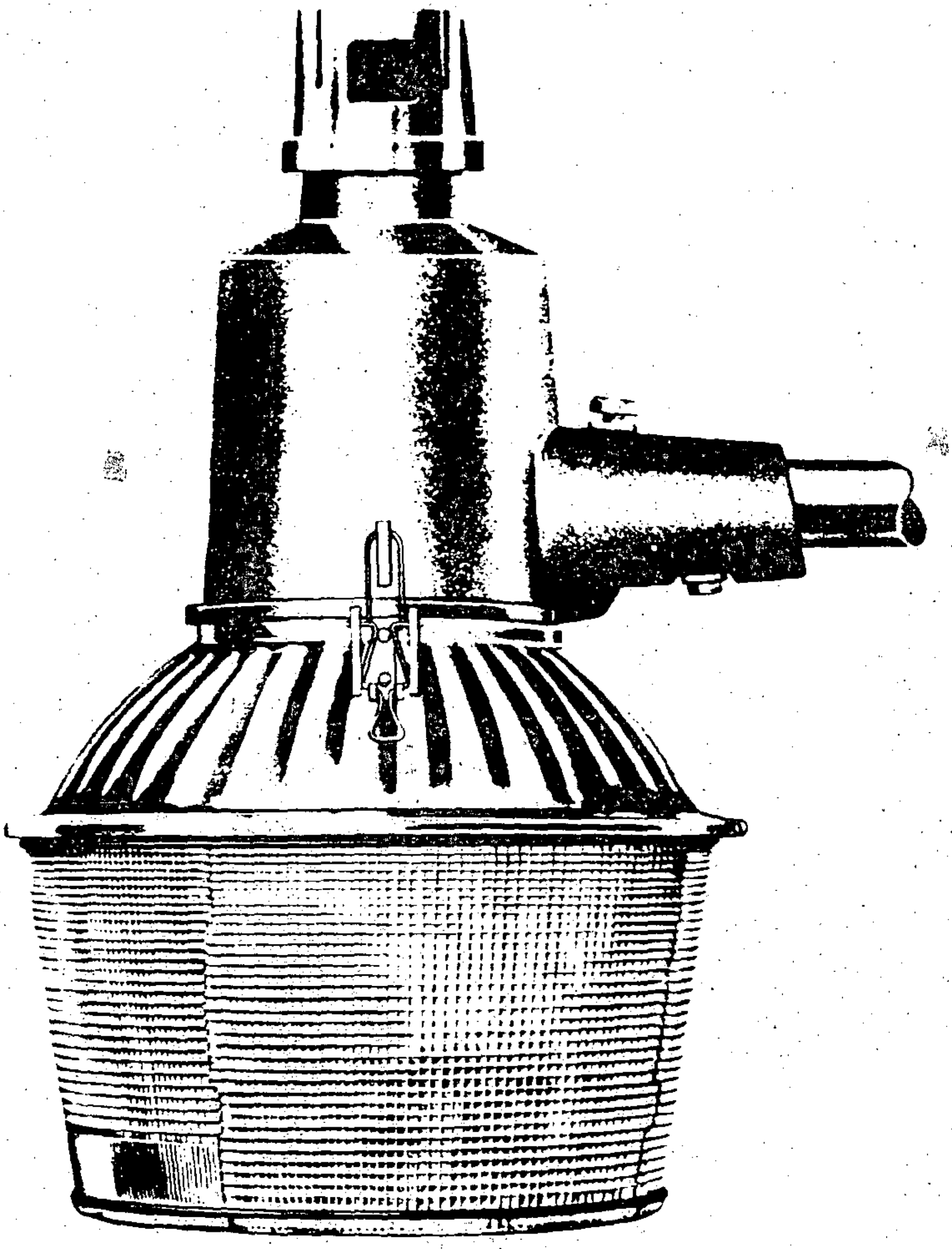


Fig. 6-10. Open bottom round luminaire.

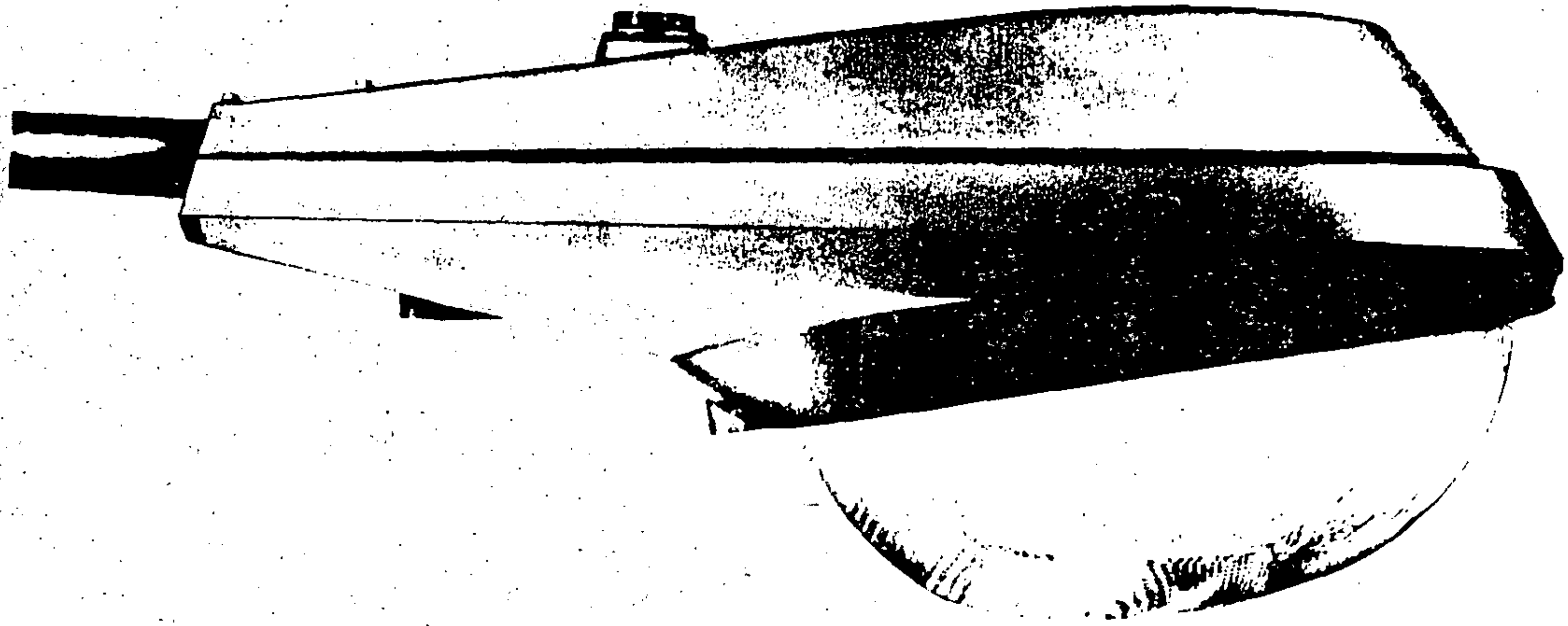


Fig. 6-11. Streamlined oval luminaire.

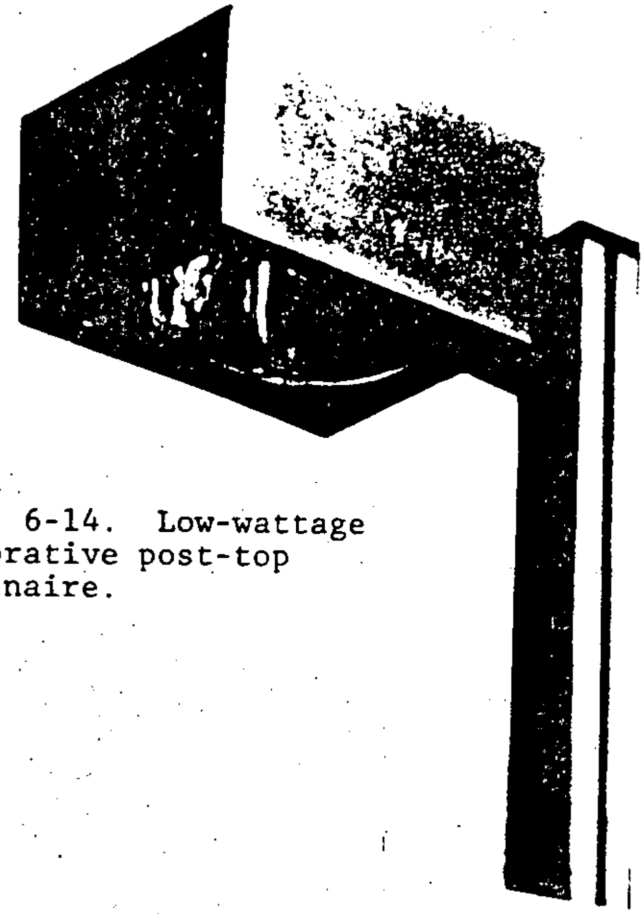


Fig. 6-14. Low-wattage decorative post-top luminaire.

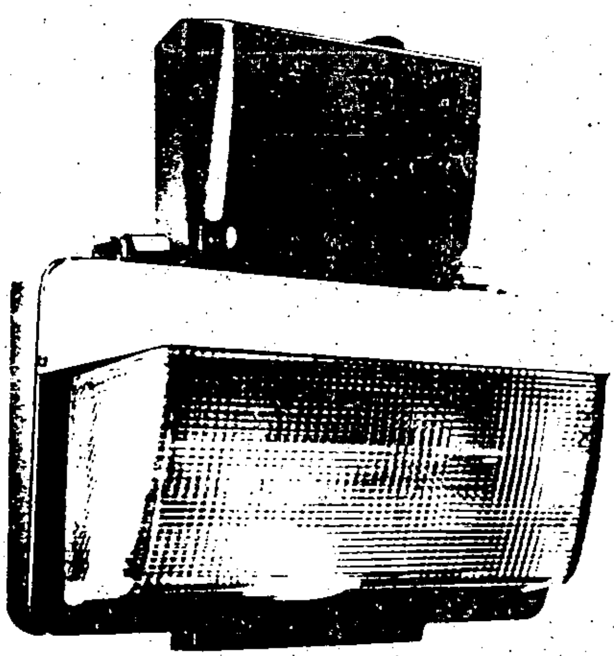


Fig. 6-16. Wall-mounted luminaire for underpasses.

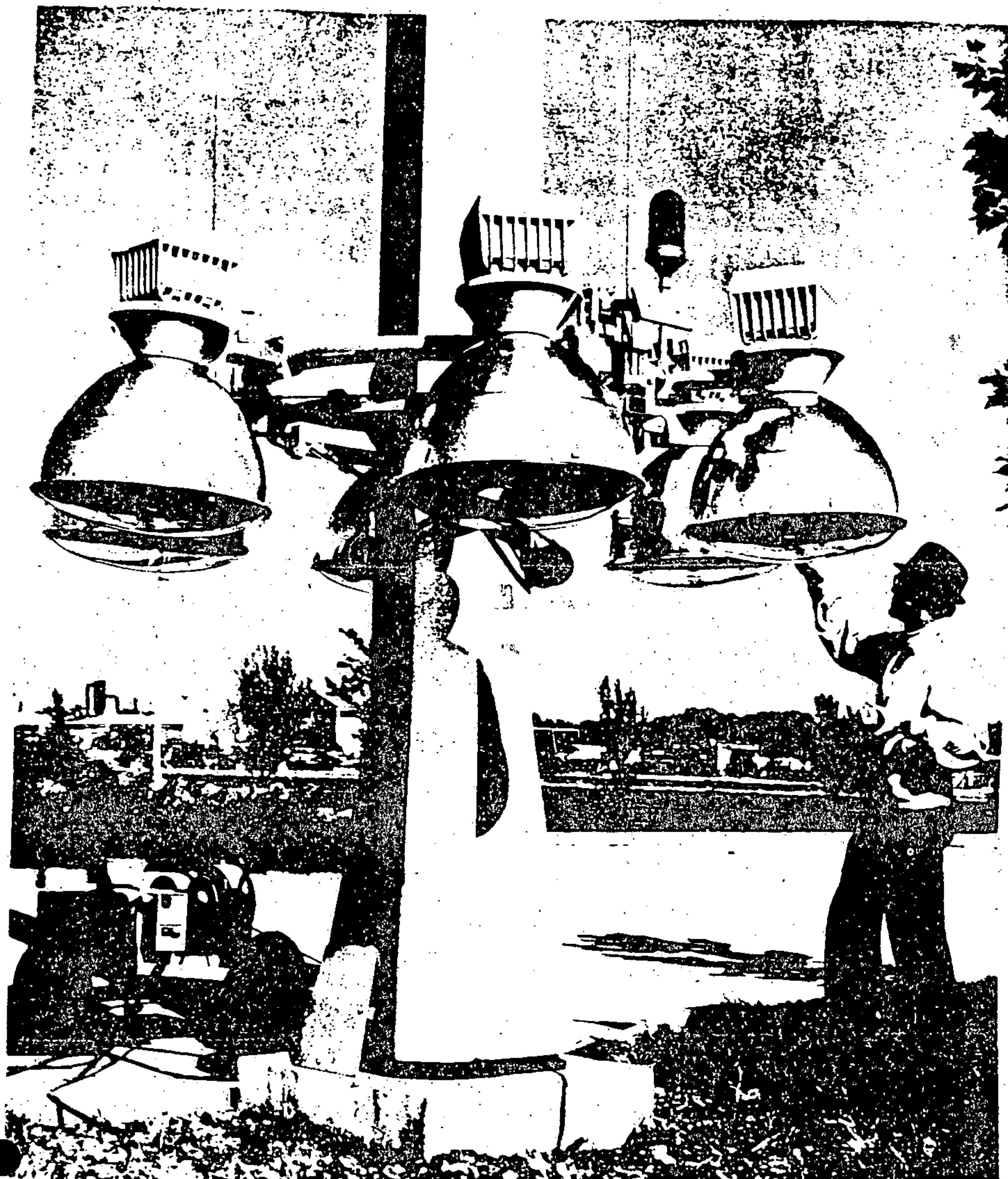


Fig. 6-15. High-wattage, high-mounted, area-lighting luminaires.

Principles of Vision in Public Lighting

Though public lighting has to satisfy both drivers and pedestrians, it is in practice the requirements of the drivers which are the more stringent.

1. Requirements for Drivers

   a. At any moment the whole of the road and its details should be clearly visible. Among the details where perception is particularly necessary are: the surrounds of the roadway and the sidewalks, the entry of side roads, and traffic signs, whether at the side or painted on the pavement surface.

   b. The clearest possible visual guidance should be provided on the alignment of the road. Perception of details of the road gives some indication of its alignment; but this should be reinforced by other means, for example, the pattern formed by the luminaires as seen by the driver, and by their color (the beacon effect).

   c. Any object which is or which may be dangerous should be seen at a distance great enough to give the driver time to make--without danger to himself or others--any maneuver which the presence of the obstacle may demand. This time must be sufficient for the perception of the obstacle, its identification, the appraisal of its direction of movement, its distance and its speed, and the taking of the decision as to the maneuvers to be effected, to carry them out, taking into account the speed of the vehicle, the reaction time of the driver and the braking time. This perception should obviously be provided over the whole of the visual field of the driver, that is to say, in the zones of both focal and peripheral vision.

   In the absence of obstacles, the presentation of the road should be such that the driver is certain that the road is clear. This condition involves affording to the driver visual comfort, such that he is not subjected to nervous fatigue, which may be dangerous.

d. The lighting of the street should appear continuous and uniform.

Special lighting, which does not alter the appearance of continuity of the lighting of the road as a whole, should be provided at critical points and areas such as curves, crossroads, bridges, tunnels, underpasses, crossings, etc.

e. Direction signs and such features as islands and guard posts should be made conspicuous at night, though without involving glare; they may be lighted either by the general installation or by special equipment.

2. Visual Field of the Driver

a. The usual field of the driver comprises, in order of decreasing importance:

- the roadway
- the surrounds to the roadway including signs and signals
- the sky, including the bright luminaires

Any obstruction or circumstance liable to lead to an obstruction should be clearly displayed in this visual field. Since perception and the speed of perception are directly related to the luminances and the contrasts in the visual field, it is necessary to understand the mechanism by which the relevant luminances are produced.

b. The luminance of the roadway results from the distribution of luminous intensity of the luminaires, from the geometry of the installation--that is to say, the siting with respect to the plan of the roadway, and the reflection characteristics of the surface of the roadway. Calculations are fairly complex; nevertheless it is possible to obtain a good idea of the influence of the light distribution and of the reflection characteristics of the roadway by examining in the visual field of the driver (i.e., in perspective) the shape of the bright patch formed on the ground by a single luminaire (curve of constant luminance, see Fig. 7-1).

This patch has the form of a letter "T" the tail of which is shorter as the road surface is more diffusing and as the distribution of luminous intensity is more cut-off (see Fig. 7-1). The head of the "T" is wider as the surface is more diffusing and as the distribution of the luminaire is wider in the direction of the width of the road.

It is also a function of the crown of the roadway.

The pattern of luminance on the roadway is produced by the juxtaposition of these patches which results from the location of the luminaires and the geometry of the road. The interdependence referred to above is obvious. The location of luminaires should therefore be carefully set out and studied in a perspective view of the road.

It should be noticed here that the ratio of the spacing to the mounting height is a predominant factor as is also the ratio of the width of the roadway to the mounting height.

c. The luminance of the surrounds to the road depends upon their nature and upon the distribution of luminous intensity of the luminaire. It is not usually calculated, but it enters into the evaluation of the degree of glare, and in the estimation of the contrasts presented by objects seen against the surrounds of the roadway.

d. The luminance of the luminaires themselves depends on the distribution of luminous intensity and on their projected area. Its order of magnitude is very much greater than that of the luminances of the roadway and of the facades. It may result in an effect of glare which reduces the visual faculties of the eye, or gives rise to a sense of discomfort which, eventually, brings about fatigue.

3. <u>Visibility</u>

The phenomenon of visibility is directly related to contrast. It follows that the visual requirements of the driver that good contrast should always be produced:

a. between the roadway and all objects which indicate its boundaries;

b. between any obstacle which may be present and the background against which it appears.

Since the characteristics of the obstacle may vary over a very wide range, any factor which tends to increase contrast should be exploited.

In the first place, the luminances of surfaces which form a background should be sufficiently high and uniform. In open country, or if the surrounds are insufficiently bright, only the luminance of the roadway is involved; but in built-up areas, the luminance of facades or of trees at the side of the road is also important. Secondly, discomfort due to glare should be reduced as far as possible within the limits of practical considerations.

The contrast of an obstacle depends on both its own luminance and on that of its background; but in most installations luminances vary in such a way that low contrasts are transient. It is, however, important to avoid situations in which low contrasts can persist over long distances.

<u>Visibility Factors which Influence Seeing and Visibility</u>

1. Most aspects of traffic safety involve visibility. The fundamental factors which directly influence visibility are:

    a. The luminance of an object on or near the roadway.

    b. The general luminance of the background of the roadway.

    c. The size of an object and its identifying detail.

    d. The contrast between an object and its surroundings.

    e. The ratio of pavement luminance (photometric brightness) to the surroundings as seen by the observer.

    f. The time available for seeing the object.

    g. Glare.

    Good visibility on roadways at night results from lighting which provides adequate pavement luminance with good uniformity and appropriate illumination of vertical surfaces within adjacent areas, together with reasonable freedom from glare.

    Visual tasks vary widely as to size, contrast, and the time available for seeing. Luminance, however, is a function of illumination and it is subject to control entirely independently of the other factors mentioned.

    In street lighting, as contrasted with interior lighting, the size of objects or of their critical detail is of little consequence. The objects to be perceived are relatively large, and visual acuity or the ability to distinguish fine detail is not involved as a general rule.

    Contrast between an object and its background and between parts of an object is an important factor in street lighting. An important objective in street lighting design is to create or enhance the brightness contrast between an object (whether it be pedestrian, vehicle, or some other obstacle on a roadway) and its background, or the roadway surface itself.

Luminance is what the eye sees; thus, it is always of prime importance. Luminance is a function not only of the illumination but of the reflectance of the object--an inherent physical property of the object itself. A light-colored surface--that is, one with a high reflectance factor--will be more readily perceived and therefore more visible than a dark surface when both are illuminated to the same footcandle level. (It is for this reason that pedestrians are cautioned to wear or carry something light in color when walking along dark streets or highways at night.)

In street lighting design, one is most often concerned with producing high and reasonably uniform pavement luminance. Pavement reflectance characteristics, therefore, and the quantity and direction of the illumination are of prime consideration.

2. The speed of vision, or the time factor, is of great importance in street lighting. Split-second seeing is required when a motorist is traveling the highway at today's speeds. See Fig. 7-2. It takes time to see a potential hazard. The time method is directly proportional to the size, luminance, and the luminance contrast of the object which constitutes the potential hazard. A well-designed street lighting system will reveal the hazard. On the other hand, a poorly designed system may not reveal the hazard.

3. To sum up, it may be said that in the design of street lighting one deals with objects or obstacles whose size is relatively large and with contrasts which are highly variable. Neither size nor contrast are controllable by the street lighting engineer. Luminance, however, is controllable to a degree but as has been indicated, one is forced by economic considerations to provide relatively low levels of illumination from widely spaced luminaires. The net result is a highly specialized design problem that cannot be approached except by careful manipulation of lamp size and luminaire selection and arrangement. Instead, there is a limit to the degree in which the scientific principles involved can be applied in order to provide effective and comfortable lighting for streets and highways.

Methods of Discernment

The peculiar nature of the street lighting design problem has required a special technique based upon so-called methods of discernment to an extent not encountered in ordinary interior lighting practice. Among the methods of discernment may be noted:

a. Seeing by surface detail. See Fig. 7-3.
b. Seeing by silhouette. See Fig. 7-4.
c. Seeing by glint of highlights.
d. Seeing by shadow.

Practical street lighting design is usually concerned with items a and b. Seeing by glint and by shadow are secondary effects and are not considered prime factors in the design of conventional lighting systems.

Pavement Luminance Requirements

1. The majority of street and highway lighting designs involve silhouette seeing--hence, the level and distribution pattern of pavement luminance as it appears to the motorist. The higher the luminance level of the pavement, the sharper the silhouette or contrast, and so the higher the visibility. See Fig. 7-5. Consequently there should be no dark patches that might conceal a defective pavement, an obstacle, or other hazardous situation. Some departure from absolute uniformity is acceptable within limits in practical design.

   In designing for uniform pavement luminance, the engineer is confronted with the technical problem of providing proper distribution of light flux on the pavement surface. Pavement luminance as such, is measured in footlamberts, and results from light reflected from the pavement to the observer's eye. Compliance with distribution prototypes in the ANSI Standard as to permissible variations in footcandles will usually insure reasonably uniform pavement luminance.

2. A more common pitfall in street lighting design is to confuse uniform illumination with uniform pavement luminance. Pavement luminance is produced by light reflected from the pavement to the observer's eye and is not only a function of the illumination falling upon the surface but also of the incident angle at which it falls. For example, illumination falling vertically upon a roadway will not produce nearly as much luminance as that which strikes the pavement at very low angles and is reflected toward the observer's eye. The observer, or motorist, normally views the pavement at low angles. See Fig. 7-6.

   As a result, a uniform distribution of illumination in footcandles does not necessarily result in a uniform pattern of luminance as observed by the motorist. See Fig. 7-7. With conventional luminaires and with the usual IES-ANSI spacings and mounting heights, pavement luminance will generally be much more uniform than measured illumination. In downtown streets where luminaires are placed at relatively close spacing and at higher mounting heights, a situation is approached much like that found in interior lighting practice where uniform illumination and uniform luminance are produced simultaneously.*

3. Pavement luminance is also influenced by the transverse location of the luminaire with respect to the paved surface. The lateral direction of the incident light determines the direction of the maximum reflected ray. Light reflected at other lateral angles if less than maximum, as shown in Fig. 7-8. The luminaire will produce maximum pavement luminance when positioned directly in line with the motorist's line of sight over the center of the traveled way. While this cannot be achieved in practice on multi-lane roadways, the principle is sound nevertheless, and every effort should be made to locate luminaires over or near the traveled way where practical.

4. In practical street lighting design, acceptable luminance patterns may be achieved by conforming to the recommendations of the ANSI Standard Practice which states, in effect, that:

   a. The ratio of average to minimum illumination (footcandles) should not exceed 3 to 1.

   b. Where vehicular traffic is very light and speeds lower, an exception is made in which case the ratio of average to minimum illumination should not exceed 6 to 1.

5. Luminaire manufacturers usually furnish data indicating conditions of use--that is to say, spacing and mounting arrangements for streets of specified widths which will insure conformity with the ANSI Standard of uniformity. In the absence of such data or where conditions are unusual, a plot of isolux curves may be made or, as indicated in the ANSI Standard Practice, average and minimum illumination levels can be calculated from the manufacturer's isolux curves for the particular luminaire to be employed.

<u>Factors Influencing Pavement Luminance</u>

1. <u>Pavement Reflectance</u>

   a. Luminance of the surface is a measure of the light flux reflected from that surface to the eye. Where the surface is nonspecular, a simple mathematical relationship exists as follows:

*See American National Standard Practice for Roadway Lighting.

$$L = E . \rho$$

Footlamberts = footcandles x reflectance

b. Where the surface is specular, however, no such simple relationship exists except in the case of highly polished surfaces such as the common mirror in which the observer actually sees an image of the light source when viewed at some particular angle. Under such conditions, the luminance of the surface (or image) will approach that of the source itself. This condition is approached on wet pavements where narrow streaks of high luminance form an entirely different pattern from that provided under dry conditions. It is well recognized that luminaires of linear form extending out over the pavement will produce a wider image under wet pavement conditions. This may improve the silhouette effect somewhat, although with commercially available luminaires, the widening effect is somewhat limited.

c. In actual design, it is necessary to deal with pavement surfaces which vary from very dark asphalt, with reflectances of the order of 3 percent, to concrete with reflectances as high as 20 percent. The natural conclusion from this is that the darker surface would require three to four times as much illumination as the lighter surfaces in order to produce the same luminance. However, in street lighting pavement luminance is greatly enhanced by two factors--namely (1) the relatively high effectiveness of light which strikes the roadway surface near grazing angles, and (2) the high specularity of the road surface due to oil and tire polish. Even an asphalt surface, which only has a reflectance of 3 percent, may reflect as much as 90 percent of light striking the surface at grazing angles. See Fig. 7-11.

d. The charts in Figs. 7-9 and 7-10 show directional reflectance factors at viewing distances of 100 feet and 400 feet (at 4 feet observer height) for a typical traffic worn asphaltic concrete pavement.

It is important to note that such specular reflection is effective primarily on that part of the pavement which is in direct line with the motorist's line of sight, and that the luminance of other pavement areas depends more on the diffuse (or spread) reflectance characteristics of the surface at any given point. To take full advantage of the directional reflectance characteristics of the pavement, luminaires are most effective when located out over the roadway and at preferred locations with respect to intersections, curves, and other roadway configurations.

e. Prior to the 1963 Standard Practice for Roadway Lighting it was proposed to increase the recommended minimum footcandles by 50 percent for very dark (3 percent reflectance) surfaces. Also, it was proposed that the stated minimum values might be reduced by 25 percent where the pavement reflectance was unusually high (20 percent reflectance). While this degree of refinement in street lighting design is no longer considered of practical significance, the fact remains that pavement surfaces having relatively high diffuse reflectances are easier to light, and will result in a brighter pavement, other things being equal.

Luminaire Distribution Characteristics

a. The improved ratio of luminance to illumination when light strikes the surface at low grazing angles points up the necessity for concentrating fairly high candlepower in the high vertical angles--that is, from 70 to 80 degrees. High angle emission poses a problem of glare and leads to the necessity for sharp cutoff above the design angle of maximum candlepower. Physical limitations posing the necessity for placing luminaires at the side of the roadway require that the maximum beam candlepower be directed inward at an angle with the curb, and aimed towards the center of the roadway. The result is often a sacrifice of pavement luminance in lanes near the curb in order to obtain adequate luminance in the far lanes.

b. It is perhaps obvious that narrow distribution patterns such as IES Types I and II are theoretically capable of producing higher pavement luminance by reason of the high candlepower emission which occurs at high or grazing angles. The problem of glare is aggravated, however, due to the high candlepower and the direction of the beam which may be close to the motorist's line of sight. Type III distribution fits most streets and highways and represents a desirable compromise in providing maximum pavement luminance with reasonable glare, the direction of its maximum candlepower being somewhat farther removed from the motorist's line of sight.*

Spacing and Arrangement

a. One-Side Arrangement. One-side arrangement of luminaires will result in a non-uniform luminance pattern, more pronounced as the roads increase in width. The driver in the near lane (on the pole side) will generally be favored, and this is unavoidable. By proper design, however, the

*See American National Standard Practice for Roadway Lighting.

far lane can be adequately provided for. See Fig. 7-12. The road width to mounting height should not exceed 1.2.

b. Staggered or Opposite Arrangement. Staggered or opposite arrangement will result in a luminance pattern which appears the same to the driver traveling in either direction. A much higher degree of uniformity is theoretically attainable and hence this arrangement is to be preferred. See Figs. 7-13 and 7-14. The roadway width to mounting height ratio should not exceed 2.5.

c. Center-Mounted Arrangement. Center-mounted arrangement results in a luminance pattern that appears the same in both lanes of travel and, on narrow streets where applicable, the uniformity can be very good. However, in practice, center-mounted Type I luminaires are commonly installed with long spacing--that is, 200 to 300 feet. Although there is the possibility of a somewhat spotty pattern, nevertheless this may be acceptable on residential or very low traffic streets. See Fig. 7-15.

Mounting Height Factor

The basic advantages of increasing the mounting height of a fixed lighting system when practical can be ennumerated as follows:

1. More effective light flux distribution coverage on wide roadways and interchange areas.

2. Usually less glare, more comfort, and better visibility.

3. Possible lower costs.

4. Lower system maintenance costs because of fewer luminaires and poles.

5. Less dirt accumulation from traffic.

6. Lower incidence of vehicle collision, fewer poles and better placement.

7. Better system appearance with no daytime forest of poles and nighttime constellation of confusing lights.

8. Use of larger lamps and/or more luminaires per location.

9. Less abrupt luminance changes on vertical surfaces.

Overhang - Bracket Lengths

Accepted good practice is to locate the luminaire immediately over the edge of the driving lane for a two-lane roadway. For three lanes and wider, locate the luminaire over the center of the adjacent driving lane.*

*See Fig. 7-8.

Negative Factors

1. Glare from Street Lighting. In street lighting, as with interior lighting, glare is described, studied, and discussed under two headings--namely, disability glare and discomfort glare. Under either description, glare itself refers to the effect of the relative high brightness of the luminaire which may be of such magnitude and so positioned in the visual field as to seriously impair vision in the extreme case, or to merely cause annoyance or discomfort in the relatively mild case. See Fig. 7-16. Actually, there is no sharp line distinguishing disability glare and discomfort glare. Every effort should be exerted by the designer to minimize its effect. Sometimes a distinction is made between preventable glare and unpreventable or uncontrollable glare.

   a. By preventable glare is meant the effect of that luminous flux which the eye receives directly from the light source of the luminaire itself. This is light which contributes negatively to visibility of objects and which can be eliminated or minimized by careful luminaire design and placement.

   b. Unpreventable glare results from light reflected from the object itself directing light flux to the eye as an essential element in the seeing process. The excess light, or luminance contrast, from the object and its surrounds tends to lower visibility because of the inability of the eye to adapt itself to varying luminances instantaneously. The eye sees most efficiently in a field of uniform luminance.

2. Practical Control of Glare.

   a. "Control of glare in street lighting is much more difficult than with interior lighting. This is due to three factors; 1) It is generally necessary from an economic standpoint to place luminaires on rather long spacings and to get uniformity of illumination or uniformity of luminance - it is necessary to send quite a bit of light at rather high angles (beam direction.) 2) Some designers feel that to achieve highest possible pavement luminance it is necessary to direct some light at very high angles toward the driver since the reflectance of the pavement is highest at near grazing angles. 3) The location of the luminaires are generally of necessity directly in the driver's field of view. Various investigators have shown that disability glare is a function of candlepower toward the eye. It has further been shown that the effect of disability glare varies inversely as the angular displacement of the luminaire from the normal line of sight. The precise mathematical relationship depends upon the square of the angle of deviation which immediately suggests to the designer the advantage of higher mounting heights, side-of-road or off-the-road mounting or any other measure which will tend to remove the glare source from the direct line of sight."

b. Skillful design of luminaires to minimize luminaire "hot spots" or excessive luminance toward the observer helps materially to reduce discomfort glare. In general, intrinsic luminance of luminaires is readily controlled and reduced by increasing the size of the luminous area.

3. Glare from Other Sources

a. It is quite obvious that it is beyond the province of the street lighting designer to exercise control of glare which may originate from other than street lighting sources. Such sources are opposing headlights, floodlights at the side of the roadway, etc. Offending floodlights and other sources of glare should be redirected, shielded, or removed where it is shown that they constitute a hazard to night driving. Such action should be taken by the public officials concerned. This is not to say, however, that with well-designed street lighting the effect of these extrinsic sources of glare cannot be minimized or entirely eliminated. Furthermore, it may be pointed out that adequate and proper street lighting makes it entirely possible to drive safely with parking lights alone.

b. Recent tests demonstrated that two footcandles of fixed lighting in combination with vehicle parking lights provided the best visibility conditions with greatest comfort. The glare from opposing low beam headlights under the same two footcandles of fixed lighting significantly reduced visibility distances and produced no discomfort glare.

c. Thus, when streets are well lighted, the attention of the driver is more readily directed to the road ahead, and distractions due to random luminances in the peripheral field are less likely to interfere with the driver's concentration on his task. Good visibility, resulting from good street lighting, permits the driver to scan a wider field of view, much as he does in the daytime, thus relieving muscular tension and fatigue so often associated with night driving where the driver is forced to concentrate his attention on a narrow area immediately ahead.

4. Weather Conditions

a. We recognize that as paved roadway surfaces become wet the normal diffuse pavement luminance almost completely disappears and auto headlights diminish in utility. They become as a boat light on the water, i.e. we see almost nothing ahead of us until an object becomes lighted with the direct light of our headlights, an effect commonly called seeing by reverse silhouette (see Fig. 7-17). This effect is particularly pronounced on smooth and worn roadway surfaces. Objects are seen reasonably well by this reverse silhouette process, but the disturbing thing is that the motorist's normal frame of reference, namely, a well lighted roadway ahead of him, disappears and it becomes difficult for him to know where the roadway really is.

   On the other hand, a lighting system whose luminaires are over or near the roadway produces mirror-like images of each luminaire on the wet surface producing streaks of luminance which define the driving lane ahead, and against which objects stand out in silhouette (see Fig. 7-18 a & b). Also as previously noted, luminaires of larger dimensions especially normal to the curb-line, produce a somewhat broader reflected image and are therefore somewhat more effective on wet pavements.*

b. Fog conditions at night are particularly hazardous for the driver. Up to now, no practical solution has been found for the night fog problem either by the use of special headlamps on the motor vehicle itself or by special street lighting equipment. Fog disperses the light from the headlights and directs much of it back toward the source, and therefore toward the driver himself. The higher the beam candlepower, the more light is directed back to the driver, producing a luminous fog screen which greatly impairs visibility. This effect is more pronounced on high beam and is reduced somewhat if the headlights are located and aimed as far away as possible from the driver's normal line of sight.

   This idea has been used by experimenters to show that visibility of roadways under fog conditions can be improved from fixed lights, placed close to the ground, which project light beams in a flat sheet crosswise of the pavement.

   Continuous or nearly continuous rows of low mounted projectors would be costly to install and maintain as compared to conventional street luminaires. It is conceivable, however, that for extreme conditions in limited areas this

*see American National Standard Practice for Roadway Lighting.

method may ultimately prove to be acceptable. The technique involves a sharp cutoff of light above the horizontal, directing light close to the pavement in a zone where the fog is of relatively low density.

In the past, fog lights employing amber lenses placed to the right of the driver's line of sight and close to the ground were used. This was advocated as a means of improving driver visibility under fog conditions. Lighting specialists generally agreed with the idea of locating such lights as far from the driver's line of sight as possible, but denied any special virtue from the use of the colored lens. Colored light is generally obtainable only with the use of a filter which passes the color desired and excludes the rest of the light. Thus color can only be obtained at the expense of beam candlepower and the loss offsets any questionable advantage to be gained by virtue of color alone.

c. Another possible approach to better seeing in fog conditions is the use of high-mounted luminaires. Research on this is not yet conclusive but there is some evidence to indicate that the directional feature of high-mounted lighting is beneficial in fog conditions (see LD & A April 1972) and many who have observed interchanges listed with high-mounted equipment agree that seeing conditions in fog definitely are improved.

Physical Factors

1. In street lighting design, the primary concern is with the area of the roadway surface itself from curb to curb and secondarily, with sidewalks and other areas immediately adjacent to the paved surface. These areas seem relatively large when compared to those encountered in typical interior lighting design. Street widths, for example, may vary all the way from 20 feet on country roads and residential streets to widths of 90 feet or more in downtown business areas and multi-lane expressways.

The number of effective lumens required to illuminate a street surface to a specified footcandle level depends upon the area of the street surface. For a roadway of indefinite length, the critical dimension from the standpoint of design is street width, usually between curb and curb, or the width of the paved surface where no curbs exist. Longitudinally, the critical dimension is the spacing between luminaires. The area to be illuminated per luminaire is the product of the street width and the luminaire spacing.

Commercially available luminaires for street lighting are designed to distribute maximum illumination from curb to curb in a generally asymmetric pattern in order to fit a long rectangular area represented by the roadway itself. Sharp cutoff of light at the curbline is neither practical nor desirable, since the spill light beyond the curb provides a most useful and often essential service in illuminating pedestrian walkways, and aids in discernment of potential hazards--either pedestrian, vehicular, or fixed objects beyond the paved surface. Also for high speed traffic, peripheral vision enables more accurate judgement of speed. For example, at 60 mph and 25° view, the angular speed is 13.5 greater in the peripheral region than in the foveal region.

2. Business and Congested Streets

Downtown business streets and similar congested areas often have certain special characteristics which will influence street lighting design. Significant factors include the following (see Fig. 7-19a):

a. Street widths, particularly in downtown city areas, may be relatively great, suggesting relatively large lamps and close spacing with IES Types III and IV distribution.

b. Traffic density, both vehicular and pedestrian, is such that roadway and sidewalk surfaces are often concealed in which case the illumination or luminance of vehicles, pedestrians, or fixed objects is the all-important criterion which determines relative visibility and therefore, safety.

c. Adjacent building facades provide vertical surfaces, the illumination of which may be highly desirable from the standpoint of overall environment, at the same time reducing contrast between luminaire and background, a condition contributing considerably to visual comfort.

d. Parking at curbs may make necessary extended mast arms and may indicate need to pay attention to the hazard from jaywalking adults and children stepping out from behind parked cars.

e. Frequent intersections, which increase the potential hazards when crossing and turning, may justify higher levels of light and careful placement of luminaires to improve visibility in the peripheral areas.

3. Outlying Streets and Highways (See Fig. 7-19b.)

a. Streets may be narrow, permitting center mounting, one-side pole locations and/or IES Types I and II distributions.

b. Sidewalks or walkways may be poorly defined, increasing the hazard to pedestrians. Such conditions require ample illumination.

c. Building setbacks may require consideration of extended patterns of illumination on the house side. This can be provided by avoiding short cutoff of illumination.

d. In order to keep light out of bedroom windows, proper luminaires should be selected; otherwise special house side shields may be required.

e. Trees are, and probably always will be, a major problem in residential street lighting, sometimes requiring special attention to mounting heights and extension of mast arms to minimize interference with the illumination.

In residential and similar areas where post-top units are most suitable, there is generally less emphasis placed on curb-to-curb or pavement illumination than upon the broader areas which includes lawns, walkways, and driveways. The post-top design is inherently advantageous for these applications since the luminaire must be located at or near the center of the illuminated area. With proper lamp size and spacing it is possible to meet ANSI requirements for both footcandles and uniformity with the modern post-top luminaire. See Fig. 7-20.

Highways and traffic streets present such characteristics as the following (see Fig. 7-19c):

a. Very wide pavements

b. Divided roadways possibly requiring consideration of twin luminaires mounted on center strip or perhaps separate treatment of each roadway.

c. Break-down lanes resulting in unusual setbacks, or grade intersections on high-speed traffic streets, requiring special attention to approach lighting from all directions.

d. Interchanges and toll plazas which require special attention to the illumination level and placement of lights with respect to curves and grade separations.

QUESTIONS:

1. Will uniform horizontal illumination on a roadway produce uniform luminance?

2. We have, for years, specified highway lighting jobs in terms of horizontal footcandles but lately there has been discussion of vertical footcandles, why?

3. What are the major factors affecting visibility?

4. There are two types of "glare". Name them and discuss each.

ANSWERS:

1. Uniform illumination on a perfectly diffuse roadway surface would produce uniform illuminance but roadway surfaces are never perfectly diffuse so that uniform illumination will <u>never</u> produce uniform luminance. Roadway surface reflectance characteristics vary from one material to another, whether the surface is scratch-finished, whether there is rubber worked into the pores, whether the surface is wet from water, or oil. There is no one system distribution that will produce perfectly uniform luminance.

2. Almost any object on the road, or even the roadway itself, being made up of small pebble-like or "stand-up" surfaces is seen (in the case of seeing by direct illumination or reverse silhouette) not predominately by the light measured horizontally, but by a vectorial component at 45^{o}. Trucks and objects on the roadway are seen predominately as a result of the vertical component of illumination. It has been suggested that uniform vertical illumination might even be a better criterion of a good lighting job than uniform horizontal illumination.

3. a. Object luminance
   b. Background luminance
   c. Contrast between object and surround
   d. Time
   d. Glare
   f. Object size

4. It is generally agreed that there are two types of glare a) discomfort, and b) disability of veiling glare. Discomfort glare is one causing fatigue of the eyes but not necessarily causing any loss in seeing ability. Disability or veiling glare is that which causes a direct loss in seeing ability. Researchers disagree as to the exact nature of relationship between the two types of glare.

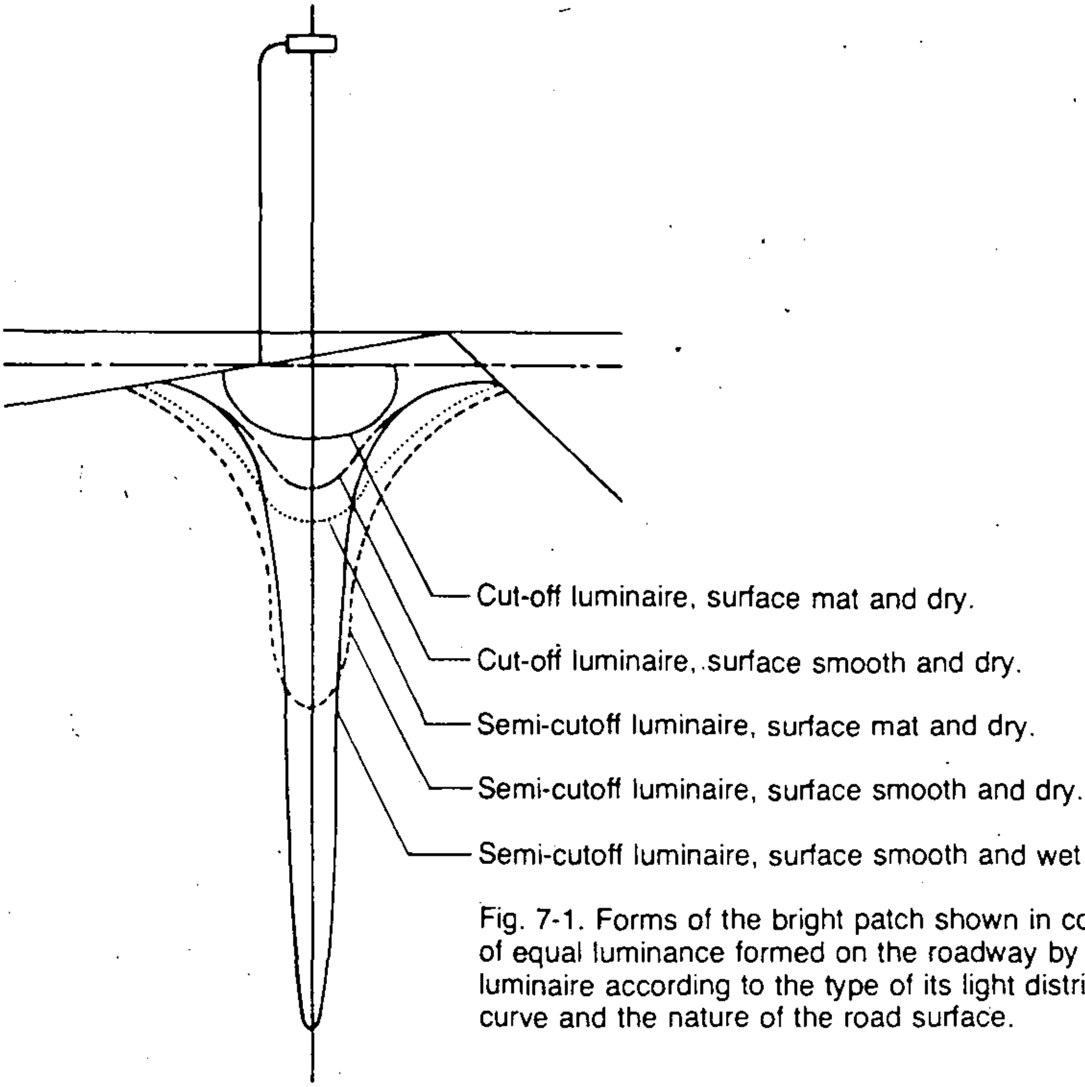


Fig. 7-1. Forms of the bright patch shown in contours of equal luminance formed on the roadway by a single luminaire according to the type of its light distribution curve and the nature of the road surface.

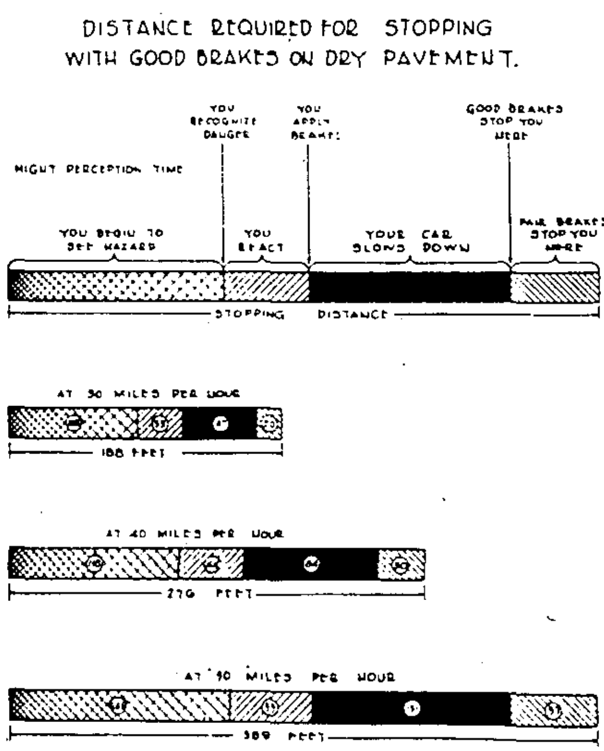


Fig. 7-2. Speed vs. stopping distance.

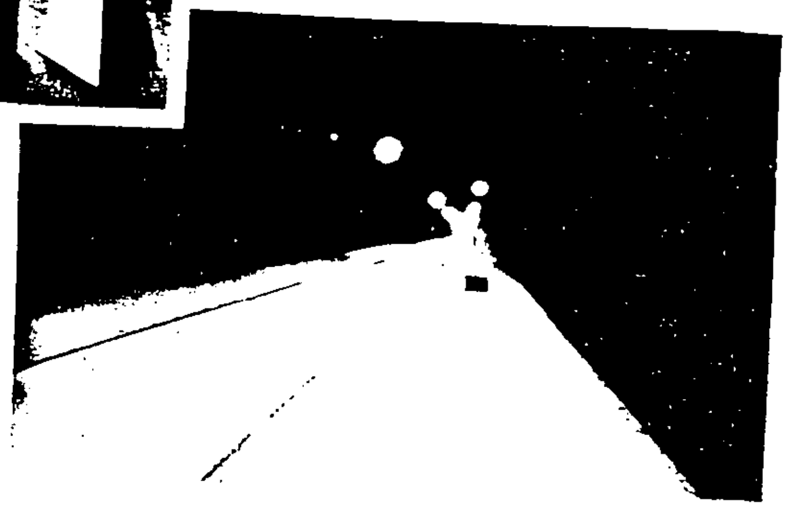


Fig. 7-3. Seeing by surface detail: (above) blocks; (right) typical street.

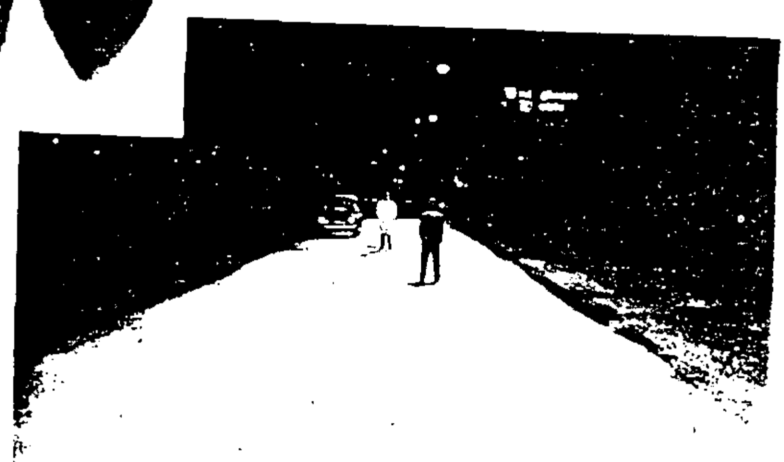


Fig. 7-4. Seeing by silhouette: (above) blocks; (right) typical street.

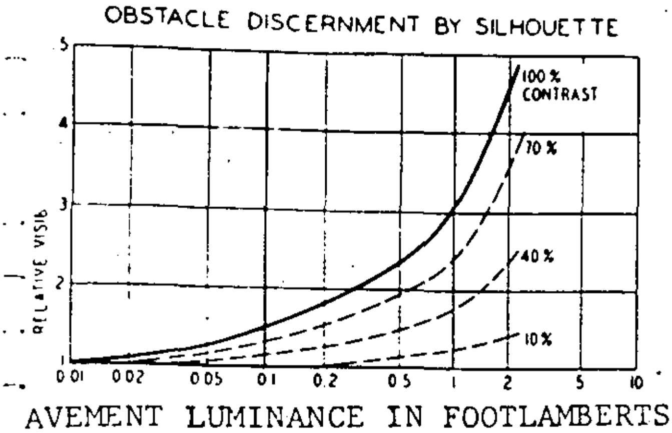


Fig. 7-5.

Discernment of a 1-foot obstacle at 200 feet for various contrasts of obstacle and pavement, with no "glare source" in the field of view. The values of relative visibility are average readings on the Luckiesh-Moss Visibility Meter by 25 observers with so-called normal eyesight. The visibility scale is carried to 1 rather than to zero, because a visibility of 1 may be considered the minimum degree of seeing having any direct value as applied to safety on streets.

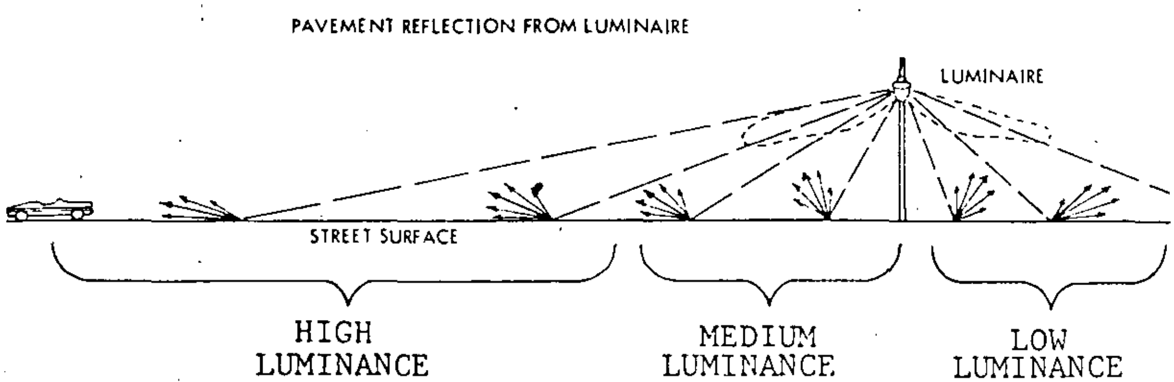


Fig. 7-6. Pavement luminance viewed by driver vs. high-angle emission.

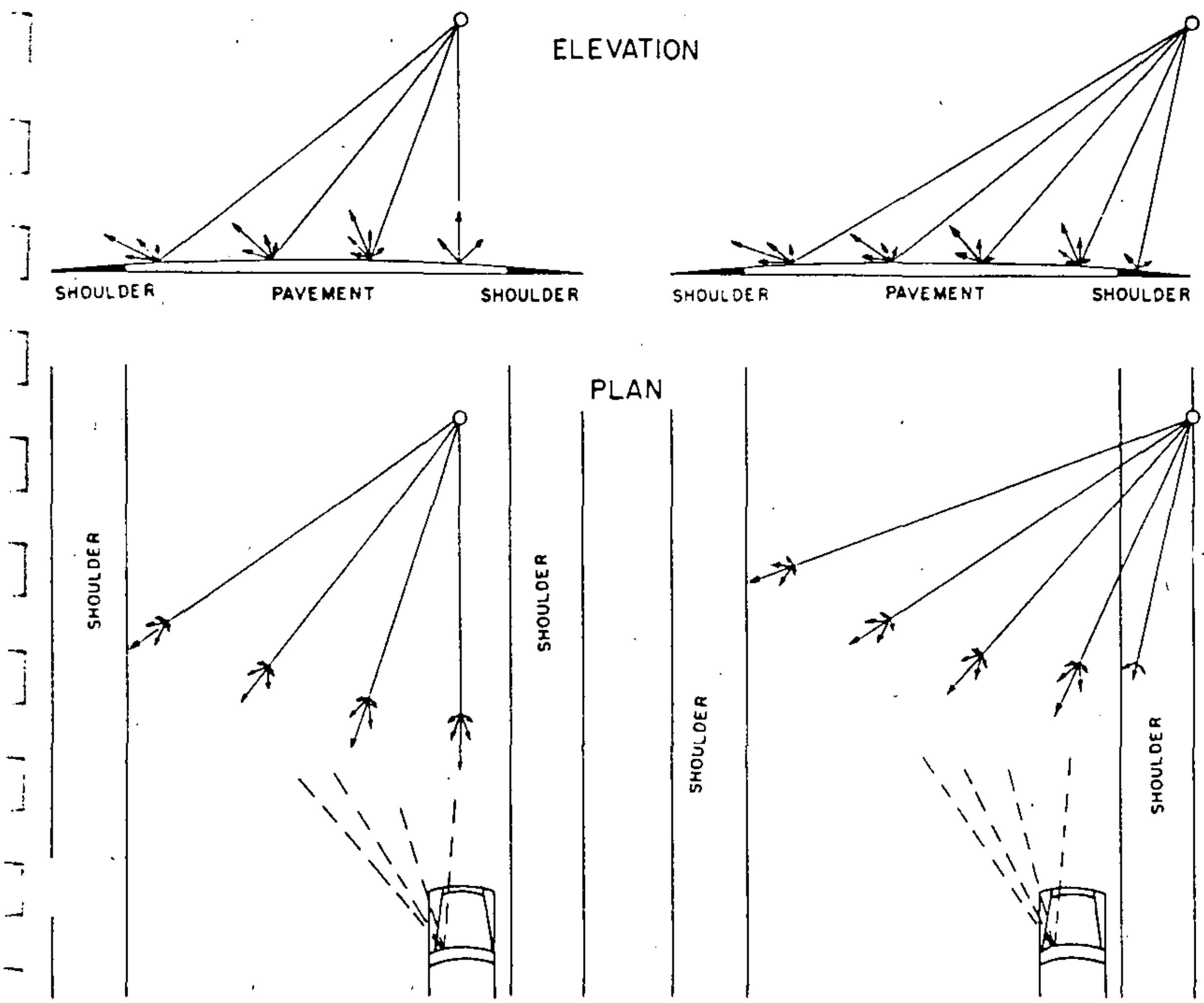


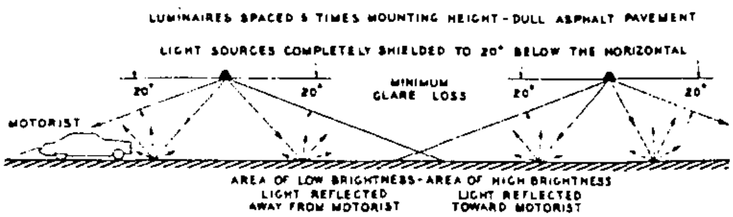
Fig. 7-8. Pavement luminance vs. transverse luminaire location.

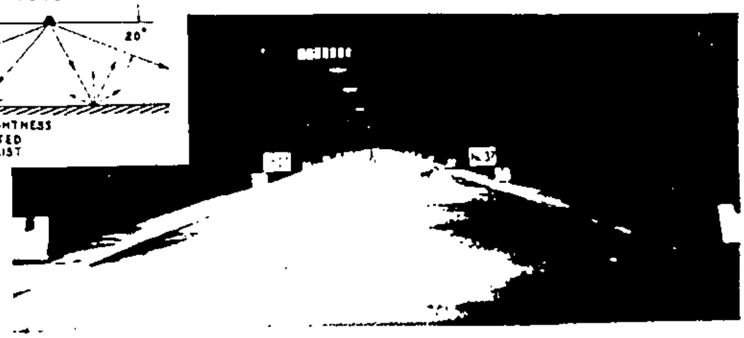
Luminaire preferably mounted over pavement produces higher luminance values.

Luminaire mounted off to side of pavement produces lower luminance values.

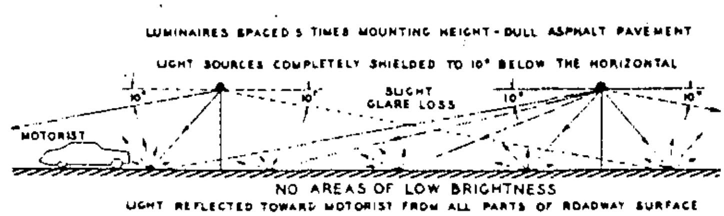
Fig. 7-7. Uniform luminance vs. uniform illumination; (left) uniform footcandles but spotty brightness; (below) uniform brightness but non-uniform foot-candles.

Pavement Luminance to Motorist Non-Uniform- Ratio 8 to 1
Horizontal Illumination - Ratio 1½ to 1





Pavement Luminance to Motorist Uniform - Ratio 1½ to 1
Horizontal Illumination - Ratio 3 to 1



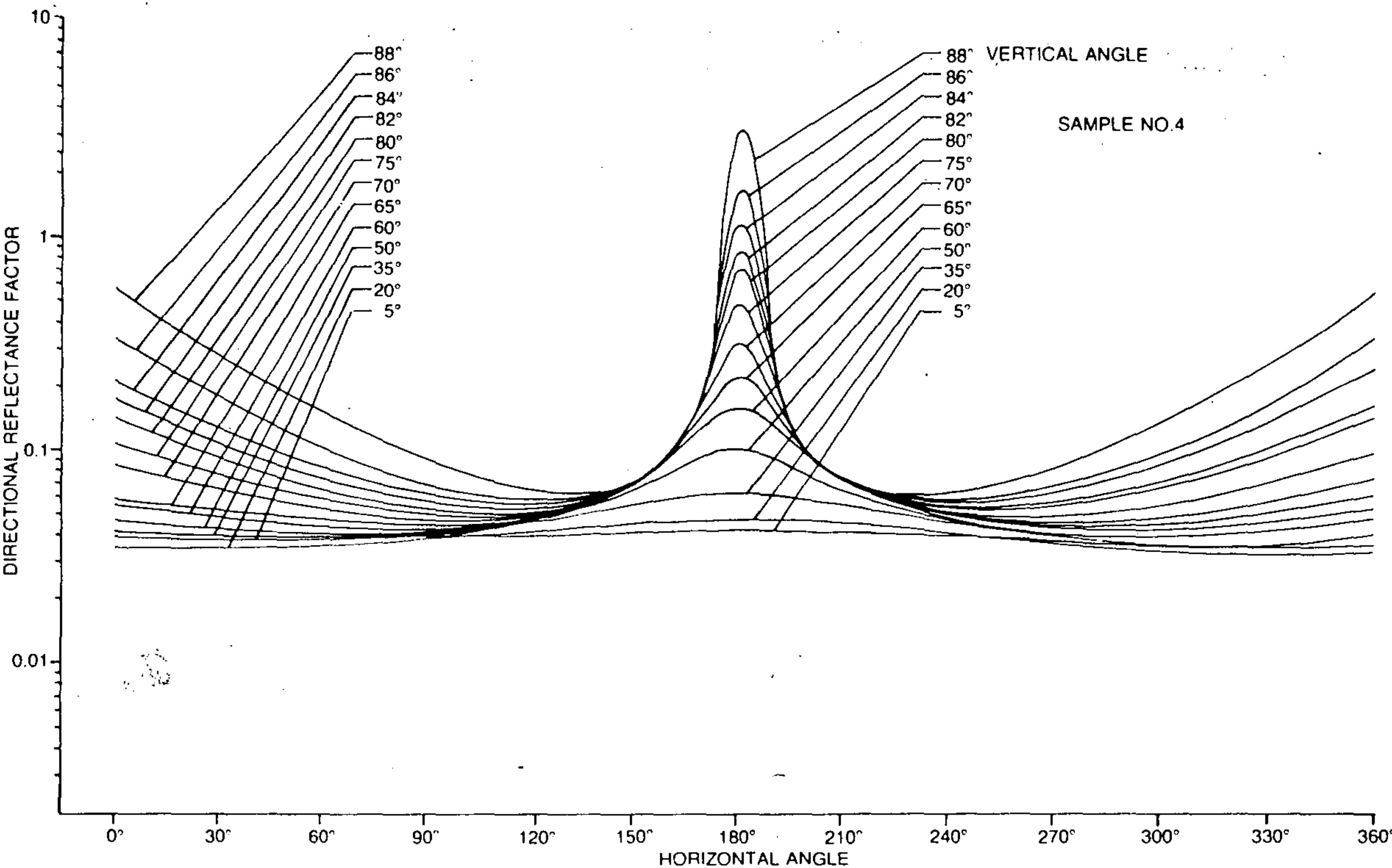


Fig. 7-9. Directional Reflectance Factors for 100′ Viewing Distance.

Fig. 7-11. Pavement luminance vs. surface reflectance.

Fig. 7-12. Luminance pattern - one-side arrangement.

Fig. 7-13. Luminance pattern - staggered arrangement.

Fig. 7-14. Luminance pattern - opposite arrangement.

Fig. 7-15. Luminance pattern - center-mounted arrangement.

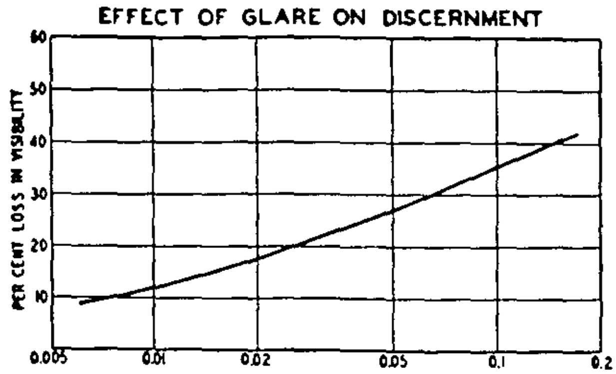
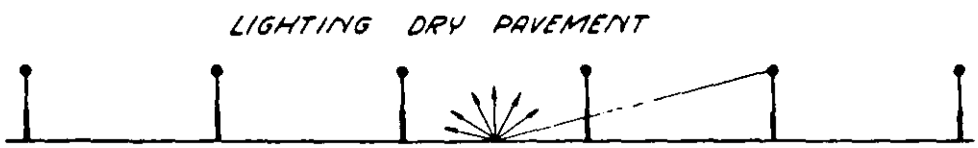


Fig. 7-16.   Veiling Luminance-Footlamberts

Effect of glare on discernment. Loss in visibility due to direct glare from the lighting system and reflected glare from the pavement, for motorists driving in the speed range of 25 to 40 miles per hour.



When pavement is dry and diffuse, light striking the road surface is diffused in all directions and produces "surface luminance" on road surface when viewed from any or all directions.

When pavement is dry and diffuse, headlight beams striking the road surface are diffused in all directions producing surface luminance on the road surface when viewed from any or all directions.

When pavement is wet the "surface luminance" is produced by the street lamp located 1000 feet or more in front of car.

When pavement is wet the headlight beams are reflected in a direction away from the driver and produce no "surface luminance.

Fig. 7-17. Pavement luminance vs. weather, and street lighting vs. headlighting: above, dry pavement; below, wet pavement.

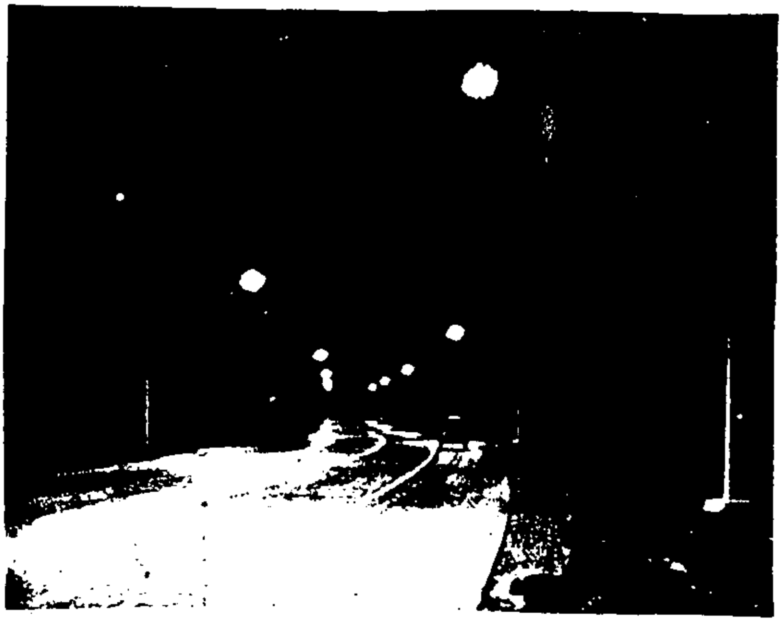


Fig. 7-18a. Visual comparison of dry vs. wet pavement - dry conditions.

Fig. 7-18b. Visual comparison of dry vs. wet pavement - wet conditions.

Fig. 7-19a. Typical street lighting installation - business street (day and night).

Fig. 7-19b. Typical street lighting installation - residential street (day and night).

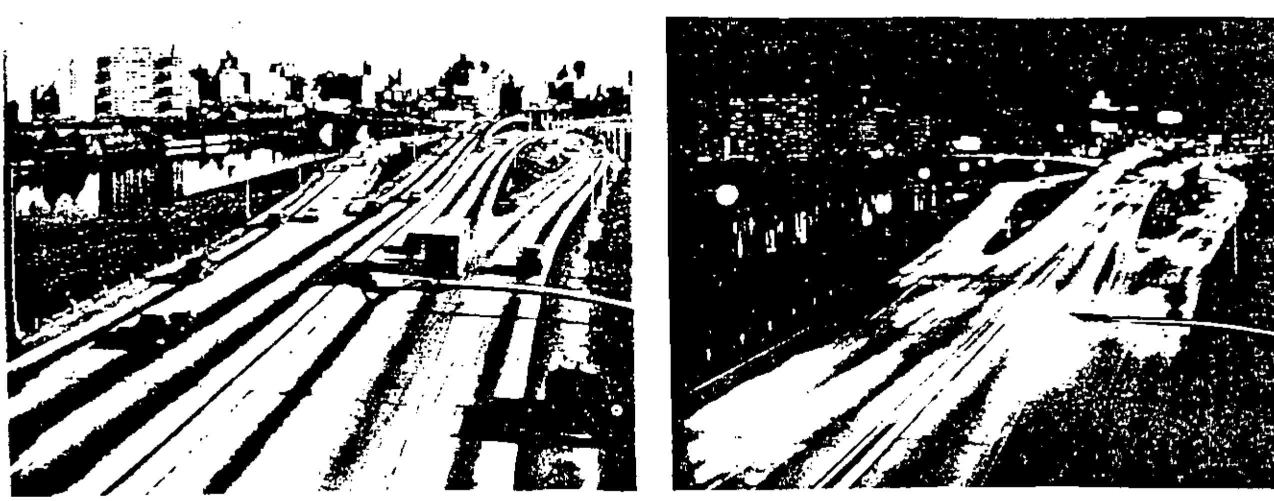


Fig. 7-19c. Typical street lighting installation - highway (day and night).

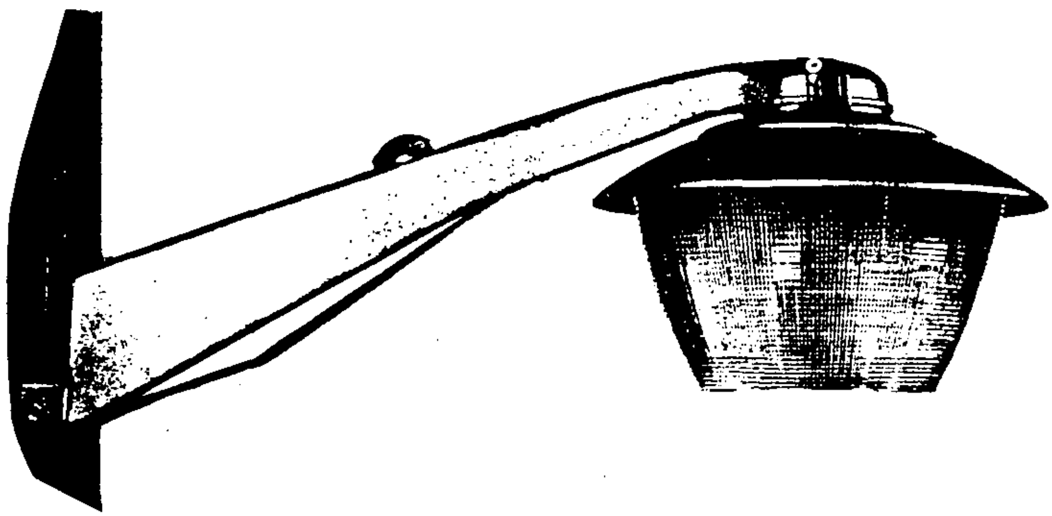


Fig. 6-6. Luminaire with reflector and open bottom refractor used with both incandescent filament and HID lamps.

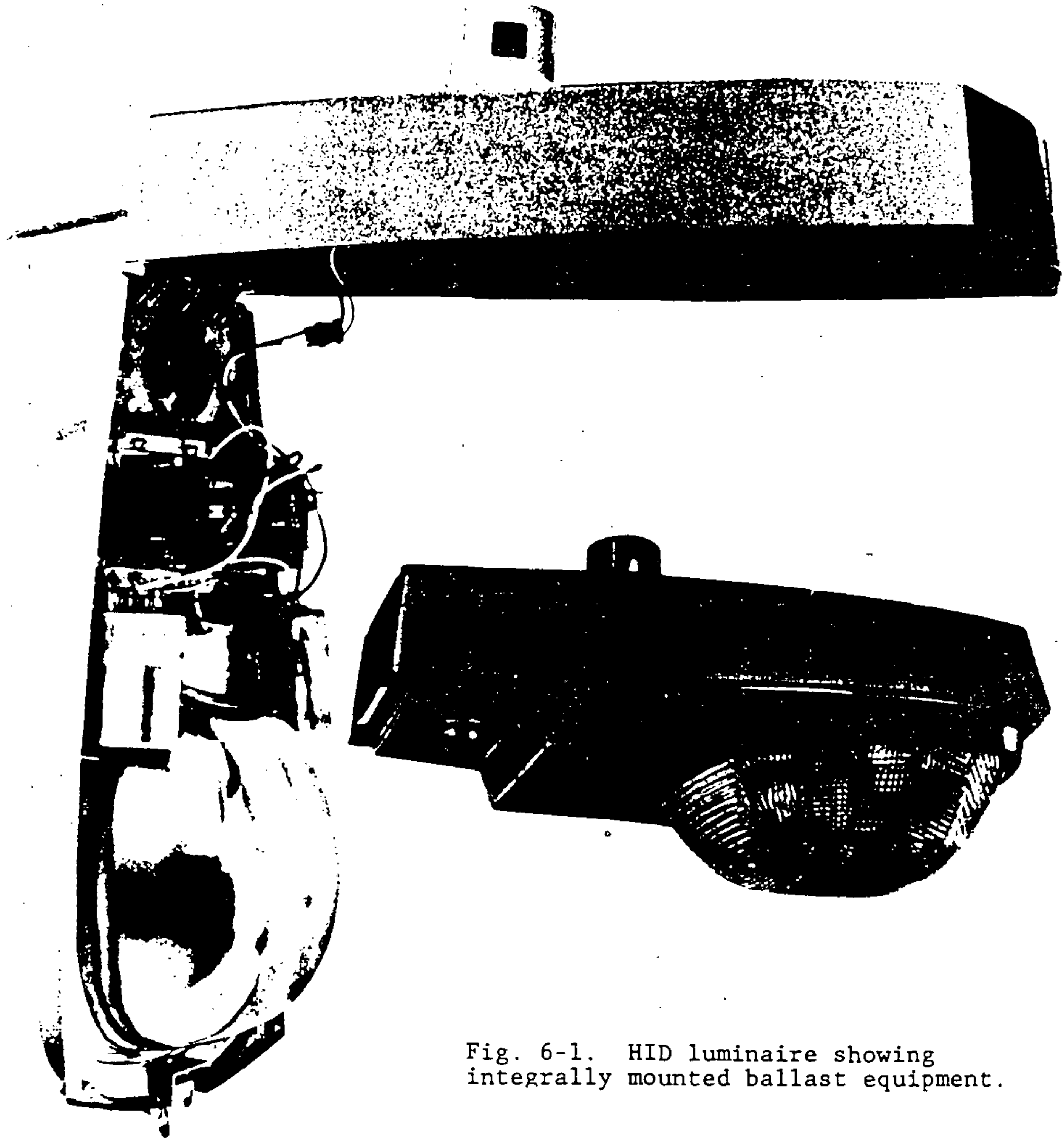


Fig. 6-1. HID luminaire showing integrally mounted ballast equipment.

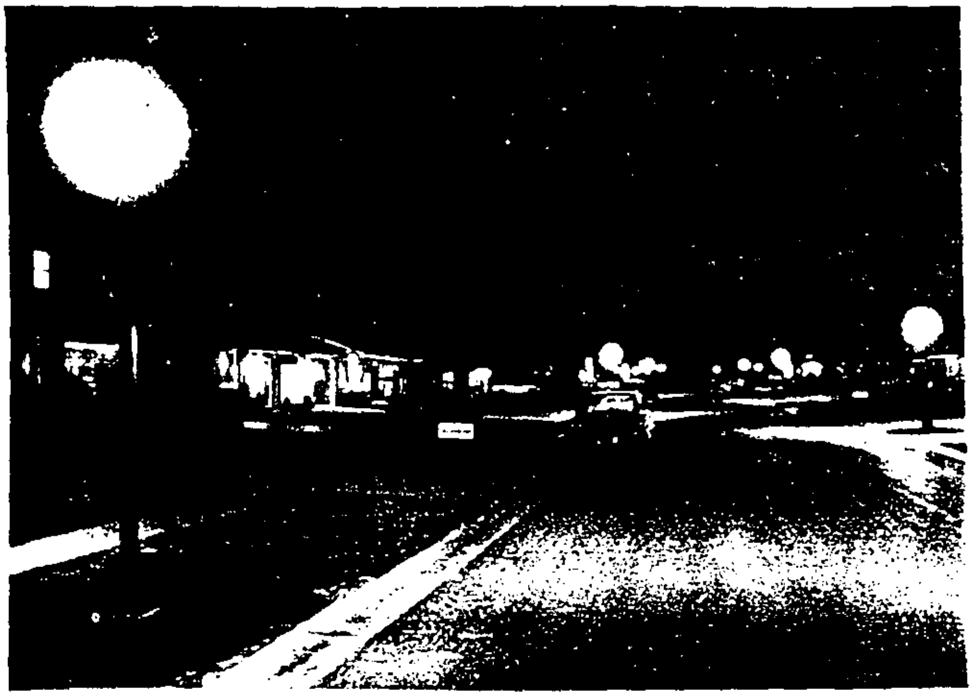


Fig. 7-20. Modern post-top installation - residential.

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

C U R S O S   A B I E R T O S

ILUMINACION EXTERIOR:
PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

DISEÑO Y CALCULO

ING. SERGIO GARCIA ANAYA

PALACIO DE MINERIA

Palacio de Minería   Calle de Tacuba 5   Primer piso   Deleg. Cuauhtémoc 06000   México, D.F.   Tels.: 521-40-20   Apdo. Postal M-2285

1. INTRODUCTION. The information in previous chapters has detailed the general information required for a general working knowledge of what can be applied to Roadways, Walkways and Bikeways. The basic examples and computations that follow apply to Roadways. It is obvious, however that the data and techniques can be applied to adjacent walkways, median strips and some other areas.

For special computations relating to Area Lighting and High Mast Lighting refer to Appendices C & D of the 1977 American National Standard Practice for Roadway Lighting.

In the Standard Practice definite facts are set up to outline what must be done to provide an installation of luminaires which will produce acceptable results. Therefore in the design of an installation all the factors, in the Standard Practice which apply to an installation must be studied carefully.

To apply these factors we must have all the physical data which will have to be considered in making the installation. A scale layout of the area which shows all the pertinent data is essential. Other information in regard to the general area, location, traffic density, local and national jurisdiction, and many other factors must be obtained for use as the project is developed.

In this Fundamentals Course there may be variables which will influence the final selection of a particular system, and each variable will have to be worked out as it arises.

2. CALCULATION PROCEDURE. The general procedure for calculating maintained Roadway Illumination consists of a series of steps. They are divided into two major groups; Objectives and Specifications (6); Light Loss Factors Not to be Recovered (6); and Light Loss Factors to be Recovered (2). The main procedure is to determine through calculations from Photometric Data which Lamp and Luminaire combination are required to provide a given intensity on a roadway of stated dimensions when the luminaire is mounted at locations which will produce a good quality of illumination.

a. Problem. To start we have a roadway we wish to illuminate so that it can be traversed safely by cars and pedestrians. This area will naturally have dimensions, width (W) and length (Y). Next we assume that the needed intensity on the roadway is for a road which requires .9 footcandles average maintained horizontal illumination.* To illuminate this roadway we need a lamp - luminaire combination mounted on a pole, which will project the light onto the roadway. The pole of course must be set back from the edge of the road so that it does not present a hazard. If this were a city street the pole might be only 2' from the curb or if it were a country road it might be 12' from the edge of the road. In our problem we will assume that the 30' pole is installed 3' from the edge of the road and that a mast arm will project the luminaire 5' over the roadway (OH). See Fig. 8-1.

3. STANDARD DATA FORM. The IES Testing Procedure Committee has recommended a standard form for reporting photometric data. See Fig. 4-17, p. 4-16 and Fig. 8-2, p. 4. The data on Fig. 8-2, p. 8-4 will be used in the next series of computations. (see following page 8-3) It is well to study the data on such reports to see if there are any figures that may have to be changed to give the proper information. One thing that will be noted immediately is that the test was made for a lamp rated at 20,500 lumens. Referring to page 5- we find that the H33-1cd lamp is now the H33CD-400 lamp which has a rating of 19,667 lumens in a horizontal burning position. In as much as the lamp in the fixture illustrated is in a horizontal position we have to use this value. We therefore have to multiply all lumen, candlepower and footcandle values by a correction factor of .96 (19,667/20,500 = .9594).

4. CALCULATIONS. Roadway illumination calculations fall into three general types of calculations:

a. Determination of the average illumination on the roadway pavement or spacing that will produce a given footcandle average illumination.

b. Determination of the illumination at a specific point on the roadway.

c. Determination of uniformity of illumination.

*Footnote - Committee on Testing Procedures of the IES: "IES Approved Method of Photometric Testing of Roadway Luminaires Using Incandescent Filament or Mercury or Sodium Electric Discharge Lamps," Illuminating Engineering, Vol. 63, October 1968, p. 541.

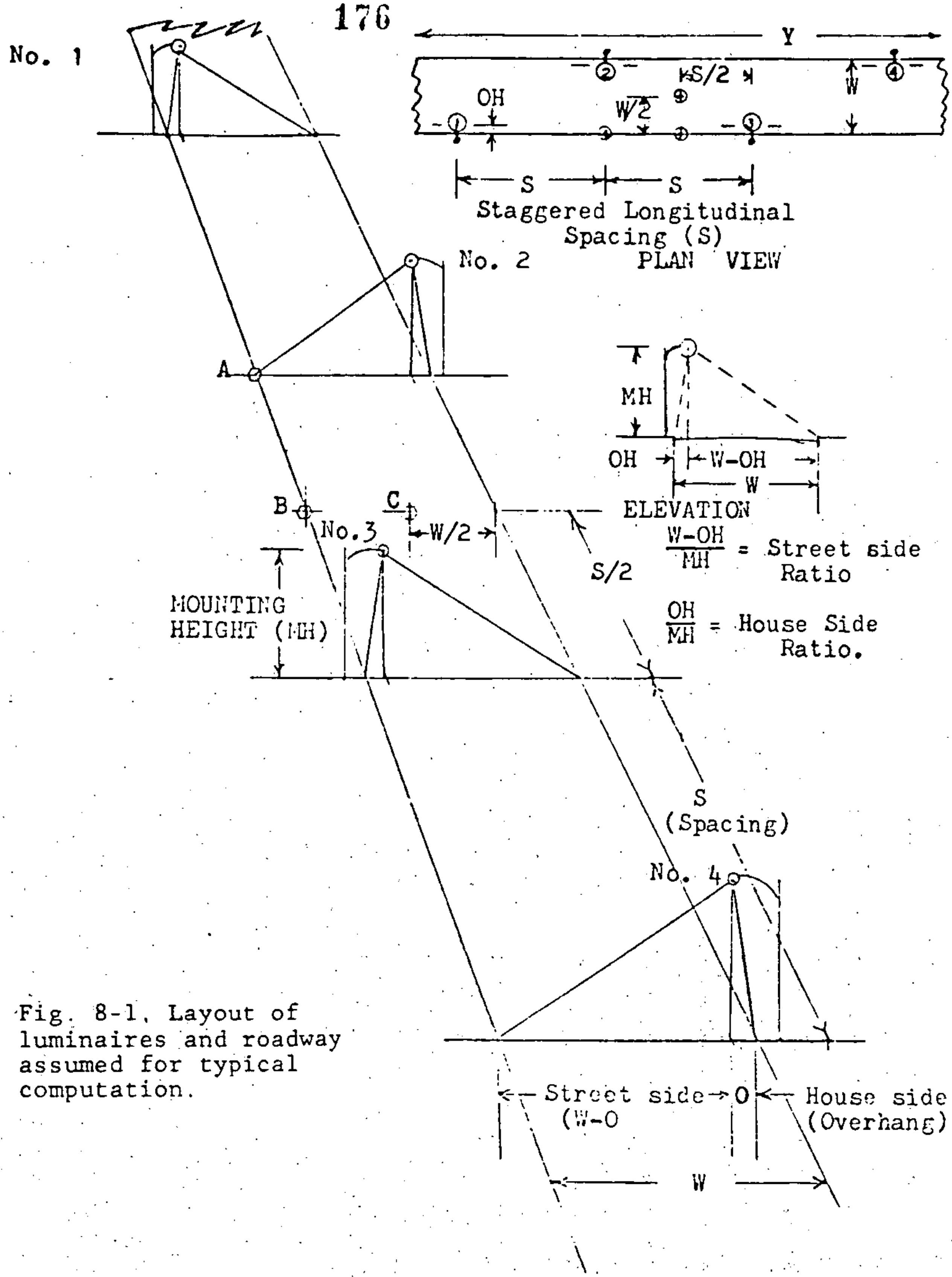


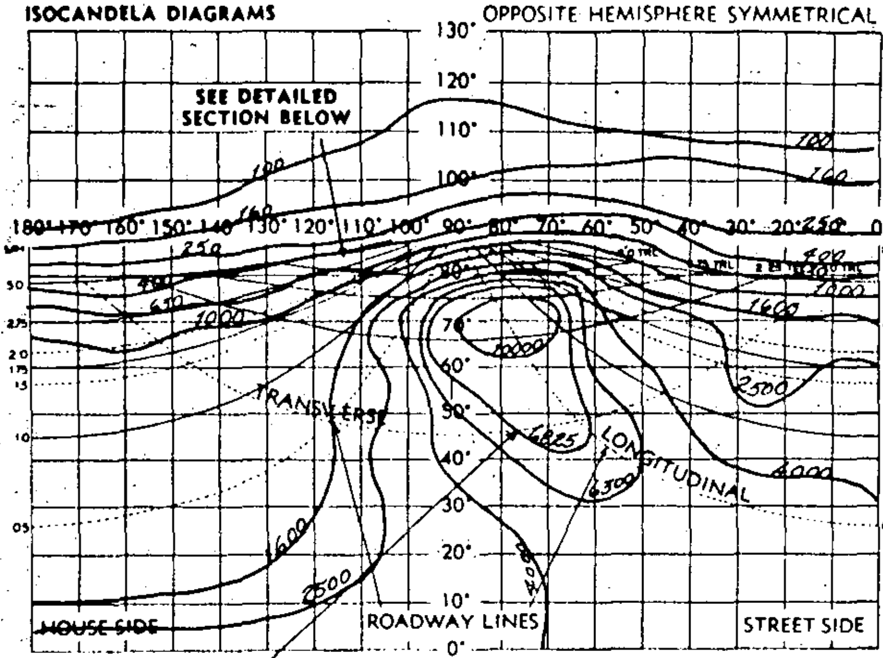
Fig. 8-1. Layout of luminaires and roadway assumed for typical computation.

PHOTOMETRIC DATA

Fig. 8-2.

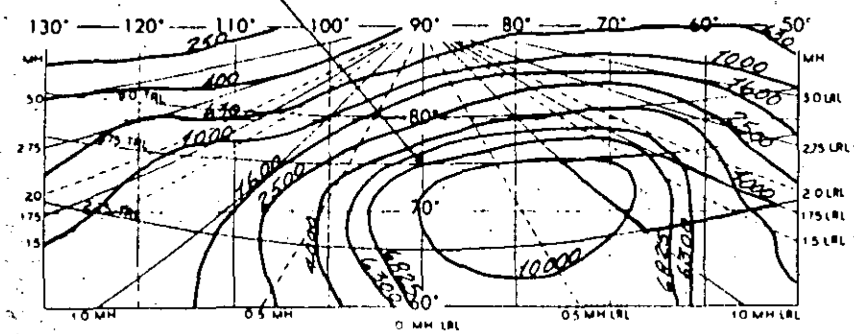
ISOCANDELA DIAGRAMS

OPPOSITE HEMISPHERE SYMMETRICAL



HALF MAX C.P. – 6825
MAX C.P. – 13650
NADIR C.P. – 3861

MAX CONE — 72.5°
MAX VER PLANE — 77.5°/282.5°

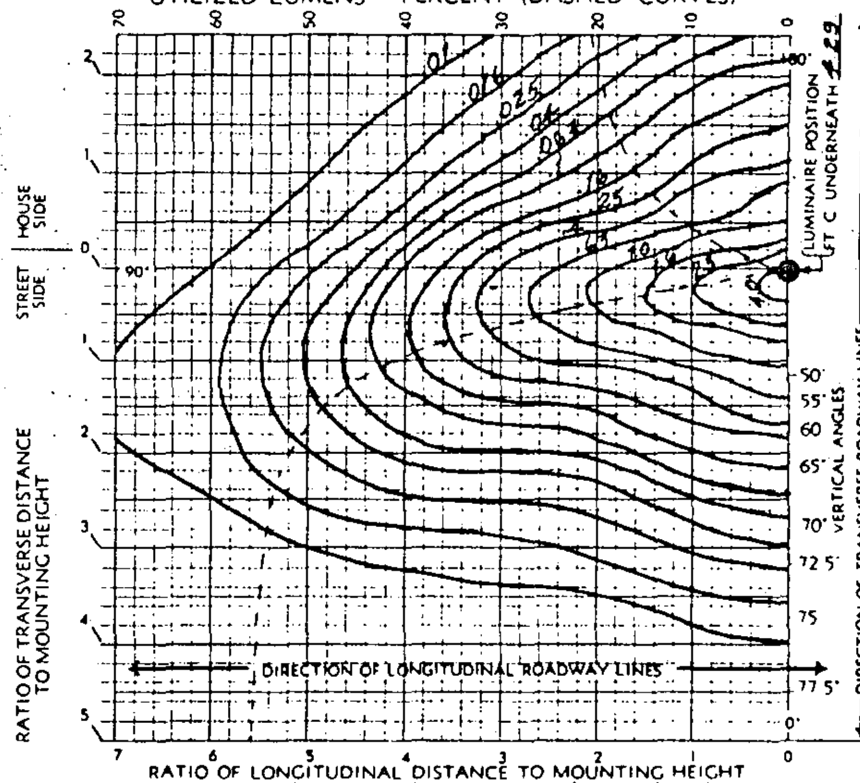


DETAILED SECTION: Based upon data taken at closer intervals than used for main diagram

VALUES OF ISOCANDELA, LUMENS, AND FOOTCANDLES ARE BASED UPON A LAMP OPERATED AT 20500 LUMENS. IF THE DATA IS DESIRED FOR A DIFFERENT LAMP LUMEN RATING, MULTIPLY ALL ISOCANDELA, LUMEN, AND FOOTCANDLE VALUES BY THE RATIO DIFFERENT LAMP LUMEN RATING ÷ 20500

LIGHT FLUX VALUES	LUMENS	PERCENT OF LAMP
DOWNWARD STREET SIDE	11562	56.4
UPWARD STREET SIDE	226	1.1
DOWNWARD HOUSE SIDE	4489	21.9
UPWARD HOUSE SIDE	123	.6
TOTAL	16400	80.0

UTILIZED LUMENS – PERCENT (DASHED CURVES)

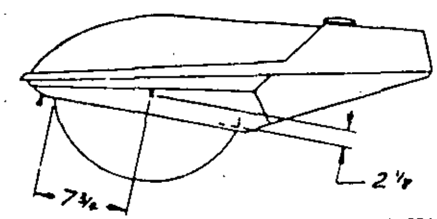


RATIO OF LONGITUDINAL DISTANCE TO MOUNTING HEIGHT

ISOFOOTCANDLE & UTILIZATION CURVES

FOOTCANDLE DATA IS BASED ON A LUMINAIRE MOUNTING HEIGHT OF 30 FEET. FOR OTHER MOUNTING HEIGHTS MULTIPLY THE VALUES OF FOOTCANDLES SHOWN BY THE FACTORS IN THE FOLLOWING TABLE. THE UTILIZATION CURVE (DASHED) IS CORRECT FOR ALL MOUNTING HEIGHTS AND DOES NOT REQUIRE CORRECTION.

MOUNTING HEIGHT - FT.	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
FACTOR	2.25	2.04	1.86	1.70	1.56	1.44	1.33	1.24	1.15	1.07	1	0.94	0.88	0.83	0.78	0.74



LUMINAIRE DESCRIPTION

STANDARD M400A/M400
SOCKET POSITION 2

LAMP – 400 WATT CLEAR MERCURY
ASA No. H33-ICD
H400A33-1

ASA/IES TYPE: TYPE II BY 1953 STANDARD
MEDIUM SEMI- CUTOFF TYPE II

NUMBER: 35-174452-00 REV. NO 05

5. DETERMINATION OF SPACING

a. Determination of the spacing between poles for an average of .9 footcandles can be done in several ways. The average illumination over a large pavement area may be calculated by means of a "Utilization Curve" of the type shown in Fig. 8-2 and 8-3, (which is an enlargement of Fig. 8-2a), or by means of computing the illumination at a large number of points (see paragraph 8.6.a) and averaging the values calculated. Since this latter method is extremely laborious and since the utilization curve is a part of the data presented as a result of following the IES Approved Method for Photometric Testing of Roadway Luminaires (*See footnote in paragraph 8.2.a) this method will be discussed.

b. Utilization Curves.

(1) Utilization curves, available for various types of luminaires, afford a practical method for the determination of illumination over the roadway surface where lamp size, mounting height, width of paved area and spacing between luminaires are known or assumed. Conversely, the desired spacing or any other unknown factor may be readily determined if the other factors are given.

(2) Fig. 8-3 illustrates an example of a utilization curve of a typical luminaire. The utilization curve indicates how much light falls on the roadway, as a percentage of initial lamp lumens but reveals little of the way in which the light is distributed. Therefore, it should be used in conjunction with the specific calculation in order to evaluate correctly the true performance of the luminaire, especially concerning uniformity or compliance with the recommended ratio of minimum illumination value to the average value.

(3) The coefficient of utilization is the percentage of the rated lamp lumens which fall into a strip-like area of infinite length. In making up the chart so that it would be the most useful a reference line has been set up so that the percent of lumens projected forward is known as the "street side" utilization. In a like manner the percentage projected in the opposite direction from the reference line is called the "house side" utilization. One thing to remember is that if the luminaire center is back of the edge of the roadway the utilization from the reference line to the edge of the roadway has to be subtracted from the "street side" value.

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Fig. 8-3. Enlarged utilization curves from Fig. 8-2. Example of coefficient of utilization curves for a luminaire providing type II medium semi-cutoff distribution.

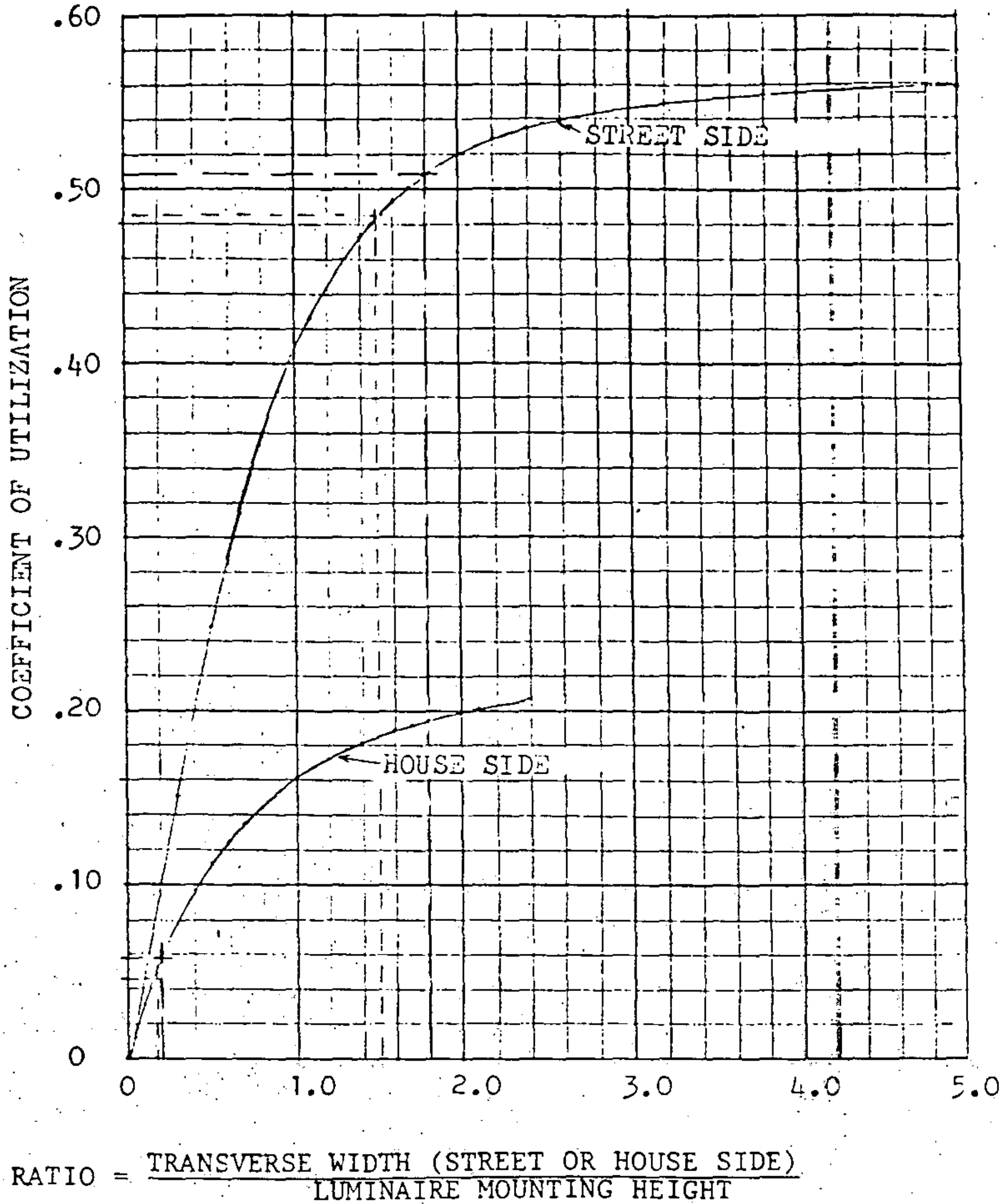
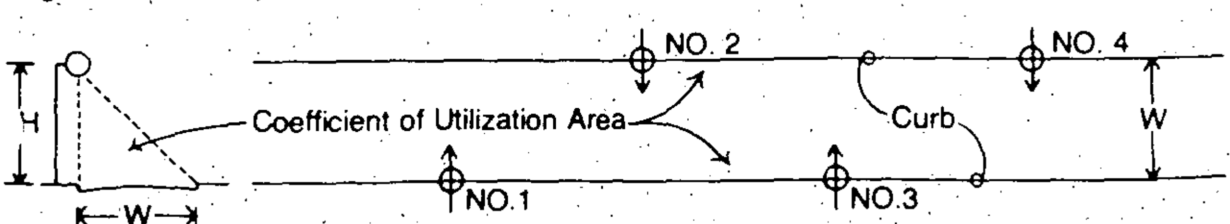


Fig. 8-4 Roadway



(4) To obtain the same results the luminaires when they are installed will have to be leveled and oriented over the roadway in a manner equivalent to that in which the unit was tested. Note that roadway width is expressed in terms of a ratio of luminaire mounting height to roadway width.

c. Formulas for Computation

(1) The basic formulas for determination of spacing follows:

$$\text{Spacing} = \frac{\text{Lamp Lumens x Coefficient of Utilization}}{\text{Width of Pavement x Average Initial Illumination}}$$

(2) The above formulas can be expanded to take care of maintained illumination by adding the necessary factors. (See 8.10)

$$\text{Spacing} = \frac{\text{Lamp Lumens} \times \text{Coef. of Utilization} \times \text{Luminaire Dirt Depreciation} \times \text{Lamp Lumen Depreciation}}{\text{Width of Pavement x Average Maintained Illumination}}$$

(3) Definitions of symbols used in above and other following formulas:

Symbol	Definition
AME	Average maintained illumination
AT	Ambient temperature
BF	Ballast factor
BO	Burn out
CD	Component depreciation
CPS	Changes in depreciation
CU	Co-efficient of Utilization
E	Illumination
FCM	Footcandles maintained
LL	Lamp Lumens
LDD	Luminaire Dirt Depreciation
LLF	Light loss factor
LLD	Lamp lumen depreciation
MH	Mounting height
OH	Overhang
S	Spacing
VF	Voltage factor
W	Width of Pavement

Basic formula with symbols for the determination of Spacing is:

$$S = \frac{LL \times CU}{W \times AME}$$

d. Typical Computations.

(1) To illustrate the use of a Utilization curve the following simple example is provided.

Fixed data:

Roadway - see Fig. 8-4
Roadway width (W) 45'
Luminaire Mounting Height (MH) 30'
Luminaire mounted directly over curb (OH) Overhang = 0'
Lamp Lumens (Horizontal) 19,667
Roadway classification - intermediate collector requiring .9 fc*

Calculation:

(a) Determine coefficient of utilization. This figure will be for the "street side" only as the luminaire is directly over the curb.

$$\text{Ratio value} = \frac{\text{Width (W)}}{\text{MH}} = \frac{45}{30} = 1.5$$

Refer to Fig. 8-3, draw vertical line on chart starting at 1.5 to the intersection of the "Street Side" utilization curve. At this point the coefficient of utilization is approximately ..485

Substituting in the formula for spacing, assuming LDD = 1 and LLD = 1, we have -

$$\text{Spacing} = \frac{19667 \times .485}{45 \times .9} = \frac{9538}{40.5} = 235.5'$$

(b) To make use of this formula in a different situation the following figures were used.

Fixed data:

Roadway as indicated in Fig. 8-1
Roadway width (W), curb to curb 50 ft.
Luminaire mounting height 30 ft.
Luminaire overhang (OH) 5 ft.

Lamp, 400 watt mercury clear, rated 19,667 lumens horizontally
Roadway classification, intermediate collector .9 fc mtd.

*Taken from Table No. 1 of the American National Standard Practice for Roadway Lighting.

1. Calculations

Coefficient of Utilization "Street Side"

$$\text{Coef. of Util.} = \frac{W-OH}{MH} = \frac{50' - 5'}{30'} = \frac{45'}{30'} = 1.50$$

Refer to chart Fig. 8-3 for a ratio of 1.50 the coef. of util. is .485

Coefficient of Utilization "House Side"

$$\text{Coef. of Util.} = \frac{OH}{MH} = \frac{5'}{30'} = .16$$

In a like manner a vertical line is drawn on Fig. 8-3 up until it intersects the House Side utilization curve. At this point the utilization is .045. The total for both house side and street side is .485 + .045 = .53.

Spacing is now determined by substituting in the formula 8.5.3a assuming LDD = 1 and LLD = 1 we have

$$\text{Spacing} = \frac{19,667 \times .53}{50 \times .9} = \frac{10,423}{45} = 231.6$$

To make this information more meaningful we must insert realistic light loss factors, so that we can get accurate maintained values. To get the spacing for a series of fixtures mounted as noted above in an area where conditions are average and a cleaning cycle of six months will be maintained we find after consulting Chart Fig. 8-5 (Fig. B-1, page 25 of the American National Standard Practice for Roadway Lighting that the factor is .95%). In choosing the point on the lamp lumen depreciation curve, to ensure the required maintained illumination, one should choose the point which coincides with a multiple of the cleaning cycles. In our example, the cleaning cytle is six months. Therefore the point on the lamp lumen depreciation curve should be a multiple of six months. Assuming 4,000 hours operation time per year, we would see that 16,000 hours represents a four year life. Four years if of course a multiple of a six months cleaning cycle. Therefore the 16,000 hour point has been chosen from the lamp lumen depreciation curve. In looking at the curve and taking the average of the span at the 16,000 hour point, we have a lamp lumen depreciation factor of 67%.

Besides these two factors others such as Allowance for Ambient Temperature, 10.a, Voltage, 10.b, Ballast factor, 10.c, Component Depreciation, 10.d, Possible Changes of Physical Surrounds, 10.e, Burn-outs, 10.f, etc. could be entered at this point if they will influence the final calculations.

With the two factors of LLD and LDD we can now use the second formula 5.c(1).

$$\text{Spacing (S)} = \frac{19{,}667 \times .53 \times .95 \times .76}{50 \times .9} = \frac{7526}{45} = 167.2'(166)$$

6. DETERMINATION OF ILLUMINATION AT A SPECIFIC POINT

a. General. The determination of the horizontal illumination in approximate footcandles at a specific point may be determined from an "isofootcandle" curve Fig. 8-6 or by means of the inverse-square method of calculation of illumination (see IES Lighting Handbook, current edition). In the later method, the candlepower of the luminaire at the particular angle involved is normally obtained from an isocandle curve, an example of which is shown in Fig. 8-2(b). Since the isofootcandle curve is a part of the data presented as a result of following the IES Approved Method for Photometric Testing of Roadway Luminaires, the isofootcandle method will be discussed.

b. Isofootcandle (isolux) Diagram.

(1) The illumination on a roadway surface produced by the light distribution from one or more luminaires may be shown by isofootcandle diagrams. Fig. 8-6 and Fig. 8-2a, p. 8- show an example of an isofootcandle diagram for a typical luminaire.

(2) An isofootcandle diagram is a graphical representation of points of equal illumination connected by a continuous line. These lines may show footcandle values on a horizontal plane from a single unit having a definite mounting height, or they may show a composite picture of the illumination from a number of sources arranged in any manner or at any mounting height. They are useful in the study of uniformity of the illumination and in the determination of the level of illumination at any specific point. In order to make these curves applicable to all conditions, they are computed for a given mounting height but horizontal distances are expressed in ratios of the actual distance to the mounting height. Correction factors for other mounting heights are usually given in the tabulation along side the isofootcandle curves.

c. Typical Computation. To illustrate the use of the isofootcandle diagram, a typical calculation is as follows:

Given: Roadway with layout as in fig. 8-1.

Staggered Luminaire spacing (S) (see 8.5.d(1))	166'
Roadway Width (W) curb to curb	50'
Luminaire Mounting Height	30'
Luminaire OverHang(OH)	5'
Luminaire Dirt Depreciation (LDD)	.95
Lamp Lumen Depreciation (LLD)	.76
Lamp - 400 watt clear mercury rated at	19,667 lumens

Required to determine:

Initial and maintained fc at points "A", "B" and "C" Fig. 8-1 To determine the fc level at point "A" the values will have to be determined from the isofootcandle diagram Fig. 8-6. Solution (1) The location of point "A" in respect to a point on the pavement directly under the luminaire is dimensioned in transverse and longitudinal multiples of the mounting height. The luminaire produces isofootcandle lines (horizontal footcandles) as shown in Fig. 8-6 Point "A" is then located on the isofootcandle diagram for its position with respect to each luminaire.

(2) To determine the contribution of each luminaire to point "A" (a) Luminaires No. 1 and No. 3

Locate point "A" - Transverse distance to "House Side"

$$\frac{OH}{MH} = \frac{5'}{30'} = 0.16$$

-Longitudinal distance along pavement

$$\frac{S}{MH} = \frac{166'}{30'} = 5.533$$

Point "A" for these luminaires on chart Fig. 8-6 is .16 toward the House side, behind the unit and .533 longitudinally. This point will be found lying about midway between isofootcandle lines of Fig. 8-6 .01 and .016 for a value of .013 fc. Therefore the two luminaires will deliver 2 x .013 or .026 fc. total.

(b) Luminaire No. 2
Locate Point "A" - Transverse distance to "Street Side"

$$\frac{W-OH}{MH} = \frac{50' - 5'}{30'} = \frac{45'}{30'} = 1.5$$

Longitudinal distance along pavement is 0' as the point is directly opposite the luminaire

Point "A" for this luminaire on chart Fig. 8-6 is 1.5 directly in front of 0^{o} or zero mounting height. This point will be found between isofootcandle lines .63 and .4. It is estimated that the value is .55.

(c) Luminaire No. 4

Locate point "A" - Transverse distance to "Street Side"

$$\frac{W\text{-}HO}{MH} = \frac{50' - 5'}{30'} = \frac{45'}{30'} = 1.5$$

Longitudinal distance along pavement is

$$332'\ (2 \times S) = \frac{332'}{30'} = 11.06$$

Point "A" for this luminaire is 1.5 directly in front of the luminaire and 11.06 left which of course is off the chart Fig. 8-6 and therefore can be ignored.

(d) Total footcandle values from all luminaires at Point "A"

is	luminaire No. 1	.013
	luminaire No. 2	.55
	luminaire No. 3	.013
	luminaire No. 4	.0
	Total fc at "A"	.576

This value is based on a clean luminaire with a lamp producing 20,500 lumens. As it is desired to express the footcandles in terms of fc. when the luminaire is at the end of the 6 month cleaning schedule and the lamp has aged to 70% of life and the correct lamp lumen factor is used so that the lowest value will be obtained we will apply the factors which will produce the desired maintained footcandle value. The correct lamp lumens are 19,667 which produces a factor of 19,667/20,500 = .96, LDD factor .95 and LLD factor .76. Total fc. at point A is fc at "A" x LL x LDD x LLD = FCM or .576 x .96 x .95 x .76 = 399 FCM.

(3) To determine the contribution of each luminaire to point "B".

(a) Luminaire No. 1
Locate point "B" - Transverse to "House Side" 5'/30' = 0.16
Longitudinal along road 249/30 = 8.3
Point "B" for these figures if off the chart.

(b) Luminaire No. 2
Locate point "B" - Transverse to H.S. = $\frac{50-5}{30} = \frac{45}{30} = 1.5$

Longitudinal along road 83'/30' = 2.766

Point "B" for No. 2 is 1.5 across the street side and 2.766 longitudinally and will be found between .10 and .16 which we will estimate as .15 fc.

(c) Luminaire No. 3

Locate Point "B" - Transverse H.S. = 5/30 = .16
Longitudinally along road = 83/30 = 2.766

Point "B" for No. 3 is .16 behind unit and left 2.766 which is found on the .4 fc line.

(d) Luminaire No. 4

Locate Point "B" - Transverse to H.S. $\frac{50-5}{30} = \frac{45}{30} = 1.5$

Longitudinal along road 240/30 = 8.3
Point "B" from these figures for No. 4 is off of the chart.

(e) Total footcandle values for all luminaires at point "B" is

Luminaire No. 1	0
Luminaire No. 2	.15 fc
Luminaire No. 3	.40 fc
Luminaire No. 4	0
Total fc. at "B"	.55

This value is of course an initial value. Using the factors of .96 for the lamp lumen factor, .95 for LDD and .76 for LLD we come up with .55 x .96 x .95 x .76 = .38 fc maintained.

(4) In a like manner the fc values are determined for point "C"

(a) Luminaires Nos. 1 and 4. From previous calculations under paragraph 3a and 3d we found that the longitudinal distance produced a point off the chart.

(b) Luminaires No. 2 and 3.
Locate point "C" - Transverse to HS

$$\frac{W/2 - OH}{MH} = \frac{50/2 - 5}{30} = \frac{20}{30} = .667$$

Longitudinal along road = 83/30 = 2.766

Point "C" for units 2 and 3 are .667 across street and 2.766 to the left. This point will be found between isofootcandle lines .4 and .63 which is about .56 fc The total then for this point "C" is 2 x .56 for 1.12 fc as luminaires No. 1 and 4 do not project any values to this point.

(c) The maintained value is obtained by using the factors of .96 for the variation in lamp lumen output, .95 for LDD, .76 for LLD. 1.12 fc x .96 x .96 x .76 = .78 fc maintained.

7. UNIFORMITY RATIOS

a. The uniformity of illumination requirements of paragraph 3.5, pages 14 and 15 of the American Standard Practice should be determined by computing the ratio:

$$\frac{\text{Minimum Horizontal Footcandles}}{\text{Average Horizontal Footcandles}}$$

It can also be expressed as the ratio:

$$\frac{\text{Average Horizontal Footcandles}}{\text{Minimum Horizontal Footcandles}}$$

b. Sufficient number of specific points over the roadway should be checked, as outlined in paragraph 8.6, to ascertain accurately the location and value of the minimum point. If the values at points "A", "B" AND "C", as shown in Fig. 8-1, are first determined, the approximate location of the minimum point may be located or its location will become more apparent.

c. The average illumination on the roadway pavement should be computed as in paragraph 5.a taking care to use the same lamp output and other conditions as used in determining the minimum illumination value.

d. Some manufacturers are now supplying curves of the type shown in Fig. 8-7a and 8-7b, which indicate the average to minimum maintained footcandle ratio for a particular arrangement of luminaires as roadway width and spacing are varied. (These are computed for the lowest value on the roadway area, not necessarily for points "A", "B" and "C".) Such curves are a convenient aid to determine the average to minimum illumination ratios for a given spacing and roadway width, or to determine the possible spacing for a required uniformity ratio. They also can be used to determine the relationship between average illumination for spacing and roadway width. Each different combination of luminaires, lamp type and arrangement of luminaires will produce a different set of these characteristic curves.

e. In the calculations the maintained footcandles at point "A" is .399 (6.c (2) (d); at point "B" the value is .38 (6.c (3e) and at point "C" the value is .78 (6.c (4 ppg. c). From these data we can assume that .38 at point "B" will be the minimum, other points between "A" and "B" could be checked if necessary. Using the value of .38 fc we have a ratio of .9 fc average maintained to .38 fc minimum maintained or a ratio of 2.37 to 1.

8. USE OF CORRECTION FACTOR FOR OTHER MOUNTING HEIGHTS

a. To use these data for a mounting height of other than the one for which the isofootcandle curves are made, it is necessary to find the correct new location on the diagram as well as apply a correction factor to the footcandle values at the new location.

b. The following items will change, Coefficient of Utilization, footcandle values and point locations. The coefficient of utilization and point locations are on a percentage ratio. Footcandles have to be changed in relationship to the mounting height. A table adjacent to the diagram will give a factor for changing the footcandle values in relation to the given mounting height (30'). In other words the footcandle values at a certain point will be multiplied by the factor for the new mounting height. This point will have been located in regard to the new mounting height. The coefficient of utilization factors are located as well in regard to the new mounting height.

c. To illustrate the problem for a lower mounting height, we will use the data used previously except the mounting height will be 25'.

Roadway width (W)	50'
Mounting Height (MH)	25'
Over Hang (OH)	5'
Rated Lamp Lumens (RLL)	19,667
Test Lamp Lumens (TLL)	20,500
Lamp Lumen Correction factor (LLC) 19,667/20,500	.96
Luminaire Dirt Depreciation (LDD)	.95
Required Average Footcandles Maintained	.9

To find coefficient of utilization

Street side = $\frac{50' - 5'}{25'} = \frac{45}{25}$ = 1.8 ratio .509 C/U Fig. 8-3

House side = $\frac{5'}{25'}$ = .2 ratio = .058 C/U Fig. 8-3

Coefficient of utilization = .509 + .058 = 0.567

To find Spacing (S)

Spacing = $\frac{19{,}667 \times .95 \times .76 \times .567}{50 \times .9} = \frac{8051}{45}$ = 178.9' (178)

In the problem where a 30' mounting height was used the spacing was 167.2'. In our calculations we used 166' as it was the next lower even number. In the following problem we will use 178'.

d. The footcandle values at points "A", "B" and "C" are determined in a similar manner, in this problem, taking into consideration the new mounting height of 25'.

Point "A" Luminaires Nos. 1 & 3
Transverse to H.S. 5/25 = .2
Long. along road 178'/25' = 7.12
This point is off the chart and has no value
Luminaire no. 2
Transverse S.S. 45/25 = 1.8
Long. along road 0
This point is between .25 and .4 estimated at .30 fc.
Luminaire No. 4
Transverse S.S. 45/25 = 1.8
Long. along road = 356/25 = 14.25 which is off the chart.

The total fc produced at point "A" is .30 from luminaire No. 2. These of course are initial. To obtain the maintained value for a 25' mounting the following factors are applied. LDD .95, LLD .76 Lumen correction factor (LCF) .96 and 1.44 which is the mounting height correction factor found in the table Fig. 8-2. So we have .30 x .95 x .76 x .96 x 1.44 = .299 fc maintained.

The footcandles at Point "B" are as follows, Luminaire no. 1 having a longitudinal distance along the road of 267'/25' = 10.68 is off the chart for no value, Luminaire no. 2 with factors of 45/25 = 1.8 and 89/25 = 3.56 produces a value of .075, Luminaire no. 3 with ratios of 5/25 = .2 and 89/25 = 3.56 produces a value of .14, Point "B" for luminaire no. 4 is off the chart for no value. The total then for point "B" is .075 + .14 totaling .215 fc. Applying the factors to get the final maintained value we use the same factors as in the above paragraph or .215 x .95 x .76 x .96 x 1.44 = .215.

The footcandles at Point "C":

Luminaire Nos. 1 & 4 Trans. = 20/25 = .8, Long. 267/25 = 10.68 off chart. Luminaire no. 2 & 3 Trans. = .8, Long.= 3.56 = .25 x 2 = .5 fc. The total of .5 fc times the various factors produces a .499 fc mtd.

e. The problem of solving for a greater mounting height is solved in a similar manner. For a 35' mounting height we would have the following data: (Only MH has been changed from previous problems).

Coefficient of utilization "Street side" ratio = $\frac{50-5}{35} = \frac{45}{35} = 1.286$

Coefficient of Util. house side = 5/35 = .1429, c.u. is .042

Total coef. of util. = .457 + .042 = .499

Substituting in Spacing formula:

Spacing (S) = $\frac{19,667 \times .499 \times .95 \times .76}{50 \times .9} = \frac{7085}{45} = 157.5'$ (158)

Footcandles at Point "A"
Luminaire No. 1 & 3 Trans. 5' MS. = 5/35 = .1429
Long. = 158/35 = 4.51
At this point each luminaire produces .032 fc. totaling .064

Luminaire No. 2 Trans. 45' s.s. 45/35 = 1.286
Long. 0
This luminaire produces .75 fc at point "A"
Luminaire No. 4 Trans. 45' s.s. 45/35 = 1.286
Long. 316/36 = 9.03 (no value)

The total at point "A" is .032 from no. 1, + .75 from no. 2 + .032 from no. 3 and .0 from no. 4 for a total of .814. To get the maintained fc at 35 feet mounting the following factors are applied:

Mounting height .74, LDD .95, LLD .76, and LCF .96
.814 x .74 x .95 x .76 x .96 = .417 fc maintained.

The four luminaires project the following values to Point "B"

Luminaire No. 1	No value
No. 2	.25
No. 3	.58
No. 4	.012
Total	.842

.842 x .74 x .95 x .76 x .96 = .432 fc mtd.

The four luminaires project the following values to point "C"
Luminaire No. 1 & 4 No value (less than .01 fc)
Luminaire No. 2 & 3 .72 fc each or 1.44 fc for both units
1.44 fc x .74 x .95 x .76 x .96 = .739 fc maintained.

The three sets of data on the same fixture under the same conditions except mounting height provide information which can be compared. This comparison will then bring in various factors which should be considered, such as economics, quality, glare and other factors.

The following gives the accumulated data.

sphere). The right hand portion of Fig. 8-5 shows five groups of typical area atmospheres.

e. Area Description - A complete description is required for each area to be lighted. This should include: the physical characteristics such as roadway width, curvatures, grade, obstructions, (trees) and border areas.

f. Selection of Luminaire - Selecting the specific luminaire requires the almost simultaneous consideration of many factors. Selection of the type of luminaire for a given roadway depends upon the requirements and conditions found above, such as dimensions of roadway and atmospheric conditions and such factors (whose relative importance will vary from project to project) as: mounting height; luminaire dirt depreciation; lamp choice; maintenance considerations, including cleaning and lamp replacement; luminaire and installation appearance; color of light; lighting and relighting time; cost of equipment; etc. All factors should be examined in detail first, then reviewed so that the proper weight will be given to everything that might effect the luminaire selection.

10. LIGHT LOSSES - NOT RECOVERABLE

Once the facts in 9 have been appraised and the luminaire is chosen, the factors that cause loss of light should be studied and evaluated. The factors immediately following are difficult to appraise and are usually of little significance. However, if it is known that a peculiar condition does exist that can be evaluated it should be included in the calculations of the maintained footcandle level. In any case, the designer should be cognizant of all the factors that can diminish the planned output of the lighting system, and evaluate where necessary and practical.

a. Luminaire Ambient Temperature - The effect of ambient temperature on the output of some fluorescent luminaires may be considerable. To apply a factor for light loss due to ambient temperature, the designer needs to know the highest and lowest temperature expected and to have data showing if there are variations in the light output with changes in ambient temperature for the specified luminaire to be used.

b. Voltage to Luminaire - In-service voltage is difficult to predict, but high or low voltage at the luminaire will affect the output of most luminaires.

c. Ballast Performance - If the ballast used in the luminaire does not provide rated watts to the lamp, the light output will differ proportionately, and a ballast factor should be applied. The manufacturer should be consulted for necessary factors.

d. Luminaire Component Depreciation - Depreciation of the light controlling elements of a luminaire, resulting from deterioration of metal, glass, plastic, paint and other reflector finishes, will result in reduced light output. However, because of the complex relationship between light controlling elements of different materials it is difficult to evaluate losses due to deterioration. Even luminaires with a single light controlling element of one type of material will show losses due to the type of atmosphere in the area. No standard factors have yet been developed to cover depreciation of components. (See Fig. 11-2)

e. Changes in Physical Surround - The designer should be aware of planned changes in the roadway conditions that may alter the effectiveness of the lighting system; such things as road widening, curbing, resurfacing, tree planting, building construction or demolishing, or anything that would change the nature of the road.

f. Burn-Outs - Unreplaced burned-out lamps will affect the quality of the lighting system. It would be ironical to incorporate a factor in the design to take care of burn-outs. Instead, a good maintenance program, including group replacement of lamps based on lamp mortality statistics, and spot replacement when necessary, should be adopted. The designer should make his client aware of the necessity for a good maintenance program.

11. LIGHT LOSSES - RECOVERABLE

a. Lamp Lumen Depreciation - Information about lamp lumen depreciation is available from manufacturers' tables and graphs for lumen depreciation and mortality of the chosen lamp. Rated average life should be determined for the specific hours per start; it should be known when burn-outs will begin in the lamp life cycle. From these facts, a practical group relamping cycle will be established and then, based on the hours elapsed to lamp removal, the specific Lamp Lumen Depreciation (LLD) factor can be determined. Consult manufacturers data or the IES Lighting Handbook, 5th Edition for LLD factors.

This factor has already been used in the problems and solutions presented. The tables for the various lamp types are found on page 5-11, Fig. 5-5 for incandescent lamps; page 5-31, Fig. 5-24 for mercury lamps; page 5-32 Fig. 5-28, for metal halide lamps. The loss for sodium is reported to run from 5 to 10% at end of lamp life according to the latest information and depending on the manufacturer contacted.

b. Luminaire Dirt Depreciation - The accumulation of dirt on luminaires results in a loss in light output, and therefore a loss on the roadway. This loss is known as the luminaire dirt depreciation (LDD) factor and is determined as follows:

(1) Determine the dirt category (very clean, clean, average, dirty or very dirty) from 10.d and Fig. 8-5 and Fig. 11-2.

(2) From the appropriate dirt condition curve in Fig. 8-4 and the proper elapsed time in years of the planned cleaning cycle, the LDD factor is found. The proper elapsed time for cleaning is determined from section 10.f and 11.a.

12. TOTAL LIGHT LOSS FACTOR - The total Light Loss factor is simply the product of multiplying all contributing factors described above. Where factors are not known, or applicable, they may be omitted. At this point, if it is found that the total light loss factor is excessive it may be desirable to reselect the luminaire.

In general it is good practice to solve a great many problems using as many different possibilities as possible so that the computations will become quite familiar. For that reason the following problems have been attached.

Appendix "A" of American National Standard Practice for Roadway Lighting should be given very careful study for many special considerations in regard to roadway complexities.

General information: If the minimum illumination of any point on the roadway is less than 1/3 the average illumination it is possible that,

1. The mounting height is too low.
2. Another light distribution pattern (if available) might be used to advantage.
3. A different overhang might be used.
4. Spacing is too great.
5. The lamp-luminaire combination has too great a lumen output for the average illumination level desired.

PROBLEMS

No. 1 Apply the new design parameters to Fig. 8-1

Roadway width (W)	44'
Mounting Height (MH)	30'
Overhang (OH)	4'
Luminaire Fig. 8-8 (McG-Ed. No. E359-280)	
ANSI/IES Type: III, Medium, Cut-off	
Lamp H33-1CD/E (Now H33Cd-400, bulb E-37)	
Test lamp rated lumens 20,500	
Commercial lamp rated 19,667 lumens (horizontal)	
Required maintained footcandles	2.0
Atmosphere - surrounds CLEAN	
Cleaning schedule - months	6
Lamp replacement 83% life	20,000 hours

a. Determine luminaire dirt depreciation (LDD) ________
b. Determine lamp lumen depreciation (LLD) ________
c. Determine commercial lamp lumen/test lamp lumen factor ________
d. Determine Coefficient of Utilization (CU) ________
e. Determine staggered spacing for 2 fc avg. mtd ________
f. Determine maintained fc to minimum fc ratio ________

Solution No. 1

a. Refer to Fig. 8.5 for a 6 months line draw a line vertically half-way between the 0 and 1 year line. Where this line intersects the clean line is just about 97%.

b. To determine LLD refer to Fig. 5-24, page 5- . Draw a line from mid point of "H33" to 100%, where this line crosses vertical line for 20,000 hours it appears that the lumen value is about 70%.

c. According to the tables page 5-33 a 400 watt H33CD-400 lamp produces approx. 19,667 lumens in a horizontal position. This value divided by the test lamp lumens gives us (19,667/20,500) a 96% factor.

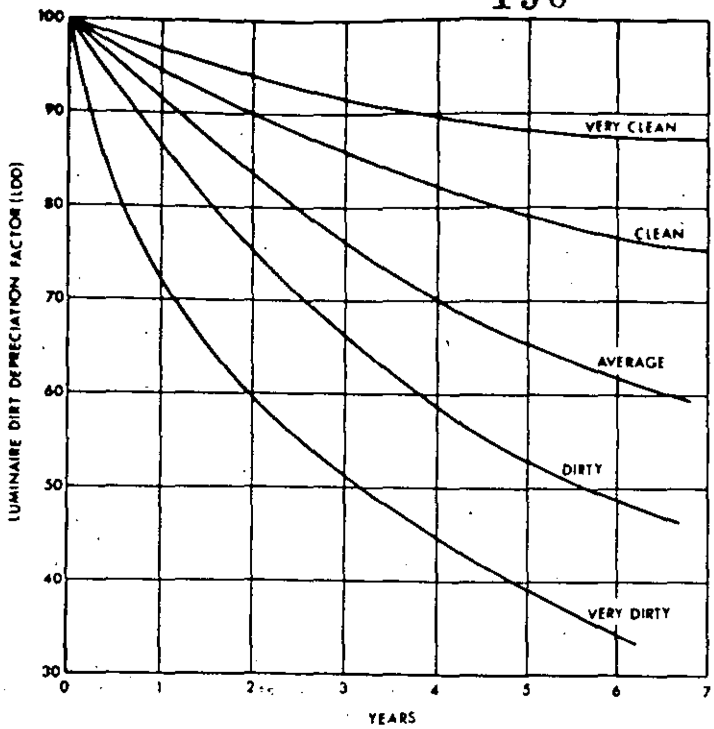
d. To determine the CU factor refer to Fig. 8-8.

CU- Street Side (S.S.) $\frac{W-OH}{MH} = \frac{44' - 4'}{30'} = \frac{40}{30} = 1.333$

Draw line from 1.333 Street Side to intersect S.S. curve at .453

CU- House Side (H.S.) $\frac{OH}{MH} = \frac{4'}{30'} = .1333$ ratio

Draw line from .1333 to intersection of H.S. curve at .057
Total CU for H.S. and S.S. is .057 + .453 = .51



SELECT APPROPRIATE DIRT CURVE FROM KIND OF CONDITIONS DESCRIBED BELOW FOR TYPE LUMINAIRE TO BE USED

Areas—Clean—Pavement—Grass. No open loose ground. Slow traffic. Little or no adhesive qualities in atmosphere. Most rural areas, residential roadways, slow traffic, no trucks.

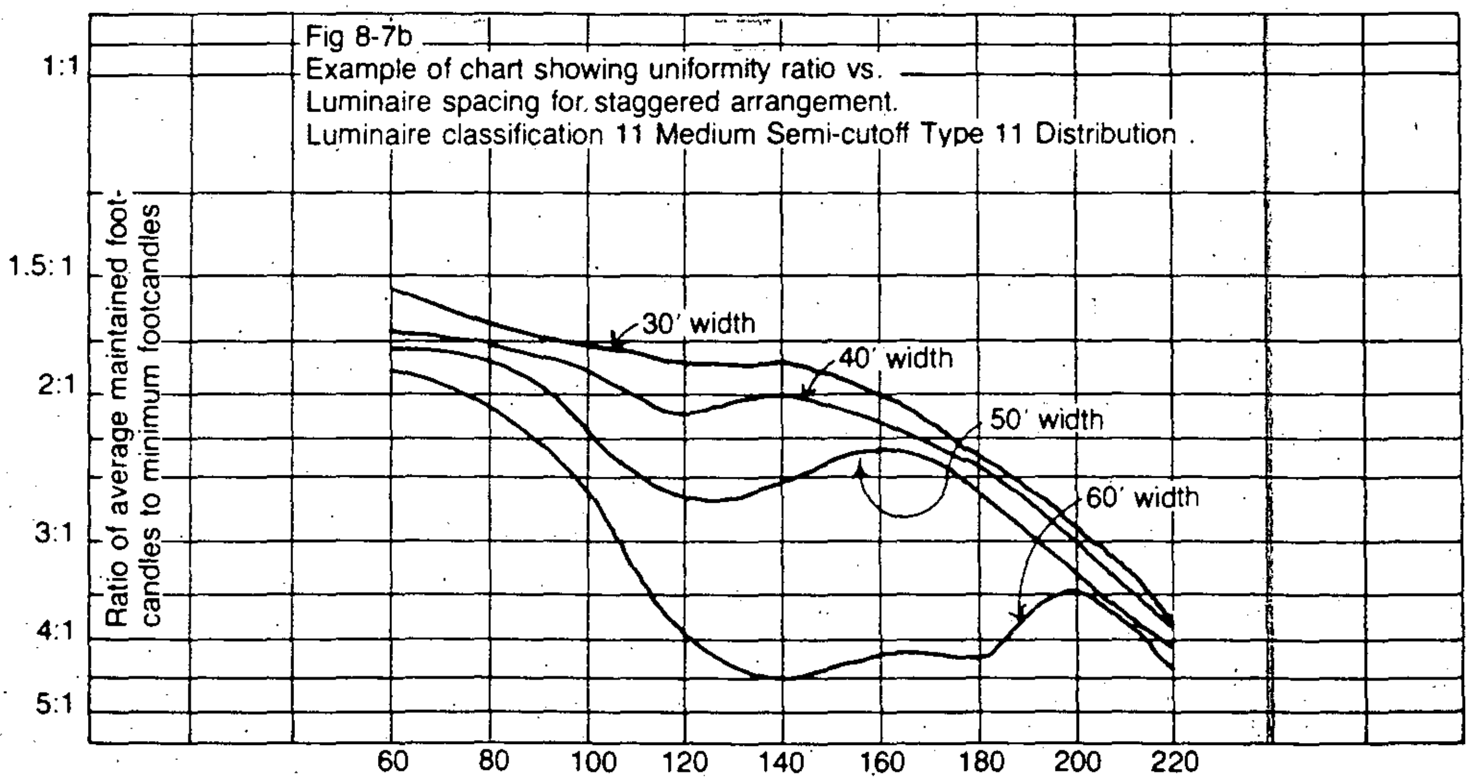
Areas—As above except average car and truck traffic. Downtown open areas. Intermediate and freeways in open areas.

Areas—As above but slightly more exposure. Residential, intermediate, local minor roads. Few trucks.

Areas—Confined. Greater than average. Cars and trucks expressway, freeways. Downtown, major, Adhesive dirt.

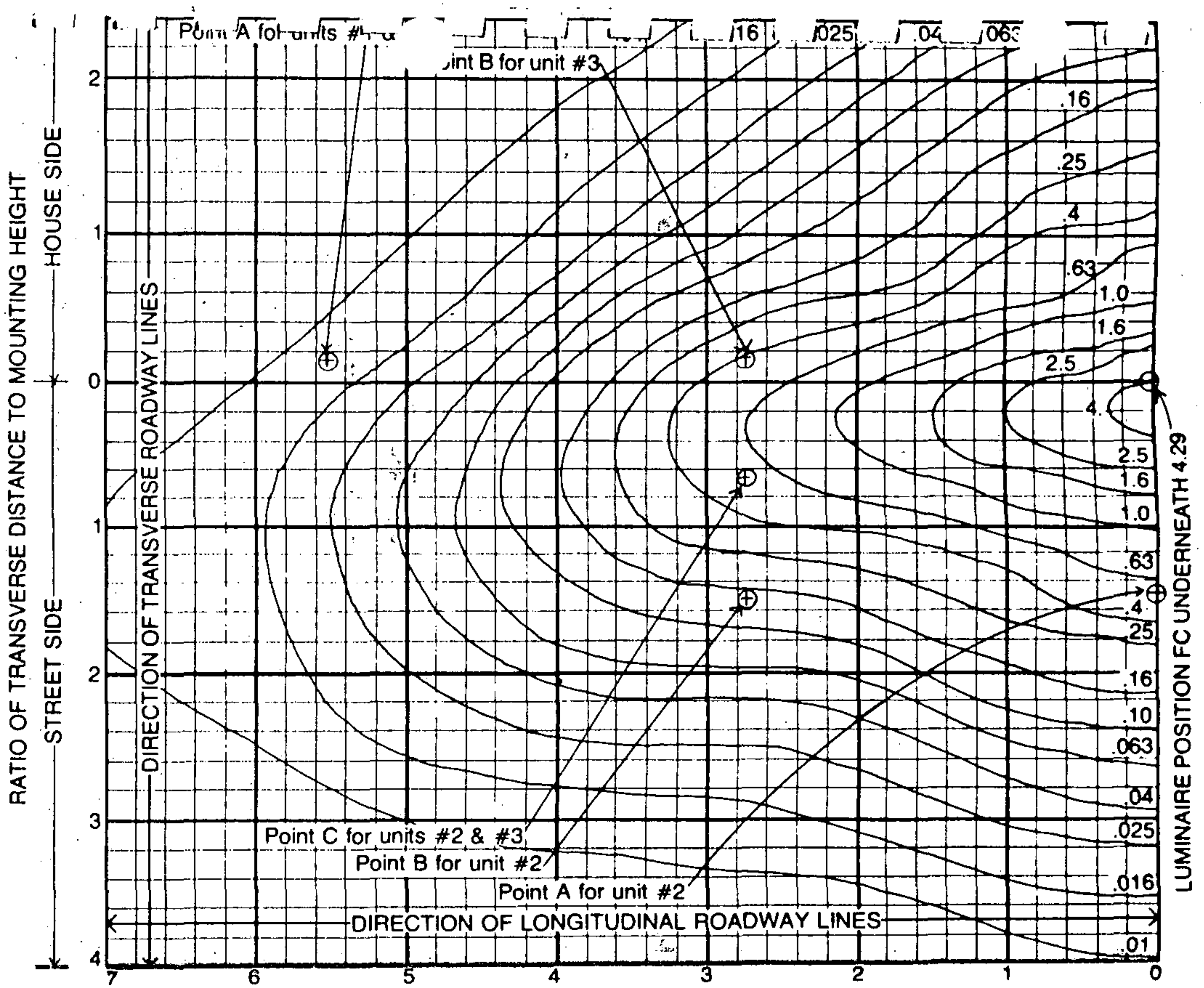
Ind./Comm. Areas. Trucks, buses, adhesive dirt, confined areas, heavy traffic.

Fig. 8-5. This chart is useful for estimating roadway luminaire dirt depreciation factors (LDD)



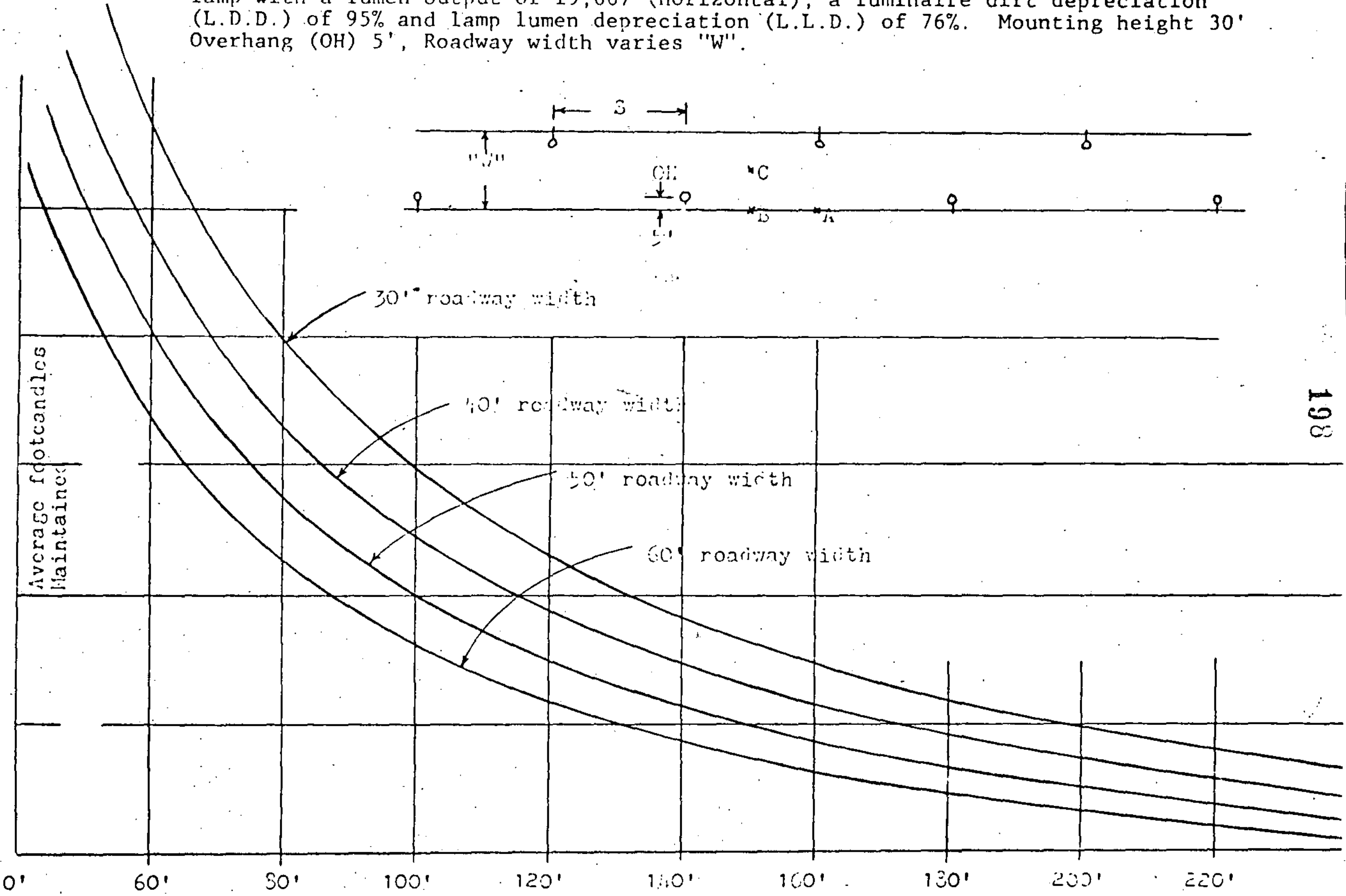
MOUNTING HEIGHT FEET	FACTOR
20	2.25
21	2.04
22	1.86
23	1.70
24	1.56
25	1.44
26	1.33
27	1.24
28	1.15
29	1.07
30	1.0
31	0.94
32	0.88
33	0.83
34	0.78
35	0.74

Fig 8-6 Enlarged section of Fig. 8-2 for isofootcandle curves only. (For easier computations).



RATIO OF LONGITUDINAL DISTANCE TO MOUNTING HEIGHT
Footcandle data is based on a luminaire mounting height of 30′. For other mounting heights multiply the values of footcandles shown by the factors in the table.

(Fig. 8-2) Maintained footcandle ·es are calculated for a 400-watt clear ·rcury lamp with a lumen output of 19,66· (horizontal), a luminaire dirt depreciation (L.D.D.) of 95% and lamp lumen depreciation (L.L.D.) of 76%. Mounting height 30' Overhang (OH) 5', Roadway width varies "W".



Spacing between luminaires in feet (staggered)

Fig. 8-7a.

199

Luminaire: Refractor Cat. No. L0330X1
Socket Setting 4C

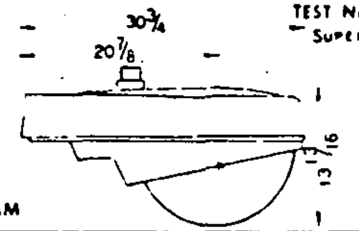
Lamp: H33-1CD/E, 400 Watts, 20,500 Lumens
E-37, Clear

ANSI IES Type III, Medium, Cut-Off

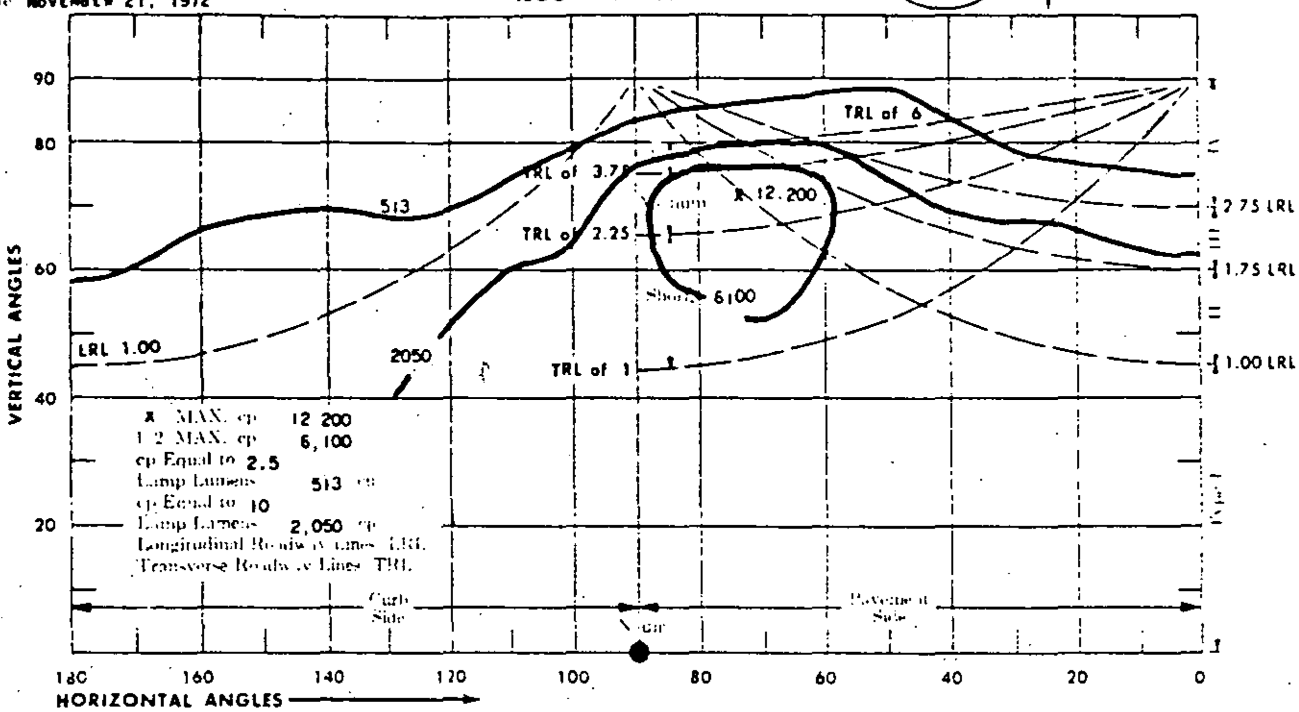
Approved By

Date November 21, 1972

TEST No E359-280
Supersedes E359-235



ISOCANDELA DIAGRAM



DASHED CURVES SHOW LUMEN UTILIZATION (IN %)

3.64	

Footcandle	Multiplier
25	1.44
26	1.33
27	1.24
28	1.15
29	1.07
30	1.00
31	0.94
32	0.88
33	0.83
34	0.78
35	0.74

	56.1	20.9
	1.7	.7
	79.4	

Test ... 25 ...

Tested ... with IES ... tests.

Data ... reproduction ... duplicating test conditions.

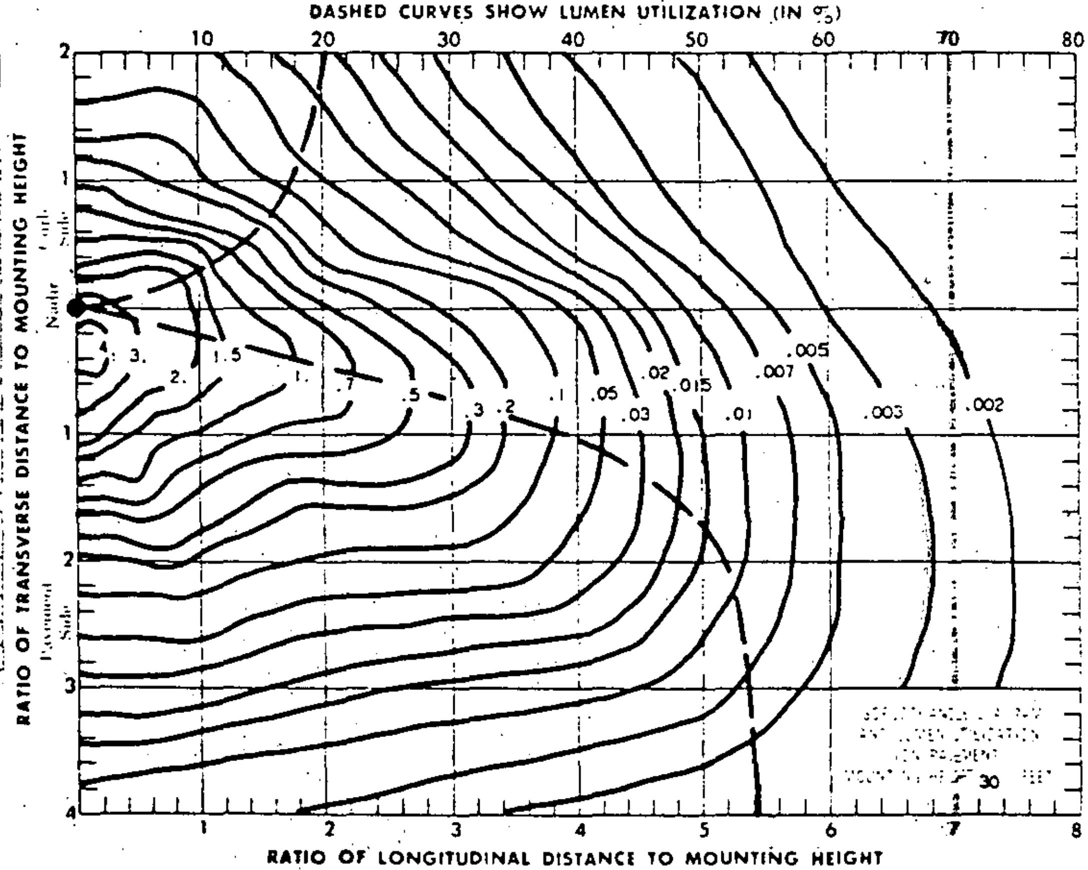


Fig. 8-8.

200

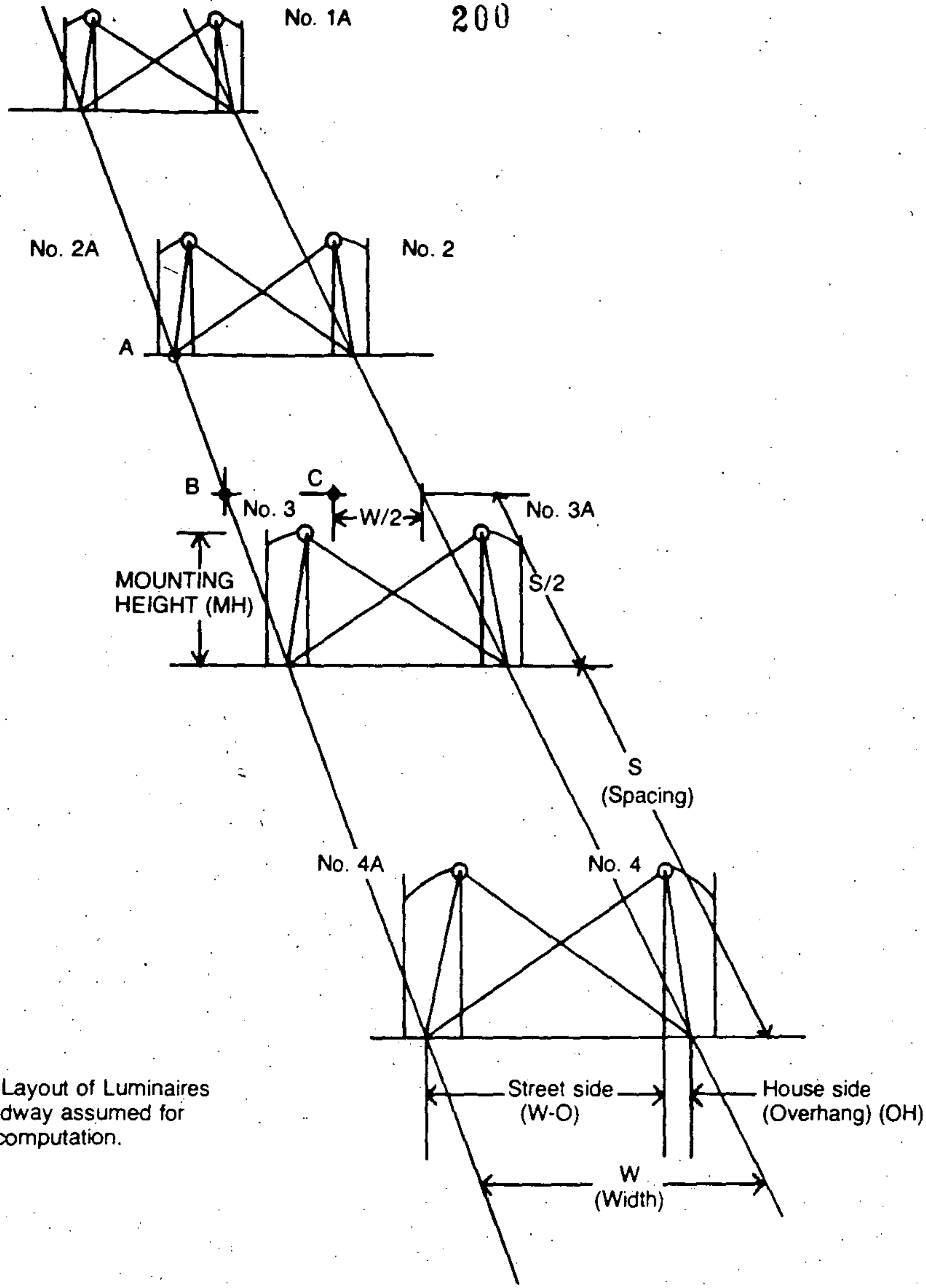


Fig 8-9 Layout of Luminaires and roadway assumed for typical computation.

. Staggered spacing using formula 5c page 8-7

Staggered spacing = $\frac{19,667 \times .51 \times .97 \times .70}{44 \times 2} = \frac{6810}{88} = 77.39'$ (76')

f. To determine average fc. to minimum fc ratio
Determine fc at point "A" luminaires no. 1 & 3
Transverse H.S. 4/30 = .1333)
Long. along R. 76/30 = 2.533) = .21 x 2 = .42 fc

Luminaire no. 2
Transverse S.S. 40/30 = 1.333)
Long along R. = 0 = 1.10 fc

Luminaire No. 4
Transverse S.S. 40/30 = 1.333)
Long. along R. 152/30 = 5.0666) = .015
Total for No. 1, No. 2, No. 3
& No. 4 1.535
Maintained FC = 1.535 x .97 x .70 x .96 = 1.0 fc maintained

Determine fc. at point "B" Luminaire No. 1
Trans. H.S. 4/30 = .1333, Long. 114/30 = 3.8 .04 fc
No. 2, Trans. S.S. 40/30 = 1.35, Long. 38/30 = 1.266 .48 fc
No. 3, Trans. H.S. 4/30 = .135, Long. 38/30 = 1.266 1.00 fc
No. 4, Trans. S.S. 40/30 = 1.53, Long.114/30 = 3.8 .085 fc
Total footcandles at point 1.605 fc

Determine fc. at Point "C" Luminaire 1 and 4
Trans. S.S. 20/30 = .667, Long. 114/30 = 3.8 = .11 fc x 2 = .22fc
No. 2 & 3 Trans. S.S. 20/30 = .667 Long. 38/30 = 1.266
= 1.15 fc x 2 = 2.30
Total footacndles at point "C" 2.52 fc

Maintained fc at point "B" = 1.605 x .97 x .70 x .96 = 1.05
Maintained fc at point "C" = 2.52 x .97 x .70 x .96 = 1.64 fc
Point "A" is low and produces a ratio of 2 avg. to 1 or a
2 to 1 ratio.

Problem No. 2

Using the same parameters as for problem no. 1 change the pole locations to opposite spacing for a 2 fc avg. maintained. See Fig. 8-9.

a. Determine spacing
   The values for coefficient of utilization, LDD, LLD, ITL, will remain the same.

b. Determine maintained fc for points "A" _____, "B" ______ and "C" ______.

c. Determine ratio for average maintained to minimum maintained ________.

Problem No. 3

Determine data for the following situation:

Roadway Width (W)	60'
Mounting Height (MH)	30'
Overhang (OH)	4'
Luminaire-See Fig. 8-8 (Opposite spacing)	
LDD	97%
LLD	70%
ITL	96%
Average maintained footcandles to be provided	2 fc

a. Determine Coefficient of Utilization (CU) ______
b. Determine opposite spacing ______
c. Determine maintained fc. at points "A", "B" and "C" ______ ______ ______
d. Determine average to minimum ratio.

Problem No. 4

Photometric Data - see Fig. 8-2, 8-3 and 8-6.
Luminaire, Medium, Semi-cutoff type II
Lamp; 400 watt clear mercury - H33-1CD (Ansi No. H33CD-400)
Test Lamp Lumens 20,500; Installed lamp lumens 19,667 - horizontal

Lamp Lumen Depreciation (LLD)	78%
Roadway Width (W)	42'
Overhang (OH)	6'
Required maintained fc	2
Luminaire Dirt Depreciation (LDD)	97%
Mounting Height	34'
Mounting Height factor (see table on data sheet)	78%
Installed - Test Lamp factor (ITL)	96%

a. Determine Utilization factor (CU)
b. Determine staggered pole spacing
c. Determine footcandle values maintained at Points "A", "B" and "C".
d. Determine average to minimum ratio.

Problem No. 5

The previous problem was on a clear mercury lamp, this one will be on a phosphor coated lamp of the same wattage, and will produce a different type of distribution.

Photometric Data - see Fig. 8-10
Luminaire, IES Type III Short, Cutoff (1972)
Lamp; 400 watt Phosphor coated H33GL-400/DX
Test Lamp Lumens 22,000
Installed Lamp Lumens, initial 21,780

Installed - Test lamp factor	.99
LLD	78%
Roadway width (W)	42'
Overhang (0)	6'
Mounting Height	34'
Mounting Height Factor	74%
LDD	97%
Footcandles maintained	2

a. Determine Coefficient of Utilization (CU)
b. Determine staggered pole spacing
c. Determine footcandles maintained at points "A", "B" and "C"
d. Determine average to minimum ratio

Problem No. 6

This problem has the same physical perameters as the two previous problems. The change is substituting a 400 watt sodium lamp fixture.

Photometric Data - See Fig. 8-11
Luminaire - IES type IV, medium, semi-cutoff
Lamp: LU-400 E-18

Test Lamp Lumens	42,000
Rated Lamp Lumens	50,000
Installed - test lamp lumen factor	1.19
LLD	.90%
Roadway Width (W)	42'
Overhang (0)	6'
Mounting Height	34'
Mounting height factor	78%
LDD	97%
Footcandles maintained	2

PHOTOMETRIC REPORT

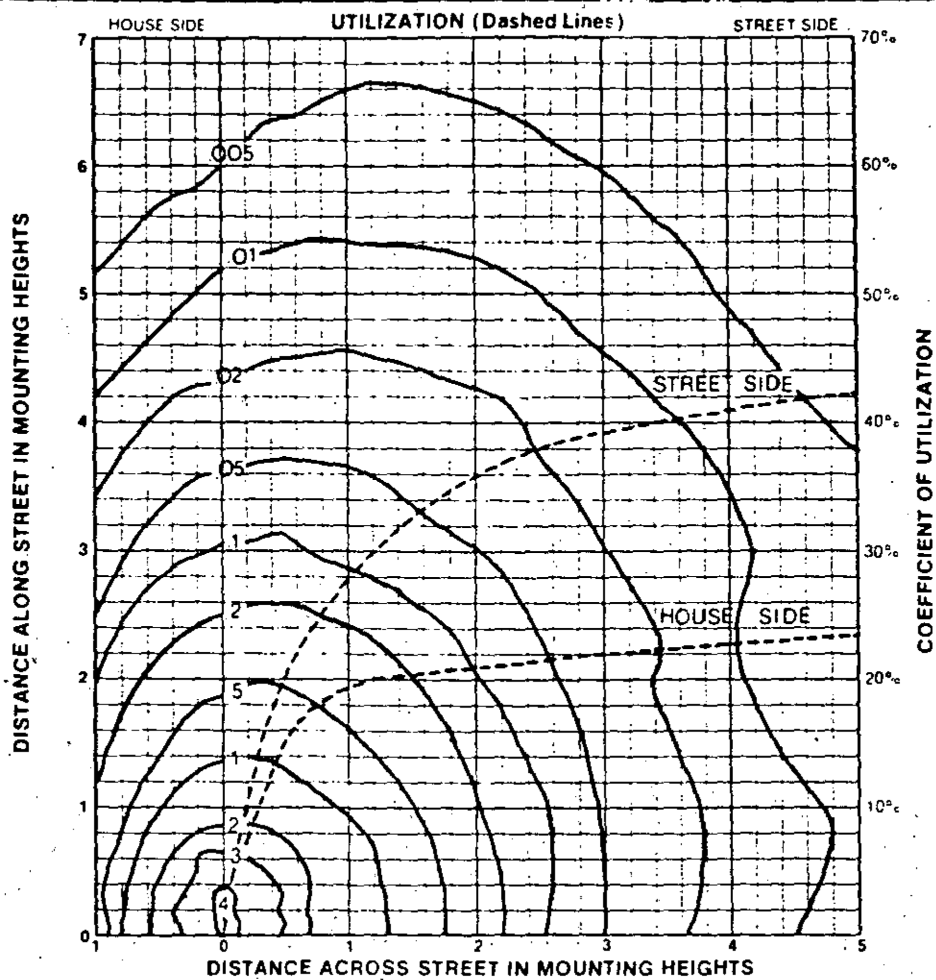
LAMP H33-1GL-DX WATTS 400
LCL 7 VOLTS
'MENS 22000

TEST NO. 25-6 DATE 11-16-72
BY T.J.S. REVISION 00
APPROVED BY J Rot

LUMINAIRE: **HORIZONTAL**
SERIES: 25 000
WATTAGE: 400

204

SOCKET POS.
DWN. & FWD.
III SHORT CUTOFF (1972)
IES TYPE: III SHORT SEMI CUTOFF (1963)



ISOFOOTCANDLE AND UTILIZATION CURVES

TEST DISTANCE 30 FT.

Footcandle data is based on a luminaire mounting height of 30 feet. For other mounting heights, multiply the values of footcandles shown by the following table. The utilization curve (dashed) is correct for all mounting heights and does not require correction.

Mounting Ht.—Ft.	10	12	14	16	18	20	25	30	35	40	45	50	60	70
FACTOR						2.25	1.44	1	.74	.56	.44	.36		

This report is based on test methods in accordance with IES Guides for Testing Procedures. Significance is limited to the degree that the tested sample is representative and that test conditions are duplicated. Voltage and characteristics of lamps and ballasts seriously affect field performance.

LIGHT FLUX VALUES
(Test Distance Shown Above)

	Lumens	Percent of Lamp
DOWNWARD STREET SIDE	9840	43.1
UPWARD STREET SIDE		
DOWNWARD HOUSE SIDE	5200	23.6
UPWARD HOUSE SIDE		
Total	14,680	66.7 %

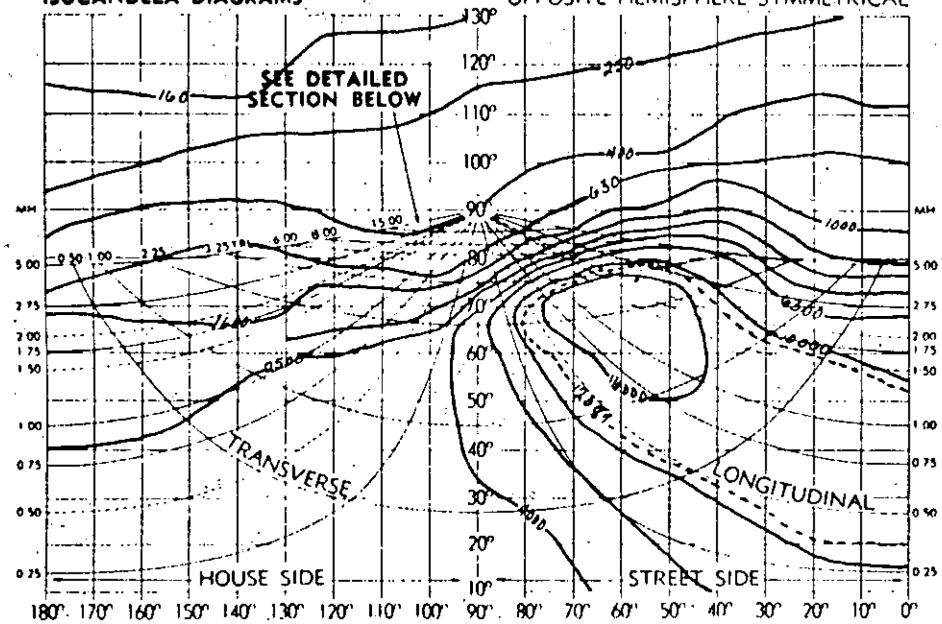
Values of isocandela, lumens, and footcandles are based upon a lamp operated at 22000 lumens. If the data is desired for a different lumen rating, multiply all isocandela, lumen, and footcandle values by the different lamp lumen rating divided by 22000

Fig. 8-10.

Fig. 8-11

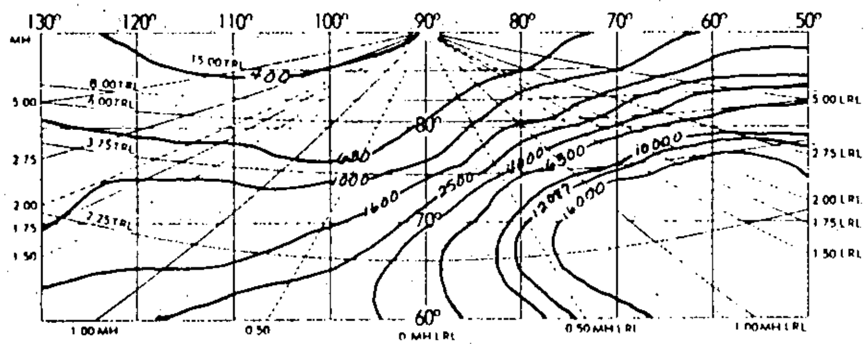
ISOCANDELA DIAGRAMS

OPPOSITE HEMISPHERE SYMMETRICAL



HALF MAX C P 12087
MAX C P 24174
NADIR C P 3186.

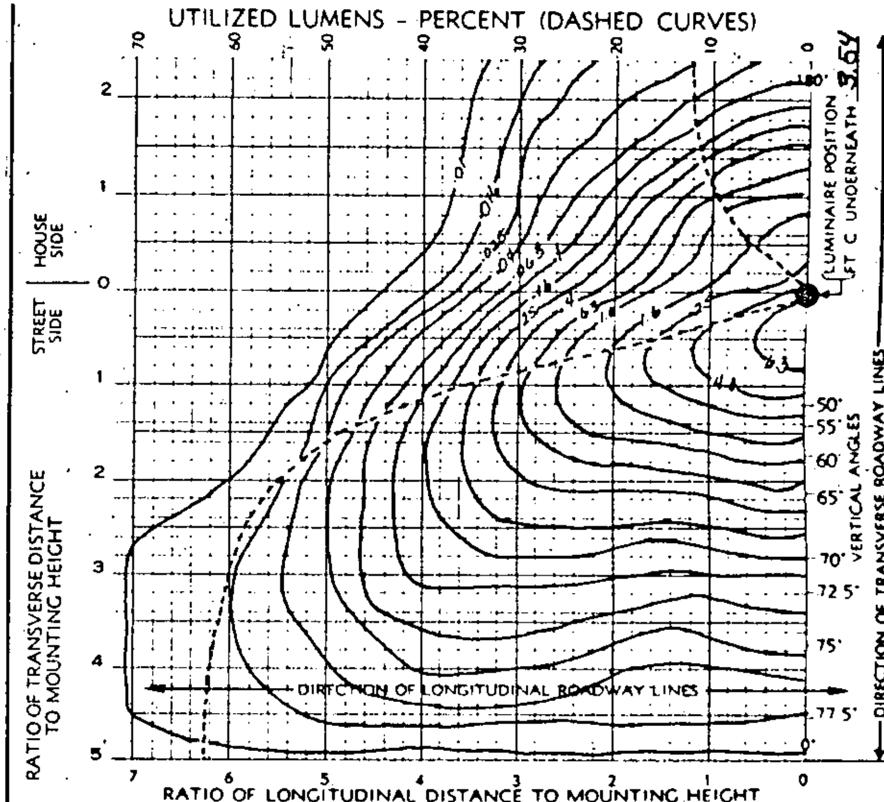
MAX CONE 70°
MAX VER PLANE 62.5/297.5°



DETAILED SECTION: Based upon data taken at closer intervals than used for main diagram.

VALUES OF ISOCANDELA, LUMENS, AND FOOTCANDLES ARE BASED UPON A LAMP OPERATED AT . 42,000 ___ LUMENS. IF THE DATA IS DESIRED FOR A DIFFERENT LAMP LUMEN RATING, MULTIPLY ALL ISOCANDELA, LUMEN, AND FOOTCANDLE VALUES BY THE RATIO DIFFERENT LAMP LUMEN RATING DIVIDED BY 42,000.

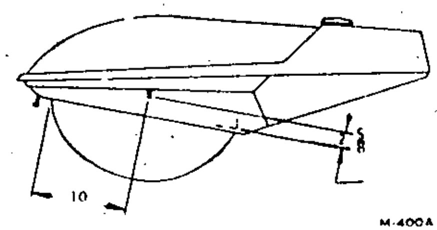
LIGHT FLUX VALUES	LUMENS	PERCENT OF LAMP
DOWNWARD STREET SIDE	26670	63.5
UPWARD STREET SIDE	840	2.0
DOWNWARD HOUSE SIDE	5670	13.5
UPWARD HOUSE SIDE	420	1.0
TOTAL	33600	80.0



ISOFOOTCANDLE & UTILIZATION CURVES

FOOTCANDLE DATA IS BASED ON A LUMINAIRE MOUNTING HEIGHT OF 30 FEET. FOR OTHER MOUNTING HEIGHTS MULTIPLY THE VALUES OF FOOTCANDLES SHOWN BY THE FACTORS IN THE FOLLOWING TABLE. THE UTILIZATION CURVE (DASHED) IS CORRECT FOR ALL MOUNTING HEIGHTS AND DOES NOT REQUIRE CORRECTION.

MOUNTING HEIGHT - FT.	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
FACTOR	2.25	2.04	1.86	1.70	1.56	1.44	1.33	1.24	1.15	1.07	1	0.94	0.88	0.83	0.78	0.74



LUMINAIRE DESCRIPTION

Reflector 35-130001-13
Refractor #510
SOC. POS. AL REAR/5

LAMP – 400 WATT
ASA No
LU-400 Note: Long arc 3½"

ASA/IES TYPE
CIE: NOT APPLICABLE
MEDIUM, SEMI-CUTOFF, TYPE IV

NUMBER 35-174846-00 | REV NO 03

a. Determine Coefficient of Utilization (CU)
b. Determine Staggered pole spacing
c. Determine footcandles maintained at points "A", "B" and "C"
d. Determine average to minimum ratio.

Problem No. 7

This problem is for a greater mounting height and a wider roadway.
Photometric Data Fig. 8-12
Luminaire IES type III, medium, semi-cutoff distribution.
Lamp: 1000 watts H36-15GV (Ansi - H36GV-1000) clear.

Test Lamp Lumens	57,000
Rated Lamp lumens initial horizontal	54,000
Installed- Test lamp lumen factor	94.74%
Roadway width (W) (Fig. 8-1)	72'
Overhang (OH)	5'
Mounting Height (MH)	50'
Footcandles maintained	2

a. Determine lamp lumen depreciation for 16,000 hours Fig. 5-24 page 5-
b. Determine luminaire dirt depreciation factor for a system of cleaning every 6 months in an avg. area.
c. Determine Coefficient of Utilization (CU)
d. Determine staggered spacing
e. Determine footcandles maintained at points "A", B" and "C"
f. Determine average to minimum ratio

Problem No. 8

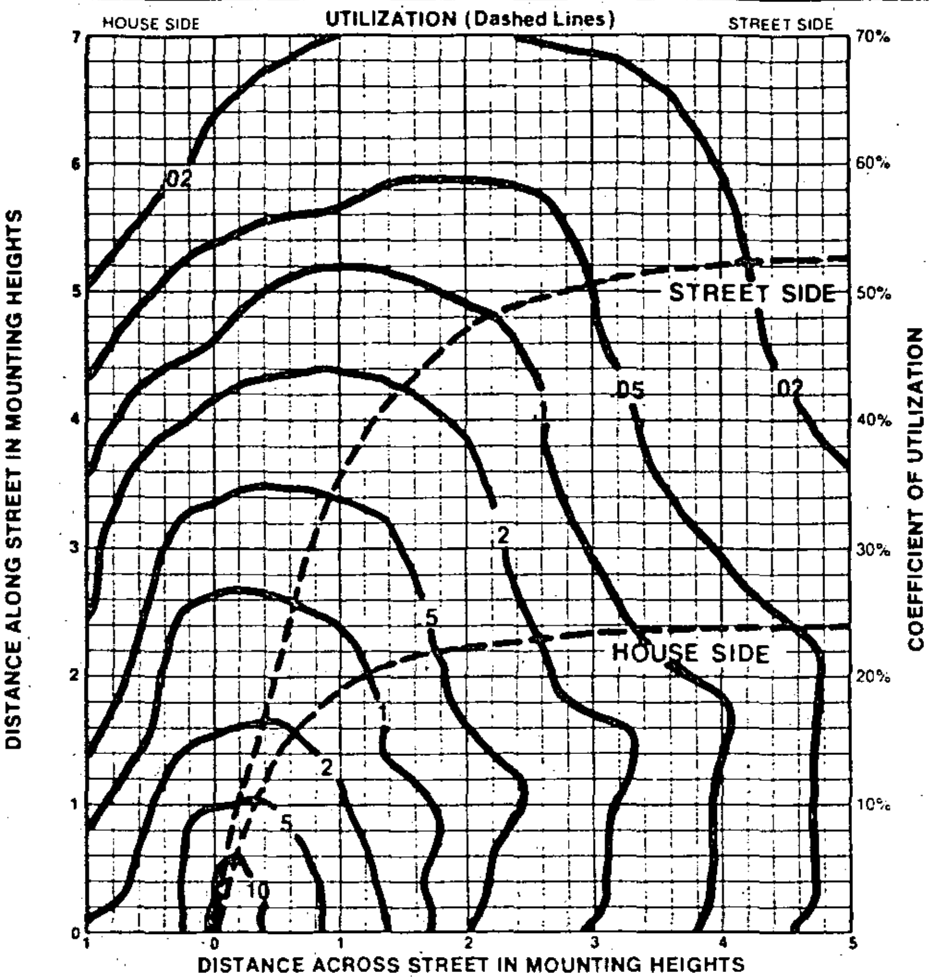
To get a comparison of a clear and phosphor coated mercury lamp the same perameters will be used on this problem as in problem no. 7., except that a 1000 watt Deluxe white lamp will be used.
Photometric data - Fig. 8-13
Luminaire Ansi/IES Type IV, short, cut-off.
Lamp: 1000 watts H36-15GW/DX (Ansi -H36GW-1000/DX)

Test Lamp Lumens	63,000
Rated Lamp Lumens initial horizontal	60,000
Installed - Test lamp lumen factor	.9524
LLD	67%
LDD	95%
Roadway width (W)	72'
Overhang (0)	5'
Mounting Height (MH)	50'
Footcandles maintained	2
Mounting height factor	49%

a. Determine Coefficient of Utilization
b. Determine staggered pole spacing
c. Determine maintained footcandles at points "A", "B" and "C"
d. Determine average to minimum ratio

PHOTOMETRIC REPORT 207

LAMP H36-15GV WATTS 1000 9.38 VOLTS —— ENS 57000	LUMINAIRE: "1000" SERIES: 227 WATTAGE: 1000
TEST NO. 227-8 DATE 7-24-73 BY JSB REVISION 0 APPROVED BY [signature]	IES TYPE: III MEDIUM SEMI-CUTOFF



ISOFOOTCANDLE AND UTILIZATION CURVES

TEST DISTANCE 25 FT.

Footcandle data is based on a luminaire mounting height of 30 feet. For other mounting heights, multiply the values of footcandles shown by the following table. The utilization curve (dashed) is correct for all mounting heights and does not require correction.

Mounting Ht.—Ft.	10	12	14	16	18	20	25	30	35	40	45	50	60	70
FACTOR	—	—	—	—	—	—	1.44	1.00	.74	.56	—	—	—	—

This report is based on test methods in accordance with IES Guides on Testing Procedures. Significance is limited to the degree that the tested sample is representative and that test conditions are duplicated. Voltage and characteristics of lamps and ballasts seriously affect field performance.

LIGHT FLUX VALUES
(Test Distance Shown Above)

	Lumens	Percent of Lamp
DOWNWARD STREET SIDE	31230	54.8
UPWARD STREET SIDE	——	——
DOWNWARD HOUSE SIDE	13897	24.4
UPWARD HOUSE SIDE	——	——
Total	45127	79.2 %

Values of isocandela, lumens, and footcandles are based upon a lamp operated at 57000 lumens. If the data is desired for a different lumen rating, multiply all isocandela, lumen, and footcandle values by the different lamp lumen rating divided by 57000

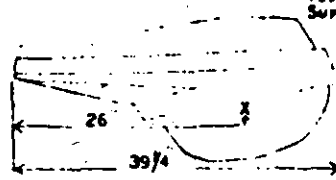
Fig. 8-12.

PHOTOMETRIC DATA

208

Luminaire
Refractor Cat. No. L088X1
Socket Setting A3
Lamp H36-15 GW/DX, 1000 Watts, 63,000 Lumens
B1-56, Deluxe White

TEST No E373-51
Supersedes E373-15

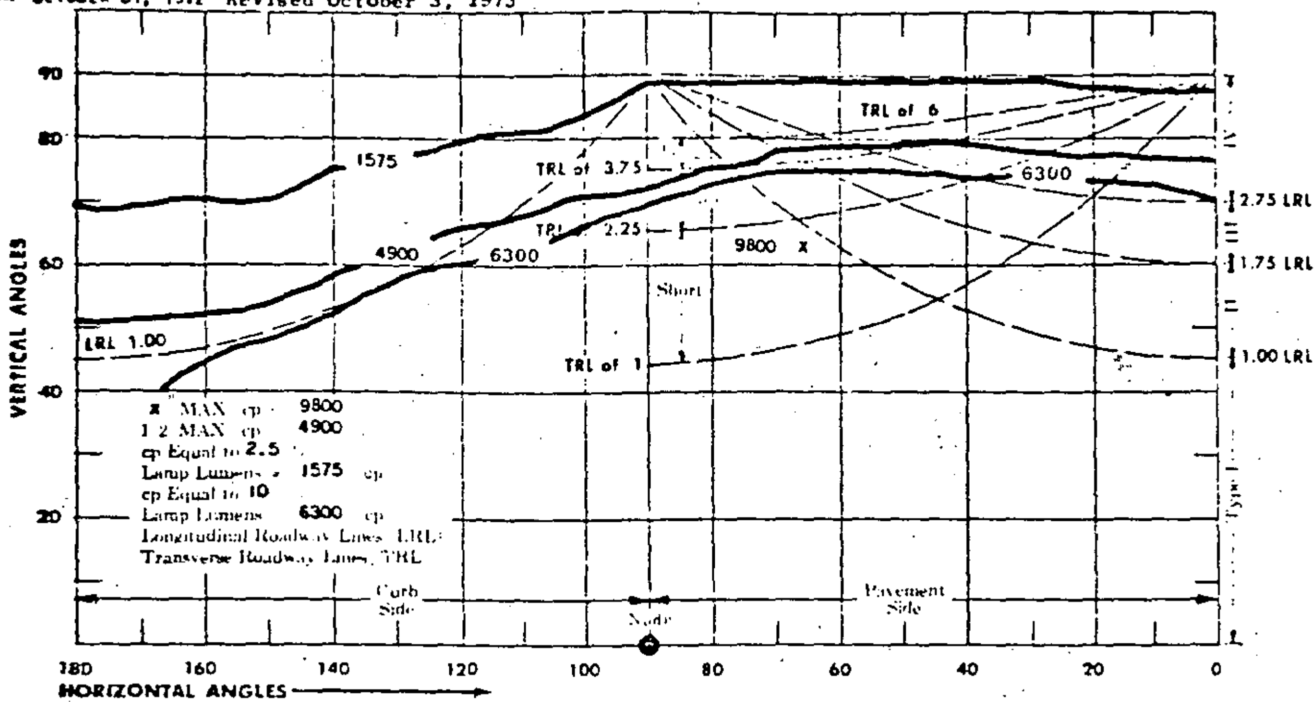


ANSI IES Type IV, Short, Cut-off

Approved By

Date October 31, 1972 Revised October 3, 1973

ISOCANDELA DIAGRAM



5.55	Footcandles At Nadir

Footcandle Multiplier

Mounting Height in feet	Factor
30	1.36
31	1.27
32	1.20
33	1.12
34	1.06
35	1.00
36	0.95
37	0.89
38	0.85
39	0.81
40	0.77

Luminaire Efficiency Bare Lamp

Direction	Pavement Side	Curb Side
Downward	34.2	23.1
Upward	1.8	1.7
Total	60.8	

Test distance 40 feet.

Tested in accordance with IES recommendations for laboratory tests.

Data reproduction contingent on duplicating test conditions.

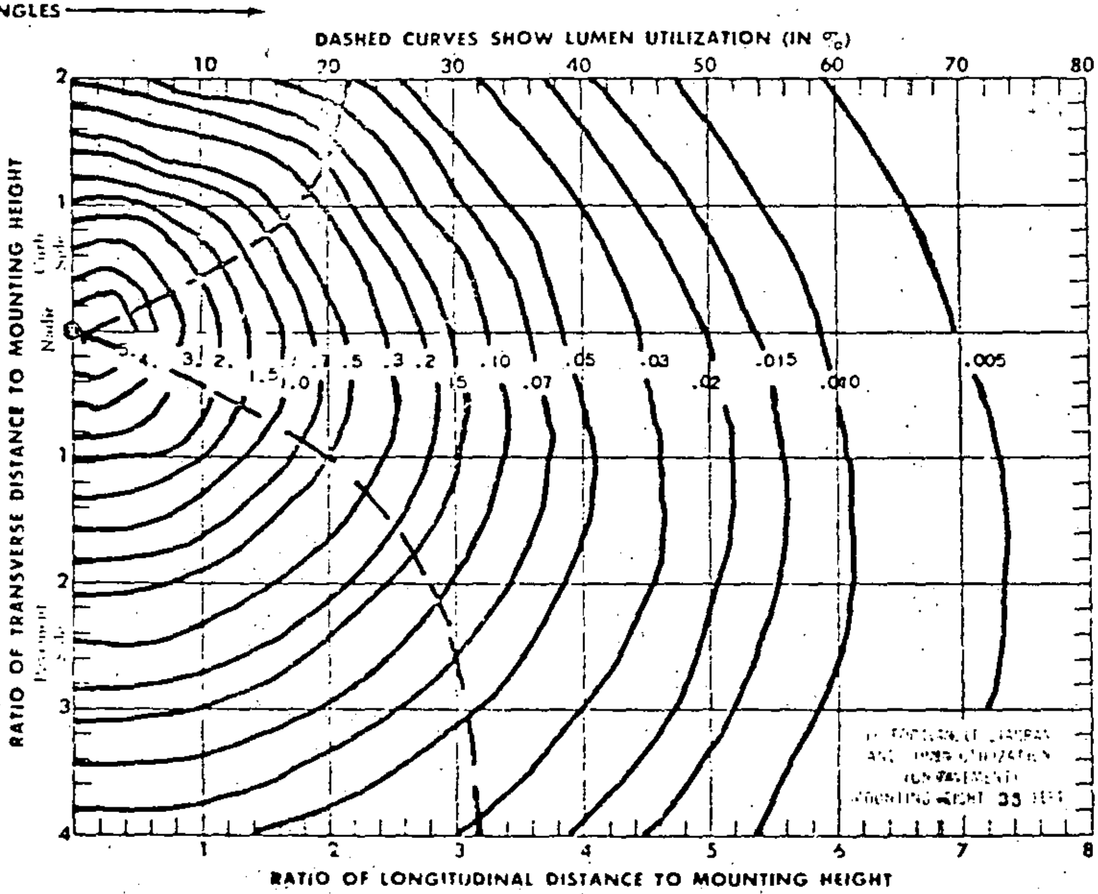


Fig. 8-13.

Problem No. 9

To compare different lamps we will take the same criteria as in problems no. 7 and 8 and now use a metal halide lamp. Photometric data Fig. 8-14 (Curve No. 630405).

Luminaire - IES type III, medium cutoff, distribution
Lamp: MH-1000 1000 watts Bt-46.

Test Lamp Lumens	90,000
Rated Lamp Lumens (Horizontal - initial)	95,000
Installed - Test lamp lumen factor	1.0555
LLD 7000 hours, 70% life	74%
LDD	95%
Roadway width (W)	72'
Overhang (0)	5'
Mounting Height (MH)	50'
Footcandle maintained	2
Mounting height factor	0

a. Determine Coefficient of Utilization (CU)
b. Determine staggered pole spacing
c. Determine maintained footcandles at points "A", "B" and "C"
d. Determine average to minimum ratio.

Problem No. 10

Many roadways are two separate roadways with a median between which may be from 2' to more than 20'. In this case we are using a 10' median and the luminaire is mounted over the edge of the roadway see Fig. 8-15. The lumens falling on the median will not be included in our calculations for CU. or footcandles.
Photometric Data Fig. 8-16
Luminaire Ansi/IES type III medium, cutoff.
Lamp; 1000 watts, M-1000/BD Bt-56 clear.

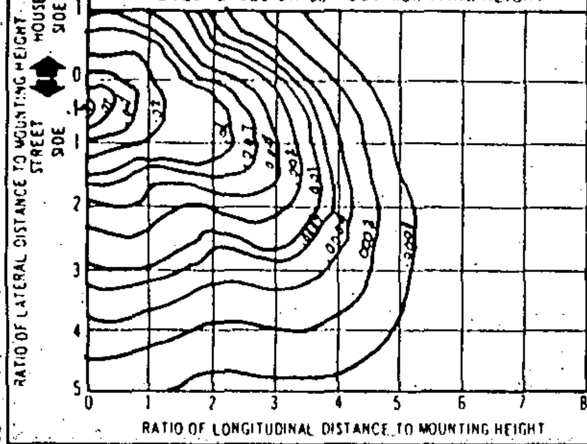
Test Lamp Lumens 90,000	90,000
Rated Lamp Lumens Horizontal initial	95,000
Installed - Test Lamp lumen factor	1.0555
LLD (70% life - 7000 hours)	74%
LDD	95%
Roadway width Fig. 8-17 (2 strips 36' wide with 10' separation).	
Mounting Height (MH)	50'
Mounting height factor	49%
Mast arms	5' (Approx.)
Overhang (0) (center of fixture over curb)	0'

2 luminaires per pole.

PHOTOMETRIC DATA

Fig. 8-14.

ISOFOOT-CANDLE DIAGRAM FOOT CANDLE VALUES* BASED ON 50 FOOT MOUNTING HEIGHT



	CORREC FACTOR
42	1.42
43	1.35
44	1.29
45	1.23
46	1.18
47	1.13
48	1.09
49	1.04
50	1.00
51	.96
52	.92
53	.89
54	.86
55	.83
56	.80
57	.77
58	.74
59	.72

Light output of lamp in specified position, specified ballast / Light output of lamp in specified position, reference ballast

LAMP DATA

SERVICE Multiple
LUMENS 90,000
AMPS. WATTS 1000 VOLTS
BULB BT-46 BASE Mog.Screw
DESIGNATION MH-1000
LIGHT CENTER LENGTH 9-1/2 in.
BURNING POSITION Horizontal

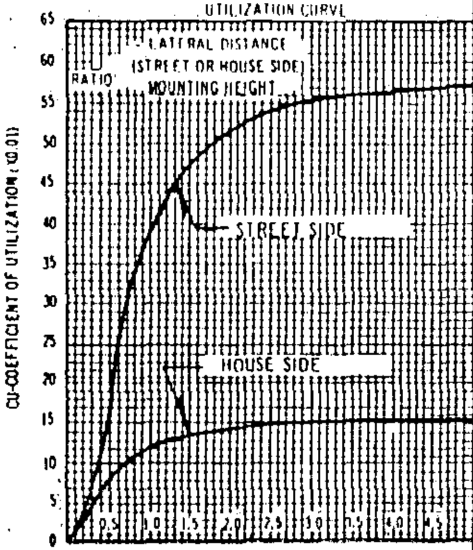
LIGHT FLUX VALUES*

	LUMENS	PERCENT OF LAMP
DOWNWARD STREET SIDE	582	58.2
UPWARD STREET SIDE	7	.7
DOWNWARD HOUSE SIDE	158	15.8
UPWARD HOUSE SIDE	1	.1
TOTAL	748	74.8

TRANSFORMER FACTOR

HI-REACTANCE TYPE		
REGULATED OUTPUT TYPE		

UTILIZATION CURVE



EFFECTIVE LUMENS = CU X BARE LAMP LUMENS
AVERAGE HORIZONTAL FOOT CANDLES ON STREET = EFFECTIVE LUMENS / SPACING X WIDTH OF STREET

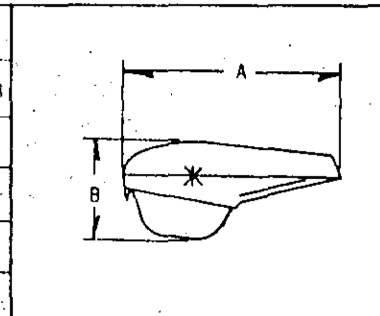
8-37

Lumen rating of lamp in specified position / 1000

*To obtain actual candela and footcandle values, multiply the values shown by the factors

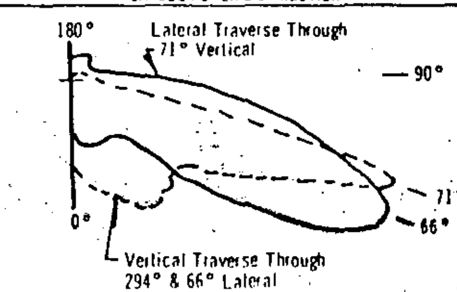
OUTLINE DIMENSIONS

A	39
B	16-1/8
C	
D	
E	
F	
G	



TEST DISTANCE 25 FEET
REFLECTOR — Specular Aluminum
SOCKET POSITION — L-D

CANDLE POWER DISTRIBUTION

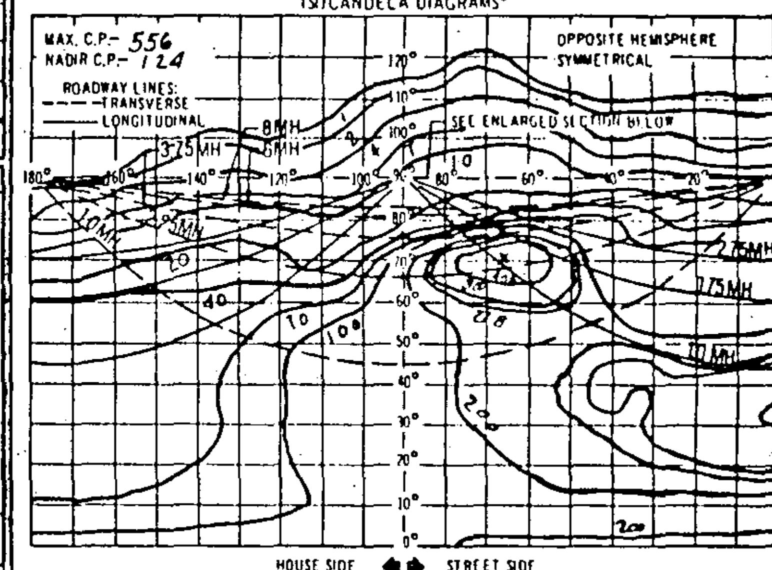


RESULTS ARE TYPICAL ONLY WHEN ALL TEST CONDITIONS, SUCH AS L.C. POSITION, LUMENS, ETC. ARE REPRODUCED.

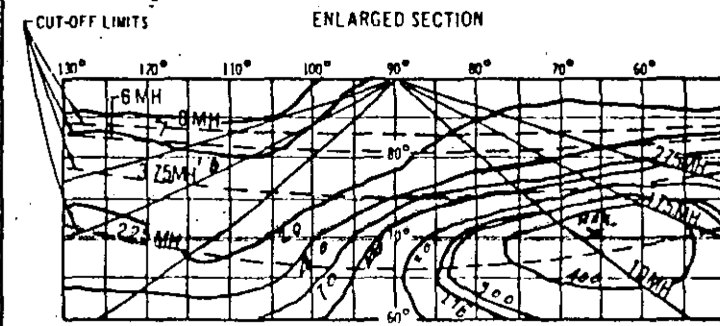
TESTED IN ACCORDANCE WITH THE IES GUIDE FOR PHOTOMETRIC TESTING OF STREETLIGHTING LUMINAIRES

TYPE* III	TEST NO. K2517977	APP'D.
DISTRIBUTION* Medium	TEST BY L.C. Sauk	DATE 8-11-69
CLASSIFICATION* Cutoff		CURVE NO. 630405

ISOCANDELA DIAGRAMS*



ENLARGED SECTION



* - CLASSIFICATION PER ANSI D12.1-1972

CURVE NO 630405

210

a. Determine Coefficient of Utilization
b. Determine Spacing for double mounting
c. Determine maintained footcandles for points "A", "B", "C" and "D".
Determine average to minimum ratio.

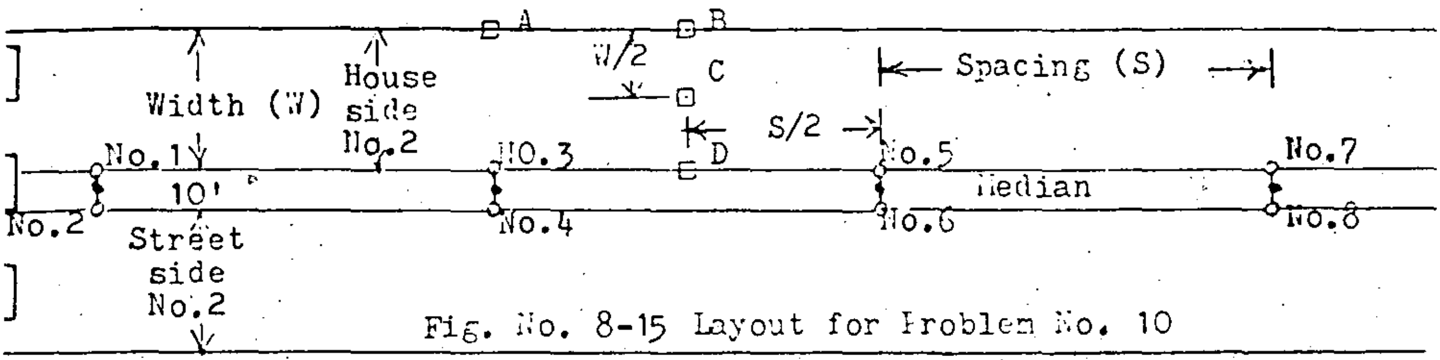


Fig. No. 8-15 Layout for Problem No. 10

PHOTOMETRIC DATA

Luminaire: Refractor Catalog No. L088X1
Socket Setting A3
Lamp: M-1000/BD, 1000 Watts, 90,000 Lumens
BT-56, Clear

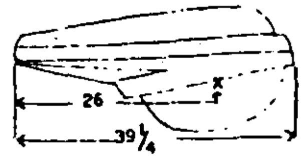
ANSI IES Type III, Medium, CutOff

Approved By: [signature]

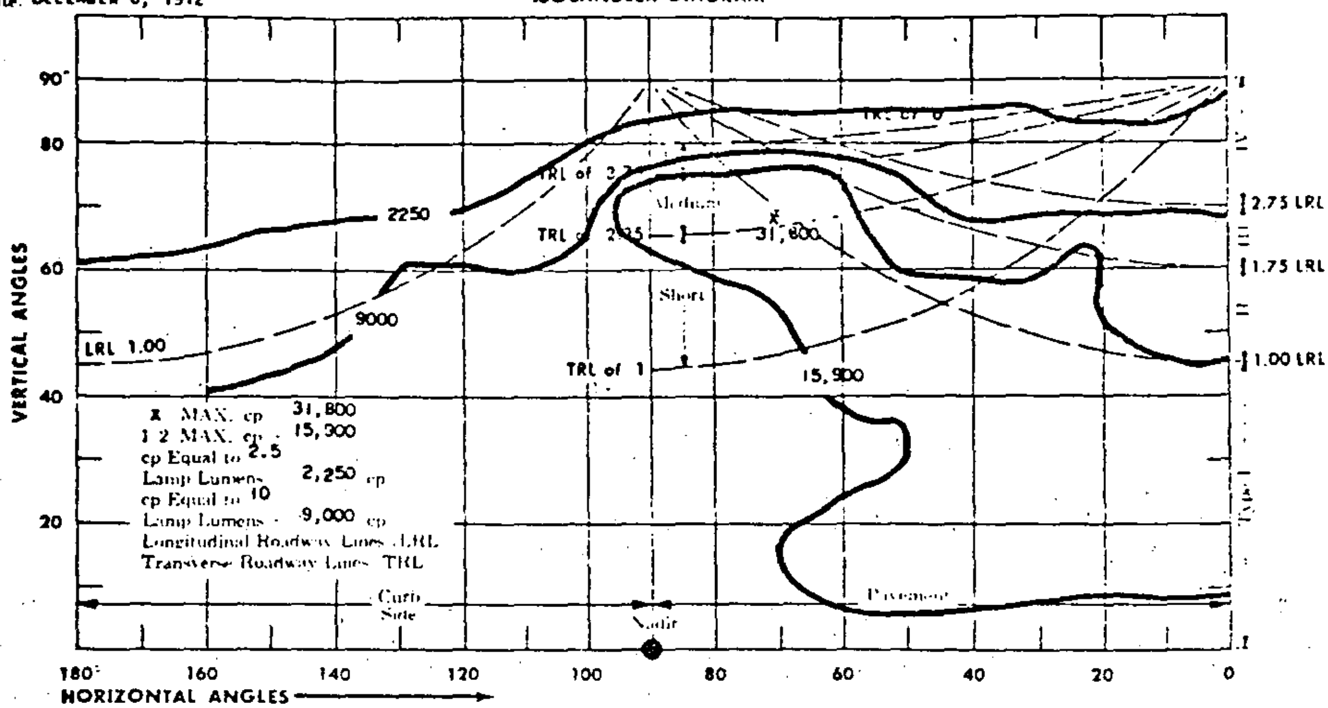
Date: December 6, 1972

212

TEST No. E373-52
Supersedes E373-16



ISOCANDELA DIAGRAM



11.8	Footcandles At Nadir

Footcandle Multiplier

Mounting Height in feet	Factor
30	1.36
31	1.27
32	1.20
33	1.13
34	1.06
35	1.00
36	0.95
37	0.89
38	0.85
39	0.81
40	0.77

Luminaire Efficiency % Bare Lamp

Direction	Pavement Side	Curb Side
Downward	46.1	21.3
Upward	1.9	1.9
Total	71.1	

Test distance 40 feet

Tested in accordance with IES recommendations for laboratory tests.

Data reproduction contingent on duplicating test conditions.

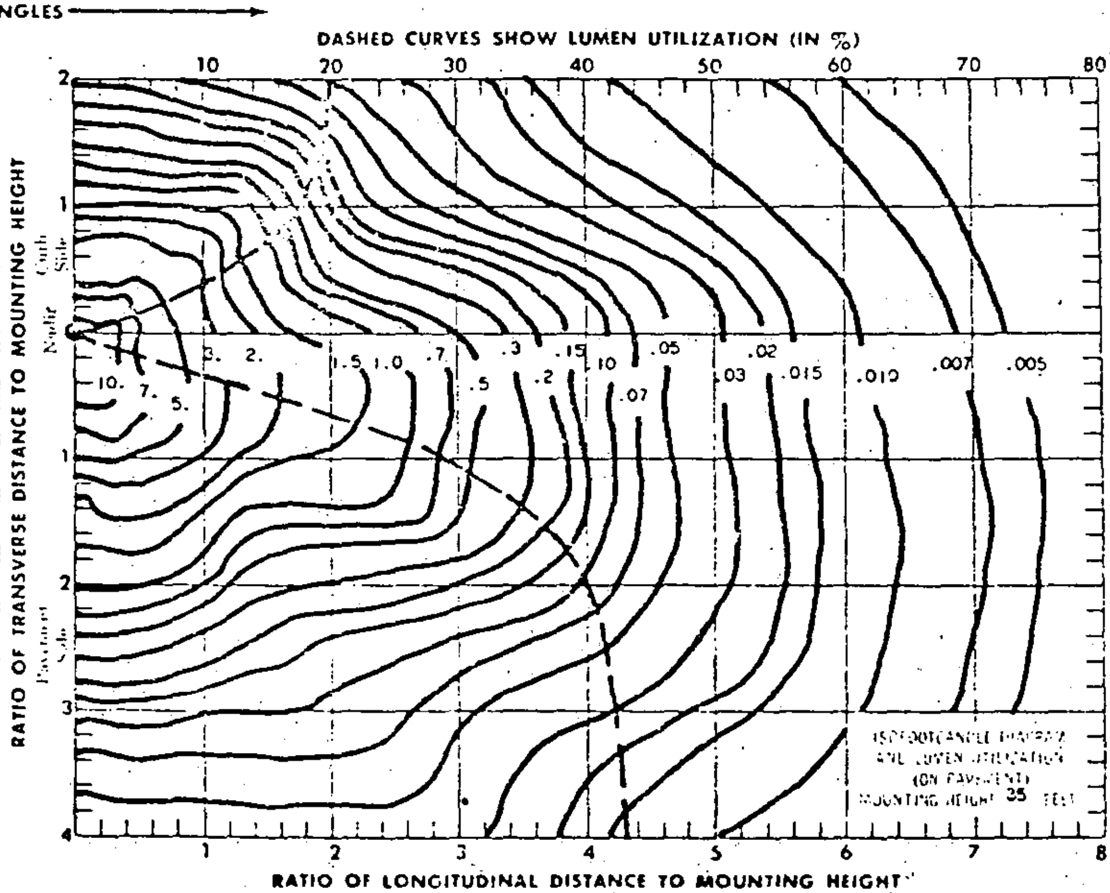


Fig. 8-16.

APPENDIX A

Answers to Problems 2 through 10

Problem 2.

- a. Opposite spacing — 154.8'
- b. Maintained footcandles at
  - Point A — 2.57
  - Point B — .71
  - Point C — 1.43
- c. Ratio average to minimum — 2.8 to 1

Problem 3.

- a. Coefficient of Utilization — .57
- b. Opposite spacing — 126.9'
- c. Maintained footcandles at
  - Point A — 2.08
  - Point B — .58
  - Point C — 1.84
- c. Ratio average to minimum — 3.52 to 1

Problem 4.

- a. Coefficient of Utilization — .47
- b. Staggered spacing — 83.6'
- c. Maintained footcandles at
  - Point A — 1.15
  - Point B — 1.17
  - Point C — 2.51
- d. Ratio — 1.72 to 1

Problem 5.

- a. Coefficient of Utilization — .351
- b. Staggered spacing — 68.8
- c. Maintained footcandles at
  - Point A — 1.3
  - Point B — 1.56
  - Point C — 1.98
- d. Ratio — 1.54 to 1

Problem 6.

- a. Coefficient of Utilization — .391
- b. Staggered spacing — 203.2'
- c. Maintained footcandles at
  - Point A — 3.48
  - Point B — .561
  - Point C — .567
- d. Ratio — 3.57 to 1

Problem 7.

a.	Determine lamp lumens depreciation (LLD)	.665
b.	Determine luminaire dirt depreciation (LDD)	.955
c.	Coefficient of Utilization	.415
d.	Staggered spacing	98.8'
e.	Maintained footcandles at	
	Point A	1.21
	Point B	1.7
	Point C	2.35
d.	Ratio	1.65 to 1

Problem 8.

a.	Coefficient of Utilization	.27
b.	Staggered spacing	70'
c.	Maintained footcandles at	
	Point A	1.33
	Point B	1.72
	Point C	2.08
d.	Ratio	1.5 to 1

Problem 9.

a.	Coefficient of Utilization	.47
b.	Staggered spacing	218'
c.	Maintained footcandles at	
	Point A	1.02
	Point B	.84
	Point C	1.14
d.	Ratio	2.27 to 1

Problem 10.

a.	Coefficient of Utilization	.335
b.	Spacing	310'
c.	Maintained footcandles at	
	Point A	3.46
	Point B	.447
	Point C	.524
	Point D	.567
d.	Ratio	4.47 to 1

Note: Where photometric data is difficult to interpret, answers within 5% of those given may be considered correct.

CIA. DE LUZ Y FUERZA DEL CENTRO S.A.
GERENCIA DE CONSTRUCCION
CALCULO DE NIVEL DE ILUMINACION

FECHA. ______________

1.– DATOS

1.1 LOCALIZACION.

Calle ______________________________

Entre ______________________________

Colonia ______________________________

Delegación ______________________________

1.2 DATOS FISICOS.

Ancho de la calle ______________

(AA) Ancho del arroyo ______________

(AB) Ancho banquetas ______________

(DIP) Distancia interpostal ______________

(AM) Altura de montaje ______________

(TA) Tipo de ambiente (Muy limpio, limpio, moderado, sucio, – muy sucio)

(TL) Tiempo de limpieza ______________

(NI) Nivel de iluminación ______________

1.3 DATOS DE LA LUMINARIA.

Marca ______________

Tipo de luminaria y/ó gráfica ______________

Gráfica fotométrica número ______________

Tipo de reflector ______________

Características de luminaria ______________

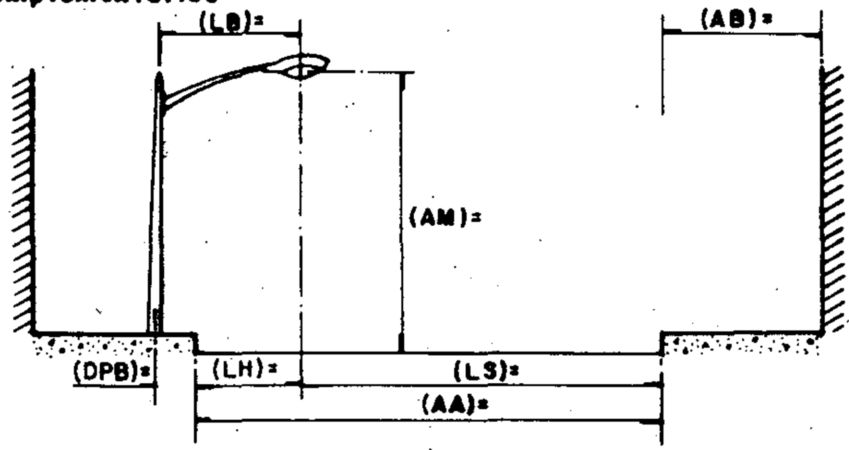
Lámpara (tipo y potencia) ______________

(LI) Lumenes iniciales de la lámpara ______________

Vida de la lampara (horas) ______________

1.4 Datos Complementarios

(AA)
(AM)
(LH)
(LS)
(AB)
(LB)
(DPB)



2.- CALCULO DEL NIVEL PROMEDIO.

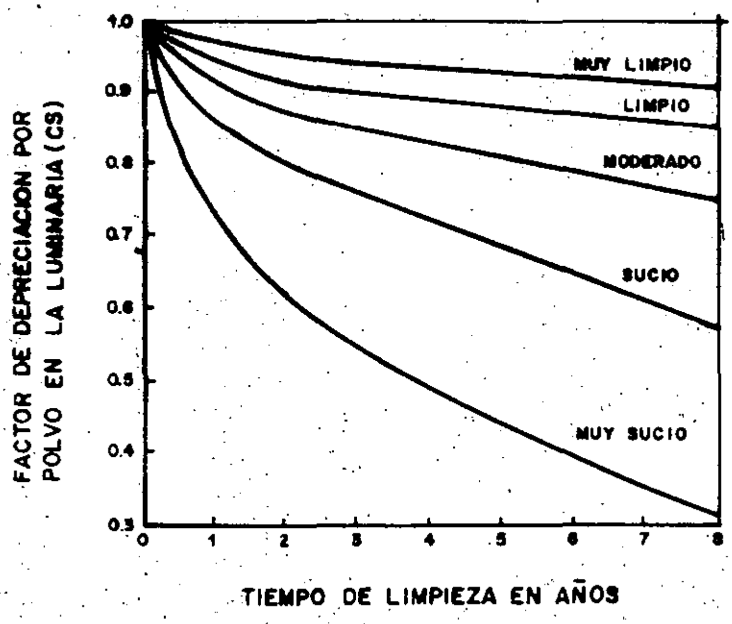
(Método de lumen)

2.1 Cálculo del factor de pérdidas totales de luz.
(FPTL)

(FD) Depreciación lumínica de la lampara al 50% de su vida (ver curvas del fabricante de lámparas) ______

(FM) Mortandad de lámparas al 50% de su vida (ver curvas del fabricante de lámparas) ______

(CS) Coeficiente de depreciación (se necesitan los datos de tipo de ambiente (TA) y tiempo de limpieza (TL) para entrar a la curva. ver inciso 1.2 ______



(FNR) FACTORES NO RECUPERABLES DE PERDIDAS DE LUZ. ______

a) Temperatura ambiente de luminario. ______

b) Voltaje de línea. ______

c) Factor de balastro. ______

d) Depreciación de la superficie del reflector. ______

(FPTL) FACTOR DE PERDIDAS TOTALES DE LUZ.

(FD) (FM) (CS) (FNR) = ______

2.2 CALCULO DEL COEFICIENTE DE UTILIZACION.

(Se calcula con la relación de la distancia del eje de la luminaria a las banquetas y la altura de montaje (AM), y las curvas de coeficiente de utilización de la luminaria).

(AM) Altura de montaje de la luminaria.

RAS = Relación de la distancia del eje de la luminaria a la banqueta opuesta/altura de montaje.

$$= \frac{(LS)}{(AM)} = \_\_\_\_\_\_ = \_\_\_\_\_\_$$

RAH = Relación de la distancia del eje de la luminaria a la banqueta adyacente/altura de montaje.

$$= \frac{(LH)}{(AM)} = \_\_\_\_\_\_ = \_\_\_\_\_\_$$

RBS = Relación de la distancia del eje de la luminaria al fin de la banqueta opuesta/altura de montaje.

$$= \frac{(LS) + (AB)}{(AM)} = \_\_\_\_\_\_ = \_\_\_\_\_\_$$

RBH = Relación de la distancia del eje de la luminaria al fin de la banqueta adyacente/altura de montaje.

$$= \frac{(LH) + (AB)}{(AM)} = \_\_\_\_\_\_ = \_\_\_\_\_\_$$

Para obtener el coeficiente de utilización se entra en la curva respectiva con el valor de las relaciones anteriores.

R A S ⟶ Curva (C U S) = ____________________

R A H ⟶ Curva (C U H) = ____________________

R B S ⟶ Curva (C U B S) = ____________________

R B H ⟶ Curva (C U B H) = ____________________

2.2.1 Coeficiente de utilización del arroyo.

(CUA) = (CUS) + (CUH) =

2.2.2 Coeficiente de utilización de banquetas

(CUB) = (CUBS) - (CUS) + (CUBH) - (CUH) = ____________________

2.3 Nivel de iluminación

2.3.1 Nivel de iluminación del arroyo

$$(NIA) = \frac{(LI) \times (FPTL) \times (CUA)}{(AA) \times (DIP)} = \_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_$$

2.3.2 Nivel de iluminación de banquetas

$$(NIB) = \frac{(LI) \times (FPTL) \times (CUB)}{(AB) \times (DIP)} = \_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_$$

2.3.3 Nivel de iluminación promedio

$$(NIP) = \frac{(NIA) + (NIB)}{2} = \_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_$$

3.— CALCULO DE NIVEL PROMEDIO

(Metodo por puntos)

3.1 Cálculo del nivel promedio por medio de la ecuación

$(EPP)\ EPP = 1/4(E5) \div 1/8(E4+E6+E8) + 1/16(E1+E3+E7+E9)$

3.1.1 Puntos utilizados en la ecuación

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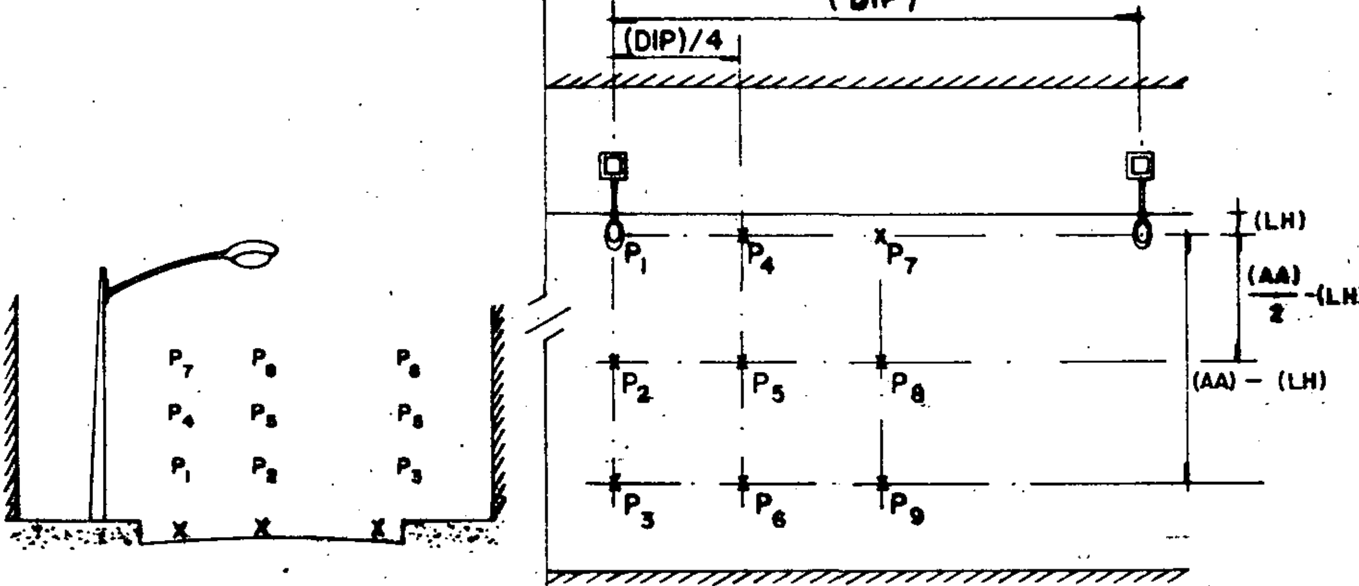
CALCULO DE NIVEL DE ILUMINACION



PERFIL PLANTA

3.2 Cálculo de relaciones.

3.2.2 Relaciones transversales para las luminarias "A" y "B"

(RTP 147) AB = 0

$$(RTP\ 258)\ AB = \frac{(AA)/2 - (LH)}{(AM)} = \_\_\_\_\_\_\_\_ \quad \_\_\_\_\_\_\_\_$$

$$(RTP\ 369)\ AB = \frac{(AA) - (LH)}{(AM)} \quad \_\_\_\_\_\_\_\_ \quad \_\_\_\_\_\_\_\_$$

3.2.3 Relaciones longitudinales para la luminaria "A"

(RLP 123) A = 0

(RLP 456) A = (DIP) / 4 (AM) = ________ ________

(RLP 789) AB = (DIP) / 2 (AM) = ________ ________

3.2.4 Relaciones longitudinales para la luminaria "B"

$$(RLP\ 123)\ B = \frac{(DIP)}{(AM)} \quad \_\_\_\_\_\_\_\_ \quad \_\_\_\_\_\_\_\_$$

$$(RLP\ 456)\ B = \frac{3\ (DIP)}{4\ (AM)} \quad \_\_\_\_\_\_\_\_ \quad \_\_\_\_\_\_\_\_$$

3.3 Calculo del factor de correccion de la grafica.
(FC)

(FL) Footcandel a luxes = 10.76

(RAM) Altura de montaje de graficas a altura de montaje de campo

$$(RAM) = \frac{(AM\ grafica)^2}{(AM)^2} = \_\_\_\_\_\_ = \_\_\_\_\_\_$$

(LL) Factor de correccion de lumenes de la grafica (1000) a lumenes de la lampara utilizada

______ ÷ (1000) ______________

(FPTL) (Ver inciso 2.1) = ______________

(FC) = (FL) x (RAM) x (LL) x (FPTL) = ______________ = ______________

3.4 Nivel de iluminacion de los puntos 1a 9 obtenidos de la grafica

3.4.1 Nivel de iluminacion de los puntos 1 a 9 debidos a la luminaria "A"

(E)	= Footcandels Lectura gráfica	x (FC) Factor de corrección	
(E 1A) =	______	______	= ______
(E 2A) =	______	______	= ______
(E 3A) =	______	______	= ______
(E 4A) =	______	______	= ______
(E 5A) =	______	______	= ______
(E 6A) =	______	______	= ______
(E 7A) =	______	______	= ______
(E 8A) =	______	______	= ______
(E 9A) =	______	______	= ______

3.4.2 Nivel de iluminacion de los puntos 1 a 9 debidos a la luminaria "B"

(E) = Footcandels x (FC) .

(E1B) ______________________ ________

(E2B) ______________________ ________

(E3B) ______________________ ________

(E4B) ______________________ ________

(E5B) ______________________ ________

(E6B) ______________________ ________

3.4.3 Cálculo del nivel promedio de los puntos considerados

E1 = (E1A) + 2(E1B)	________	x 1/16 =	________
E2 = (E2A) + 2(E2B)	________	x 1/8 =	________
E3 = (E3A) + 2(E3B)	________	x 1/16 =	________
E4 = (E4A) + (E4B)	________	x 1/8 =	________
E5 = (E5A) + (E5B)	________	x 1/4 =	________
E6 = (E6A) + (E6B)	________	x 1/8 =	________
E7 = 2(E7A)	________	x 1/16 =	________
E8 = 2(E8A)	________	x 1/8 =	________
E9 = 2(E9A)	________	x 1/16	________

(NIPP) Nivel de iluminación promedio por puntos. (Suma) = ________ Lux

4.- RESULTADOS Y CONCLUSIONES

NIPP = Nivel de iluminación promedio (Método de puntos) (inciso 3.4.3) = ______

NIP = Nivel de iluminación promedio (Método de lúmen) (inciso 2.3.3) = ______

NIPPI = Nivel de iluminación inicial

$= \frac{NIPP}{(FPTL)}$ (ver inciso 2.1) ______ = ______

Emín = Nivel de iluminación del punto de menor intensidad (ver inciso 3.4.3) ______

Emáx = Nivel de iluminación del punto de mayor intensidad (ver inciso 3.4.3) ______

Relación de uniformidad de promedio a mínima $\frac{NIPP}{Emín}$ = ______ = ______

Relación de uniformidad de promedio a máxima $\frac{NIPP}{Emáx}$ = ______ = ______

Relación de uniformidad de máxima a mínima $\frac{Emáx}{Emín}$ = ______ = ______

Anexos

Gráfica fotométrica de la luminaria.

Fecha ______________________

CALCULO ______________________
Nombre y Firma

ALUMBRADO DE AREAS

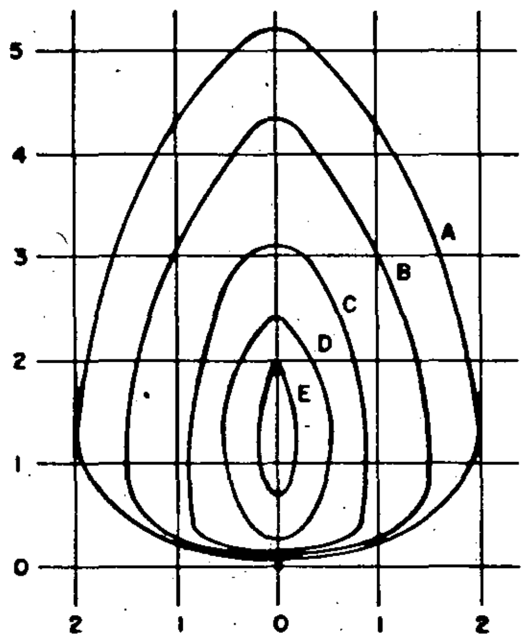
Designacion de los Proyectores.

Los proyectores son designados por su tipo y potencia de lámpara utilizada así como por su distribución de luz y apertura del haz. La apertura del haz puede darse en grados ó por el tipo NEMA (ver tabla 1). La abertura del haz se basa en el ángulo a cualquier lado del eje del punto de enfoque donde las candelas tienen un valor del 10% de su máximo valor. El tipo NEMA solo debe usarse como una referencia. Este no describe la forma y patrón de luz que produce un proyector ni tampoco proporciona el nivel de iluminancia (lux). Los proyectores simétricos tienen la misma abertura del haz tanto horizontal como vertical y son clasificados con un número NEMA. Las aberturas de haz asimétricas tienen una designación horizontal y una vertical. El valor horizontal siempre se da primero.

DESIGNACION DE LUMINARIOS TIPO PROYECTOR PARA EXTERIORES	
ABERTURA DEL HAZ EN GRADOS	TIPO NEMA
10 a 18	1
18 a 29	2
29 a 46	3
46 a 70	4
70 a 100	5
100 a 130	6
130 ó mas	7

DIAGRAMA ISOLUX;

Las dimensiones para los diagramas isolux están basadas en la altura de montaje de los luminarios. La forma de los diagramas isolux no cambia con las diferentes alturas de montaje por lo que solo se requiere un diagrama por cada punto de enfoque. El punto de enfoque (▲) también está basado en la altura de montaje.



PUNTO DE ENFOQUE AMx2

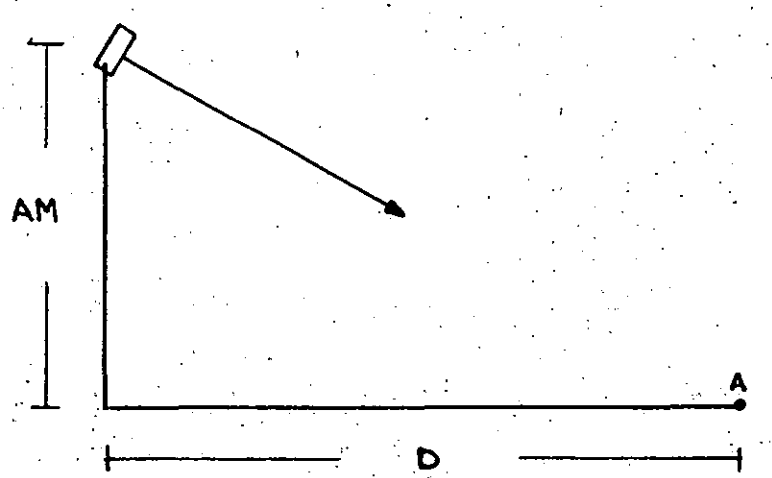
En este ejemplo (punto de enfoque = 2 x AM) el proyector está enfocado a una distancia de 2 veces la altura de montaje desde un punto en el piso directamente abajo del proyector. Esta distancia podría ser de 24 metros para una altura de montaje de 12 metros. Cada línea isolux muestra los lugares donde el nivel de iluminación es el mismo. Cuando el punto del cual se desea conocer su iluminación queda entre dos líneas isolux, se puede interpolar para obtener su valor. La retícula tambien está basada en la altura de montaje.

Los valores de las líneas de la retícula a la izquierda y a la derecha dan la distancia a cada lado del proyector.

Los valores hacia arriba de cada uno de los lados tambien muestran la distancia en la dirección del enfoque del proyector. El número 5, por ejemplo, representa 5 x 12 ó 60 metros para una altura de montaje de 12 metros. Para instalaciones complejas los diagramas isolux puedan redibujarse a la misma escala de los dibujos de trabajo.

ILUMINACION VERTICAL.

El diseño con diagramas isolux también puede usarse para determinar el nivel de iluminación vertical. La relación entre los valores de iluminación vertical y horizontal es la misma relación entre la distancia horizontal del proyector al punto y la altura de montaje (AM). Para un punto a una distancia de 2 veces la altura de montaje, el nivel de iluminación vertical es dos veces mayor que el horizontal.



EN EL PUNTO A

$$\text{LUX (VERT)} = \text{LUX (HOR)}\left(\frac{D}{AM}\right)$$

Esto es útil para áreas muy grandes que requieren distancias de proyección de 4 ó 5 veces la altura de montaje. En estas aplicaciones los Lux horizontales serán muy bajos al final del área pero la iluminación vertical será 4 ó 5 veces mayor.

VALORES ISOLUX.

Para convertir los valores isolux a otras alturas de montaje (AM) se utiliza la siguiente fórmula:

$$(LX)\ (AM^2) = (LX)\ (AM^2)$$

VALORES DEL DIAG. NUEVOS VALORES

Por ejemplo, para un nivel de 50 Lux a 15 metros, se tendría un valor de 28 lux a 20 metros.

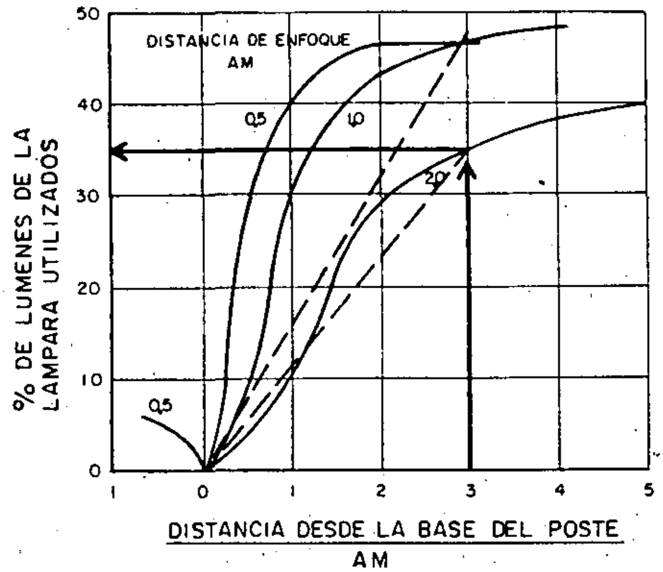
$$(50)\ (15^2) = (LX)\ (20^2)$$

$$LX = (50)\ (225/400) = 28$$

MAXIMO VALOR ISOLUX.

Las líneas isolux del centro de la gráfica dan el valor máximo de iluminación que proporciona el proyector a un punto de enfoque particular y una altura de montaje. Para obtener buena uniformidad este valor no debe ser mayor a tres veces el nivel inicial promedio de iluminación. Se pueden obtener valores mayores, pero daría como resultado puntos calientes cerca de los proyectores y menores niveles de luz alrededor.

COEFICIENTE DE UTILIZACION



Las curvas en la gráfica anterior proporcionan el porcentaje de los lúmenes iniciales de la lámpara que alcanzan un área adelante de la base de la localización del proyector.

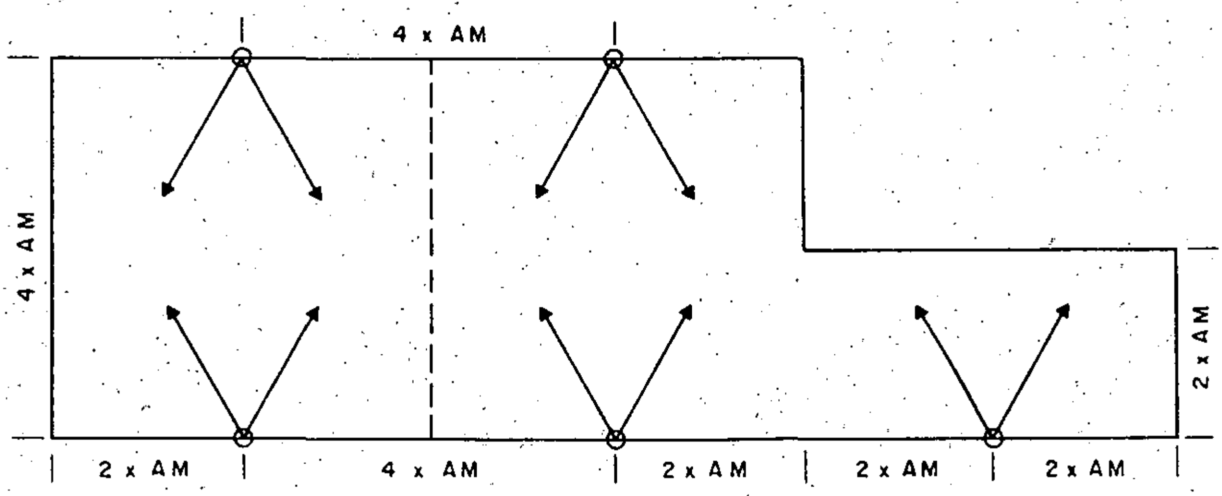
El número al lado de cada curva identifica el punto de enfoque por lo que la curva de utilización puede ser identificada con el diagrama isolux asociado. En las curvas mostradas anteriormente, por ejemplo, el proyector enfocado a 2 veces la altura de montaje desde el poste, tendrá una utilización de 35% si este estuviera alumbrando un área de 3 alturas de montaje de ancho. El mismo proyector enfocado a una vez la altrua de montaje desde el poste tendría una utilización de 45% para la misma área.

La selección del punto de enfoque apropiado se basa tanto en la uniformidad como en la utilización. La mejor uniformidad se obtiene cuando la luz es igualmente distribuida en toda el área. Una curva de utilización que diera este efecto sería una línea recta, como las indicadas en la figura con línea punteada. En este ejemplo, la curva para el punto de enfoque a dos veces la altura de montaje proporciona un 10% de los lúmenes en la zona de 0 a 1 vez la altura de montaje, un 20% adicional en la zona de la 2 veces la altura de montaje y un 5% en la zona de 2 a 3 veces la altura de montaje. Para el enfoque a una vez la altura de montaje (AM) se proporciona 30% en la zona 0 a 1 veces AM, 15% para la 2 AM y 2 a 3% para 2 a 3 AM. El enfoque a 2 veces AM proporcionará mejor uniformidad.

El seleccionar el enfoque adecuado requiere algo de conocimiento de las necesidades de la aplicación particular.

Como una regla los proyectores se enfocan a 2/3 o 3/4 de distancia transversal del área iluminada. También se requiere hacer algunos ajustes en el campo para producir los mejores resultados.

Localización de proyectores y alturas de montaje.



Un proyector puede iluminar adecuadamente un área de hasta 2 veces su altura de montaje por lado. Para separar más los postes se requiere aumentar el ángulo de enfoque, dando como resultado una menor utilización y un aumento de deslumbramiento debido al equipo. Con las separaciones mostradas en la figura anterior, habrá suficiente traslape entre los proyectores adyacentes lo cual asegura una iluminación uniforme y sombras reducidas

FACTOR DE PERDIDA DE LUZ PARA PROYECTORES DE ALUMBRADO EXTERIOR

En el diseño de una instalación de alumbrado calculada para proporcionar valores específicos de iluminación, utilizando una cantidad dada de luminarios, es necesario suponer (asumir) factores específicos de pérdida de luz así como eficiencias mínimas. Para los cálculos del diseño de iluminación se recomienda utilizar luminarios que cumplan con las normas NEMA, lo cual permite utilizar los factores de pérdida de luz normalizados de 75% del valor inicial para luminarios cerrados y del 65% para luminarios abiertos.

CALCULOS DE ILUMINACION EXTERIOR

Introducción (a) El método de cálcular el nivel de lux que se pueden esperar de cualquier arreglo y número de proyectores requeridos para producir un nivel dado, es más complicado que el cálculo de iluminación interior. Esto es debido a que hay muchos factores variables, tales como la distancia del área de juego a los luminarios, la altura de montaje y el enfoque de los luminarios.

7 a

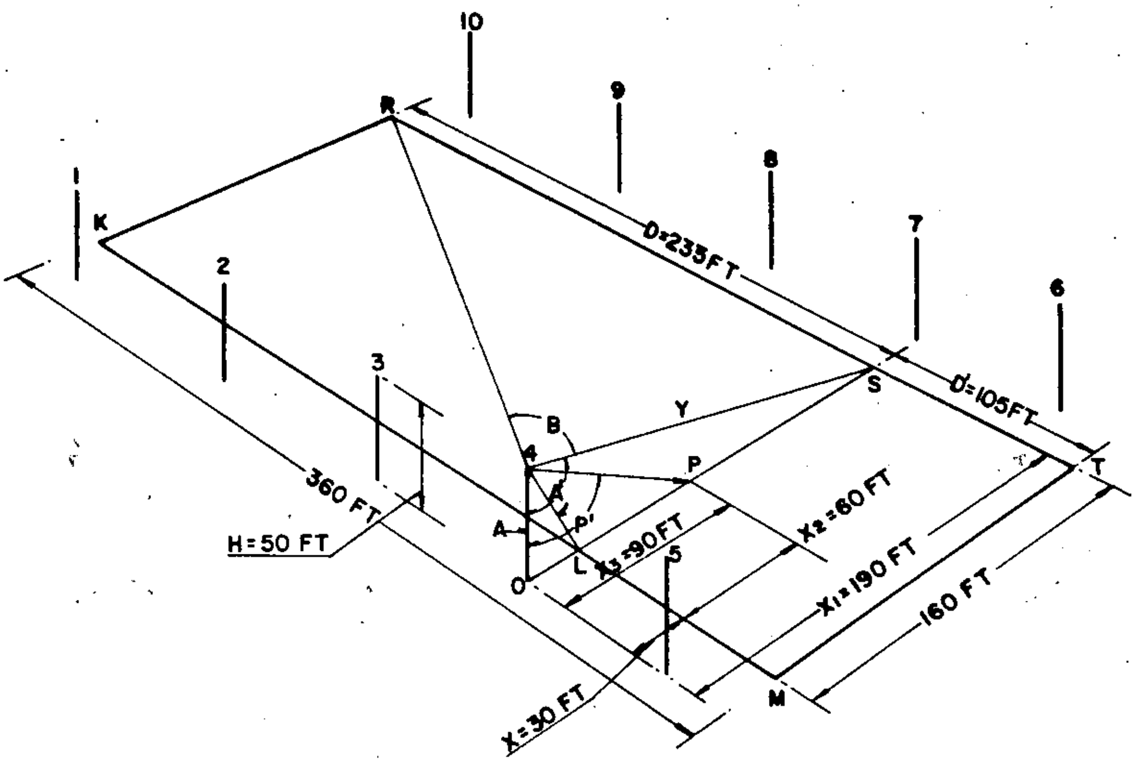


FIGURA C-1 CAMPO DE FOOT BALL ILUMINADO EN FORMA TIPICA, UTILIZADO PARA EL EJEMPLO DE CALCULO DE LUX PROMEDIO HORIZONTALES.

Algunos métodos aproximados de cálculo han sido desarrollados y estan a disponibilidad con los fabricantes de equipo de iluminación.

El método más exacto de calcular el nivel en lux producido por una instalación de alumbrado se reproduce en la figura C-1. Este método involucra el uso de curvas de distribución de luz del tipo isocandela en las cuales el área es dibujada alrededor del eje del haz.

Para propósitos de cálculo, dependiendo de la exactitud requerida, deben seleccionarse uno ó más patrones representativos de haces de luz para cada uno de los postes donde puedan variar las utilizaciones.

El método de cálculo consiste en dibujar el área a ser iluminada en la curva fotométrica para luego sumar los lumenes contenidos dentro del área. El número de lúmenes dividido por el área en metros cuadrados da como resultado la iluminación promedio proporcionada por la unidad en lux.

Ejemplo de cálculo. Un ejemplo de un área típica a ser iluminada se da en la figura C-1. El problema es obtener el perímetro del área en términos de los grados laterales y verticales y transferirlos a la curva isocandela de la figura C-2.

Para simplificar el problema, el eje vertical del haz del proyector se considera perpendicular a los lados del área, decir, un plano vertical a través del eje del proyector es perpendicular a la línea KLM de la figura C-1. Los dos lados del área, KM y RT, aparecerán en la curva isocandela como líneas rectas paralelas al eje horizontal del haz. Por lo que solo es necesario calcular los ángulos verticales A y A' que se forman entre el poste y los lados del área a iluminar y relacionarlos con el ángulo de enfoque P', el cual es el punto de cero-cero grados en la curva isocandela, con objeto de dibujar los lados en la curva. Las extremidades de estas líneas, puntos K,M,R y T, deben encontrarse obteniendo el ángulo lateral B en el plano que pasa a través del proyector y el lado del campo en el cual se localiza el punto. El contorno de los lados KR o MT se encuentra asumiendo un número de puntos en la línea y encontrando sus correspondientes ángulos lateral y vertical. Los ángulos verticales A, A' y P' se obtienen del nomograma mostrado en la figura C-3. Los ángulos laterales B se encuentran en la figura C-4. El procedimiento exacto es el siguiente:

1).- Refiriendonos a la figura C-3. Se coloca una regla con un extremo en la distancia X (30 pies ó 9.1 metros) y otro extremo coincidiendo con la altura de montaje H (50 pies ó 15.2 metros). En el centro de la figura se lee el ángulo vertical A entre el poste y el rayo de luz que incide en el lado cercano del campo de juego (31°). De la misma manera, usando H=15.2 metros (50 pies) y X_1= 57.9 metros (190 pies), se encuentra el ángulo vertical A' correspondiente al lado mas alejado del campo (75.2°). El ángulo P' es 61° (H=15.2 metros, X=27.4 metros).

2.- Refiriendonos a la figura C-2. La localización de área en la curva isocandela depende del ángulo el cual esta enfocado el proyector, es decir el ángulo de enfoque P' . Debido a que el punto de enfoque es el punto de cero-cero grados de la gráfica, el lado más cercano del campo será dibujado en la gráfica a 61° - 31° = 30° abajo de la línea horizontal de cero grados y el lado lejano a 75.2° - 61° = 14.2° arriba de la línea horizontal de cero grados. Las líneas horizontales que representan los lados cercano y lejano pueden dibujarse en la gráfica (fig. C-2) con los anteriores ángulos verticales.

3.- Para determinar el punto R nos referimos a la figura C-4. Colocamos una regla con un extremo en la altura de montaje H= 15.2 metros (50 pies) y el otro en el ángulo vertical A' = 75.2° y leemos en la columna Y=59.7 metros (196 pies). Ahora unimos el punto Y=59.7 metros con la distancia lateral D=77.7 metros (255 pies) y leemos el ángulo lateral B=52.5°. Dibujamos este punto en la línea horizontal superior. De la misma forma, encontramos el punto K utilizando A=31° y D=77.7 metros (255 pies). Los puntos M y T se encuentran usando los mismos ángulos verticales con que se encontró K y R respectivamente, y D' = 32 metros (105 pies).

4.- Ahora ya tenemos localizadas las cuatro esquinas del área, pero dos de los lados no aparecen como líneas rectas, por lo que es necesario dibujar suficientes puntos para determinar la curvatura. Los primeros puntos en determinarse son los que se encuentran en el eje de 0°. El ángulo vertical para usarse en la figura C-4 es 61°. Con este ángulo y la distancia D=77.7 metros al punto del lado izquierdo se obtiene un ángulo lateral de 68°, para el punto del lado derecho se tiene una distancia D' = 32 metros (105 pies) y se obtiene un ángulo de 45.5°. Se deben determinar al menos otros dos puntos para cada lado una arriba y uno abajo del eje de cero grados. Estos puntos pueden encontrarse considerando ángulos verticales de +7° y -7° arriba y abajo del eje. Con estos puntos dibujados en el diagrama, ya se puede dibujar el contorno del campo.

c).- Con el campo dibujado en la gráfica, se suman los lumenes que quedan dentro del campo, estimando la proporción de lúmenes que quedan de las zonas no incluidos totalmente. En la tabla C-1 se muestran tabulados estos valores.

d).- Volviendo a la figura C-2 se puede notar que aunque los cálculos se hicieron para el poste No. 4 los mismos resultados se pueden utilizar para los postes 2,9 y 7. Por lo que solo es necesario hacer dos cálculos más (postes 3 y 8 y postes 1,5,6 y 10).

e).- Puede suceder que se logre obtener un mejor factor de utilización enfocando el proyector a un ángulo diferente. Esto puede determinarse rápidamente estudiando la suma de lúmenes en las zonas laterales, dados a un lado de la gráfica isocandela. Se puede corregir el ángulo de enfoque subiendo o bajando el área entera en la gráfica.

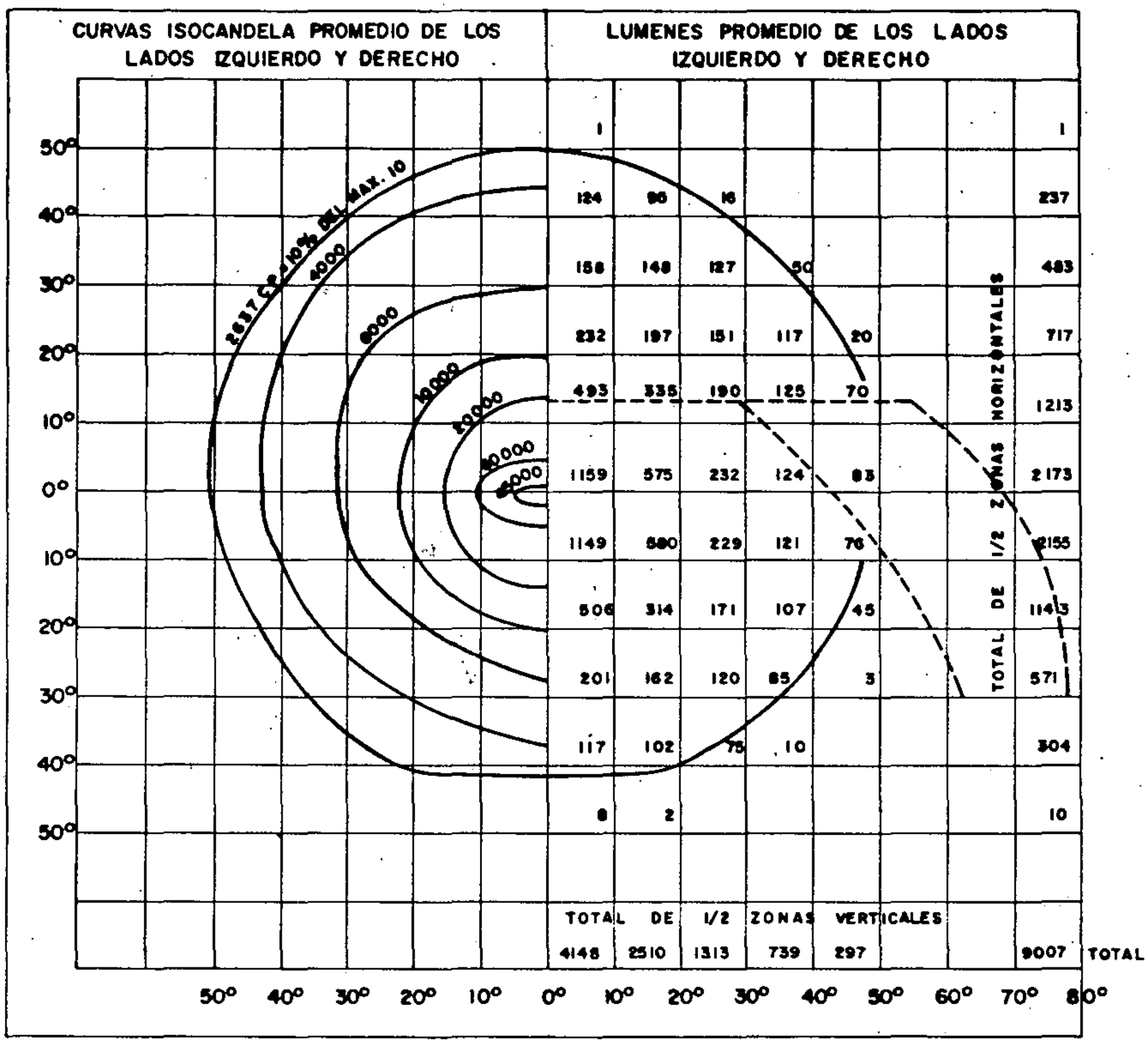


FIGURA C-2 CURVA ISOCANDELA

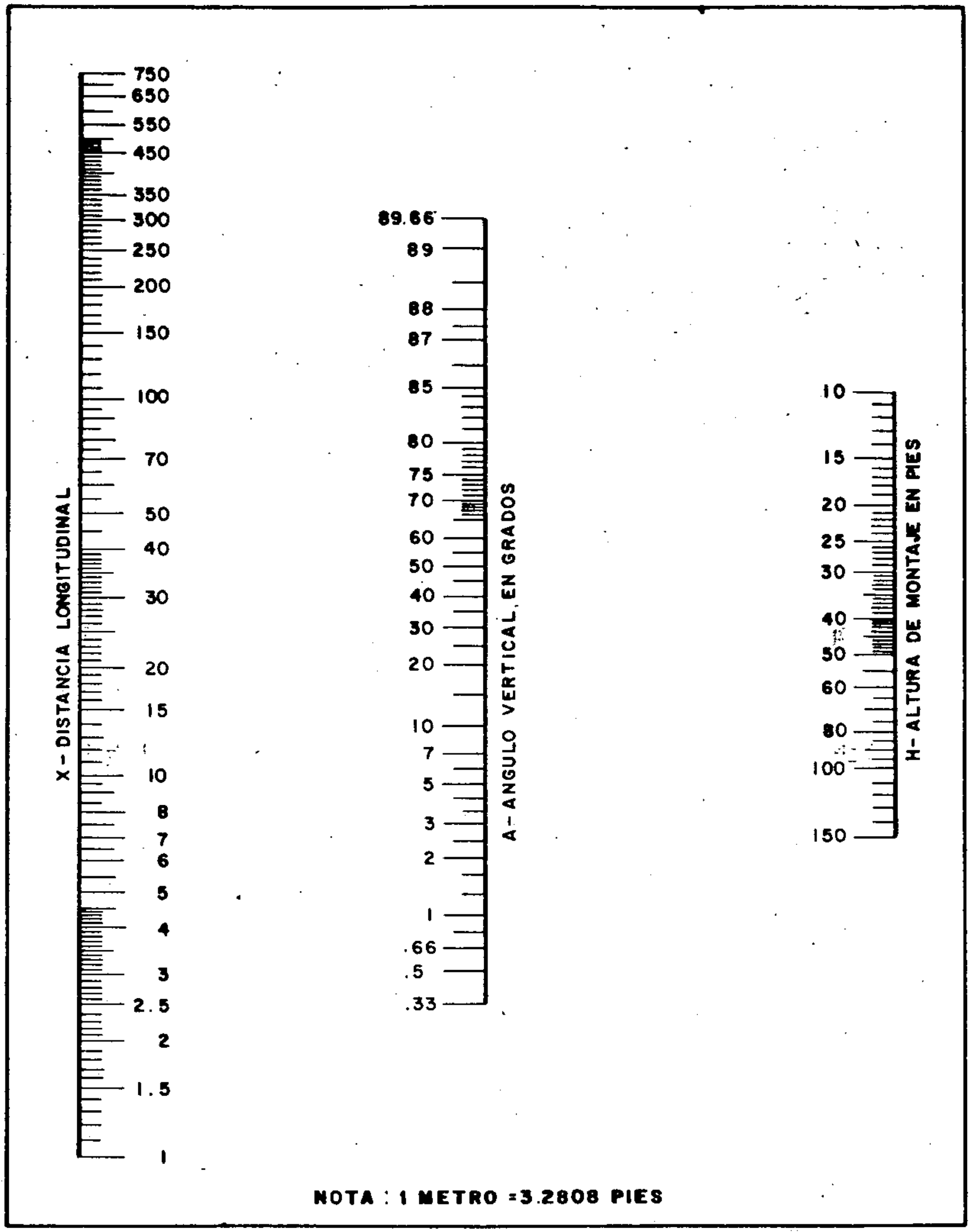


FIGURA C-3 NOMOGRAMA PARA DETERMINAR EL ANGULO VERTICAL (ANGULO A DE LA FIG. C-1) EN TERMINOS DE LA DISTANCIA LONGITUDINAL "X" Y LA ALTURA DE MONTAJE H.

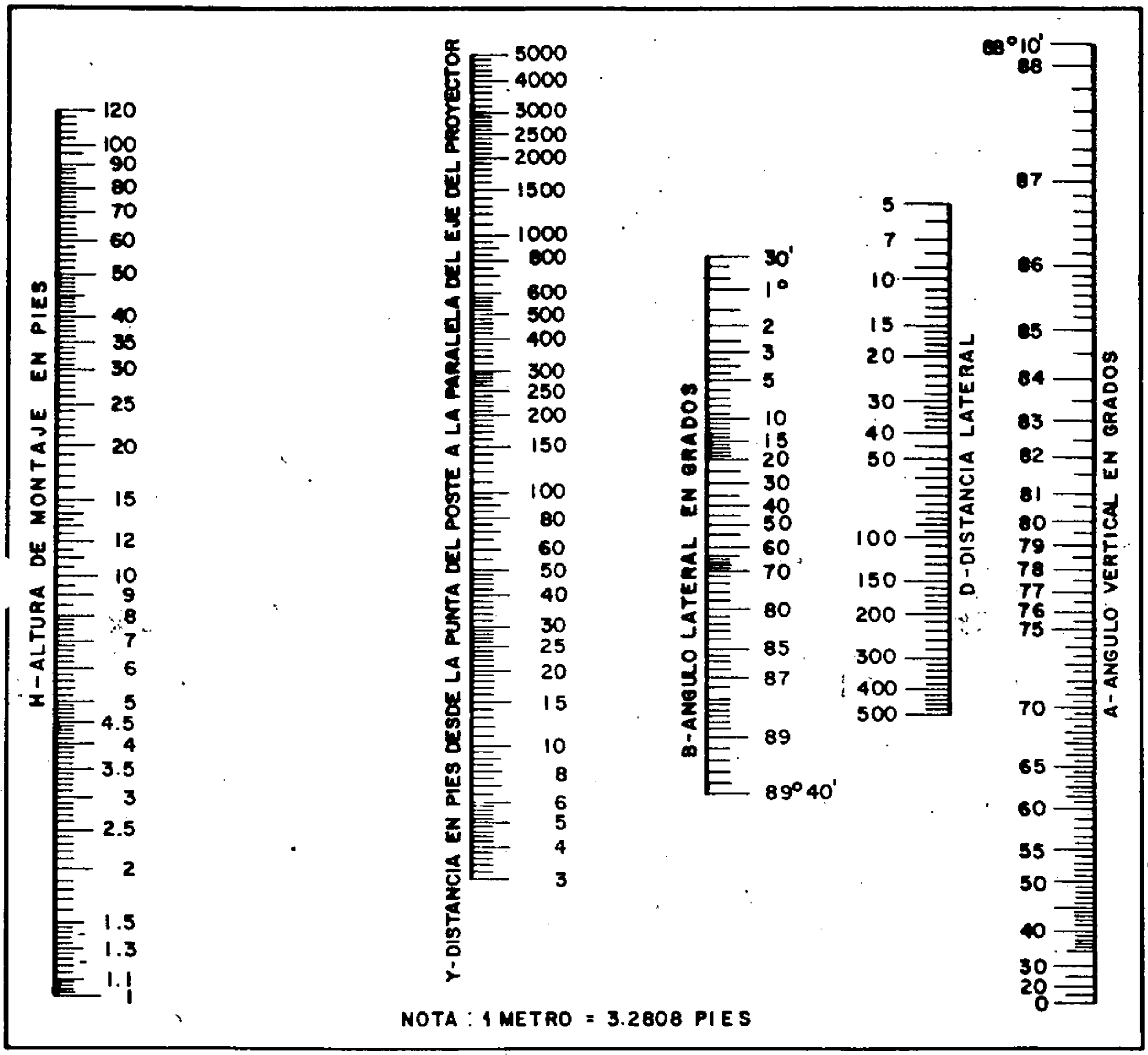


FIGURA C-4 NOMOGRAMA PARA DETERMINAR EL ANGULO LATERAL EN TERMINOS DEL ANGULO VERTICAL A LA ALTURA DE MONTAJE H Y LAS DISTANCIAS Y y D.

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CURSOS ABIERTOS

ILUMINACION EXTERIOR:
PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

ILUMINACION CON SUPERPOSTES

ING. CARLOS GARCIA ROMERO

PALACIO DE MINERIA

Table B2. r-Table for standard surface R2.*†

β tan γ	0	2	5	10	15	20	25	30	35	40	45	60	75	90	105	120	135	150	165	180
0	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390
0.25	411	411	411	411	411	411	411	411	411	411	379	368	357	357	346	346	346	335	335	335
0.5	411	411	411	411	403	403	384	379	370	346	325	303	281	281	271	271	271	260	260	260
0.75	379	379	379	368	357	346	325	303	281	260	238	216	206	206	206	206	206	206	206	206
1	335	335	335	325	292	291	260	238	216	195	173	152	152	152	152	152	141	141	141	141
1.25	303	303	292	271	238	206	184	152	130	119	108	100	103	106	108	108	114	114	119	119
1.5	271	271	260	227	179	152	141	119	108	93	80	76	76	80	84	87	89	91	93	95
1.75	249	238	227	195	152	124	106	91	78	67	61	52	54	58	63	67	69	71	73	74
2	227	216	195	152	117	95	80	67	61	52	45	40	41	45	49	52	54	56	57	58
2.5	195	190	146	110	74	58	48	40	35	30	27	24	26	28	30	33	35	38	40	41
3	160	155	115	67	43	33	26	21	18	17	16	16	17	17	18	21	22	24	26	27
3.5	146	131	87	41	25	18	15	13	12	11	11	11	11	11	12	14	15	17	18	21
4	132	113	67	27	15	12	10	9.4	8.7	8.2	7.9	7.6	7.9	8.7	9.6	11	12	13	15	17
4.5	118	95	50	20	12	8.9	7.4	6.6	6.3	6.1	5.7	5.6	5.8	6.3	7.1	8.4	10	12	13	14
5	106	81	38	14	8.2	6.3	5.4	5.0	4.8	4.7	4.5	4.4	4.8	5.2	6.2	7.4	8.5	9.5	10	11
5.5	96	69	29	11	6.3	5.1	4.4	4.1	3.9	3.8										
6	87	58	22	8.0	5.0	3.9	3.5	3.4	3.2											
6.5	76	50	17	6.1	3.8	3.1	2.8	2.7												
7	71	43	14	4.9	3.1	2.5	2.3	2.2												
7.5	67	38	12	4.1	2.6	2.1	1.9													
8	63	33	10	3.4	2.2	1.8	1.7													
8.5	58	28	8.7	2.9	1.9	1.6	1.5													
9	55	25	7.4	2.5	1.7	1.4														
9.5	52	23	6.5	2.2	1.5	1.3														
10	49	21	5.6	1.9	1.4	1.2														
10.5	47	18	5.0	1.7	1.3	1.2														
11	44	16	4.4	1.6	1.2	1.1														
11.5	42	14	4.0	1.5	1.1															
12	41	13	3.6	1.4	1.1															

Q0 = 0.07; S1 = 0.58; S2 = 1.80

*All values have been multiplied by 10,000. For angles, see Fig. B1.
†Adapted from reference 37.

Table 3. Recommended maintained illuminance design levels for high mast lighting.*†

Road Classification	Horizontal Illuminance (E_{avg}) in Lux Commercial Area	Intermediate Area	Residential Area
Freeways	6	6	6
Expressways	10	8	6
Major	12	9	6
Collector	8	6	6

*Recommended uniformity of illumination is 3 to 1 or better; average-to-minimum for all road classifications at the illuminance levels recommended above.

†These design values apply only to the travelled portions of the roadway. Interchange roadways are treated individually for purposes of uniformity and illuminance level analysis.

B5. Calculation procedure for high mast interchange lighting

B5.1 Introduction. The computation of roadway luminance as previously described in this Appendix is not applicable for area lighting with high mast equipment. The reason for this is lack of applicable experience either in this country or overseas in the design of such lighting on a luminance basis or in consideration of pavement reflectance values. Past experience has indicated that a system designed to an illuminance criteria meeting the values in Table 3 of this Standard Practice will give satisfactory results.

High mast interchange lighting is defined as the lighting of a large area by means of a group of luminaires that are designed to be mounted in a fixed orientation (usually level) at the top of a high mast (generally 20 meters or higher). The area will normally contain a group of roadways such as an interchange or parking lots. (This procedure is not applicable for luminaires with both vertical and horizontal adjustments to be made on site, which is termed floodlighting.)

The high mast computation procedure will indicate an approximate number of luminaires per pole and pole spacing to provide the intended average illuminance and uniformity over the area in question. Specific locations for the poles are then determined to insure that all locations on the individual roadways within the area receive illuminance levels at least as high as the minimum value required to meet the uniformity criteria. There are a number of methods for computing high mast interchange lighting sys-

Table B3. r-Table for standard surface R3.*†

6 tan Y	0	2	5	10	15	20	25	30	35	40	45	60	75	90	105	120	135	150	165	180
0	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294
0.25	326	326	321	321	317	312	308	308	303	298	294	280	271	262	258	253	249	244	240	240
0.5	344	344	339	339	326	317	308	298	289	276	262	235	217	204	199	199	199	199	194	194
0.75	357	353	353	339	321	303	285	267	244	222	204	176	158	149	149	149	145	136	136	140
1	362	362	352	326	276	249	226	204	181	158	140	118	104	100	100	100	100	100	100	100
1.25	357	357	348	298	244	208	176	154	136	118	104	83	73	70	71	74	77	77	77	78
1.5	353	348	326	267	217	176	145	117	100	86	78	72	60	57	58	60	60	60	61	62
1.75	339	335	303	231	172	127	104	89	79	70	62	51	45	44	45	46	45	45	46	47
2	326	321	280	190	136	100	82	71	62	54	48	39	34	34	34	35	36	36	37	36
2.5	289	280	222	127	86	65	54	44	38	34	25	23	22	23	24	24	24	24	24	25
3	253	235	163	85	53	38	31	25	23	20	18	15	15	14	15	15	16	16	17	17
3.5	217	194	122	60	35	25	22	19	16	15	13	9.9	9.0	9.0	9.9	11	11	12	12	13
4	190	163	90	43	26	20	16	14	12	9.9	9.0	7.4	7.0	7.1	7.5	8.3	8.7	9.0	9.0	9.9
4.5	163	136	73	31	20	15	12	9.9	9.0	8.3	7.7	5.4	4.8	4.9	5.4	6.1	7.0	7.7	8.3	8.5
5	145	109	60	24	16	12	9.0	8.2	7.7	6.8	6.1	4.3	3.2	3.3	3.7	4.3	5.2	6.5	6.9	7.1
5.5	127	94	47	18	14	9.9	7.7	6.9	6.1	5.7										
6	113	77	36	15	11	9.0	8.0	6.5	5.1											
6.5	104	68	30	11	8.3	6.4	5.1	4.3												
7	95	60	24	8.5	6.4	5.1	4.3	3.4												
7.5	87	53	21	7.1	5.3	4.4	3.6													
8	83	47	17	6.1	4.4	3.6	3.1													
8.5	78	42	15	5.2	3.7	3.1	2.6													
9	73	38	12	4.3	3.2	2.4														
9.5	69	34	9.9	3.8	3.5	2.2														
10	65	32	9.0	3.3	2.4	2.0														
10.5	62	29	8.0	3.0	2.1	1.9														
11	59	26	7.1	2.6	1.9	1.8														
11.5	56	24	6.3	2.4	1.8															
12	53	22	5.6	2.1	1.8															

Q0 = 0.07; S1 = 1.11; S2 = 2.38

*All values have been multiplied by 10,000. For angles, see Fig. B1.
†Adapted from reference 37.

tems. Two basic procedures are described as follows:

(1) *Method A* utilizes curves similar to those illustrated in Figures B8 and B9 as aids in calculating initial trial values of luminaire quantities and pole spacing. These curves may be computed by the luminaire manufacturer.

(2) *Method B* does not require the availability of these curves, but utilizes an assumed spacing ratio as a starting point for determining the initial trial values.

After the trial values have been determined by either method, the exact placement of poles and luminaires are determined.

The general procedure for determining maintained illuminance includes the steps described in Section B3. It is important that these be followed and the various factors determined before proceeding with the special computations.

B5.2 Initial considerations. Determine the outline of the area to be lighted and select a tentative pole height. This height may be limited by soil conditions, maintenance concerns, grade differences, or other special factors. Select a tentative luminaire and lamp type.

B5.2.1 Method A.

(*1*) Calculate the area ratio (AR) by the for-

Figure B8. Example of CU (Coefficient of Utilization) versus AR (Area Ratio) curve.

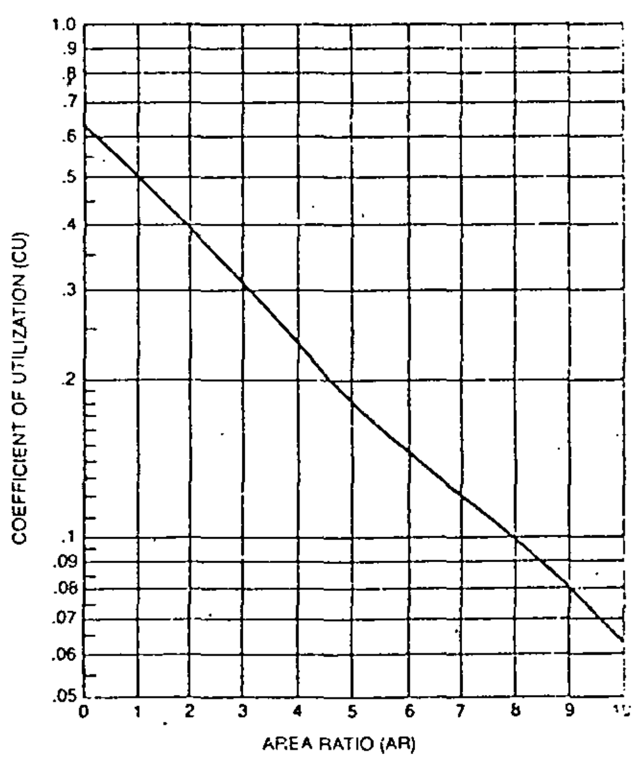


Table B4. r-Table for standard surface R4.*†

θ / tan γ	0	2	5	10	15	20	25	30	35	40	45	60	75	90	105	120	135	150	165	180
0	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	254	264	264	264
0.25	297	317	317	317	317	310	304	290	284	277	271	244	231	224	224	218	218	211	211	211
0.5	330	343	343	343	330	310	297	284	277	264	251	218	198	185	178	172	172	165	165	165
0.75	376	383	370	350	330	304	277	251	231	211	198	165	139	132	132	125	125	125	119	119
1	396	396	395	330	290	251	218	198	185	165	145	112	86	86	86	86	86	87	67	87
1.25	403	409	370	310	251	211	178	152	132	115	103	77	66	65	65	63	65	66	67	68
1.5	409	396	356	284	218	172	139	115	100	88	79	61	50	50	50	50	52	55	55	55
1.75	409	396	343	251	178	139	108	88	75	66	59	44	37	37	37	38	40	41	42	45
2	409	383	317	224	145	106	86	71	59	53	45	33	29	29	29	30	32	33	34	37
2.5	396	356	264	152	100	73	55	45	37	32	28	21	20	20	20	21	22	24	25	26
3	370	304	211	95	63	44	30	25	21	17	16	13	12	12	13	13	15	16	17	19
3.5	343	271	165	63	40	26	19	15	13	12	11	9.8	9.1	8.8	8.8	9.4	11	12	13	15
4	317	238	132	45	24	16	13	11	9.6	9.0	8.4	7.5	7.4	7.4	7.5	7.9	8.6	9.4	11	12
4.5	297	211	106	33	17	11	9.2	7.9	7.3	6.6	6.3	6.1	6.1	6.2	6.5	6.7	7.1	7.7	8.7	9.6
5	277	185	79	24	13	8.3	7.0	6.3	5.7	5.1	5.0	5.0	5.1	5.4	5.5	5.8	6.1	6.3	6.9	7.7
5.5	257	161	59	19	9.9	7.1	5.7	5.0	4.6	4.2										
6	244	140	46	13	7.7	5.7	4.8	4.1	3.8											
6.5	231	122	37	11	5.9	4.6	3.7	3.2												
7	218	106	32	9.0	5.0	3.8	3.2	2.6												
7.5	205	94	26	7.5	4.4	3.3	2.8													
8	193	82	22	6.3	3.7	2.9	2.4													
8.5	184	74	19	5.3	3.2	2.5	2.1													
9	174	66	16	4.6	2.8	2.1														
9.5	169	59	13	4.1	2.5	2.0														
10	164	53	12	3.7	2.2	1.7														
10.5	158	49	11	3.3	2.1	1.7														
11	153	45	9.5	3.0	2.0	1.7														
11.5	149	41	8.4	2.6	1.7															
12	145	37	7.7	2.5	1.7															

Q0 = 0.08; S1 = 1.55; S2 = 3.03

*All values have been multiplied by 10,000. For angles, see Fig. B1.
†Adapted from reference 37.

mula:

$$AR = \frac{2.5 \times \text{Pole Height} \times \text{Perimeter of Area}}{\text{Area}}$$

(2) Obtain the coefficient of utilization (CU) value from the CU versus AR curve for the luminaire involved (for typical curve, see Fig. B8).

The value for NLP should be rounded off to a whole number.

B5.2.2 Method B

(1) Assume a spacing-to-mounting height ratio typical for the type of luminaire involved. A value of 5 is common.

B5.3 Number of Poles. The number of poles (NP) is dependent on the area and spacing ratio and can be determined by the formula:

$$NP = \frac{\text{Area}}{(H \times SR)}$$

(3) Determine the spacing-to-mounting-height ratio (SR) as a function of the uniformity ratio (UR) desired by use of the SR versus UR curve for the luminaire involved (for a typical curve, see Fig. B9 and Section B5.7).

(4) Calculate the number of luminaires per pole (NLP) using the formula:

$$NLP = \frac{(AMI) \times (MH \times SR)^2}{(LL/L) \times (CU) \times (LLF)}$$

Note: MH = mounting height; LL/L = Lamp Lumens per Luminaire; and LLF = Light Loss Factor.

(2) Assume a value of average distance (pole to outer edge of lighted area) to mounting height ratio. Use this to obtain a coefficient of utilization value from utilization curve for the luminaire involved. (For typical curve see Fig. B10.)

(3) Calculate the total number of luminaires required (NL) using the formula:

$$NL = \frac{(AMI) \times (A)}{(LL/L) \times (CU) \times (LLF)}$$

$$A = \text{Area}$$

B5.4 Pole locations. From an isolux chart of the type shown in Fig. B10, determine two boundaries (usually circles); one for the minimum initial illuminance and the other for one-half the minimum initial illuminance value as follows:

(1) Minimum initial illuminance is average

Table B5—Example of Luminaire Distribution of Luminous Intensity

ACTUAL CANDLEPOWER VALUES FOR 22000. LUMENS. TEST NO 100715.

DEG H	0.0	4.9	14.9	24.9	34.8	44.8	54.9	64.9	69.9	74.9	79.9	84.9
0.0	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.
2.5	4580.	4648.	4580.	4648.	4535.	4580.	4558.	4637.	4555.	4626.	4694.	4637.
5.0	4694.	4739.	4694.	4660.	4739.	4535.	4614.	4637.	4614.	4614.	4694.	4660.
7.5	4626.	4626.	4592.	4694.	4694.	4535.	4637.	4637.	4580.	4671.	4524.	4654.
10.0	4626.	4535.	4671.	4637.	4694.	4535.	4592.	4614.	4614.	4603.	4637.	4535.
12.5	4626.	4535.	4614.	4637.	4694.	4580.	4580.	4614.	4671.	4637.	4671.	4614.
15.0	5714.	4648.	5567.	5034.	5601.	4535.	4716.	4694.	4671.	4637.	4660.	4637.
17.5	5759.	4646.	5748.	5555.	5669.	5611.	5669.	4716.	5487.	5068.	4614.	4558.
20.0	5627.	5762.	6145.	5737.	5782.	5714.	5782.	5748.	5657.	5112.	5147.	4592.
22.5	5759.	5669.	5627.	6632.	6961.	5873.	6201.	5855.	5771.	5612.	5147.	4614.
25.0	5782.	5762.	5805.	6825.	6916.	6734.	6224.	5759.	6145.	5850.	5714.	4660.
27.5	5827.	5669.	5748.	6825.	6916.	6916.	6372.	6201.	6258.	5714.	5850.	4716.
30.0	5782.	5782.	5805.	6802.	6734.	6916.	6315.	6258.	6315.	5805.	5816.	4671.
32.5	5782.	5669.	5771.	6712.	5782.	6576.	6394.	6360.	6179.	5771.	5805.	5112.
35.0	5782.	5827.	5714.	6621.	5782.	5759.	6394.	6315.	5725.	5771.	5771.	5090.
37.5	5646.	5669.	5691.	6247.	5627.	5873.	6236.	6734.	5725.	5805.	5793.	4662.
40.0	4694.	5442.	5487.	5669.	5759.	5669.	5771.	6167.	5771.	5827.	5665.	4558.
42.5	4535.	4739.	4637.	5691.	5487.	5714.	5578.	5748.	5746.	5725.	5204.	4614.
45.0	4422.	4535.	4149.	4614.	3492.	4648.	4535.	5771.	5748.	5714.	5147.	4654.
47.5	3560.	4308.	3638.	3877.	3560.	4328.	4467.	5748.	5657.	5204.	5034.	4585.
50.0	3447.	3515.	2880.	2744.	2267.	3560.	4388.	5683.	5290.	5034.	4694.	4614.
52.5	2267.	3288.	2347.	2211.	2313.	3401.	3560.	4671.	4637.	4614.	4614.	4524.
55.0	2381.	2267.	1757.	2211.	2381.	2313.	3310.	4535.	4592.	4535.	4537.	4592.
57.5	1338.	2267.	1723.	2256.	2381.	2267.	2880.	4569.	4592.	4614.	5782.	4614.
60.0	1134.	1179.	1236.	2324.	2426.	2381.	3533.	4637.	5714.	5746.	6984.	5816.
62.5	1224.	1336.	1213.	2335.	2358.	2381.	3447.	4671.	6791.	7313.	8582.	6646.
65.0	907.	1179.	1122.	1723.	2159.	2381.	3560.	6201.	6201.	7961.	11383.	9093.
67.5	907.	1247.	1088.	1213.	1224.	2472.	3174.	5873.	5601.	9013.	13627.	12516.
70.0	907.	1111.	1066.	1179.	1134.	2267.	2041.	3458.	5356.	9682.	13627.	15872.
72.5	0.	159.	57.	703.	1066.	1224.	1236.	2369.	4556.	9217.	12437.	15759.
75.0	45.	0.	23.	159.	113.	1179.	1077.	1723.	3935.	8662.	8038.	10855.
77.5	159.	0.	102.	23.	113.	907.	136.	1667.	2369.	4585.	3885.	5147.
80.0	91.	113.	68.	136.	113.	0.	68.	612.	556.	1780.	1213.	2211.
82.5	45.	45.	45.	91.	45.	159.	79.	102.	125.	1100.	136.	1089.
85.0	45.	45.	0.	45.	45.	113.	136.	79.	23.	159.	45.	136.
87.5	0.	45.	0.	45.	0.	45.	91.	181.	136.	161.	159.	23.
90.0	0.	0.	204.	0.	0.	45.	0.	91.	45.	136.	113.	102.
92.5	204.	204.	159.	181.	159.	0.	102.	68.	45.	136.	91.	113.
95.0	159.	159.	159.	159.	159.	204.	161.	0.	0.	45.	45.	102.
97.5	159.	159.	159.	159.	159.	159.	159.	102.	0.	0.	23.	68.
100.0	159.	159.	159.	136.	113.	159.	136.	204.	204.	0.	0.	45.
102.5	159.	159.	113.	113.	113.	159.	113.	159.	159.	204.	204.	0.
105.0	113.	159.	113.	113.	113.	113.	113.	159.	136.	181.	159.	102.
107.5	113.	113.	113.	113.	113.	113.	113.	136.	113.	181.	159.	159.
110.0	113.	113.	113.	113.	91.	91.	91.	113.	113.	113.	113.	155.
112.5	113.	113.	113.	91.	91.	91.	91.	113.	113.	113.	113.	136.
115.0	113.	113.	91.	91.	45.	45.	45.	91.	91.	113.	113.	136.
117.5	91.	91.	91.	91.	45.	45.	45.	91.	68.	91.	91.	125.
120.0	51.	91.	45.	45.	45.	45.	45.	45.	45.	45.	45.	51.
122.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
180.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

DEG H	89.9	94.9	104.9	114.9	124.9	134.9	144.9	154.9	164.9	174.9	179.9
0.0	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.
2.5	4648.	4637.	4614.	4614.	4671.	4637.	4660.	4660.	5034.	4637.	4648.
5.0	4614.	4614.	4637.	4648.	4648.	4716.	5345.	4716.	4637.	4671.	4648.
7.5	4546.	4560.	4127.	4552.	4637.	4648.	4592.	5000.	4694.	4614.	4535.
10.0	4569.	4444.	4551.	4104.	4270.	4682.	4359.	5011.	4592.	4614.	4654.
12.5	4614.	4551.	4496.	3968.	3934.	3979.	3503.	4660.	4551.	4580.	3560.
15.0	4580.	4535.	4070.	3781.	3512.	3481.	3481.	3424.	3503.	3481.	3570.
17.5	4614.	4540.	3945.	3747.	3526.	3552.	3333.	3413.	3549.	3447.	3515.
20.0	4592.	4580.	3481.	3520.	3424.	3547.	2800.	2834.	2347.	3197.	2381.
22.5	4660.	4535.	3549.	3515.	3254.	2623.	2347.	2392.	2313.	2293.	2358.
25.0	4671.	4467.	3481.	3447.	2823.	2347.	2256.	2313.	2222.	2347.	2086.
27.5	4558.	4551.	3491.	3332.	2392.	2290.	2267.	2399.	1190.	1712.	1247.
30.0	4671.	4551.	3481.	2744.	2369.	2313.	1610.	1667.	1213.	1179.	1134.
32.5	4637.	4407.	3527.	2359.	2426.	2143.	1213.	1213.	1270.	1315.	1252.
35.0	4663.	4648.	3424.	2744.	2256.	2041.	1156.	1236.	1270.	1292.	1338.
37.5	4569.	4467.	3481.	2857.	2313.	1644.	1338.	1315.	1292.	1134.	1134.
40.0	4422.	3991.	3481.	3412.	2267.	1689.	1315.	1315.	1124.	1179.	1224.
42.5	4493.	3991.	3526.	3465.	2778.	2177.	1190.	1315.	1202.	1247.	1292.
45.0	4422.	3551.	3481.	3503.	3356.	2426.	1315.	1338.	1279.	1338.	2086.
47.5	4524.	4551.	3424.	3526.	3481.	2330.	1236.	1179.	2109.	2120.	2313.
50.0	4558.	4694.	3424.	3345.	3197.	2301.	1179.	1224.	2154.	2256.	2313.
52.5	4535.	4614.	3537.	2993.	2857.	2058.	1202.	1247.	2199.	2290.	2381.
55.0	4444.	4524.	3458.	2973.	2721.	2175.	1156.	1292.	2177.	2324.	2381.
57.5	4648.	4546.	3549.	2857.	2449.	2109.	1236.	1247.	2063.	2347.	2267.
60.0	5725.	4614.	3560.	2861.	2449.	2177.	1179.	1270.	1292.	2165.	1224.
62.5	7279.	5158.	3481.	2840.	2324.	1644.	1213.	1179.	1213.	1281.	1224.
65.0	10226.	7936.	3447.	2347.	1655.	1225.	533.	1179.	590.	1247.	1111.
67.5	15385.	10872.	3526.	1825.	1270.	1202.	45.	204.	158.	1066.	159.
70.0	14818.	13148.	3345.	1043.	79.	1009.	79.	23.	23.	136.	91.
72.5	10906.	10328.	2392.	45.	136.	57.	22.	136.	159.	23.	159.
75.0	6757.	7426.	1130.	102.	45.	79.	79.	45.	23.	113.	45.
77.5	3537.	4422.	136.	0.	181.	23.	136.	147.	0.	0.	204.
80.0	1179.	1757.	113.	159.	113.	181.	112.	136.	159.	204.	159.
82.5	113.	907.	57.	113.	68.	113.	68.	113.	79.	181.	113.
85.0	136.	57.	136.	91.	45.	45.	23.	102.	23.	102.	45.
87.5	102.	23.	113.	45.	45.	23.	0.	79.	23.	45.	0.
90.0	159.	159.	113.	45.	23.	0.	0.	57.	0.	0.	0.
92.5	113.	113.	91.	45.	0.	0.	204.	57.	204.	102.	204.
95.0	113.	113.	45.	23.	0.	0.	181.	204.	181.	204.	159.
97.5	45.	68.	23.	0.	0.	204.	159.	159.	159.	159.	159.
100.0	45.	45.	0.	102.	204.	159.	159.	159.	113.	159.	113.
102.5	102.	0.	204.	181.	159.	159.	113.	113.	102.	113.	113.
105.0	204.	204.	159.	159.	159.	136.	113.	113.	68.	45.	45.
107.5	159.	181.	159.	159.	113.	113.	102.	102.	45.	45.	45.
110.0	136.	159.	159.	113.	113.	113.	45.	68.	45.	23.	0.
112.5	113.	159.	113.	113.	91.	91.	45.	45.	0.	45.	0.
115.0	113.	113.	113.	113.	91.	45.	45.	45.	0.	23.	0.
117.5	91.	113.	91.	91.	45.	45.	0.	0.	0.	23.	0.
120.0	91.	91.	45.	68.	45.	23.	0.	0.	0.	0.	0.
122.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
180.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

mounting height ratios to d lop a curve such as that shown in Fig. B9. This is primarily applicable to symmetric luminaires but can be used with asymmetric luminaires with little loss in accuracy.

B6. Computation of walkway and bikeway illuminance

B6.1 Introduction. The procedure to determine the horizontal illuminance values on pedestrian ways for safe and comfortable use is similar to that followed for roadways as explained in the various steps under Section B3. In the case of isolated pedestrian ways, such as park walkways and Type B bikeways where the lighting provided is exclusively for the walkway and is arranged on either one or both sides of the paved area, the procedure is identical to computing roadway illuminance values, even to the point of using street side data from various luminaire curves. In the case of sidewalks (adjacent to roadways) and Type A bikeways, the procedure is very nearly the same as for roadway computation except that the house side curve data is often used. Because the area to be lighted for a Type A bikeway (roadside) is virtually identical to a sidewalk area, the sidewalk computation procedure suggested herein can be assumed to apply also for Type A bikeways (without further mention below to bikeways).

Because the design of roadway lighting places greater emphasis on achieving proper illuminance on the roadway, it is customary that the lighting system be initially selected to suit the needs of the roadway. Then, the system is checked to determine if the sidewalk illuminance levels and uniformity are adequate. If desired si alk requirements are lacking, the designer may m fy the luminaire type and/or spacing or may pr supplemental lighting primarily for the sid area, or may implement a combination of bo chniques to achieve proper illuminance on bo roadway and sidewalk. This procedure is sometimes reversed when greater emphasis is placed on the need for adequate sidewalk lighting, in which case Type I or II luminaires or post top luminaires are initially chosen primarily for sidewalk distribution and, when found satisfactory, are later checked for adequacy of roadway illuminance level and uniformity.

In some areas where personal security is a problem and identification of another pedestrian at a distance is important, the recommended levels on the right-hand side of Table 4 in the Standard Practice apply. These recommendations are stated in terms of the average vertical illuminance reaching a plane surface 1.8 meters above the walkway and perpendicular to the centerline of the walkway. The calculation procedure for vertical illuminance is discussed in paragraph B6.3.

B6.2 Determining horizontal illuminance. To calculate the average level of illuminance on the entire sidewalk with luminaires in their maintained condition, proceed as follows:

(1) Determine the coefficient of utilization (CU) for the sidewalk area only, as in paragraph B3.5.2., being sure to subtract from these calculations that portion of the CU that lated to flux falling on the street itself due to the transverse location of the luminaire.

(2) Calculate the average maintained illuminance level on the sidewalk due solely to the immediately adjacent luminaires, using the formula given in paragraph B3.5.3.

(3) For the same sidewalk area, determine the CU for the street side of the luminaires across the street.

(4) Calculate the average maintained illuminance level on the sidewalk due solely to the luminaires across the street, and add to that the illuminance coming from the luminaires on the same side of the street.

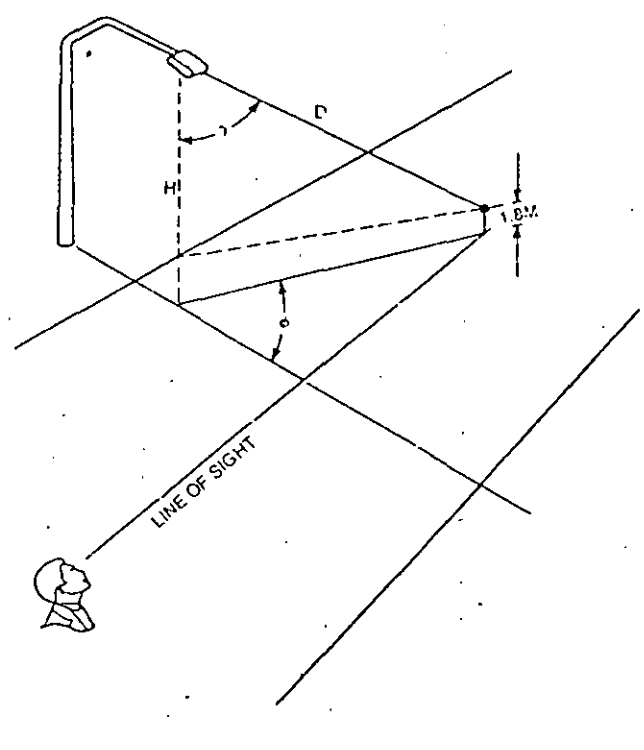
(5) Having calculated the average illuminance level across the entire sidewalk, it is now necessary to calculate the minimum level of illuminance, as described in paragraph B3.6 in order to compute the uniformity ratio.

B6.3 Determining vertical illuminance for security areas. The vertial illuminance at a specific point can be calculated by the inverse-square method of calculating illuminance (See the current edition of the *IES Lighting Handbook, Reference Volume*).[1] In this method, the candlepower of the luminaire at the particular angle involved is normally obtained from a luminous intensity chart, as shown in Table B5. The relevant geometry is shown in Fig. B11. The general form of the relationship is given by:

$$E_v = \frac{I(\phi, \gamma) \times \sin\gamma \times \sin\phi \times LLF}{D^2}$$

If it is assumed that the typical pedestrian facial area is approximately 1.8 meters above the sidewalk,

Figure B11. Geometric relationship for determining vertical illuminance on the face of a pedestrian.



FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

C U R S O S   A B I E R T O S

ILUMINACION EXTERIOR:
PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

COSTOS EN SISTEMAS DE ALUMBRADO PUBLICO

PALACIO DE MINERIA

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COMPAÑIA DE LUZ Y FUERZA DEL CENTRO S.A.
(EN LIQUIDACION)

GERENCIA DE CONSTRUCCION
SUPERINTENDENCIA TECNICO ADMINISTRATIVA
ANALISIS ECONOMICO DE ALTERNATIVAS
ALUMBRADO PUBLICO

C O N C E P T O	S I S T E M A S			
I.- INVERSION INICIAL EN EQUIPO				
1.- Cantidad de luminarias Dato				
2.- Costo de cada luminaria Dato				
3.- Costo total de luminarias 1 x 2				
4.- Cantidad de postes Dato				
5.- Altura de montaje Dato				
6.- Costo de poste y brazo Dato				
7.- Costo total de postes 4 x 6				
8.- Costo de base para postes Dato				
9.- Costo total de postes y bases 4 x (6+8)				
10.- Cantidad de lámparas por luminaria Dato				
11.- Cantidad de lámparas 1 x 10				
12.- Costo de cada lámpara Dato				
13.- Costo total de lámparas 11 x 12				
14.- Costo de cable y equipo de protección Dato				
15.- Total inversión inicial menos lámparas 3 + 9 + 14				
16.- Total inversión inicial con lámparas 15 + 13				
17.- Inversión inicial relativa en equipo 16 / valor del sistema más bajo				

CONCEPTO	SISTEMAS			
54.- Costos de operación anual por Lux sin considerar costos fijos 53 / 28				
VI.- COSTOS FIJOS ANUALES				
55.- Costos fijos por inversión. 20 % x (15 + 22)				
56.- Costo de operación anual total. 53 + 55				
57.- Costo anual por Lux. 56 / 28				
VII.- COSTOS RELATIVOS DE LUZ				
58.- Inversión inicial total relativa por Lux 29/costo sistema mas bajo.				
59.- Costo anual relativo por Lux incluyendo costos fijos. 57/costo sistema mas bajo				
60.- Costo anual relativo por Lux sin considerar costos fijos. 54/costo sistema mas bajo.				
* Formula para cuando se efectúa el reemplazo en grupo, si se efectúa el reemplazo individual se aplica la siguiente formula:				
39.- Cantidad de lamparas reemplazadas 11 x 32/38 A				
43.- Reemplazo en grupo por año, por luminaria 0				
43A.- Reemplazo individual por año, por luminaria 32 / 38 A				
44.- Costo de labor de reemplazo 1 x 41 x 42 A x 43 A				

CONCEPTO	SISTEMAS			
37.- Costo anual de KWH 33 x 34				
38.- Periodo de reemplazo en grupo Dato				
38A.- Vida de lámpara (para reemplazo individual) Dato				
38B.- Porción de lámpara, reemplazo individual Dato				
* 39.- Cantidad de Lámparas reemplazadas 11 + (1x38 B) x 32 / 38 *				
40.- Costo de lámparas reemplazadas 39 x 12				
V.- MANTENIMIENTO ANUAL LABOR Y MATERIALES.				
41.- Costo de labor por hora hombre Dato				
42.- Tiempo de reemplazo en grupo por luminaria Dato				
42A.- Tiempo de reemplazo individual por luminaria Dato				
* 43.- Reemplazo en grupo por año, por luminaria 32 x 38 *				
43A.- Reemplazo individual por año por luminaria 38 B x 43				
* 44.- Costo de labor de reemplazo 1 x 41 x (42 x 43 + 42 A x 43 A) *				
45.- Tiempo de limpieza por luminaria Dato				
46.- Limpiezas por año por luminaria Dato				
47.- Costo de labor de limpieza 1 x 41 x 45 x 46				
48.- Tiempo de pintura por poste Dato				
49.- Pintado por año por poste 0.20				
50.- Costo de labor por pintura 4 x 41 x 48 x 49				
51.- Partes de repuesto pintura, etc. 1 % x 15				
52.- Costo total de mantenimiento anual 44 + 47 + 50 + 51				
53.- Costo de operación anual sin considerar costos fijos 36 + 37 + 40 + 52				

CONCEPTO	SISTEMAS			
II.- COSTOS ESTIMADOS POR LABOR INICIAL				
18.- Montaje de poste y pintado Dato				
19.- Montaje de luminaria Dato				
20.- Montaje de poste y luminaria (4 x 18) + (1 x 19)				
21.- Montaje de equipo de protección y alambrado Dato				
22.- Total de labor 20 + 21				
23.- Total de inversión inicial 16 + 22				
24.- Inversión inicial relativa 23 / valor del sistema más bajo				
III.- CALCULOS DE ILUMINACION				
25.- Espaciamiento o área Dato				
26.- Factor de utilización Dato				
27.- Factor de mantenimiento Dato				
28.- Promedio de iluminación en lux Dato				
29.- Inversión inicial por lux 23 / 28				
IV.- COSTOS ANUALES				
30.- KW por luminaria (incluye pérdidas) Dato				
31.- KW totales del sistema 1 x 30				
32.- Horas de operación anual Dato				
33.- KWH totales por año 31 x 32				
34.- Costo de la energía por KWH Dato				
35.- Cargo por KW / mes demandado Dato				
36.- Cargo por demanda anual 31 x 35 x (12 meses)				

FACULTAD DE INGENIERIA U.N.A.M.
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C U R S O S   A B I E R T O S

ILUMINACION EXTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

ILUMINACION DE PASOS VEHICULARES A DESNIVEL

PALACIO DE MINERIA

ANSI/IES RP-22-1987

American National Standard Practice for Tunnel Lighting

Approved August 17, 1986
IESNA Board of Directors as a Transaction of the Illuminating Engineering Society of North America.

Approved December 15, 1987
American National Standards Institute, Inc.

Abstract
This standard reflects the state of the art in tunnel lighting and presents recommendations aimed at aiding the motorist in traveling safely through a tunnel. It provides information that will assist in determining lighting needs, provides solutions, and evaluates resulting visibility within vehicular roadway tunnels.

American National Standard

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Foreword

This foreword is not part of American National Standard ANSI/IES RP-22-1987.)

In September, 1970, the Illuminating Engineering Society published the report "Lighting of Tunnels." Since that time much experience has been gained as many tunnels have been lighted or relighted throughout the world. In addition, research has been conducted with regard to objects of focus, field of view and the eye adaptation process as a motorist approaches the entrance to a tunnel. The speed at which the eye adapts to rapid changes in luminance has also been investigated.

This Standard reflects *the state-of-the-art* in tunnel lighting and presents recommendations aimed at aiding the motorist in traveling safely through a tunnel. Suggestions for improvement of this standard will be welcome. They should be sent to the Technical Director, Illuminating Engineering Society of North America, 345 East 47th Street, New York, NY 10017.

The Subcommittee on Tunnels and Underpasses of the IES Roadway Lighting Committee, which has been primarily responsible for this revision, acknowledges the material contributions of the technical committees of the Illuminating Engineering Society in providing suggested information pertinent to their specialized activities. The members of the Subcommittee and Committee are listed on the preceeding page.

1. Introduction

This Standard Practice has the goal of providing information that will assist in determining lighting needs, provide solutions, and evaluate resulting visibility within vehicular roadway tunnels. Pedestrian and other non-vehicular tunnels are not addressed. This Practice is intended for use by engineers, consultants, technicians, and administrators charged with the responsibility of providing a safe environment within a tunnel - day and night.

It is not possible to provide one set of specific recommendations because of the variety of tunnels. Several methods used throughout the world in recent years have been made known to planners in North America, resulting in marked changes in the application of tunnel lighting. No longer is one system considered the best and only solution to the lighting of the many different types of tunnels.

Good visibility is the goal. The design must consider the tunnel and adjacent areas as well. Many factors contribute to, or detract from, visibility; therefore, it is important that all these factors be identified and their specific importance determined for each tunnel. These factors include:

1. Characteristics of the roadway approaches.
2. Characteristics of the tunnel roadway, walls, and ceiling.
3. Characteristics of the area surrounding the tunnel portal.
4. Atmospheric and environmental conditions.
5. Characteristics of vehicular traffic operations.
6. Orientation of tunnel with respect to sun and sky.

These factors and how they relate to each other are discussed in this document. Information is presented relative to visibility needs in both the approaches to the tunnel and the tunnel itself. Included are tunnels and underpasses (long or short), lighting at night as well as daytime, treatment of interior and exterior surfaces, electrical systems, lighting equipment, maintenance, and adjacent roadway lighting approach systems.

2. Physical Characteristics

2.1 Definition of a Tunnel. A tunnel may be defined as any enclosure over a roadway that restricts the normal illumination of the roadway by daylight, thus requiring an evaluation of the need for supplemental lighting so that adequate visibility can be provided for the motorist. This enclosure may be created either by boring through natural materials — such as earth and rock — or by construction with materials such as steel and concrete.

For clarity, the terms shown under Fig. 1 will be used in this discussion.

2.2 Classification. A tunnel may be classified into two categories as either a short tunnel or a long tunnel, depending upon length.

2.2.1 Short Tunnel. A tunnel having an overall length from portal to portal along the centerline which is equal to, or less than, the Safe Stopping Sight Distance (SSSD) appropriate to the speed of traffic entering the tunnel (see Table 1).

2.2.2 Long Tunnel. A tunnel with an overall length greater than the SSSD.

2.3 Visibility Optimization of the Tunnel and Its Approach Features. The critical task facing the driver approaching the tunnel entrance portal during the daytime is to overcome the *black hole effect* created by the high ratio of external to internal luminance. In addition to the design of a lighting system to increase luminance inside the tunnel, it is important that the physical design of the tunnel approach structure and its environs give due consideration to design features that will assist the lighting system in reducing the high external luminance ratio. Often these physical features, favorable to lighting needs, add little or nothing to tunnel structure costs, and can be incorporated into new or existing tunnels.

The factors outlined in the following paragraphs contribute to improved tunnel visibility and should be fully explored as a prerequisite to the development of supplementary daytime tunnel lighting design.

2.3.1 Reduction of Ambient Daytime Luminances. Tunnel portals, adjacent walls, approach pavement, and other external features in the motorists' field of view, should be darkened to an extent that will reduce the high ratio of external to internal luminance. The use

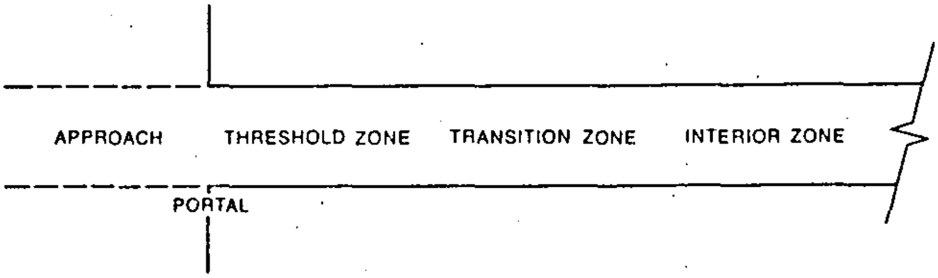

Figure 1. Descriptive terms associated with tunnel lighting.
Approach: **the external roadway area leading to the tunnel.**
Portal: **the plane of entrance into the tunnel.**
Threshold zone: **the area where a transition is made from the high lighting level to the threshold of the lower lighting level of the interior.**
Interior Zone: **the innermost part of the tunnel where the lowest level of lighting is provided.**
(*Note:* Lengths of zones will vary with the design parameters.)

of surface treatments, admixtures, overlays, vegetation, or other methods that result in low reflectance, nonspecular surfaces are recommended.

The darkening of these external surfaces reduces the luminance level to which the eye is adapted prior to entering the tunnel, thus shortening the time to adapt to the lower luminances within the tunnel.

Tunnels having a predominant sky background immediately above their entrance portals should be reviewed for the possibility of using plants, screens, or panels to increase the size of the darkened area above the portals.

2.3.2 Approach and Portal Design Factors. The amount and extent of daylight penetration into the tunnel entrance is largely dependant upon the orientation of the tunnel with respect to the sun's path in the sky. Since the orientation of a tunnel is generally dictated by criteria other than illumination considerations, the tunnel lighting systems must be able to accommodate the entrance orientation conditions.

The use of increased tunnel entrance height and upsweep ceilings in the portal entrance areas may result in increasing the length and amount of daylight penetration, thus reducing the lighting required. The upsweep ceiling may, however, result in increased tunnel structure costs.

Table 1—Safe Stopping Sight Distance*

Traffic Speed		Minimum Safe Stopping Sight Distance (SSSD)†	
Kilometers per Hour	Miles per Hour	Meters	Feet
48	30	60	200
64	40	90	300
80	50	140	450
88	55	165	540
96	60	200	650
104	65	220	720

* Based on American Association of State Highway and Transportation Officials (AASHTO) recommendations. See *A Policy on Geometric Design of Highways and Streets*, 1984, AASHTO, 444 N. Capitol Street N.W., Capitol Street., Suite 225, Washington, DC 20001.
† Assumes average prevailing speeds in a straight and level tunnel approach roadway are at, or near, the posted speed limit of the facility. For other geometric conditions, refer to the AASHTO standard as referenced.

Properly designed screens or louvers placed over tunnel entrance roadways at, and in advance of, the entrance portal have been used to progressively reduce ambient brightness to lower levels commensurate with tunnel entrance portal conditions.

Although this technique can reduce the required level of lighting in the tunnel, thus saving electrical energy, sun screens now in use have been difficult to maintain due to dirt accumulation, permanent depreciation of reflective and light transmitting properties, and snow and ice accumulation on the screen and roadway. The high initial costs of such systems coupled with high maintenance costs have precluded their extensive application in North America.

2.3.3 Visibility Optimization of Tunnel Interiors. To effectively use daylight and supplemental electric lighting, it is recommended that wall surfaces be of an easily maintained, highly reflective, nonspecular finish having a reflectance of at least 50 percent initially.

In tunnels where ceiling surface reflectance will contribute to the utilization of the lighting system, such as those with curved (barrel) ceilings, these surfaces should receive similar treatment. Interior walls having vertical surface relief, to reduce traffic noise, will result in higher wall luminance.

In tunnels having curved roadways or tunnels having curved approach roadways, development of high wall luminance is of great value in meeting visibility needs. Relatively narrow tunnels where the width-to-height ratios are approximately three or less will normally develop good tunnel visibility as a result of reflected light from highly reflective walls. Tunnels having greater width-to-height ratios will normally require supplemental lighting of the roadway surface.

In entrance portal areas, sunlight penetration can be improved by use of wall, ceiling, and roadway surface texture control. The use of vertical wall corrugations, coarse finished pavements, or other treatments that produce surface relief will increase the retro-reflection of light entering the portal over that of smooth surfaces.

2.3.4 Types of Pavement Surfaces. The use of dark finish material on the approach road surface to the tunnel portal, and light finish material on the road surface inside the portal, for a distance at least equal to the safe stopping distance, will reduce the external to internal luminance difference. However, the designer must recognize the probability of future resurfacing with other than light finish material.

3. Lighting Design Considerations

3.1 General. Tunnel lighting design considerations consist of the following:

1. Volume of speed of traffic.
2. External luminance.
3. Tunnel classification.
4. Tunnel luminances during both daytime and nighttime conditions.
5. Lighting and electrical equipment.
6. Flicker effect.

Refer to Appendix A for design computational methods.

3.2 Volume and Speed of Traffic. Tunnels with high traffic volume and tunnels with high speed traffic require higher luminance levels than tunnels with lower volume and slower traffic. High luminance levels aid the motorist in performing the more difficult driving tasks. High volume traffic increases the probability of having to stop quickly or take evasive action. Higher speeds reduce the time available for eye adaptation and reaction to driving difficulties.

3.3 External Luminance. External luminance must be considered because one's eyes are adapted to the exterior brightness level prior to entering the tunnel. Since an approaching motorist will be looking at the tunnel entrance, the luminance characteristics of the portal area and the surrounding visual scene must be considered. Figure 2 lists the various factors that will produce the highest to the lowest tunnel external luminance.

3.4 Tunnel Classification. Short tunnels, with a length of less than the SSSD having straight, relatively level approach alignment and a straight and level tunnel roadway may have adequate visibility without supplemental daytime lighting. In these cases, visibility is provided by negative contrast silhouette, with high luminance values provided by the exit portal.

In tunnels with curved roadways, where the exit portal is not visible, supplemental lighting may be required. These short tunnels should have a single lighting zone equal to the threshold zone luminance taken from Table 2. Long tunnels require several zones of lighting.

3.5 Tunnel Luminances

3.5.1 Threshold Zone. Daytime tunnel luminance in the threshold zone must be relatively high to provide visibility during eye adaptation as the motorist enters the tunnel. Select the appropriate threshold zone luminance from Table 2. As indicated, the required luminance is dependant upon both the characteristics of the tunnel, and the traffic speed and volume in the tunnel. Length of the threshold zone lighting should be 15 meters less than SSSD (SSSD - 15 meters). At approximately 15 meters before the portal, the tunnel dominates the visual scene. SSSD can be determined from Table 1.

3.5.2 Interior Zone. Daytime lighting in the interior of a long tunnel can be reduced since the motorist's eyes will have adapted to the lower luminance of the threshold zone. Luminance of the tunnel interior zone should be a minimum of five candelas per square meter with a uniformity not exceeding 3 to 1, average to minimum.

3.5.3 Transition Zone. Daytime luminance in the transition zone should taper from the threshold zone luminance to the interior zone luminance over a length equal to SSSD. Transition zone lighting can be accomplished in various ways: greater spacing between luminaires, fewer lamps per luminaire in the case of fluorescent, lower wattage lamps, or combinations of the above.

The number of selections within the transition zone using different lighting arrangements should be such that a relatively even transition will occur.

Luminance may be reduced in steps of equal length. The first step should be greater than or equal to one-quarter of the threshold zone luminance. The last step should be less than or equal to two times the interior zone luminance. Immediate steps should be greater than or equal to one-third of the preceding zone. Figure 3 shows an example of tunnel luminance levels in the transition zone.

3.5.4 Nighttime. During nighttime the motorist's eyes are adapted to the low exterior luminance; there-

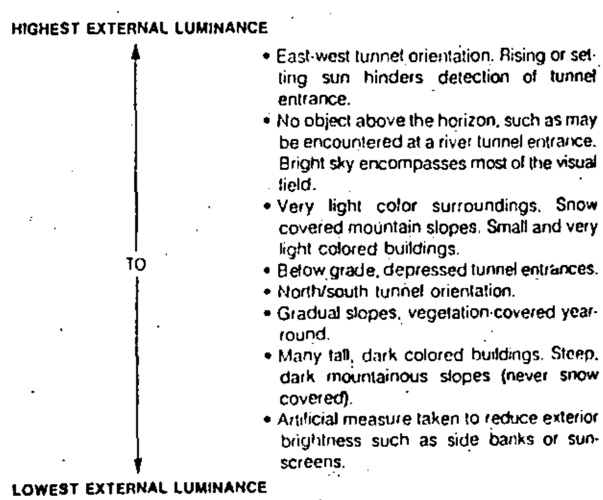

Figure 2. Factors affecting tunnel external luminance.

Table 2—Recommended Maintained Threshold Zone Average Pavement Luminance Values or Tunnel Roadways

Characteristics of Tunnel	Traffic Speed Kilometers per Hour	Traffic Speed Miles per Hour	Traffic Volume AADT* <25,000	25-89,999	90-150,000	>150,000
			Candelas per Square Meter†			
Mountain tunnels, gradual slopes where snow can accumulate or river tunnels with few surrounding buildings. East/west tunnel orientation.	≥81	50	210	250	290	330
	61-80	38-49	180	220	260	300
	≤60	37	140	185	230	270
Mountain tunnels with steep, dark slopes or climate conditions where snow cannot accumulate. Portal surroundings have medium brightness year round.	≥81	50	145	175	205	235
	61-80	38-49	130	160	190	220
	≤60	37	105	140	170	200
Concealed portals, dark surfaces, or buildings surrounding entrance. Artificial measures taken to reduce exterior brightnesses. North/south orientation.	≥81	50	80	100	115	130
	61-80	38-49	70	90	105	120
	≤60	37	60	80	95	110

*Average Annual Daily Traffic in both directions.
†For approximate values in candelas per square foot, multiply by 0.1.

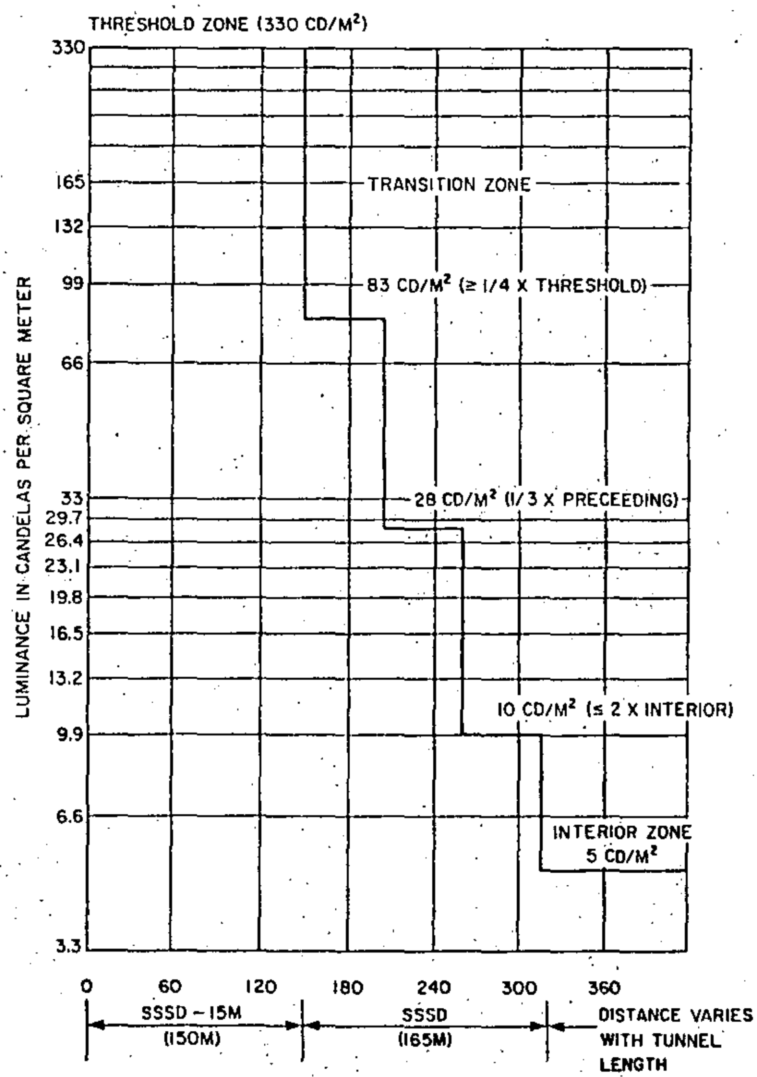

Figure 3. Example of tunnel lighting: portal with very bright surroundings (high external luminance); traffic speed 99 kilometers per hour; and Average Annual Daily Traffic (AADT) in both directions is greater than 150,000. Required threshold zone luminance from Table 2 is 330 candelas per square meter. Safe Stopping Sight Distance (SSSD) from Table 1 is 165 meters.

fore, a nighttime luminance of 2.5 candelas per square meter minimum is recommended for the entire length of the tunnel.

3.5.5 Uniformity Ratios. Uniformity ratios within the tunnel zones should be the same as those used for general roadway lighting. See Appendix B.

3.5.6 Maintenance Considerations. The recommended luminance values in Table 2 represent the lowest in-service values that should be allowed throughout the operating life of the system; therefore, the initial luminance figures in the tunnel, when the lighting system is initially turned on, may have to be higher to compensate for Lamp Lumen Depreciation (LLD), Luminaire Dirt Depreciation (LDD), and tunnel surface reflectance depreciation.

Lamp lumen depreciation will depend upon the lamp used, and depreciation factors are available from lamp manufacturers. Luminaire dirt depreciation will depend upon the luminaire construction and the luminaire cleaning cycle. If the luminaires are well sealed and the lenses are washed frequently, the light loss, due to dirt accumulation, may be moderate. If maintenance and lamp replacement are replacement schedules are poor, the light loss will be severe. The reflectance deterioration of the tunnel surfaces will depend on the frequency and thoroughness of the cleaning of these surfaces.

When the three depreciation factors (LLD, LDD, and tunnel surface reflectance depreciation) are taken into account, the resultant light loss factor may be in the range of 0.25 to 0.60. Before the final lighting system is chosen, it is good practice to do a detailed cost analysis comparing the estimated initial installation costs, plus electrical energy costs using various schedules of routine maintenance (changing of lamps, cleaning of luminaires and cleaning of tunnel surfaces). A decision on the final system may then be made based on the lighting system design and maintenance schedule that offers the greatest economy.

3.6 Lighting and Electrical Equipment

3.6.1 Light Sources. Fluorescent, High Intensity Discharge (HID), and Low Pressure Sodium (LPS) are the light sources used almost exclusively for tunnel lighting installations. Incandescent lamps are seldom used in new installations because of their lower efficacy and shorter life.

The following factors affect the selection of a light source for tunnel lighting:

1. Efficacy.
2. Color rendition and its effect on signs and traffic signals.
3. Wattages or lumen outputs available.
4. Life.
5. Lamp lumen depreciation.
6. Ambient temperatures.
7. Cost.
8. Restrike time.
9. Ability to control the light distribution.
10. Dimming capability.
11. Physical size.
12. Physical durability.

Different light sources have various advantages and disadvantages.

3.6.2 Luminaires. Tunnel lighting luminaires must be ruggedly constructed to withstand the harsh environment found in most tunnels. Vibration, air turbulence caused by vehicles, exhaust fumes, road dirt, salt, and the periodic washing of tunnels with industrial detergents and high pressure jet spray equipment are some of the conditions to which luminaires are exposed.

The following are factors that must be evaluated in the design, selection, installation, and testing of tunnel lighting equipment:

1. Prevention of vapor, dust and water jet spray from entering into the luminaires.
2. Ease of cleaning, relamping and replacement of parts.
3. Resistance to corrosion.
4. Physical strength sufficient to prevent warping, twisting, or deforming during installation, use and servicing.
5. Highest and lowest ambient operating temperature within the tunnel.
6. Excessive glare from the luminaire.

3.6.3 Electric Power Control and Switching. Power supply for tunnel lighting must be reliable. Even a momentary loss of power cannot be tolerated, since it can lead to serious accidents as people are plunged into complete darkness. Safety can be greatly improved by providing power from two separate sources to the entire tunnel lighting system with transfer devices that automatically switch from one power source to the other in the event of a power failure. Consideration should be given to the installation of an emergency power supply to luminaires providing at least one-fifth of the design nighttime lighting level.

Tunnel lighting requirements may vary during daily operation as a result of external luminances varying with weather or position of the sun. Installations may be provided with luminaires that can be switched and/or dimmed automatically with changes in the outdoor luminance or with changes in the effective light output of the luminaires. Tunnel systems may also have a manned control room with closed circuit television surveillance that allows monitoring of tunnel conditions and provides manual override of the automatic operations.

3.7 Flicker Effect. In the interior of a lighted tunnel where luminaires or their reflected images are in full or partial view of the vehicle occupants, the stroboscopic effect of passing closely spaced light sources may produce undesirable behavioral sensations. The flicker effect depends upon the candlepower intensity of the source reaching the observers' eyes, the location of the source in the motorists' viewing field, and the frequency or rate at which successive light sources appear to be moving. Figure 4 illustrates the range of luminaire cycles per second that are most likely to produce these undesirable flicker effects. The designer should avoid

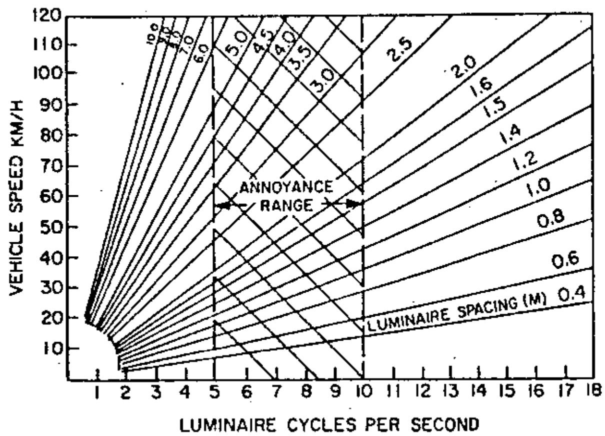

Figure 4. Flicker effect.[22]

luminaire spacings within the annoyance range shown (5 to 10 cycles per second).

Appendix A — Computational Methods

(This Appendix is not part of American National Standard ANSI/IES RP-22-1987.)

A1 Design Considerations

A1.1 General. The success in designing a well balanced lighting system for a vehicular tunnel to a large extent will depend on the logic and sequence of the steps taken by the designer. It should be pointed out that designers, in the process of designing a lighting system, should coordinate their work by closely cooperating with traffic planners, designers of the tunnel structure and portal, maintenance forces, and traffic system operators.

A1.2 Tunnel Structural Features. Considerations of the structural features will assist the lighting designer in determining the luminaire location (wall or ceiling), luminaire photometric characteristics and may influence the light source selection. The tunnel portal design and its surface treatment is also of considerable importance in the threshold zone lighting design. The interior wall, ceiling and pavement textures and reflectances are important in calculating the luminance in the interior.

A1.3 Traffic Lane Arrangement. Coordination between the luminaire arrangement and the traffic lanes is an important factor. Where practical, luminaire location should permit continuation of traffic operation during lighting system maintenance work. In the case of merging or diverging traffic, suitable luminaire location may provide visual guidance to the motorist.

A1.4 Physical Safety of Lighting Equipment. In a case where luminaires are mounted on the surface of walls or ceiling, particular attention should be given to vertical anu lateral clearances to minimize damage by vehicles or loads permitted to pass through the tunnel. Clearances should be based on the traffic standards established for the particular road system. In the case of wall-mounted luminaires, the presence of escape sidewalks or curbs are helpful to protect the luminaires from damage.

A2 Calculation Procedure

A2.1 General. Before the design calculations are started, the following should be determined:

1. Illuminances required in the threshold zone, transition zone and the tunnel interior. See Table 2.
2. Acceptable uniformity ratios. See paragraph 3.5.5.
3. Light sources and lamp sizes to be used. See paragraph 3.6.1.
4. Luminaire types and photometric characteristics.

Actual design calculations can be conveniently executed with the aid of a computer. The following calculation example is provided for those who do not have access to a suitable computer program.

A2.2 Design Data (Example)

A2.2.1 Tunnel Characteristics:

Length	= 1000 meters divided
Tube Dimensions	= 15 meters wide and 5.5 meters high
Pavement	= Portland cement concrete (R1)
Surface reflectances:	
ceiling	= 50 percent
wall	= 50 percent
pavement	= 10 percent

A2.2.2 Luminance Levels:

Threshold zone = 190 candelas per square meter
(See Table 2, middle category of tunnel characteristics, 80 km/h, and 90 to 150,000 traffic volume.)

Transition zone sections:
No. 1: 1/4 X 190 equals approximately 50 candelas per square meter.
No. 2: 1/2 X 50 = 25 candelas per square meter (see paragraph 3.5.3).
No. 3: 2 X 6 = 12 candelas per square meter.

Tunnel interior = 6 candelas per square meter - daytime (see paragraph 3.5.2).
Tunnel interior = 3 candelas per square meter - nighttime (see paragraph 3.5.4).

Uniformity ratios (see Appendix B): E_{avg} to E_{min} = 3 to 1 (within same zone).

A2.2.3 Lamp Data:

Threshold zone	= 400-watt high pressure sodium - 50,000 lumens.
Transition zone sections	= 250-watt high pressure sodium - 30,000 lumens.
Tunnel interior	= 100-watt high pressure sodium - 9500 lumens.

A.2.2.4 Luminaires. The luminaires selected are ceiling mounted type for use with high pressure sodium lamps. A coefficient of utilization chart is shown in Table A1.

A2.3 Illuminance Method of Calculation. Tables 2a and 2b from ANSI/IES RP-8-1983 provide the conversion ratios between luminance and illuminance for road classifications R1, R2, R3, and R4. (These conversion

Table A1—Coefficients of Utilization for Typical High Pressure Sodium Luminaire

Effective Floor Cavity Reflectance =.10

CC	80				70				[50]			30			10			0
Wall	70	50	30	10	70	50	30	10	[50]	30	10	50	30	10	50	30	10	0
RCR																		
1	.72	.68	.65	.62	.69	.66	.63	.60	.61	.59	.56	.57	.55	.53	.53	.51	.50	.48
[1.9]									.54									
2	.65	.59	.54	.50	.63	.57	.52	.48	.53	.49	.46	.49	.46	.43	.46	.43	.41	.39
3	.59	.52	.46	.41	.57	.50	.44	.40	.46	.42	.38	.43	.39	.36	.40	.37	.34	.32
4	.54	.46	.39	.34	.52	.44	.38	.34	.41	.36	.32	.38	.34	.31	.36	.32	.29	.27
5	.49	.40	.34	.29	.47	.39	.33	.28	.36	.31	.27	.34	.29	.26	.31	.28	.25	.23
6	.45	.36	.29	.25	.43	.34	.28	.24	.32	.27	.23	.30	.26	.22	.28	.24	.21	.20
7	.42	.32	.26	.21	.40	.31	.25	.21	.29	.24	.20	.27	.23	.19	.25	.21	.18	.17
8	.38	.28	.22	.18	.37	.28	.22	.18	.26	.21	.17	.24	.20	.16	.23	.19	.16	.14
9	.35	.26	.20	.16	.34	.25	.19	.15	.23	.18	.15	.22	.17	.14	.21	.17	.14	.12
0	.33	.23	.17	.14	.31	.23	.17	.13	.21	.16	.13	.20	.15	.12	.19	.15	.12	.11

Note: This table is for a typothetical luminaire and should be used for this example only. Consult manufacturer's published photometric data on the luminaire (s) being considered when designing an actual installation.

ratios are approximations of what occurs in real situations. Calculation procedures that will provide greater accuracy when converting roadway illuminance to luminance are currently being developed). Since the pavement of this tunnel is that of cement concrete or R1, the ɔ of candelas per square meter is 1 to 10 (as com-.ed to 1 to 15 for an R3 pavement, for example). Thus, the luminance levels outlined in paragraph A2.2 can be rewritten in terms of illuminance as follows:

Threshold zone:

190 X 10 = 1900 lux

Transition zone sections:

No.1: 50 X 10 = 500 lux

No.2: 25 X 10 = 250 lux

No.3: 12 X 10 = 120 lux

Tunnel interior = 60 lux (daytime)

Tunnel interior = 30 lux (nighttime)

In the manual calculation procedures, the tunnel interior can be considered as an infinitely long room.

The number of luminaires for various zones can be calculated from the following equation:

$$N_L = \frac{E_h \times A}{\phi \times CU \times LLF}$$

where

N_L = number of luminaires

E_h = horizontal illuminance (lux)

A = area of the zone in square meters

ϕ = initial lamp lumens per luminaire

CU = coefficient of utilization

LLF = light loss factor

Before the actual number of the luminaires can be de-ᵐined, the values of *CU* and *MF* must be determined.

he *CU* can be determined by calculating the cavity ...ıo and reading the *CU* value from the information provided by the specific luminaire manufacturer.

$$\text{Cavity Ratio} = \frac{2.5 \times \text{Cavity Height} \times \text{Cavity Perimeter}}{\text{Area of Cavity Base}}$$

$$\text{Cavity Ratio} = \frac{2.5 \times 5.5 \times (1000 + 15 + 1000 + 15)}{(1000 \times 15)} = 1.9$$

From Table A1, using reflectances of 50 percent ceiling, 50 percent wall and 10 percent floor (pavement) and a cavity ratio of 1.9, the *CU*, by interpolation, is 0.54.

The recommended range for *LLF* as discussed in paragraph 3.5.6 is *LLF* = 0.25 to 0.60. For this example, the value of 0.5 has been selected.

A2.4 Calculation of Daytime Lighting System for Tunnel Interior.

For E_h = 60 *lux*,

$$N_L = \frac{60 \times (1000 \times 15)}{9500 \times 0.54 \times 0.5} = \frac{900{,}000}{2565} = 351 \text{ units}$$

Arranging the luminaires in two rows, the number of luminaires in each row will be:

$$\frac{351}{2} = 176 \text{ units}$$

Since the tunnel length is 1000 meters, the spacing for the luminaires will be:

$$\frac{1000}{2} = 5.68 \text{ meters}$$

With a spacing of 5.68 meters, the spacing-to-mounting-height ratio is

$$\left(\frac{5.5}{5.68}\right)$$

approximately 1.0. Such spacing-to-mounting height ratio, in most cases, will give an excellent uniformity. In fact, symmetrical distribution luminaires can be often spaced as far apart as 2.2 to 1, and obtain a uniformity ratio better that 3 to 1 E_{avg} to E_{min}.

When a specific luminaire is selected for a given tunnel, uniformity ratios on the pavement can be checked by using point calculation methods (reading the contribution of illuminance value by each luminaire from isolux curves gives a close approximation).

The luminaire spacing should also be checked to ensure that no *flicker effect* problems might exist. See paragraph 3.7.

A2.5 Calculation of Nighttime Lighting System for the Tunnel Interior. The nighttime lighting system design should be closely related to that of daytime since the nighttime lighting level is 30 lux (or one-half of that of the daytime system). Nighttime lighting levels can be created by switching off every second luminaire of the daytime lighting system in a staggered arrangement.

Since the spacing of the luminaires will be effectively changed to $5.68 \times 2 = 11.36$ meters, the uniformity ratio should be checked again.

A2.6 Calculation of Lighting System for the Threshold Zone: Since Traffic speed is 80 kilometers per hour, SSSD is 140 meters; therefore, the threshold zone will be 140 - 15 = 125 meters long. Illuminance required is 1900 - 60 = 1840 lux, the 60 lux already having been provided by the daytime interior system.

$$N_L = \frac{1840 \times 15 \times 125}{50{,}000 \times 0.54 \times 0.5} = \frac{3{,}450{,}000}{12{,}500}$$

= 256 luminaires additional.

If the 256 luminaires are mounted in two rows, then 128 luminaires would be required in each row with spacing of .98 meter. These luminaires will be mounted in the same two rows used for the daytime interior system; therefore, the spacing may need to be adjusted slightly to evenly intersperse them between those luminaires. Adequate space should be left between the luminaires to facilitate cleaning and relamping. If adequate space is not available, then the luminaires should be arranged in three (or more) rows. The final luminaire spacing also often necessitates adjustment to accommodate the structure expansion joints, coordination with ventilation ducts and other equipment in the tunnel interior. In all cases, the spacing should be checked for uniformity and flicker effect at design speed.

A2.7 Calculation of Lighting System for the Transition Zones. The calculation of illuminance in the transition zones can be carried out in a similar manner as for the threshold zone.

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(This Appendix is not part of the American National Standard ANSI/IES RP-22-1987.)

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Appendix B — / Recommended Uniformity Ratios and Veiling Luminance Ratios for Tunnels*

(This Appendix is not part of the American National Standard ANSI/IES RP-22-1987.)

Road and Area Classification		Luminance Uniformity L_{avg} to L_{min}	L_{max} to L_{min}	Veiling Luminance Ratio (maximum) L_v to L_{avg}	Illuminance Uniformity Ratio E_{avg} to E_{min}
Freeway Class A		3.5 to 1	6 to 1	0.3 to 1	3 to 1
Freeway Class B		3.5 to 1	6 to 1	0.3 to 1	
	Commercial	3 to 1	5 to 1		
Expressway	Intermediate	3 to 1	5 to 1	0.3 to 1	3 to 1
	Residential	3.5 to 1	6 to 1		
	Commercial	3 to 1	5 to 1		
Major	Intermediate	3 to 1	5 to 1	0.3 to 1	3 to 1
	Residential	3.5 to 1	6 to 1		
	Commercial	3 to 1	5 to 1		
Collector	Intermediate	3 to 1	6 to 1	0.4 to 1	4 to 1
	Residential	4 to 1	8 to 1		
	Commercial	6 to 1	10 to 1		
Local	Intermediate	6 to 1	10 to 1	0.4 to 1	6 to 1
	Residential	6 to 1	10 to 1		

*Adapted from the *American National Standard Practice for Roadway Lighting*, ASNI/IES RP-8-1983.

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vision and the visual process.

(3) The design of a roadway lighting system involves consideration of visibility, economics, esthetics, safety, and environmental conditions, as well as appropriate material and equipment. The design process follows these major steps:

(*a*) Determination of roadway classification and abutting land uses along the specific road section to be lighted (Fig. 1). If the pavement classification is unknown, use the R3 values of Table 2.

(*b*) Selection of the level and uniformity of pavement luminance and assessment of the relationship between the veiling luminance and the average pavement luminance, as recommended in Table 2(a) for each different land use along the section, or

(*c*) Determination of roadway pavement classification, desired average horizontal levels of illuminance, and uniformity for design as recommended in Table 2(b).

(*d*) Selection of several tentative luminaires and light sources.

(*e*) Selection of one or more tentative lighting system geometric arrangements, including mounting heights and lateral luminaire positions, which may provide an acceptable design based on recommended level, uniformity, and/or veiling luminance control.

(*f*) Calculation of pole spacing for the various luminaire-lamp combinations under study (if for a new system) or of lamp output requirements (if existing poles are to be used), based on illuminance values. Variables of mounting height or lateral luminaire positions may also be considered to verify meeting the requirements of Table 2(a) or 2(b).

(*g*) When luminaires have been selected, borderline situations quickly become evident during the application stage. In most cases skilled judgment must be exercised when considering luminaires for a specific system. It may not be appropriate to specify only one light distribution when it is obvious that several luminaire light distributions will provide equivalent performance for a specific application.

Table 3. Recommended maintained illuminance design levels for high mast lighting.*†

Road Classification	Horizontal Illuminance (E_{avg}) in Lux: Commercial Area	Intermediate Area	Residential Area
Freeways	6	6	6
Expressways	10	8	6
Major	12	9	6
Collector	8	6	6

*Recommended uniformity of illumination is 3 to 1 or better; average-to-minimum for all road classifications at the illuminance levels recommended above.

†These design values apply only to the travelled portions of the roadway. Interchange roadways are treated individually for purposes of uniformity and illuminance level analysis.

Table 4. Recommended average maintained illuminance levels for pedestrian ways* in lux.

Walkway and Bikeway Classification†	Minimum Average Horizontal Levels (E_{avg})	Average Vertical Levels For Special Pedestrian Security (E_{avg})‡
Sidewalks (roadside) and Type A bikeways:		
Commercial areas	10	22
Intermediate areas	6	11
Residential areas	2	5
Walkways distant from roadways and Type B bikeways:		
Walkways, bikeways, and stairways	5	5
Pedestrian tunnels	43	54

*Crosswalks traversing roadways in the middle of long blocks and at street intersections should be provided with additional illumination.

†See Section 2.1.

‡For pedestrian identification at a distance. Values are 1.8 meters above walkway.

(*h*) Selection of final design or reentry of the design process at any step above to advise on optimal design.

(*i*) Selection of luminaire supports (pole and bracket) which results in an acceptable esthetic appearance, adherence to traffic safety practice, low initial construction cost, and minimal operation and maintenance expenses.

(*j*) Recommended illuminance values for high mast lighting are shown in Table 3. For separate walkways or bicycle routes, recommended illuminances are shown in Table 4. The steps to develop optimal design are similar to those given above.

(4) The formation of a tentative design concept involves many variables. The choice of light source, the extent to which available electrical distribution facilities are used, and the types of poles, brackets and luminaires selected are some of the factors that will influence the economics of lighting. Any consideration of appearance is ultimately resolved by professional judgment; however, elaborate or ornate designs, purely for the purpose of satisfying an esthetic desire, cannot be justified unless the basic requirements of good visibility have first been attained. It is important that roadway lighting is planned on the basis of traffic information, which includes the factors necessary to provide for traffic safety and pedestrian security. Some of the factors applicable to the specific problems that should be considered are:

(a) Type of land use development abutting the roadway or walkway (see Section 2.2, "Area Classifications")

(b) Type of route (see Section 2.1, "Roadway, Pedestrian Walkway, and Bikeway Classifications)

Table B3. r-Table for standard surface R3.*†

θ tan γ	0	2	5	10	15	20	25	30	35	40	45	60	75	90	105	120	135	150	165	180
0	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294	294
0.25	326	326	321	321	317	312	308	308	303	298	294	280	271	262	258	253	249	244	240	240
0.5	344	344	339	339	326	317	308	298	289	276	262	235	217	204	199	199	199	199	194	194
0.75	357	353	353	339	321	303	285	267	244	222	204	176	158	149	149	149	145	136	136	140
1	362	362	352	326	276	249	226	204	181	158	140	118	104	100	100	100	100	100	100	100
1.25	357	357	348	298	244	208	176	154	136	118	104	83	73	70	71	74	77	77	77	78
1.5	353	348	326	267	217	176	145	117	100	86	78	72	60	57	58	60	60	60	61	62
1.75	339	335	303	231	172	127	104	89	79	70	62	51	45	44	45	46	45	45	46	47
2	326	321	280	190	136	100	82	71	62	54	48	39	34	34	34	35	36	36	37	38
2.5	289	280	222	127	86	65	54	44	38	34	25	23	22	23	24	24	24	24	24	25
3	253	235	163	85	53	38	31	25	23	20	18	15	15	14	15	15	16	16	17	17
3.5	217	194	122	60	35	25	22	19	16	15	13	9.9	9.0	9.0	9.9	11	11	12	12	13
4	190	163	90	43	26	20	16	14	12	9.9	9.0	7.4	7.0	7.1	7.5	8.3	8.7	9.0	9.0	9.9
4.5	163	136	73	31	20	15	12	9.9	9.0	8.3	7.7	5.4	4.8	4.9	5.4	6.1	7.0	7.7	8.3	8.5
5	145	109	60	24	16	12	9.0	8.2	7.7	6.8	6.1	4.3	3.2	3.3	3.7	4.3	5.2	6.5	6.9	7.1
5.5	127	94	47	18	14	9.9	7.7	6.9	6.1	5.7										
6	113	77	36	15	11	9.0	8.0	6.5	5.1											
6.5	104	68	30	11	8.3	6.4	5.1	4.3												
7	95	60	24	8.5	6.4	5.1	4.3	3.4												
7.5	87	53	21	7.1	5.3	4.4	3.6													
8	83	47	17	6.1	4.4	3.6	3.1													
8.5	78	42	15	5.2	3.7	3.1	2.6													
9	73	38	12	4.3	3.2	2.4														
9.5	69	34	9.9	3.8	3.5	2.2														
10	65	32	9.0	3.3	2.4	2.0														
10.5	62	29	8.0	3.0	2.1	1.9														
11	59	26	7.1	2.6	1.9	1.8														
11.5	56	24	6.3	2.4	1.8															
12	53	22	5.6	2.1	1.8															

Q0 = 0.07; S1 = 1.11; S2 = 2.38

*All values have been multiplied by 10,000. For angles, see Fig. B1.
†Adapted from reference 37.

tems. Two basic procedures are described as follows:

(1) *Method A* utilizes curves similar to those illustrated in Figures B8 and B9 as aids in calculating initial trial values of luminaire quantities and pole spacing. These curves may be computed by the luminaire manufacturer.

(2) *Method B* does not require the availability of these curves but utilizes an assumed spacing ratio as a starting point for determining the initial trial values.

After the trial values have been determined by either method, the exact placement of poles and luminaires are determined.

The general procedure for determining maintained illuminance includes the steps described in Section B3. It is important that these be followed and the various factors determined before proceeding with the special computations.

B5.2 Initial considerations. Determine the outline of the area to be lighted and select a tentative pole height. This height may be limited by soil conditions, maintenance concerns, grade differences, or other special factors. Select a tentative luminaire and lamp type.

B5.2.1 Method A.

(*1*) Calculate the area ratio (AR) by the for-

Figure B8. Example of CU (Coefficient of Utilization) versus AR (Area Ratio) curve.

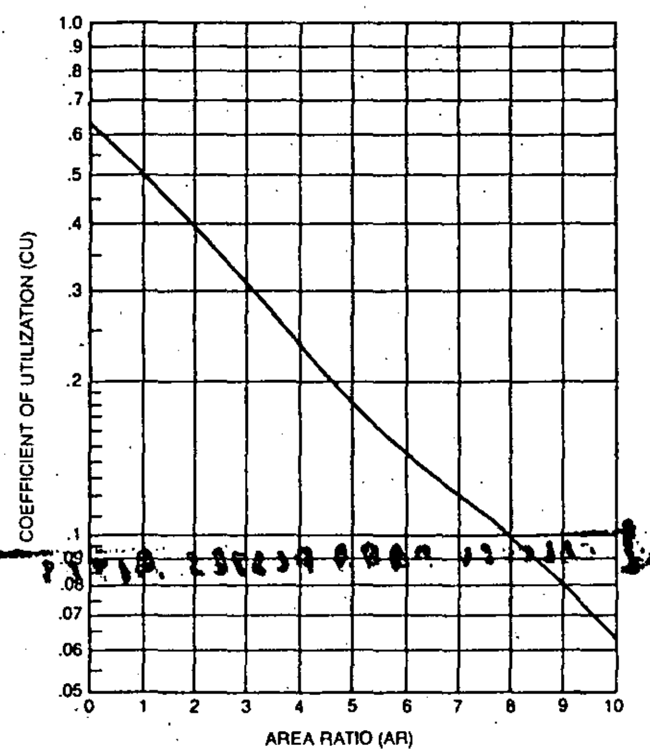


Table B2. r-Table for standard surface R2.*†

θ / tan γ	0	2	5	10	15	20	25	30	35	40	45	60	75	90	105	120	135	150	165	180
0	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390
0.25	411	411	411	411	411	411	411	411	411	411	379	368	357	357	346	346	346	335	335	335
0.5	411	411	411	411	403	403	384	379	370	346	325	303	281	281	271	271	271	260	260	260
0.75	379	379	379	368	357	346	325	303	281	260	238	216	206	206	206	206	206	206	206	206
1	335	335	335	325	292	291	260	238	216	195	173	152	152	152	152	152	141	141	141	141
1.25	303	303	292	271	238	206	184	152	130	119	108	100	103	106	108	108	114	114	119	119
1.5	271	271	260	227	179	152	141	119	108	93	80	76	76	80	84	87	89	91	93	95
1.75	249	238	227	195	152	124	106	91	78	67	61	52	54	58	63	67	69	71	73	74
2	227	216	195	152	117	95	80	67	61	52	45	40	41	45	49	52	54	56	57	58
2.5	195	190	146	110	74	58	48	40	35	30	27	24	26	28	30	33	35	38	40	41
3	160	155	115	67	43	33	26	21	18	17	16	16	17	17	18	21	22	24	26	27
3.5	146	131	87	41	25	18	15	13	12	11	11	11	11	11	12	14	15	17	18	21
4	132	113	67	27	15	12	10	9.4	8.7	8.2	7.9	7.6	7.9	8.7	9.6	11	12	13	15	17
4.5	118	95	50	20	12	8.9	7.4	6.6	6.3	6.1	5.7	5.6	5.8	6.3	7.1	8.4	10	12	13	14
5	106	81	38	14	8.2	6.3	5.4	5.0	4.8	4.7	4.5	4.4	4.8	5.2	6.2	7.4	8.5	9.5	10	11
5.5	96	69	29	11	6.3	5.1	4.4	4.1	3.9	3.8										
6	87	58	22	8.0	5.0	3.9	3.5	3.4	3.2											
6.5	78	50	17	6.1	3.8	3.1	2.8	2.7												
7	71	43	14	4.9	3.1	2.5	2.3	2.2												
7.5	67	38	12	4.1	2.6	2.1	1.9													
8	63	33	10	3.4	2.2	1.8	1.7													
8.5	58	28	8.7	2.9	1.9	1.6	1.5													
9	55	25	7.4	2.5	1.7	1.4														
9.5	52	23	6.5	2.2	1.5	1.3														
10	49	21	5.6	1.9	1.4	1.2														
10.5	47	18	5.0	1.7	1.3	1.2														
11	44	16	4.4	1.6	1.2	1.1														
11.5	42	14	4.0	1.5	1.1															
12	41	13	3.6	1.4	1.1															

Q0 = 0.07; S1 = 0.58; S2 = 1.80

*All values have been multiplied by 10,000. For angles, see Fig. B1.
†Adapted from reference 37.

Luminance (L): to be printed and/or recorded at the same points as horizontal illuminance values.

Average luminance (L_{avg}): to be determined by averaging all values of the evaluated roadway section.

Longitudinal luminance uniformity: lane uniformity (L_L) to be determined as the ratio of the maximum-to-minimum luminance in any one single quarter-lane line, taking the worst (highest ratio) as the rating for the roadway.

Average luminance uniformity (L_{avg}): to be determined by rating the average luminance (L_{avg}) to the minimum found in any of the lines within the roadway.

Maximum luminance uniformity (L_{max}): to be determined by rating the maximum luminance found in any of the lines to the minimum found in any of the lines within the roadway.

Table B5 is an illustration of a luminaires's distribution of luminous intensity.

The IES proposes to develop a simplified method of luminance calculations as a separate publication to supplement this Standard Practice.

CALCULO PARA POSTES ALTOS

B5. Calculation procedure for high mast interchange lighting

B5.1 Introduction. The computation of roadway luminance as previously described in this Appendix is not applicable for area lighting with high mast equipment. The reason for this is lack of applicable experience either in this country or overseas in the design of such lighting on a luminance basis or in consideration of pavement reflectance values. Past experience has indicated that a system designed to an illuminance criteria meeting the values in Table 3 of this Standard Practice will give satisfactory results.

High mast interchange lighting is defined as the lighting of a large area by means of a group of luminaires that are designed to be mounted in a fixed orientation (usually level) at the top of a high mast (generally 20 meters or higher). The area will normally contain a group of roadways such as an interchange or parking lots. (This procedure is not applicable for luminaires with both vertical and horizontal adjustments to be made on site, which is termed floodlighting.)

The high mast computation procedure will indicate an approximate number of luminaires per pole and pole spacing to provide the intended average illuminance and uniformity over the area in question. Specific locations for the poles are then determined to insure that all locations on the individual roadways within the area receive illuminance levels at least as high as the minimum value required to meet the uniformity criteria. There are a number of methods for computing high mast interchange lighting sys-

Table B4. r-Table for standard surface R4.*†

β / tan γ	0	2	5	10	15	20	25	30	35	40	45	60	75	90	105	120	135	150	165	180
0	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264	264
0.25	297	317	317	317	317	310	304	290	284	277	271	244	231	224	224	218	218	211	211	211
0.5	330	343	343	343	330	310	297	284	277	264	251	218	198	185	178	172	172	165	165	165
0.75	376	383	370	350	330	304	277	251	231	211	198	165	139	132	132	125	125	125	119	119
1	396	396	396	330	290	251	218	198	185	165	145	112	86	86	86	86	86	87	87	87
1.25	403	409	370	310	251	211	178	152	132	115	103	77	66	65	65	63	65	66	67	68
1.5	409	396	356	284	218	172	139	115	100	88	79	61	50	50	50	50	52	55	55	55
1.75	409	396	343	251	178	139	108	88	75	66	59	44	37	37	37	38	40	41	42	45
2	409	383	317	224	145	106	86	71	59	53	45	33	29	29	29	30	32	33	34	37
2.5	396	356	264	152	100	73	55	45	37	32	28	21	20	20	20	21	22	24	25	26
3	370	304	211	95	63	44	30	25	21	17	16	13	12	12	13	13	15	16	17	19
3.5	343	271	165	63	40	26	19	15	13	12	11	9.8	9.1	8.8	8.8	9.4	11	12	13	15
4	317	238	132	45	24	16	13	11	9.6	9.0	8.4	7.5	7.4	7.4	7.5	7.9	8.6	9.4	11	12
4.5	297	211	106	33	17	11	9.2	7.9	7.3	6.6	6.3	6.1	6.1	6.2	6.5	6.7	7.1	7.7	8.7	9.6
5	277	185	79	24	13	8.3	7.0	6.3	5.7	5.1	5.0	5.0	5.1	5.4	5.5	5.8	6.1	6.3	6.9	7.7
5.5	257	161	59	19	9.9	7.1	5.7	5.0	4.6	4.2										
6	244	140	46	13	7.7	5.7	4.8	4.1	3.8											
6.5	231	122	37	11	5.9	4.6	3.7	3.2												
7	218	106	32	9.0	5.0	3.8	3.2	2.6												
7.5	205	94	26	7.5	4.4	3.3	2.8													
8	193	82	22	6.3	3.7	2.9	2.4													
8.5	184	74	19	5.3	3.2	2.5	2.1													
9	174	66	16	4.6	2.8	2.1														
9.5	169	59	13	4.1	2.5	2.0														
10	164	53	12	3.7	2.2	1.7														
10.5	158	49	11	3.3	2.1	1.7														
11	153	45	9.5	3.0	2.0	1.7														
11.5	149	41	8.4	2.6	1.7															
12	145	37	7.7	2.5	1.7															

Q0 = 0.08; S1 = 1.55; S2 = 3.03

*All values have been multiplied by 10,000. For angles, see Fig. B1.
†Adapted from reference 37.

mula:

$$AR = \frac{2.5 \times \text{Pole Height} \times \text{Perimeter of Area}}{\text{Area}}$$

(2) Obtain the coefficient of utilization (CU) value from the CU versus AR curve for the luminaire involved (for typical curve, see Fig. B8).

The value for NLP should be rounded off to a whole number.

B5.2.2 Method B

(*1*) Assume a spacing-to-mounting height ratio typical for the type of luminaire involved. A value of 5 is common.

B5.3 Number of Poles. The number of poles (NP) is dependent on the area and spacing ratio and can be determined by the formula:

$$NP = \frac{\text{Area}}{(H \times SR)^2}$$

(3) Determine the spacing-to-mounting-height ratio (SR) as a function of the uniformity ratio (UR) desired by use of the SR versus UR curve for the luminaire involved (for a typical curve, see Fig. B9 and Section B5.7).

(4) Calculate the number of luminaires per pole (NLP) using the formula:

$$NLP = \frac{(AMI) \times (MH \times SR)^2}{(LL/L) \times (CU) \times (LLF)}$$

Note: MH = mounting height; LL/L = Lamp Lumens per Luminaire; and LLF = Light Loss Factor.

(*2*) Assume a value of average distance (pole to outer edge of lighted area) to mounting height ratio. Use this to obtain a coefficient of utilization value from utilization curve for the luminaire involved. (For typical curve see Fig. B10.)

(*3*) Calculate the total number of luminaires required (NL) using the formula:

$$NL = \frac{(AMI) \times (A)}{(LL/L) \times (CU) \times (LLF)}$$

A = Area

B5.4 Pole locations. From an isolux chart of the type shown in Fig. B10, determine two boundaries (usually circles); one for the minimum initial illuminance and the other for one-half the minimum initial illuminance value as follows:

(*1*) Minimum initial illuminance is average

Table B5—Example of Luminaire Distribution of Luminous Intensity

ACTUAL CANDLEPOWER VALUES FOR 22000. LUMENS. TEST NO 100715.

DEG H	0.0	6.5	14.9	24.9	34.8	44.8	54.9	64.9	69.9	74.9	79.9	84.9
0.0	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.
2.5	4580.	4648.	4580.	4648.	4535.	4580.	4558.	4637.	4580.	4626.	4694.	4637.
5.0	4694.	4739.	4694.	4660.	4739.	4535.	4614.	4637.	4614.	4614.	4694.	4660.
7.5	4626.	4626.	4592.	4694.	4694.	4535.	4637.	4637.	4580.	4671.	4524.	4654.
10.0	4626.	4535.	4671.	4637.	4694.	4535.	4592.	4614.	4614.	4603.	4637.	4535.
12.5	4626.	4535.	4614.	4637.	4694.	4580.	4580.	4614.	4671.	4637.	4671.	4614.
15.0	5714.	4648.	5567.	5034.	5601.	4535.	4716.	4694.	4671.	4637.	4660.	4637.
17.5	5759.	4648.	5748.	5555.	5669.	5601.	5669.	4716.	5487.	5068.	4614.	4558.
20.0	5827.	5782.	6145.	5737.	5782.	5714.	5782.	5748.	5657.	5113.	5147.	4592.
22.5	5759.	5669.	5827.	6632.	6961.	5873.	6201.	5850.	5771.	5612.	5147.	4614.
25.0	5782.	5782.	5805.	6825.	6916.	6734.	6224.	5759.	6145.	5850.	5714.	4660.
27.5	5827.	5669.	5748.	6825.	6916.	6916.	6372.	6201.	6258.	5714.	5850.	4716.
30.0	5782.	5782.	5805.	6802.	6734.	6916.	6315.	6258.	6315.	5805.	5816.	4671.
32.5	5782.	5669.	5771.	6712.	5782.	6576.	6394.	6360.	6179.	5771.	5805.	5113.
35.0	5782.	5827.	5714.	6621.	5782.	5759.	6394.	6315.	5725.	5771.	5771.	5099.
37.5	5646.	5669.	5691.	6247.	5827.	5873.	6236.	6734.	5725.	5805.	5793.	4660.
40.0	4694.	5442.	5487.	5669.	5759.	5669.	5771.	6167.	5771.	5827.	5669.	4558.
42.5	4535.	4739.	4637.	5691.	5487.	5714.	5578.	5748.	5748.	5725.	5204.	4614.
45.0	4422.	4535.	4149.	4614.	3492.	4648.	4535.	5771.	5748.	5714.	5147.	4654.
47.5	3560.	4308.	3038.	3877.	3560.	4308.	4467.	5748.	5657.	5204.	5034.	4580.
50.0	3447.	3515.	2680.	2744.	2267.	3560.	4388.	5680.	5590.	5034.	4694.	4614.
52.5	2267.	3288.	2347.	2211.	2313.	3401.	3560.	4671.	4637.	4614.	4614.	4524.
55.0	2381.	2267.	1757.	2211.	2381.	2313.	3310.	4535.	4592.	4535.	4637.	4552.
57.5	1338.	2267.	1723.	2256.	2381.	2267.	2880.	4569.	4592.	4614.	5782.	4614.
60.0	1134.	1179.	1236.	2324.	2426.	2381.	3503.	4637.	5714.	5748.	6504.	5816.
62.5	1224.	1338.	1213.	2335.	2358.	2381.	3447.	4671.	6791.	7313.	8582.	6848.
65.0	907.	1179.	1122.	1723.	2199.	2381.	3560.	6201.	6201.	7981.	11383.	9093.
67.5	907.	1247.	1088.	1213.	1224.	2472.	3174.	5873.	5601.	9013.	13627.	12516.
70.0	907.	1111.	1066.	1179.	1134.	2267.	2041.	3458.	5056.	9682.	13627.	15872.
72.5	0.	159.	57.	703.	1066.	1224.	1236.	2369.	4558.	9217.	12437.	15759.
75.0	45.	0.	23.	159.	113.	1179.	1077.	1723.	3900.	8662.	8038.	10850.
77.5	159.	0.	102.	23.	113.	907.	136.	1667.	2369.	4580.	3889.	5147.
80.0	91.	113.	68.	136.	113.	0.	68.	612.	556.	1780.	1213.	2211.
82.5	45.	45.	45.	91.	45.	159.	79.	102.	125.	1100.	136.	1088.
85.0	45.	45.	0.	45.	45.	113.	136.	79.	23.	159.	45.	136.
87.5	0.	45.	0.	45.	0.	45.	91.	181.	136.	181.	159.	23.
90.0	0.	0.	204.	0.	0.	45.	0.	91.	45.	136.	113.	102.
92.5	204.	204.	159.	181.	159.	0.	102.	68.	45.	136.	91.	113.
95.0	159.	159.	159.	159.	159.	204.	181.	0.	0.	45.	45.	102.
97.5	159.	159.	159.	159.	159.	159.	159.	102.	0.	0.	23.	68.
100.0	159.	159.	159.	136.	113.	159.	136.	204.	204.	0.	0.	45.
102.5	159.	159.	113.	113.	113.	159.	113.	159.	159.	204.	204.	0.
105.0	113.	159.	113.	113.	113.	113.	113.	159.	136.	181.	159.	102.
107.5	113.	113.	113.	113.	113.	113.	113.	136.	113.	181.	159.	159.
110.0	113.	113.	113.	113.	91.	91.	91.	113.	113.	113.	113.	159.
112.5	113.	113.	113.	91.	91.	91.	91.	113.	113.	113.	113.	136.
115.0	113.	113.	91.	91.	45.	45.	45.	91.	91.	113.	113.	136.
117.5	91.	91.	91.	91.	45.	45.	45.	91.	68.	91.	91.	125.
120.0	91.	91.	45.	45.	45.	45.	45.	45.	45.	45.	45.	91.
122.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
180.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

DEG H	89.9	94.9	104.9	114.9	124.5	134.9	144.9	154.9	164.9	174.9	179.9
0.0	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.	4631.
2.5	4648.	4637.	4614.	4614.	4671.	4637.	4660.	4660.	5034.	4637.	4648.
5.0	4614.	4614.	4637.	4648.	4648.	4716.	5045.	4716.	4637.	4671.	4648.
7.5	4546.	4580.	4127.	4592.	4637.	4648.	4592.	5056.	4694.	4614.	4535.
10.0	4569.	4444.	4591.	4104.	4070.	4682.	4059.	5011.	4592.	4614.	4694.
12.5	4614.	4501.	4490.	3968.	3934.	3979.	3503.	4660.	4501.	4580.	3560.
15.0	4580.	4535.	4070.	3781.	3503.	3481.	3481.	3424.	3503.	3481.	3560.
17.5	4614.	4546.	3945.	3747.	3526.	3583.	3333.	3413.	3549.	3447.	3515.
20.0	4592.	4580.	3481.	3520.	3424.	3447.	2800.	2834.	2347.	3197.	2381.
22.5	4660.	4535.	3549.	3515.	3254.	2823.	2347.	2392.	2313.	2290.	2358.
25.0	4671.	4467.	3481.	3447.	2823.	2347.	2256.	2313.	2222.	2347.	2086.
27.5	4558.	4501.	3401.	3333.	2392.	2290.	2267.	2199.	1190.	1712.	1247.
30.0	4671.	4501.	3481.	2744.	2369.	2313.	1610.	1667.	1213.	1179.	1134.
32.5	4637.	4467.	3537.	2365.	2426.	2143.	1213.	1213.	1270.	1315.	1292.
35.0	4660.	4648.	3424.	2744.	2256.	2041.	1156.	1236.	1270.	1292.	1338.
37.5	4569.	4467.	3481.	2857.	2313.	1644.	1338.	1315.	1292.	1134.	1134.
40.0	4422.	3591.	3481.	3413.	2267.	1689.	1315.	1315.	1134.	1179.	1224.
42.5	4490.	3991.	3526.	3465.	2778.	2177.	1190.	1315.	1202.	1247.	1292.
45.0	4422.	3591.	3481.	3503.	3356.	2426.	1315.	1338.	1270.	1338.	2086.
47.5	4524.	4501.	3424.	3526.	3481.	2330.	1236.	1179.	2109.	2120.	2313.
50.0	4558.	4694.	3424.	3345.	3197.	2301.	1179.	1224.	2154.	2256.	2313.
52.5	4535.	4614.	3537.	2993.	2857.	2058.	1202.	1247.	2199.	2290.	2381.
55.0	4444.	4524.	3458.	2970.	2721.	2075.	1156.	1292.	2177.	2324.	2381.
57.5	4648.	4546.	3549.	2857.	2449.	2109.	1236.	1247.	2063.	2347.	2267.
60.0	5725.	4614.	3560.	2880.	2449.	2177.	1179.	1270.	1292.	2165.	1224.
62.5	7279.	5158.	3481.	2846.	2324.	1644.	1213.	1179.	1213.	1281.	1224.
65.0	10226.	7936.	3447.	2347.	1655.	1236.	533.	1179.	590.	1247.	1111.
67.5	15385.	10872.	3526.	1825.	1270.	1202.	45.	204.	159.	1066.	159.
70.0	14818.	13140.	3345.	1043.	79.	1009.	79.	23.	23.	136.	91.
72.5	10906.	10328.	2392.	45.	136.	57.	23.	136.	159.	23.	159.
75.0	6757.	7426.	1190.	102.	45.	79.	79.	45.	23.	113.	45.
77.5	3537.	4422.	136.	0.	181.	23.	136.	147.	0.	0.	204.
80.0	1179.	1757.	113.	159.	113.	181.	102.	136.	159.	204.	159.
82.5	113.	907.	57.	113.	68.	113.	68.	113.	79.	181.	113.
85.0	136.	57.	136.	91.	45.	45.	23.	102.	23.	102.	45.
87.5	102.	23.	113.	45.	45.	23.	0.	79.	23.	45.	0.
90.0	159.	159.	113.	45.	23.	0.	0.	57.	0.	0.	0.
92.5	113.	113.	91.	45.	0.	0.	204.	57.	204.	102.	204.
95.0	113.	113.	45.	23.	0.	0.	181.	204.	181.	204.	159.
97.5	45.	68.	23.	0.	0.	204.	159.	159.	159.	159.	159.
100.0	45.	45.	0.	102.	204.	159.	159.	159.	113.	159.	113.
102.5	102.	0.	204.	181.	159.	159.	113.	113.	102.	113.	113.
105.0	204.	204.	159.	159.	159.	136.	113.	113.	68.	45.	45.
107.5	159.	181.	159.	159.	113.	113.	102.	102.	45.	45.	45.
110.0	136.	159.	159.	113.	113.	113.	45.	68.	45.	23.	0.
112.5	113.	159.	113.	113.	91.	91.	45.	45.	0.	45.	0.
115.0	113.	113.	113.	113.	91.	45.	45.	45.	0.	23.	0.
117.5	91.	113.	91.	91.	45.	45.	0.	0.	0.	23.	0.
120.0	91.	91.	45.	68.	45.	23.	0.	0.	0.	0.	0.
122.5	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
180.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.

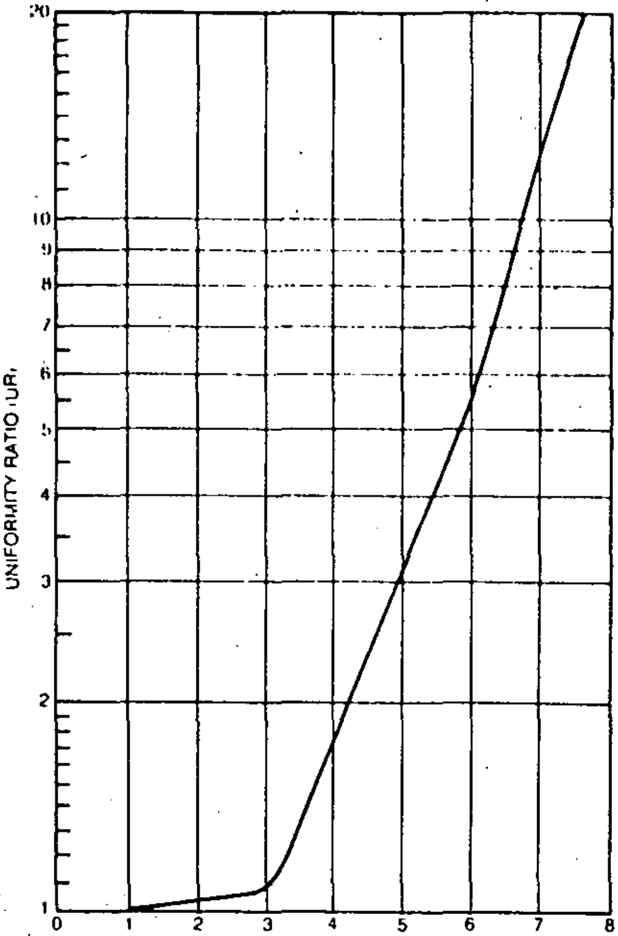


Figure B9. Example of spacing-to-mounting height ratio to average-to-minimum uniformity ratio curve.

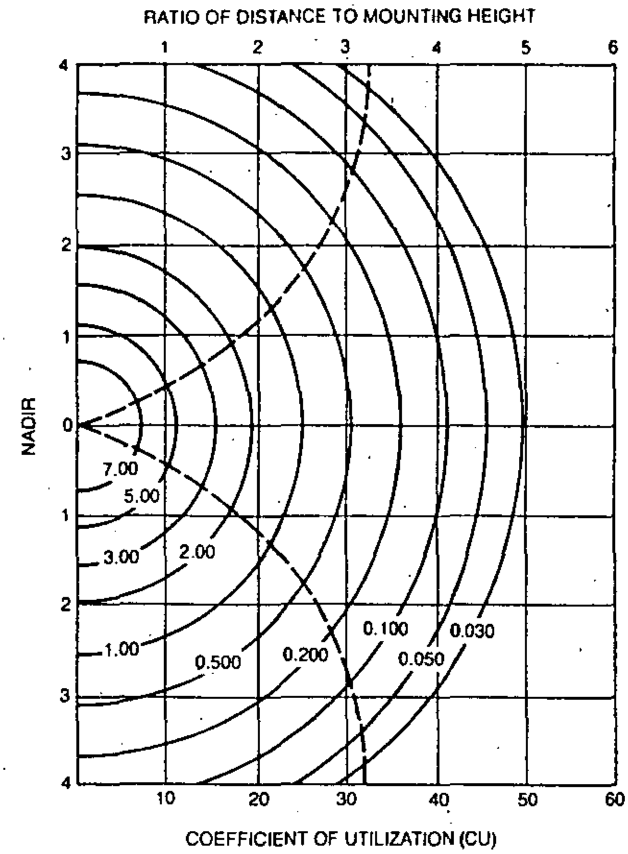


Figure B10. Example of isolux diagram and utilization curves on pavement (mounting height; 30 meters) for symmetric luminaire (110,000 lumen lamp). Dashed curve shows lumen utilization (in percent).

maintained illuminance divided by (Uniformity Ratio × Light Loss Factor).

(2) Either draw circles to scale or prepare templates to scale and superimpose these on the layout making certain that all roadway areas are covered by the minimum illuminance boundaries or by the overlap of two one-half minimum illuminance level boundaries.

(3) If the luminaires on a pole are not symmetric and are at varied orientations, the isolux chart should be a composite representing the array on the pole. Otherwise use the chart for an individual luminaire and multiply the curve values by the number of luminaires per pole.

B5.5 Recalculations. If suitable mounting locations can be found, determine by inspection if higher or lower pole heights may be more suitable, or if one or more poles should be located differently. Repeat the calculations above for a new trial and continue to repeat until a satisfactory solution is reached.

B5.6 Coefficient of utilization vs. area ratio curve. The curve shown in Fig. B8 can be prepared by combining concepts from the zonal cavity method with elements from the flux transfer theory.* Calculations are made in which:

(*1*) Area corresponds to cavity;

(*2*) Area Ratio corresponds to cavity ratio;

(*3*) Area-plane corresponds to work-plane.

The fraction of luminaire flux reaching the area-plane (which represents CU) is then determined for an arbitrary series of area ratios. This is done on a computer by summing the downward flux in a nested series of conic solid angles, ranging from nadir to horizontal about the luminaire. The flux, adjusted by zonal multipliers, are added together and then multiplied by the total downward utilization of the luminaire to produce the various CU values. (The CU for an area ratio of zero is taken equal to the total downward utilization of the luminaire.) The overall results can then be displayed in a CU versus AR curve. Such a curve can be prepared for either a symmetric or an asymmetric luminaire.

B5.7 Spacing ratio vs. uniformity ratio curve. This curve can be determined by calculating the uniformity ratio within a square shaped area bounded by four of the luminaires in question. All the luminaires are to face in the same direction. Each side of the square equals the spacing distance. This involves point calculations and can best be accomplished by use of a computer. Uniformity is to be calculated for a sufficient number of spacing-to-

* Material on these two subjects appears in the *IES Lighting Handbook, 1981 Reference Volume*, starting on page 9-6 under "Cavity Ratios" and on page 9-37 under "Coefficient Tables."

mounting height ratios to develop a curve such as that shown in Fig. B9. This is primarily applicable to symmetric luminaires but can be used with asymmetric luminaires with little loss in accuracy.

B6. Computation of walkway and bikeway illuminance

B6.1 Introduction. The procedure to determine the horizontal illuminance values on pedestrian ways for safe and comfortable use is similar to that followed for roadways as explained in the various steps under Section B3. In the case of isolated pedestrian ways, such as park walkways and Type B bikeways where the lighting provided is exclusively for the walkway and is arranged on either one or both sides of the paved area, the procedure is identical to computing roadway illuminance values, even to the point of using street side data from various luminaire curves. In the case of sidewalks (adjacent to roadways) and Type A bikeways, the procedure is very nearly the same as for roadway computation except that the house side curve data is often used. Because the area to be lighted for a Type A bikeway (roadside) is virtually identical to a sidewalk area, the sidewalk computation procedure suggested herein can be assumed to apply also for Type A bikeways (without further mention below to bikeways).

Because the design of roadway lighting places greater emphasis on achieving proper illuminance on the roadway, it is customary that the lighting system be initially selected to suit the needs of the roadway. Then, the system is checked to determine if the sidewalk illuminance levels and uniformity are adequate. If desired sidewalk requirements are lacking, the designer may modify the luminaire type and/or spacing or may provide supplemental lighting primarily for the sidewalk area, or may implement a combination of both techniques to achieve proper illuminance on both roadway and sidewalk. This procedure is sometimes reversed when greater emphasis is placed on the need for adequate sidewalk lighting, in which case Type I or II luminaires or post top luminaires are initially chosen primarily for sidewalk distribution and, when found satisfactory, are later checked for adequacy of roadway illuminance level and uniformity.

In some areas where personal security is a problem and identification of another pedestrian at a distance is important, the recommended levels on the right-hand side of Table 4 in the Standard Practice apply. These recommendations are stated in terms of the average vertical illuminance reaching a plane surface 1.8 meters above the walkway and perpendicular to the centerline of the walkway. The calculation procedure for vertical illuminance is discussed in paragraph B6.3.

B6.2 Determining horizontal illuminance. To calculate the average level of illuminance on the entire sidewalk with luminaires in their maintained condition, proceed as follows:

(1) Determine the coefficient of utilization (CU) for the sidewalk area only, as in paragraph B3.5.2., being sure to subtract from these calculations that portion of the CU that is related to flux falling on the street itself due to the transverse location of the luminaire.

(2) Calculate the average maintained illuminance level on the sidewalk due solely to the immediately adjacent luminaires, using the formula given in paragraph B3.5.3.

(3) For the same sidewalk area, determine the CU for the street side of the luminaires across the street.

(4) Calculate the average maintained illuminance level on the sidewalk due solely to the luminaires across the street, and add to that the illuminance coming from the luminaires on the same side of the street.

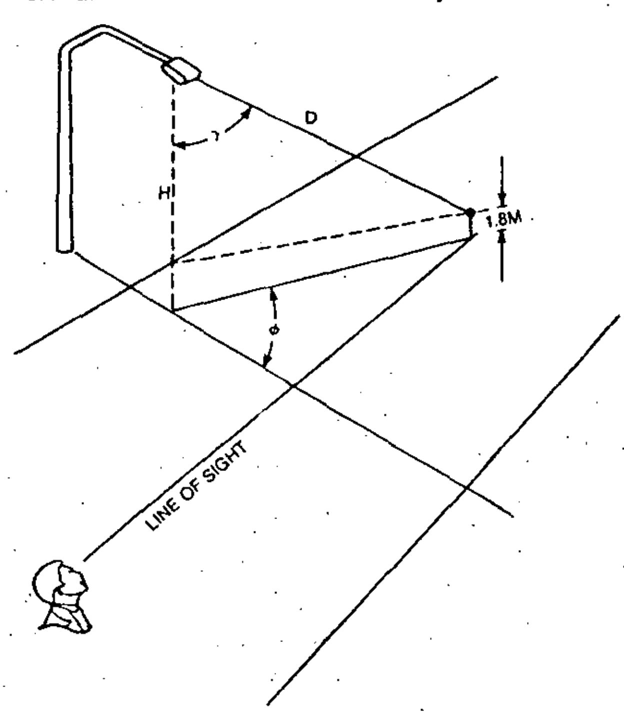
(5) Having calculated the average illuminance level across the entire sidewalk, it is now necessary to calculate the minimum level of illuminance, as described in paragraph B3.6 in order to compute the uniformity ratio.

B6.3 Determining vertical illuminance for security areas. The vertial illuminance at a specific point can be calculated by the inverse-square method of calculating illuminance (See the current edition of the *IES Lighting Handbook, Reference Volume*).[1] In this method, the candlepower of the luminaire at the particular angle involved is normally obtained from a luminous intensity chart, as shown in Table B5. The relevant geometry is shown in Fig. B11. The general form of the relationship is given by:

$$E_v = \frac{I(\phi, \gamma) \times \sin\gamma \times \sin\phi \times LLF}{D^2}$$

If it is assumed that the typical pedestrian facial area is approximately 1.8 meters above the sidewalk,

Figure B11. Geometric relationship for determining vertical illuminance on the face of a pedestrian.



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CURSOS ABIERTOS

ILUMINACION EXTERIOR:
PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

ILUMINACION DE AREAS DEPORTIVAS

PALACIO DE MINERIA

Current Recommended Practice for Sports Lighting

Prepared by the Committee on Sports and Recreational Areas of the Illuminating Engineering Society

The Illuminating Engineering Society, founded in 1906, is a non-profit organization devoted exclusively to the advancement and dissemination of theoretical and practical knowledge of the science and art of illumination, and supported by the membership of individuals and their companies.

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foreword

This report is a complete revision of the 1960 "Current Recommended Practice for Sports Lighting" and is the result of a continuing study of current practice, existing installations, and standards used in the sports lighting field. New features of this revised Practice include not only modifications which update the old recommendations, but also several additional sports are covered as well as a significantly enlarged section covering indoor sports. The recommendations contained herein do not necessarily represent all that might be considered acceptable, but they do reflect key elements considered necessary for acceptable quality installations.

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Approved as a transaction by the Council of the Illuminating Engineering Society, September, 1968

Table I—Current Illumination Recommendations[a]

Due to the wide choice of both lamps and lighting units, lamp sizes and quantities are not shown. The many factors governing the individual situation should be taken into consideration in recommending lamp sizes and quantities necessary to meet the desired classifications.

Lay-out on Pg. No.	Sport	Classification	Footcandles[b] Indoor			Footcandles[b] Outdoor		Dekalux[b,c] Indoor			Dekalux[b,c] Outdoor	
35	Archery	Target, Tournament	50[e]			10[e]		54[e]			11[e]	
		Target, Recreational	30[e]			5[e]		32[e]			5.4[e]	
		Shooting Line, Tournament	20			10		22			11	
		Shooting Line, Recreational	10			5		11			5.4	
	Audience Seating		See Seating									
26, 35	Badminton	Tournament	30			30		32			32	
		Club	20			20		22			22	
		Recreational	10			10		11			11	
	Baseball					Infield	Outfield				Infield	Outfield
35, 36	Jr. League Class I[f]	I (baselines 60′ or less)	—			30	20	—			32	22
	Jr. League Class II[g]	II (baselines 60′ & up to 75′)	—			30	20	—			32	22
	Baseball		Infield	Outfield				Infield	Outfield			
28, 35	Regulation	Major League	150	100		150	100	160	110		160	110
		AAA-AA	—			70	50	—			75	54
		A-B	—			50	30	—			54	32
		C-D	—			30	20	—			32	22
		Semi-Pro & Municipal	—			20	15	—			22	16
		Recreational	—			15	10	—			16	11
		Combination with Football	See Combination					See Combination				
18, 36	Basketball	College & Professional	50			—		54			—	
		College & Intramural & High School	30			—		32			—	
		Recreational	—			10		—			11	
37	Bathing Beaches	On Land	—			1		—			1.1	
		150′ from Shore	—			3[e]		—			3.2	
	Bicycle Track		See Racing					See Racing				
	Billiards	Tournament	50			—		54			—	
		Recreational	30			—		32			—	
24	Bowling		Approaches	Lanes	Pins			Approaches	Lanes	Pins		
		Tournament	10	20	50[e]	—		11	22	54[e]		
		Recreational	10	10	30[e]	—		11	11	32[e]	—	
		(For visual Considerations)										
		Tournament	70	100	200[e]	—		75	110	220[e]	—	
		Recreation	50	70	150[e]	—		54	75	160[e]	—	
		(For public attraction & increased business considerations)										

37	**Bowling on the Green**	Tournament	—		10		—		11	
		Recreational	—		5		—		5.4	
23, 37	**Boxing or Wrestling**	Championship	500		—		540		—	
		Professional	200		—		220		—	
		Amateur	100		—		110		—	
40	**Canadian Football-Rugby**	—	See Football				See Football			
37, 38	**Casting:**				Pier	Target			Pier	Target
	Bait, dry or wet	Recreational	—		10	5[v,b]	—		11	.54[v,b]
38, 39	**Combination**				Infield	Outfield & Football			Infield	Outfield & Football
		Baseball/Football	—		20	15	—		22	16
		Industrial Softball/Football	—		20	15	—		22	16
		Industrial Softball/6-man Football	—		20	15	—		22	16
39	**Croquet or Roque**	Tournament	—		10		—		11	
		Recreational	—		5		—		5.4	
26	**Curling**		Tees	Rink			Tees	Rink		
		Tournament	50	30	—		54	32	—	
		Recreational	20	10	—		22	11	—	
	Dragstrips	—	See Racing				See Racing			
40, 52	**Football (Regulation, Rugby or Soccer) Classification Index: Distance from nearest sideline to farthest row of spectators.**	Class I: over 100′	—		100		—		110	
		Class II: 50-100′	—		50		—		54	
		Class III: 30-50′	—		30		—		32	
		Class IV: under 30′	—		20		—		22	
		Class V: no fixed seating facilities	—		10		—		11	
		Combination with baseball	See Combination				See Combination			
41	**Football, Six-Man**	High School or College	—		20		—		22	
		Jr. High School or Recreational	—		10		—		11	
29, 41, 42, 45	**Golf**	Tee	—		5		—		5.4	
		Fairway	—		1, 3[*]		—		1.1, 3.2[*]	
		Green	—		5		—		5.4	
		Driving Range	—		10, 5[*]		—		11, 5.4[*]	
		Miniature	—		10		—		11	
		Practice Putting Green	—		10		—		11	
18	**Gymnasiums**	Exhibitions, Matches	50		—		54		—	
		General Exercising & Recreation	30		—		32		—	
		Assemblies	10		—		11		—	
		Dances	5		—		5.4		—	
		Locker & Shower Rooms	20		—		22		—	
		Audience Seating	See Seating				See Seating			
22, 42	**Handball —Four Wall or Squash**	Tournament	50		—		54		—	
		Club	30		—		32		—	
		Recreational	20		—		22		—	
	—Two-Court	Club	—		20		—		22	
		Recreational	—		10		—		11	

Table I—Current Illumination Recommendations*

Due to the wide choice of both lamps and lighting units, lamp sizes and quantities are not shown. The many factors governing the individual situation should be taken into consideration in recommending lamp sizes and quantities necessary to meet the desired classifications.

Lay-out on Pg. No.	Sport	Classification	Footcandles[h] Indoor	Footcandles[h] Outdoor	Dekalux[h,i] Indoor	Dekalux[h,i] Outdoor
25, 43	**Hockey** Field (180′ × 300′)	College or High School	—	20	—	22
	Hockey Ice (85′ × 200′)	Professional or College	100	50	110	54
		Amateur	50	20	54	22
		Recreational	20	10	22	11
43	**Horse Shoe Courts**	Tournament	—	10	—	11
		Recreational	—	5	—	5.4
44	**Horse Shows**	—	—	20	—	22
26	**Jai Alai**	Professional	100	—	110	—
		Amateur	70	—	75	—
44	**Lacrosse**	College & High School	—	20	—	22
	Ping Pong	—	See Table Tennis		See Table Tennis	
44	**Playgrounds**	—	—	5	—	5.4
	Putting Greens	—	—	See Golf	—	See Golf
45	**Quoits**	—	—	5	—	5.4
31, 32, 45, 46, 47, 48	**Racing**	Auto	—	20	—	22
		Bicycle Tournament	—	30	—	32
		Competitive	—	20	—	22
		Recreational	—	10	—	11
		Dog	—	30	—	32
		Dragstrip—Staging Area	—	10	—	11
		Acceleration 1,320′	—	20	—	22
		Deceleration, first 660′	—	15	—	16
		" second 660′	—	10	—	11
		Shutdown, 820′	—	5	—	5.4
		Horse	—	20	—	22
		Motor (midget or motorcycle)	—	20	—	22
	Rifle (50 Yards)	—	—	Firing Points 10; Range 5; Targets 50[v]	—	Firing Points 11; Range 5.4; Targets 54
23, 46	**Rifle & Pistol**		Firing Points 20; Range 10; Targets 100[v]	—	Firing Points 22; Range 11; Targets 110[v]	—
48	**Rodeo**	Professional	—	Arena 50; Pens & Chutes 5	—	Arena 54; Pens & Chutes 5.4
		Amateur	—	Arena 30; Pens & Chutes 5	—	Arena 32; Pens & Chutes 5.4
		Recreational	—	Arena 10; Pens & Chutes 5	—	Arena 11; Pens & Chutes 5.4

	Roque	—	—	See Croquet	—	See Croquet
	Seating	Before & After Event	5	5	5.4	5.4
		During Event	2	2	2.2	2.2
49	Shuffleboard	Tournament	30	10	32	11
		Recreational	20	5	22	5.4
50	Skating	Roller Rink	10	—	11	—
		Ice	10	5	11	5.4
		Lagoon, Pond or Flooded Area	—	1	—	1.1
29, 50	Skeet	—	—	Firing Points: 5; Targets: 30[e]	—	Firing Points: 5.2; Targets: 32
51	Skeet & Trap	Combination		Firing Points: 5; Targets: 30[d,e]		Firing Points: 5.4; Targets: 32[d,e]
51	Ski slope	Recreational	—	1	—	1.1
52	Soccer	—	—	See Football	—	See Football
39, 52, 53	Softball			Infield / Outfield		Infield / Outfield
		Professional & Championship	—	50 / 30	—	54 / 32
		Semi-Professional	—	30 / 20	—	32 / 22
		Industrial League	—	20 / 15	—	22 / 16
		Recreational (6-pole)	—	10 / 7	—	11 / 7.5
		Slow Pitch, Tournament	—	20 / 15	—	22 / 16
		Slow Pitch, Recreational (6-pole)	—	10 / 7	—	11 / 7.5
		Combination with football	—	See Combination	—	See Combination
	Squash	—	See Handball		See Handball	
27, 53	Swimming	Exhibitions	50	20	54	22
		Recreational	30	10	32	11
		Underwater	100[a]	60[a]	110[a]	65[a]
21	Tennis, Table	Tournament	50	—	54	—
		Club	30	—	32	—
		Recreational	20	—	22	—
25, 30, 54	Tennis, Lawn	Tournament	50	30	54	32
		Club	30	20	32	22
		Recreational	20	10	22	11
54	Trap			Firing Points: 5; Targets: 30[d]		Firing Points: 5.4; Targets: 32
33, 55	Volley Ball	Tournament	—	20	—	22
		Recreational	—	10	—	11
	Wrestling		See Boxing			See Boxing

[*] Telecasting or other special considerations may require higher levels of illumination. See Section 2.2.
[a] lamp lumens per square foot of water surface.
[b] footcandles (dekalux), vertical, at 80 feet (24.4 meters) for Bait Casting; 50 feet (15.2 meters) for wet or dry-fly casting.
[c] 5 footcandles (5.4 dekalux), vertical, at 200 yards (183 meters) and 10 footcandles (11 dekalux), horizontal, over tee area.
[d] 30 footcandles (32 dekalux), vertical, on trap target at 100 feet (30.5 meters).
[e] 30 footcandles (32 dekalux), vertical, on skeet target at 60 feet (18.3 meters)
[f] Class I Jr. League Baseball includes Little League, Little Boys League, Khoury League, etc.
[g] Class II Jr. League Baseball includes Pony League, Bigger League, etc.
[h] all values represent minimum maintained illumination in a horizontal plane unless otherwise indicated.
[i] one dekalux equals ten lux, the SI unit for illumination.
[v] illumination on a vertical plane.

1. Introduction

1.1 General. **(a)** We have witnessed an unparalleled growth in sports and recreational lighting. Baseball, with its various leagues, has probably led the way to public acceptance for the lighting of practically every outdoor sport. This is evidenced by more and more lighted football fields, softball diamonds, golf driving ranges, and a host of sport and recreational play areas for player and spectator night participation.

(b) The lighting of areas used for various sports activities, especially those located outdoors, involves problems not encountered in other fields of lighting. Some of these problems, including, for example, the selection of proper floodlight locations, aiming techniques, and provisions for multiple uses of an area and its lighting facilities have not previously been covered by other Illuminating Engineering Society recommended practices.

1.2 Purpose. The purposes of this report are to aid in the design of new lighting systems and in the evaluation of existing installations.

1.3 Content. The text of the report consists of four basic parts: (1) recommended footcandle (lux) levels satisfactory to both players and spectators, (2) quality requirements prerequisite to good visibility, (3) recommendations of floodlight types, mounting heights, and mounting locations for specific sports, and (4) layouts of typical and existing illustrative sports lighting installations which conform to current good practice.

1.4 Scope. This recommended practice covers all forms of sports from the so-called major professional sports, such as baseball and football, to the recreational and playground sports, such as horseshoe pitching and croquet. It also includes recommendations for the lighting of gymnasiums and other interior areas specifically designed for sports activities, such as squash, handball, and bowling.

2. Factors of Good Illumination

2.1 Illumination Levels. **(a)** It is important that levels of illumination be sufficient for comfortable and accurate seeing and to enable (1) the players to perform their visual task and (2) the spectators to follow the course of the play.

(b) In those sports where large numbers of spectators are expected, as in large football and baseball stadiums, the illumination level is determined by the amount required for the spectators, in the row of seats farthest removed from the playing area, to follow the course of play. This condition may require several times the amount of light found satisfactory for the players. The illumination levels suggested by Table I are those which are currently considered minimum values of good practice, taking into consideration both players and spectators.* In commercial establishments, much higher levels may be a profitable investment in increasing patronage and sales. It should also be borne in mind that nearly all sports evolved under daytime levels and that they can usually be played best and enjoyed most under these levels.

(c) *It is important to note that the illumination values in Table I are, in most cases, stated as horizontal footcandles (lux) maintained in service.* It is recognized that the vertical component of the illumination on the playing area is important in most sports. Particularly in the "aerial" games, both players and spectators rely, to a considerable degree, on the vertical illumination on or near the playing area and, in some cases, well above the playing area. The same is true of movies and television, for the normal viewing position. In full recognition of the importance of *vertical* illumination, the recommended footcandle (lux) values for most sports and recreational areas are given in terms of horizontal illumination for two reasons: (1) values of horizontal footcandles (lux) are much less complicated to compute and measure in the field, and (2) the vertical components of illumination have been found adequate when the horizontal illumination meets the values in Table I, and when lighting equipment of the proper type (see Table II) is positioned at mounting heights and locations conforming to accepted good practice. Unless otherwise noted, the recommended values in this table are horizontal footcandles (lux) on the playing surface, or for "aerial" sports, horizontal footcandles (lux) on a plane 36 inches (91 centimeters) above the ground or floor.

2.2 Movie and Television Lighting Requirements. **(a)** When expanding the audience of athletic events by television or by recording the events on motion picture film, it is usually required that special attention be given to lighting. Lighting layouts that provide a high photographic quality of light are necessary. Definite consideration should be given to the type of sport and playing conditions in designing this lighting. Events requiring great depth of field will obviously require higher lighting levels.

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*It will be found that in Table I, several sports are shown with two or more recommended illumination levels for what appear to be identical visual tasks, such as indoor and outdoor lawn tennis, or golf driving ranges and golf courses. Actually, the visual tasks are not identical. In the case of lawn tennis, the contrast between the ball and the background wall indoors is more often less than the contrast realized outdoors at night; therefore, higher levels are required indoors. Golf driving ranges require higher levels than regular courses because one of the driving range tasks involves identifying one golf ball from a background of many—a more difficult situation than that usually found in a golf course.

Table II—Outdoor Floodlight Luminaire Designations*

Beam Spread Degrees	NEMA Type	Minimum Efficiencies (per cent)**				
		Incandescent Lamps		Mercury Lamps		Fluorescent Lamps
		Effective Reflector Area in Square Inches (Square Centimeters)				
		Under 227 (1460)	Over 227 (1460)	Under 227 (1460)	Over 227 (1460)	Any
10 up to 18	1	34	35	—	—	20
18 up to 29	2	36	36	22	30	25
29 up to 46	3	39	45	24	34	35
46 up to 70	4	42	50	35	38	42
70 up to 100	5	46	50	38	42	50
100 up to 130	6	—	—	42	46	55
130 and up	7	—	—	46	50	55

* Taken from National Electrical Manufacturers' Association, 155 East 44th Street, New York, New York 10017, Publication #FL 1-1964.

** Indicative of what can be expected from typical equipment.

(b) The actual footcandle (lux) level requirement will vary depending upon the lens opening, the type of pick-up tube or film, color or black and white, and other circumstances peculiar to the athletic event. Care should be taken to insure proper contrast between equipment used in the sporting event such as balls, bats, uniforms, etc. and the background. Normal luminance ratios for television pickup should be on the order of 20:1. If the luminance ratio is exceeded, there will be accompanying loss of detail in highlights and shadows. When the luminance ratio is less than 20:1, contrast and resultant differentiation between objects is lessened. Placement of lighting equipment to provide light from at least two directions is suggested to model participants. This modeling light can easily provide the brightness difference to separate objects from their background.

2.3 Quality of Illumination

2.3.1 *General.* The quality of lighting, whether daylight or electric light, is highly important in providing good seeing conditions. *Glare control, uniformity, and direction are the most significant factors in determining the quality of illumination.*

2.3.2 *Glare Control.* A floodlight is inherently a glare source; therefore, one of the primary tasks of the illumination designer should be to reduce the objectionable effects of glare to a minimum. The basic factors with which the designer may accomplish this task are: proper beam spread, adequate mounting heights, proper luminaire locations, and proper floodlight aiming.

2.3.2.1 *Beam Spread.* As the distance from the floodlight to the area to be lighted increases, the beam spread of the floodlight used should be decreased (see Fig. 1). The use of a floodlight with too great a vertical beam spread for a particular application can result in glare and ineffective utilization of available light (Fig. 2).

2.3.2.2 *Mounting Height.* Recommended minimum mounting heights are shown on the recommended layouts. Where, for physical or economic reasons, it is considered necessary to utilize lower mounting heights, the possibility of objectionable glare should be considered (see Fig. 3). For floodlighting applications, the following basis may be used to determine mounting heights which are minimum from the standpoint of glare: (1) *The angle between the horizontal playing surface and a line drawn through the lowest mounted floodlight and a point 1/3 the distance across the playing field should not be less than 30 degrees,* and (2) in addition to meeting the requirements above, *the minimum mounting height should not be less than 20 feet (6.1 meters) for ground sports and 30 feet (9.1 meters) for aerial sports.* See Fig. 4.

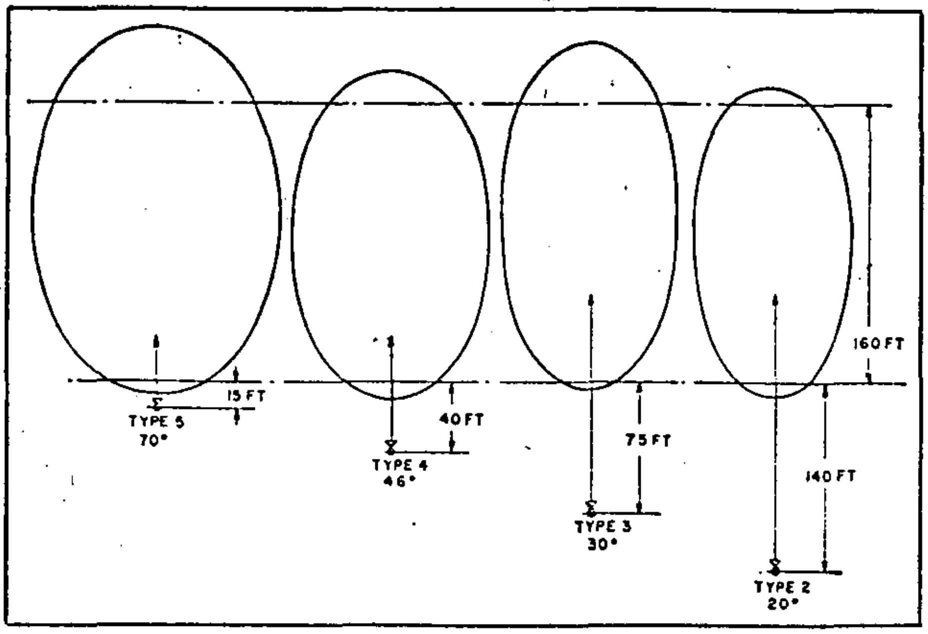

Figure 1. To maintain same beam pattern with varying distances from area to be lighted, beam spread must be reduced. (Mounting height is as recommended in mounting height chart, page 55.)

Note: 15 ft = 4.6 m; 40 ft = 12.2 m; 75 ft = 22.9 m; 140 ft = 42.7 m; 160 ft = 48.8 m.

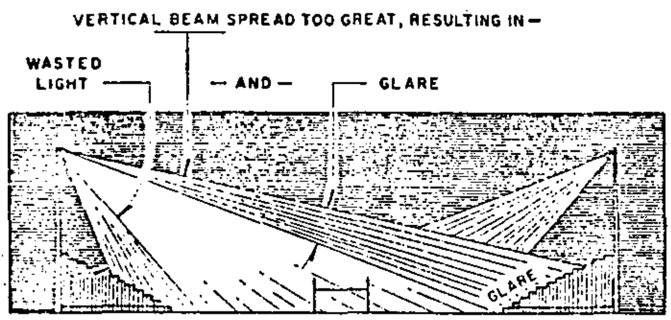

Figure 2. Floodlights with too great a vertical beam spread waste light and cause glare.

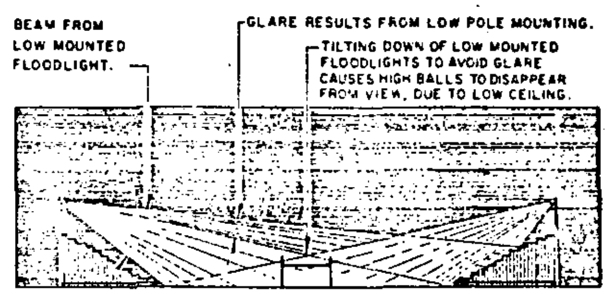

Figure 3. Sports floodlights mounted on poles that are too low either cause glare in the spectators' eyes or do not illuminate high-flying balls.

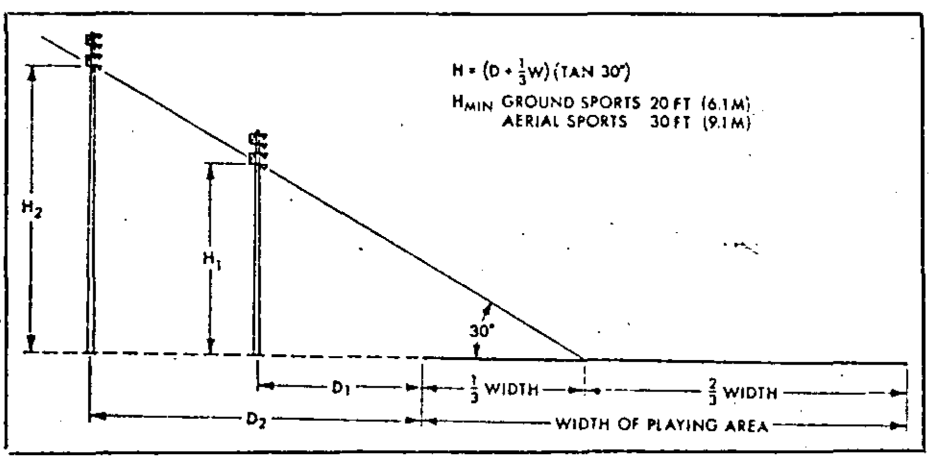

Figure 4. For adequate mounting heights, a line drawn from a point one-third the distance across the playing field to the lowest mounted floodlight should form an angle with the horizontal of not less than 30 degrees. In addition, minimum height for ground sports should not be less than 20 feet (6.1 meters); for aerial sports, not less than 30 feet (9.1 meters).

2.3.2.3 *Luminaire Location.* (a) The effects of glare are diminished as the luminaires are removed from the normal lines of sight of players and spectators. The angle between the luminaire and the normal line of sight depends upon both the distance of the luminaire from the observer and the luminaire's mounting height.

(b) The luminance of floodlights, particularly narrow beam types, is lower as they are viewed at increasing angles to the axis of the beam. For this reason, particular emphasis should be placed on location and aiming so that, within practical limits, floodlights are not directed along normal lines of sight of spectators or players (see Fig. 5).

(c) The recommended layouts show luminaire locations which reflect balanced judgment with regard to providing light from the proper direction, and at the same time locating the luminaires out of

the normal lines of sight. Where physical obstructions require changes from these typical locations, all lines of sight of both players and spectators should be carefully evaluated in determining the new locations of the luminaires.

(d) With indoor applications, where fixed equipment is mounted on or near the ceiling, two angular regions are involved: (1) the angle between a horizontal line through the light center and the line of sight at which the bare source first becomes visible (called the shielded zone) and (2) the angle within which the lamps are visible (called the unshielded zone).

(e) Excessive luminance within the shielded zone may cause glare, particularly in large spaces. Luminance in the unshielded zone may cause direct glare or glare by reflection from the specular surfaces of bowling lanes, the surface of the water in swimming pools, or from polished floors and walls. In addition, the luminance of the luminaire in the unshielded zone may cause discomfort or even disability glare as players or spectators look upward. This possibility is minimized by so locating the luminaires that they are moved as far as possible from the normal line of sight and/or by using sources of low luminance.

2.3.2.4 *Luminaire Luminance Reduction.* (a) In the many sports where light must come into the playing area from many different locations, it is not always possible to remove all of the luminaires from the normal lines of sight of both players and spectators. Where this situation exists, the use of glare shields or some form of louvering (see Fig. 6) should be considered to reduce the high luminance of excessive spill light which might cause discomfort to spectators, or even to inhabitants of the surrounding area. The annoyance of light spilling into the region surrounding the playing area is often overlooked in the design of a sports lighting installation.

(b) Both glare shields and louvers can be designed to control only that light at certain angles which might cause annoyance. It is not necessary that such a device block all of the spill light or excessively reduce the light output of the luminaire. However, the amount of light reduction will depend upon the particular louver design employed. For any specific louver-floodlight combination, some reduction in the published lumen output of the floodlight alone may have to be allowed for in the installation design. It is recommended that a qualified engineer be consulted before attempting a specific louver design.

2.3.2.5 *Surround Luminance.* Increasing the luminance of the surround reduces the luminance difference between luminaire and surround and improves visibility. This can be done very effectively for

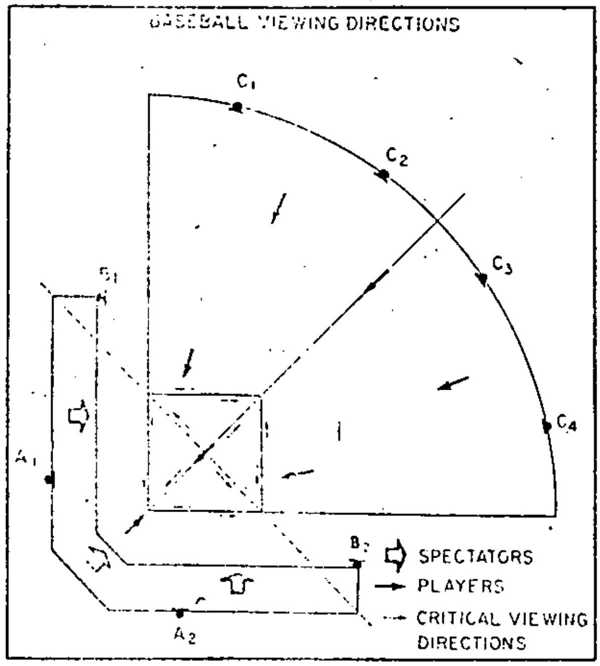

Figure 5. Where physical obstructions require changes from the recommended pole locations, an analysis should be made of possible lines of sight of both players and spectators before new positions are selected. Poles should never be located directly in line with critical viewing directions.

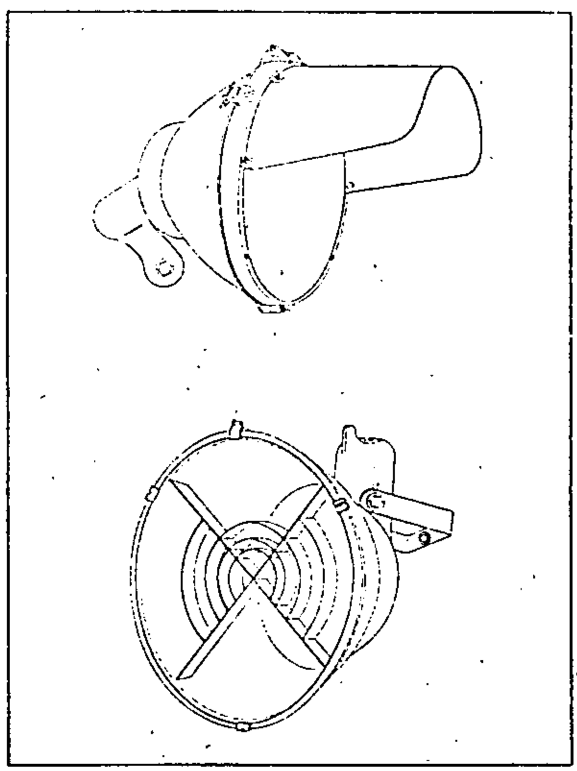

Figure 6. Properly designed glare shields (top) or louvers (below) can effectively eliminate, at certain angles, the high luminaire luminance that might cause annoyance either inside or outside the playing area.

indoor sports by finishing the walls and ceilings of the rooms in light colors. Control of the surround luminance is much more difficult in outdoor locations; however, a great deal can be done in this regard. Adequate light in the stands and light colored fences, together with provisions for providing some illumination on the ground immediately around the playing field, aids considerably in improving the surround conditions.

2.3.3 *Uniformity.* Reasonable uniformity of illumination over a playing area, and throughout the entire space above the playing area, is required for satisfactory seeing by players and spectators. Sharp changes in the illumination level in the space above the playing area through which the ball may travel will result in making a fast moving ball appear to accelerate as it passes from a light to a dark space. This occurs when there is inadequate overlap of floodlight beams. Such a condition distorts the player's judgment of ball trajectory. Expressed in terms of horizontal illumination, *acceptable uniformity occurs when the ratio of maximum to minimum illumination does not exceed three to one within a specified area* for those sports in which play is skillful, the visual task is severe, or there are likely to be spectators.

2.3.4 *Direction of Light.* (a) The luminance difference between an object and its surround, as well as the luminance difference between the various surfaces of an object, provide the contrast required for the eye to see. Since the visual tasks of the spectators and players involve seeing vertical surfaces as well as horizontal surfaces, it is essential to provide adequate illumination on both the horizontal surfaces and the vertical surfaces of a solid object. However, as the objects of view in sports are not flat-faced solids, it is not essential to provide uniform illumination on all surfaces; in fact, semidirectional illumination provides shading and modeling which aids seeing. To eliminate harsh shadows, however, and to permit good visibility at any location in the playing area for both players and spectators, it is generally necessary to provide light from several different directions at each point throughout the area. Good directional quality of the lighting in a sports installation is not characterized by the absence of shadows (since the very nature of floodlighting tends to produce shadows) but rather by the number of shadows produced (Fig. 7).

(b) For unidirectional sports, such as bowling, driving golf balls, racing, handball, archery, etc., it is permissible and desirable to provide much higher footcandles (lux) from one direction. This makes it possible to locate the luminaires so that they are almost completely removed or shielded from the normal field of view.

(c) The aiming of the floodlights, even with the correct luminaire locations and mounting heights, determines to a large extent whether the uniformity, direction and candlepower toward the eye are satisfactory. For information concerning the correct fundamentals of aiming floodlights, see Appendix A, Fig. A-1.*

2.4 **Maintenance.** See Appendix B.**

3. Classification of Play

3.1 Player Requirements. Player requirements vary with the class of play. The *tournament* classification applies to the caliber of play as found in tournaments and exhibitions; the *club* classification applies to good, fast play; the *recreational* classification applies to amateur play for fun and relaxation.

3.2 Spectator Requirements. Spectator requirements for satisfactory seeing vary with the type of sport, distance from and orientation to the playing field. A stadium where the last row of spectators is several hundred feet away from the playing area

*See Illuminating Engineering, Vol. 56, February 1961, p. 76.
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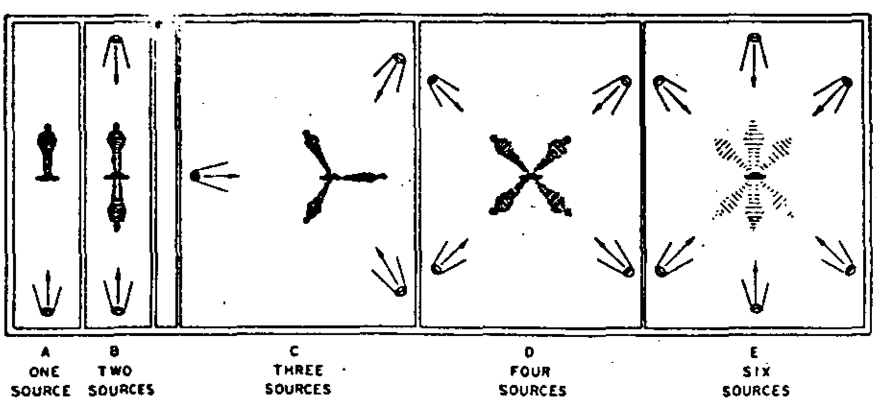

Figure 7. Shadows occur on floodlighted fields but their effect is minimized by proper aiming of lights. Note how an increase in the number of light sources (from A to E) reduces the effects of shadows.

must be lighted to a high level of illumination if the more remote spectators are to follow the play. If the spectator section is limited to small bleachers along sides of the field, the illumination level which .d provide good playing conditions will adequately serve the spectators.

3.3 Commercial Requirements. It is recognized that many sports are played or watched in commercial establishments where levels of illumination must be based on additional factors of atmosphere, attraction value, and better than adequate seeing. This has been true in major league baseball for some time, but applies also, for example, to racing, bowling, archery, and all sports in commercial arenas. Since recommended levels based on commercial considerations depend on many factors which require further study, such considerations are not necessarily included in the values in Table I except where shown as in the case of bowling.

4. Equipment Classification

4.1 General. (a) The optical characteristics of the luminaire affect, to a large extent, such important factors as direct and reflected glare, shadows, distribution and diffusion. Because there are wide variations in these optical characteristics, the selection of the correct luminaire for a particular application deserves careful consideration.

(b) Luminaires should be designated so as to describe the manner in which the light from the lamp is controlled by the lighting unit, the degree of concentration of zonal lumens (concentration of light), and mechanical details. Since in sports and recreational area lighting there are both outdoor and indoor lighting problems, the lighting equipment should necessarily be selected to qualify for the service designated. There are, therefore, separate designations and classifications pertaining to outdoor and indoor lighting equipment.

4.2 Outdoor Floodlight Luminaire Designations

4.2.1 *Floodlight Classes.* (a) *Enclosed Heavy-Duty (HD).* This class is weatherproof, having a substantially constructed housing into which is placed a separate and removable reflector. The assembly is enclosed by a weatherproof hinged door with cover glass, which provides an unobstructed light opening at least equal to the effective diameter of the reflector.

(b) *Enclosed Ground-Area and General Purpose (GP).* This class is weatherproof and so constructed that the housing forms the reflecting surface. The assembly is enclosed by a cover glass.

(c) *Ground-Area Open (O).* This class provides a weatherproof enclosure for the lamp socket and housing. No cover glass is required.

(d) *Ground-Area Open with Reflector Insert (OI).* This class is weatherproof and so constructed that the housing forms only a part of the reflecting surface. An auxiliary reflector is used to modify the distribution of light. No cover glass is required.

4.2.2 *Beam Data.* (a) The choice of the light distribution of a luminaire may be selected and designated by type as shown in Table II. *Beam spread is the average of the horizontal and vertical spreads,* and for the purpose of classifying floodlights, the method of determining and recording the beam spread should be in accordance with the adopted report of the IES Committee on Testing Procedures for Illumination Characteristics.*

(b) Asymmetrical beam floodlights may be designated by a combination type designation which indicates the horizontal and vertical beam spreads in that order; e.g., a floodlight with a horizontal beam spread of 75 degrees (Type 5) and a vertical beam of 35 degrees (Type 3) would be designated as a Type 5 X 3 floodlight.

4.2.3 *Method of Designation.* Floodlights covered by the above may be designated as Heavy Duty, Type 1, 2, 3, etc., General Purpose, Type 1, 2, 3, etc., and Open Type 4, 5, 6, etc.

4.2.4 *Performance Characteristics.* In addition to beam types and floodlight class characteristics, the National Electrical Manufacturers Association's "Standards Publication for Floodlights" specifies the minimum beam efficiency that each class and type of floodlight should provide. The summary of photometric data in Table II is indicative of what can be expected from typical equipment.

4.3 Reflectorized Lamps. Lamps having integral reflectors are applied particularly to the minor sports. Outdoor types with heat resistant glass bulbs may be considered as physically corresponding to the general purpose category. Substitution of reflectorized lamps for floodlighting luminaires should be on the basis of equal lumens delivered in service. See manufacturers' publications for photometric data and application.

4.4 Interior Lighting Luminaire Design. (a) Interior lighting luminaires may be classed into five different types, based on the manner in which light is distributed from the luminaire. These classifica-

*"IES Guide for the Photometric Testing of Floodlights of 10 to 160 Degrees Total Beam Spread." ILLUMINATING ENGINEERING, Vol. 46, March 1951, p. 163.

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tions apply to all interior luminaires regardless of the type of source the luminaire employs. The type designations do not in themselves imply quality of lighting or luminaire efficiency. The figures given in Table III indicate the percentage of the total luminaire light output emitted upward and downward.

(b) Direct luminaires may be further classified so as to denote concentration of zonal lumens (concentration of light), such as concentrating, medium spread and wide spread.

4.5 Photometric Data. The method of determining and recording photometric data should be in accordance with the adopted report of the IES Committee on Testing Procedures for Illumination Characteristics.*

5. Lighting Systems

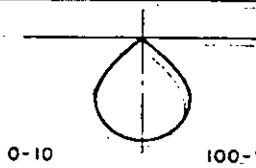
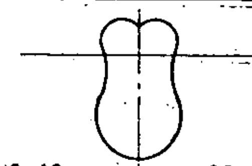
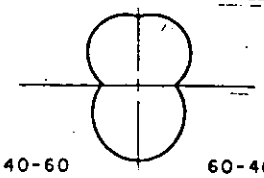
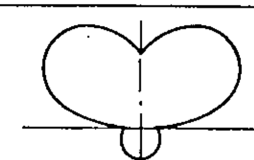
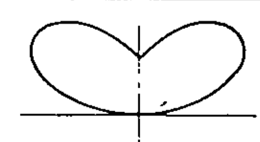
5.1 General. For sports lighting applications, there are three basic types of light sources in use today: incandescent, fluorescent, and high intensity discharge. Each type has certain advantages and disadvantages and the proper selection, from among these sources, will depend upon the particular requirements of the installation being considered, the economics (see Appendix F** for a suggested format of an economic analysis), and perhaps some personal preference of the system designer or owner.

5.2 Incandescent Filament Lighting. (a) The chief advantages of incandescent lighting are its low initial cost, good color rendering properties, and good optical control capabilities. Disadvantages are shorter lamp life and lower lamp efficacy (lumens-per-watt) as compared to the other light sources. Included in the family of incandescent are the tungsten-halogen lamps, having a much better light output maintenance characteristic and longer lamp life than standard incandescent lamps. In addition, the tungsten-halogen lamp can be compact in physical size and of a shape that results in small luminaires.

(b) Overvoltage operation of incandescent lamps, including tungsten-halogen lamps, can often be used to economic advantage in sports lighting. This is especially important if a lighting system is used for only a few hundred hours or less each year. In general, operation at 10 per cent above rated voltage (resulting in an approximate 35 per cent increase in light output, 15 per cent increase in lamp wattage, and a reduction in lamp average life to 30 per cent) is recommended if the lighting system is in use for less than 200 hours. Operation at 5 per cent above rated voltage (resulting in an approximate 17 per cent increase in light output, 7 per cent increase in lamp wattage, and a reduction in lamp average life to 50 per cent) is recommended if the lighting system is used from 200 to 500 hours per year. If annual use exceeds 500 hours, lamp operation at rated voltage is recommended.

5.3 Fluorescent Lighting. A fluorescent lighting system provides high lumens per watt, long lamp life, low brightness, and good color rendition, but is generally higher in initial cost than its incandescent filament counterpart. For indoor applications, louvers are desirable for use with fluorescent luminaires to provide lamp protection as well as maximum shielding. The semi-direct type luminaire is recommended for use where the luminaire is mounted in

TABLE III
Interior Luminaire Designations

TYPE (CIE CLASSIFICATION)	APPROXIMATE DISTRIBUTION OF LIGHT EMITTED BY LUMINAIRE		
	UPWARD PER CENT		DOWNWARD PER CENT
DIRECT	0-10		100-90
SEMI-DIRECT	10-40		90-60
GENERAL DIFFUSE	40-60		60-40
SEMI-INDIRECT	60-90		40-10
INDIRECT	90-100		10-0

*IES Guide for Reporting General Lighting Equipment Engineering Data," ILLUMINATING ENGINEERING, Vol. 54, August 1959, p. 530.
**In reprint only.

reasonably close proximity to the ceiling to reduce luminance differences and to provide adequate diffusion over the area. Fluorescent luminaires are applicable for certain outdoor sports and recreational eas where mounting heights are relatively low and equired projection distances are short. Typical applications would include bowling, curling, tennis and similar sports.

5.4 High Intensity Discharge Lighting. The family of high intensity discharge lamps include the mercury lamps, the metal halide lamps, and the high pressure sodium lamps. Although each of these lamp types has its own specific characteristics, they have the following characteristics in common: long lamp life and high luminous efficacy when compared to incandescent lamps, a time delay and slow build up of light output when the lighting system is first energized or when there is a power interruption. Because of this time delay characteristic, it may be desirable to include an incandescent lighting system to provide emergency stand-by illumination, particularly over spectator areas. Properly designed, a high intensity discharge lighting system may require fewer luminaires for a given lighting requirement, but these luminaires are usually higher in initial cost than incandescent luminaires. See Appendix F.*

5.4.1 *Mercury Lighting.* In those sports where color rendition is of some importance, improved-color phosphor-coated mercury lamps are usually recommended rather than clear mercury lamps. It should be noted, however, that phosphor-coated lamps provide inherently wide beam spreads. Over-wattage operation of mercury lamps is feasible, within limits, resulting in an increase in light output proportional to the increase in lamp wattage with a major reduction in mercury lamp life.

5.4.2 *Metal Halide Lighting.* The metal halide lamp is basically a mercury lamp to which has been added metal halides. In comparison to mercury lamps, the metal halide lamp provides higher luminous efficacy and good color rendition coupled with good optical control characteristics; however, the metal halide lamp has a shorter life.

5.4.3 *High-Pressure Sodium Lighting.* The high pressure sodium lamp has a higher luminous efficacy than the metal halide lamps, coupled with good optical control characteristics, and a light output maintenance characteristic similar to the mercury lamp. The life of this lamp is approximately equal to that of the metal halide lamp.

5.5 Light Source Summary. A comparison of the major characteristics of the various light sources provides a guidance for choosing the light source for a particular application. The chart shown in Fig. 8 has been prepared by the Light Sources Com-

*In reprint only.

	LUMEN OUTPUT PER LAMP	EFFICACY	LIFE EXPECTANCY	COLOR ACCEPTABILITY	DEGREE OF LIGHT CONTROL	MAINTENANCE OF LUMEN OUTPUT
INCANDESCENT	FAIR	LOW	LOW	HIGH	HIGH	GOOD
TUNGSTEN HALOGEN	FAIR	LOW	LOW	HIGH	HIGH	HIGH
MERCURY	GOOD	FAIR	HIGH	LOW	GOOD	GOOD
PHOSPHOR MERCURY	GOOD	FAIR	HIGH	FAIR TO GOOD	FAIR	FAIR
METAL HALIDE	HIGH	GOOD	FAIR	GOOD TO HIGH	GOOD	FAIR
HIGH-PRESSURE SODIUM	HIGH	HIGH	FAIR	FAIR	GOOD	GOOD
40-WATT FLUORESCENT	LOW	GOOD	GOOD	GOOD TO HIGH	LOW	GOOD
HIGH-OUTPUT FLUORESCENT	FAIR	GOOD	GOOD	GOOD TO HIGH	LOW	GOOD
1500-MA FLUORESCENT	GOOD	GOOD	FAIR	GOOD TO HIGH	LOW	FAIR

Figure 8. Comparative characteristics of light sources for general lighting purposes. There are four ratings for each characteristic—high, good, fair and low.

mittee of the Illuminating Engineering Society.* Further information on the characteristics of light sources can be found in the latest edition of the *I.E.S. Lighting Handbook.* This chart must be tempered by the actual application for the light source which might alter the rating shown. For example, in the case of a low ceiling interior lighting installation, the "low" rating given in the lumen output per lamp, and the degree of light control ratings for the 40-watt fluorescent source, might be considered most advantageous to obtain a low-source brightness and a wide beam spread.

5.6 Special Design Considerations. In selecting either a mercury, metal halide, high-pressure sodium, or a fluorescent lighting system for use in a sports or multipurpose area, some important factors should be given special consideration: (1) These light sources, when operated singly on alternating current circuits, produce a noticeable flicker on rapidly moving objects. This condition, stroboscopic effect, may be minimized by connecting lamps or luminaires on alternate phases of a three-phase supply, or by employing two-lamp lead-lag or series sequence start ballasts where available. (2) In multipurpose areas, if a quiet surround is an important factor, the possible objectionable disturbance resulting from ballast "hum" should be considered. Remote mounting of the ballasting equipment may be desirable. (3) When fluorescent lamps are used outdoors, they should be protected from the wind in order to maintain maximum light output.

6. Design Factors

6.1 General. (a) The correct choice among the various design factors of luminaire type, lamp type, lamp voltage, wiring method, etc., depends upon a balancing of economic costs against such factors as appearance, relative safety, and reliability.

(b) The overall cost for lighting should include: (1) an amortization of the first cost, (2) the cost of electrical energy consumed, (3) cost of lamp replacements, and (4) an estimate for maintenance expense exclusive of lamp replacement.

(c) Comparison of lighting systems on this basis, perhaps with different luminaires, or different wiring methods, may be made by means of a cost analysis. A true comparison should involve systems providing comparable quality and quantity of illumination. A suggested format for an economic analysis is shown in Appendix F.**

*Illuminating Engineering, May 1967, p. 319.
**In reprint only.

6.2 Choice of Equipment. (a) Floodlights, due to their larger size, more elaborate mounting requirements, and in some cases cover glasses, are more expensive than normal indoor type luminaires. The use of floodlights is economically justified on any outdoor area where the light must be projected a considerable distance. The comparison can be readily calculated by methods outlined in Appendix C.*

(b) Floodlights are available with beam spreads of various degrees, and can be used economically to concentrate light on and near the playing area, even when they must be mounted several hundred feet from the playing area. On the other hand, some of the playground sports such as horseshoe pitching, shuffleboard, etc., may in some cases be lighted by indoor type units suitably adapted to outdoor use.

6.3 Choice of Beam Spreads. Most open floodlights provide inherently wide beam spreads. Enclosed floodlights are available in a range of beam spreads from wide to narrow. *The choice of beam spread depends largely on the distance from the floodlights to the area to be lighted: the greater the distance, the narrower the beam spread for high utilization, efficiency and restriction of glare.* See Fig. 9. Conversely, when floodlights are located relatively close to the playing area, wide beam spreads can be used with good economy.

6.4 Open and Enclosed Floodlights. The choice between open and enclosed floodlights depends chiefly on differences in cost and in rate of depreciation. Open floodlights cost less, but depreciate more rapidly due to collection of dirt, soot, etc., on reflecting surfaces and light sources. *It is generally accepted practice to allow a light loss factor of 75 per cent for enclosed floodlights, and 65 per cent for open floodlights when calculating the maintained footcandle (lux) level.* Although these factors are empirical, they are based on considerable experience. The cleanliness of the surroundings, the frequency of cleaning of the units and replacement of lamps will affect the light loss factors to a considerable extent.

6.5 Wiring. (a) Outdoor floodlighting installations can be made with either overhead or underground distribution. From the standpoint of appearance and minimum interference, the underground system is more desirable where large playing areas are involved. The underground system may be made using either direct burial conductors or wire in conduit. While overhead distribution may be less expensive with regard to conductors, conduit and installation costs, additional items may be required. For example,

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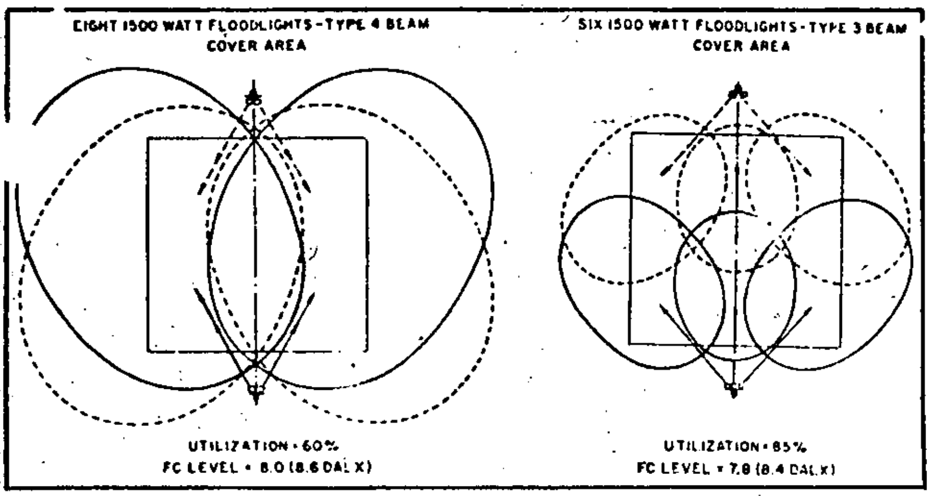

Figure 9. Selecting proper beam spread for specific applications results in better utilization and lower over-all costs. On the 100-by 100-foot (30.5 meter) area shown, eight Type 4 floodlights are required to produce about the same footcandle level obtained with six Type 3 floodlights of the same wattage. Mounting height is 60 feet (18.3 meters) in both cases.

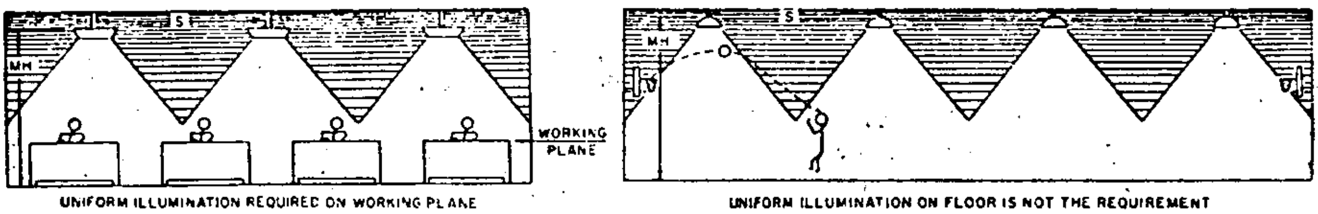

Figure 10. For many interior sports lighting installations uniform illumination on the floor is not the requirement. Adequate vertical distribution is required to the maximum height the object might travel during normal play.

extra poles to keep wires away from the playing area, and guys on poles where there is a change in direction of feeders, or where the feeders dead-end. The choice of installation to use will depend on local practice, and should include a consideration of the economics and other factors, such as appearance, safety and reliability.

(b) Some installations may justify a separate transformer on each pole or tower with primary wiring to each location. In smaller installations, it may be more economical to reduce the number of transformers by serving several locations from a single transformer through secondary wiring. This decision will also depend upon the rules and practices of the local utility company.

(c) The utility should, of course, be consulted as to the type of service available, whether primary or secondary, single-phase or three-phase, wye or delta. The rates for the various services should also be considered before a decision is made as to the preferred installation. Whether to wire one or more lighting units on each circuit is determined by local practice and economic considerations as limited by local and national code rules.

7. Lighting For Indoor Sports

7.1 General. **(a)** The walls and ceilings of interiors used for sports provide a means for controlling background luminances, assist in diffusing the available light, and make possible a variety of convenient lighting equipment arrangements. The design and calculation procedures for interior sports lighting are similar to those followed in design of any interior lighting system. (See Appendix D).* However, in addition to luminaire mounting height, spacing, lumen output, and illumination uniformity on a horizontal reference plane, which are important factors in all installation plans, it is necessary in designing sports lighting to consider the following factors:

(1) Observers have no fixed visual axis or field of view. During the course of the game, the ceiling and luminaires may frequently be included in the visual field.

(2) The object of regard will have no fixed location, and may be viewed at floor level, near the ceiling, or at any level in between. See Fig. 10.

(3) It is particularly important for observers to be able to estimate accurately object velocity and trajectory.

(b) The location of sport play can be divided into general areas used for more than one sport and areas designed for a particular sport. The lighting system must meet the varied or particular requirements for the sport, or sports, played in the given area.

(c) The sports, themselves, may be generally divided into two classes: sports which are aerial in part or whole, and sports which are at or close to floor level.

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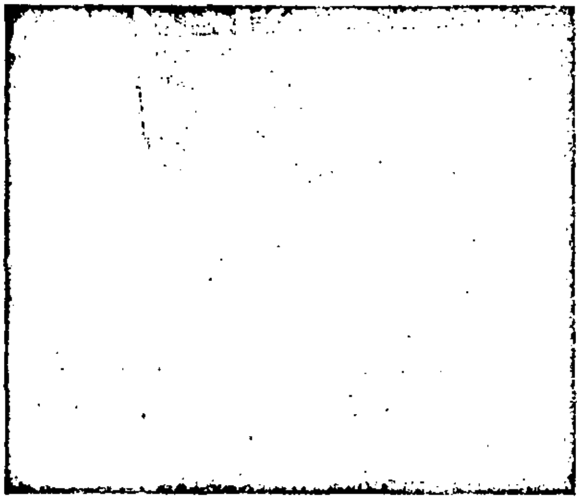


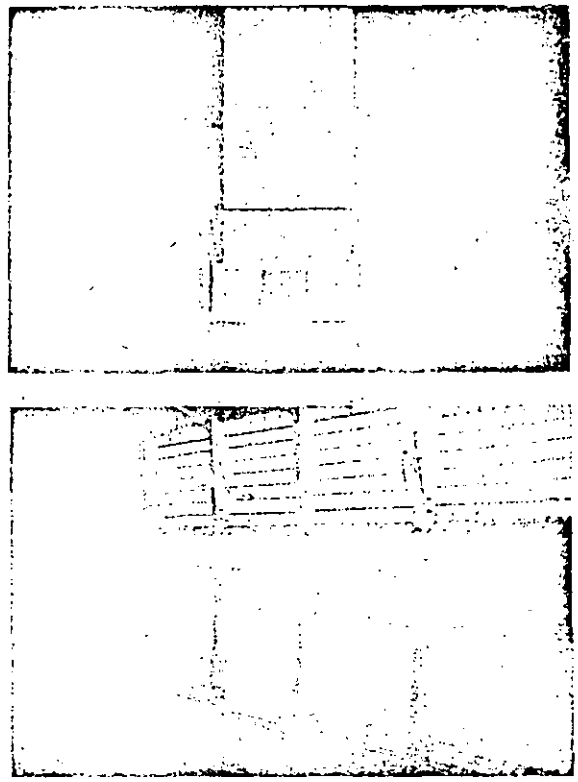


Figure 12. Caution should be exercised in positioning luminaires relative to critical surfaces such as glass basketball backboards (above), to avoid blinding, reflected glare. Windows behind glass backboards in gymnasium (above right) can produce direct glare, and unshielded windows (right) are a potential source of both direct and reflected glare. Note how reflections on the floor veil the floor markings.

lighting levels may be desirable because of the wide divergence in seeing tasks that can be encountered. Such variations in the general illumination are most often achieved through the incorporation of dimming, split-switching, or other means of lighting level control into the overall scheme of design. For special activities, such as dances, where the creation of mood or atmosphere is the primary lighting objective, quite low illumination values are desired. The most satisfactory results can often be achieved through the use of portable or temporary auxiliary lighting equipment, such as floodlights of reflectorized lamps, and colored filters. To prevent breakage, it may be necessary to cover luminaires with a protective cover or wire grid. This will reduce their efficiency and should be compensated for in the initial system design by multiplying the luminaire's efficiency by the average transmittance of the cover or grid.

(c) The position of luminaires and windows in a gymnasium can present serious problems. Fig. 12 demonstrates the hazards of improperly located luminaires and unshielded fenestration. The recommended lighting layout for the gymnasium is shown in Figs. 13 and 14.

7.2.1.1 *Interior Finishes.* **(a)** Light finished ceilings, walls and floors not only enhance the appearance of a gymnasium, but increase the utilization of light and improve visibility. Ceiling reflectances of 80 to 85 per cent are attainable on smooth surfaces with good grades of white non-glossy paint. The same paints on acoustical materials have somewhat lower reflectances because of the porous nature of these surfaces.

(b) Walls of matte-glazed tile or other non-abrasive material are widely used in modern gymnasiums up to heights of approximately seven feet. Above this area, light-colored cinder blocks, brick, or wood paneling provide a wall reflectance in the desirable range of 50 to 60 per cent.

(c) Natural hardwood floors, sealed with a non-glossy finish, have reflectances of 15 to 30 per cent.

7.2.2 *Field Houses.* The field house and the gymnasium closely resemble each other as far as sports activities are concerned. The field house may, however, be larger in dimension and serve a somewhat wider range of sports. Among these are indoor track and field events, skating, and such outdoor sports as may be driven indoors by inclement weather. Portable floors and seating facilities are in common use. General lighting levels and methods dictated by particular sports will meet the needs for the participants, but may require considerable increases to meet the needs of the spectators. The resultant lighting system design should therefore meet the requirements for the anticipated activities in the field house as well as provide for the spectators. This could include consideration for aerial and low level sports, versatile control or individual systems for the various sports,

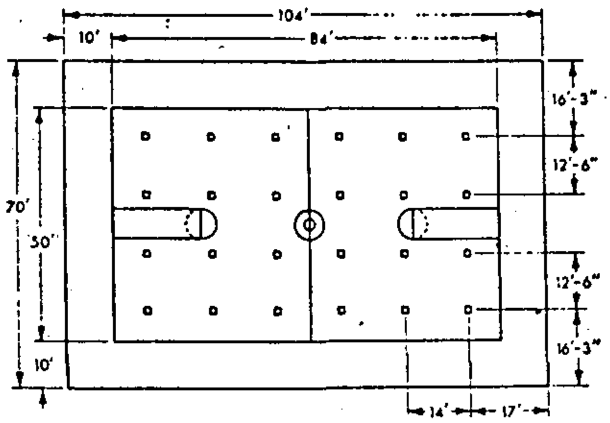


Figure 13. Lighting layout for an indoor basketball court. A distance of 10 feet (3.0 meters) between court boundary and wall is recommended. Minimum luminaire mounting height should be 22 feet (6.7 meters).

Note: 10 ft = 3.1 m; 12½ ft = 3.8 m; 14 ft = 4.3 m; 16¼ ft = 5.0 m; 17 ft = 5.2 m; 50 ft = 15.2 m; 70 ft = 21.3 m; 84 ft = 25.6 m; 104 ft = 31.7 m.

Class of Play	Current Recommended Practice— Footcandles (Dekalux) Maintained in Service	Minimum Recommended Mounting Height in Feet (Meters)
College and professional	50 (54)	22 (6.7)
College intramural and high school	30 (32)	

and increased illumination levels and beam control to meet the needs of the spectators.

7.2.3 *Other Areas (Community Centers, Etc.).* The illumination methods utilized in the recommended practice for the gymnasium can be utilized for such areas; however, general illumination systems normal to multi-purpose halls will meet the requirements for table tennis, fencing, and shuffleboard with little need for special consideration. Fig. 15 provides a recommended practice for table tennis to meet the particular needs of this aerial sport.

7.3 Specialized Areas. Lighting layouts which illustrate the adaption of the previously stated principles to certain specialized indoor sports areas are shown in Figs. 16 through 22. It is important to recognize that these layouts are not the only acceptable method which can be used for lighting a particular sports area. Other types of luminaires, light sources and, in some instances, luminaire locations, may be used satisfactorily. These layouts merely

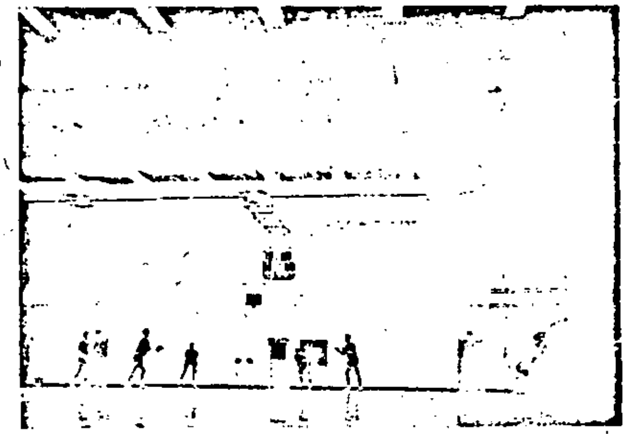


Figure 14a. A gymnasium illuminated to 100 footcandles (110 dekalux) by the use of 1500 mA fluorescent lamps in suspended semi-direct, porcelain enamel reflector units with prismatic plastic shielding.

Figure 14b. A gymnasium illuminated by continuous rows of louvered fluorescent units.

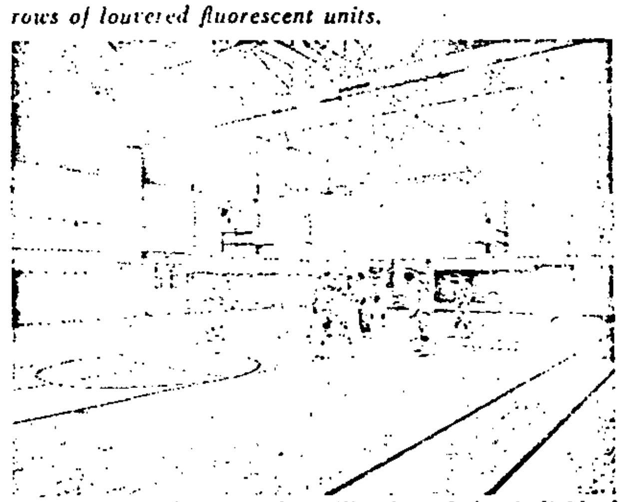


Figure 14c. A gymnasium illuminated by individual direct luminaires in layout as shown in Fig. 12.

show one or more ways in which the lighting objective has been accomplished.

7.3.1 *Badminton.* Badminton is an aerial sport, and requires ceiling heights of 25 feet (7.6 meters) minimum and upwards to 40 feet (12.2 meters) desirable. A brown or green color is recommended

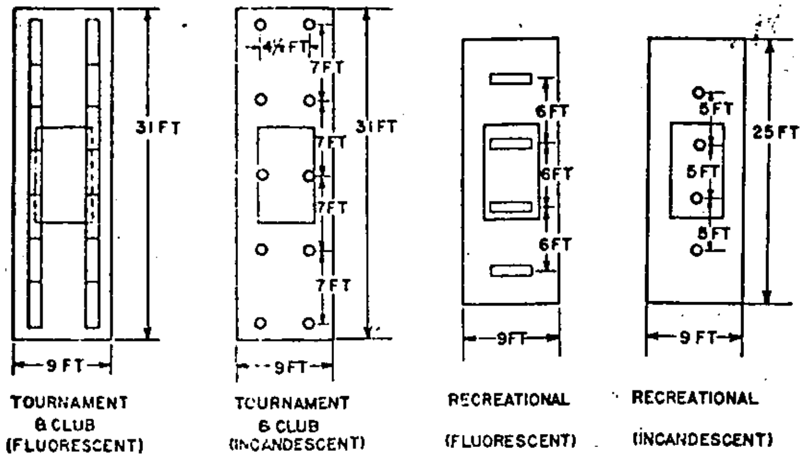


Figure 15. Recommended lighting layouts for table tennis. Lamp size and luminaire quantities for each class of play are dependent upon the specific room characteristics and luminaires used.

Note: 4½ ft = 1.4 m; 5 ft = 1.5 m; 6 ft = 1.8 m; 7 ft = 2.1 m; 9 ft = 2.7 m; 25 ft = 7.6 m; 31 ft = 9.5 m.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Luminaires
Tournament	50 (54)	Direct (Spread Distribution)
Club	30 (32)	
Recreational	20 (22)	

Mounting: Ceiling height approximately 12 feet (3.7 meters).

for the walls and ceiling to provide good contrast for the white shuttle. A dark finish is also recommended for the floor. To minimize glare, a well controlled lighting system mounted along the sideline, or an indirect system, is recommended. See Fig. 23.

7.3.2 *Billiards.* The lighting of billiard tables can be executed in many ways. It would be preferable to have a layout of the location of the tables themselves before establishing the location of the lights, so that the lights can be placed over the tables, thereby providing the best lighting possible and creating the fewest number of shadows. Luminous ceilings or other general lighting systems could also be utilized. Billiard tables are approximately 5 by 9 feet (1.5 by 2.7 meters) in size and are usually located so that they are five feet (1.5 meters) apart, side by side and at least six feet (1.8 meters) from the adjoining wall. The minimum recommended mounting height of the ceiling and light source is seven and one-half feet (2.3 meters). The preferred height is ten to twelve feet (3.1 to 3.7 meters). The ceiling should be a light color with a reflectance of 75 to 85 per cent. The recommended illumination levels might be substantially increased for public attraction or business considerations.

7.3.3 *Bowling.* Lighting for bowling is often governed more by public attraction and increased business considerations than any other factor. Bowling is considered a low-level sport which is divided into three areas—the approaches, the lanes, and the pins. General illumination methods are utilized in the approach area. This area often includes seating for spectators as well as participants with lighting utilized to create a pleasant atmosphere. The lighting of the lanes should be well shielded for the bowler and the shielding is often an architectural element of the structure. This ceiling area should be finished with a high reflectance, non-gloss, light paint which maintains a 70 to 85 per cent reflectance. The illumination of the pins is so directed as to provide high vertical footcandle (lux) levels as seen by the bowler. The recommended layout is shown in Fig. 19.

7.3.4 *Boxing and Wrestling.* These sports are considered low-level sports. The recommendations for illumination are governed by the requirements of the spectators which completely outweigh the requirements of the participants. A recommended layout is shown in Fig. 18.

7.3.5 *Curling.* The indoor curling rink is classified as a low-level installation system. Direct or semi-direct luminaires, with wide spread distribution, mounted between rinks provide the best method of illumiation. The minimum mounting height of the luminaires is twelve feet and the ceiling and wall finishes should have a reflectance of over 60 per cent to provide good luminance ratios. Fig. 24 shows a recommended layout for curling.

7.3.6 *Handball and Squash.* The handball and squash court with its white walls and ceiling presents defi-

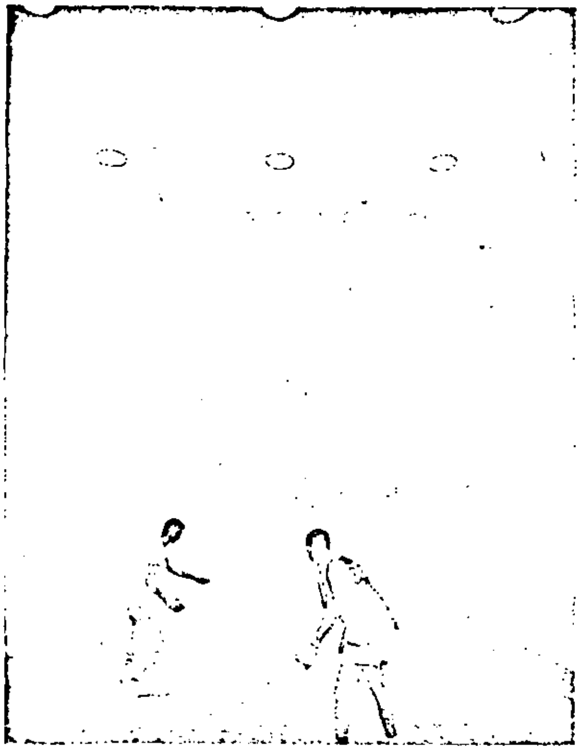
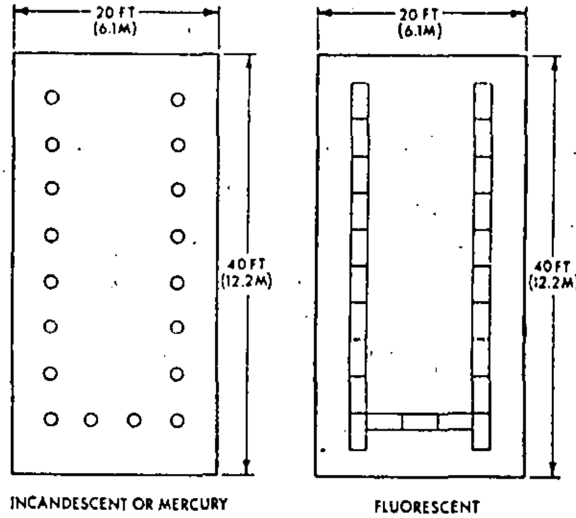


Figure 16. Recommended lighting layouts for squash and four-wall handball. Lamp size and luminaire quantities for each class of play are dependent upon the specific room characteristics and luminaires employed.

nite luminaire beam control problems for this aerial sport. The wall and ceiling finish should be a white, non-glossy paint with a reflectance of 75 to 85 per cent. The luminaires should be recess-mounted in the ceiling with a carefully shielded spread distribution. In these areas, adequate protection of the luminaires from possible breakage through the use of guards or impact-resistant covers is vitally important. See Fig. 16.

7.3.7 *Hockey*. Lighting for indoor hockey rinks requires extreme care in selection and location of luminaires. Not only should direct glare from the luminaires be considered, but the possible loss of visibility due to reflected glare from the ice is of equal importance. Care should be exercised so that no shadows from the boards and nets cause difficulty in following the course of play. All luminaires should be mounted above the line of sight of the spectator in the most elevated seat at the greatest distance from the playing area. This provides an uninterrupted view of the playing area, minimizes possible direct glare to the spectators, and improves appearance. See Fig. 21.

7.3.8 *Jai Alai*. Due to the extreme speed of the ball in play (over 150 miles (240 kilometers) per hour), careful consideration must be given to level of illumination, shielding of luminaires, and surface texture of paint on the court walls and floor. Glare is to be avoided at all costs. Play is fast and serious accidents are not uncommon. Colors recommended are: grass green for the frontis, lateral, and rebote; off-white for the floor; and dark red for the foul stripes. Luminaires should be mounted above the top screen for physical protection. Viewing is done from the open side of the court, again through a protective screen. It is good practice to provide for dimming in the audience area at the start of play. See Fig. 22.

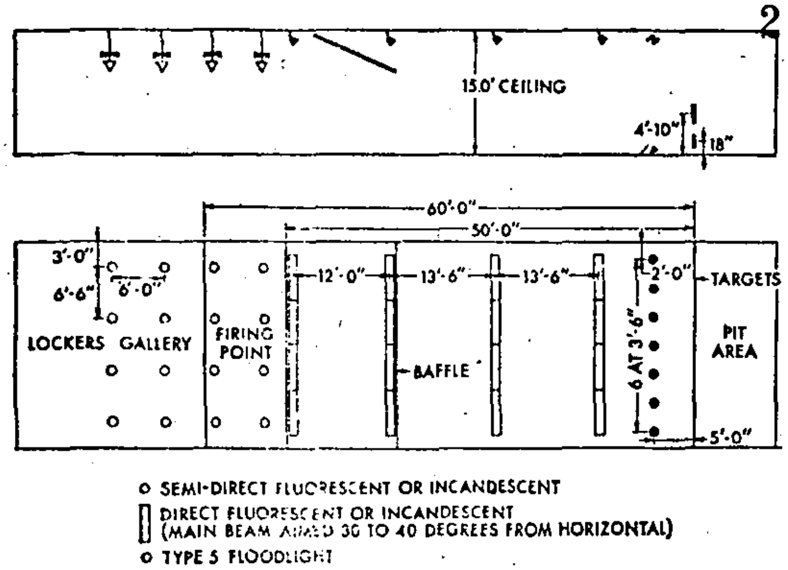


Note: 20 ft = 6.1 m; 40 ft = 12.2 m.

Class of Play	Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Type of Luminaires
Tournament*	50 (54)	Direct recessed, spread distribution, carefully shielded.
Club	30 (32)	
Recreational	20 (22)	

* Illustrated above.

7.3.9 *Shooting (Archery, Pistol and Rifle Ranges)*. Indoor archery, pistol and rifle ranges present similar illumination problems for these low-level classification sports. Major emphasis is placed upon the illumination at the target and the distance from the firing line to the target. In the case of the indoor pistol and rifle range, which has a 50 foot (15.2 meter) distance, the recommended vertical illumination on the target meets the requirements for the distance from the firing line to the targets and the size of the targets. In the case of archery, distances of 60 to 150 feet (18.3 to 45.7 meters) are normal between the firing line and target. The recommended



Note: 18 in = 46 cm; 2 ft = .61 m; 3 ft = .91 m; 3½ ft = 1.1 m; 4 ft 10 in = 1.47 m; 5 ft = 1.5 m; 6 ft = 1.8 m; 6 ft 6 in = 2.0 m; 12 ft = 3.7 m; 13 ft 6 in = 4.1 m; 15 ft = 4.6 m; 50 ft = 15.2 m; 60 ft = 18.3 m.

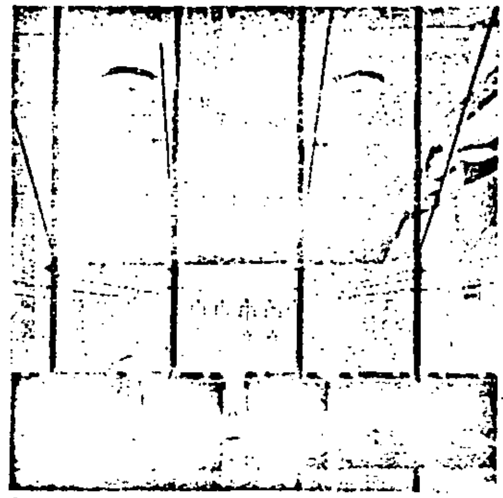


Figure 17. Recommended layout for an indoor rifle and pistol range. Note: lamp size and luminaire quantities for each class of play are dependent on the specific room characteristics and luminaires employed.

vertical footcandle (lux) level on the target again considers the distance and the size of the target. The typical layout for shooting ranges is shown by the example in Fig. 17 which illustrates the standard pistol and rifle range.

Location	Current Recommended Practice—Footcandles (Dekalux) Maintained in Service
Firing point	20 (22)
Range	10 (11)
Target (vertical)	100 (110)

7.3.10 *Swimming.* **(a)** The lighting of swimming ... is multi-fold. It is to: (1) light the water sur- ... (2) the floor of the pool; and (3) the deck area around the pool adequately, and for the safety of the persons using the pool. Underwater luminaires should be so located to give complete illumination to all underwater areas. Refer to National Electric Code and applicable local codes for specific placement of luminaires.

(b) For underwater lighting, luminaires should be properly located in the pool walls to provide adequate illumination throughout the pool, but should not be placed in line with a swimming lane where competitive swimmers would make a turn and possibly kick the light during the turn. It is therefore quite important that the luminaires should be located between the lanes so that it would not in any way interfere with competitive swimming.

(c) The overhead lighting of the indoor pools can be executed in a way similar to lighting any indoor space with proper spacing and location

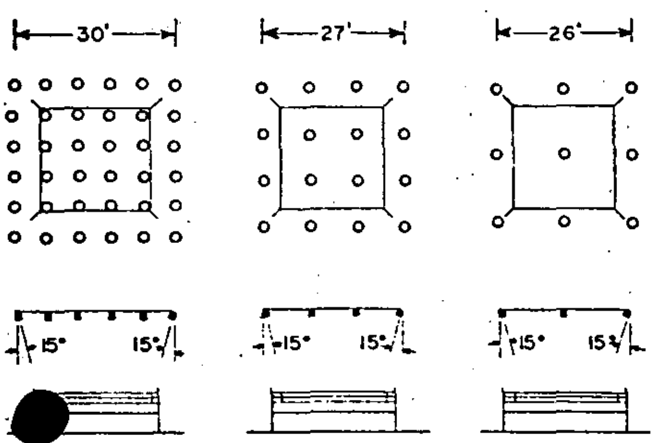


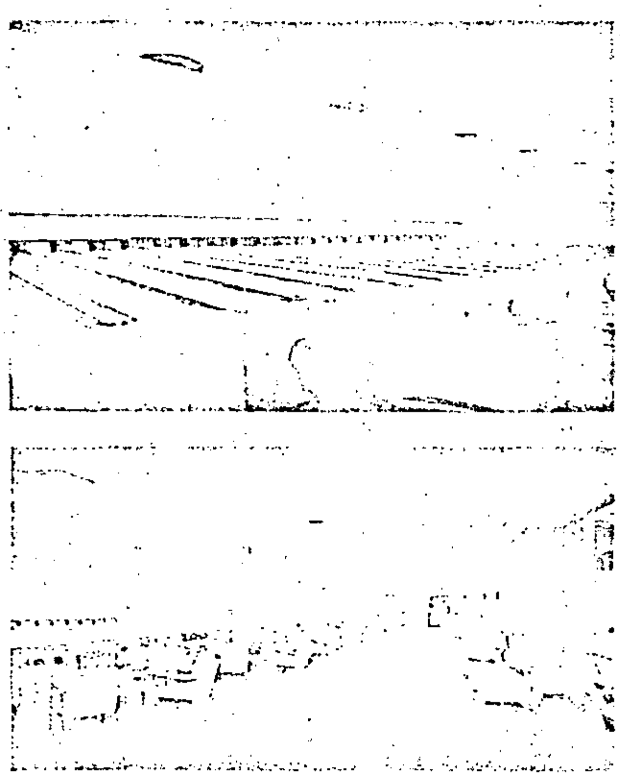
Figure 18. Recommended layouts for indoor boxing or wrestling rings.

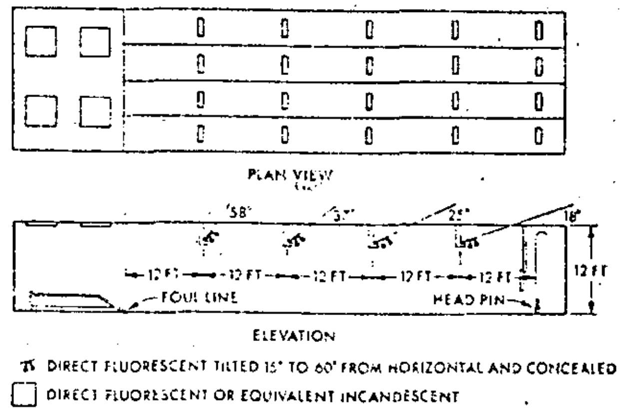
Class of Play	Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Type of Luminaires
Championship	500 (540)	Direct with concentrating distribution from 20-foot (6.1 meters) mounting height.
Professional	200 (220)	
Amateur	100 (110)	

Note: 26 ft = 7.9 m; 27 ft = 8.2 m; 30 ft = 9.1 m.

Class of Play	Current Recommended Practice—Footcandles (Dekalux) Maintained in Service					
	For Visual Considerations			For Public Attraction and Increased Business Considerations		
	Approaches	Lanes	Pins	Approaches	Lanes	Pins
Tournament	10 (11)	20 (22)	50 (54)*	70 (75)	100 (110)	200 (220)*
Recreational	10 (11)	20 (22)	50 (54)*	50 (54)	70 (75)	150 (160)*

* Vertical footcandles (dekalux).





Note: 12 ft = 3.7 m.

Figure 19. Typical lighting arrangements for bowling. The ceiling luminaires should be completely shielded from the view of the bowler. To avoid severe luminance differences and to make maximum use of reflected light, the ceiling should be maintained at a reflected light, at a reflectance of 70 or better.

throughout the ceiling. In the event there is crawl space above the ceiling, it is desirable to select luminaires that could be relamped from above. In the event the luminaires must be relamped from below, it would seem desirable to locate them over the deck rather than over the water and aim some of them toward the water. This will eliminate the need for servicing the overhead luminaires from a pool location. Fig. 25 illustrates the recommended practice for swimming pools.

7.3.11 *Tennis.* The area under consideration for indoor play should approximate that recommended for outdoor, *i.e.*, 120 feet (36.6 meters) by 48 feet (14.6 meters). Suggested interior finishes are: ceiling and upper walls, light non-glossy, 80 to 85 per cent reflectance; floors, natural hardwood, clay or concrete, non-glossy, 15 to 30 per cent reflectance; walls, lower 8 feet (2.4 meters), gray, non-glossy, with a maximum reflectance of 60 per cent. The luminaire should be provided with vertical baffles, louvers, or other shielding techniques to reduce the possibility of glare distracting the players. These shielding elements should provide cut-off at 45 degrees in the direction of play. This shielding design should be such as to allow adequate illumination to reach high balls. The luminaires should be mounted toward the side of the courts or between courts as shown in the recommended layout in Fig. 20.

7.4 Indirect Lighting. **(a)** Many aerial sports require the upper walls and ceiling to be finished with a high reflectance semi-gloss white paint. This area is illuminated by the upward component of the semi-direct type luminaires and becomes an added factor in the overall quality of illumination. One method

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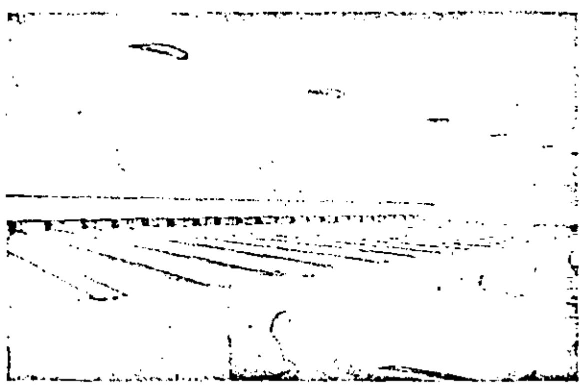
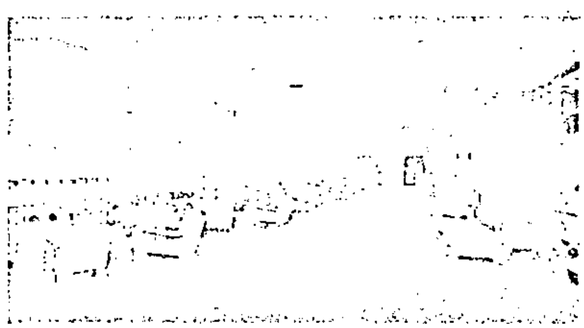
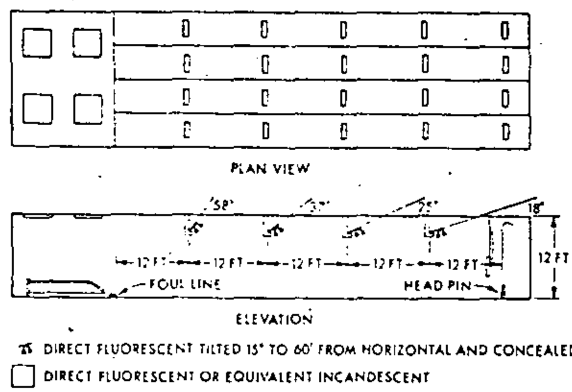
Class of Play	Current Recommended Practice—Footcandles (Dekalux) Maintained in Service					
	For Visual Considerations			For Public Attraction and Increased Business Considerations		
	Approaches	Lanes	Pins	Approaches	Lanes	Pins
Tournament	10 (11)	20 (22)	50 (54)*	70 (75)	100 (110)	200 (220)*
Recreational	10 (11)	20 (22)	50 (54)*	50 (54)	70 (75)	150 (160)*

* Vertical footcandles (dekalux).







Note: 12 ft = 3.7 m.

Figure 19. Typical lighting arrangements for bowling. The ceiling luminaires should be completely shielded from the view of the bowler. To avoid severe luminance differences and to make maximum use of reflected light, the ceiling should be maintained at a reflected light, at a reflectance of 70 or better.

throughout the ceiling. In the event there is crawl space above the ceiling, it is desirable to select luminaires that could be relamped from above. In the event the luminaires must be relamped from below, it would seem desirable to locate them over the deck rather than over the water and aim some of them toward the water. This will eliminate the need for servicing the overhead luminaires from a pool location. Fig. 25 illustrates the recommended practice for swimming pools.

7.3.11 *Tennis.* The area under consideration for indoor play should approximate that recommended for outdoor, *i.e.*, 120 feet (36.6 meters) by 48 feet (14.6 meters). Suggested interior finishes are: ceiling and upper walls, light non-glossy, 80 to 85 per cent reflectance; floors, natural hardwood, clay or concrete, non-glossy, 15 to 30 per cent reflectance; walls, lower 8 feet (2.4 meters), gray, non-glossy, with a maximum reflectance of 60 per cent. The luminaire should be provided with vertical baffles, louvers, or other shielding techniques to reduce the possibility of glare distracting the players. These shielding elements should provide cut-off at 45 degrees in the direction of play. This shielding design should be such as to allow adequate illumination to reach high balls. The luminaires should be mounted toward the side of the courts or between courts as shown in the recommended layout in Fig. 20.

7.4 Indirect Lighting. (a) Many aerial sports require the upper walls and ceiling to be finished with a high reflectance semi-gloss white paint. This area is illuminated by the upward component of the semi-direct type luminaires and becomes an added factor in the overall quality of illumination. One method

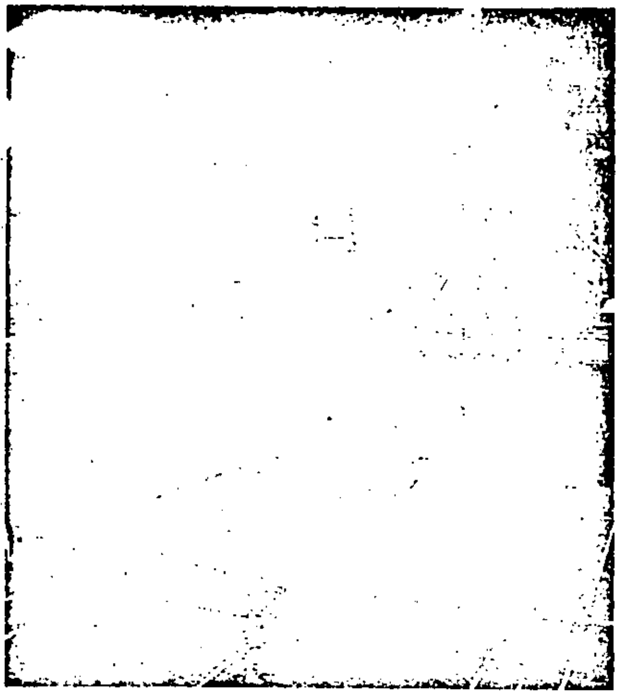


Figure 20. Lighting layout for indoor tennis court.

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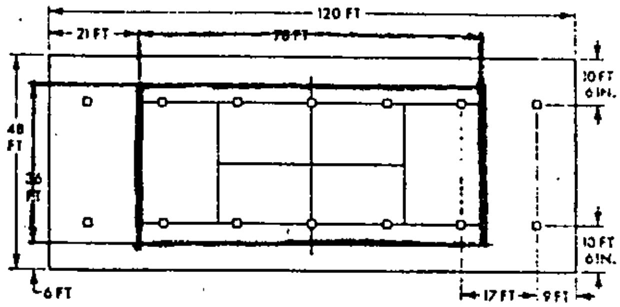
Class of Play	Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Minimum Mounting Height in Feet (Meters)
Professional	50 (54)	
Club	30 (32)	22 (6.7)
Recreational	20 (22)	



Note: 6 ft = 1.8 m; 9 ft = 2.7 m; 10½ ft = 3.2 m; 17 ft = 5.2 m; 21 ft = 6.4 m; 36 ft = 11.0 m; 48 ft = 14.6 m; 78 ft = 23.8 m; 120 ft = 36.6 m.

of increasing the quality of illumination is to utilize a totally indirect lighting system. Such systems are less efficient than a semi-direct system, but often provide other benefits and at times present the only adequate method of obtaining satisfactory results.

(b) Inflatable structures are finding a wide usage in the sports field. This is especially true for skating rinks, swimming pools and tennis courts. These inflatable structures normally mount on a foundation that varies between ground level and a wall of up to 8-foot (2.4-meter) height. The structures cannot support overhead items such as luminaires and, therefore, indirect lighting answers the lighting need. The design of such structures normally employs the use of materials which provide a high reflectance matte surface. It is very important that such material is utilized to eliminate glare caused by specular reflections and to prevent increasing the lighting load as the surface reflectance decreases.

(c) A major consideration in the design of an indirect lighting system is the uniformity of illumination over the entire surface. Hot spots around the luminaire's location can be as distracting as a direct view of the luminaire or light source by the participant. The number of luminaire locations need only be governed by the uniformity which can be achieved and architectural or surface elements which could create deep shadows on the surface being illuminated. These could be as distracting as a black cloud might be in an otherwise clear blue sky. An example of the results obtained in an indirect lighting system utilized in an inflatable structure is shown in Fig. 26.

Class of Play	Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Type of Luminaire
Professional	100 (110)	Semi-direct, carefully shielded
Amateur	50 (54)	
Recreational	20 (22)	

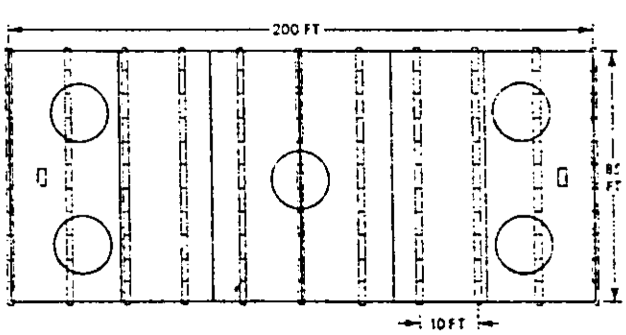


Figure 21. Typical lighting layout of semi-direct fluorescent luminaires on an indoor hockey arena.

Note: 10 ft = 3.1 m; 85 ft = 25.9 m; 200 ft = 61.0 m.

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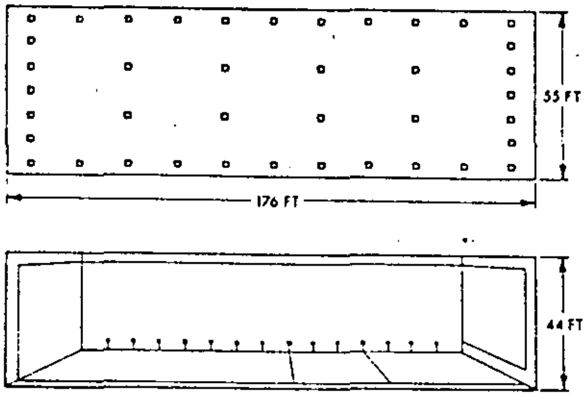


Figure 22. Typical lighting layout for jai-alai court with basic dimensions of 176 X 44 X 55 feet (53.6 X 13.4 X 16.8 meters).

Note: 44 ft = 13.4 m; 55 ft = 16.8 m; 176 ft = 53.6 m.

Class of Play	Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Luminaire Mounting
Professional	100 (110)	Mount above top screen.
Amateur	70 (75)	

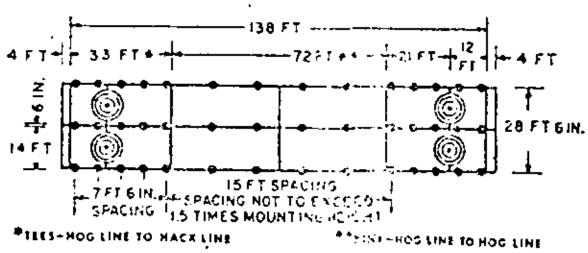


Figure 24. Recommended lighting layout for curling. Lamp size and luminaire quantities for each class of play are dependent upon the specific room characteristics and luminaires used.

Note: 6 in = 15.2 cm; 4 ft = 1.2 m; 7 ft 6 in = 2.3 m; 12 ft = 3.7 m; 14 ft = 4.3 m; 15 ft = 4.6 m; 21 ft = 6.4 m; 28 ft = 8.5 m; 33 ft = 10.1 m.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service		Luminaires Required	Minimum Mounting Height in Feet (Meters)
	Tees	Rink		
Tournament (Double Sheet)	20 (22)	10 (11)	Direct or Semi-Direct Wide Spread Distribution.	12 (3.7)

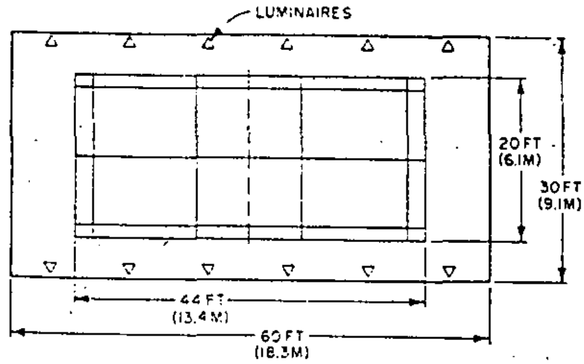


Figure 23. Recommended lighting layout for badminton. Lamp size and luminaire quantities for each class of play are dependent upon the specific room characteristics and luminaires used.

Note: 20 ft = 6.1 m; 30 ft = 9.1 m; 44 ft = 13.4 m; 60 ft = 18.3 m.

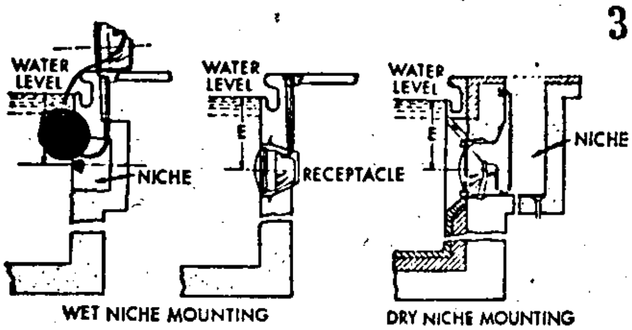
Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Luminaires
Tournament	30 (32)	Semi-direct carefully shielded.*
Club	20 (22)	
Recreational	10 (11)	

* May use any lamps including fluorescent.

8. Lighting for Outdoor Sports

8.1 Representative Layouts. Illumination levels obtained with the illustrative layouts presented in this report equal or surpass the current footcandle (lux) values recommended for the class of play under consideration. The recommended values are intended to be minimum values. In any installation, the illumination obtained is subject to unpredictable variations in installation, aiming, luminaires, lamps, voltage at the lamps, and atmospheric transmission. Some typical installations for several outdoor sports areas are shown in Figs. 27-33.

8.2 Recommended Layouts for Outdoor Sports. (a) In the following discussion, where various "classes" of sports are indicated, the classifications follow league ratings where they exist. In general, these ratings are indicative of the skill and speed of play to be expected, and correlate closely with the relative number of spectators regularly accommodated. This latter factor determines the maximum



UNDERWATER*

Location of Pool	Lamp Lumens Per Square Foot (Square Meter) of Pool Surface (width × length)
Outdoors	60 (650)
Indoors	100 (1100)

Dimensions

np Lumens	A Maximum In Feet (Meters) where D is over 5 feet (1.5 meters)	B Maximum In Feet (Meters) where D is under 5 feet (1.5 meters)	E in inches (centimeters) below water line	
			Minimum	Maximum
3750 to 8000	8 (2.4)	10 (3.1)	12 (31)	15 (38)
9900 to 33,000	12 (3.7)	15 (4.6)	18 (46)	24 (61)

* C dimension is equal to the swimming lane width to minimize glare and accidental damage.

Above lighting uses especially designed floodlights not covered by IES Classification or Type. Two systems are used—wet niche and dry niche. The former uses submersible units, while in the latter the casings or niche linings are cast in the pool walls with the floodlights behind them. Use minimum number of floodlights that will satisfy distribution and lumens per square foot (square meter). At the ends of the pool, the C dimension can be doubled or units eliminated especially at the shallow end or for narrow pools.

OVERHEAD*

Class of Play	Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Minimum Luminaire Mounting Height in Feet (Meters)
ibition	50 (54)	20 (6.1)
Recreational	30 (32)	

* A method should be provided for easy maintenance of lights especially over pool.

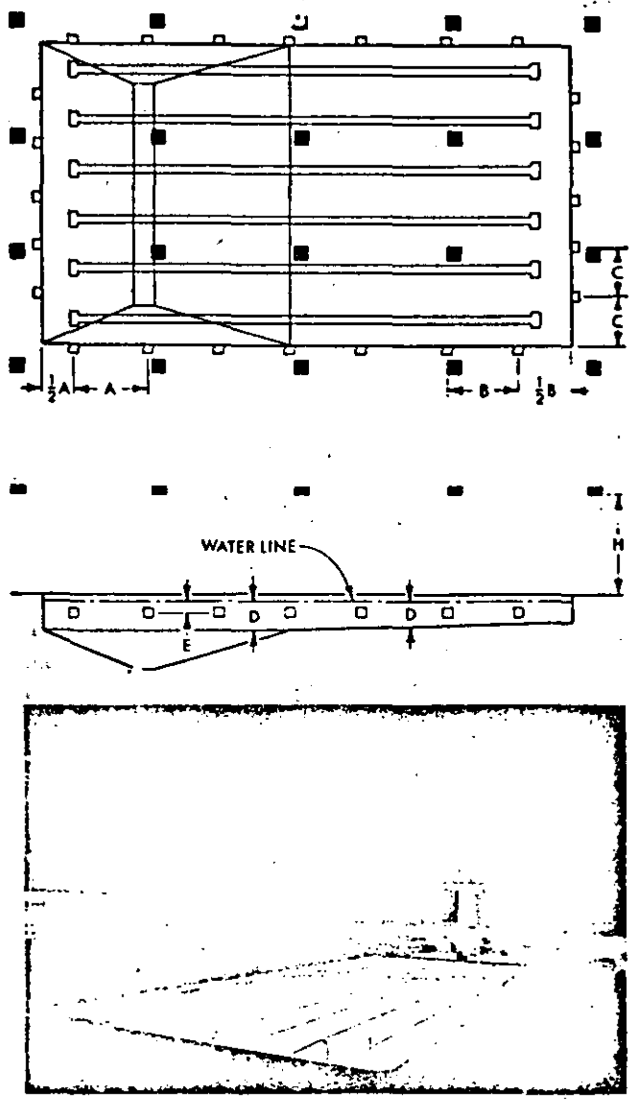


Figure 25. Lighting recommendations for swimming pools. Locate lighting equipment or life guards' positions so as to minimize direct and reflected glare.

distance at which a spectator may be observing the playing area, and consequently has a direct bearing on the angular size of the object to be seen and, therefore, on the quantity of light required.

(b) Pages 35 through 47 show data for sports lighting layouts considered to be good practice. There follows comments pertinent to a few of the more popular sports.

8.2.1 *Baseball.* (a) Baseball presents a severe, though not prolonged, seeing task. The ball is small, moves rapidly, and is viewed at varying distances against variable background brightness. The necessity for concentration is intermittent. The large number of possible observer locations and the movement of the players also introduce difficulties. See layout shown on page 36.

(b) In providing adequate and uniform illumination for baseball, it is standard practice to consider

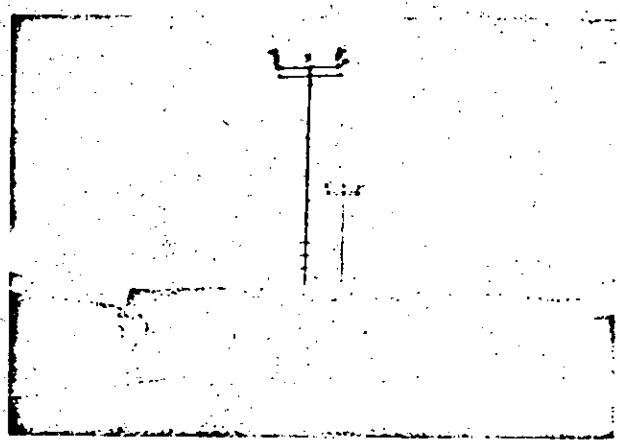


Figure 26. Indirect lighting in an inflatable structure.

the infield as including a 30-foot (9.1-meter) strip outside all baselines and to consider the outfield as including a 30-foot strip outside each foul line.

(c) The floodlights should be aimed so that the beam overlap will provide lighting from two directions at almost every outfield point and from four directions over most of the infield.

8.2.2 *Junior League Baseball.* This classification of baseball includes such leagues as Pony, Colt, Khoury, Little, Teen-Age, etc. In general, the standard baseball principles apply here also. However, an auxiliary strip outside the baselines and foul lines equal to one-third the length of the baseline is recommended in each instance to be lighted to the same level of illumination as the adjacent playing area. See layouts on pages 35, 36.

8.2.3 *Combination Sports Field.* (a) The combination layout is never as satisfactory as two individual lighting systems. Nevertheless, athletic fields are laid out for daytime seasonable playing of several sports, usually for a two or three game combination of baseball, softball, and football. Lighting such a combination field for night play requires special attention, since the lighting requirements for each individual sport must be considered in developing the final lighting plan. The final design will be largely affected by the relative location of the several fields, and the limiting restrictions which each specific arrangement may impose.

No. of Poles	Mounting Height in Feet (Meters)	Floodlights								Total Load (KW)
		Total No.	No. Per Pole			Type	Class	Beam (Degrees)	Efficiency (Per Cent)	
			A	B	C					
10	95 (29)	240	12	8	10	5	GP	76	58	418
			12	40	14	3		32	49	

Lamps: 1500-watt PS-52 clear, general service, operated at 10 per cent over rated voltage.

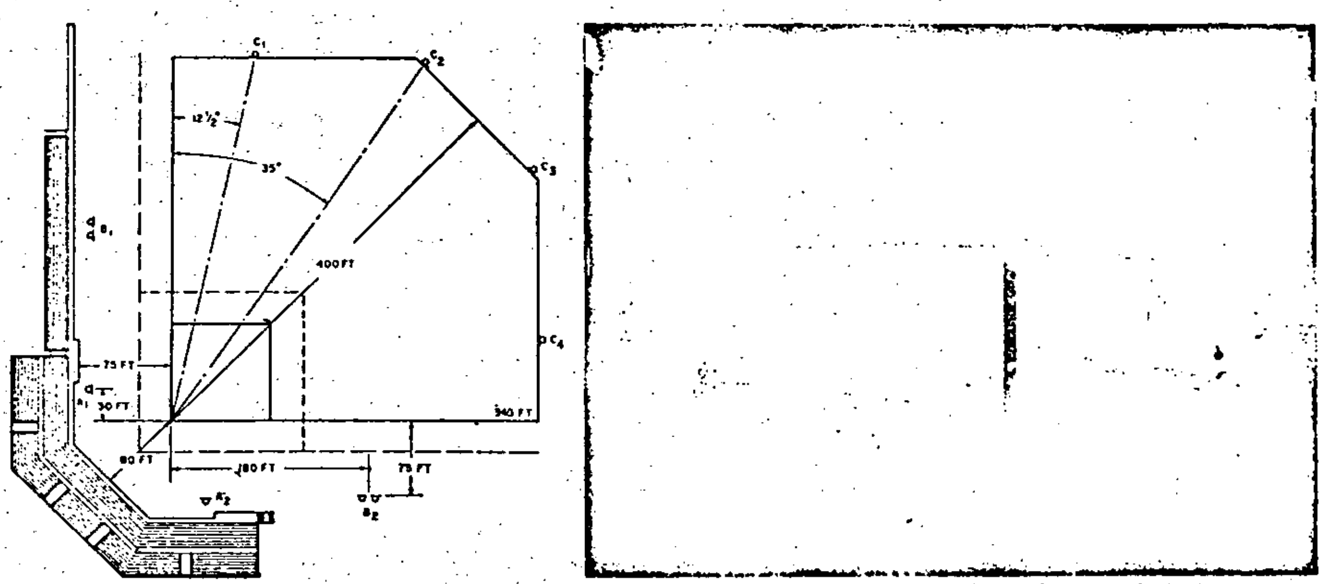


Figure 27. Typical Baseball Installation—Class C. Footcandles (lux) Maintained in Service—Infield, 44 (47.3 dekalux); Outfield, 23 (24.7 dekalux).

Note: 30 ft = 9.1 m; 75 ft = 22.9 m; 80 ft = 24.4 m; 180 ft = 54.9 m; 340 ft = 103.6 m; 400 ft = 121.9 m.

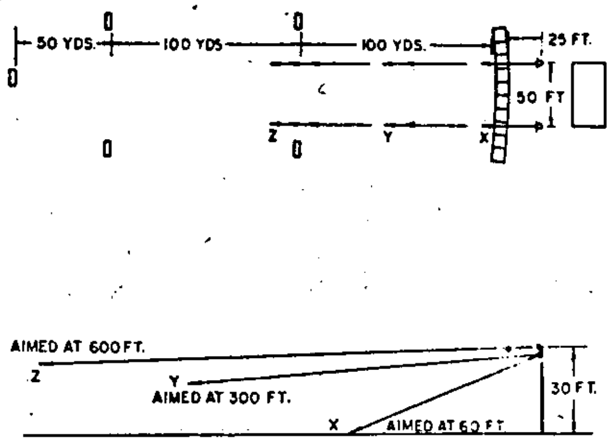


Figure 28. Typical Golf Driving Range. Footcandles (lux) Maintained in Service—Tees, 10 (10.8 dekalux); at 200 yards 5 Vertical (53.8 lux).

Note: 25 ft = 7.6 m; 30 ft = 9.1 m; 50 ft = 15.2 m; 60 ft = 18.3 m; 100 yds = 91.4 m.

No. of Poles	Mounting Height in Feet (Meters)	Floodlights					
		Total No.	No. Per Pole	Type	Class	Beam Spread (Degrees)	Efficiency (Per Cent)
2	30 (9.1)	X-2	1	5	GP	78	58
		Y-4	2	3	GP	34	49
		Z-6	3	1	GP	11	30

Lamps: X and Y—1500-watt, PS-52, clear, general service; Z—1000-watt G-40 clear floodlight service lamp. Operated at rated voltage.

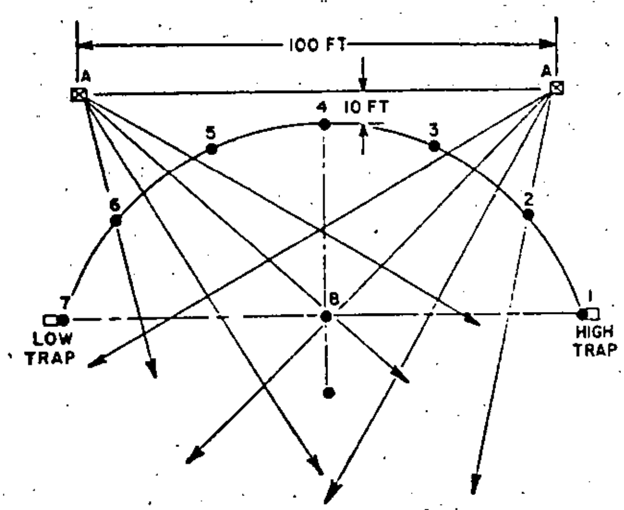
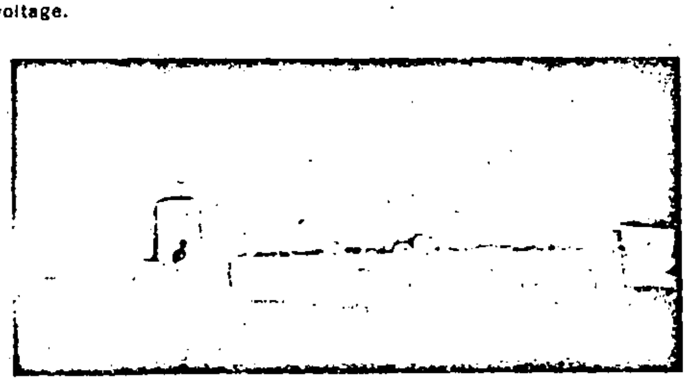


Figure 29. Typical Skeet Installation. Footcandles (lux) Maintained in Service—Target (vertical surface at 60 feet or 18.3 meters), 30 (32.3 dekalux); Firing Point, 10 (10.8 dekalux).

Note: 10 ft = 3.1 m; 100 ft = 30.5 m.

No. of Poles	Mounting Height in Feet (Meters)	Floodlights					
		Total No.	No. Per Pole	Type	Class	Beam Spread (Degrees)	Efficiency (Per Cent)
2	20 (6.1)	8	4	2	GP	24	45

Lamps: 1500-watt, PS-52, clear, general service, operated at rated voltage.



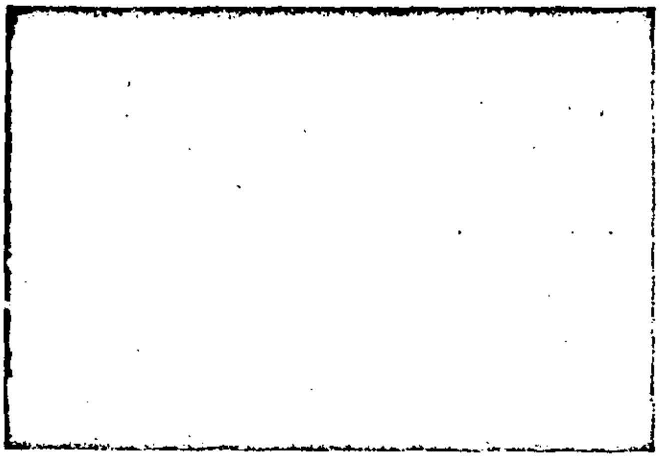
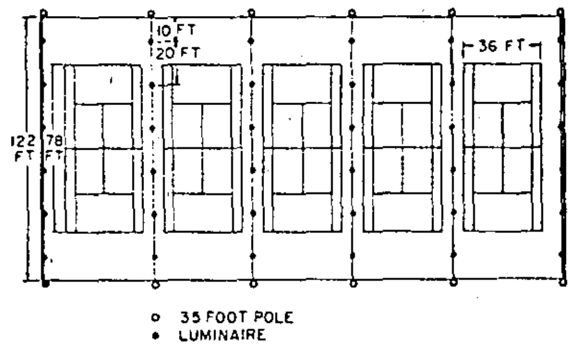


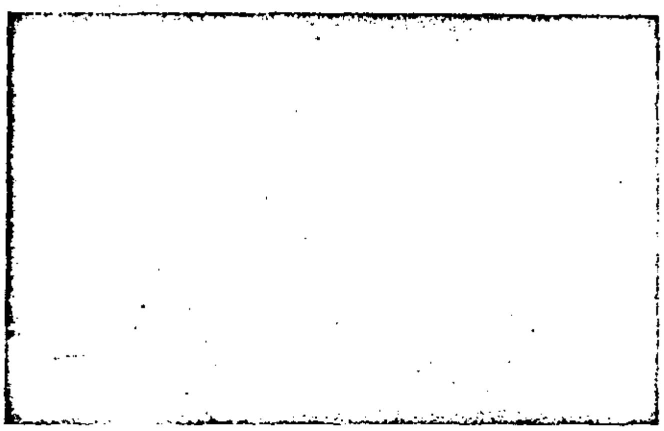
Figure 30. Typical Tennis Installation—Overhead Suspended Luminaires. Footcandles (lux) Maintained in Service, 10 (10.8 dekalux).

No. of Poles	Mounting Height in Feet (Meters)	Floodlights				
		Total No.	No. per Messenger	Type	Distribution	Efficiency (Per Cent)
12	30 (9.1)	36	6	Industrial High Bay	Wide	78

Lamps: 1500-watt, PS-52, clear general service operated at rated voltage.



Note: 10 ft = 3.1 m; 20 ft = 6.1 m; 36 ft = 11.0 m; 78 ft = 23.8 m; 122 ft = 37.2 m.



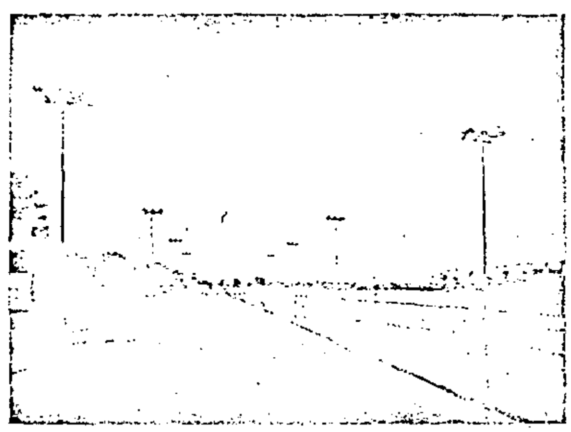
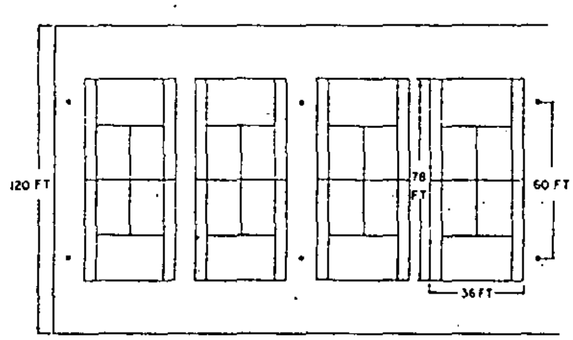


Figure 31. Typical Tennis Installation—Pole Mounted Floodlights. Footcandles (lux) Maintained in Service—10 (10.8 dekalux).

No. of Poles	Mounting Height in Feet (Meters)	Floodlights					
		Total No.	No. Per Pole	Type	Class	Beam Spread (Degrees)	Efficiency (Per Cent)
12	30 (9.1)	60	3–6	5	GP	78	58

Lamps: 1500-watt, PS-52 clear, general service, operated at rated voltage



Note: 36 ft = 11.0 m; 60 ft = 18.3 m; 78 ft = 23.8 m; 120 ft = 36.6 m.

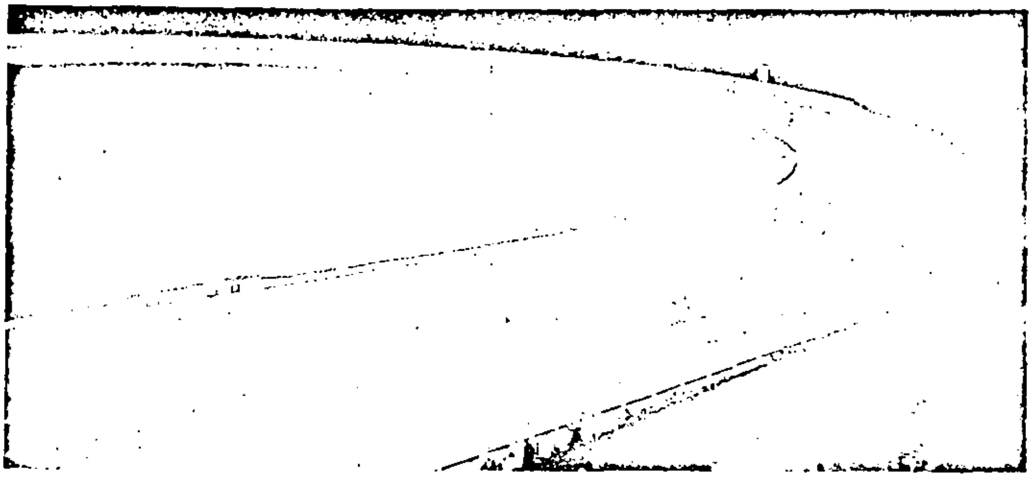
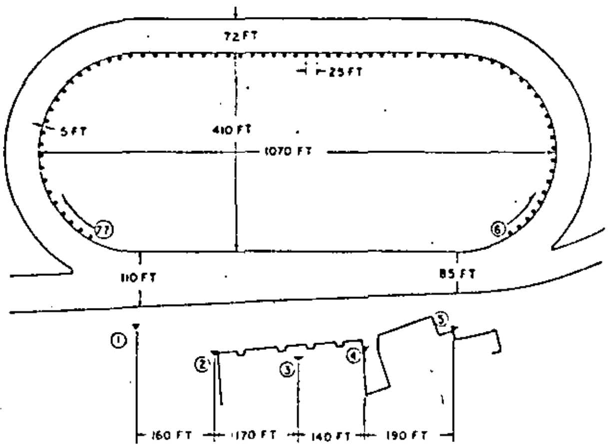


Figure 33. Typical Half-Mile Race Track Installation.



Note: 5 ft = 1.5 m; 25 ft = 7.6 m; 72 ft = 22.0 m; 85 ft = 25.9 m; 110 ft = 33.5 m; 140 ft = 42.7 m; 160 ft = 48.8 m; 170 ft = 51.8 m; 190 ft = 57.9 m; 410 ft = 125.0 m; 1070 ft = 326.8 m.

Pole No.	Floods Per Pole	Class	Type	Beam Spread (Degrees)	Efficiency (Per Cent)	Mounting Height in Feet (Meters)
1, 5	16 8	GP GP	3 5	32 76	49 58	80 (24.4)
2, 4	24	GP	2	26	44	80 (24.4)
3	32	GP	2	26	44	80 (24.4)
6-77	2	0	6	136	72	20 (24.4)
Total	272	Total Load 473—KW				

NOTES: (1) All lamps are 1500-watt PS-52, clear, general service lamps operated at 10 per cent over rated voltage. (2) Calculated average illumination level, footcandles (dekalux) maintained in service—20 (22).

(b) The tee should be lighted so that neither a right- nor left-hand player shadow his ball. High vertical values of illumination down the fairway should be provided to permit the player to follow the small sphere for the full length of that area while it is traveling at a speed of 100 miles (160 kilometers) per hour or more and to locate it after it has come to rest.

(c) Each green should be lighted from at least two directions to minimize harsh shadows. Care should be taken in the selection and aiming of the floodlights so that glare from the units does not handicap either the player or those on adjacent fairways.

(d) See pages 29, 41-2, 45 for recommended lighting layouts for tees, fairway, greens, driving ranges, practice putting greens, and minature golf.

(e) Special consideration must be given areas not covered by the general lighting system. Some will present physical hazards or require special accent. Examples: sand traps, water hazards, bridges, steep grades, roughs, areas adjacent to greens, pathways, etc.

8.2.6 *Softball.* Lighting for softball follows the same general principles as for baseball. Fields may vary in outfield distance from 160 (48.9 meters) to 280 feet (85.3 meters). Dimensions for slow-pitch softball are essentially the same as standard softball. See layout and footnotes relative to slow-pitch softball on pages 52, 53.

8.2.7 *Tennis.* Tennis is a fast, aerial sport, confined to a smaller area than are baseball, football, and softball. Consequently, less equipment is required to provide the recommended illumination. In order to maintain the recommended quality, however, particular care should be employed in designing for play behind the baselines. See layouts on pages 25, 30, 54.

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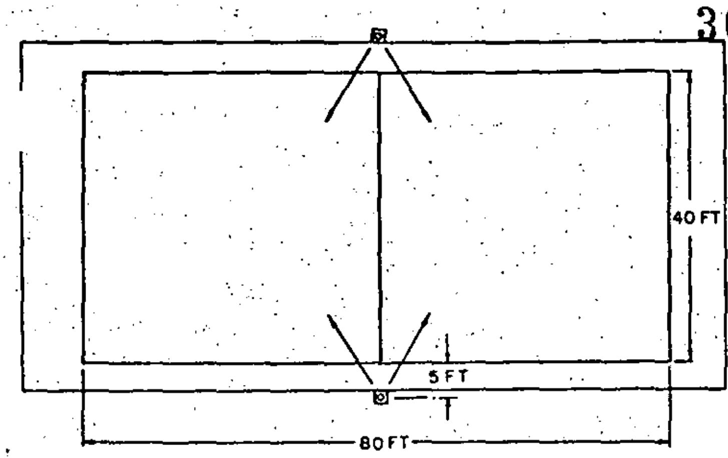

Figure 34. Typical Volleyball Installation. Footcandles (lux) Maintained in Service—10 (10.8 dekalux).

No. of Poles	Mounting Height in Feet (Meters)	Floodlights					
		Total No.	No. Per Pole	Type	Class	Beam Spread (Degrees)	Efficiency (Per Cent)
2	30 (9.1)	4	2	5	GP	78	58

Note: 40 ft = 12.2 m; 5 ft = 1.5 m; 80 ft = 24.4 m.

Lamps: 1500-watt, PS-52, clear, general service, operated at rated voltage.

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5. "Alaska Ballpark," Vol. 61, April 1966, p. 24A.
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7. "Natureproof Astrodome Gets Controlled Lighting," Vol. 61, December 1966, p. 714.
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C. Billiards

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10. Faucett, R. E. and Cruikshank, J. P., Discussion of Previously Published Conference Papers, "Practical Aspects of Lighting Golf Courses," Vol. 59, December 1964, p. 808.
11. "Night Golf at Pecan Valley," Vol. 62, July 1967, p. 414.

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1. "Golfing Under Mercury," Vol. 54, May 1959, p. 290.
2. "Quartz Lamp Lighting for Golf Course," Vol. 56, April 1961, p. 27A.
3. IES Lighting Data Sheet (21-25), "Lighting a Miniature Golf Course," Vol. 59, January 1964, p. 72.
4. "Private Pitch and Putt Golf," Vol. 59, November 1964, p. 710.

I. Gymnasium and Field House

1. IES Lighting Data Sheet (20-32), "Floodlighting a Field House," Vol. 54, January 1959, p. 51.
2. "High Levels in a Multi-Use Arena," Vol. 54, May 1959, p. 275.
3. IES Lighting Data Sheet (20-23), "Mercury Lighting in a College Field House," Vol. 54, July 1959, p. 441.
4. "High School Gym and Pool," Vol. 55, February 1960, p. 74.
5. IES Lighting Data Sheet (20-35), "Lighting a Gymnasium," Vol. 55, June 1960, p. 349.
6. Lantz, Fred L., "Detroit's Convention Arena," Vol. 57, December 1962, p. 755.
7. Long, Carl J., "Retractable Roof," Vol. 57, December 1962, p. 761.
8. IES Lighting Data Sheet (20-43), "Lighting a Gymnasium," Vol. 58, July 1963, p. 521.
9. IES Lighting Data Sheet (20-44), "Lighting a Windowless Gymnasium, Vol. 58, September 1963, p. 607.
10. IES Lighting Data Sheet (20-47), "Lighting a Gymnasium," Vol. 58, November 1963, p. 695.
11. "All in One Lighting for Multipurpose Gym," Vol. 59, January 1964, p. 21.
12. "1 + 1 + 1 for Multipurpose Gym," Vol. 59, March 1964, p. 21A.
13. "Mercury Plus Panel Fluorescent Lights College Field House," Vol. 60, April 1965, p. 301.
14. "Lighting for Indoor Sports," Vol. 61, May 1966, p. 11A.
15. "Relighting an Old Gym," Vol. 62, May 1967, p. 294.
16. "School Field House Uses Metal Halide," Vol. 62, October 1967, p. 28A.

J. Ice Hockey

1. IES Lighting Data Sheet (20-42), "Lighting a Hockey Rink," Vol. 57, October 1962, p. 668.
2. "H[illegible]ey Rinks," Vol. 58, March 1963, p. 118.
3. "[illegible]ew Lift from New Sources for College Hockey," Vol. [illegible] May 1967, p. 295.

K. [illegible] Alai

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L. [illegible] Track

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2. "[illegible] Auto Racing—Under Lights," Vol. 57, May 1962, p. 3[illegible]
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4. "L[illegible]g Remodels a Race Track," Vol. 59, March 1964, p. 140.
5. "Nig[illegible] Racing at *La Rinconada*," Vol. 63, July 1968, p. 347.

M. Skating

1. "Polar Palace Relighted," Vol. 54, February 1959, p. 121.
2. "Ice Skating Rink," Vol. 55, February 1960, p. 75.
3. "Nighttime Lighting Creates Gay Atmosphere," Vol. 56, November 1961, p. 30A.
4. "Near-Daylight Ice Skating at Night," Vol. 61, April 1966, p. 16A.
5. "Lighting for Future Olympic Glory," Vol. 63, April 1968, p. 208.

N. Skiing

1. "Lighting the Slopes," Vol. 59, April 1964, p. 42A.
2. "Floodlighted Golf and Ski Center," Vol. 59, July 1964, p. 486.
3. "Dual-Purpose Sports Lighting System," Vol. 59, October 1964, p. 18A.
4. "Illuminated Ski Slope," Vol. 60, January 1965, p. 31.
5. "Successful Lighting for a Night Ski Run," Vol. 64, February 1969, p. 78.

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1. "High School Gym and Pool," Vol. 55, February 1960, p. 74.
2. IES Lighting Data Sheet (20-36), "Lighting an Indoor Swimming Pool," Vol. 55, August 1960, p. 453.
3. "Winter Swimming Thrives Under Heat Lamps," Vol. 56, April 1961, p. 18A.
4. IES Lighting Data Sheet (20-45), "Lighting an Indoor Swimming Pool," Vol. 58, October 1963, p. 638.
5. "Mercury Light for Swimming after Dark," Vol. 58, December 1963, p. 34A.
6. IES Lighting Data Sheet (20-48), "Lighting an Indoor Swimming Pool," Vol. 59, March 1964, p. 161.
7. "Community Swimming Pool," Vol. 59, May 1964, p. 389.
8. "Lighting for an Indoor Swimming Pool," Vol. 59, July 1964, p. 20A.
9. "An Indoor Swimming Pool," Vol. 62, October 1967, p. 585.
10. "Multipurpose System for Swimming Pools," Vol. 63, January 1968, p. 23.

P. Tennis Court

1. IES Lighting Data Sheet (20-38), "Lighting for Indoor Tennis," Vol. 56, February 1961, p. 111.
2. IES Lighting Data Sheet (20-41), "Lighting for Indoor Tennis," Vol. 57, August 1962, p. 515.
3. "New High Levels for Tennis," Vol. 58, June 1963, p. 28A.
4. IES Lighting Data Sheet (20-46), "Lighting for Indoor Tennis," November 1963, p. 705.
5. "Indoor Tennis Courts," Vol. 61, June 1966, p. 18A.
6. "Lighting Night Tennis," Vol. 61, December 1966, p. 22A.

Q. Television Lighting Requirements

1. Frick, D. W., "Indoor Hockey Arenas Lighted for Color TV," Vol. 62, May 1967, p. 289.
2. Neenan, Charles, "Color Television—A Major Consideration in Lighting for Stadiums and Arenas," Vol. 62, June 1967, p. 348.
3. Faucett, R. E., "Lighting for Sports," Vol. 62, June 1967, p. 354.
4. Bishop, Vernon, "Color from the Ballpark—A TV Special," Vol. 62, October 1967, p. 577.
5. Distler, Arnold, "Montreal Forum: Lighting System for Color Telecasting in an Indoor Hockey Arena," Vol. 63, April 1968, p. 203.
6. Neenan, C. J. and Lemons, T. M., "Lighting for Color Television, Vol. 64, March 1969, p. 154.
7. Committee on Sports and Recreational Areas and the Committee on Theatre, Television and Film Lighting, "Interim Report—Design Criteria for Lighting of Sports Events for Color Television Broadcasting," Vol. 64, March 1969, p. 191.

R. Tobogganing

1. "The World's First Refrigerated Toboggan Chute," Vol. 64, February 1969, p. 75.

S. Trampoline Court

1. IES Lighting Data Sheet (21-34), "Lighting a Trampoline Court," Vol. 57, January 1962, p. 28.

T. Track and Field

1. IES Lighting Data Sheet (20-23), "Lighting for Track," Vol. 56, Septem[illegible] 1961, p. 536.

U. Related

1. Committee on Testing Procedures, "IES Guide for Photometric Measurements of Mercury Lamps," Vol. 54, August 1959, p. 655.
2. Herrick, P. R. and Wenner, R. E., "Measuring F-Lamp Characteristics for the Outdoor Environment," Vol. 54, November 1959, p. 686.
3. Keck, M. E., "Evaluation of Methods for Localized Cooling of Fluorescent Lamps in Outdoor Luminaires," Vol. 55, February 1960, p. 102.
4. Husby, D. E. and Anderson, M. R., "Light Transmitting Plastic Enclosure for Outdoor Lighting," Vol. 56, April 1961, p. 273.
5. Committee on Testing Procedures, "IES Guide for Photometric Measurements of Reflector-Type Lamps," Vol. 57, October 1962, p. 688.
6. McMillan, W. R., "Floodlighting Calculation—A Different Approach," Vol. 60, December 1960, p. 691.
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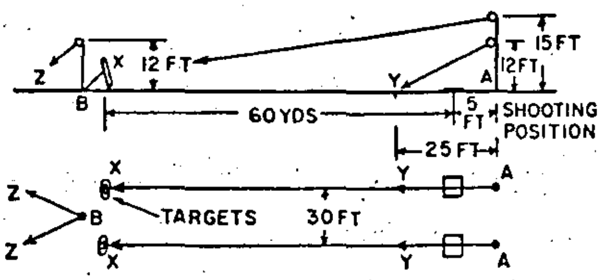
Outdoor Sports—Recommended Layouts 38

1. Archery—Outdoor Range

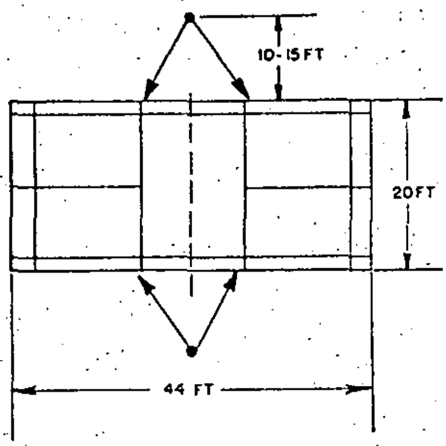


Note: 5 ft = 1.5 m; 12 ft = 3.7 m; 15 ft = 4.6 m; 25 ft = 7.6 m; 30 ft = 9.1 m; 60 yds = 54.9 m.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		
		Aiming Point	Type	Class
Tournament	10 (11)	X	1	GP
		Y	5	GP
Recreational	5 (5.4)	Z	5	GP

Locate pole B to one side of single target

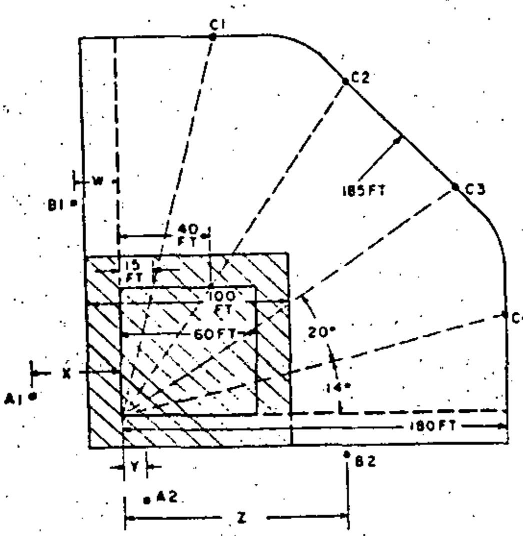
2. Badminton—Outdoor Courts



Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		Mounting Height in Feet (Meters)
		Type	Class	
Tournament	30 (32)	5	GP	
		6	O	
Club	20 (22)	5	GP	20–2 (6.1–7.56)
		6	O	
Recreational	10 (11)	5	GP	
		6	O	

Note: 10 ft = 3.1 m; 15 ft = 4.6 m; 20 ft = 6.1 m; 44 ft = 13.4 m.

3. Baseball—Class I Junior League (Baselines 60 feet (18.3 meters) or less)

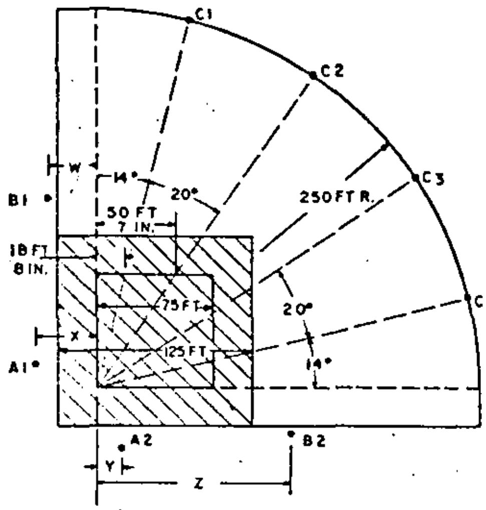


This layout is based on the following total playing area including a strip 20 feet wide (6.1 meters) outside each foul line. Infield area—10,000 square feet (929 square meters). Outfield Area—24,700 square feet (2295 square meters) (approximately). Dimensions: W = 20 feet to 30 feet (6.1 meters to 9.1 meters); X = 30 feet to 50 feet (9.1 meters to 15.2 meters); Y = 5 feet to 15 feet (1.5 meters to 4.6 meters); Z = 90 feet to 110 feet (27.4 meters to 33.5 meters).

Class of Baseball	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service		Floodlights		Minimum Mounting Height to Bottom Floodlight Crossarm in Feet (Meters)	
	Infield	Outfield	Type	Class	A & B Poles	C Poles
Class I	30 (32)	20 (22)	3, 4 or 5	GP	40 (12.2)	50 (15.2)
			4, 5 or 6	O or OI		

Note: 20 ft = 6.1 m; 60 ft = 18.3 m; 185 ft = 56.4 m.

4. Baseball—Class II Junior League 39
(Baselines longer than 60 ft. (18.3 m.) and up to 75 ft. (22.9 m.)



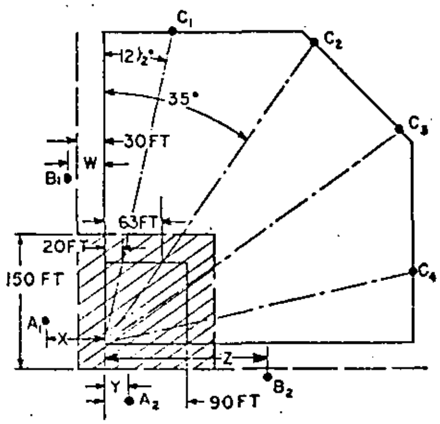
This layout is based on the following total playing area including a strip 25 feet wide (7.6 meters) outside each foul line: Infield Area—15,625 square feet (1450 square meters). Outfield Area—46,600 square feet (4330 square meters). Dimensions: W = 25 feet to 45 feet (7.6 meters to 13.7 meters); X = 35 feet to 65 feet (10.7 meters to 19.8 meters); Y = 10 feet to 25 feet (3.1 to 7.6 meters); Z = 110 feet to 145 feet (33.5 meters to 44.2 meters).

Class of Baseball	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service		Floodlights		Minimum Mounting Height to Bottom Floodlight Crossarm in Feet (Meters)	
	Infield	Outfield	Type	Class	A & B Poles	C Poles
Class II	30 (32)	20 (22)	3, 4 or 5	GP	50 (15.2)	60 (18.3)
			4, 5 or 6	OI		

Note: 18 ft 8 in = 5.7 m; 50 ft 7 in = 15.4 m; 75 ft = 22.9 m; 125 ft = 38.1 m.

5. Baseball—Regulation

Class of Baseball (Regulation)	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service		Floodlights		Minimum Mounting Height to Bottom Crossarm in Feet (Meters)
	Infield	Outfield	Type	Class	
Major League	150 (160)	100 (110)	3, 4 or 5	GP	120 (36.6)
AAA or AA	70 (75)	50 (54)	3, 4 or 5	GP	110 (33.5)
A and B	50 (54)	30 (32)	3, 4 or 5	GP	90 (27.4)
C and D	30 (32)	20 (22)	3, 4 or 5	GP	70 (21.3)
Semi-Professional and Municipal	20 (22)	15 (16)	3, 4 or 5	GP	70 (21.3)
			4, 5 or 6	OI	
Recreational	15 (16)	10 (11)	3, 4 or 5	GP	70 (21.3)
			4, 5 or 6	OI	

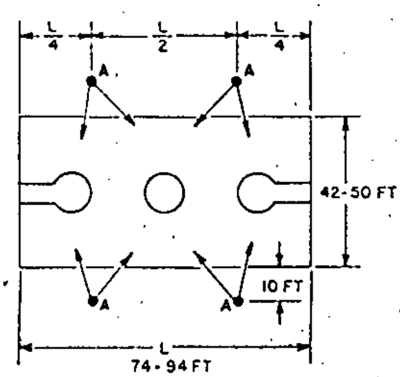


These layouts are based on the following total playing area including a strip 30 feet wide (9.1 meters) outside each foul line—132,500 square feet (12,320 square meters). Infield Area (shaded)—22,500 square feet (2090 square meters). Outfield Area—110,000 square feet (10,230 square meters). Dimensions: W = 30 feet to 60 feet (9.1 meters to 18.3 meters); X = 40 feet to 80 feet (12.2 meters to 24.4 meters); Z = 130 feet to 180 feet (39.6 meters to 54.9 meters).

Note: 20 ft = 6.1 m; 30 ft = 9.1 m; 63 ft = 19.2 m; 90 ft = 27.4 m; 150 ft = 45.7 m.

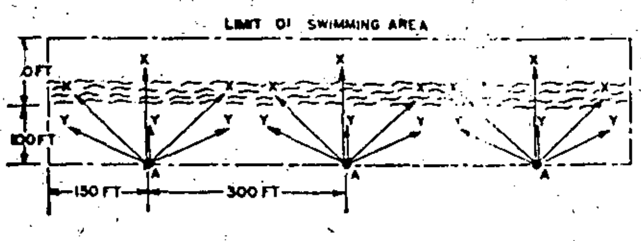
6. Basketball—Outdoor Courts

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		Minimum Mounting Height in Feet (Meters)
		Type	Class	
Recreational	10 (11)	5 or	GP	30 (9.1)
		6	O	



Note: 10 ft = 3.1 m; 42-50 ft = 12.8-[illegible] m; 74 ft = 22.6 m; 94 ft = 28.7 m.

7. Bathing Beaches

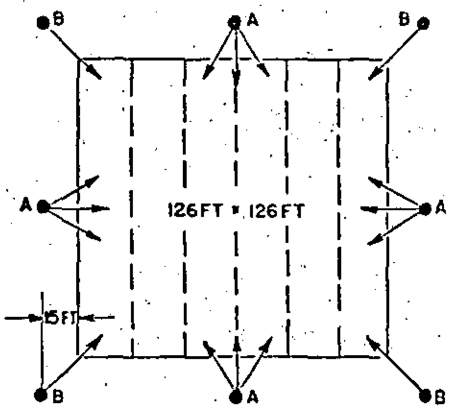


Note: 100 ft = 30.5 m; 150 ft = 45.7 m; 300 ft = 91.4 m.

IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		
	Aiming Point	Type	Class
3 (3.2) (vertical) in surf at 150 feet (45.7)	X	3	GP
1 (1.1) on beach	Y	5	GP

Mounting Height: 60 feet (18.3 meters) above beach.

8. Bowling Greens

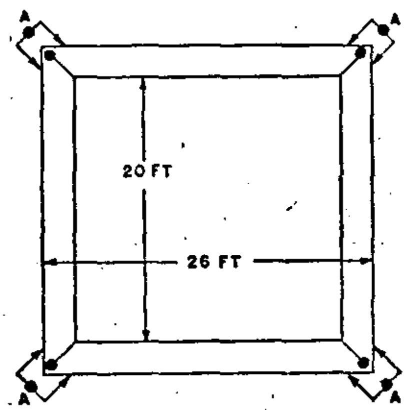


Note: 15 ft = 4.6 m; 126 ft = 38.4 m.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		Minimum Mounting Height in Feet (Meters)
		Type	Class	
Tournament	10 (11)	5	GP	25 (7.6)
		6	O	
Recreational	5 (5.4)	5	GP	
		6	O	

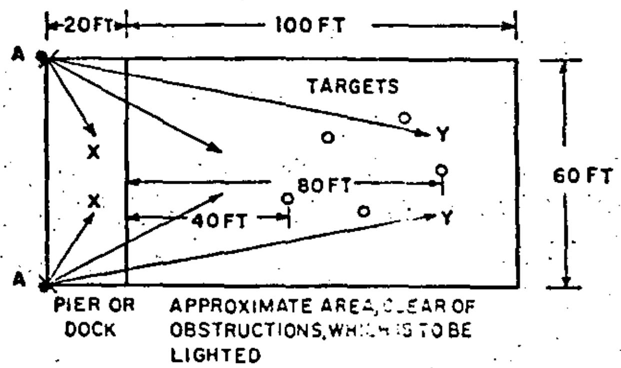
9. Boxing—Outdoor Rings

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		Mounting Height in Feet (Meters)
		Type	Class	
Championship	500 (540)	3 or 4	GP O	15–20 (4.6–6.1)
Professional	200 (220)	4 or 4	GP O	
Amateur	100 (110)	4 or 4	GP O	



Note: 20 ft = 6.1 m; 26 ft = 7.9 m.

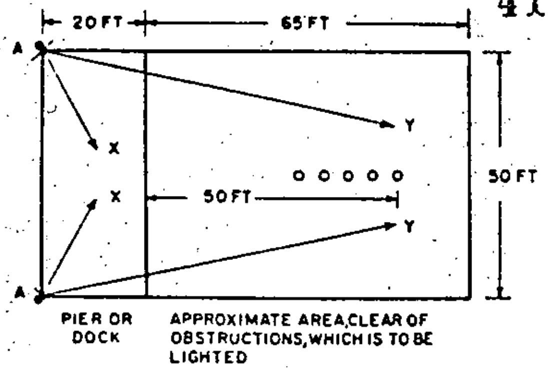
10. Casting—Bait



Note: 20 ft = 6.1 m; 40 ft = 12.2 m; 60 ft = 18.3 m; 80 ft = 24.4 m; 100 ft = 30.5 m.

IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights			Mounting Height in Feet (Meters)
	Letter Designation	Type	Class	
General on pier or dock—10 (11)	X	5 or 6	GP O	25 (7.6)
On vertical surface at 80 feet (24.4 meters)—5 (5.4)	Y	3	GP	25 (7.6)

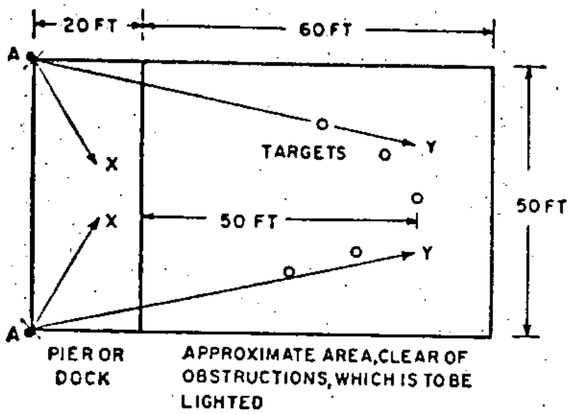
11. Casting—Wet Fly



Note: 20 ft = 6.1 m; 50 ft = 15.2 m; 65 ft = 19.8 m.

IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights			Mounting Height in Feet (Meters)
	Letter Designation	Type	Class	
General on pier or dock—10 (11)	X	5 or 6	GP O	25 (7.6)
On vertical surface at 50 feet (15.2 meters)—5 (5.4)	Y	3	GP	25 (7.6)

12. Casting—Dry Fly

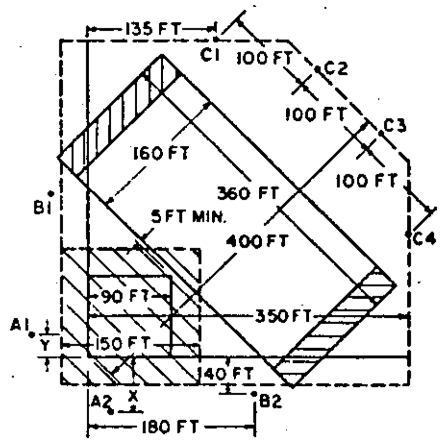


Note: 20 ft = 6.1 m; 50 ft = 15.2 m; 60 ft = 18.3 m.

IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights			Mounting Height in Feet (Meters)
	Letter Designation	Type	Class	
General on pier or dock—10 (11)	X	5 or 6	GP O	25 (7.6)
On vertical surface at 50 feet (15.2 meters)—5 (5.4)	Y	3	GP	25 (7.6)

13. Combination Baseball and Football

Sport (Class)	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service		Floodlights		Minimum Mounting Height to Bottom Floodlight Crossarm in Feet (Meters)	
	Infield	Outfield	Type	Class	Poles A1, A2, B1, B2, C1 & C4	Poles C2 & C3
Baseball (Semi-Professional and Municipal)	20 (22)	15 (16)	3, 4 or 5	GP	70 (21.3)	90 (27.4)
Football	15 (16)		4, 5 or 6	OI		



Note: 5 ft = 1.52 m; 40 ft = 12.2 m; 90 ft = 27.4 m; 100 ft = 30.5 m; 135 ft = 41.1 m; 150 ft = 45.7 m; 160 ft = 48.8 m; 180 ft = 54.9 m; 350 ft = 106.7 m; 360 ft = 109.7 m; 400 ft = 121.9 m.

This combination layout is not as satisfactory for either sport as individu[illegible] [illegible]youts. Re-aiming for each sport will increase the effectiveness. The layouts are based on the following: Total playing area, including a strip 30 feet (9.1 [illegible]) outside each foul line—132,500 square feet (12,300 square meters). Infield Area (baseball)—22,500 square feet (2,090 square meters). Outfield Ar[illegible] [illegible],000 square feet (10,200 square meters). Dimensions: X = 40 feet to 80 feet (12.2 meters to 24.4 meters); Y = 20 feet to 30 feet (6.1 meters to [illegible] meters).

14. Combination Football and Softball

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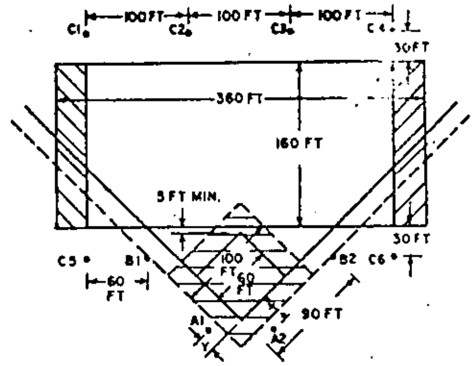
Sport (Class)	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service		Floodlights		Minimum Mounting Height to Bottom Floodlight Crossarm in Feet (Meters)
	Infield	Outfield	Type	Class	
Softball (Industrial)	20 (22)	15 (16)	3, 4 or 5	GP	
Football	15 (16)		4, 5 or 6	OI	50 (15.2)



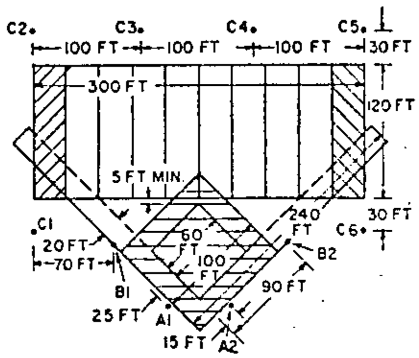
Note: 5 ft = 1.52 m; 30 ft = 9.1 m; 60 ft = 18.2 m; 90 ft = 27.4 m; 100 ft = 30.5 m; 160 ft = 48.8 m; 360 ft = 109.7 m.

The combination layout is not as satisfactory for either sport as individual layouts. Re-aiming for each sport will increase the effectiveness.
Use all floodlights on all poles except poles C5 and C6 for softball and floodlights on B and C only for football.
The layout is based on the following: Total playing area for softball including a strip 20 feet (6.1 meters) outside each foul line—85,700 square feet (7,970 square meters). Infield Area (softball)—10,000 square feet (930 square meters). Outfield Area—75,700 square feet (7,040 square meters). Dimensions: X = 25 feet to 50 feet (7.6 meters to 15.2 meters) Y = 5 feet to 15 feet (1.5 meters to 4.6 meters).

15. Combination 6-Man Football and Softball

Sport (Class)	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service		Floodlights		Poles		
	Infield	Outfield	Type	Class	Locations	No.	Mounting Height in Feet (Meters)
Softball (Industrial)	20 (22)	15 (16)	5 4	GP OI	A, B & C	10	50 (15.2)
Football (6-Man)	15 (16)		5 4	GP OI	B & C	8	50 (15.2)

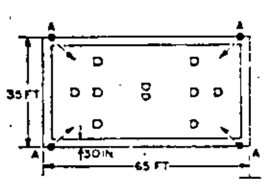
NOTE: "A" poles used only for softball.

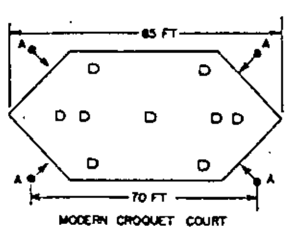


Note: 5 ft = 1.52 m; 15 ft = 4.6 m; 20 ft = 6.1 m; 25 ft = 7.6 m; 30 ft = 9.1 m; 60 ft = 18.3 m; 70 ft = 21.3 m; 90 ft = 27.4 m; 100 ft = 30.5 m; 240 ft = 73.2 m; 300 ft = 91.4 m.

The combination layout is not as satisfactory for either sport as individual layouts. Re-aiming for each sport will increase the effectiveness.

16. Croquet or Roque Courts

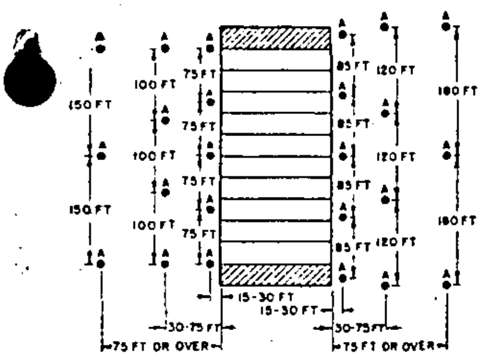




Note: 30 in = 76.2 cm; 35 ft = 10.7 m; 65 ft = 19.8 m; 70 ft = 21.3 m; 85 ft = 25.9 m.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		Mounting Height in Feet (Meters)
		Type	Class	
Tournament	10 (11)	5 or 6	GP O	20–25 (6.1–7.6)
Recreational	5 (5.4)	5 or 6	GP O	

17. Football—Regulation



Any of the above six pole plans or any intermediate longitudinal spacings are considered good practice with local field conditions dictating exact pole locations.

Note: 15 ft = 4.6 m; 30 ft = 9.1 m; 75 ft = 22.9 m; 85 ft = 25.9 m; 120 ft = 36.6 m; 150 ft = 45.7 m; 180 ft = 54.9 m.

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CLASSIFICATION

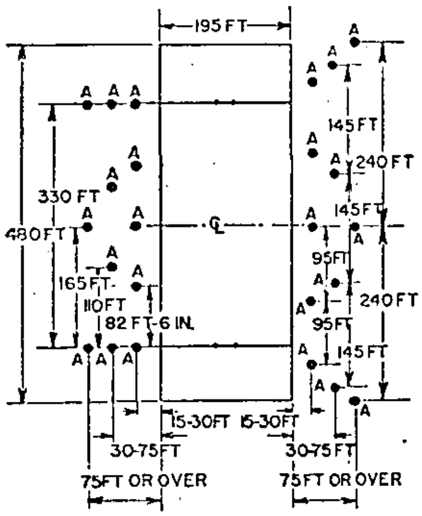
It is generally conceded that distance between the spectators and the play is the first consideration in determining the class and lighting requirements. However, the potential seating capacity of the stands should also be considered.

Class	Distance—Nearest Sideline to Farthest Row of Spectators in Feet (Meters)	Spectator Seating Capacity
I	over 100 (30.5)	Over 30,000 spectators
II	50-100 (15.2-30.5)	10,000-30,000
III	30-50 (9.1-15.2)	5,000-10,000
IV	Under 30 (9.1)	5,000
V	No fixed seating facilities	

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Distance—Nearest Sideline to Floodlight Poles in Feet (Meters)	No. of Poles	Floodlights	
				Type	Class
I	100 (110)	Over 140 (42.7) 100-140 (30.5-42.7)	6 6	1 or 2 2 or 3	GP GP
II	50 (54)	75-100 (22.9-30.5) 50-75 (15.2-22.9)	6 8	3 3, 4	GP GP
III	30 (32)	30-50 (9.1-15.2)	8	4	GP
IV	20 (22)	15-30 (4.6-9.1) 15-30 (4.6-9.1) 15-30 (4.6-9.1)	10 10 10	5 6 6	GP OI O
V	10 (11)	15-30 (4.6-9.1) 15-30 (4.6-9.1) 15-30 (4.6-9.1)	10 10 10	5 6 6	GP OI O

For minimum mounting height see chart, page 55.

18. Canadian Football—Rugby



Any of the above six pole plans or any intermediate longitudinal spacings are considered good practice with local field conditions dictating exact pole locations.

Note: 15 ft = 4.6 m; 30 ft = 9.1 m; 75 ft = 22.9 m; 82 ft 6 in = 25.1 m; 95 ft = 29.0 m; 110 ft = 33.5 m; 145 ft = 44.2 m; 165 ft = 50.3 m; 195 ft = 59.4 m; 240 ft = 73.2 m; 330 ft = 100.6 m; 480 ft = 146.3 m.

CLASSIFICATION

It is generally conceded that distance between the spectators and the play is the first consideration in determining the class and lighting requirements. However, the potential seating capacity of the stands should also be considered.

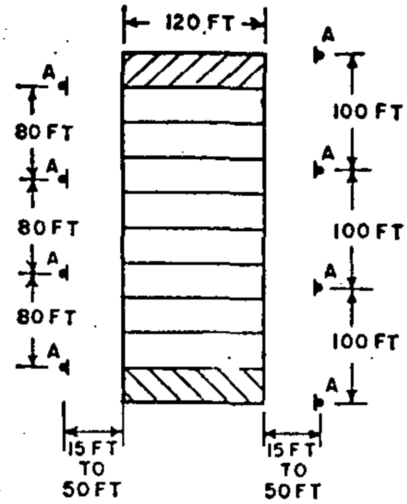
Class	Distance—Nearest Sideline to Farthest Row of Spectators in Feet (Meters)	Spectator Seating Capacity
I	over 100 (30.5)	Over 30,000 spectators
II	50-100 (15.2-30.5)	10,000-30,000
III	30-50 (9.1-15.2)	5,000-10,000
IV	Under 30 (9.1)	5,000
V	No fixed seating facilities	

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Distance—Nearest Sideline to Floodlight Poles in Feet (Meters)	No. of Poles	Floodlights	
				Type	Class
I	100 (110)	over 140 (42.7) 100-140 (30.5-42.7)	6 6	1 or 2 2 or 3	GP GP
II	50 (54)	75-100 (22.9-30.5) 50-75 (15.2-22.9)	6 8	3 3, 4	GP GP
III	30 (32)	30-50 (9.1-15.2)	8	3, 4, 5	GP
IV	20 (22)	15-30 (4.6-9.1) 15-30 (4.6-9.1) 15-30 (4.6-9.1)	10 10 10	5 5 or 6 6	GP OI O
V	10 (11)	15-30 (4.6-9.1) 15-30 (4.6-9.1) 15-30 (4.6-9.1)	10 10 10	5 5 or 6 6	GP OI O

For minimum mounting height, see chart page 55.

19. Football–6-Man

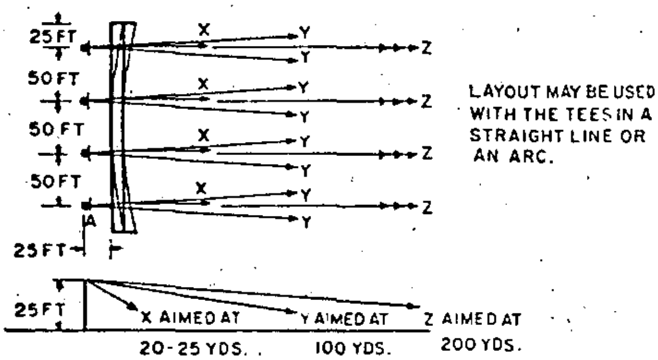
Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Distance Nearest Sideline to Floodlight Poles in Feet (Meters)	No. of Poles	Floodlights	
				Type	Class
High School or College	20 (22)	15–30 (4.6–9.1)	8	5 or 6	GP or OI
		30–50 (9.1–15.2)	8	5	GP
Jr. High School or Recreation	10 (11)	15–30 (4.6–9.1)	8	5 or 6	GP or OI
		30–50 (9.1–15.2)	8	5	GP



Either of the pole plans at right or any intermediate longitudinal spacings are considered good practice with local field conditions dictating exact pole locations.

Note: 15 ft = 4.6 m; 50 ft = 15.2 m; 80 ft = 24.4 m; 100 ft = 30.5 m; 120 ft = 36.6 m.

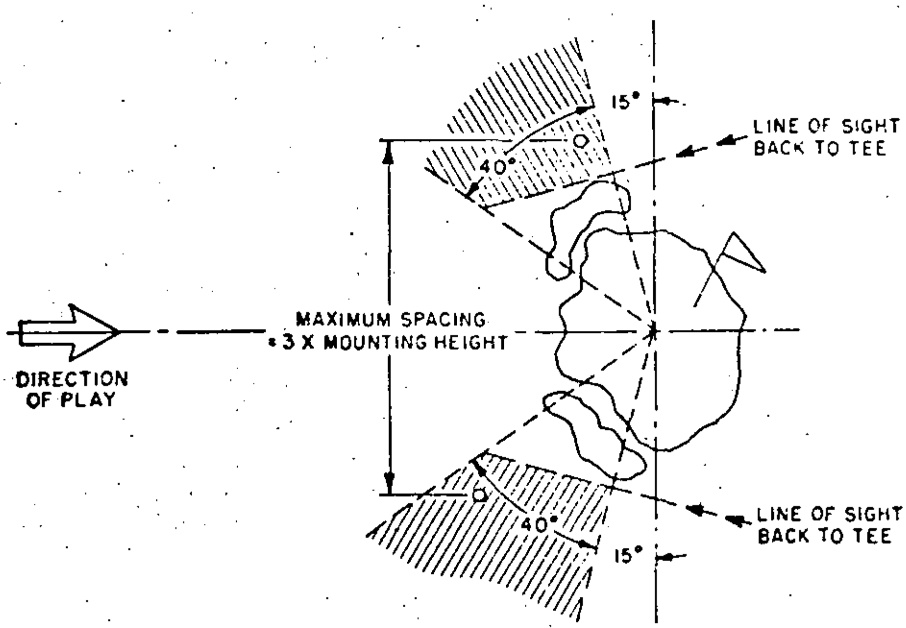
20-A. Golf–Driving Range



IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		
	Aiming Point	Type	Class
10 (11)—general on tees	X	5	GP
	Y	3	GP
5 (5.4)—on vertical surface at 200 yards (180 meters)	Z	1	GP

Minimum mounting height: 25 feet (7.6 meters) above tees.

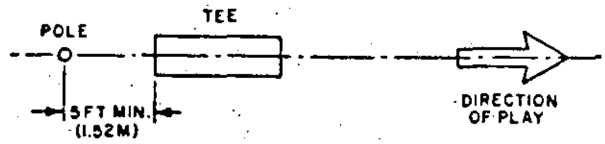
20-B. Golf Course Greens



1. Each green shall be lighted from at least two directions to minimize harsh shadows.
2. The average maintained horizontal illumination over the green area shall be 5 footcandles (5.4 dekalux).
3. Pole locations should be confined to the 40° cross-hatched zone indicated in front of the green.
4. Pole spacing should be equal to or less than 3 times mounting height.
5. The maximum horizontal illumination measured at any place on the green area shall not be greater than 3 times the minimum illumination measured at any other place on the green area.
6. Care should be taken in placement of luminaire poles around green so as to neither obstruct the approaching drive nor create objectionable glare in the eyes of the approaching golfer.
7. Special consideration must be given areas not covered by the general lighting system. Some will present physical hazards or require special accent. Examples: sand traps, water hazards, bridges, steep grades, roughs, areas adjacent to greens, pathways, etc.

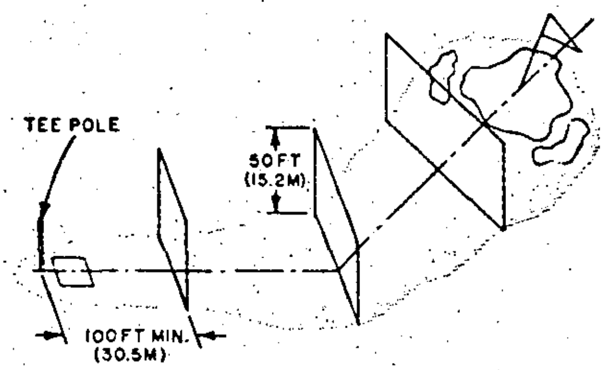
20-C. Golf Course Tees

45



1. Use one pole located a minimum of 5 feet (1.52 meters) behind back edge of tee. Extremely wide tees may require more than one floodlight location.
2. Floodlight mounting height above tee should be equal to or greater than one half the width of the tree but in no caseless than 30 feet (9.1 meters) Good practice indicates higher mounting heigh s for deep tees.
3. The average maintained horizontal illumination over the tee area should be 5 footcandles (5.4 dekalux).

20-D. Golf Course Fairways



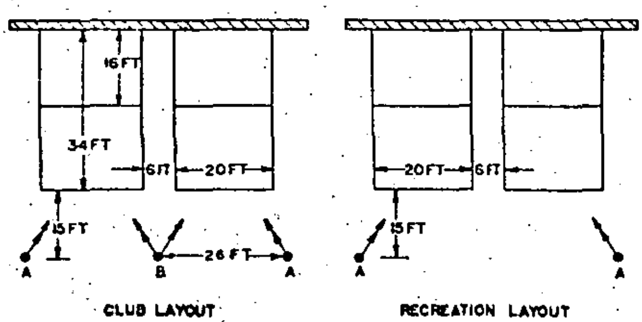
IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service			Maximum Uniformity Ratio
Plane	Average	Minimum	
Horizontal	1.0 (1.1)	0.2 (.22)	7:1
Vertical	3.0 (3.2)	1.0 (1.1)	7:1

* Uniformity Ratio is defined as the ratio of average to minimum illumination at any point in the plane under consideration.

— Special Notes —

1. Vertical planes should be considered to:
   (a) Extend the full width of the fairway at the point in question,
   (b) Be perpendicular to the centerline of the fairway,
   (c) Extend from fairway centerline elevation to a point 50 feet (15.2 meters) above the fairway centerline.
2. Vertical planes should be considered to be at points midway between fairway poles.
3. The first vertical plane should be considered to be no less than 100 feet (30.5 meters) from the tee pole.
4. Minimum mounting height should be 35 feet (10.7 meters) above the pole base; however, it may be necessary to adjust this if unusual terrain features exist.
5. Spacing between poles must be coordinated wtih photometric characteristics of floodlight employed, terrain existing at site and other lighting design criteria.

21. Handball—Outdoor Courts

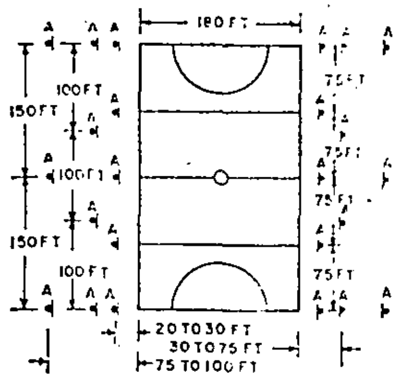


Note: 6 ft = 1.83 m; 15 ft = 4.6 m; 16 ft = 4.9 m; 20 ft = 6.1 m; 26 ft = 7.9 m; 34 ft = 10.4 m.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights	
		Type	Class
Club	20 (22)	5 or 6	GP O
Recreational	10 (11)	5 or 6	GP O

Minimum mounting height: 25 feet (7.6 meters).

22. Hockey—Field 46



Any of the 6 pole plans or any intermediate longitudinal spacings are considered good practice with local field conditions dictating the exact locations.

Note: 20 ft = 6.1 m; 30 ft = 9.1 m; 75 ft = 22.9 m; 100 ft = 30.5 m; 150 ft = 45.7 m; 180 ft = 54.9 m.

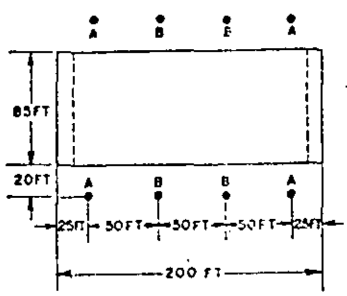
CLASSIFICATION

It is generally conceded that the distance between the spectators and the play is the first consideration in determining the class and lighting requirements. However, the potential seating capacity of the stands should also be considered.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Distance Nearest Sideline to Floodlight Pole in Feet (Meters)	No. of Poles	Floodlights	
				Type	Class
High School or College	20 (22)	75–100 (22.9–30.5)	6	3	GP
		30–75 (9.1–22.9)	8	4	GP
		20–30 (6.1–9.1)	10	4, 5 or 6	GP or OI

For minimum mounting height see chart, page 55.

23. Hockey—Outdoor Ice Rinks

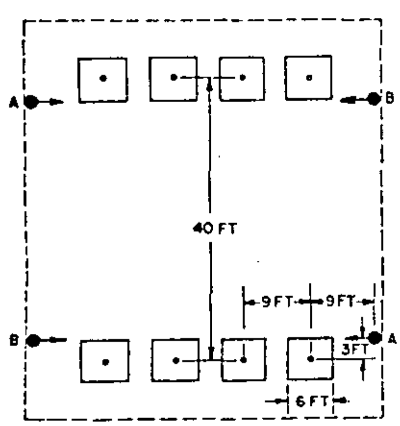


Note: 20 ft = 6.1 m; 25 ft = 7.6 m; 50 ft = 15.2 m; 85 ft = 25.9 m; 200 ft = 61.0 m.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service		Floodlights		Mounting Height in Feet (Meters)
	Outdoor	Indoor	Type	Class	
Professional	50 (54)	100 (110)	5	GP	40 (12.2)
			6	OI	
Amateur	20 (22)	50 (54)	5	GP	
			6	OI	
Recreational	10 (11)	20 (22)	5	GP	
			6	OI	

Poles: 8

24. Horseshoe Courts



Note: 3 ft = .91 m; 6 ft = 1.83 m; 9 ft = 2.74 m; 40 ft = 12.2 m.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	No. of Courts	Floodlights		Minimum Mounting Height in Feet (Meters)
			Type	Class	
Tournament	10 (11)	4–6	5 or 6	GP O	20 (6.1)
		1–3	5 or 6	GP O	20 (6.1)
Recreational	5 (5.4)	4–6	5 or 6	GP O	20 (6.1)
		1–3	5 or 6	GP O	20 (6.1)

For 1-3 courts no "B" poles are required.
Poles: 4 for 4-6 court layout, 2 for 1-3 court layout.

25. Horse Show Ring

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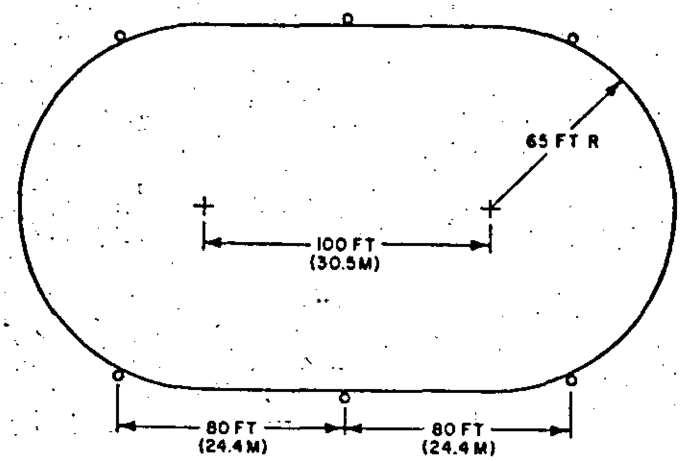
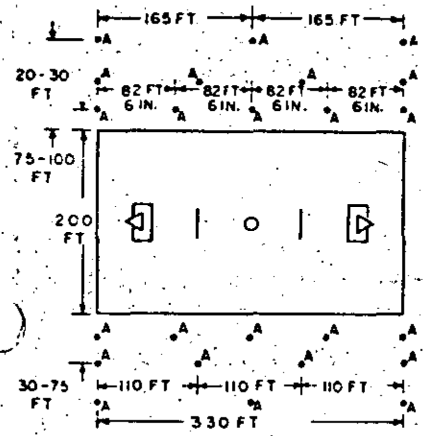
IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		Minimum Mounting Height in Feet (Meters)
	Type	Class	
10 (11)	3, 4, 5 or 6	GP	30 (9.1)



26. Lacrosse



Any of the 6 pole plans or any intermediate longitudinal spacings are considered good practice with local field conditions dictating the exact locations.

Note: 20 ft = 6.1 m; 30 ft = 9.1 m; 75 ft = 22.9 m; 82 ft 6 in = 25.2 m; 100 ft = 30.5 m; 110 ft = 33.5 m; 165 ft = 50.3 m; 200 ft = 61.0 m; 330 ft = 100.6 m.

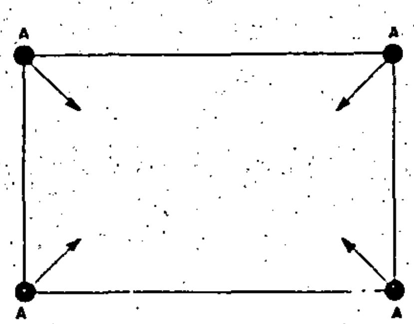
CLASSIFICATION

It is generally conceded that the distance between the spectators and the play is the first consideration in determining the class and lighting requirements. However, the potential seating capacity of the stands should also be considered.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Distance—Nearest Sideline to Floodlight Pole in Feet (Meters)	No. of Poles	Floodlights	
				Type	Class
High School or College	20 (22)	75–100 (22.9–30.5)	6	3	GP
		30–75 (9.1–22.9)	8	4	GP
		20–30 (6.1–9.1)	10	4, 5 or 6	GP or OI

For minimum mounting height see chart, page 55.

27. Playgrounds



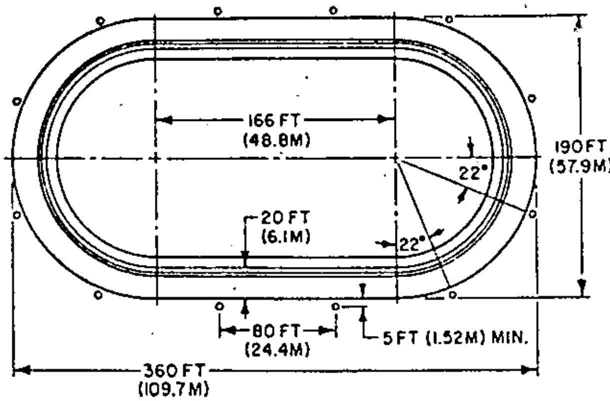
Pole spacing not to exceed 4 times mounting height.

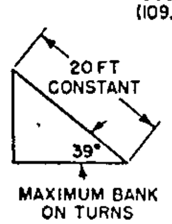
IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		Minimum Mounting Height in Feet (Meters)
	Type	Class	
5 (5.4)	5	GP	20 (6.1)
	6	O	

34. A 250 Meter Bicycle Track

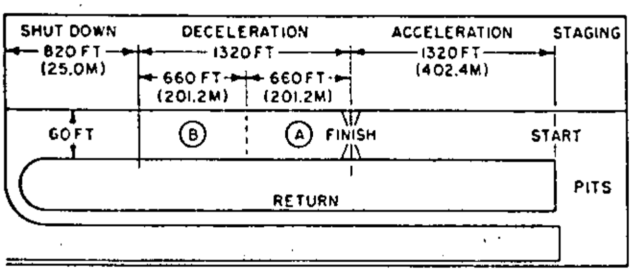
50

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights Type	Floodlights Class	Minimum Mounting Height in Feet (Meters)
Recreational	10 (11)	6 x 4 or 4, 5 or 6	GP	40 (12.2)
Tournament	30 (32)		GP	40 (12.2)





35. Drag Strip

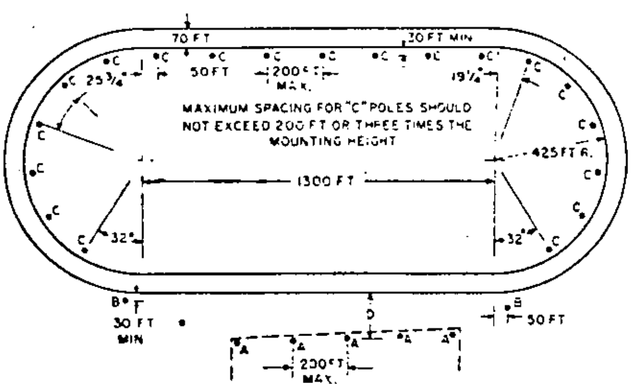


The spacing ratio is 2 times the mounting height. Special consideration must be given to areas not covered by the main track lighting system. Poles should be located outside of danger zone of strip and may be either on one or both sides.

Area	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	
Staging	10 (11)	
Acceleration	20 (22)	
Deceleration	A	15 (16)
	B	10 (11)
Shut Down	5 (5.4)	

For minimum mounting height see the Chart (page 55).

36. Racing—One Mile (1609 Meter) Horse Track (High Mounting)



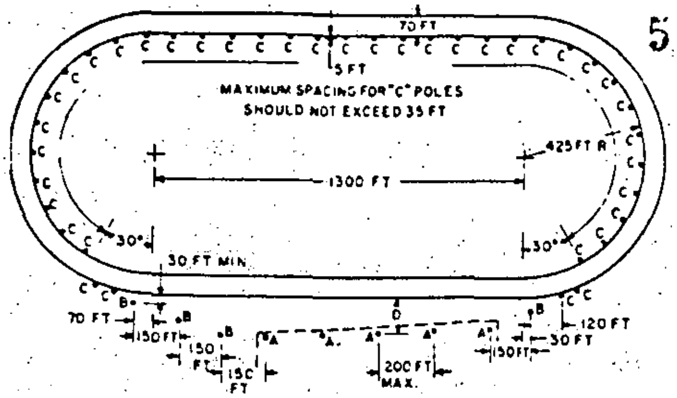
MAXIMUM SPACING FOR "A" AND OR "B" POLES SHOULD NOT EXCEED 200 FT (61.0M) OR THREE TIMES THE MOUNTING HEIGHT

Variations in quantity and type of floodlights as well as mounting heights may be required under conditions different from those shown in the above layout. Special consideration should be given to the lighting of finish line. Floodlights may be mounted on grandstand roof if desired. "Type" specification and mounting height depend upon floodlight location setback "D".

Note: 30 ft = 9.1 m; 50 ft = 15.2 m; 70 ft = 21.3 m; 200 ft = 61.0 m; 425 ft = 130.0 m; 1300 ft = 396.3 m.

IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights Type	Floodlights Class	Minimum Mounting Height in Feet (Meters)	Position Designation
	2, 3 or 5	GP	See Chart page 55	A
20 (22)	2, 3 or 5	GP	60 (18.3)	B
	3 or 5	GP	60 (18.3)	C

37. Racing—One Mile (1609 Meter) Horse Track (Low Mounting)



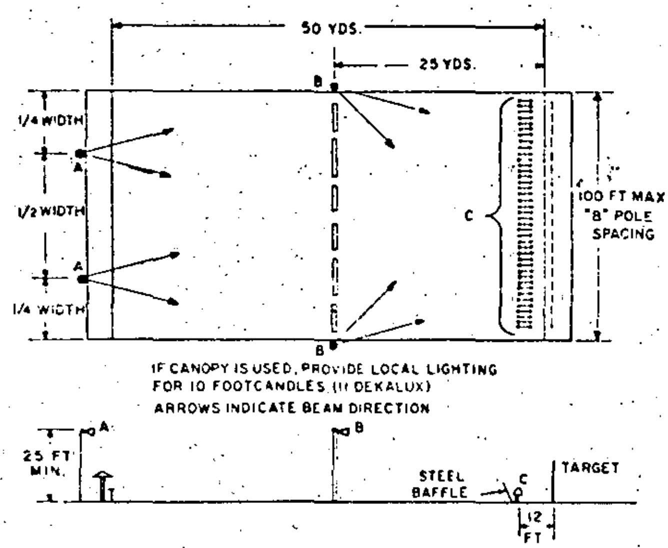
MAXIMUM SPACING FOR "A" AND OR "B" POLES SHOULD NOT EXCEED 200 FT (61.0M) OR THREE TIMES THE MOUNTING HEIGHT

Note: 5 ft = 1.52 m; 30 ft = 9.1 m; 35 ft = 10.7 m; 70 ft = 21.3 m; 120 ft = 83.5 m; 150 ft = 45.7 m; 425 ft = 130.0 m; 1300 ft = 396.2 m.

IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Position Designation	Floodlights		Minimum Mounting Height in Feet (Meters)
		Type	Class	
20 (22)	A	2, 3 or 5	GP	See Chart, page 55
	B	2, 3 or 5	GP	
	C	4, 5 or 6	OI	30 (9.1)

Variations may be required in the type of floodlight at the "A" and "B" locations, as well as the mounting height under conditions different from those shown in the layout. Special consideration should be given to the lighting of the finish line. Floodlights may be mounted on grandstand roof if desired. "Type" specification and mounting height depend upon floodlight location setback "D."

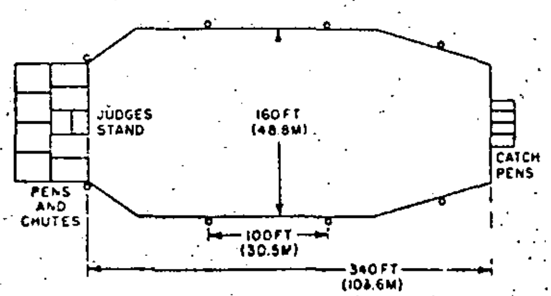
38. Rifle and Pistol—50-yard (46.7 Meter) Outdoor Range



Note: 12 ft = 3.7 m; 25 ft = 7.6 m; 100 ft = 30.5 m; 25 yds = 22.9 m; 50 yds = 45.7 m.

IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights			Mounting Height in Feet (Meters)
	Position Designation	Average Type	Class	
10 (11) at firing point	A	5	GP	25 (7.6)
5 (5.4) on range	B	5	GP	25 (7.6)
50 (54) on target	C	4	GP	on ground

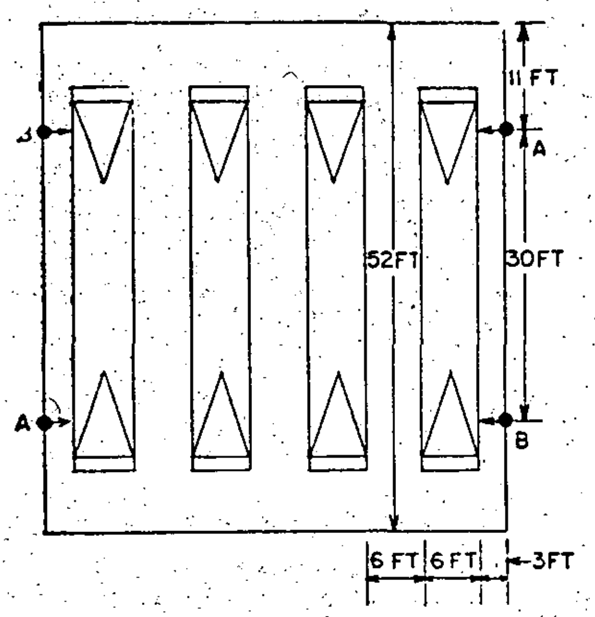
39. Rodeo Arena



Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlight		Minimum Mounting Height in Feet (Meters)
		Type	Class	
Professional	50 (54)	3, 4, 5 or 6	GP	30 (9.1)
Amateur	30 (32)			
Recreational	10 (11)			

To minimize glare for calf roping, a relatively close pole spacing is recommended.

40-A. Shuffleboard—Outdoor Courts Using Floodlights

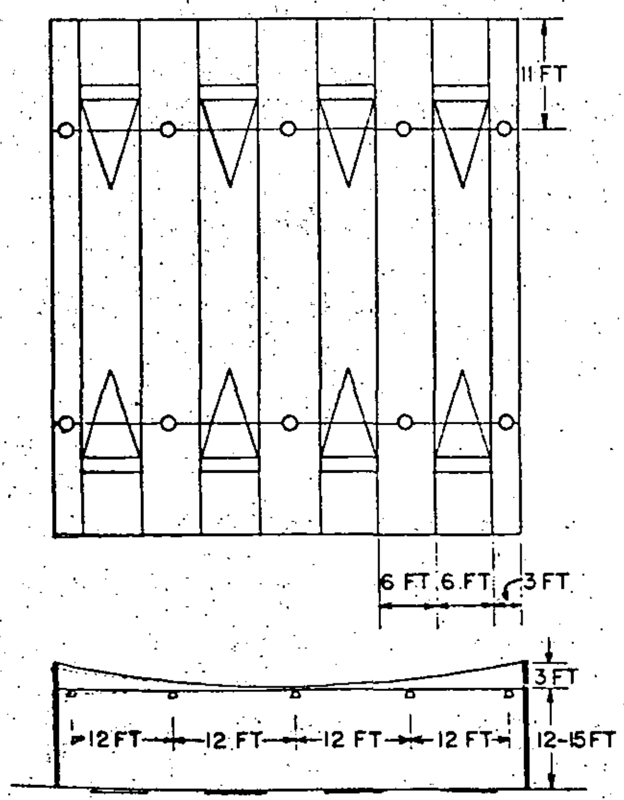


Note: 3 ft = .91 m; 6 ft = 1.83 m; 11 ft = 3.35 m; 30 ft = 9.1 m; 52 ft = 15.9 m.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	No. of Courts	Floodlights Type	Floodlights Class
Tournament	10 (11)	4-6	5 or 6	GP O
		1-3	5 or 6	GP O
Recreational	5 (5.4)	4-6	5 or 6	GP O
		1-3	5 or 6	GP O

NOTE: For 1-3 courts no "B" poles are required
Mounting height: At least 20 feet (6.1 meters) above courts
Poles: Four for 4-6 court layout two for 1-3 court layout

40-B. Shuffleboard—Outdoor Courts Using Indoor Type Lighting Units (Adapted for Outdoor Use)

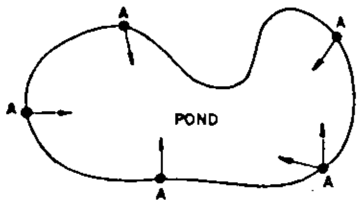


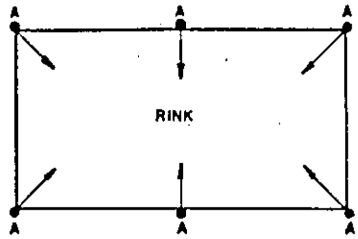
Note: 3 ft = .91 m; 6 ft = 1.83 m; 11 ft = 3.35 m; 12 ft = 3.7 m; 15 ft = 4.6 m.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Luminaire Designation
Tournament	10 (11)	Direct (spread distribution)
Recreational	5 (5.4)	Direct (spread distribution)

Mounting Height: As shown.

41. Skating—Outdoor Rink and Pond

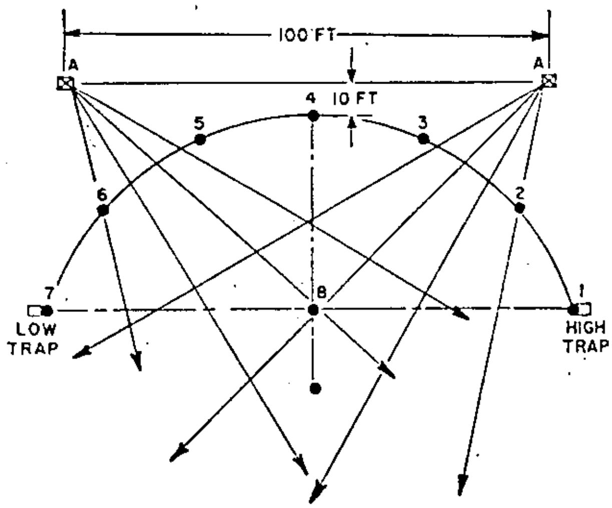




	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights	
		Type	Class
Rinks	5 (5.4)	5	GP
		6	O
Ponds	1 (1.1)	5	GP
		6	O

Pole Spacing: Not to exceed 4 times mounting height. For minimum mounting height see chart, page 55.

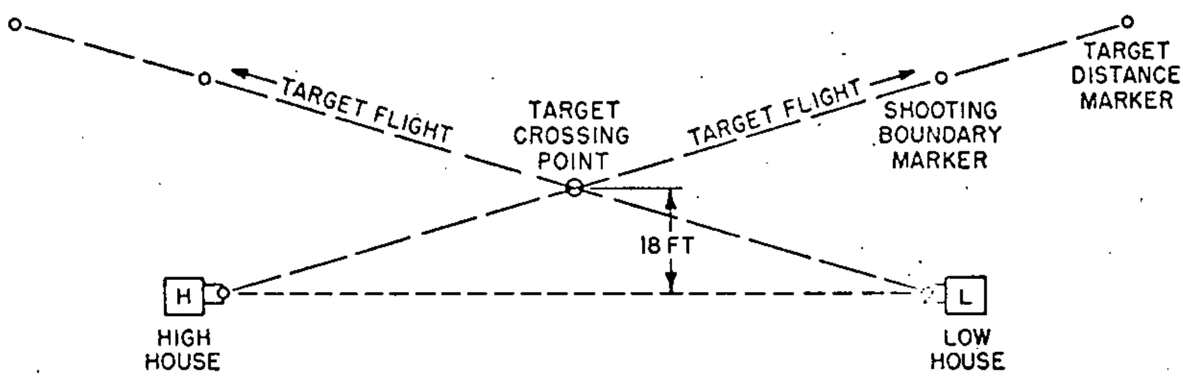
42. Skeet Shooting

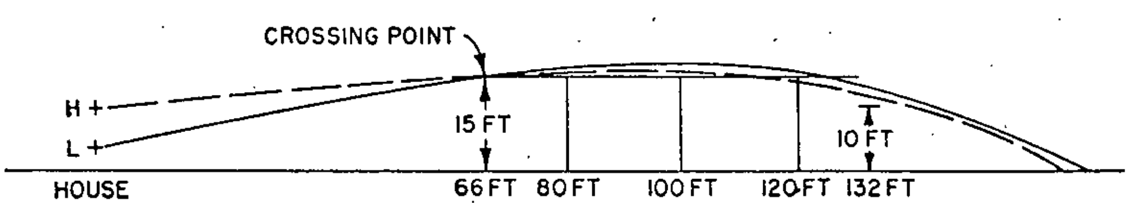


Note: 10 ft = 3.1 m; 15 ft = 4.6 m; 18 ft = 5.5 m; 66 ft = 20.1 m; 80 ft = 24.4 m; 100 ft = 30.5 m; 120 ft = 36.6 m; 132 ft = 40.2 m.

IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		Minimum Mounting Height in Feet (Meters)
	Type	Class	
Target (vertical) at 60 feet (18.3 meters)—30 (32)* Firing Point—5 (5.4)	2	GP	20 (6.1)

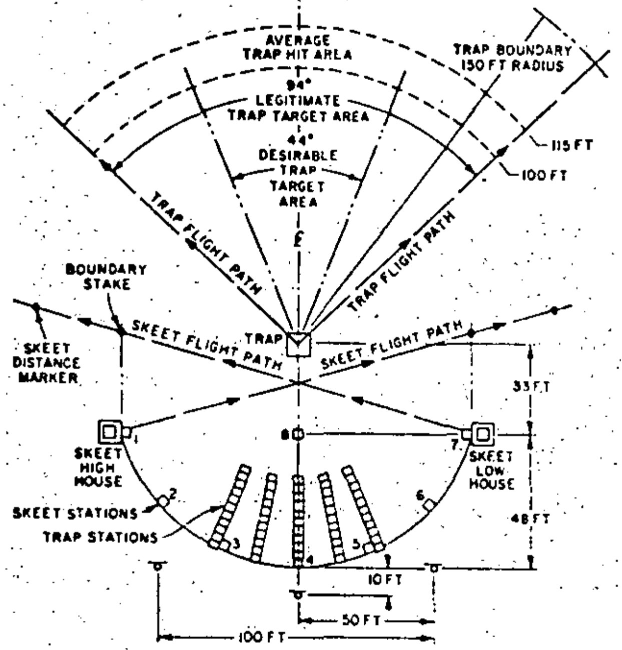
Poles: 2.
* Normal to all shooting positions from trap to boundary post.





SKEET
TRAJECTORIES OF TARGETS
(APPROXIMATE)

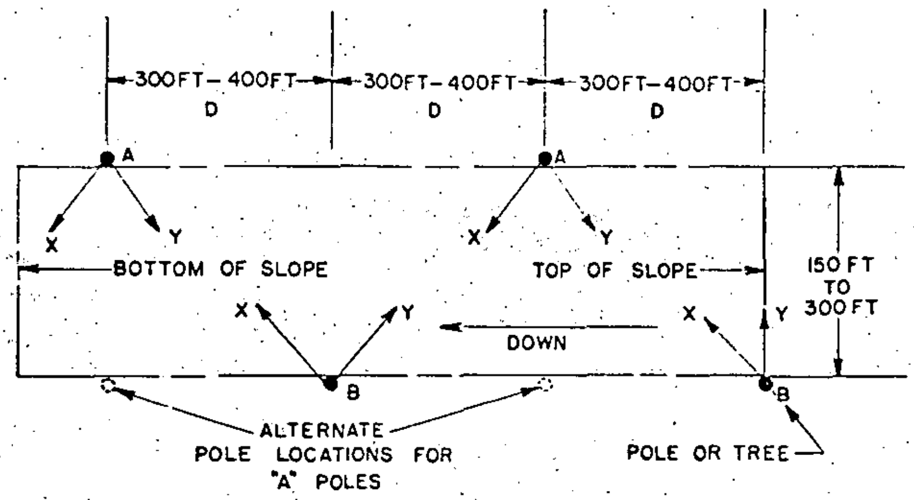
43. Combination Skeet and Trap



Note: 10 ft = 3.1 m; 33 ft = 10.6 m; 48 ft = 14.6 m; 50 ft = 15.2 m; 100 ft = 30.5 m; 115 ft = 45.7 m.

Target	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		Minimum Mounting Height in Feet (Meters)
		Type	Class	
TRAP: (Vertical at 100 ft. (30.5 m.) from trap house)	30 (32)	2	GP	20 (6.1)
SKEET: (Vertical, at 60 ft. (18.3 m.) from shooting position)	30 (32)	2	GP	20 (6.1)

44. Skiing—Practice Slopes



Note: 150 ft = 45.7 m; 300 ft = 91.4 m; 400 ft = 121.9 m.

IES Current Recommended Practice

Footcandles (Dekalux) maintained in service—1.0 (1.1)

Floodlights

DESCRIPTION: Floodlights marked "X"—Type 3, 4 or 5, class GP. Floodlights marked "Y"—Type 3, 4 or 5, class GP.

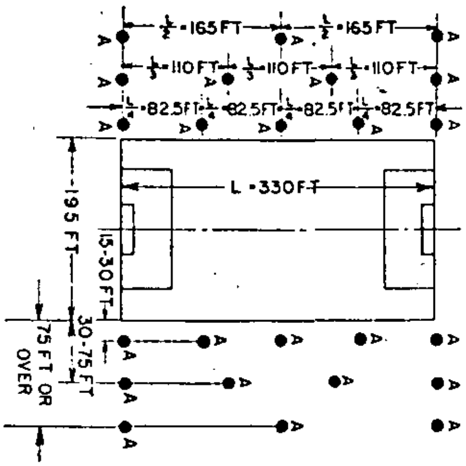
NUMBER: Provide single floodlights or banks of floodlights according to area to be lighted, based on 10 lamp lumens per square foot (square meter) of area.

DISTRIBUTION: Distribute floodlights to project approximately 2 lumens in the direction of travel ("X" arrows) and one lumen opposing direction of travel ("Y" arrows).

Mounting Height

Not less than 1/10 dimension "D".

45. Soccer

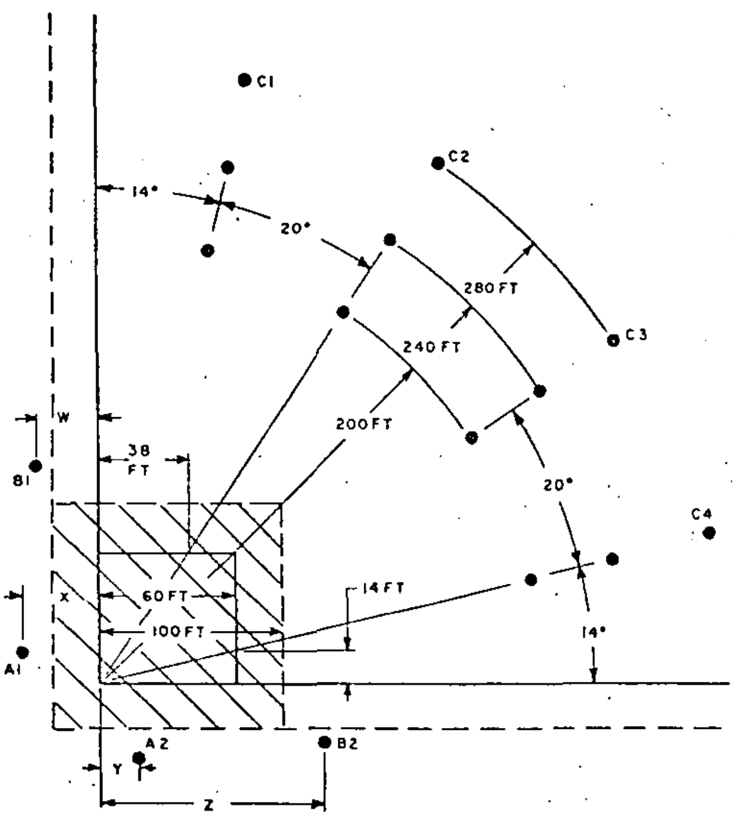


Note: 15 ft = 4.6 m; 30 ft = 9.1 m; 75 ft = 22.9 m; 82.5 ft = 25.1 m; 110 ft = 33.5 m; 165 ft = 50.3 m; 195 ft = 59.4 m; 330 ft = 100.6 m.

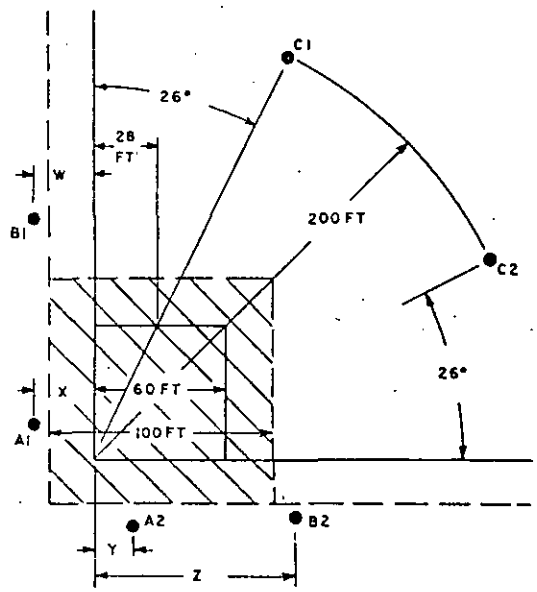
Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Distance—Nearest Sideline to Floodlight Poles in Feet (Meters)	No. of Poles	Floodlights	
				Type	Class
Professional and College	30 (32)	over 140 (42.7)	6	1 or 2	GP
		100-140 (30.5-42.7)	6	2 or 3	GP
		75-100 (22.9-30.5)	6	3	GP
		50-75 (15.2-22.9)	8	3	GP
High School	20 (22)	30-50 (9.1-15.2)	8	4	GP
		15-30 (4.6-9.1)	10	5	GP
		15-30 (4.6-9.1)	10	5 or 6	OI
		15-30 (4.6-9.1)	10	6	O
Recreational	10 (11)	15-30 (4.6-9.1)	10	5	GP
		15-30 (4.6-9.1)	10	5 or 6	OI
		15-30 (4.6-9.1)	10	6	O

For minimum mounting height see chart, page 55.

46. Softball



8 POLE LAYOUT



6 POLE LAYOUT

Note: 15 ft = 4.6 m; 28 ft = 8.5 m; 40 ft = 12.2 m; 60 ft = 18.3 m; 100 ft = 30.5 m; 200 ft = 61.0 m; 240 ft = 73.2 m; 280 ft = 85.3 m.

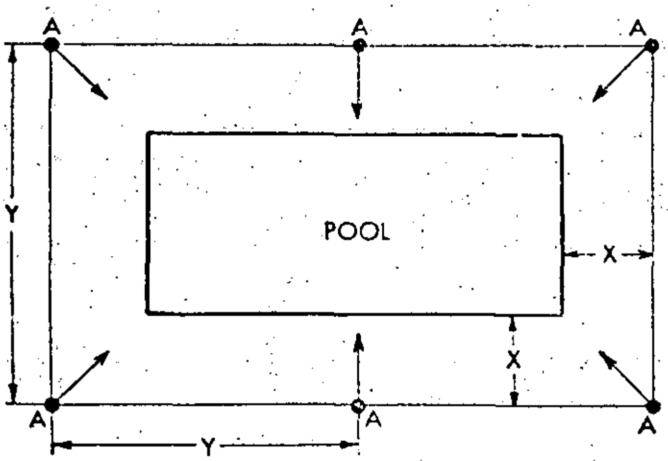
These layouts are based on the following total playing area including a strip 20 feet wide outside each foul line: Infield Area—10,000 square feet; Outfield Area (200 feet)—29,815 square feet; Outfield Area (240 feet)—45,240 square feet; Outfield Area (280 feet)—70,330 square feet. Dimensions: W = 20 feet to 30 feet; X = 25 feet to 50 feet; Y = 5 feet to 15 feet; Z = 90 feet to 110 feet.

These layouts are based on the following total playing area including a strip 20 feet wide (6.1 meters) outside each foul line. Infield Area—10,000 square feet (930 square meters); Outfield Area 200 feet (61.0 meters)—29,815 square feet (2,770 square meters); Outfield Area 240 feet (73.2 meters)—63,200 square feet (5,877 square meters); Outfield Area 280 feet (85.3 meters)—70,330 square feet (6,540 square meters). Dimensions: W = 20 feet to 30 feet (6.1 meters to 9.1 meters); X = 25 feet to 50 feet (7.6 meters to 15.2 meters); Y = 5 feet for 15 feet (1.5 meters to 4.6 meters); Z = 90 feet to 110 feet (27.4 meters to 33.5 meters).

Class	Outfield in Feet (Meters)	IES Current Recommended Practice—Footcandles (Dekalux) Maintained In Service		Floodlights		Minimum Mounting Height to Bottom Floodlight Crossarm In Feet (Meters)	
		Infield	Outfield	Type	Class	A & B Poles	C & D Poles
8-Pole Layout							
Professional and Championship	280 (85.3) 240 (73.2)	50 (54)	30 (32)	3, 4 or 5	GP	50 (15.2)	60 (18.3)
Semi-Professional	280 (85.3) 240 (73.2)	30 (32)	20 (22)	3, 4 or 5 4, 5 or 6	GP OI	40 (12.2) 40 (12.2)	55 (16.8) 50 (15.2)
Industrial League	280 (85.3) 240 (73.2) 200 (61.0)	20 (22)	15 (16)	3, 4 or 5 4, 5 or 6 6	GP OI O	35 (10.7) 35 (10.7) 35 (10.7)	50 (15.2) 45 (13.7) 40 (12.2)
6-Pole Layout							
Recreational	200 (61.0)	10 (11)	7 (7.5)	5 4, 5 or 6 6	GP OI O	35 (10.7)	40 (12.2)

Poles: 6 for recreational; 8 for other classes
NOTE: Supplementary corner poles may be installed to carry overhead wire around boundary rather than across playing area
Slow-pitch softball, Tournament Class to be same as Industrial League above
Slow-pitch softball recreational Class to be same as Recreational above

47. Swimming–Outdoor Pools Overhead Lighting (For Underwater Lighting See Fig. 25 in Text)

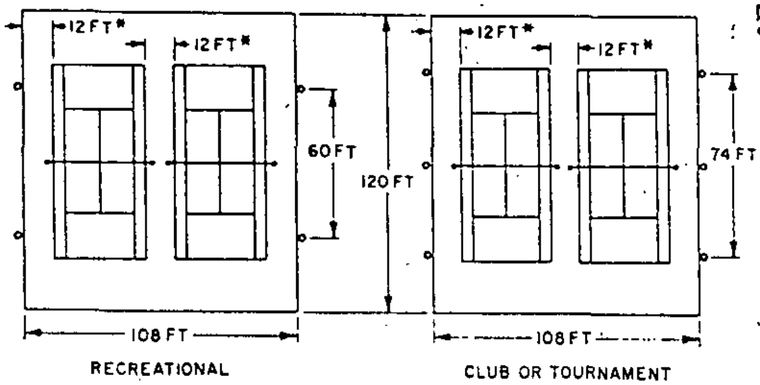


DIMENSIONS
X – 20 FT (6.1M) OR MORE
Y – NOT TO EXCEED 4 TIMES MOUNTING HEIGHT

IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		Minimum Mounting Height in Feet (Meters)
	Type	Class	
10 (11)	5, 6	GP	20 (6.1)

The pole locations outline the area to be lighted. Pole spacing not to exceed 4 times mounting height.

48. Tennis

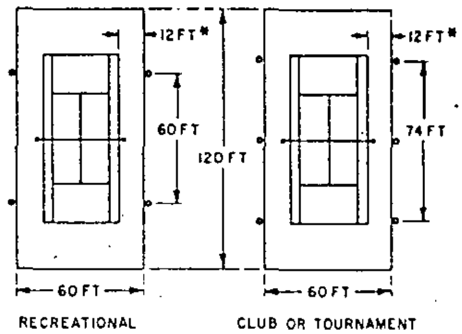


TENNIS – TWO COURTS
POLES

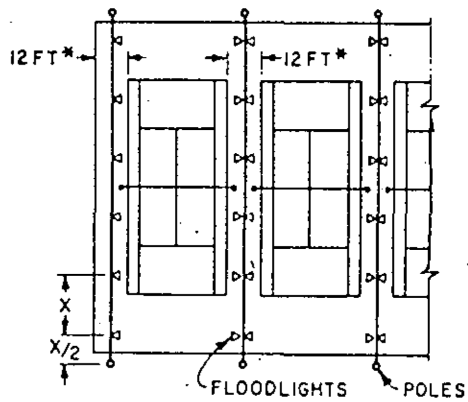
Note: 12 ft = 3.7 m; 60 ft = 18.3 m; 74 ft = 22.6 m; 108 ft = 32.9 m; 120 ft = 36.6 m.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Uniformity Ratio Maximum & Minimum
Tournament	30 (32)	2:1
Club	20 (22)	2:1
Recreational	10 (11)	3:1

Minimum Mounting Height in Feet (Meters) = 30 (9.1)
All floodlights to be IES Types 5 or 6
●—Recommended pole locations
* These clearances are to be considered minimum; greater distances are desirable when space permits



TENNIS – ONE COURT
POLES



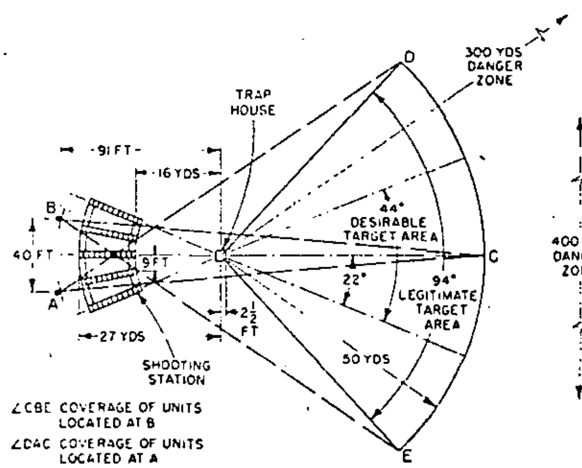
TENNIS – ONE OR MORE COURTS
MESSENGER CABLE MOUNTING

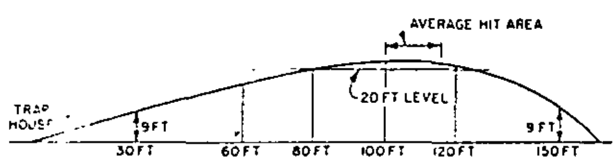
Floodlights suspended on messenger cable as indicated here may use any lamps including fluorescent.

49. Trap Shooting

IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Floodlights		Mounting Height in Feet (Meters)
	Type	Class	
Target (vertical at 100 feet (30.5m) from trap)—30 (32)	2	GP	20 (6.1)
Firing point—5 (5.4)			

Poles: 2.



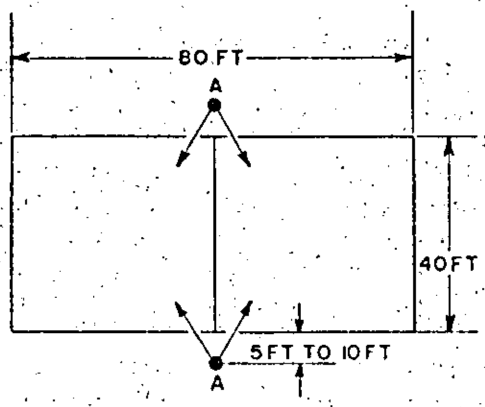


TRAP
TRAJECTORY OF TARGET (APPROXIMATE)

Note: 2½ ft = .76 m; 9 ft = 2.74 m; 20 ft = 6.1 m; 30 ft = 9.1 m; 40 ft = 12.2 m; 60 ft = 18.3 m; 80 ft = .4 m; 91 ft = 27.7 m; 100 ft = 30.5 m; 120 ft = 36.6 m; 150 ft = 45.7 m; 16 yds = 14.6 m; 27 yds = 24.7 m; 50 yds = 45.7 m; 300 yds = 274 m; 366 yds = 334 m.

50. Volleyball—Outdoor Courts

58

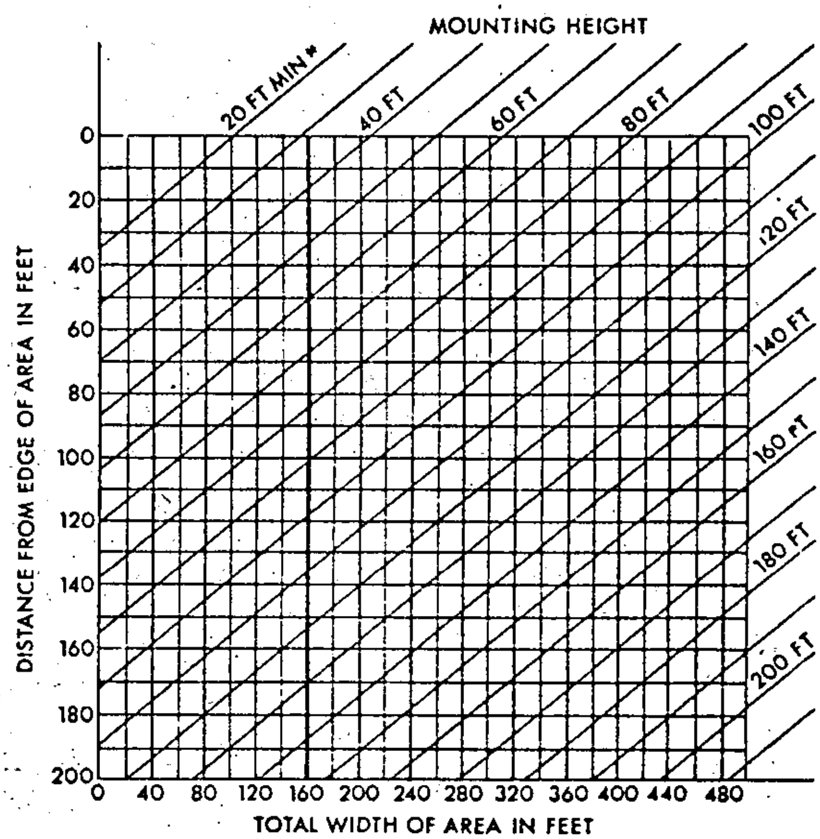


Note: 5 ft = 1.52 m; 10 ft = 3.1 m; 40 ft = 12.2 m; 80 ft = 24.4 m.

Class	IES Current Recommended Practice—Footcandles (Dekalux) Maintained in Service	Type	Class	Mounting Height in Feet (Meters)
Tournament	20 (22)	5 or 6	GP O	30 (9.1)
Recreational	10 (11)	5 or 6	GP O	30 (9.1)

Poles: 4.

MOUNTING HEIGHT CHART



NOTE: 1 METER = 3.2808 FEET

***20 FEET MINIMUM FOR GROUND AREA SPORTS.** **30 FEET MINIMUM FOR AERIAL SPORTS**

Mounting height chart for all sports areas—minimum height to bottom floodlight crossarm. Read mounting height along diagonal at intersection of appropriate horizontal and vertical lines. For example, where Area Width = 160 feet (48.8 meters) and Pole Setback = 50 feet (15.2 meters), minimum height of 160 feet (48.8 meters) is indicated by diagonal at intersection of 50 feet (15.2 meters) and 160 feet (48.8 meters).

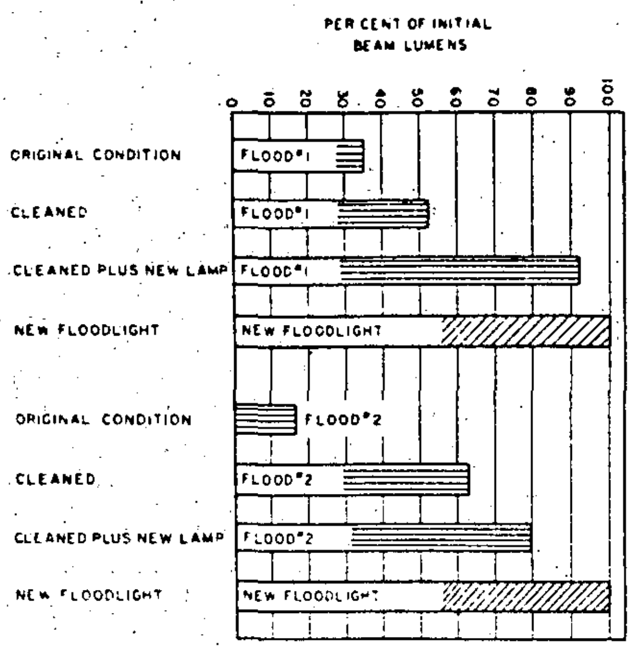


Figure B-1. Necessity for adequate cleaning and relamping program is vividly illustrated by these test results of two floodlights removed from a major league baseball stadium after two seasons of operations.

B-3 Light Loss Factors for Indoor Design Calculations. For interior lighting calculations the light loss factor used will depend upon the design of the specific luminaire chosen. For suggested light loss factors for typical luminaires refer to Appendix D.

B-4 Frequency of Cleaning. (a) Since accumulation of foreign matter upon a luminaire depends upon the local atmospheric conditions, it follows that the frequency of cleaning the equipment must be determined on the basis of the existing atmospheric conditions and the type of lighting system employed. It is recommended that floodlight luminaires or industrial type luminaires used out-of-doors be thoroughly cleaned as follows:

(1) At the beginning of each season.

(2) Whenever a lamp is replaced.

(3) In extremely smoky areas at least once and preferably two to three times during the season.

(b) For interior lighting systems a suitable cleaning schedule should be established by a periodic check of the illumination with a light meter. When the illumination has decreased to 75 per cent of its initial value, the equipment should be washed. A thorough washing of interior lighting equipment at least twice a year is justified in most locations. In dirtier areas, three or four cleanings per year are needed to achieve the lowest cost operation in terms of footcandle-hours (lux-hours) per dollar.

(c) The frequency of cleaning the surrounds such as walls and ceilings is determined to a large extent by the amount and character of dirt contained in the atmosphere. Regular inspection and adequate cleaning are recommended to maintain the relative efficiency and brightness ratios between luminaires and surrounds.

B-5 Lamp Replacement. (a) Replacement of lamps which are badly blackened or considerably depreciated in lumen output is important in maintaining the illumination level for which an installation is designed.

(b) To minimize lamp labor replacement costs and outages during the playing season, a group replacement plan is recommended. Group replacement of all lamps in an installation can be combined effectively with annual luminaire inspection and cleaning. Because each of the three light sources, incandescent, fluorescent and mercury, has a different rate of failure over its respective life, the time for group replacement may be different in each case.

(c) The lamps removed should be visually inspected and the better ones saved for replacement at burnouts prior to the next group replacement. There are, of course, many variables, depending on the type of installation in group replacement, and any particular installation should be gone over thoroughly with lighting engineers to determine the replacement system that will best suit the needs of that installation from both a light and economic standpoint.

B-6 Cleaning Agents. Neutral soap or neutral detergents completely dissolved in water, or mild cleaning agents will generally clean lighting equipment satisfactorily. Special cleaners are available for extremely dirty equipment.

B-7 Physical Inspection. Every time a luminaire is cleaned or relamped, it should also be inspected for mechanical defects. Prompt correction of any defects will serve to prolong the life of the equipment and minimize frequency of cleaning. Service men should be instructed to exercise reasonable care in handling lighting equipment, especially in not forcing the cover-glass doors or globes shut when incorrectly aligned.

Appendix C—Outdoor Illumination Calculations

C-1 Introduction. (a) The method of calculating the footcandle (lux) level which can be expected from any given number and arrangement of floodlights, or of calculating the number of floodlights required to produce a given level, is more complicated than the interior lighting calculation. This is true because there are many variable factors such as the distance from the playing area to the floodlights, the mounting height, and the aiming of the floodlights.

(b) Some approximate methods of calculation have been developed and are available from the manufacturers of lighting equipment. The most accurate method of calculating the footcandles (lux) produced by a floodlight installation is reproduced in Fig. C-1. This method involves the use of light distribution curves of the isocandela type on which the area to be lighted is plotted around the beam axis.

(c) For calculation purposes, depending upon the accuracy required, one or more representative floodlight beam patterns should be chosen for each pole location where varying utilizations may result.

(d) The method of computation consists of plotting the area to be lighted on the photometric curve and then adding up the number of lumens contained inside the area. The number of lumens divided by the area in square feet (square meters) gives the average illumination from the unit in footcandles (lux).

C-2 Sample Computation. (a) An example of a typical area to be lighted is given in Fig. C-1. The problem is to obtain the outline of the area in terms of lateral and vertical degrees and transfer it to the isocandela curve in Fig. C-2.

(b) To simplify the problem, the vertical axis of the floodlight beam is assumed to be normal to the sides of the area, *i.e.*, a vertical plane through the floodlight's axis is perpendicular to the line *KLM* in Fig. C-1. The two sides of the area, *KM* and *RT*, will appear on the isocandela curve as straight lines parallel to the horizontal beam axis. It is, therefore, necessary to calculate only the vertical angles *A* and *A'* from the pole to the near and far sides of the area and relate them to the aiming angle *P'*, which is the zero-zero degree point on the isocandela curve, in order to draw the sides on the curve. The extremities of these lines, points *K*, *M*, *R* and *T*, must be found by obtaining the true lateral angle *B* in the plane passing through the floodlight and the side of the field in which the point is located. The contour of the side *KR* or *MT* is found by assuming a number of points on the line and finding the corresponding lateral and vertical angles. The vertical angles *A*, *A'* and *P'* are found from the nomogram in Fig. C-3. The lateral angles B are found from Fig. C-4. The exact procedure is as follows:

(1) Refer to Fig. C-3. Lay a straightedge across the chart *X* connecting the distance *X* (30 feet or 9.1 meters) with the mounting height *H* (50 feet or 15.2 meters). On the centerline *A*, read the vertical angle *A* from the pole to the ray of light reaching the near side of the field (31°). In the same way, using $H = 50$ feet (15.2 meters) and $X_1 = 190$ feet (57.9) meters), the vertical angle *A'* to the far side of the field is found to be 75.2°. Angle *P'* ($X_3 = 90$ feet or 27.4 meters) is 61°.

(2) Refer to Fig. C-2. The location of the area on the isocandela curve depends on the angle at which the floodlight is tilted, *i.e.*, the aiming angle *P'*. Since the aiming point is the zero-zero degree point on the curve, the near side of the field would be plotted 61 degrees — 31 degrees = 30 degrees below the zero degree vertical line, and the far side 75.2 degrees — 61 degrees = 14.2 degrees above the

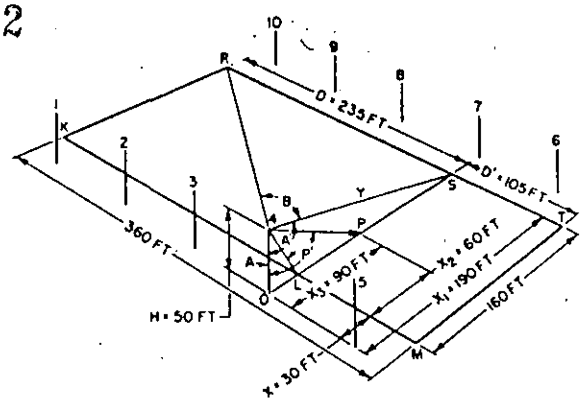


Figure C-1. Typical floodlighted football field used in sample calculation of average horizontal footcandles (lux).

Note: 30 ft = 9.1 m; 50 ft = 15.2 m; 60 ft = 18.3 m; 90 ft = 27.4 m; 105 ft = 32.0 m; 160 ft = 48.8 m; 190 ft = 57.9 m; 235 ft = 68.6 m; 360 ft = 109.7 m.

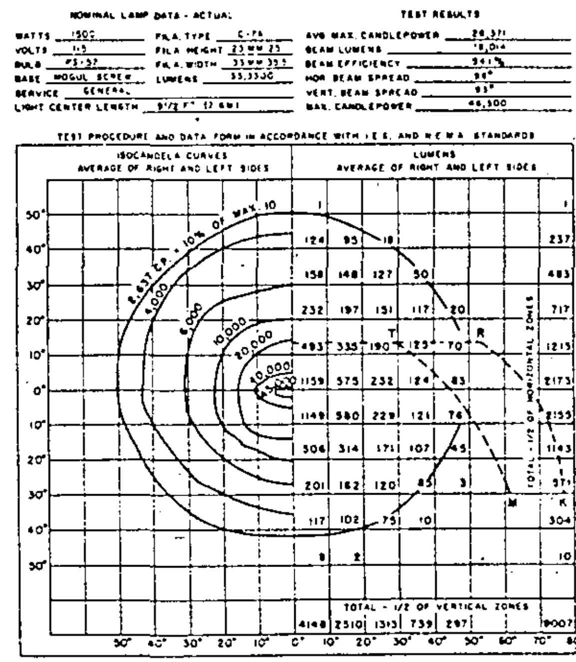


Figure C-2. Floodlight distribution data sheet.

zero degree vertical line. Horizontal lines representing the near and far sides of the field can be plotted on the curve (Fig. C-2) through these vertical angles.

(3) To determine point *R* refer to Fig. C-4. Lay a straightedge across the chart from the mounting height $H = 50$ feet (15.2 meters) to the vertical angle $A' = 75.2$ degrees and read on line *Y* (196 feet or 59.7 meters). Now connect 196 feet on line *Y* with $D = 255$ feet (77.7 meters) on line *D*, and read on line *B* the lateral angle (52.5 degrees). Plot this point on the top horizontal line. In the same way, find point *K* by using $A = 31$ degrees and $D = 255$ feet (77.7 meters). Points *M* and *T* are found using the same vertical angles as for *K* and *R*, respectively, and $D' = 105$ feet (32.0 meters).

(4) The four corners of the area are now located, but the ends of the area will not appear as straight lines, so it is necessary to plot sufficient points to determine the curvature. The first points to be determined are those on the 0 degree center axis. The vertical angle to use on Fig. C-4 is 61 degrees. From this and $D = 255$ feet (77.7 meters) at the point at the left is found to be 68 degrees, and from $D' = 105$ feet (32.0 meters) the point at the right is 45.5 degrees. At least one additional point above the axis and one below should be determined. These may be found by assuming vertical angles such as seven degrees above the axis, or $A = (61 + 7) = 68$ degrees. With these points plotted on the isocandela curve, the ends of the field can be drawn.

(c) With the field plotted on the curve, the lumens which fall on field are added up. In the zones cut by the sides of the field, estimate the proportion of the lumens included within the boundary. A tabulation of these values is given in Table C-1.

(d) Referring to Fig. C-2, it will be noted that while the calculations have been made for a unit on pole 4 the same result applies to similar units on poles 2, 9 and 7. It is then necessary to make a similar calculation for the remaining poles.

(e) It may happen that a better utilization factor and increased lumens can be obtained by tilting the floodlight at a different vertical angle. This can readily be determined by studying the summation of lumens in the lateral zones, given at the side of the isocandela curve. Tilting the beam up or down merely involves shifting the entire diagram of the field up or down the required number of degrees on the curve.

C-3 Irregular Areas. In the case of irregular areas, the sides of the field, such as *KR* and *MT*, may not be straight lines or may not be parallel. In that case it will be necessary to determine both the vertical and lateral angles for several points on each line.

C-4 Special Cases. (a) In computing values for a closed projector installation where the projectors can be so located that all of the beams will fall on the area involved. the average initial level can be computed by dividing the sum of beam lumens of all of the floodlights by total area. In cases where the entire beam will not fall on the areas involved, the method of computation described in Section C-2 should be used.

(b) For a baseball field installation where the average level for the infield is given, the computations should be made by the method given in Section C-2 or by the point-by-point method, selecting a sufficient number of stations within the area to give a true average. If values are required at specified points, the point-by-point method of computation should be used.

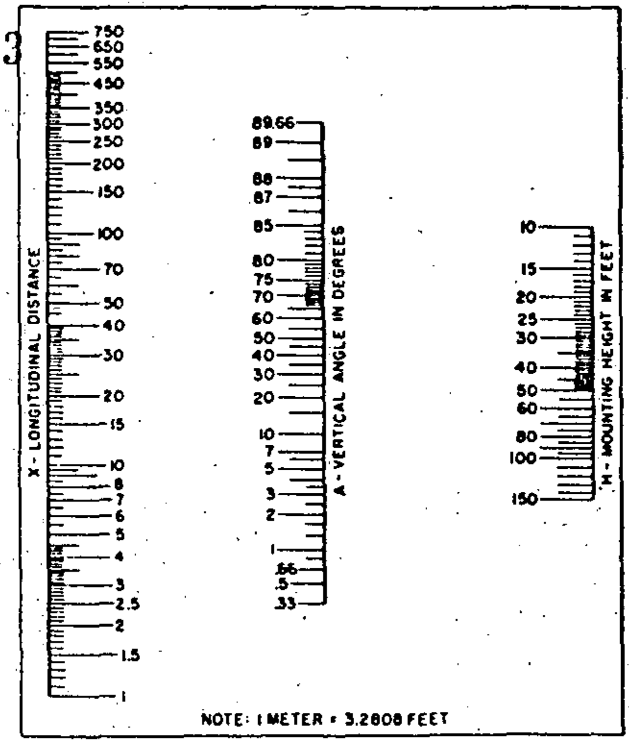


Figure C-3. Nomogram for determining vertical angle (angle A in Fig. C-1) in terms of longitudinal distance X and mounting height H.

C-5 Illumination Level at Various Points. If further details on illumination level at various points are desired, it is recommended that the so-called point-by-point method be used in computing values. In view of the lengthy process and its well-known principle, it is not included in this discussion.

Appendix D—Interior Illumination Calculations

Recommended levels of illumination are the minimum values required on the tasks found in various types of interiors; however. it is usually more practical to design lighting systems to provide an average

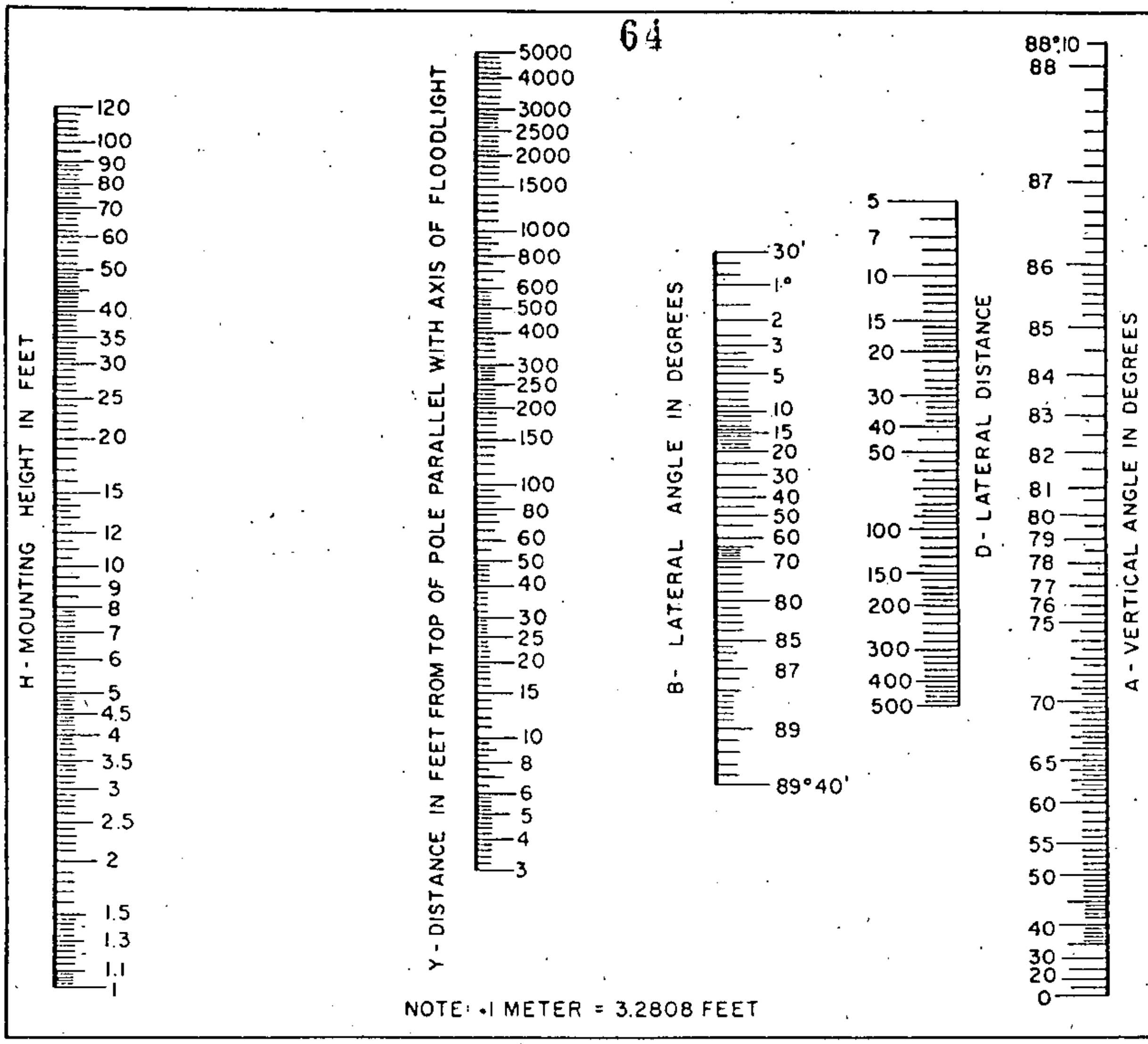


Figure C-4. Nomogram for determining lateral angle B in terms of vertical angle A, mounting height H, distances Y and D.

Table C-1. Summation Of Lumens On Field

Vertical Zones	Lateral Zones					
From	0	10	20	30	40	
To	10	20	30	40	50	
	Field To Right Of Unit					
10–20	207	141	77	10		
0–10 Above	1,159	575	232	109	14	
0–10 Below	1,149	580	229	121	60	
10–20	506	314	171	107	45	
20–30	201	162	120	85	3	
Total	3,222	1,772	829	432	122	6,377
	Field To Left Of Unit					
10–20	207	141	80	53	27	
0–10 Above	1,159	575	232	124	83	
0–10 Below	1,149	580	229	121	76	
10–20	506	314	171	107	45	
20–30	201	162	120	85	3	
Total	3,222	1,772	832	490	234	6,550
Grand Total						12,927

CBU = 12,927 ÷ 18,014 = 71.7%

illumination level with a reasonable degree of uniformity throughout the area. Such calculations may be made by *The Lumen Method.*

The lumen method for calculating the illumination that represents the average of all points on the playing area in an interior is based on the definition of a footcandle as one lumen per square foot (a lux as one lumen per square meter), or:

$$\text{Footcandles} = \frac{\text{Lumens}}{\text{Area in square feet}}$$

$$\text{Lux} = \frac{\text{Lumens}}{\text{Area in square meters}}$$

Not all the lamp lumens will reach the playing area because of losses in the luminaire and at the room surfaces. To take this into account, lamp lumens are multiplied by a "coefficient of utilization" which represents the portion of the lumens that actually reaches the work plane. Thus:

$$\text{Initial Footcandles (Lux)} = \frac{\text{Lamp Lumens} \times \text{Coefficient of Utilization}}{\text{Area in sq. ft. (meters)}}$$

Since the design objective is usually the minimum maintained illumination, factors must be applied to account for the estimated depreciation in lamp lumens and the estimated losses from dirt collection on the luminaire surfaces (including lamps). Thus, the formula becomes:

$$\text{Maintained Footcandles (Lux)} = \frac{\text{Lamp Lumens} \times CU \times LLD \times LDD}{\text{Area in square feet (meters)}}$$

where:

CU = the Coefficient of Utilization

LLD = the Lamp Lumen Depreciation Factor selected from Table D-1

LDD = the Luminaire Dirt Depreciation Factor selected from Fig. D-1

The lamp lumens in the formula are most conveniently taken as the total rated lumens in the luminaire, and the area then becomes the area per luminaire. Thus:

$$\text{Maintained Footcandles (Lux)} = \frac{\text{Lamp Lumens per Luminaire} \times CU \times LLD \times LDD}{\text{Area per Luminaire in square feet (meters)}}$$

or, if the desired footcandles (lux) are known, the area per luminaire (and hence the spacing between luminaires) to produce this illumination can be obtained by:

$$\text{Area per Luminaire in square feet (meters)} = \frac{\text{Lamp Lumens per Luminaire} \times CU \times LLD \times LDD}{\text{Maintained Footcandles (Lux)}}$$

A lighting system can be designed with spacings between units to approximate this area, but if the total number of luminaires is also desired, then:

$$\text{Total Number of Luminaires} = \frac{\text{Total Room Area}}{\text{Area Per Luminaire}}$$

For additional information on illumination calculations, see the latest edition of the *IES Lighting Handbook.*

Table D-1. Lamp Lumen Depreciation (LLD) (Per cent of initial lumens produced at 70 per cent of life*)

Lamp Description		LLD Factor
Incandescent		
General service	to 150 W	91
	250 to 500 W	90
	750 to 1500 W	86
Silver-bowl	200 to 500 W	75
Reflector	R40	86
	R52 and R57	81
Projector	PAR 38 to 64	84
Mercury		
H39-22 KB	175 W	85
H39-22 KC/C	175 W	83
H39-22 KC/W	175 W	75
H37-5 KB	250 W	85
H37-5 KC/C	250 W	83
H37-5 KC/W	250 W	73
H33-1 CD	400 W	86
H33-1 GL/C	400 W	83
H33-1 GL/W	400 W	74
H36-15 GV	1000 W	77
H36-15 GW/C	1000 W	72
H36-15 GW/W	1000 W	61

Fluorescent	Hours per Start		
	6	12	18
Instant start 425 ma			
Standard colors**	88	87	85
Improved-color types***	82	80	78
Rapid start 430 ma			
Standard colors**	87	86	85
Improved-color types***	81	80	79
Rapid start 800 ma			
Standard colors**	81	79	77
Rapid start 1500 ma			
Tubular**	76	74	72
Others**	70	68	64

* Factors shown are averages for groups of lamps at design conditions and should be compensated to reflect operations in the field. Improvements in lamp design are being made so rapidly that it is important, for accuracy, to consult the manufacturer's up-to-date statistics for the particular lamp considered.

** Cool white, warm white, white, daylight.

*** Deluxe cool white and deluxe warm white.

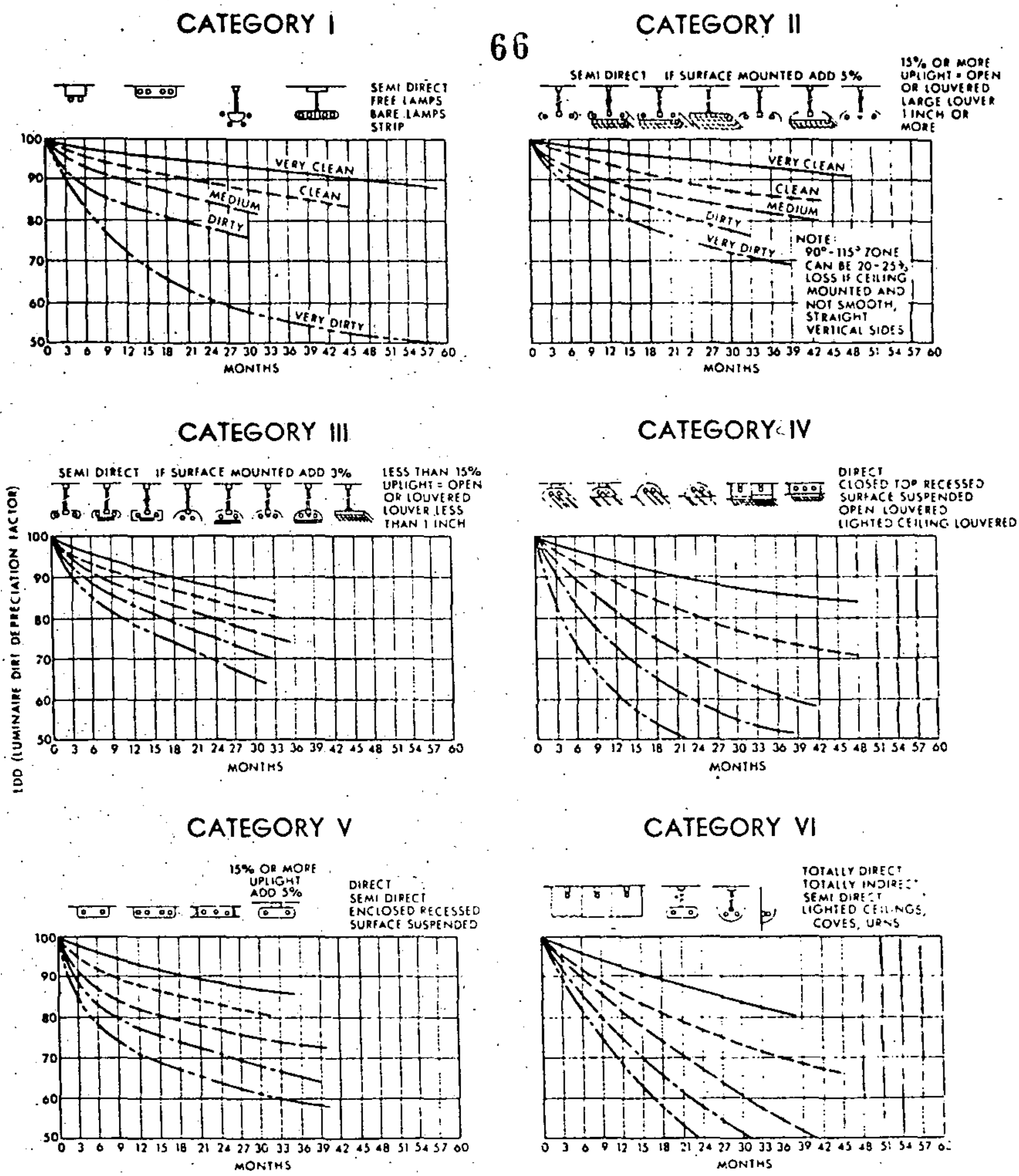


Figure D-1. Luminaire Dirt Depreciation factors (LDD) for six luminaire categories (I to VI) and for five degrees of dirtiness.

Appendix E—Power Supply and Distribution for Floodlighting Installations

The electric utility serving the sports lighting project should be consulted as to the type and rates for service available, as well as rules for use of this service before plans are developed for the wiring.

In many communities the installation of wiring is governed by local ordinances based on the National Electric Code. In other communities provisions of the Code might well be followed because the merits of the Code are indicated by its widespread acceptance.

Wiring plans will normally be prepared by the electrical engineer, after consultation with the electric utility, giving due consideration to the various factors involved such as service voltage, line voltage drop and voltage ratings of the lamps. These factors should be given consideration in order to secure the most effective use of the complete installation.

Appendix F
Suggested Form for Economic Analyses of Different Sports Lighting Systems.

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ITEM No.	CALCULATION	System I	System II	System III
I. Illumination Calculations				
1. Photometric Data Utilized		XYZ-4		
2. Spacing of Poles or Area Being Illuminated	Feet or Square Feet	600 sq. ft.		
3. Utilization Factor	Decimal	0.75		
4. Light-Loss Factor	Decimal	0.60		
5. Average Maintained Illumination	Footcandles	9		
II. Initial Equipment Investment				
6. Luminaire Cat. No.		XYZ		
7. Quantity of Luminaires		20		
8. Net Cost, Luminaire, Each		$100		
9. Net Cost, Luminaires, Total	(7)×(8)	$2,000		
10. Ballast Cat. No. (if needed and not included in 6 above)		QRS		
11. Quantity Ballasts		10 (A)		
12. Net Cost, Ballast, Each		$40		
13. Net Cost, Ballasts, Total	(11)×(12)	$400		
14. Pole Cat. No.		LMN		
15. Quantity of Poles—and Mounting Height		2—50 ft.		
16. Net Cost, Pole, Each, including brackets & mounting accessories		$500		
17. Net Cost, Poles, Total	(15)×(16)	$1,000		
18. Net Cost, Pole Foundation, Each		$250		
19. Net Cost, Poles & Foundation, Total	(17)+(15)+(18)	$1,500		
20. Lamp Cat. No.		PQR		
21. Quantity, Lamps per Luminaire		1		
22 Quantity, Lamps	(7)×(21)	20		
23. Net Cost, Lamp, Each		$20		
24. Net Cost, Lamps, Total	(22)×(23)	$400		
25. Transformers, Wire, Photocells, Switching, Miscellaneous Control, etc.		$180 (B)		
26. Total Initial Equipment, Less Lamps	(9)+(13)+(19)+(25)	$4,080		
27. Total Initial Equipment, Including Lamps	(24)+(26)	$4,480		
28. Stores Charges (initial warehousing, etc.)		$672 (C)		
29. Total Initial Equipment Investment	(27)+(28)	$5,152		
30. Relative Initial Equipment Investment	(29) ÷ (lowest system value)	1.0		
III. Initial Labor, Estimates (includes Miscellaneous Hardware)				
31. Pole Erection and Painting, Each		$100		
32. Luminaire (including its lamps), Each		$10		
33. Ballast, Each		$10		
34. Net Labor, Poles, Luminaires & Ballasts	(15)×(31)+(7)×(32)+(11)×(33)	$500		

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RP-6A

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Reprinted from the July 1975 issue
JOURNAL OF THE ILLUMINATING ENGINEERING SOCIETY

Tennis court lighting— a revision to the IES sports lighting practice

Prepared by the
Committee on Sports and Recreational Areas of the IES

Foreword—With the increased popularity of tennis and more experience in play under new types of light sources, it was desirable to revise the tennis recommendations in the IES Sports Lighting Practice. In this revision, special consideration was given to surface reflectance, luminaire distribution and mounting height, layout and recommended levels to include lighting for indoor exhibition (levels for the viewer).

Committee on Sports and Recreational Areas

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Introduction

The following represents a complete revision of paragraphs 7.3.11 and 8.2.7 and their associated tables and layouts on indoor and outdoor lighting of tennis courts as previously published in the IES Sports Lighting Practice.* It is assumed that the user of this revision is also familiar with the previous publication which contains specific recommendations associated with good lighting practice.

Indoor tennis courts*

The area under consideration for indoor play approximates 50 by 120 feet (15 by 37 meters) per court. The speed of the ball at times exceeds 100 mph (160 km/h) in this fast aerial sport. Suggested interior finishes are: ceilings and upper walls—light, non-glossy 80 to 90 per cent reflectance; walls, lower 12 feet (3.7 meters)—dark, non-glossy, maximum reflectance 60 per cent (usually dark green); court surfaces—porous or nonporous with low reflectance, typically 25 per cent.

The luminaires for direct lighting should provide a minimum of 20 per cent up-light. The direct light from the luminaires should be controlled with baffles, louvers or other shielding techniques to reduce the possibility of glare that would distract the players. The baffles should provide cut-off at 45 degrees in the direction of play.

For indirect lighting, the luminaires should provide a wide beam spread so that there is a high degree of beam overlap, producing "even" illumination on the ceiling (reflecting surface). Although 20

* Committee on Sports and Recreational Areas of the IES, "Current recommended practice for sports and recreational area lighting," ILLUMINATING ENGINEERING, Vol. 64, No. 7, July 1969, p. 457 (also available as a separate publication under the IES designation RP-6).

Approved by the Board of Directors of the Illuminating Engineering Society, January 1975, as a Transaction of the IES.

* Replaces Paragraph 7.3:11 of the IES "Current recommended practice for sports and recreational area lighting."

Printed in the U.S.A.

footcandles (220 lux) for indoor lighting is the minimum requirement for normal play, 100 footcandles (1100 lux) or more may be necessary when lighting for public attractions, competitive business or exhibitions.

Figure 1* shows a typical layout for an indoor lighting system with these special considerations:

(1) The choice of lamps and luminaires is critical and careful consideration should be given to their selection (direct or indirect luminaires may use any lamp, including fluorescent lamps).

(2) Luminaires in the back court may be tilted slightly toward the back of the enclosure so that the light source or its reflected image cannot be seen from the opposite court.

(3) The number of squares in Fig. 1 do not necessarily indicate quantities.

(4) Where courts are more than 18 feet (5.5 meters) apart, two rows of luminaires are necessary.

(5) If guards on indirect luminaires are visible, they may be finished flat black to reduce reflected glare.

Outdoor tennis courts†

Being a fast aerial sport, outdoor tennis is confined to a smaller area than sports like baseball and football. In order to produce the best quality, luminaire beam control and luminaire location must be considered. Typical ligh ' ıg systems for various classes of play are illustrated in Fig. 2.*

Side lighting of the courts, end-to-end, produces the most acceptable results. Luminaires located at the back court lines should provide beam control that will cut off objectionable glare in the opposite court. This can be done by directional aiming and shielding of the light source. The mounting height of uncontrolled luminaires should be considerably greater than those providing beam control and light source shielding.

The minimum mounting height for continuous rows of luminaires along the sideline, provided by cable mounting, is 25 feet (7.6 meters). See Layout 1 for Messenger Cable Mounting in Fig. 2. For luminaires mounted on messenger cable, the direct light should be controlled with baffles, louvers or other shielding techniques to reduce the possibility of glare that would distract the players. The baffles should provide cutoff at 45 degrees in the direction of play.

For pole mounting, even with the use of 20-foot (6.1-meter) crossarms along the side line, mounting heights of 40, 45, and 50 feet (12.2, 13.7 and 15 meters) provide improved quality, especially where luminaires do not provide satisfactory beam control or for systems using only four-corner poles (see Fig. 2, layout 4 for Recreational Only).

Note: It is not advisable to attempt the lighting of more than two courts side-by-side from the indicated pole locations in Fig. 2, unless higher than recommended minimum mounting heights are considered.

In the layouts of Fig. 2, the following should be observed:

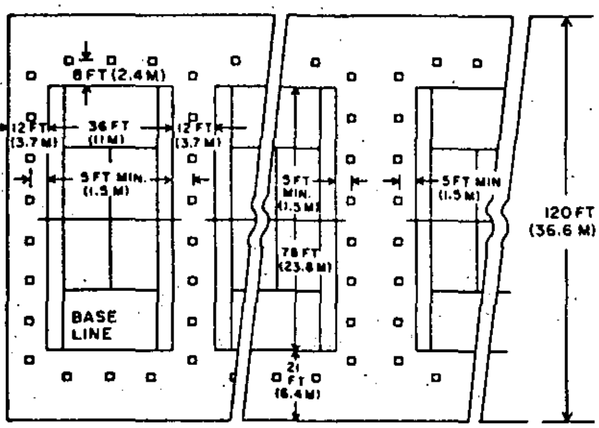
(1) Floodlights on corner poles should have louvers or shields that will provide shielding of the light source in the opposite courts. Proper shielding and glare control is not only necessary

* Replaces Fig. 20 of the "Current recommended practice for sports and recreational area lighting."

† Replaces Paragraph 8.2.7 of the "Current recommended practice for sports and recreational area lighting."

* Replaces Figs. 30 and 31 and Recommended Layout No. 48 of the IES "Current recommended practice for sports and recreational area lighting."

Figure 1. Recommended layout for indoor tennis court only.



INDOOR TENNIS COURT ONLY

Class of play	IES current recommended practice—footcandles (lux) maintained in service[a]	Minimum mounting height from floor		
		Direct	Indirect[c]	
Indoor		See note[b]	Between base lines and outside lines	Behind base lines
Recreational	20 (220)			
Club[d]	30 (320)	23 ft	16 ft	13 ft
Professional	50 (540)	(7 m)	(4.9 m)	(4 m)
Exhibitions	100 (1100)			

[a] Uniformity ratio of 2.0 to 1.0.
[b] Spacing (spacing-to-mounting height)—2.0 to 1.0 between rows.
[c] Spacing (spacing-to-distance from ceiling)—2.0 to 1.0 between luminaires in a row.
[d] May be increased for commercial considerations.

for the players, but also to confine the light to the playing area when the courts are in a residential location. In any case, the floodlights should have adequate shielding.

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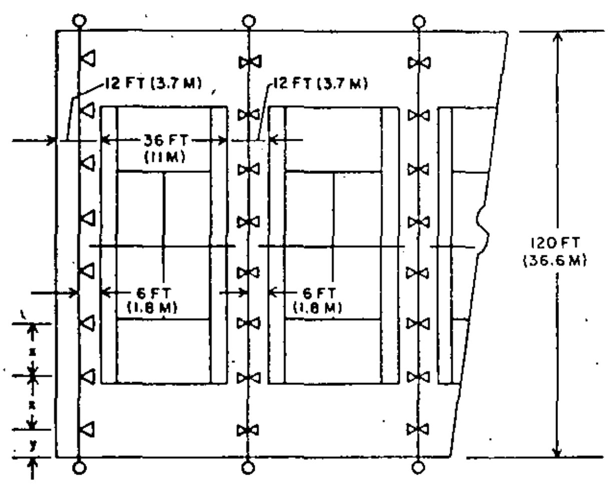
(2) Net or interior poles should have 20 foot (6.1-meter) crossarms to provide a minimum spacing of 16 feet (4.9 meters) between floodlights directed to the same court.

Figure 2. Recommended layouts for outdoor tennis courts.

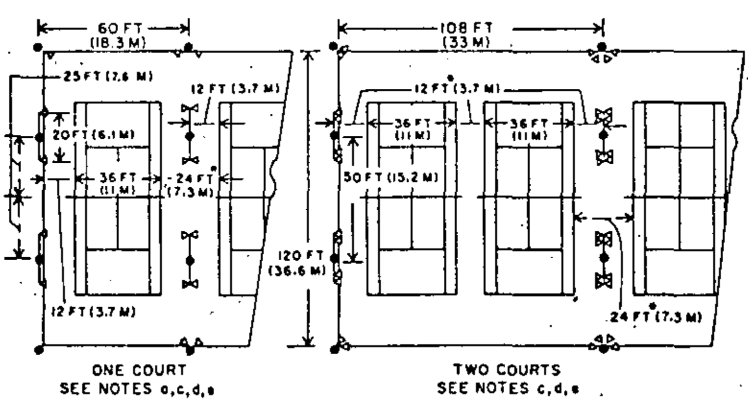
Class	IES current recommended practice—footcandles (lux) maintained in service	Uniformity ratio maximum-to-minimum	Minimum mounting height in feet (meters)	
			Corner	Intermediate
Tournament	30 (320)	2.0 to 1.0	35 (10.7)	35 (10.7)
Club	20 (220)	2.0 to 1.0	35 (10.7)	35 (10.7)
Recreational	10 (110)	2.0 to 1.0	35 (10.7)	35 (10.7)
Recreational only	10 (110)	3.1 to 1.0	40 (12.2) (See note[f].)	



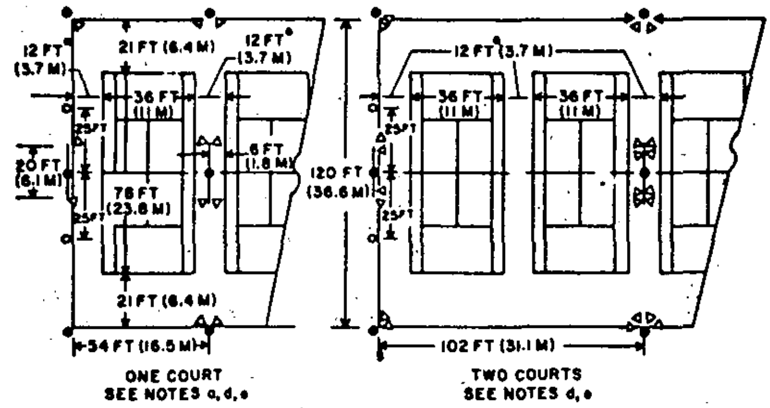
LAYOUT 1—RECREATIONAL, CLUB OR TOURNAMENT PLAY (MESSENGER CABLE MOUNTING[b])

Special Notes

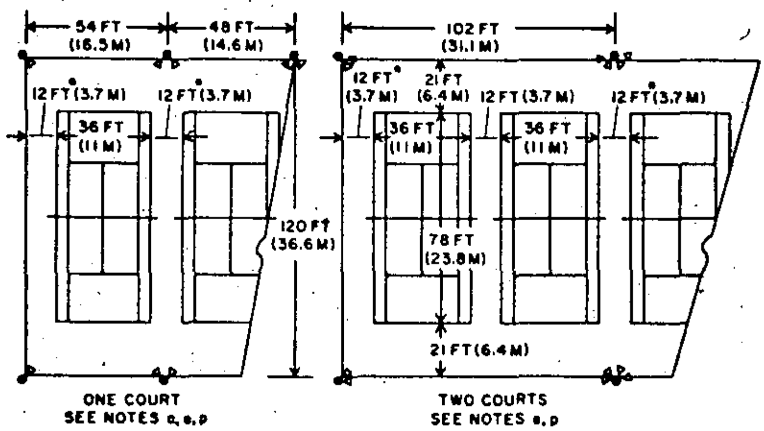
All floodlights should be IES Type 5 or 6, Class GP.
Floodlight symbol (▽) does not indicate quantity of floodlights.
● Recommended pole locations.
○ Alternate pole locations used only on outside courts.
* These clearances are to be considered minimum, greater distances are desirable where space permits.
[a] Can be used for coin meter operation.
[b] Poles should be 30 feet (9.1 meters) or more high.
[c] It is advisable to provide pads around poles that are not located at the net line or corners.
[d] Where courts are less than 24 feet (7.3 meters) apart, the poles should be located at the corners and net lines if center poles are used.
[e] Poles located on the back court lines may have a davit arm to place the floodlights on the side of the courts.
[f] Where only four poles are installed (corners), they should be 40 feet (12.2 meters) or more high.



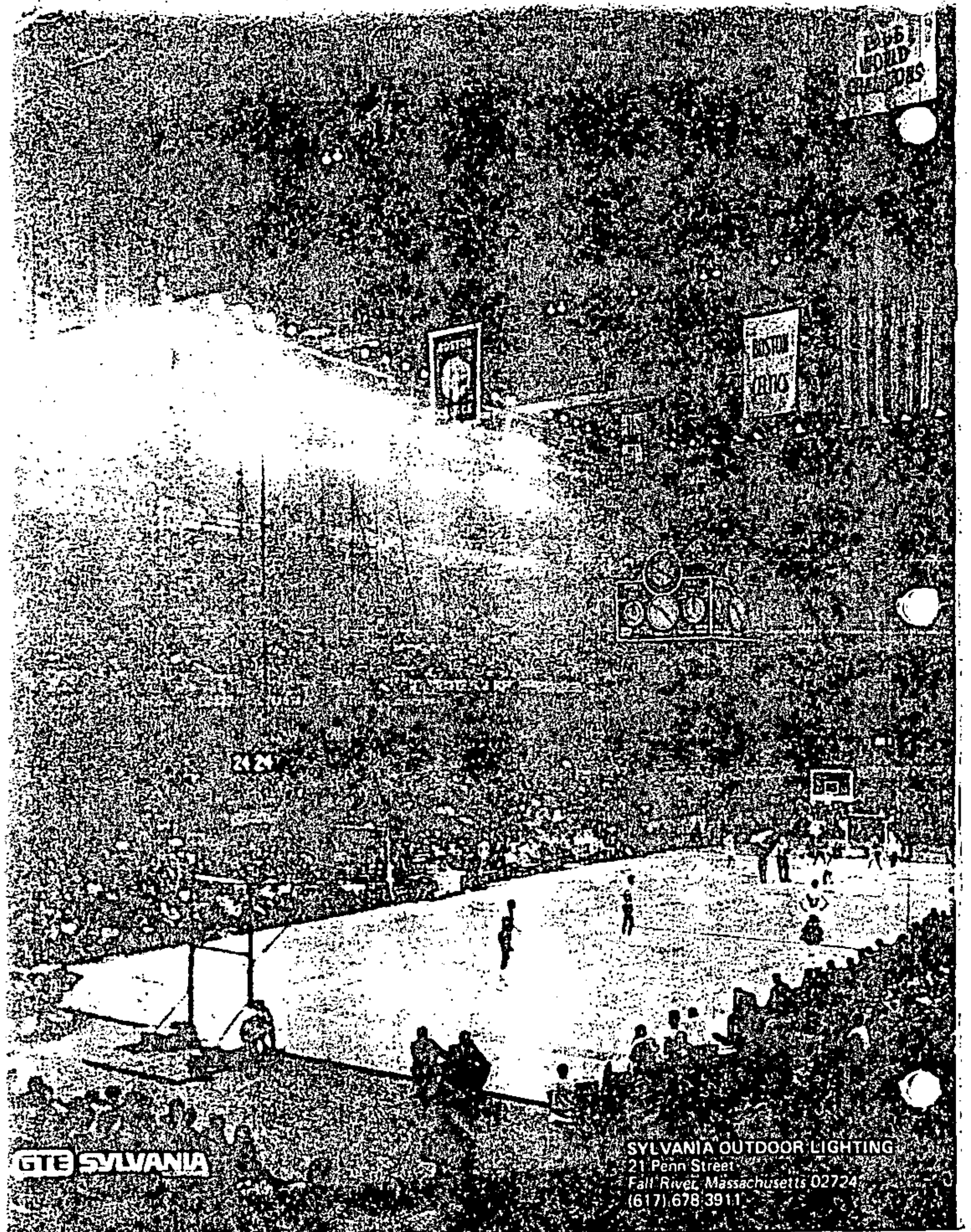
LAYOUT 2—TOURNAMENT PLAY



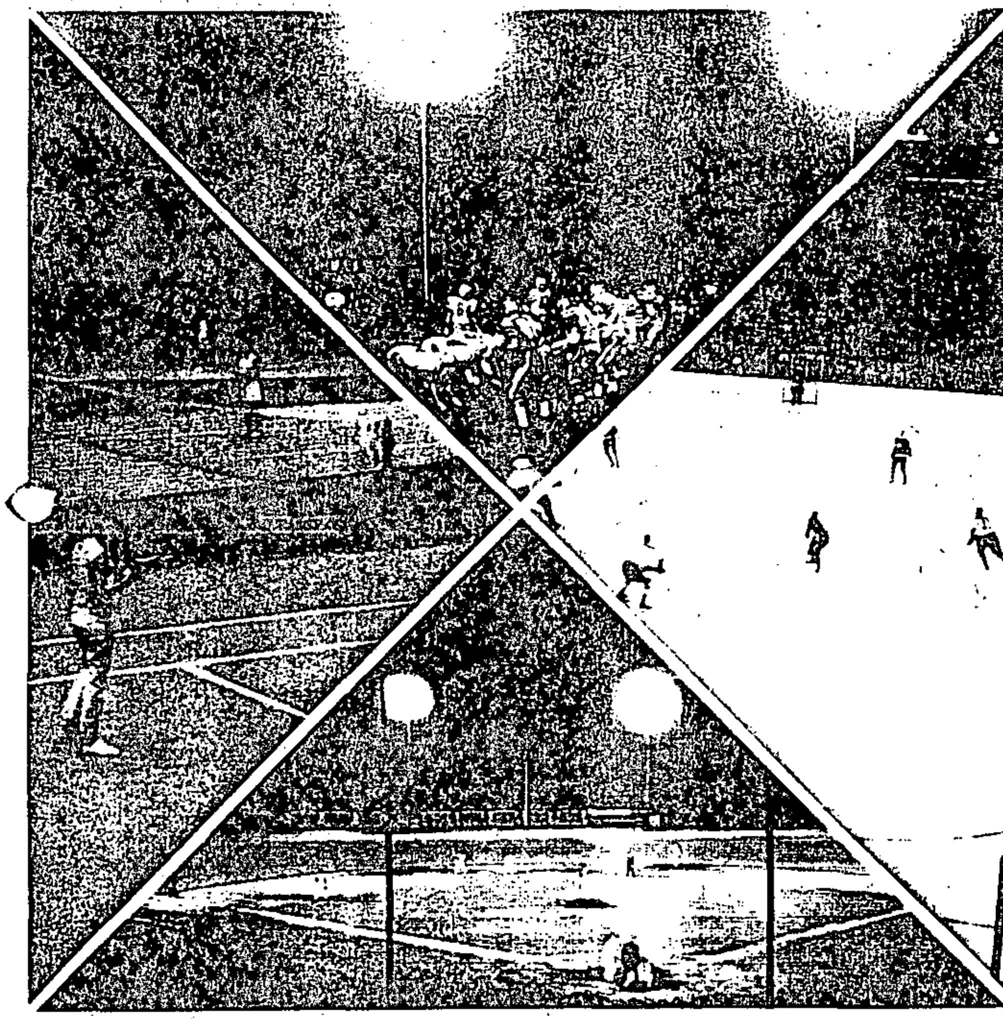
LAYOUT 3—RECREATIONAL, CLUB OR TOURNAMENT PLAY



LAYOUT 4—RECREATIONAL ONLY



SPORTS LIGHTING MADE EASY



SYLVANIA OUTDOOR LIGHTING

BULLETIN SP-2

Introductio..

The purpose of this bulletin is to aid in the design of new illumination systems to meet the unparalleled growth of sports lighting. The recommendations included do not necessarily represent all that might be considered acceptable, but they do reflect key elements considered necessary for acceptable quality installations.

For other sports and recreational areas not included as well as custom lighting recommendations for unusual or combination areas, Sylvania Outdoor Lighting offers the services of their experienced lighting engineers. This service is available through your local Sylvania representative or nearest Sylvania distributor.

Ind..

Current Illumination Recommendations*

Sport	Classification	Footcandles[h] Indoor			Outdoor	
Bowling on the Green	Tournament	—			10	
	Recreational	—			5	
Boxing or Wrestling	Championship	500			—	
	Professional	200			—	
	Amateur	100			—	
Canadian Football — Rugby	—	See Football				
Casting:					Pier	Target
Bait, dry or wet	Recreational	—			10	5[v,b]
Combination					Infield	Outfield & Football
	Baseball/Football	—			20	15
	Industrial Softball/Football	—			20	15
	Industrial Softball/6-man Football	—			20	15
Archery	Target, Tournament	50[v]			10[v]	
	Target, Recreational	30[v]			5[v]	
	Shooting Line, Tournament	20			10	
	Shooting Line, Recreational	10			5	
Audience Seating		See Seating				
Badminton	Tournament	30			30	
	Club	20			20	
	Recreational	10			10	
Baseball					Infield	Outfield
Jr. League Class I	I (baselines 60' or less)	—			30	20
Jr. League Class II	II (baselines 60' & up to 75')	—			30	20
Baseball	Infield	Infield	Outfield			
Regulation	Major League	150	100		150	100
	AAA-AA	—			70	50
	A-B	—			50	30
	C-D	—			30	20
	Semi-Pro & Municipal	—			20	15
	Recreational	—			15	10
	Combination with Football	See Combination				
Basketball	College & Professional	50			—	
	College & Intramural & High School	30			—	
	Recreational	—			10	
Bathing Beaches	On Land	—			1	
	150' from Shore	—			3[v]	
Bicycle Track		See Racing				
Billiards	Tournament	50			—	
	Recreational	30			—	
Bowling		Approaches	Lanes	Pins		
	Tournament	10	20	50[v]	—	
	Recreational	10	10	30[v]	—	
	(For visual Considerations)					
	Tournament	70	100	200[v]	—	
	Recreation	50	70	150[v]	—	
	(For public attraction & increased business considerations)					
Croquet or Roque	Tournament	—			10	
	Recreational	—			5	
Curling		Tees	Rink			
	Tournament	50	30		—	
	Recreational	20	10		—	
Dragstrips		See Racing				

Current Illumination Recommendations*

Sport	Classification	Footcandles[h] Indoor	Footcandles[h] Outdoor
Football (Regulation: Rugby or Soccer) Classification Index: Distance from nearest sideline to farthest row of spectators.	Class I: over 100'	—	100
	Class II: 50-100'	—	50
	Class III: 30-50'	—	30
	Class IV: under 30'	—	20
	Class V: no fixed seating facilities	—	10
	Combination with baseball	See Combination	
Football, Six-Man	High School or College	—	20
	Jr. High School or Recreational	—	10
Golf	Tee	—	5
	Fairway	—	1, 3[v]
	Green	—	5
	Driving Range	—	10, 5[c]
	Miniature	—	10
	Practice Putting Green	—	10
Gymnasiums	Exhibitions, Matches	50	—
	General Exercising & Recreation	30	—
	Assemblies	10	—
	Dances	5	—
	Locker & Shower Rooms	20	—
	Audience Seating	See Seating	
Handball Four Wall or Squash	Tournament	50	—
	Club	30	—
	Recreational	20	—
Two-Court	Club	—	20
	Recreational	—	10
Hockey (Field (180' × 300')	College or High School	—	20
Hockey Ice (85' × 200')	Professional or College	100	50
	Amateur	50	20
	Recreational	20	10
Horse Shoe Courts	Tournament	—	10
	Recreational	—	5
Horse Shows		—	20
Jai Alai	Professional	100	—
	Amateur	70	—
Lacrosse	College & High School	—	20
Ping Pong		See Table Tennis	
Playgrounds		—	5
Putting Greens	—	—	See Golf
Quoits	—	—	5
Racing	Auto	—	20
	Bicycle Tournament	—	30
	Competitive	—	20
	Recreational	—	10
	Dog	—	30
	Dragstrip - Staging Area	—	10
	Acceleration 1,320'	—	20
	Deceleration, first 660'	—	15
	Deceleration, second 660'	—	10
	Shutdown, 820'	—	5
	Horse	—	20
	Motor (midget or motorcycle)	—	20
Rifle (50 Yards)			Firing Points / Range / Targets
			10 / 5 / 50[v]
Rifle & Pistol		Firing Points / Range / Targets	
		20 / 10 / 100[v]	—

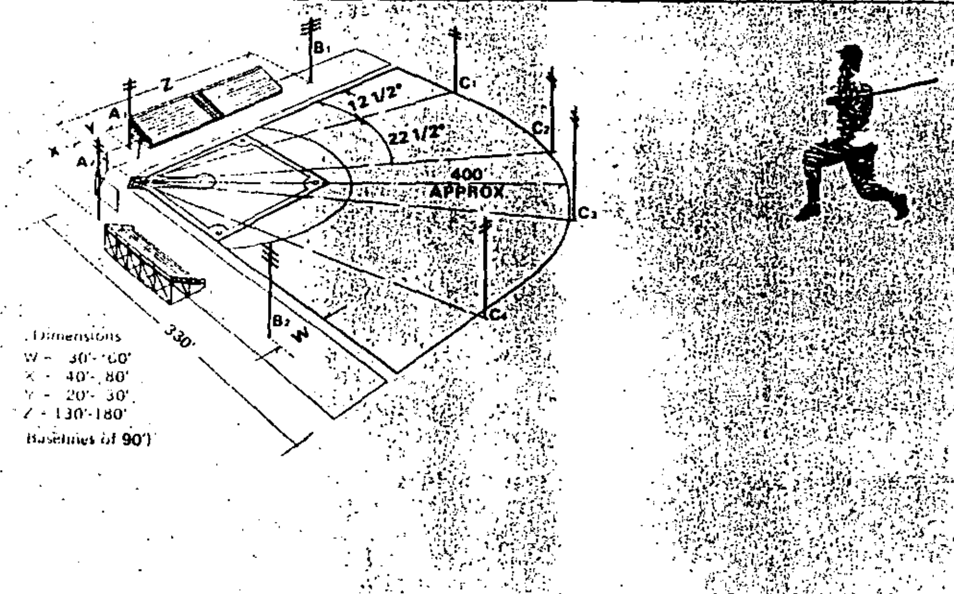
Current Illumination Recommendations*

Sport	Classification	Footcandles[h] Indoor	Footcandles[h] Outdoor	
Rodeo			Arena	Pens & Chutes
	Professional	—	50	5
	Amateur	—	30	5
	Recreational	—	10	5
Roque	—	—	See Croquet	
Seating	Before & After Event	5	5	
	During Event	2	2	
Shuffleboard	Tournament	30	10	
	Recreational	20	5	
Skating	Roller Rink	10	—	
	Ice	10	5	
	Lagoon, Pond or Flooded Area	—	1	
Skeet			Firing Points	Targets
	—	—	5	30[e]
Skeet & Trap			Firing Points	Targets
	Combination		5	30[d, e]
Ski slope	Recreational	—	1	
Soccer	—	—	See Football	
Softball			Infield	Outfield
	Professional & Championship	—	50	30
	Semi-Professional	—	30	20
	Industrial League	—	20	15
	Recreational (6-pole)	—	10	7
	Slow Pitch, Tournament	—	20	15
	Slow Pitch, Recreational (6-pole)	—	10	7
	Combination with football	—	See Combination	
Squash	—	See Handball		
Swimming	Exhibitions	50	20	
	Recreational	30	10	
	Underwater	100[a]	60[a]	
Tennis, Table	Tournament	50	—	
	Club	30	—	
	Recreational	20	—	
Tennis, Lawn	Tournament	50	30	
	Club	30	20	
	Recreational	20	10	
Trap			Firing Points	Targets
			5	30[d]
Volley Ball	Tournament	—	20	
	Recreational	—	10	
Wrestling		See Boxing		

*Levels based on player and spectator visibility — telecasting or other special considerations may require higher levels of illumination.

[a] lamp lumens per square foot of water surface.
[b] footcandles vertical, at 80 feet for Bait Casting; 50 feet for wet or dry-fly casting.
[c] 5 footcandles vertical, at 200 yards and 10 footcandles horizontal, over tee area.
[d] 30 footcandles vertical, on trap target at 100 feet.
[e] 30 footcandles vertical, on skeet target at 60 feet.
[f] Class I Jr. League Baseball includes Little League, Little Boys League, Khoury League, etc.
[g] Class II Jr. League Baseball includes Pony League, Bigger League, etc.
[h] all values represent minimum maintained illumination in a horizontal plane unless otherwise indicated.
[v] illumination on a vertical plane.

Incandescent Systems Metalarc Systems



INCANDESCENT SYSTEM – 1500 WATT (Rated Lamp Life – 300 Hours)

Class	Poles			Floodlights per Pole			Accessories per Pole		KW[3] Load	Footcandles[4] Maintained	
	Desig.	Qnty.	Min.[1] Mntg. Hgt.	GPF1500-104	GPF1500-102	Total	Mounting Adapter A100-222	Lamp[2] 1500		In-Field	Out-Field
Recreational	A	2	70'	4	8	12	12	12	20.88		
	B	2	70'	8	16	24	24	24	41.76		
	C	4	70'	8	4	12	12	12	20.88		
	Total	8		56	64	120	120	120	208.80	15	10
Semi-Pro & Municipal	A	2	70'	5	11	16	16	16	27.84		
	B	2	70'	10	22	32	32	32	55.68		
	C	4	70'	9	7	16	16	16	27.84		
	Total	8		66	94	160	160	160	278.40	20	15
C-D	A	2	70'	8	16	24	24	24	41.76		
	B	2	70'	12	36	48	48	48	83.52		
	C	4	70'	12	12	24	24	24	41.76		
	Total	8		88	152	240	240	240	417.60	30	20
A-B	A	2	90'	8	24	32	32	32	55.68		
	B	2	90'	14	50	64	64	64	111.36		
	C	4	90'	12	20	32	32	32	55.68		
	Total	8		92	228	320	320	320	556.80	50	30
AAA-AA	A	2	110'	12	38	50	50	50	87.00		
	B	2	110'	20	80	100	100	100	174.00		
	C	4	110'	18	38	50	50	50	87.00		
	Total	8		124	376	500	500	500	870.00	75	50

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Lamps to be operated at 10% over rated voltage.
3. Load based on 1.74 KW per fixture.
4. Footcandle levels conform to IES recommendations.

METALARC – 1000 WATT (Rated Lamp Life – 10,000 Hours)

Class	Poles			Floodlights and Ballasts per Pole			Accessories per Pole		KW[4] Load	Footcandles[5] Maintained	
	Desig.	Qnty.	Min.[1] Mntg. Hgt.	HIF1000-108-121[2]	HIF1000-106-121[2]	Total	Mounting Adapter A100-222	Lamp[3] M1000/BU-HOR		In-Field	Out-Field
Recreational	A	2	70'	2	2	4	4	4	4.34		
	B	2	70'	3	5	8	8	8	8.68		
	C	4	70'	2	2	4	4	4	4.34		
	Total	8		18	22	40	40	40	43.40	15	10
Semi-Pro & Municipal	A	2	70'	3	3	6	6	6	6.51		
	B	2	70'	4	8	12	12	12	13.02		
	C	4	70'	3	3	6	6	6	6.51		
	Total	8		26	34	60	60	60	65.10	20	15
C-D	A	2	70'	3	5	8	8	8	8.68		
	B	2	70'	4	12	16	16	16	17.36		
	C	4	70'	3	5	8	8	8	8.68		
	Total	8		26	54	80	80	80	86.80	30	20
A-B	A	2	90'	4	8	12	12	12	13.02		
	B	2	90'	6	18	24	24	24	26.04		
	C	4	90'	4	8	12	12	12	13.02		
	Total	8		36	84	120	120	120	130.20	50	30
AAA-AA	A	2	110'	6	14	20	20	20	21.70		
	B	2	110'	8	32	40	40	40	43.40		
	C	4	110'	6	14	20	20	20	21.70		
	Total	8		52	148	200	200	200	217.00	75	50

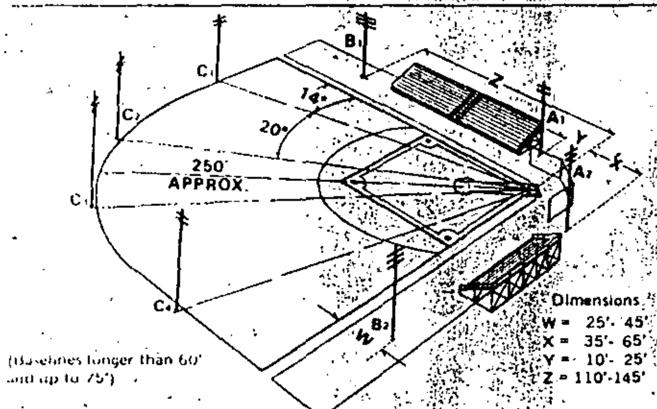
METALARC – 1500 WATT (Rated Lamp Life – 1,500 Hours)

Class	Poles			Floodlights and Ballasts Per Pole			Accessories Per Pole		KW[4] Load	Footcandles[5] Maintained	
	Desig.	Qnty.	Min.[1] Mntg. Hgt.	HIF1500-108-121[2]	HIF1500-106-121[2]	Total	Mounting Adapter A100-222	Lamp[3] M1500/BU-HOR		In-Field	Out-Field
Recreational	A	2	70'	2	1	3	3	3	4.89		
	B	2	70'	3	3	6	6	6	9.78		
	C	4	70'	2	1	3	3	3	4.89		
	Total	8		18	12	30	30	30	48.90	15	10
Semi-Pro & Municipal	A	2	70'	2	2	4	4	4	6.52		
	B	2	70'	3	5	8	8	8	13.04		
	C	4	70'	2	2	4	4	4	6.52		
	Total	8		18	22	40	40	40	65.20	20	15
C-D	A	2	70'	2	3	5	5	5	8.15		
	B	2	70'	4	6	10	10	10	16.30		
	C	4	70'	2	3	5	5	5	8.15		
	Total	8		20	30	50	50	50	81.50	30	20
A-B	A	2	90'	3	5	8	8	8	13.04		
	B	2	90'	4	12	16	16	16	26.08		
	C	4	90'	3	5	8	8	8	13.04		
	Total	8		26	54	80	80	80	130.40	50	30
AAA-AA	A	2	110'	5	9	14	14	14	22.83		
	B	2	110'	8	20	28	28	28	45.66		
	C	4	110'	5	9	14	14	14	22.83		
	Total	8		46	94	140	140	140		75	50

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Ballasts shown are 120 volt. For 208, 240, 277 or 480 volt ballast – refer to page 35.
3. Lamps operated at normal wattage.
4. Load based on 1.085 KW per 1000 Watt fixture and 1.63 KW per 1500 Watt fixture.
5. Footcandle levels conform to IES recommendations.

Baseball / Class II - Junior League

Incandescent & Metalarc Systems



INCANDESCENT SYSTEM – 1500 WATT (Rated Lamp Life – 300 Hours)

Class	Poles: Desig.	Poles: Qnty.	Poles: Min.[1] Mntg. Hgt.	Floodlights per Pole: GPF1500-104	Floodlights per Pole: GPF1500-102	Floodlights per Pole: Total	Accessories per Pole: Mounting Adapter A100-222	Accessories per Pole: Lamp[2] 1500	KW[3] Load	Footcandles[4] Maintained: In-Field	Footcandles[4] Maintained: Out-Field
II	A	2	50'	10		10	10	10	17.40		
	B	2	50'	10	10	20	20	20	34.80		
	C	4	60'	6	4	10	10	10	17.40		
	Total	8		64	36	100	100	100	174.00	30	20

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm. 2. Lamps to be operated at 10% over rated voltage. 3. Load based on 1.74 KW per fixture. 4. Footcandle levels based on IES recommendations.

METALARC SYSTEM – 1000 WATT (Rated Lamp Life – 10,000 Hours)

Class	Poles: Desig.	Poles: Qnty.	Poles: Min.[1] Mntg. Hgt.	Floodlights and Ballasts per Pole: HIF1000-108-121[2]	Floodlights and Ballasts per Pole: HIF1000-106-121[2]	Floodlights and Ballasts per Pole: Total	Accessories per Pole: Mounting Adapter A100-222	Accessories per Pole: Lamp[3] M1000/BU-HOR	KW[4] Load	Footcandles[5] Maintained: In-Field	Footcandles[5] Maintained: Out-Field
II	A	2	50'	5		5	5	5	5.425		
	B	2	50'	4	5	9	9	9	9.765		
	C	4	60'	2	2	4	4	4	4.340		
	Total	8		26	18	44	44	44	47.740	30	20

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm. 2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballasts refer to page 35. 3. Lamps operated at normal wattage. 4. Load based on 1.085 KW per fixture. 5. Footcandle levels are based on IES recommendations.

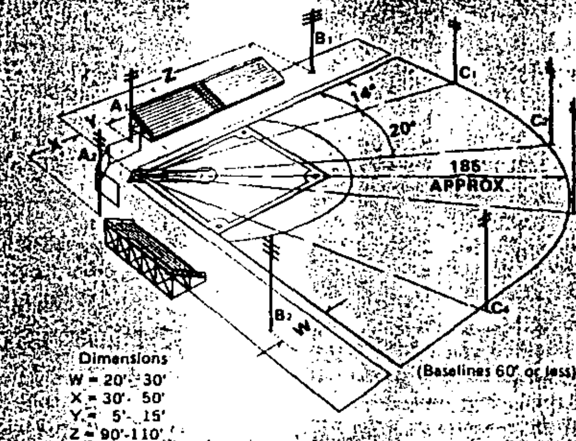
METALARC – 1500 WATT (Rated Lamp Life – 1,500 Hours)

Class	Poles: Desig.	Poles: Qnty.	Poles: Min.[1] Mntg. Hgt.	Floodlights and Ballasts per Pole: HIF1500-108-121[2]	Floodlights and Ballasts per Pole: HIF1500-106-121[2]	Floodlights and Ballasts per Pole: Total	Accessories per Pole: Mounting Adapter A100-222	Accessories per Pole: Lamp[3] M1500/BU-HOR	KW[4] Load	Footcandles[5] Maintained: In-Field	Footcandles[5] Maintained: Out-Field
II	A	2	50'	3		3	3	3	4.89		
	B	2	50'	3	3	6	6	6	9.78		
	C	4	60'	2	1	3	3	3	4.89		
	Total	8		20	10	30	30	30	48.90	30	20

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm. 2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballasts refer to page 35. 3. Lamps operated at normal voltage. 4. Load based on 1.63 KW per fixture. 5. Footcandle levels are based on IES recommendations.

Baseball / Class I - Junior League

Incandescent & Metalarc Systems



INCANDESCENT SYSTEM – 1500 WATT (Rated Lamp Life – 300 Hours)

Class	Poles: Desig.	Poles: Qnty.	Poles: Min.[1] Mntg. Hgt.	Floodlights per Pole: GPF1500-104	Floodlights per Pole: Total	Acces. per Pole: Mounting Adapter A100-222	Acces. per Pole: Lamp[2] 1500	KW[3] Load	Footcandles[4] Maintained: In-Field	Footcandles[4] Maintained: Out-Field
I	A	2	40'	6	6	6	6	10.44		
	B	2	40'	12	12	12	12	20.88		
	C	4	50'	6	6	6	6	10.44		
	Total	8		60	60	60	60	104.40	30	20

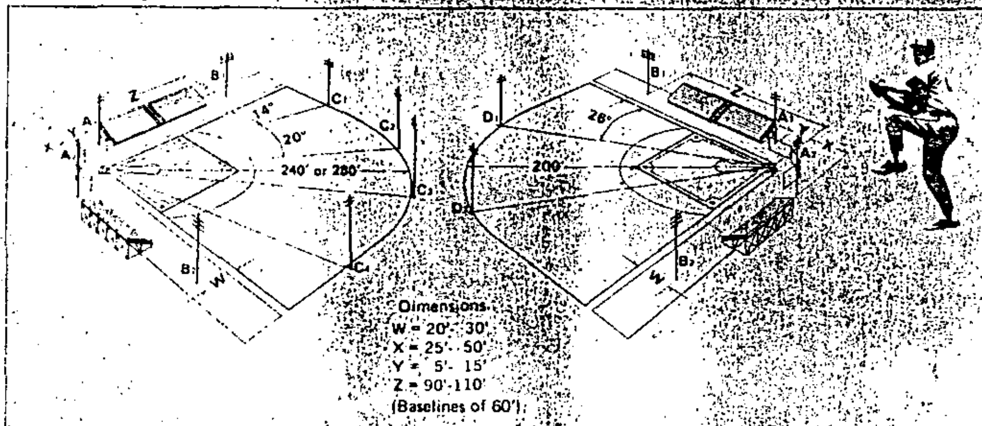
NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Lamps to be operated at 10% over rated voltage.
3. Load based on 1.74 KW per fixture.
4. Footcandle levels are based on IES recommendations.

METALARC SYSTEM – 1000 WATT (Rated Lamp Life – 10,000 Hours)

Class	Poles: Desig.	Poles: Qnty.	Poles: Min.[1] Mntg. Hgt.	Floodlights and Ballasts per Pole: HIF1000-108-121[2]	Floodlights and Ballasts per Pole: Total	Acces. per Pole: Mounting Adapter A100-222	Acces. per Pole: Lamp[3] M1000/BU-HOR	KW[4] Load	Footcandles[5] Maintained: In-Field	Footcandles[5] Maintained: Out-Field
I	A	2	40'	3	3	3	3	3.255		
	B	2	40'	5	5	5	5	5.425		
	C	4	50'	2	2	2	2	2.170		
	Total	8		24	24	24	24	26.040	30	20

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballasts refer to page 35.
3. Load based on 1.085 KW per fixture.
5. Footcandle levels are based on IES recommendations.

Incandescent Systems



INCANDESCENT – 1500 WATT (Rated Lamp Life – 300 Hours)

Class	Poles: Desig.	Poles: Qnty.	Poles: Min.[1] Mntg. Hgt.	Floodlights per Pole: GPF1500-104	Floodlights per Pole: GPF1500-102	Floodlights per Pole: Total	Accessories per Pole: Mounting Adapter A100-222	Accessories per Pole: Lamp[2] 1500	KW[3] Load	Footcandles[4] Maintained: In-Field	Footcandles[4] Maintained: Out-Field
Recreational 200' Outfield 6 Pole Layout*	A	2	35'	3		3	3	3	5.22		
	B	2	35'	4		4	4	4	6.96		
	D	2	40'	5		5	5	5	8.70		
	Total	6		24		24	24	24	41.76	10	7
Industrial** 200' Outfield	A	2	35'	5		5	5	5	8.70		
	B	2	35'	7		7	7	7	12.18		
	C	4	40'	5		5	5	5	8.70		
	Total	8		44		44	44	44	76.56	20	15
Industrial** 240' Outfield	A	2	35'	6		6	6	6	10.44		
	B	2	35'	7	3	10	10	10	17.40		
	C	4	45'	5	2	7	7	7	12.18		
	Total	8		46	14	60	60	60	104.40	20	15
Industrial** 280' Outfield	A	2	35'	6		6	6	6	10.44		
	B	2	35'	8	6	14	14	14	24.36		
	C	4	50'	7	3	10	10	10	17.40		
	Total	8		56	24	80	80	80	139.20	20	15
Semi-Pro 240' Outfield	A	2	40'	8		8	8	8	13.92		
	B	2	40'	8	6	14	14	14	24.36		
	C	4	50'	7	3	10	10	10	17.40		
	Total	8		60	24	84	84	84	146.16	30	20
Semi-Pro 280' Outfield	A	2	40'	8		8	8	8	13.92		
	B	2	40'	9	9	18	18	18	31.32		
	C	4	55'	9	5	14	14	14	24.36		
	Total	8		70	38	108	108	108	187.92	30	20
Prof. 240' Outfield	A	2	50'	10	4	14	14	14	24.36		
	B	2	50'	8	12	20	20	20	34.80		
	C	4	60'	8	5	13	13	13	22.62		
	Total	8		68	52	120	120	120	208.80	50	30
Prof. 280' Outfield	A	2	50'	10	4	14	14	14	24.36		
	B	2	50'	10	20	30	30	30	52.20		
	C	4	60'	10	8	18	18	18	31.32		
	Total	8		80	80	160	160	160	278.40	50	30

NOTES: 1. Minimum height from playing field to bottom crossarm.
2. Lamps to be operated at 10% over rated voltage.
3. Load based on 1.74 KW per fixture.
4. Footcandle levels based on IES recommendations.

*Also for slow pitch recreational play
**Also for slow pitch tournament play

METALARC – 400 AND 1000 WATT (Rated Lamp Life – 15,000 and 10,000 Hours)

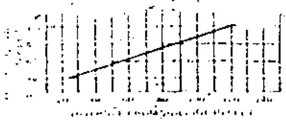
Class	Poles: Desig.	Poles: Qnty.	Poles: Min.[1] Mntg. Hgt.	Floodlights and Ballasts per Pole: HIF 400-107-121[2]	Floodlights and Ballasts per Pole: HIF 1000-108-121[2]	Floodlights and Ballasts per Pole: HIF 1000-106-121[2]	Floodlights and Ballasts per Pole: Total	Accessories per Pole: Mounting Adapter A100-222	Accessories per Pole: Lamps[3] M400/BU-HOR	Accessories per Pole: Lamps[3] M1000/BU-HOR	KW[4] Load	Footcandles[5] Maintained: In-Field	Footcandles[5] Maintained: Out-Field
Recreational 200' Outfield 6 Pole Layout*	A	2	35'	3			3	3	3		1.305		
	B	2	35'	4			4	4	4		1.740		
	D	2	40'	5			5	5	5		2.170		
	Total	6		24			24	24	24		10.44	10	7
Industrial** 200' Outfield	A	2	35'		2		2	2		2	2.17		
	B	2	35'		4		4	4		4	4.34		
	C	4	40'		2		2	2		2	2.17		
	Total	8			20		20	20		20	21.70	20	15
Industrial** 240' Outfield	A	2	35'		2		2	2		2	2.170		
	B	2	35'		3	2	5	5		5	5.425		
	C	4	45'		2	1	3	3		3	3.255		
	Total	8			18	8	26	26		26	28.210	20	15
Industrial** 280' Outfield	A	2	35'		3		3	3		3	3.255		
	B	2	35'		4	3	7	7		7	7.595		
	C	4	50'		2	2	4	4		4	4.340		
	Total	8			22	14	36	36		36	39.060	20	15
Semi-Pro 240' Outfield	A	2	40'		3		3	3		3	3.255		
	B	2	40'		4	3	7	7		7	7.595		
	C	4	50'		2	2	4	4		4	4.340		
	Total	8			22	14	36	36		36	39.060	30	20
Semi-Pro 280' Outfield	A	2	40'		4		4	4		4	4.340		
	B	2	40'		5	4	9	9		9	9.765		
	C	4	55'		3	3	6	6		6	6.510		
	Total	8			30	20	50	50		50	54.250	30	20
Prof. 240' Outfield	A	2	50'		4	2	6	6		6	6.510		
	B	2	50'		4	6	10	10		10	10.850		
	C	4	60'		3	3	6	6		6	6.510		
	Total	8			28	28	56	56		56	60.760	50	30
Prof. 280' Outfield	A	2	50'		4	2	6	6		6	6.510		
	B	2	50'		5	10	15	15		15	16.275		
	C	4	60'		3	5	8	8		8	8.680		
	Total	8			30	44	74	74		74	80.290	50	30

METALARC – 1500 WATT (Rated Lamp Life – 1500 Hours)

Class	Poles: Desig.	Poles: Qnty.	Poles: Min.[1] Mntg. Hgt.	Floodlights and Ballasts per Pole: HIF1500-108-121[2]	Floodlights and Ballasts per Pole: HIF1500-106-121[2]	Floodlights and Ballasts per Pole: Total	Accessories per Pole: Mounting Adapter A100-222	Accessories per Pole: Lamp[3] M1500/BU-HOR	KW[4] Load	Footcandles[4] Maintained: In-Field	Footcandles[4] Maintained: Out-Field
Semi-Pro 240' Outfield	A	2	40'	2	0	2	2	2	3.26		
	B	2	40'	3	2	5	5	5	8.15		
	C	4	50'	2	1	3	3	3	4.89		
	Total	8		18	8	26	26	26	42.38	30	20
Semi-Pro 280' Outfield	A	2	40'	3	0	3	3	3	4.89		
	B	2	40'	3	3	6	6	6	9.78		
	C	4	55'	2	2	4	4	4	6.52		
	Total	8		20	14	34	34	34	55.42	30	20
Prof. 240' Outfield	A	2	50'	4	0	4	4	4	6.52		
	B	2	50'	4	3	7	7	7	11.41		
	C	4	60'	2	2	4	4	4	6.52		
	Total	8		24	14	38	38	38	61.94	50	30
Prof. 280' Outfield	A	2	60'	4	0	4	4	4	6.52		
	B	2	60'	4	6	10	10	10	16.30		
	C	4	60'	2	4	6	6	6	9.78		
	Total	8		24	28	52	52	52	84.76	50	30

NOTES: 1. Minimum height from playing field to bottom crossarm.
2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballast refer to page 35.
3. Lamps are operated at normal wattage.
4. Load based on .455 KW per 400 watt fixture
1.085 KW per 1000 watt fixture.
1.630 KW per 1500 watt fixture.
5. Footcandle levels based on IES recommendations.

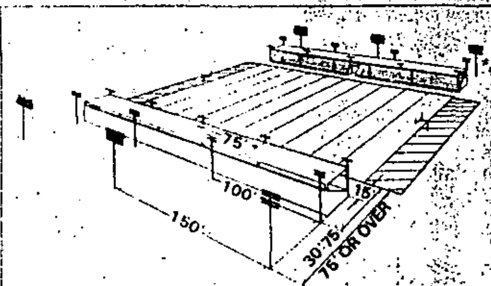
*Also for slow pitch recreational play.
**Also for slow pitch tournament play.



MOUNTING HEIGHT SELECTOR CHART
Chart showing minimum mounting height from field to bottom floodlight crossarm.

Football / Standard Layou

Incandescent & Metalarc Systems



CLASSIFICATION

It is generally conceded that distance between the spectators and the play is the first consideration in determining the class and lighting requirements. However, the potential seating capacity of the stands should be considered.

Class	Distance — Nearest Sideline to Farthest Row of Spectators	Spectator Seating Capacity
I	Over 100'	Over 30,000 spectators
II	50'-100'	10,000-30,000
III	30'-50'	5,000-10,000
IV	Under 30'	5,000
V	No fixed seating facilities	

INCANDESCENT SYSTEMS — 1500 WATT (Rated Lamp Life — 300 Hours)

Class	Setback	Qnty. of Poles	Min.[1] Mntg. Hgt.	Floodlight Type	Floodlights per Pole	Acces. per Pole: Mounting Adapter A100-222	Acces. per Pole: Lamp[2] #1500	KW[3] Load	Footcandles[4] Maintained
V	15'-30'	10	*	GPF1500-104	4	4	4	6.96	
	Total	10			40	40	40	69.60	10
IV	15'-30'	10	*	GPF1500-104	8	8	8	13.92	
	Total	10			80	80	80	139.20	20
III	30'-50'	8	*	GPF1500-103	16	16	16	27.84	
	Total	8			128	128	128	222.72	30
II	50'-75'	8	*	GPF1500-102	24	24	24	41.76	
	Total	8			192	192	192	334.08	50
II	75'-100'	6	*	GPF1500-102	36	36	36	62.64	
	Total	6			216	216	216	375.84	50
I	100'-140'	6	*	GPF1500-101	80	80	80	139.20	
	Total	6			480	480	480	835.20	100

*See Mounting Height Selector Chart

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm. 2. Lamps to be operated at 10% over rated voltage. 3. Load based on 1.74 KW per fixture. 4. Footcandle levels based on IES recommendations.

METALARC SYSTEMS — 1000 WATT (Rated Lamp Life — 10,000 Hours)

Class	Setback	Qnty. of Poles	Min.[1] Mntg. Hgt.	Floodlight and Ballast Type[2]	Floodlights per Pole	Acces. per Pole: Mounting Adapter A100-222	Acces. per Pole: Lamps[3] M1000/BU	KW[4] Load	Footcandles[5] Maintained
V	15'-30'	10	*	HIF1000-108-121	3	3	3	3.255	
	Total	10			30	30	30	32.55	10
IV	15'-30'	10	*	HIF1000-107-121	5	5	5	5.425	
	Total	10			50	50	50	54.25	20
III	30'-50'	8	*	HIF1000-104-121	8	8	8	8.68	
	Total	8			64	64	64	69.44	30
II	50'-75'	8	*	HIF1000-106-121	14	14	14	15.19	
	Total	8			112	112	112	121.52	50
II	75'-100'	6	*	HIF1000-101-121	22	22	22	23.87	
	Total	6			132	132	132	143.22	50
I	100'-140'	6	*	HIF1000-101-121	48	48	48	52.08	
	Total	6			288	288	288	312.48	100

*See Mounting Height Selector Chart

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm. 2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballast refer to page 35. 3. Lamps operated at normal wattage. 4. Load based on 1.085 KW per fixture. 5. Footcandle levels based on IES recommendations.

Football

Four Pole System

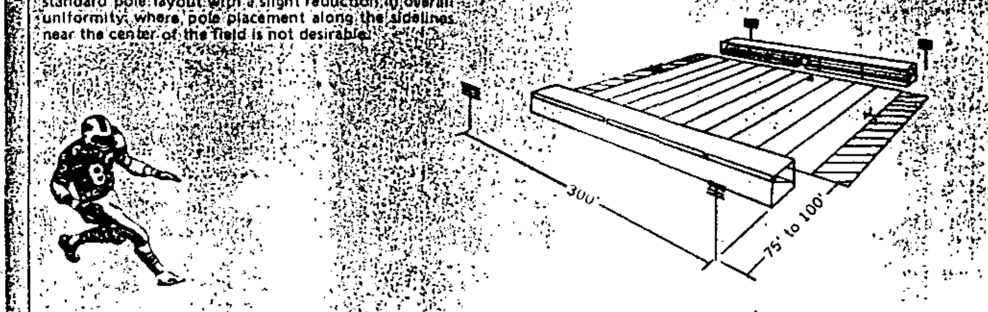
METALARC SYSTEMS — 1500 WATT (Rated Lamp Life — 1,500 Hours)

Class	Setback	Qnty. of Poles	Min.[1] Mntg. Hgt.	Floodlight and Ballast Type[2]	Floodlights and Ballasts per Pole	Acces. per Pole: Mounting Adapter A100-222	Acces. per Pole: Lamps[3] M1500/BU-HOR	KW[4] Load	Footcandles[5] Maintained
V	15'-30'	10	*	HIF1500-108-121	2	2	2	3.26	
	Total	10			20	20	20	32.60	10
IV	15'-30'	10	*	HIF1500-108-121	3	3	3	4.89	
	Total	10			30	30	30	48.90	20
III	30'-50'	8	*	HIF1500-107-121	6	6	6	9.78	
	Total	8			48	48	48	78.24	30
II	50'-75'	8	*	HIF1600-106-121	9	9	9	14.67	
	Total	8			72	72	72	117.36	50
II	75'-100'	6	*	HIF1500-101-121	14	14	14	22.82	
	Total	6			84	84	84	136.92	50
I	100'-140'	6	*	HIF1500-101-121	32	32	32	52.16	
	Total	6			192	192	192	312.96	100

*See Mounting Height Selector Chart.

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm. 2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballast refer to page 35. 3. Lamps operated at normal wattage. 4. Load based on 1.63 KW per fixture. 5. Footcandle levels based on IES recommendations.

The four pole layout can be used in place of the standard pole layout with a slight reduction in overall uniformity, where pole placement along the sidelines near the center of the field is not desirable.



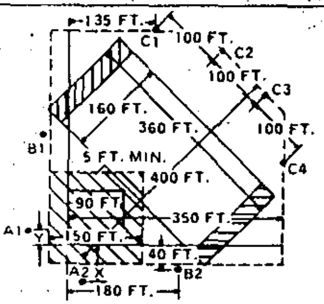
METALARC SYSTEMS — 1500 WATT (Rated Lamp Life — 1,500 Hours)

Class	Setback	Qnty. of Poles	Min.[1] Mntg. Hgt.	Floodlight and Ballast Type[2]	Floodlights and Ballasts per Pole	Acces. per Pole: Mounting Adapter A100-222	Acces. per Pole: Lamps[3] M1500/BU-HOR	KW[4] Load	Footcandles[5] Maintained
IV	75'-100'	4	100'	HIF1500-101-121	8	8	8	13.04	
	Total	4			32	32	32	52.16	20
III	75'-100'	4	100'	HIF1500-101-121	12	12	12	19.56	
	Total	4			48	48	48	78.24	30
II/III	75'-100'	4	100'	HIF1600-101-121	16	16	16	26.08	
	Total	4			64	64	64	104.32	40
II	75'-100'	4	100'	HIF1500-101-121	20	20	20	32.60	
	Total	4			80	80	80	130.40	50

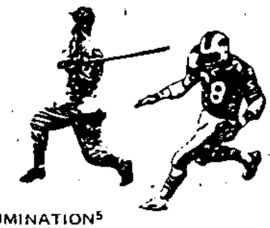
NOTES: 1. Minimum height from playing field to bottom floodlight crossarm. 2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballast refer to page 35. 3. Lamps operated at normal wattage. 4. Load based on 1.63 KW per fixture. 5. Footcandle levels based on IES recommendations.

Combination Municipal Baseball and Footba… / …ombination Football and Softball

Combination Municipal Baseball and Football



DIMENSIONS
X = 40'-80'
Y = 20'-30'



ILLUMINATION[5]
20 Footcandles maintained baseball infield
15 Footcandles maintained baseball outfield
15 Footcandles maintained football field

INCANDESCENT SYSTEM – 1500 WATT (Rated Lamp Life – 300 Hours)

Poles			Total Floodlights per Pole — Baseball			Total Accessories per Pole				
Desig.	Qnty.	Min.[1] Mntg. Hgt.	GPF1500-104	GPF1500-102	Total	Mounting Adapter A100-222	Lamp[2] 1500	Baseball KW[3] Load	Total Floodlights Used for Football Only	Football KW[3] Load
[illegible]	2	70'	5	11	16	16	16	27.84		
[illegible]	2	70'	10	22	32	32	32	55.68	32	55.68
[illegible]	4	70'	9	7	16	16	16	27.84	16	27.84
Total	8		66	94	160	160	160	278.40	128	222.72

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Lamps to be operated at 10% over rated voltage.
3. Load based on 1.74 KW per fixture.
5. Footcandle levels based on IES recommendations.

METALARC SYSTEM – 1000 WATT (Rated Lamp Life – 10,000 Hours)

Poles			Total Floodlights per Pole — Baseball			Total Accessories per Pole				
Desig.	Qnty.	Min.[1] Mntg. Hgt.	HIF1000-108-121[2]	HIF1000-106-121[2]	Total	Mounting Adapter A100-222	Lamp[3] M1000/ BU-HOR	Baseball KW[4] Load	Total Floodlights Used for Football Only	Football KW[4] Load
A	2	70'	3	3	6	6	6	6.51		
B	2	70'	4	8	12	12	12	13.02	12	13.02
C	4	70'	3	3	6	6	6	6.51	6	6.51
Total	8		26	34	60	60	60	65.10	48	52.08

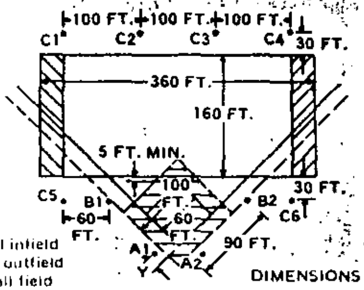
NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballasts refer to page 35.
3. Lamps operated at normal wattage.
4. Load based on 1.085 KW per fixture.
5. Footcandle levels are based on IES recommendations.

METALARC SYSTEM – 1500 WATT (Rated Lamp Life – 1,500 Hours)

Poles			Total Floodlights per Pole — Baseball			Total Accessories per Pole				
Desig.	Qnty.	Min.[1] Mntg. Hgt.	HIF1500-108-121[2]	HIF1500-106-121[2]	Total	Mounting Adapter A100-222	Lamp[3] M1500/ BU-HOR	Baseball KW[4] Load	Total Floodlights Used for Football Only	Football KW[4] Load
A	2	70'	2	2	4	4	4	6.52		
B	2	70'	3	5	8	8	8	13.04	8	13.04
C	4	70'	2	2	4	4	4	6.52	4	6.52
Total	8		18	22	40	40	40	65.20	32	52.16

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballasts refer to page 35.
3. Lamps operated at normal wattage.
4. Load based on 1.63 KW per fixture.
5. Footcandle levels are based on IES recommendations.

Combination Football and Softball



ILLUMINATION[5]
20 Footcandles maintained softball infield
15 Footcandles maintained softball outfield
15 Footcandles maintained football field

DIMENSIONS
X = 25'-50'
Y = 5'-15'

INCANDESCENT SYSTEM – 1500 WATT (Rated Lamp Life – 300 Hours)

Poles			Total Floodlights per Pole — Softball			Total Accessories per Pole — Softball				
Desig.	Qnty.	Min.[1] Mntg. Hgt.	GPF1500-104	GPF1500-102	Total	Mounting Adapter A100-222	Lamp[2] 1500	Softball KW[3] Load	Total Floodlight Used for Football Only	Football KW[3] Load
A	2	40'	6		6	6	6	10.44		
B	2	50'	8	6	14	14	14	24.36	14	24.36
C	6	50'	7	3	10	10	10	17.40	10	17.40
Total	10		70	30	100	100	100	174.00	88	153.12

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Lamps to be operated at 10% over rated voltage.
3. Load based on 1.74 KW per fixture.
5. Footcandle levels based on IES recommendations.

METALARC SYSTEM – 1000 WATT (Rated Lamp Life – 10,000 Hours)

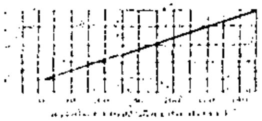
Poles			Total Floodlights per Pole — Softball			Total Accessories per Pole				
Desig.	Qnty.	Min.[1] Mntg. Hgt.	HIF1000-108-121[2]	HIF1000-106-121[2]	Total	Mounting Adapter A100-222	Lamp[3] M1000/ BU-HOR	Softball KW[4] Load	Total Floodlights Used for Football Only	Football KW[4] Load
A	2	40'	3		3	3	3	3.255		
B	2	50'	4	3	7	7	7	7.595	7	7.595
C	6	50'	2	2	4	4	4	4.340	4	4.340
Total	10		26	18	44	44	44	47.740	38	41.230

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballasts refer to page 35.
3. Lamps operated at normal wattage.
4. Load based on 1.085 KW per fixture.
5. Footcandle levels are based on IES recommendations.

METALARC SYSTEM – 1500 WATT (Rated Lamp Life – 1,500 Hours)

Poles			Total Floodlights per Pole — Softball			Total Accessories per Pole				
Desig.	Qnty.	Min.[1] Mntg. Hgt.	HIF1500-108-121[2]	HIF1500-106-121[2]	Total	Mounting Adapter A100-222	Lamp[3] M1500/ BU-HOR	Softball KW[4] Load	Total Floodlights Used for Football Only	Football KW[4] Load
A	2	40'	2		2	[illegible]	2	[illegible]		
B	2	50'	3	2	5	5	5	8.15	5	8.15
C	6	50'	2	1	3	3	3	4.89	3	4.89
Total	10		22	10	32	32	32	52.16	28	45.64

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballast refer to page 35.
3. Lamps operated at normal wattage.
4. Load based on 1.63 KW per fixture.
5. Footcandle levels are based on IES recommendations.



MOUNTING HEIGHT SELECTOR CHART
Chart showing minimum mounting height from field to bottom floodlight crossarm.

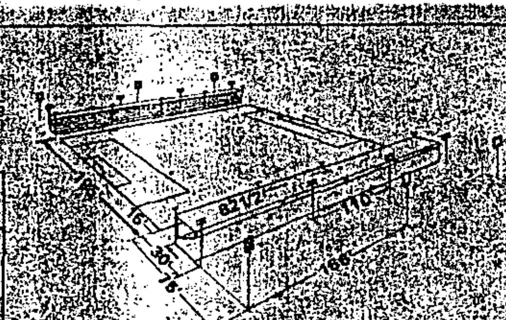
Soccer / Standard Layo…

Incandescent & Metalarc Systems

CLASSIFICATION

It is generally conceded that distance between the spectators and the play is the first consideration in determining the class and lighting requirements. However, the potential seating capacity of the stands should be considered.

Class	Distance — Nearest Sideline to Farthest Row of Spectators	Spectator Seating Capacity
I	Over 100'	Over 30,000 spectators
II	50'-100'	10,000-30,000
III	30'-50'	5,000-10,000
IV	Under 30'	5,000
V	No fixed seating facilities	



INCANDESCENT — 1500 WATT (Rated Lamp Life — 300 Hours)

Class	Setback	Qnty. of Poles	Min.[1] Mntg. Hgt.	Floodlight Type	Floodlights per Pole	Acces. per Pole: Mounting Adapter A100-222	Acces. per Pole: Lamp[2] 1500	KW[3] Load	Footcandles[4] Maintained
V	15'-30'	10	*	GPF1500-104	6	6	6	10.44	
	Total	10			60	60	60	104.40	10
IV	15'-30'	10	*	GPF1500-104	10	10	10	17.40	
	Total	10			100	100	100	174.00	20
III	30'-50'	8	*	GPF1500-103	18	18	18	31.32	
	Total	8			144	144	144	250.56	30
II	50'-75'	8	*	GPF1500-102	28	28	28	48.72	
	Total	8			224	224	224	389.76	50
II	75'-100'	6	*	GPF1500-102	40	40	40	69.60	
	Total	6			240	240	240	417.60	50
I	100'-140'	6	*	GPF1500-101	92	92	92	160.08	
	Total	6			552	552	552	960.48	100

*See Mounting Height Selector Chart

NOTES: 1. Minimum height from playing field to bottom crossarm. 2. Lamps to be operated at 10% over rated voltage. 3. Load based on 1.74 KW per fixture. 4. Footcandle levels based on IES recommendations.

METALARC — 1000 WATT (Rated Lamp Life — 10,000 Hours)

Class	Setback	Qnty. of Poles	Min.[1] Mntg. Hgt.	Floodlight and Ballast Type[2]	Floodlights per Pole	Acces. per Pole: Mounting Adapter A100-222	Acces. per Pole: Lamp[3] 1500 M1000/BU	KW[4] Load	Footcandles[5] Maintained
V	15'-30'	10	*	HIF1000-108-121	3	3	3	3.255	
	Total	10			30	30	30	32.55	10
IV	15'-30'	10	*	HIF1000-107-121	5	5	5	5.425	
	Total	10			50	50	50	54.25	20
III	30'-50'	8	*	HIF1000-104-121	9	9	9	9.765	
	Total	8			72	72	72	78.12	30
II	50'-75'	8	*	HIF1000-106-121	14	14	14	15.19	
	Total	8			112	112	112	121.52	50
II	75'-100'	6	*	HIF1000-101-121	20	20	20	21.70	
	Total	6			120	120	120	130.20	50
I	100'-140'	6	*	HIF1000-101-121	46	46	46	49.91	
	Total	6			276	276	276	299.46	100

*See Mounting Height Selector Chart

NOTES: 1. Minimum height from playing field to bottom crossarm. 2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballasts — refer to page 35. 3. Lamps are operated at normal wattage. 4. Load based on 1.085 KW per fixture. 5. Footcandle levels based on IES recommendations.

…occer

Four Pole System

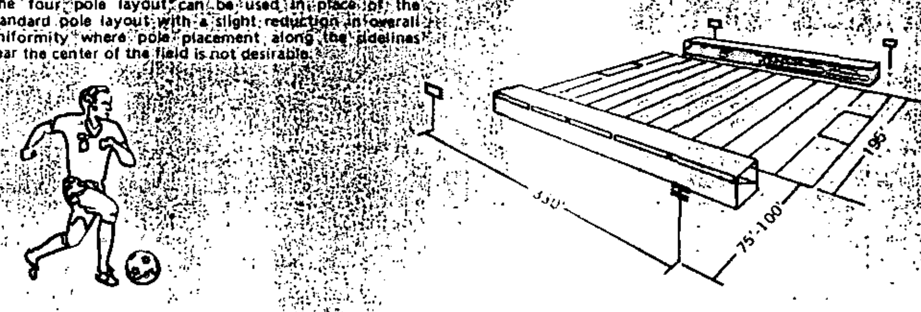
METALARC — 1500 WATT (Rated Lamp Life — 1,500 Hours)

Class	Setback	Qnty. of Poles	Min.[1] Mntg. Hgt.	Floodlight and Ballast Type[2]	Floodlights and Ballasts per Pole	Acces. per Pole: Mounting Adapter A100-222	Acces. per Pole: Lamp[3] M1500/BU-HOR	KW[4] Load	Footcandles[5] Maintained
V	15'-30'	10	*	HIF1500-108-121	2	2	2	3.26	
	Total	10			20	20	20	32.60	10
IV	15'-30'	10	*	HIF1500-108-121	3	3	3	4.89	
	Total	10			30	30	30	48.90	20
III	30'-50'	8	*	HIF1500-107-121	6	6	6	9.78	
	Total	8			48	48	48	78.24	30
II	50'-75'	8	*	HIF1500-106-121	9	9	9	14.67	
	Total	8			72	72	72	117.36	50
II	75'-100'	6	*	HIF1500-101-121	14	14	14	22.82	
	Total	6			84	84	84	136.92	50
I	100'-140'	6	*	HIF1500-101-121	32	32	32	52.16	
	Total	6			192	192	192	312.96	100

*See Mounting Height Selector Chart

NOTES: 1. Minimum height from playing field to bottom crossarm. 2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballasts — refer to page 35. 3. Lamps are operated at normal wattage. 4. Load based on 1.63 KW per fixture. 5. Footcandle levels based on IES recommendations.

The four pole layout can be used in place of the standard pole layout with a slight reduction in overall uniformity where pole placement along the sidelines near the center of the field is not desirable.



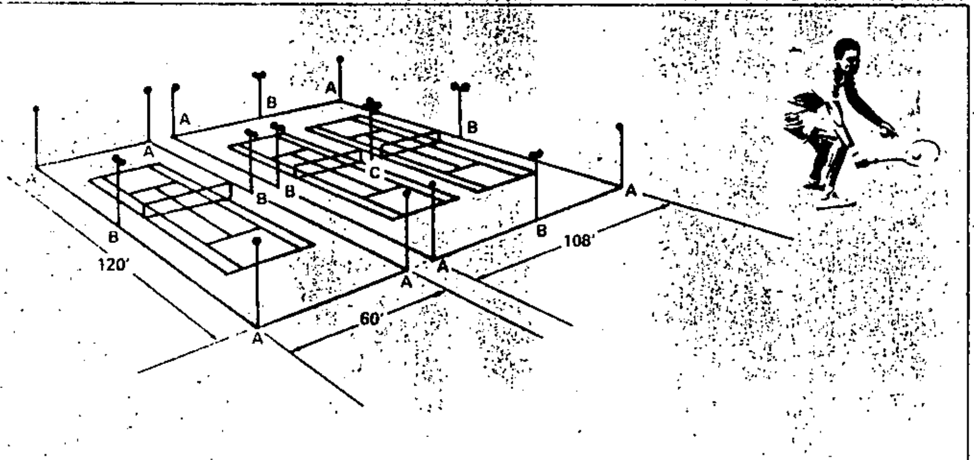
METALARC — 1500 WATT (Rated Lamp Life — 1,500 Hours)

Class	Setback	Qnty. of Poles	Min.[1] Mntg. Hgt.	Floodlight and Ballast Type[2]	Floodlights and Ballasts per Pole	Acces. per Pole: Mounting Adapter A100-222	Acces. per Pole: Lamp[3] M1500/BU-HOR	KW[4] Load	Footcandles[5] Maintained
IV	75'-100'	4	100'	HIF1500-101-121	8	8	8	13.04	
	Total	4			32	32	32	52.16	20
III	75'-100'	4	100'	HIF1500-101-121	12	12	12	19.56	
	Total	4			48	48	48	78.24	30
II/III	75'-100'	4	100'	HIF1500-101-121	16	16	16	26.08	
	Total	4			64	64	64	104.32	40
II	75'-100'	4	100'	HIF1500-101-121	20	20	20	32.60	
	Total	4			80	80	80	130.40	50

*See Mounting Height Selector Chart

NOTES: 1. Minimum height from playing field to bottom crossarm. 2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballasts — refer to page 35. 3. Lamps are operated at normal wattage. 4. Load based on 1.63 KW per fixture. 5. Footcandle levels based on IES recommendations.

Tournament Club



INCANDESCENT – 1500 WATT (Rated Lamp Life – 1000 Hours)

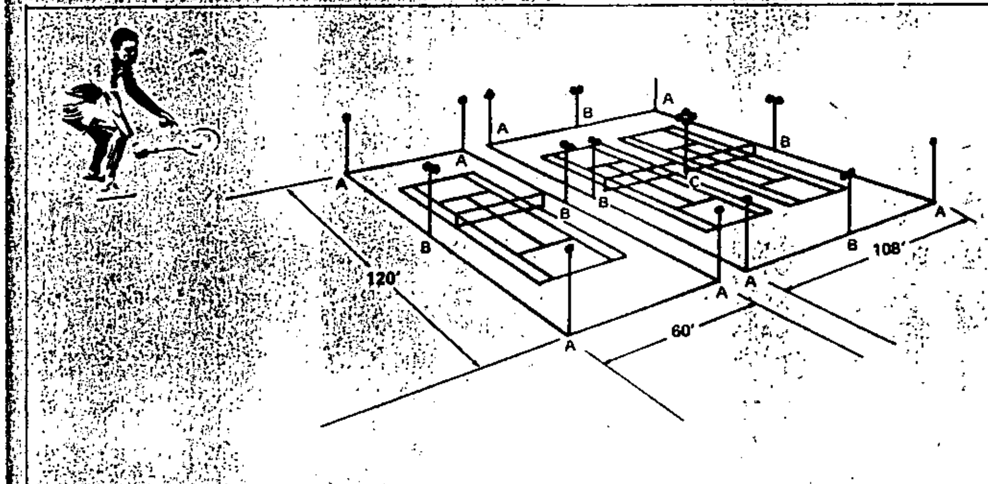
Class	Poles Desig.	Poles Qnty.	Poles Min. Mntg. Hgt.[1]	Floodlights per Pole GPF1500-104	Mounting Adapter A100-222	Lamps[2] 1500	KW Load[3]	Footcandles Maintained[4]
Tournament 1 Court	A	4	35'	3	3	3	4.500	
	B	2	35'	5	5	5	7.500	
	Total	6		22	22	22	33.000	30
Tournament 2 Court	A	4	35'	3	3	3	4.500	
	B	4	35'	5	5	5	7.500	
	C	1	35'	10	10	10	15.000	
	Total	9		42	42	42	63.000	30

NOTES: 1. Minimum mounting height from playing field to bottom crossarm.
2. Lamps to be operated at normal voltage.
3. Load based on 1.5 KW per fixture.
4. Footcandle levels based on IES recommendations.

METALARC – 1000 WATT (Rated Lamp Life – 10,000 Hours)

Class	Poles Desig.	Poles Qnty.	Poles Min.[1] Mntg. Hgt.	Floodlights and Ballasts per Pole HDF1000-121[2]	Mounting Adapter A100-222	Lamps[3] M1000/BD	KW[4] Load	Footcandles[5] Maintained
Tournament 1 Court	A	4	35'	1	1	1	1.085	
	B	2	35'	2	2	2	2.170	
	Total	6		8	8	8	8.680	30
Tournament 2 Court	A	4	35'	1	1	1	1.085	
	B	4	35'	2	2	2	2.170	
	C	1	35'	4	4	4	4.340	
	Total	9		16	16	16	17.360	30

NOTES: 1. Minimum mounting height from playing field to bottom crossarm.
2. Ballasts shown above are 120 volt. For 208, 240, 277 and 480 volt ballasts — refer to page 35.
3. Lamps operated at normal wattage.
4. Load based on 1.085 KW per fixture.
5. Footcandle levels based on IES recommendations.



INCANDESCENT – 1500 WATT (Rated Lamp Life – 1000 Hours)

Class	Poles Desig.	Poles Qnty.	Poles Min. Mntg. Hgt.[1]	Floodlights per Pole GPF1500-104	Mounting Adapter A100-222	Lamps 1500[2]	KW Load[3]	Footcandles[4] Maintained
Club 1 Court	A	4	35'	2	2	2	3.000	
	B	2	35'	3	3	3	4.500	
	Total	6		14	14	14	21.000	20
Club 2 Court	A	4	35'	2	2	2	3.000	
	B	4	35'	3	3	3	4.500	
	C	1	35'	6	6	6	9.000	
	Total	9		26	26	26	39.000	20

NOTES: 1. Minimum mounting height from playing field to bottom crossarm.
2. Lamps to be operated at normal voltage.
3. Load based on 1.5 KW per fixture.
4. Footcandle levels based on IES recommendations.

METALARC – 400 WATT (Rated Lamp Life – 15,000 Hours)

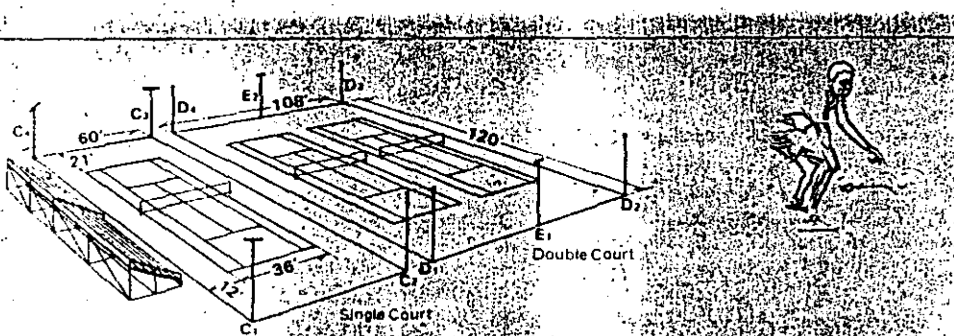
Class	Poles Desig.	Poles Qnty.	Poles Min. Mntg. Hgt.[1]	Floodlights and Ballasts per Pole[2] HDF400-121	Mounting Adapter A100-222	Lamps M400/BD[3]	KW Load[4]	Footcandles[5] Maintained
Club 1 Court	A	4	35'	2	2	2	.910	
	B	2	35'	3	3	3	1.365	
	Total	6		14	14	14	6.370	20
Club 2 Court	A	4	35'	2	2	2	.910	
	B	4	35'	3	3	3	1.365	
	C	1	35'	6	6	6	2.730	
	Total	9		26	26	26	11.830	20

NOTES: 1. Minimum mounting height from playing field to bottom crossarm.
2. Ballasts shown are for 120 volt. For 208, 240, 277 and 480 volt ballasts — refer to page 35.
3. Lamps operated at normal wattage.
4. Load based on .455 KW per 400 watt fixture.
5. Footcandle levels based on IES recommendations.

Tennis - Outdoor

Club or Tournament

...ggested layout for existing courts where ...e pavement between courts is not ...ctical.



INCANDESCENT – 1500 WATT (Rated Lamp Life – 1000 Hours)

Class	Poles: Desig.	Poles: Qnty.	Poles: Min.[1] Mntg. Hgt.	Floodlights per Pole GPF1500-104	Mounting Adapter A100-222	Lamps[2] 1000	Lamps[2] 1500	KW[3] Load	Footcandles[4] Maintained
Club	C	4	40'	3	3	—	3	4.5	
1 Court	Total	4		12	12	—	12	18.0	20
Club	D	4	40'	3	3	—	3	4.5	
2 Courts	E	2	40'	6	6	—	6	9.0	
	Total	6		24	24	—	24	36.0	20
[illegible]nament	C	4	40'	5	5	—	5	7.6	
1 Court	Total	4		20	20	—	20	30.0	30
[illegible]nament	D	4	40'	5	5	—	5	7.50	
2 Courts	E	2	40'	8	8	—	8	12.0	
	Total	6		36	36	—	36	54.0	30

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Lamps to be operated at normal voltage.
3. Load based on 1.5 KW per 1500 watt fixture.
4. Footcandle levels based on IES recommendations.

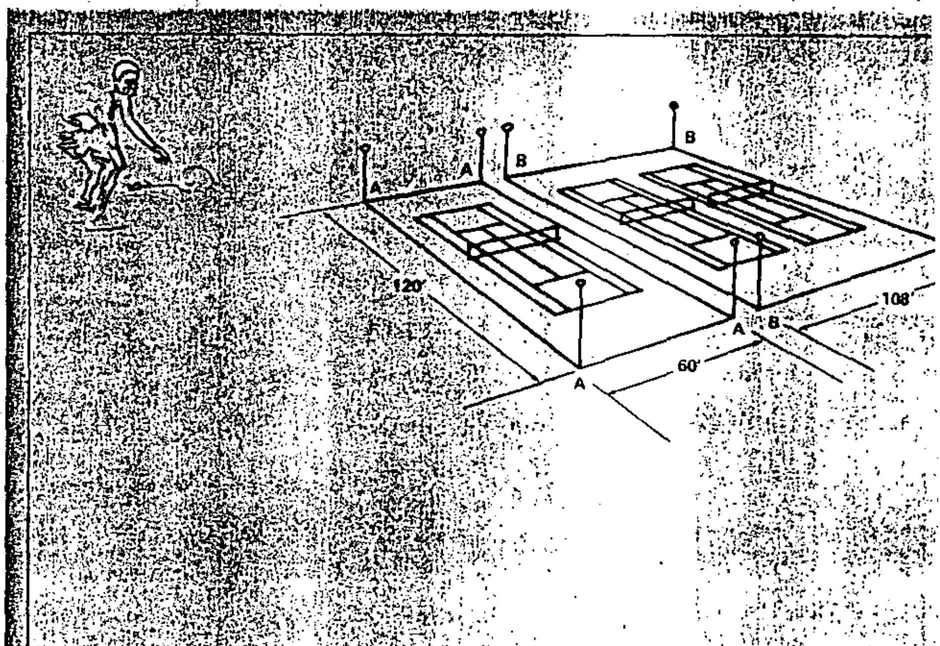
METALARC – 400 AND 1000 WATT (Rated Lamp Life – 15,000 and 10,000 Hours)

Class	Poles: Desig.	Poles: Qnty.	Poles: Min.[1] Mntg. Hgt.	Floodlights and Ballasts per Pole: HDF400-121[2]	Floodlights and Ballasts per Pole: HDF1000-121[2]	Accessories per Pole: Mounting Bracket A100-222	Accessories per Pole: Lamps[3] M400/BU	Accessories per Pole: Lamps[3] M1000/BU	KW[4] Load	Footcandles[5] Maintained
Club	C	4	40'	3		3	3		1.305	
1 Court	Total	4		12		12	12		5.220	20
Club	D	4	40'		1	1		1	1.085	
2 Court	E	2	40'		2	2		2	2.170	
	Total	6			8	8		8	8.680	20
[illegible]nament	C	4	40'		2	2		2	2.170	
1 Court	Total	4			8	8		8	8.680	30
[illegible]nament	D	4	40'		2	2		2	2.170	
2 Court	E	2	40'		3	3		3	3.255	
	Total	6			14	14		14	15.190	30

NOTES: 1. Minimum height from playing field to bottom crossarm.
2. Ballasts shown above are 120 volt. For 208, 240, 277 and 480 volt ballasts — refer to page 35.
3. Lamps operated at normal wattage.
4. Load based on .455 KW per 400 watt fixture.
1.085 KW per 1000 watt fixture.
5. Footcandle levels are based on IES recommendations.

Tennis - Outdoor

Recreational Play



INCANDESCENT – 1500 WATT (Rated Lamp Life – 1,000 Hours)[2]

Class	Poles: Desig.	Poles: Qnty.	Poles: Min.[1] Mntg. Hgt.	Floodlights per Pole GPF1500-104	Mounting Adapter A100-222	Lamps[2] 1500	KW[3] Load	Footca[illegible] Maint[illegible]
Recreational	A	4	35'	2	2	2	3.000	
1 Court	Total	4		8	8	8	12.000	1[illegible]
Recreational	B	4	40'	4	4	4	6.000	
2 Court	Total	4		16	16	16	24.000	1[illegible]

NOTES: 1. Minimum mounting height from playing field to bottom crossarm.
2. Lamps to be operated at normal voltage.
3. Load based on 1.5 KW per 1500 watt fixture.
4. Footcandle levels based on IES recommendations.

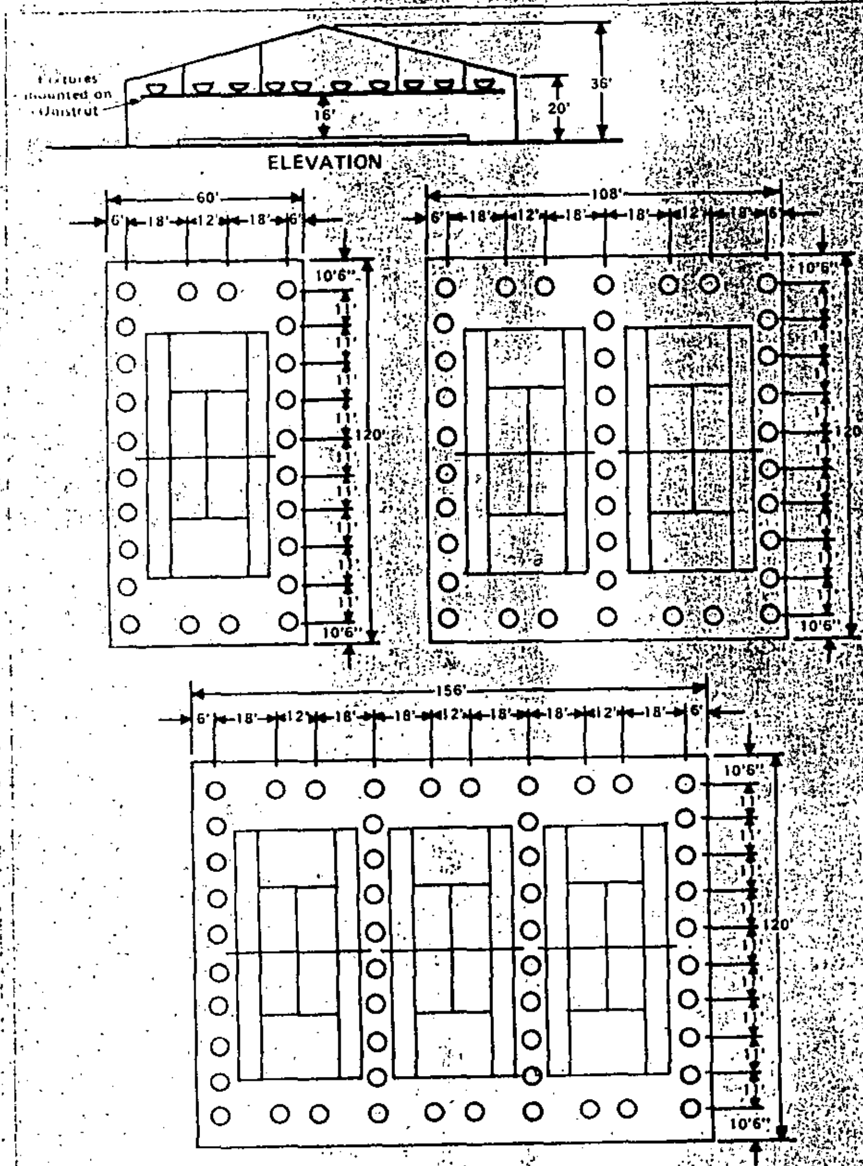
METALARC – 400 WATT (Rated Lamp Life – 15,000 Hours)

Class	Poles: Desig.	Poles: Qnty.	Poles: Min.[1] Mntg. Hgt.	Floodlights and Ballasts per Pole HDF400-121[2]	Mounting Adapter A100-222	Lamps M400/BD[3]	KW[4] Load	Footca[illegible] Maint[illegible]
Recreational	A	4	35'	2	2	2	.910	
1 Court	Total	4		8	8	8	3.640	1[illegible]
Recreational	B	4	40'	4	4	4	1.820	
2 Court	Total	4		16	16	16	7.280	1[illegible]

NOTES: 1. Minimum mounting height from playing field to bottom crossarm.
2. Ballasts shown are for 120 volt. For 208, 240, 277 and 480 volt ballasts — refer to page 35.
3. Lamps operated at normal wattage.
4. Load based on .455 KW per fixture.
5. Footcandle levels based on IES recommendations.

Tennis - Indoc

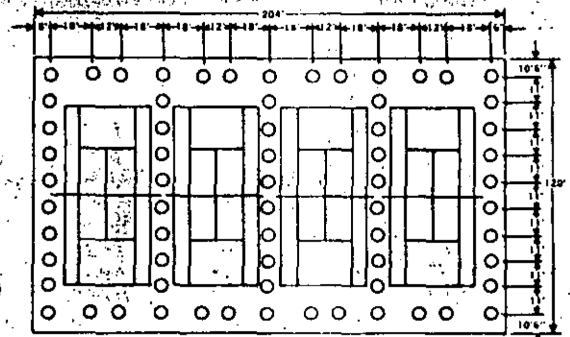
Indirect System



ennis - Indoor

Indirect System

METALARC SYSTEMS
400 and 1000 Watt
(Rated Lamp Life – 15,000 and 10,000 Hours)



FOUR COURT LAYOUT

SINGLE COURT

Class	Mounting Height	Qnty.	Fixture with Integral Ballast[4]	Lamps[1] (Metalarc) M1000/BD	M400/BD	KW[2] Load	Footcandles[3] Maintained
Exhibition	16'	24	V5-21-S-1-1000-120-C-IM	24		26.040	100
Tournament	16'	24	V5-21-S-2-400-120-C-IM		48	21.840	60
Club and Recreational	16'	24	V5-21-S-1-400-120-C-IM		24	10.920	30

TWIN COURTS

Class	Mounting Height	Qnty.	Fixture with Integral Ballast[4]	Lamps[1] (Metalarc) M1000/BD	M400/BD	KW[2] Load	Footcandles[3] Maintained
Exhibition	16'	38	V5-21-S-1-1000-120-C-IM	38		41.230	100
Tournament	16'	38	V5-21-S-2-400-120-C-IM		76	34.580	60
Club and Recreational	16'	38	V5-21-S-1-400-120-C-IM		38	17.290	30

THREE COURTS

Class	Mounting Height	Qnty.	Fixture with Integral Ballast[4]	Lamps[1] (Metalarc) M1000/BD	M400/BD	KW[2] Load	Footcandles[3] Maintained
Exhibition	16'	52	V5-21-S-1-1000-120-C-IM	52		56.420	100
Tournament	16'	52	V5-21-S-2-400-120-C-IM		104	47.320	60
Club and Recreational	16'	52	V5-21-S-1-400-120-C-IM		52	23.660	30

FOUR COURTS

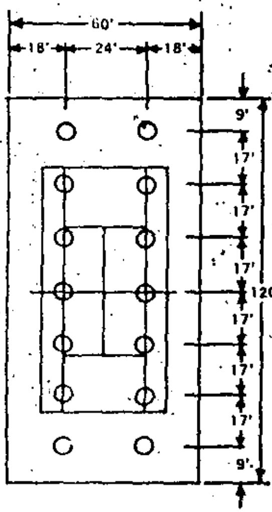
Class	Mounting Height	Qnty.	Fixture with Integral Ballast[4]	Lamps[1] (Metalarc) M1000/BD	M400/BD	KW[2] Load	Footcandles[3] Maintained
Exhibition	16'	66	V5-21-S-1-1000-120-C-IM	66		71.610	100
Tournament	16'	66	V5-21-S-2-400-120-C-IM		132	60.060	60
Club and Recreational	16'	66	V5-21-S-1-400-120-C-IM		66	30.030	30

NOTES: 1. Lamps operated at normal wattage 2. Load based on 1.085 KW per 1000 watt and .455 KW per 400 watt lamp (includes ballast loss). 3. Footcandle levels based on IES recommendations. 4. Ballasts shown are 120 volt. For 208, 240, 277 or 480 volt ballasts — refer to page 35.

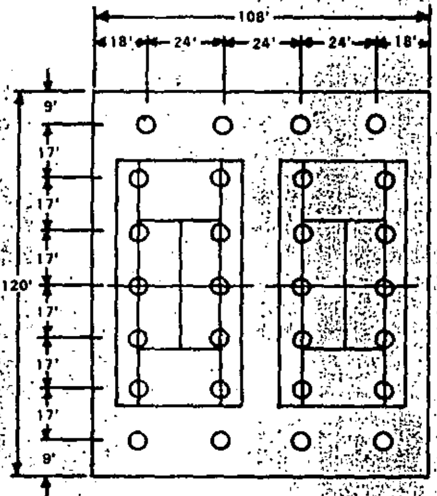
 ..nnis - Indoor

Direct System

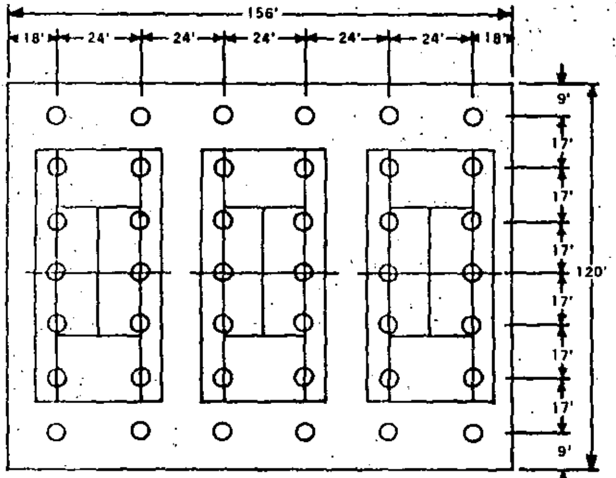
Direct System



SINGLE COURT LAYOUT

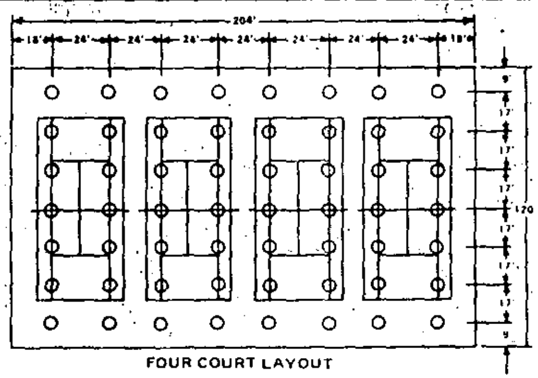


TWIN COURT LAYOUT



THREE COURT LAYOUT

METALARC SYSTEMS
400 and 1000 Watt
(Rated Lamp Life –
15,000 and 10,000 Hours)



FOUR COURT LAYOUT

SINGLE COURT

Class	Mounting Height	Qnty.	Fixture with Integral Ballast[4]	Lamps[1] (Metalarc) M1000/ BU-HOR	M400/ BU-HOR	KW[2] Load	Footcandles[3] Maintained
Exhibition	20'-30'	14	V5-21-W-1-1000-120-C	14		15.190	100
Tournament	20'-30'	14	V5-21-W-2-400-120-C		28	12.740	60
Club and Recreational	20'-30'	14	V5-21-W-1-400-120-C		14	6.370	30

TWIN COURTS

Class	Mounting Height	Qnty.	Fixture with Integral Ballast[4]	Lamps[1] (Metalarc) M1000/ BU-HOR	M400/ BU-HOR	KW[2] Load	Footcandles[3] Maintained
Exhibition	20'-30'	28	V5-21-W-1-1000-120-C	28		30.380	100
Tournament	20'-30'	28	V5-21-W-2-400-120-C		56	25.480	60
Club and Recreational	20'-30'	28	V5-21-W-1-400-120-C		28	12.740	30

THREE COURTS

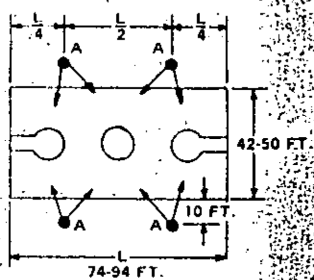
Class	Mounting Height	Qnty.	Fixture with Integral Ballast[4]	Lamps[1] (Metalarc) M1000/ BU-HOR	M400/ BU-HOR	KW[2] Load	Footcandles[3] Maintained
Exhibition	20'-30'	42	V5-21-W-1-1000-120-C	42		45.570	100
Tournament	20'-30'	42	V5-21-W-2-400-120-C		84	38.220	60
Club and Recreational	20'-30'	42	V5-21-W-1-400-120-C		42	19.110	30

FOUR COURTS

Class	Mounting Height	Qnty.	Fixture with Integral Ballast[4]	Lamps[1] (Metalarc) M1000/ BU-HOR	M400/ BU-HOR	KW[2] Load	Footcandles[3] Maintained
Exhibition	20'-30'	56	V5-21-W-1-1000-120-C	56		60.760	100
Tournament	20'-30'	56	V5-21-W-2-400-120-C		112	50.960	60
Club and Recreational	20'-30'	56	V5-21-W-1-400-120-C		56	25.480	30

NOTES:
1. Lamps operated at normal wattage.
2. Load based on 1.085 KW per 1000 watt lamp and .455 KW per 400 watt lamp (includes ballast loss).
3. Footcandle levels based on IES recommendations.
4. Ballasts shown are 120 volt. For 208, 240, 277 or 480 volt ballasts — refer to page 35.

Basketball – Outdoor Courts



INCANDESCENT – 1500 WATT (Rated Lamp Life – 1,000 Hours)

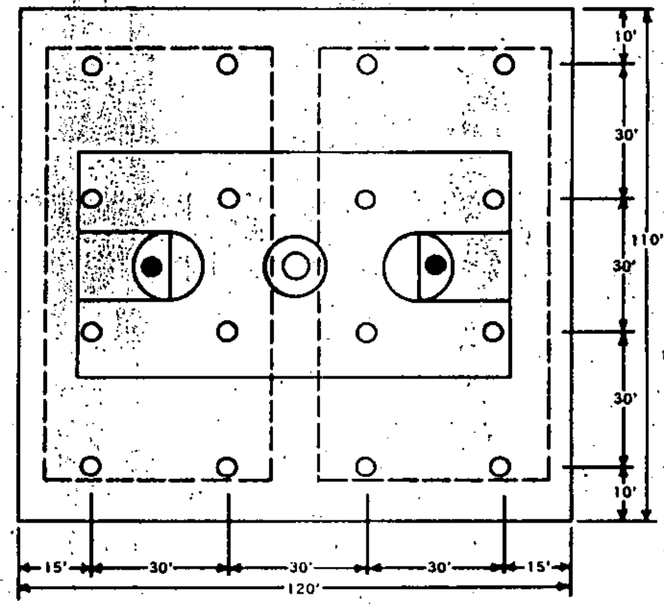
	Poles			Floodlights per Pole	Total Accessories per Pole			
Class	Desig.	Qnty.	Min.[1] Mntg. Hgt.	GPF1500-104	Mounting Adapter A100	Lamp[2] 1500	KW[4] Load	Footcandles[5] Maintained
Recreational	A	4	30'	2	2	2	3.000	
	Total			8	8	8	24.000	10

METALARC – 400 WATT (Rated Lamp Life – 15,000 Hours)

	Poles			Floodlights and Ballasts per Pole	Total Accessories per Pole			
Class	Desig.	Qnty.	Min.[1] Mntg. Hgt.	HDF400-121[6]	Mounting Adapter A100-222	Lamp[3] M400/BD	KW[4] Load	Footcandles[5] Maintained
Recreational	A	4	30'	2	2	2	.910	
	Total			8	8	8	3.640	10

NOTES:
1. Minimum height from playing field to bottom crossarm.
2. Lamps operated at normal voltage.
3. Lamps operated at normal wattage.
4. Load based on 1.5 KW per GPF1500 fixture and .455 KW per HDF400 fixture.
5. Footcandle levels are based on IES recommendations.
6. Ballasts shown are 120 volt. For 208, 240, 277 or 480 volt ballasts — refer to page 35.

Basketball – Indoor

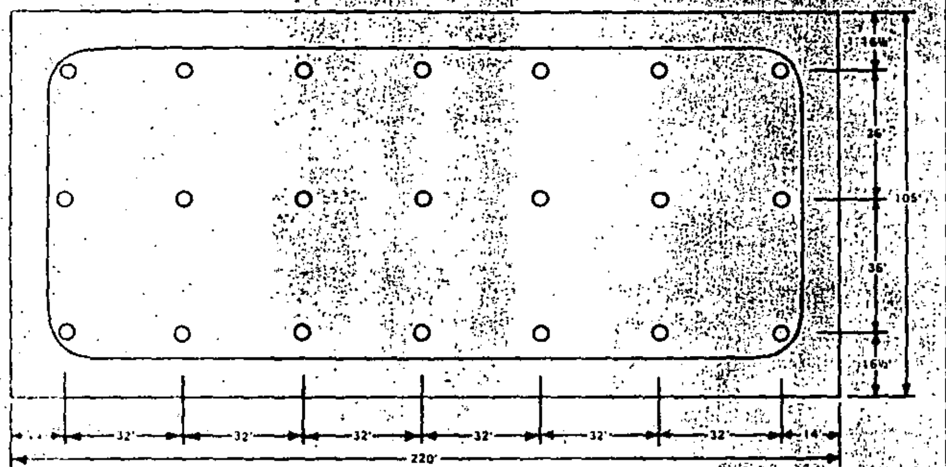


METALARC – 1000 WATT (Rated Lamp Life – 10,000 Hours)

Class	Mounting Height	Qnty.	Fixture with Integral Ballast[4]	Lamps[1] (Metalarc) M1000/BU-HOR	Lamps[1] (Metalarc) M400/BU-HOR	KW[2] Load	Footcandles Maintained[3]
Professional	25'-35'	16	V5-21-W-2-1000-D-120	32		34.720	100
	25'-35'	18	V5-21-W-2-1000-D-120	36		39.060	100[4]
College	25'-35'	16	V5-21-W-1-1000-D-120	16		17.360	50
	25'-35'	18	V5-21-W-1-1000-D-120	18		19.530	50[4]
Intramural and High School	25'-35'	16	V5-21-W-2-400-D-120		32	14.560	30

NOTES:
1. Lamps operated at normal wattage.
2. Load based on 1,085 KW per 1000 watt lamp and .455 KW per 400 watt lamp (includes ballast loss).
3. Footcandle levels based on IES recommendations.
4. Separate circuit for highlighting basket area of main court during games.
5. Ballasts shown are 120 volt. For 208, 240, 277 or 480 volt ballasts – refer to page 35.

Hockey - Indoor

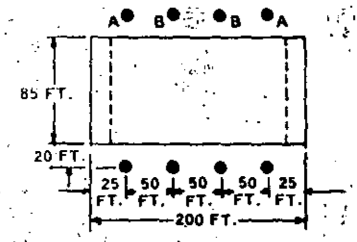


METALARC — 1000 WATT (Rated Lamp Life — 10,000 Hours)

Class	Mounting Height	Qnty.	Fixture with Integral Ballast[4]	Lamps[1] (Metalarc) M1000/ BU-HOR	Lamps[1] (Metalarc) M400/ BU-HOR	KW Load[2]	Footcandles[3] Maintained
Professional & College	20'-30'	21	V5-21-W-2-1000-120-C	42		45,570	100
Amateur	20'-30'	21	V5-21-W-1-1000-120-C	21		22,785	50
Recreational	20'-30'	21	V5-21-W-2-400-120-C		42	19,110	30

NOTES: 1. Lamps operated at normal wattage.
2. Load based on 1,085 KW per 1000 watt lamp and .455 KW per 400 watt lamp (includes ballast loss).
3. Footcandle levels based on IES recommendations.
4. Ballasts shown are 120 volt. For 208, 240, 277 or 480 volt ballasts — refer to page 35.

Hockey - Outdoor Ice Rinks



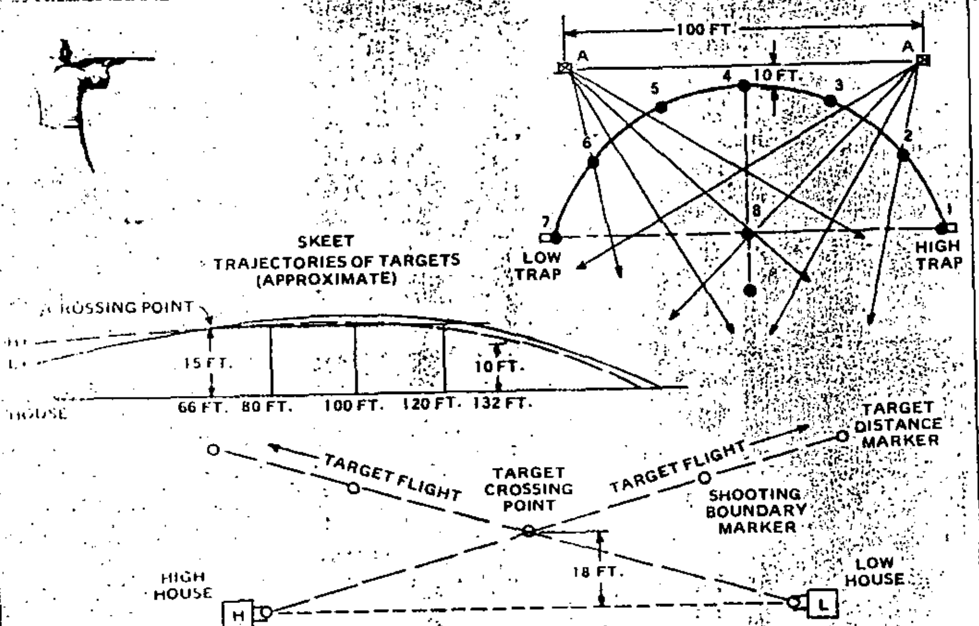
INCANDESCENT — 1500 WATT (Rated Lamp Life — 300 Hours)

Class	Poles Desig.	Poles Qnty.	Poles Min.[1] Mntg. Hgt.	Floodlights per Pole GPF1500-104	Total Accessories per Pole Mounting Adapter A100-222	Total Accessories per Pole Lamp[2] 1500	KW[4] Load	Footcandles[5] Maintained
Recreational	A	4	50'	3	3	3	5.220	
	B	4	50'	2	2	2	3.480	
	Total			20	20	20	34.800	10
Amateur	A	4	50'	4	4	4	6.960	
	B	4	50'	4	4	4	6.960	
	Total			32	32	32	55.680	20
Professional or College	A	4	50'	10	10	10	17.400	
	B	4	50'	10	10	10	17.400	
	Total			80	80	80	139.200	50

METALARC — 1000 WATT (Rated Lamp Life — 10,000 Hours)

Class	Poles Desig.	Poles Qnty.	Poles Min.[1] Mntg. Hgt.	Floodlights and Ballasts per Pole HIF400-108-121[6]	Floodlights and Ballasts per Pole HIF1000-106-121[6]	Total Accessories per Pole Mounting Adapter A100-222	Total Accessories per Pole Lamps[3] M400/ BU-HOR	Total Accessories per Pole Lamps[3] M1000/ BU-HOR	KW[4] Load	Footcandles[5] Maintained
Recreational	A	4	50'	3		3	3		1.365	
	B	4	50'	3		3	3		1.365	
	Total			24		24	24		10.920	10
Amateur	A	4	50'		2	2		2	2.170	
	B	4	50'		2	2		2	2.170	
	Total				16	16		16	17.360	20
Professional or College	A	4	50'		5	5		5	5.425	
	B	4	50'		4	4		4	4.340	
	Total				36	36		36	39.060	50

NOTES: 1. Minimum height from playing field to bottom crossarm.
2. Lamps operated at 10% over rated voltage.
3. Lamps operated at normal wattage.
4. Load based on 1.74 KW per GPF1500 fixture .455 KW per HIF 400 fixture and 1,085 KW per HIF1000 fixture.
5. Footcandle levels are based on IES recommendations.
6. Ballasts shown are 120 volt. For 208, 240, 277 or 480 volt ballasts — refer to page 35.



INCANDESCENT – 1500 WATT (Rated Lamp Life – 300 Hours)

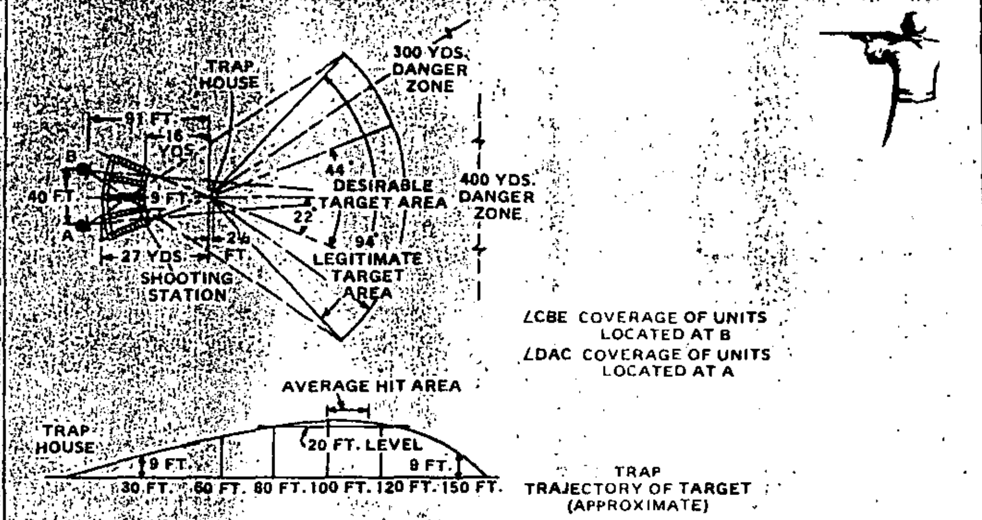
Poles			Total Floodlights per Pole	Total Accessories per Pole		KW[3] Load	Footcandles[4] Maintained	
Desig.	Qnty.	Min.[1] Mntg. Hgt.	GPF1500-101	Mounting Adapter A100-222	Lamp[2] 1500		Horiz. at Firing Point	Vert. on Target at 60'
[illegible]	2	20'	4	4	4	6.96		
Total	2		8	8	8	13.92	5	30

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Lamps operated at 10% over rated voltage.
3. Load based on 1.74 KW per fixture.
4. Footcandle levels conform to IES recommendations.

METALARC – 1000 WATT (Rated Lamp Life – 10,000 Hours)

Poles			Total Floodlights and Ballasts per Pole	Total Accessories per Pole		KW[4] Load	Footcandles[5] Maintained	
Desig.	Qnty.	Min.[1] Mntg. Hgt.	HIF1000-106-121[2]	Mounting Adapter A100-222	Lamps[3] M1000/BU-HOR		Horiz. at Firing Point	Vert. on Target at 60'
[illegible]	2	20'	2	2	2	2.17		
Total	2		4	4	4	4.34	5	30

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Ballasts shown are 120 volt. For 208, 240, 277, or 480 volt ballasts – refer to page 35.
3. Lamps operated at normal wattage.
4. Load based on 1.085 KW per fixture.
5. Footcandle levels conform to IES recommendations.



INCANDESCENT – 1500 WATT (Rated Lamp Life – 300 Hours)

Poles			Total Floodlights per Pole	Total Accessories per Pole		KW[3] Load	Footcandles[4] Maintained	
Desig.	Qnty.	Min.[1] Mntg. Hgt.	GPF1500-101	Mounting Adapter A100-222	Lamp[2] 1500		Horiz. at Firing Point	Vert. on Target at 100'
A	1	20'	4	4	4	6.96		
B	1	20'	4	4	4	6.96		
Total	2		8	8	8	13.92	5	30

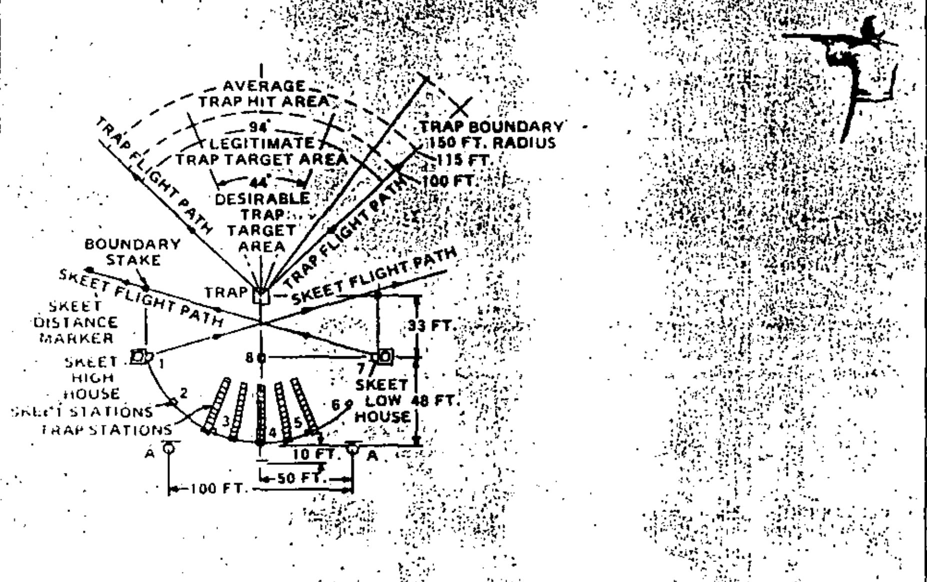
NOTES: 1. Minimum height from playing field to bottom crossarm.
2. Lamps operated at 10% over rated voltage.
3. Load based on 1.74 KW per fixture.
4. Footcandle levels conform to IES recommendations.

METALARC – 1000 WATT (Rated Lamp Life – 10,000 Hours)

Poles			Total Floodlights and Ballasts per Pole	Total Accessories per Pole		KW[4] Load	Footcandles[5] Maintained	
Desig.	Qnty.	Min.[1] Mntg. Hgt.	HIF1000-106-121[2]	Mounting Adapter A100-222	Lamps[3] M1000/BU-HOR		Horiz. at Firing Point	Vert. on Target at 100'
A	1	20'	2	2	2	2.17		
B	1	20'	2	2	2	2.17		
Total	2		4	4	4	4.34	5	30

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Ballasts shown are 120 volt. For 208, 240, 277 or 480 volt ballasts – refer to page 35.
3. Lamps operated at normal wattage.
4. Load based on 1.085 KW per fixture.
5. Footcandle levels conform to IES recommendations.

Combination Skeet and Trap



INCANDESCENT – 1500 WATT (Rated Lamp Life – 300 Hours)

Poles			Total Floodlights per Pole	Total Accessories per Pole			Footcandles⁴ Maintained	
Desig.	Qnty.	Min.¹ Mntg. Hgt.	GPF1500-101	Mounting Adapter A100-222	Lamp² 1500	KW³ Load	Horiz. at Firing Point	Vert. on Target at 100'
A	2	20'	4	4	4	6.96		
Total	2		8	8	8	13.92	5	30

NOTES: 1. Minimum height from playing field to bottom crossarm.
2. Lamps operated at 10% over rated voltage.
3. Load based on 1.74 KW per fixture.
4. Footcandle levels conform to IES recommendations.

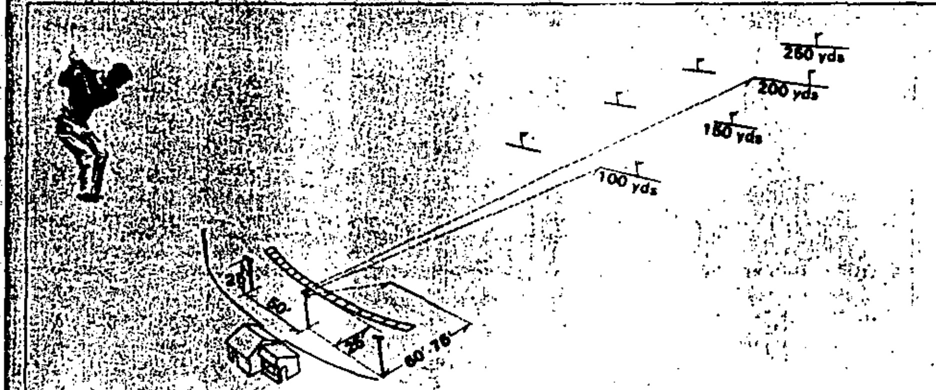
METALARC – 1000 WATT (Rated Lamp Life – 10,000 Hours)

Poles			Total Floodlights and Ballasts per Pole	Total Accessories per Pole			Footcandles⁵ Maintained	
Desig.	Qnty.	Min.¹ Mntg. Hgt.	HIF1000-106-121²	Mounting Adapter A100-222	Lamps³ M1000/BU-HOR	KW⁴ Load	Horiz. at Firing Point	Vert. on Target at 100'
A	2	20'	2	2	2	2.17		
Total	2		4	4	4	4.34	5	30

NOTES: 1. Minimum height from playing field to bottom floodlight crossarm.
2. Ballasts shown are 120 volt. For 208, 240, 277 or 480 volt ballasts — refer to page 35.
3. Lamps operated at normal wattage.
4. Load based on 1.085 KW per fixture.
5. Footcandle levels conform to IES recommendations.

Golf Driving Range

Incandescent & Metalarc Systems



INCANDESCENT – 1500 WATT (Rated Lamp Life – 1,000 Hours)

Qnty. of Poles	Min.¹ Mntg. Hgt.	Floodlights per Pole				Accessories per Pole		KW³ Load	Footcandles⁴ Maintained
		GPF 1500-104	GPF 1500-102	GPF 1500-101	Total	Mounting Adapter A100-222	Lamp² 1500		
4	25'	1	2	3	6	6	6	9.0	10 horizontal on tees
Total		4	8	12	24	24	24	36.0	5 vertical at 200 yds.

NOTES: 1. Minimum height from playing field to bottom crossarm.
2. Lamps to be operated at normal voltage.
3. Load based on 1.5 KW per fixture.
4. Footcandle levels and floodlight quantities based on IES recommendations.

METALARC SYSTEM – 1000 WATT (Rated Lamp Life – 10,000 Hours)

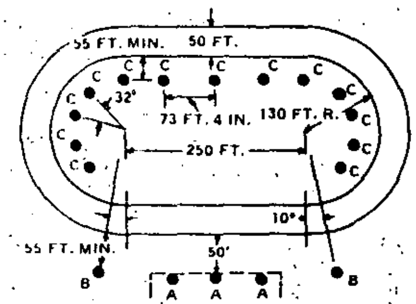
Qnty. of Poles	Min.¹ Mntg. Hgt.	Floodlights per Pole				Accessories per Pole		KW⁴ Load	Footcandles⁵ Maintained
		GPF 1000-108-121²	GPF 1000-106-121²	GPF 1000-101-121²	Total	Mounting Adapter A100-222	Lamp³ M1000/BU-HOR		
4	25'	1	1	2	4	4	4	4.34	10 horizontal on tees
Total		4	4	8	16	16	16	17.36	5 vertical at 200 yds.

METALARC SYSTEM – 1500 WATT (Rated Lamp Life – 1,500 Hours)

Qnty. of Poles	Min.¹ Mntg. Hgt.	Floodlights and Ballasts per Pole				Accessories per Pole		KW⁴ Load	Footcandles⁵ Maintained
		HIF1500-108-121²	HIF1500-106-121²	HIF1500-101-121²	Total	Mounting Adapter A100-222	Lamp³ M1500/BU-HOR		
4	25'	1	1	1	3	3	3	4.890	10 horizontal on tees
Total		4	4	4	12	12	12	19.560	5 vertical at 200 yds.

NOTES: 1. Minimum height from playing field to bottom crossarm.
2. Ballasts shown are 120 volt. For 208, 240, 277 and 480 volt ballasts – refer to page 35.
3. Lamps are operated at normal wattage.
4. Load based on 1.085 KW per 1000 watt fixture and 1.630 KW per 1500 watt fixture.
5. Footcandle levels are based on IES recommendations.

Racing - 1/4 Mile Auto Track



INCANDESCENT – 1500 WATT (Rated Lamp Life – 300 Hours)

Class	Poles			Floodlights per Pole	Total Accessories per Pole		KW[4] Load	Footcandles[5] Maintained
	Desig.	Qnty.	Min.[1] Mntg. Hgt.	GPF1500-102	Mounting Adapter A100-222	Lamps[2] 1500		
Regulation	A	3	40'	8	8	8	13.920	
	B	2	40'	8	8	8	13.920	
	C	13	40'	8	8	8	13.920	
	Total			144	144	144	250.560	20

METALARC – 1000 WATT (Rated Lamp Life – 10,000 Hours)

Class	Poles			Floodlights and Ballasts per Pole	Total Accessories per Pole		KW[4] Load	Footcandles[5] Maintained
	Desig.	Qnty.	Min.[1] Mntg. Hgt.	HIF1000-106-121[6]	Mounting Adapter A100-222	Lamps[3] M1000/BU-HOR		
Regulation	A	3	40'	4	4	4	4.340	
	B	2	40'	4	4	4	4.340	
	C	13	40'	4	4	4	4.340	
	Total			72	72	72	78.120	20

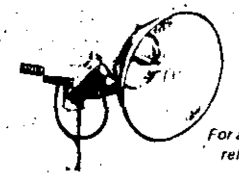
METALARC – 1500 WATT (Rated Lamp Life – 1,500 Hours)

Class	Poles			Floodlights and Ballasts per Pole	Total Accessories per Pole		KW[4] Load	Footcandles[5] Maintained
	Desig.	Qnty.	Min.[1] Mntg. Hgt.	HIF1500-106-121[6]	Mounting Adapter A100-222	Lamps[3] M1000/BU-HOR		
Regulation	A	3	40'	3	3	3	4.890	
	B	2	40'	3	3	3	4.890	
	C	13	40'	3	3	3	4.890	
	Total			54	54	54	88.020	20

NOTES: 1. Minimum height from playing field to bottom crossarm.
2. Lamps operated at 10% over rated voltage.
3. Lamps operated at normal wattage.
4. Load based on 1.740 KW per GPF 1500 fixture, 1.085 KW per HIF 1000 fixture and 1.630 KW per HIF 1500 fixture.
5. Footcandle levels are based on IES recommendations.
6. Ballast shown are 120 volt. For 208, 240, 277 or 480 volt ballasts — refer to page 35.

Application Products

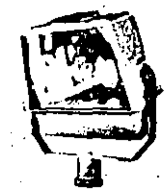
HIF SERIES



For additional information refer to Bulletin #106-20

VOLTAGE OPTIONS		
Typical Catalog No.	Voltage Suffix	Voltage
HIF1500-	121	120
	123	208
	122	240
	124	277
	125	480

HDF SERIES



For additional information refer to Bulletin #106-8

VOLTAGE OPTIONS		
Typical Catalog No.	Voltage Suffix	Voltage
HDF1000-	121	120
	123	208
	122	240
	124	277
	125	480

VANGUARD-5 SERIES

For additional information refer to Bulletin #103-34

VOLTAGE OPTIONS	
Typical Catalog No.	Insert Desired Voltage
V5-21-S-1-1000-120-C	120
	208
	240
	277
	480

INDIRECT VANGUARD-5 SERIES

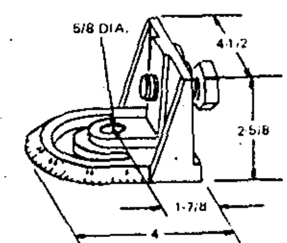
For additional information refer to Bulletin #103-36

VOLTAGE OPTIONS	
Typical Catalog No.	Insert Desired Voltage
V5-21-S-1-1000-120-C-IM	120
	208
	240
	277
	480

GPF SERIES

For additional information refer to Bulletin #106-5

MOUNTING ADAPTER #A100-222



FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

C U R S O S   A B I E R T O S

ILUMINACION EXTERIOR:
PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

CALCULO DE ALUMBRADO PUBLICO

PALACIO DE MINERIA

ROADWAY LIGHTING DESIGN AND COMPUTATIONS 8

1. INTRODUCTION. The information in previous chapters has detailed the general information required for a general working knowledge of what can be applied to Roadways, Walkways and Bikeways. The basic examples and computations that follow apply to Roadways. It is obvious, however that the data and techniques can be applied to adjacent walkways, median strips and some other areas.

   For special computations relating to Area Lighting and High Mast Lighting refer to Appendices C & D of the 1977 American National Standard Practice for Roadway Lighting.

   In the Standard Practice definite facts are set up to outline what must be done to provide an installation of luminaires which will produce acceptable results. Therefore in the design of an installation all the factors, in the Standard Practice which apply to an installation must be studied carefully.

   To apply these factors we must have all the physical data which will have to be considered in making the installation. A scale layout of the area which shows all the pertinent data is essential. Other information in regard to the general area, location, traffic density, local and national jurisdiction, and many other factors must be obtained for use as the project is developed.

   In this Fundamentals Course there may be variables which will influence the final selection of a particular system, and each variable will have to be worked out as it arises.

2. CALCULATION PROCEDURE. The general procedure for calculating maintained Roadway Illumination consists of a series of steps. They are divided into two major groups; Objectives and Specifications (6); Light Loss Factors Not to be Recovered (6); and Light Loss Factors to be Recovered (2). The main procedure is to determine through calculations from Photometric Data which Lamp and Luminaire combination are required to provide a given intensity on a roadway of stated dimensions when the luminaire is mounted at locations which will produce a good quality of illumination.

a. Problem. To start we have a roadway we wish to illuminate so that it can be traversed safely by cars and pedestrians. This area will naturally have dimensions, width (W) and length (Y). Next we assume that the needed intensity on the roadway is for a road which requires .9 footcandles average maintained horizontal illumination.* To illuminate this roadway we need a lamp - luminaire combination mounted on a pole, which will project the light onto the roadway. The pole of course must be set back from the edge of the road so that it does not present a hazard. If this were a city street the pole might be only 2' from the curb or if it were a country road it might be 12' from the edge of the road. In our problem we will assume that the 30' pole is installed 3' from the edge of the road and that a mast arm will project the luminaire 5' over the roadway (OH). See Fig. 8-1.

3. STANDARD DATA FORM. The IES Testing Procedure Committee has recommended a standard form for reporting photometric data. See Fig. 4-17, p. 4-16 and Fig. 8-2, p. 4. The data on Fig. 8-2, p. 8-4 will be used in the next series of computations. (see following page 8-3) It is well to study the data on such reports to see if there are any figures that may have to be changed to give the proper information. One thing that will be noted immediately is that the test was made for a lamp rated at 20,500 lumens. Referring to page 5- we find that the H33-1cd lamp is now the H33CD-400 lamp which has a rating of 19,667 lumens in a horizontal burning position. In as much as the lamp in the fixture illustrated is in a horizontal position we have to use this value. We therefore have to multiply all lumen, candlepower and footcandle values by a correction factor of .96 (19,667/20,500 = .9594).

4. CALCULATIONS. Roadway illumination calculations fall into three general types of calculations:

a. Determination of the average illumination on the roadway pavement or spacing that will produce a given footcandle average illumination.

b. Determination of the illumination at a specific point on the roadway.

c. Determination of uniformity of illumination.

*Footnote - Committee on Testing Procedures of the IES: "IES Approved Method of Photometric Testing of Roadway Luminaires Using Incandescent Filament or Mercury or Sodium Electric Discharge Lamps," Illuminating Engineering, Vol. 63, October 1968, p. 541.

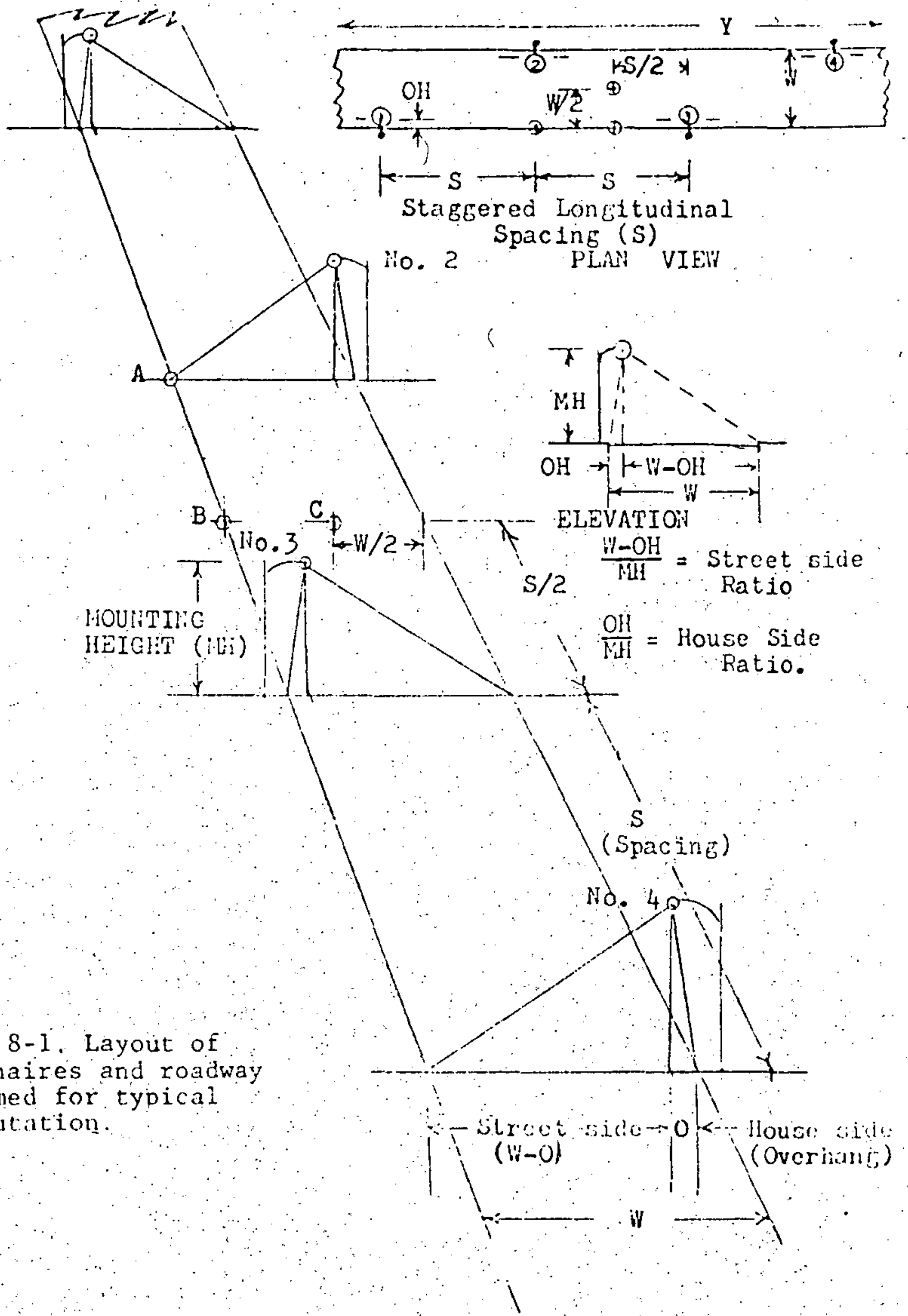


Fig. 8-1. Layout of luminaires and roadway assumed for typical computation.

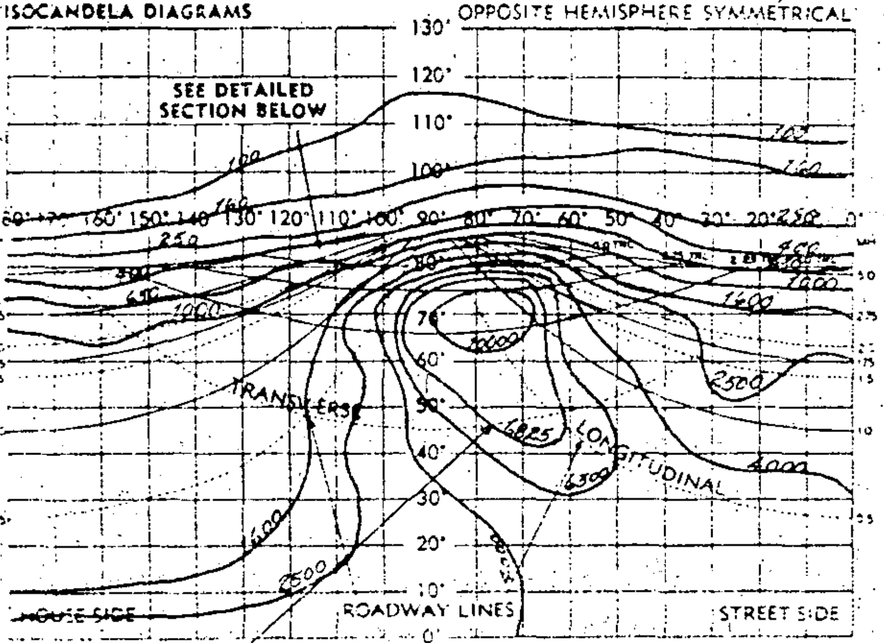
PHOTOMETRIC DATA

Fig. 8-2

8-4

ISOCANDELA DIAGRAMS

OPPOSITE HEMISPHERE SYMMETRICAL



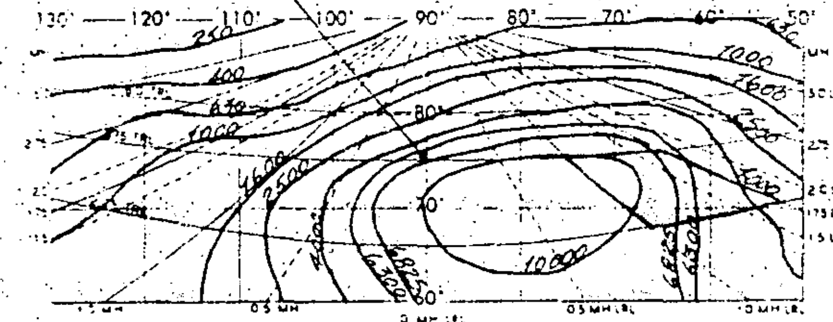
MAX C.P. — 6825

MAX C.P. — 13650

NADIR C.P. — 3861

MAX CONE — 72.5°

MAX VER. PLANE — 77.5/282.5°

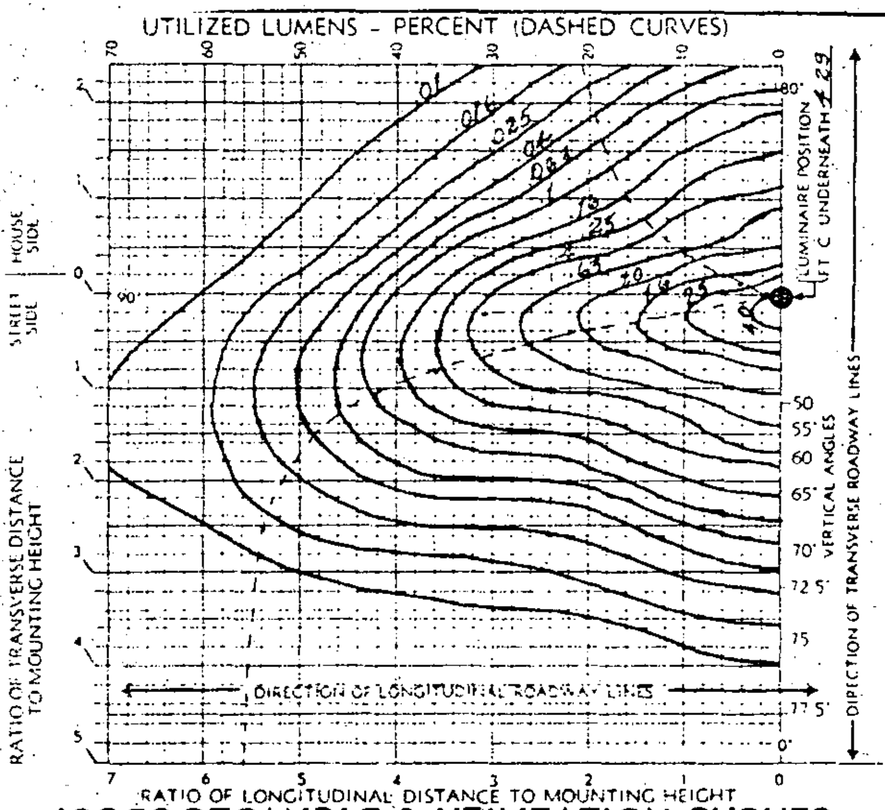


DETAILED SECTION: Based upon data taken at closer intervals than used for main diagram.

VALUES OF ISOCANDELA, LUMENS AND FOOTCANDLES ARE BASED UPON A LAMP OPERATED AT 20500 LUMENS. IF THE DATA IS DESIRED FOR A DIFFERENT LAMP LUMEN RATING MULTIPLY ALL ISOCANDELA, LUMEN AND FOOTCANDLE VALUES BY THE RATIO DIFFERENT LAMP LUMEN RATING ÷ 20500

LIGHT FLUX VALUES	LUMENS	PERCENT OF LAMP
[illegible]	11562	56.4
[illegible]	226	1.1
[illegible]	4489	21.9
[illegible]	122	.6
TOTAL	16400	80.0

UTILIZED LUMENS – PERCENT (DASHED CURVES)

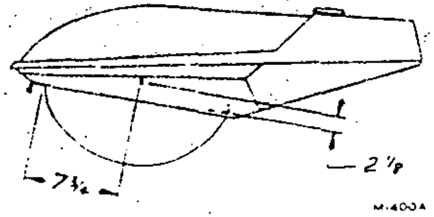


RATIO OF LONGITUDINAL DISTANCE TO MOUNTING HEIGHT

ISOFOOTCANDLE & UTILIZATION CURVES

FOOTCANDLE DATA IS BASED ON A LUMINAIRE MOUNTING HEIGHT OF 30 FEET. FOR OTHER MOUNTING HEIGHTS MULTIPLY THE VALUES OF FOOTCANDLES SHOWN BY THE FACTORS IN THE FOLLOWING TABLE. THE UTILIZATION CURVE (DASHED) IS CORRECT FOR ALL MOUNTING HEIGHTS AND DOES NOT REQUIRE CORRECTION.

MOUNTING HEIGHT - FT.	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
FACTOR	2.25	2.04	1.86	1.70	1.56	1.44	1.33	1.24	1.15	1.07	1	0.94	0.88	0.83	0.78	0.74



LUMINAIRE DESCRIPTION

STANDARD M400A/M400

SOCKET POSITION 2

LAMP – 400 WATT CLEAR MERCURY
ASA No. H33-ICD
H400A33-1

ASA TEST TYPE — TYPE II BY 1953 STANDARD

MEDIUM SEMI- CUTOFF TYPE II

NUMBER 35 17 445200 — 05

5. DETERMINATION OF SPACING

a. Determination of the spacing between poles for an average of .9 footcandles can be done in several ways. The average illumination over a large pavement area may be calculated by means of a "Utilization Curve" of the type shown in Fig. 8-2 and 8-3, (which is an enlargement of Fig. 8-2a), or by means of computing the illumination at a large number of points (see paragraph 8.6.a) and averaging the values calculated. Since this latter method is extremely laborious and since the utilization curve is a part of the data presented as a result of following the IES Approved Method for Photometric Testing of Roadway Luminaires (*See footnote in paragraph 8.2.a) this method will be discussed.

b. Utilization Curves.

(1) Utilization curves, available for various types of luminaires, afford a practical method for the determination of illumination over the roadway surface where lamp size, mounting height, width of paved area and spacing between luminaires are known or assumed. Conversely, the desired spacing or any other unknown factor may be readily determined if the other factors are given.

(2) Fig. 8-3 illustrates an example of a utilization curve of a typical luminaire. The utilization curve indicates how much light falls on the roadway, as a percentage of initial lamp lumens but reveals little of the way in which the light is distributed. Therefore, it should be used in conjunction with the specific calculation in order to evaluate correctly the true performance of the luminaire, especially concerning uniformity or compliance with the recommended ratio of minimum illumination value to the average value.

(3) The coefficient of utilization is the percentage of the rated lamp lumens which fall into a strip-like area of infinite length. In making up the chart so that it would be the most useful a reference line has been set up so that the percent of lumens projected forward is known as the "street side" utilization. In a like manner the percentage projected in the opposite direction from the reference line is called the "house side" utilization. One thing to remember is that if the luminaire center is back of the edge of the roadway the utilization from the reference line to the edge of the roadway has to be subtracted from the "street side" value.

Fig. 8-3. Enlarged utilization curves from Fig. 8-2. Example of coefficient of utilization curves for a luminaire providing type II medium semi-cutoff distribution.

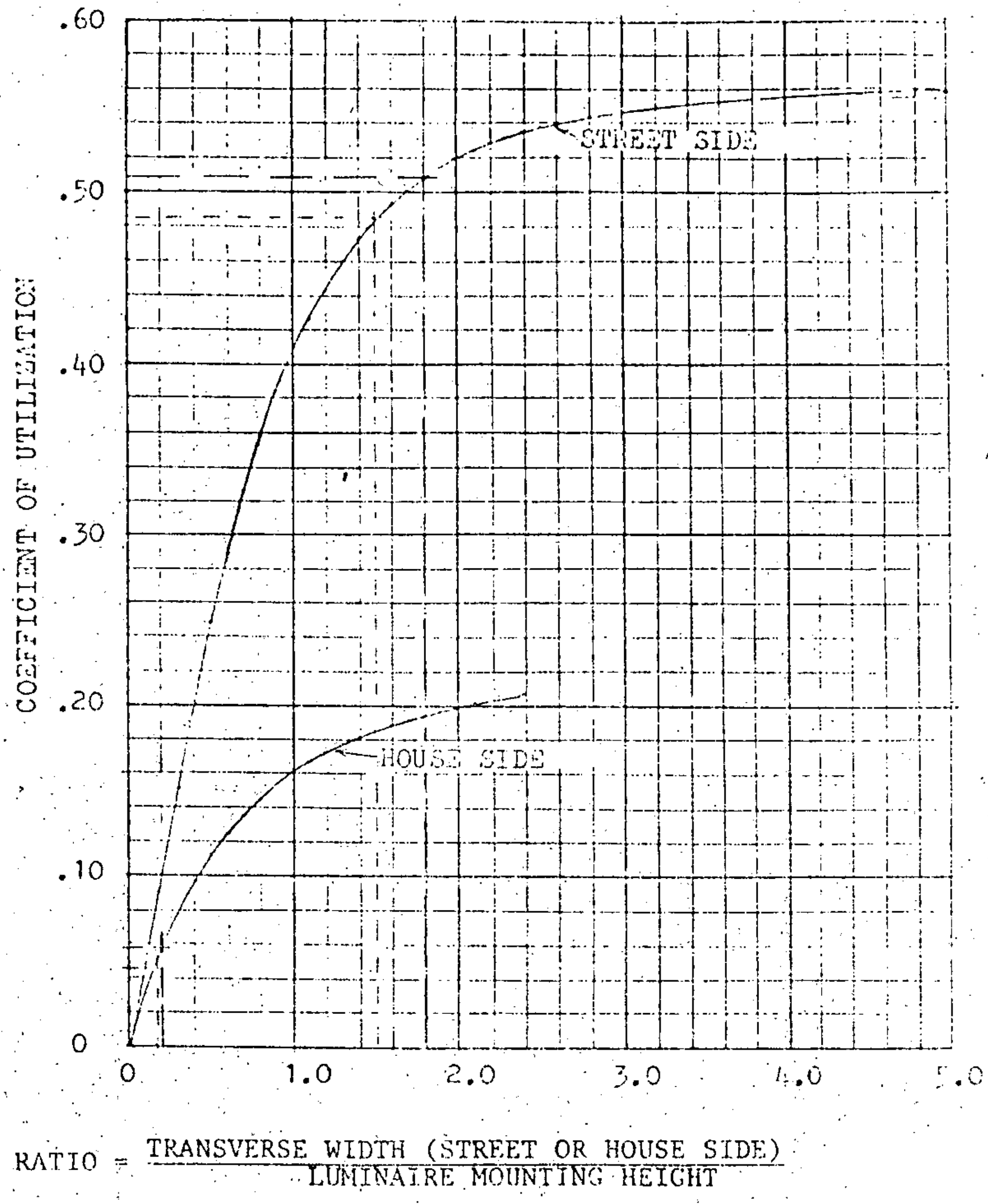
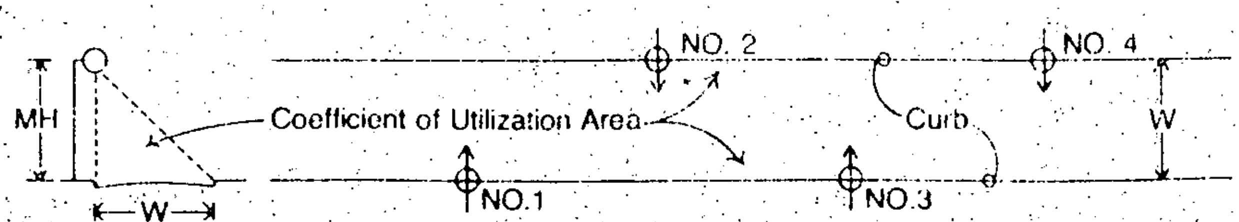


Fig. 8-4. Roadway



(4) To obtain the same results the luminaires when they are installed will have to be leveled and oriented over the roadway in a manner equivalent to that in which the unit was tested. Note that roadway width is expressed in terms of a ratio of luminaire mounting height to roadway width.

c. Formulas for Computation

(1) The basic formulas for determination of spacing follows:

$$\text{Spacing} = \frac{\text{Lamp Lumens x Coefficient of Utilization}}{\text{Width of Pavement x Average Initial Illumination}}$$

(2) The above formulas can be expanded to take care of maintained illumination by adding the necessary factors. (See 8.10)

$$\text{Spacing} = \frac{\text{Lamp Lumens} \times \text{Coef. of Utilization} \times \text{Luminaire Dirt Depreciation} \times \text{Lamp Lumen Depreciation}}{\text{Width of Pavement x Average Maintained Illumination}}$$

(3) Definitions of symbols used in above and other following formulas:

Symbol	Definition
AME	Average maintained illumination
AT	Ambient temperature
BF	Ballast factor
BO	Burn out
CD	Component depreciation
CPS	Changes in depreciation
CU	Co-efficient of Utilization
E	Illumination
FCM	Footcandles maintained
LL	Lamp Lumens
LDD	Luminaire Dirt Depreciation
LLF	Light loss factor
LLD	Lamp lumen depreciation
MH	Mounting height
OH	Overhang
S	Spacing
VF	Voltage factor
W	Width of Pavement

Basic formula with symbols for the determination of Spacing is:

$$S = \frac{LL \times CU}{W \times AME}$$

1. Calculations

Coefficient of Utilization "Street Side"

$$\text{Coef. of Util.} = \frac{W-OH}{MH} = \frac{50' - 5'}{30'} = \frac{45'}{30'} = 1.50$$

Refer to chart Fig. 8-3 for a ratio of 1.50 the coef. of util. is .485

Coefficient of Utilization "House Side"

$$\text{Coef. of Util.} = \frac{OH}{MH} = \frac{5'}{30'} = .16$$

In a like manner a vertical line is drawn on Fig. 8-3 up until it intersects the House Side utilization curve. At this point the utilization is .045. The total for both house side and street side is .485 + .045 = .53.

Spacing is now determined by substituting in the formula 8.5.3a assuming LDD = 1 and LLD = 1 we have

$$\text{Spacing} = \frac{19,667 \times .53}{50 \times .9} = \frac{10,423}{45} = 231.6$$

To make this information more meaningful we must insert realistic light loss factors, so that we can get accurate maintained values. To get the spacing for a series of fixtures mounted as noted above in an area where conditions are average and a cleaning cycle of six months will be maintained we find after consulting Chart Fig. 8-5 (Fig. B-1, page 25 of the American National Standard Practice for Roadway Lighting that the factor is .95%). In choosing the point on the lamp lumen depreciation curve, to ensure the required maintained illumination, one should choose the point which coincides with a multiple of the cleaning cycles. In our example, the cleaning cytle is six months. Therefore the point on the lamp lumen depreciation curve should be a multiple of six months. Assuming 4,000 hours operation time per year, we would see that 16,000 hours represents a four year life. Four years if of course a multiple of a six months cleaning cycle. Therefore the 16,000 hour point has been chosen from the lamp lumen depreciation curve. In looking at the curve and taking the average of the span at the 16,000 hour point, we have a lamp lumen depreciation factor of 67%.

Besides these two factors others such as Allowance for Ambient Temperature, 10.a, Voltage, 10.b, Ballast factor, 10.c, Component Depreciation, 10.d, Possible Changes of Physical Surrounds, 10.e, Burn-outs, 10.f, etc. could be entered at this point if they will influence the final calculations.

With the two factors of LLD and LDD we can now use the second formula 5.c(1).

$$\text{Spacing (S)} = \frac{19{,}667 \times .53 \times .95 \times .76}{50 \times .9} = \frac{7526}{45} = 167.2'(166)$$

6. DETERMINATION OF ILLUMINATION AT A SPECIFIC POINT

a. General. The determination of the horizontal illumination in approximate footcandles at a specific point may be determined from an "isofootcandle" curve Fig. 8-6 or by means of the inverse-square method of calculation of illumination (see IES Lighting Handbook, current edition). In the later method, the candlepower of the luminaire at the particular angle involved is normally obtained from an isocandle curve, an example of which is shown in Fig. 8-2(b). Since the isofootcandle curve is a part of the data presented as a result of following the IES Approved Method for Photometric Testing of Roadway Luminaires, the isofootcandle method will be discussed.

b. Isofootcandle (isolux) Diagram.

(1) The illumination on a roadway surface produced by the light distribution from one or more luminaires may be shown by isofootcandle diagrams. Fig. 8-6 and Fig. 8-2a, p. 8- show an example of an isofootcandle diagram for a typical luminaire.

(2) An isofootcandle diagram is a graphical representation of points of equal illumination connected by a continuous line. These lines may show footcandle values on a horizontal plane from a single unit having a definite mounting height, or they may show a composite picture of the illumination from a number of sources arranged in any manner or at any mounting height. They are useful in the study of uniformity of the illumination and in the determination of the level of illumination at any specific point. In order to make these curves applicable to all conditions, they are computed for a given mounting height but horizontal distances are expressed in ratios of the actual distance to the mounting height. Correction factors for other mounting heights are usually given in the tabulation along side the isofootcandle curves.

c. Typical Computation. To illustrate the use of the isofootcandle diagram, a typical calculation is as follows:

Given: Roadway with layout as in fig. 8-1.

Staggered Luminaire spacing (S) (see 8.5.d(1))	166'
Roadway Width (W) curb to curb	50'
Luminaire Mounting Height	30'
Luminaire OverHang(OH)	5'
Luminaire Dirt Depreciation (LDD)	.95
Lamp Lumen Depreciation (LLD)	.76
Lamp - 400 watt clear mercury rated at	19,667 lumens

Required to determine:

Initial and maintained fc at points "A", "B" and "C" Fig. 8-1 To determine the fc level at point "A" the values will have to be determined from the isofootcandle diagram Fig. 8-6. Solution (1) The location of point "A" in respect to a point on the pavement directly under the luminaire is dimensioned in transverse and longitudinal multiples of the mounting height. The luminaire produces isofootcandle lines (horizontal footcandles) as shown in Fig. 8-6 Point "A" is then located on the isofootcandle diagram for its position with respect to each luminaire.

(2) To determine the contribution of each luminaire to point "A" (a) Luminaires No. 1 and No. 3

Locate point "A" - Transverse distance to "House Side"

$$\frac{OH}{MH} = \frac{5'}{30'} = 0.16$$

-Longitudinal distance along pavement

$$\frac{S}{MH} = \frac{166'}{30'} = 5.533$$

Point "A" for these luminaires on chart Fig. 8-6 is .16 toward the House side, behind the unit and .533 longitudinally. This point will be found lying about midway between isofootcandle lines of Fig. 8-6 .01 and .016 for a value of .013 fc. Therefore the two luminaires will deliver 2 x .013 or .026 fc. total.

(b) Luminaire No. 2

Locate Point "A" - Transverse distance to "Street Side"

$$\frac{W-OH}{MH} = \frac{50' - 5'}{30'} = \frac{45'}{30'} = 1.5$$

Longitudinal distance along pavement is 0' as the point is directly opposite the luminaire

Point "A" for this luminaire on chart Fig. 8-6 is 1.5 directly in front of 0° or zero mounting height. This point will be found between isofootcandle lines .63 and .4. It is estimated that the value is .55.

(c) Luminaire No. 4

Locate point "A" - Transverse distance to "Street Side"

$$\frac{W-HO}{MH} = \frac{50' - 5'}{30'} = \frac{45'}{30'} = 1.5$$

Longitudinal distance along pavement is

$$332' \ (2 \times S) = \frac{332'}{30'} = 11.06$$

Point "A" for this luminaire is 1.5 directly in front of the luminaire and 11.06 left which of course is off the chart Fig. 8-6 and therefore can be ignored.

(d) Total footcandle values from all luminaires at Point "A"?

is luminaire No. 1	.013
luminaire No. 2	.55
luminaire No. 3	.013
luminaire No. 4	.0
Total fc at "A"	.576

This value is based on a clean luminaire with a lamp producing 20,500 lumens. As it is desired to express the footcandles in terms of fc. when the luminaire is at the end of the 6 month cleaning schedule and the lamp has aged to 70% of life and the correct lamp lumen factor is used so that the lowest value will be obtained we will apply the factors which will produce the desired maintained footcandle value. The correct lamp lumens are 19,667 which produces a factor of 19,667/20,500 = .96, LDD factor .95 and LLD factor .76. Total fc. at point A is fc at "A" x LL x LDD x LLD = FCM or .576 x .96 x .95 x .76 = 399 FCM.

(3) To determine the contribution of each luminaire to point "B".

(a) Luminaire No. 1
Locate point "B" - Transverse to "House Side" 5'/30' = 0.16
Longitudinal along road 249/30 = 8.3
Point "B" for these figures if off the chart.

(b) Luminaire No. 2
Locate point "B" - Transverse to H.S. $= \frac{50-5}{30} = \frac{45}{30} = 1.5$

Longitudinal along road 83'/30' = 2.766

Point "B" for No. 2 is 1.5 across the street side and 2.766 longitudinally and will be found between .10 and .16 which we will estimate as .15 fc.

(c) Luminaire No. 3

Locate Point "B" - Transverse H.S. = 5/30 = .16
Longitudinally along road = 83/30 = 2.766

Point "B" for No. 3 is .16 behind unit and left 2.766 which is found on the .4 fc line.

(d) Luminaire No. 4

Locate Point "B" - Transverse to H.S. $\frac{50-5}{30} = \frac{45}{30} = 1.5$

Longitudinal along road 240/30 = 8.3
Point "B" from these figures for No. 4 is off of the chart.

(e) Total footcandle values for all luminaires at point "B" is

Luminaire No. 1	0
Luminaire No. 2	.15 fc
Luminaire No. 3	.40 fc
Luminaire No. 4	0
Total fc. at "B"	.55

This value is of course an initial value. Using the factors of .96 for the lamp lumen factor, .95 for LDD and .76 for LLD we come up with .55 x .96 x .95 x .76 = .38 fc maintained.

(4) In a like manner the fc values are determined for point "C"

(a) Luminaires Nos. 1 and 4. From previous calculations under paragraph 3a and 3d we found that the longitudinal distance produced a point off the chart.

(b) Luminaires No. 2 and 3.
Locate point "C" - Transverse to HS

$$\frac{W/2 - OH}{MH} = \frac{50/2 - 5}{30} = \frac{20}{30} = .667$$

Longitudinal along road = 83/30 = 2.766

Point "C" for units 2 and 3 are .667 across street and 2.766 to the left. This point will be found between isofootcandle lines .4 and .63 which is about .56 fc The total then for this point "C" is 2 x .56 for 1.12 fc as luminaires No. 1 and 4 do not project any values to this point.

(c) The maintained value is obtained by using the factors of .96 for the variation in lamp lumen output, .95 for LDD, .76 for LLD. 1.12 fc x .96 x .96 x .76 = .78 fc maintained.

7. UNIFORMITY RATIOS

a. The uniformity of illumination requirements of paragraph 3.5, pages 14 and 15 of the American Standard Practice should be determined by computing the ratio:

$$\frac{\text{Minimum Horizontal Footcandles}}{\text{Average Horizontal Footcandles}}$$

It can also be expressed as the ratio:

$$\frac{\text{Average Horizontal Footcandles}}{\text{Minimum Horizontal Footcandles}}$$

b. Sufficient number of specific points over the roadway should be checked, as outlined in paragraph 8.6, to ascertain accurately the location and value of the minimum point. If the values at points "A", "B" AND "C", as shown in Fig. 8-1, are first determined, the approximate location of the minimum point may be located or its location will become more apparent.

c. The average illumination on the roadway pavement should be computed as in paragraph 5.a taking care to use the same lamp output and other conditions as used in determining the minimum illumination value.

d. Some manufacturers are now supplying curves of the type shown in Fig. 8-7a and 8-7b, which indicate the average to minimum maintained footcandle ratio for a particular arrangement of luminaires as roadway width and spacing are varied. (These are computed for the lowest value on the roadway area, not necessarily for points "A", "B" and "C".) Such curves are a convenient aid to determine the average to minimum illumination ratios for a given spacing and roadway width, or to determine the possible spacing for a required uniformity ratio. They also can be used to determine the relationship between average illumination for spacing and roadway width. Each different combination of luminaires, lamp type and arrangement of luminaires will produce a different set of these characteristic curves.

e. In the calculations the maintained footcandles at point "A" is .399 (6.c (2) (d); at point "B" the value is .38 (6.c (3e) and at point "C" the value is .78 (6.c (4 ppg. c). From these data we can assume that .38 at point "B" will be the minimum, other points between "A" and "B" could be checked if necessary. Using the value of .38 fc we have a ratio of .9 fc average maintained to .38 fc minimum maintained or a ratio of 2.37 to 1.

8. USE OF CORRECTION FACTOR FOR OTHER MOUNTING HEIGHTS

a. To use these data for a mounting height of other than the one for which the isofootcandle curves are made, it is necessary to find the correct new location on the diagram as well as apply a correction factor to the footcandle values at the new location.

b. The following items will change, Coefficient of Utilization, footcandle values and point locations. The coefficient of utilization and point locations are on a percentage ratio. Footcandles have to be changed in relationship to the mounting height. A table adjacent to the diagram will give a factor for changing the footcandle values in relation to the given mounting height (30'). In other words the footcandle values at a certain point will be multiplied by the factor for the new mounting height. This point will have been located in regard to the new mounting height. The coefficient of utilization factors are located as well in regard to the new mounting height.

c. To illustrate the problem for a lower mounting height, we will use the data used previously except the mounting height will be 25'.

Roadway width (W)	50'
Mounting Height (MH)	25'
Over Hang (OH)	5'
Rated Lamp Lumens (RLL)	19,667
Test Lamp Lumens (TLL)	20,500
Lamp Lumen Correction factor (LLC)	
· 19,667/20,500	.96
Luminaire Dirt Depreciation (LDD)	.95
Required Average Footcandles Maintained	.9

To find coefficient of utilization

Street side = $\frac{50' - 5'}{25'} = \frac{45}{25}$ = 1.8 ratio .509 C/U Fig. 8-3

House side = $\frac{5'}{25'}$ = .2 ratio = .058 C/U Fig. 8-3

Coefficient of utilization = .509 + .058 = 0.567

To find Spacing (S)

Spacing = $\frac{19,667 \times .95 \times .76 \times .567}{50 \times .9} = \frac{8051}{45}$ = 178.9' (178)

In the problem where a 30' mounting height was used the spacing was 167.2'. In our calculations we used 166' as it was the next lower even number. In the following problem we will use 178'.

d. The footcandle values at points "A", "B" and "C" are determined in a similar manner, in this problem, taking into consideration the new mounting height of 25'.

Point "A" Luminaires Nos. 1 & 3
Transverse to H.S. 5/25 = .2
Long. along road 178'/25' = 7.12
This point is off the chart and has no value
Luminaire no. 2
Transverse S.S. 45/25 = 1.8
Long. along road 0
This point is between .25 and .4 estimated at .30 fc.
Luminaire No. 4
Transverse S.S. 45/25 = 1.8
Long. along road = 356/25 = 14.25 which is off the chart.

The total fc produced at point "A" is .30 from luminaire No. 2. These of course are initial. To obtain the maintained value for a 25' mounting the following factors are applied. LDD .95, LLD .76 Lumen correction factor (LCF) .96 and 1.44 which is the mounting height correction factor found in the table Fig. 8-2. So we have .30 x .95 x .76 x .96 x 1.44 = .299 fc maintained.

The footcandles at Point "B" are as follows, Luminaire no. 1 having a longitudinal distance along the road of 267'/25' = 10.68 is off the chart for no value, Luminaire no. 2 with factors of 45/25 = 1.8 and 89/25 = 3.56 produces a value of .075, Luminaire no. 3 with ratios of 5/25 = .2 and 89/25 = 3.56 produces a value of .14. Point "B" for luminaire no. 4 is off the chart for no value. The total then for point "B" is .075 + .14 totaling .215 fc. Applying the factors to get the final maintained value we use the same factors as in the above paragraph or .215 x .95 x .76 x .96 x 1.44 = .215.

The footcandles at Point "C":

Luminaire Nos. 1 & 4 Trans. = 20/25 = .8, Long. 267/25 = 10.68 off chart. Luminaire no. 2 & 3 Trans. = .8, Long.= 3.56 = .25 x 2 = .5 fc. The total of .5 fc times the various factors produces a .499 fc mtd.

e. The problem of solving for a greater mounting height is solved in a similar manner. For a 35' mounting height we would have the following data: (Only MH has been changed from previous problems).

Coefficient of utilization "Street side" ratio = $\frac{50-5}{35} = \frac{45}{35}$ = 1.286

Coefficient of Util. house side = 5/35 = .1429, c.u. is .042

Total coef. of util. = .457 + .042 = .499

Substituting in Spacing formula:

Spacing (S) = $\frac{19{,}667 \times .499 \times .95 \times .76}{50 \times .9} = \frac{7085}{45}$ = 157.5' (158)

Footcandles at Point "A"
Luminaire No. 1 & 3 Trans. 5' MS. = 5/35 = .1429
Long. = 158/35 = 4.51
At this point each luminaire produces .032 fc. totaling .064

Luminaire No. 2 Trans. 45' s.s. 45/35 = 1.286
Long. 0
This luminaire produces .75 fc at point "A"
Luminaire No. 4 Trans. 45' s.s. 45/35 = 1.286
Long. 316/36 = 9.03 (no value)

The total at point "A" is .032 from no. 1, + .75 from no. 2 + .032 from no. 3 and .0 from no. 4 for a total of .814. To get the maintained fc at 35 feet mounting the following factors are applied:

Mounting height .74, LDD .95, LLD .76, and LCF .96
.814 x .74 x .95 x .76 x .96 = .417 fc maintained.

The four luminaires project the following values to Point "B"

Luminaire No. 1	No value
No. 2	.25
No. 3	.58
No. 4	.012
Total	.842

.842 x .74 x .95 x .76 x .96 = .432 fc mtd.

The four luminaires project the following values to point "C"
Luminaire No. 1 & 4 No value (less than .01 fc)
Luminaire No. 2 & 3 .72 fc each or 1.44 fc for both units
1.44 fc x .74 x .95 x .76 x .96 = .739 fc maintained.

The three sets of data on the same fixture under the same conditions except mounting height provide information which can be compared. This comparison will then bring in various factors which should be considered, such as economics, quality, glare and other factors.

The following gives the accumulated data.

sphere). The right hand portion of Fig. 8-5 shows five groups of typical area atmospheres.

e. Area Description - A complete description is required for each area to be lighted. This should include: the physical characteristics such as roadway width, curvatures, grade, obstructions, (trees) and border areas.

f. Selection of Luminaire - Selecting the specific luminaire requires the almost simultaneous consideration of many factors. Selection of the type of luminaire for a given roadway depends upon the requirements and conditions found above, such as dimensions of roadway and atmospheric conditions and such factors (whose relative importance will vary from project to project) as: mounting height; luminaire dirt depreciation; lamp choice; maintenance considerations, including cleaning and lamp replacement; luminaire and installation appearance; color of light; lighting and relighting time; cost of equipment; etc. All factors should be examined in detail first, then reviewed so that the proper weight will be given to everything that might effect the luminaire selection.

10. LIGHT LOSSES - NOT RECOVERABLE

Once the facts in 9 have been appraised and the luminaire is chosen, the factors that cause loss of light should be studied and evaluated. The factors immediately following are difficult to appraise and are usually of little significance. However, if it is known that a peculiar condition does exist that can be evaluated it should be included in the calculations of the maintained footcandle level. In any case, the designer should be cognizant of all the factors that can diminish the planned output of the lighting system, and evaluate where necessary and practical.

a. Luminaire Ambient Temperature - The effect of ambient temperature on the output of some fluorescent luminaires may be considerable. To apply a factor for light loss due to ambient temperature, the designer needs to know the highest and lowest temperature expected and to have data showing if there are variations in the light output with changes in ambient temperature for the specified luminaire to be used.

b. Voltage to Luminaire - In-service voltage is difficult to predict, but high or low voltage at the luminaire will affect the output of most luminaires.

c. Ballast Performance - If the ballast used in the luminaire does not provide rated watts to the lamp, the light output will differ proportionately, and a ballast factor should be applied. The manufacturer should be consulted for necessary factors.

d. Luminaire Component Depreciation - Depreciation of the light controlling elements of a luminaire, resulting from deterioration of metal, glass, plastic, paint and other reflector finishes, will result in reduced light output. However, because of the complex relationship between light controlling elements of different materials it is difficult to evaluate losses due to deterioration. Even luminaires with a single light controlling element of one type of material will show losses due to the type of atmosphere in the area. No standard factors have yet been developed to cover depreciation of components. (See Fig. 11-2)

e. Changes in Physical Surround - The designer should be aware of planned changes in the roadway conditions that may alter the effectiveness of the lighting system; such things as road widening, curbing, resurfacing, tree planting, building construction or demolishing, or anything that would change the nature of the road.

f. Burn-Outs - Unreplaced burned-out lamps will affect the quality of the lighting system. It would be ironical to incorporate a factor in the design to take care of burn-outs. Instead, a good maintenance program, including group replacement of lamps based on lamp mortality statistics, and spot replacement when necessary, should be adopted. The designer should make his client aware of the necessity for a good maintenance program.

11. LIGHT LOSSES - RECOVERABLE

a. Lamp Lumen Depreciation - Information about lamp lumen depreciation is available from manufacturers' tables and graphs for lumen depreciation and mortality of the chosen lamp. Rated average life should be determined for the specific hours per start; it should be known when burn-outs will begin in the lamp life cycle. From these facts, a practical group relamping cycle will be established and then, based on the hours elapsed to lamp removal, the specific Lamp Lumen Depreciation (LLD) factor can be determined. Consult manufacturers data or the IES Lighting Handbook, 5th Edition for LLD factors.

This factor has already been used in the problems and solutions presented. The tables for the various lamp types are found on page 5-11, Fig. 5-5 for incandescent lamps; page 5-31, Fig. 5-24 for mercury lamps; page 5-32 Fig. 5-28, for metal halide lamps. The loss for sodium is reported to run from 5 to 10% at end of lamp life according to the latest information and depending on the manufacturer contacted.

b. Luminaire Dirt Depreciation - The accumulation of dirt on luminaires results in a loss in light output, and therefore a loss on the roadway. This loss is known as the luminaire dirt depreciation (LDD) factor and is determined as follows:

(1) Determine the dirt category (very clean, clean, average, dirty or very dirty) from 10.d and Fig. 8-5 and Fig. 11-2.

(2) From the appropriate dirt condition curve in Fig. 8-4 and the proper elapsed time in years of the planned cleaning cycle, the LDD factor is found. The proper elapsed time for cleaning is determined from section 10.f and 11.a.

12. TOTAL LIGHT LOSS FACTOR - The total Light Loss factor is simply the product of multiplying all contributing factors described above. Where factors are not known, or applicable, they may be omitted. At this point, if it is found that the total light loss factor is excessive it may be desirable to reselect the luminaire.

In general it is good practice to solve a great many problems using as many different possibilities as possible so that the computations will become quite familiar. For that reason the following problems have been attached.

Appendix "A" of American National Standard Practice for Roadway Lighting should be given very careful study for many special considerations in regard to roadway complexities.

General information: If the minimum illumination of any point on the roadway is less than 1/3 the average illumination it is possible that,

1. The mounting height is too low.
2. Another light distribution pattern (if available) might be used to advantage.
3. A different overhang might be used.
4. Spacing is too great.
5. The lamp-luminaire combination has too great a lumen output for the average illumination level desired.

PROBLEMS

No. 1 Apply the new design parameters to Fig. 8-1

Roadway width (W)	44'
Mounting Height (MH)	30'
Overhang (OH)	4'
Luminaire Fig. 8-8 (McG-Ed. No. E359-280)	
ANSI/IES Type: III, Medium, Cut-off	
Lamp H33-1CD/E (Now H33Cd-400, bulb E-37)	
Test lamp rated lumens 20,500	
Commercial lamp rated 19,667 lumens (horizontal)	
Required maintained footcandles	2.0
Atmosphere - surrounds CLEAN	
Cleaning schedule - months	6
Lamp replacement 83% life	20,000 hours

a. Determine luminaire dirt depreciation (LDD) ________

b. Determine lamp lumen depreciation (LLD) ________

c. Determine commercial lamp lumen/test lamp lumen factor ________

d. Determine Coefficient of Utilization (CU) ________

e. Determine staggered spacing for 2 fc avg. mtd ________

f. Determine maintained fc to minimum fc ratio ________

Solution No. 1

a. Refer to Fig. 8.5 for a 6 months line draw a line vertically half-way between the 0 and 1 year line. Where this line intersects the clean line is just about 97%.

b. To determine LLD refer to Fig. 5-24, page 5- . Draw a line from mid point of "H33" to 100%, where this line crosses vertical line for 20,000 hours it appears that the lumen value is about 70%.

c. According to the tables page 5-33 a 400 watt H33CD-400 lamp produces approx. 19,667 lumens in a horizontal position. This value divided by the test lamp lumens gives us (19,667/20,500) a 96% factor.

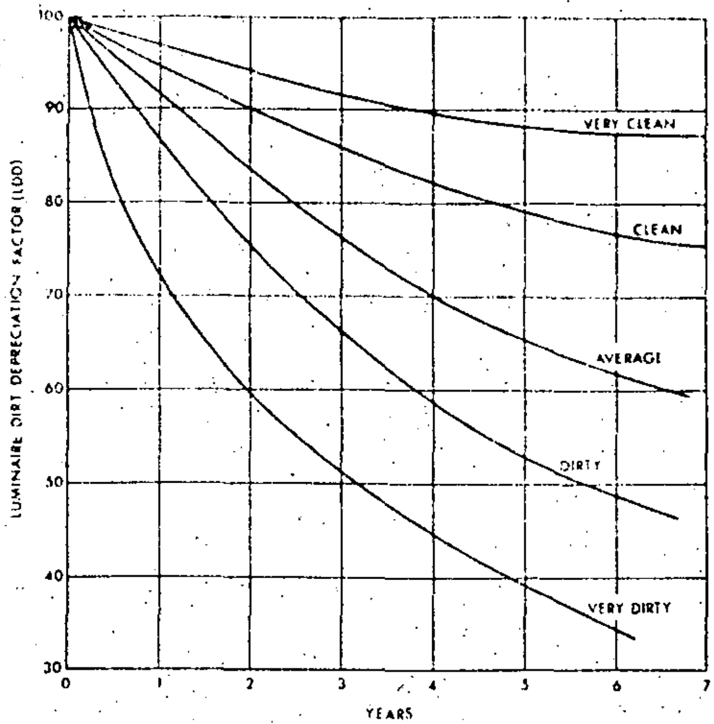
d. To determine the CU factor refer to Fig. 8-8.

CU- Street Side (S.S.) $\frac{W-OH}{MH} = \frac{44' - 4'}{30'} = \frac{40}{30} = 1.333$

Draw line from 1.333 Street Side to intersect S.S. curve at .453

CU- House Side (H.S.) $\frac{OH}{MH} = \frac{4'}{30'} = .1333$ ratio

Draw line from .1333 to intersection of H.S. curve at .057
Total CU for H.S. and S.S. is .057 + .453 = .51



SELECT APPROPRIATE DIRT CURVE FROM KIND OF CONDITIONS DESCRIBED BELOW FOR TYPE LUMINAIRE TO BE USED

Areas—Clean—Pavement—Grass. No open loose ground. Slow traffic. Little or no adhesive qualities in atmosphere. Most rural areas, residential roadways, slow traffic, no trucks.

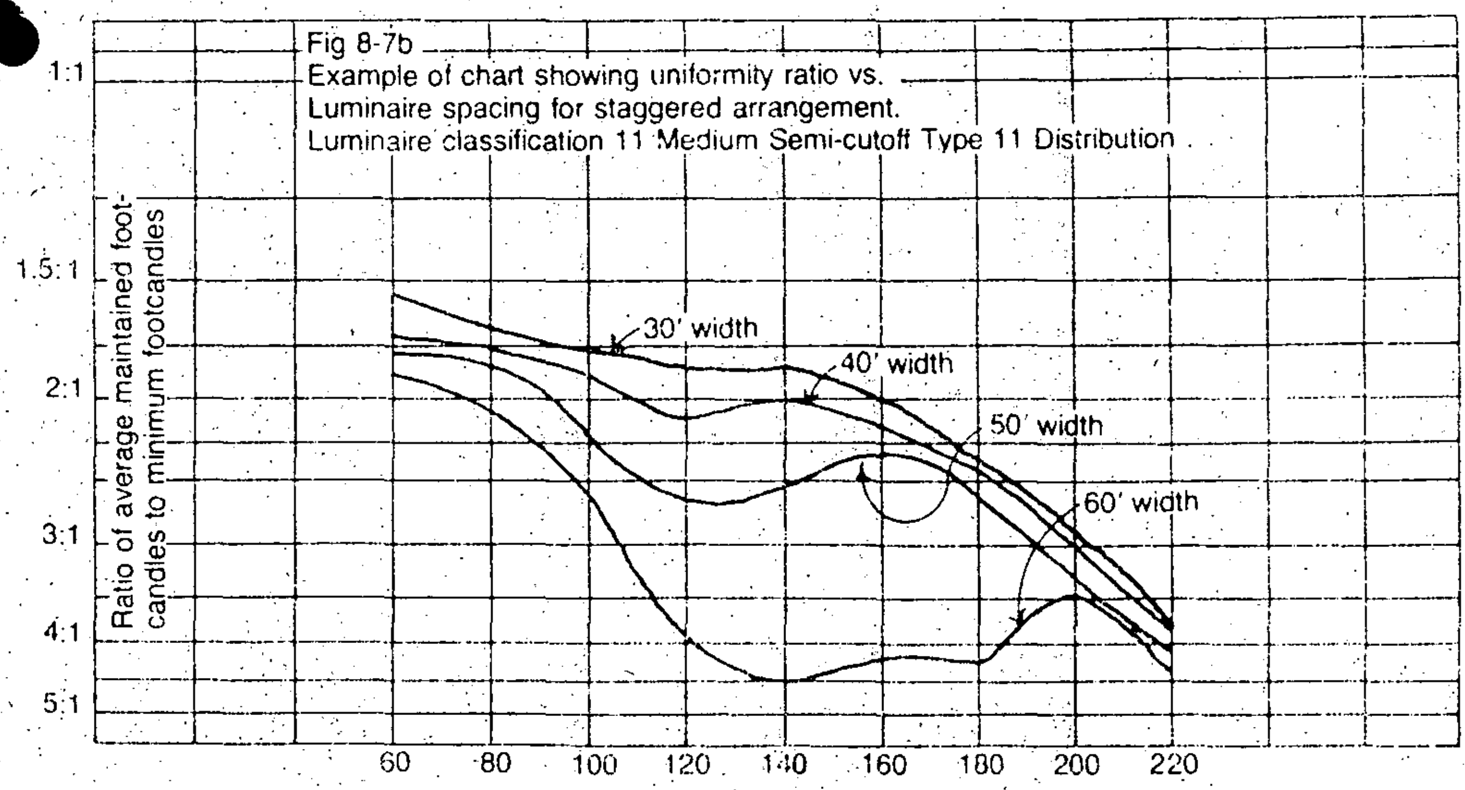
Areas—As above except average car and truck traffic. Downtown open areas. Intermediate and freeways in open areas.

Areas—As above but slightly more exposure. Residential, intermediate, local minor roads. Few trucks.

Areas—Confined. Greater than average. Cars and trucks expressway, freeways. Downtown, major, Adhesive dirt.

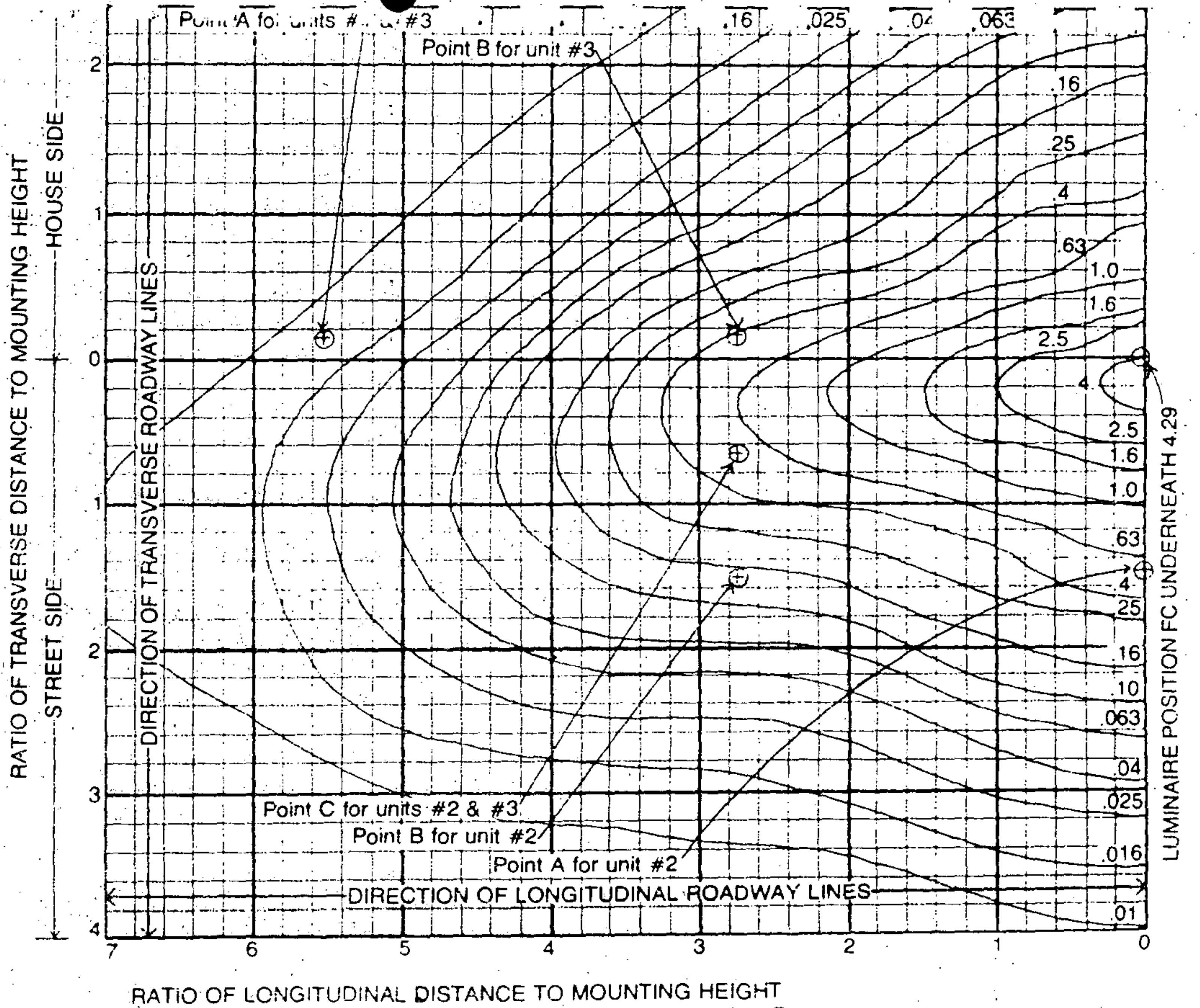
Ind./Comm. Areas. Trucks, buses, adhesive dirt, confined areas, heavy traffic.

Fig. 8-5. This chart is useful for estimating roadway luminaire dirt depreciation factors (LDD)



MOUNTING HEIGHT FEET	FACTOR
20	2.25
21	2.04
22	1.86
23	1.70
24	1.56
25	1.44
26	1.33
27	1.24
28	1.15
29	1.07
30	1.0
31	0.94
32	0.88
33	0.83
34	0.78
35	0.74

Fig.8-6 Enlarged section of Fig. 8-2 for isofootcandle curves only. (For easier computations).



Footcandle data is based on a luminaire mounting height of 30'. For other mounting heights multiply the values of footcandles shown by the factors in the table.

(Fig. 8-2) Maintained footcandle values are calculated for a 400-watt clear mercury lamp with a lumen output of 19,667 (horizontal), a luminaire dirt depreciation (L.D.D.) of 95% and lamp lumen depreciation (L.L.D.) of 76%. Mounting height 30' Overhang (OH) 5', Roadway width varies "W".

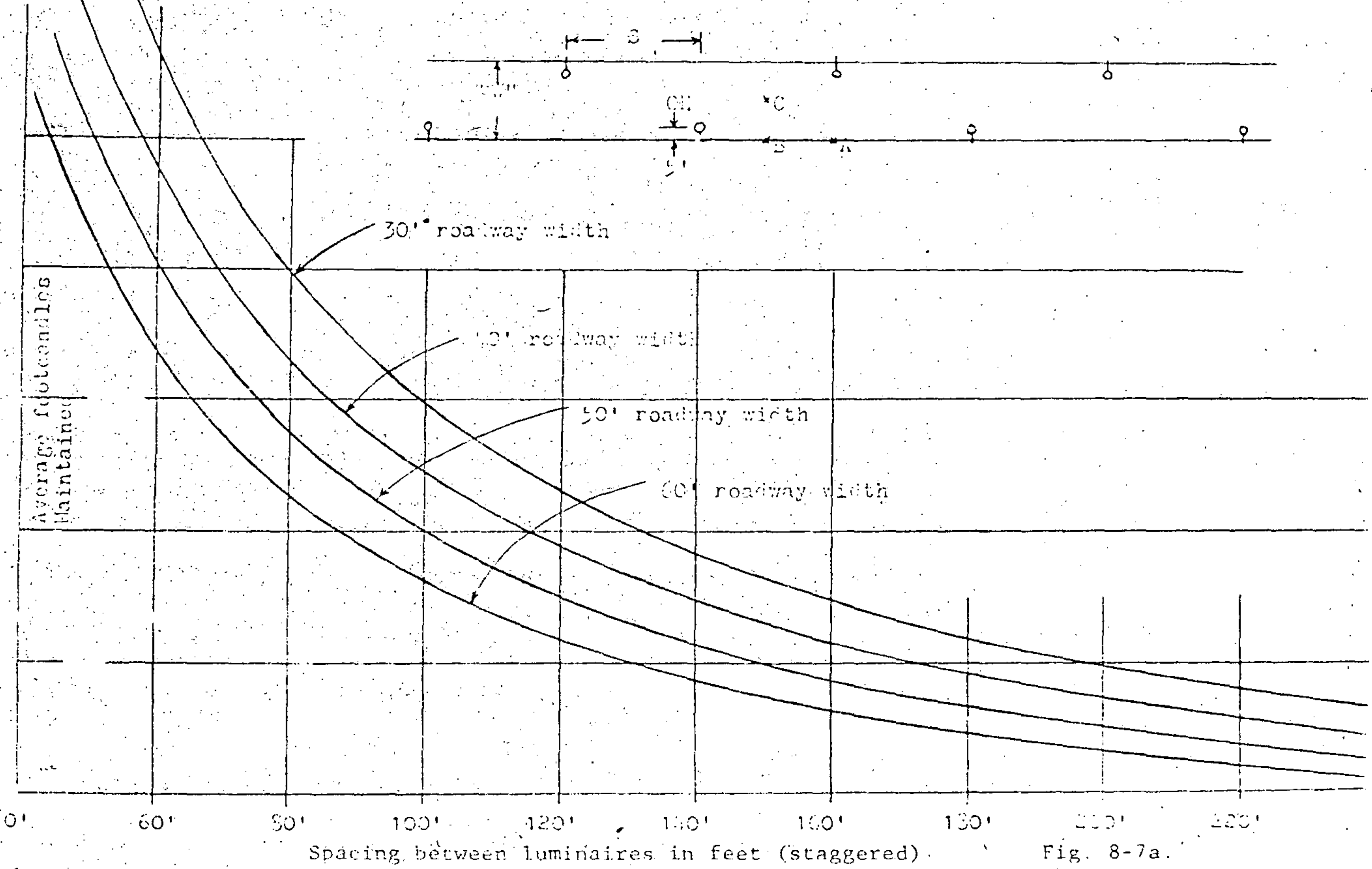


Fig. 8-7a.

PHOTOMETRIC DATA

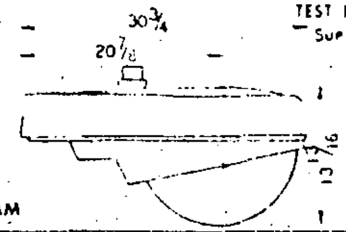
Luminaire
Refractor Cat. No. L0330X1
Socket Setting 4C
Lamp H33-1CD/E, 400 watts, 20,500 lumens
E-37, Clear

ANSI-IES Type I-I, Medium, Cut-Off

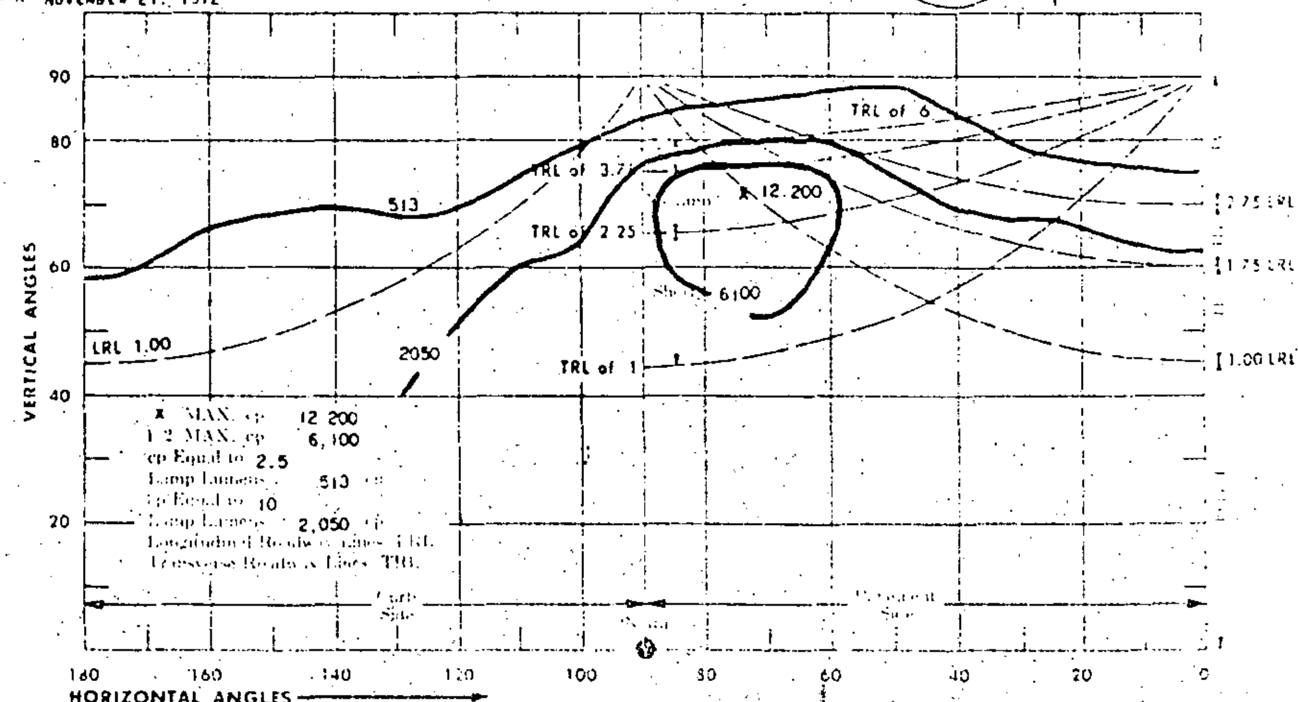
Approved By

Date November 21, 1972

TEST No. E359-280
Supersedes E359-225



ISOCANDELA DIAGRAM



DASHED CURVES SHOW LUMEN UTILIZATION (IN %)

3.64	
Mounting Height	Multiplier
25	1.44
26	1.33
27	1.24
28	1.15
29	1.07
30	1.00
31	0.94
32	0.88
33	0.83
34	0.78
35	0.74

Luminaire Efficiency

	56.1	20.9
	1.7	.7
	79.4	

Test Mounting 25

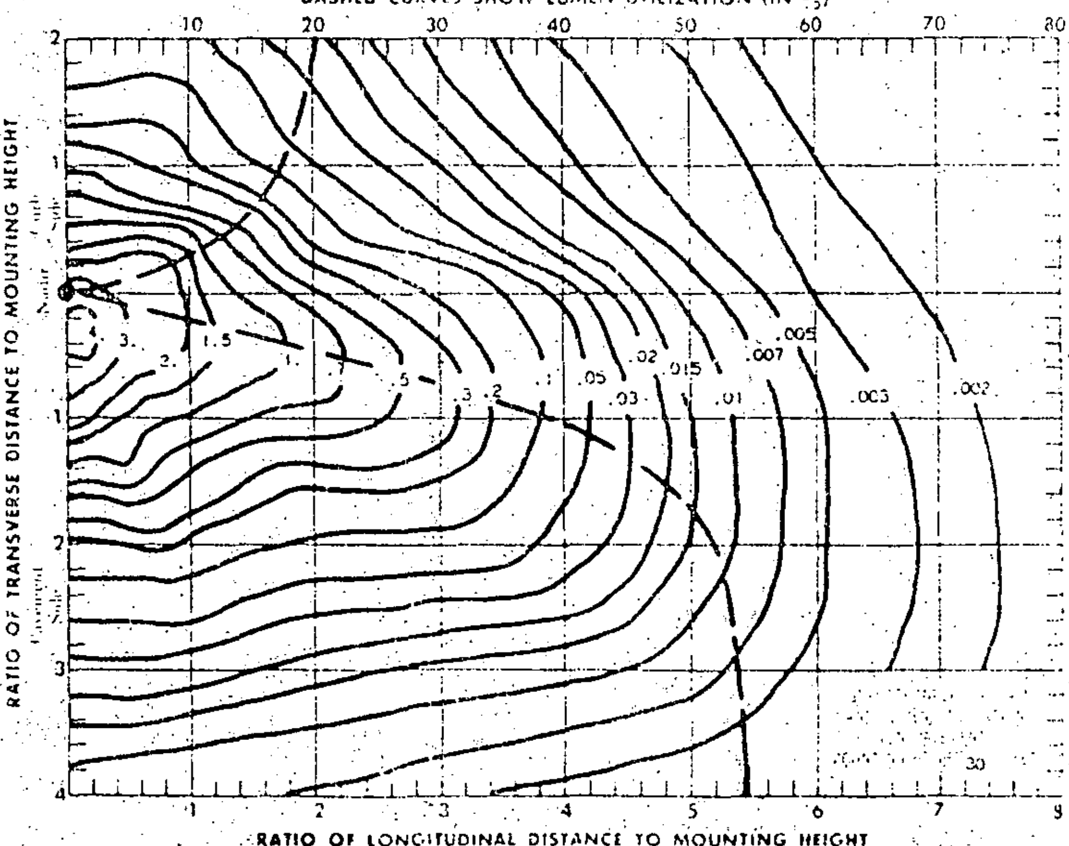


Fig. 8-8.

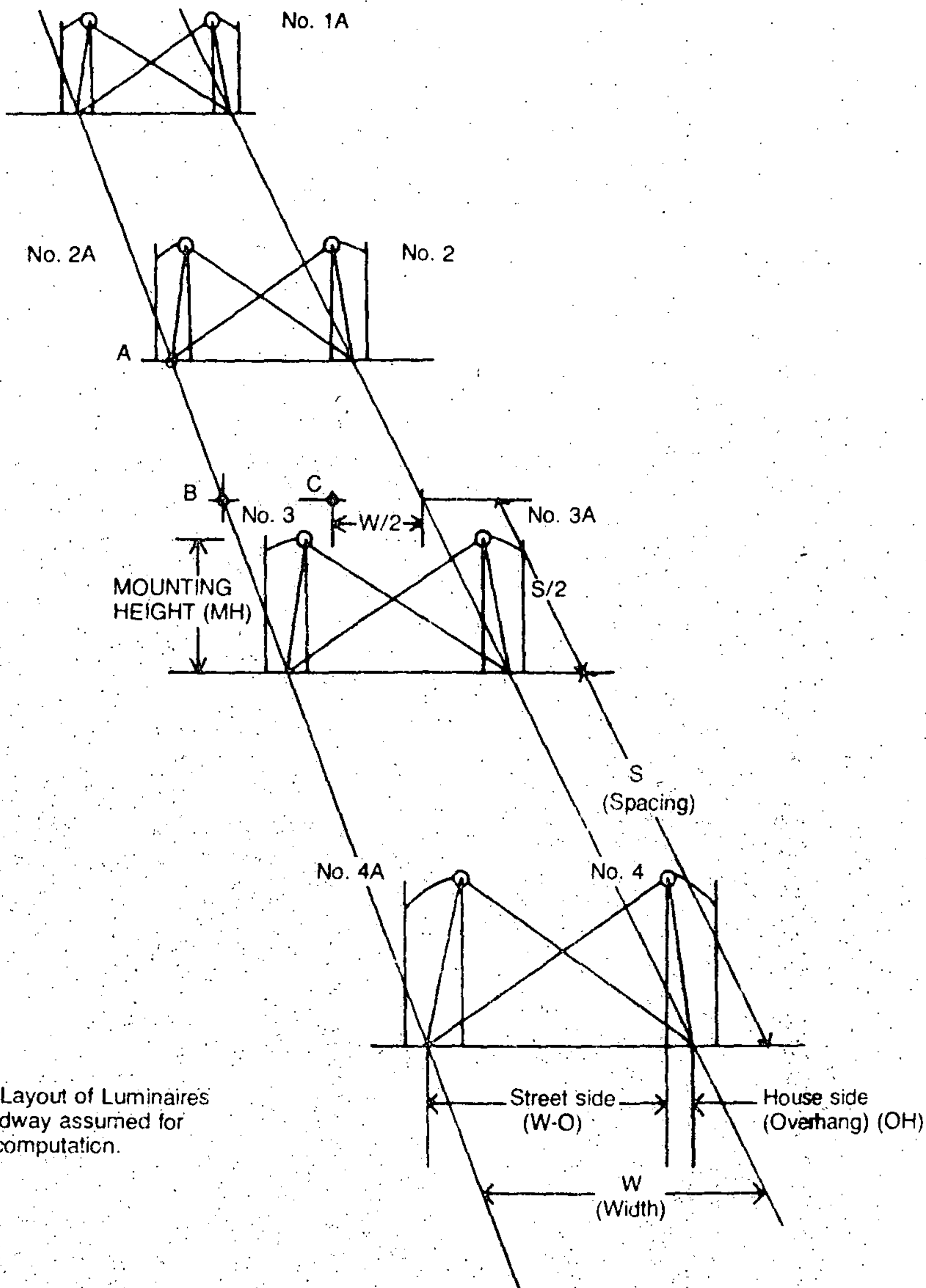


Fig 8-9 Layout of Luminaires and roadway assumed for typical computation.

e. Staggered spacing using formula 5c page 8-7

Staggered spacing = $\frac{19,667 \times .51 \times .97 \times .70}{44 \times 2} = \frac{6810}{88}$ = 77.39' (76')

f. To determine average fc. to minimum fc ratio
Determine fc at point "A" luminaires no. 1 & 3
Transverse H.S. 4/30 = .1333) = .21 x 2 = .42 fc
Long. along R. 76/30 = 2.533)

Luminaire no. 2
Transverse S.S. 40/30 = 1.333) = 1.10 fc
Long along R. = 0

Luminaire No. 4
Transverse S.S. 40/30 = 1.333) = .015
Long. along R. 152/30 = 5.0666)
Total for No. 1, No. 2, No. 3
& No. 4 1.535
Maintained FC = 1.535 x .97 x .70 x .96 = 1.0 fc maintained

Determine fc. at point "B" Luminaire No. 1
Trans. H.S. 4/30 = .1333, Long. 114/30 = 3.8 .04 fc
No. 2, Trans. S.S. 40/30 = 1.35, Long. 38/30 = 1.266 .48 fc
No. 3, Trans. H.S. 4/30 = .135, Long. 38/30 = 1.266 1.00 fc
No. 4, Trans. S.S. 40/30 = 1.53, Long. 114/30 = 3.8 .085 fc
Total footcandles at point 1.605 fc

Determine fc. at Point "C" Luminaire 1 and 4
Trans. S.S. 20/30 = .667, Long. 114/30 = 3.8 = .11 fc x 2 = .22fc
No. 2 & 3 Trans. S.S. 20/30 = .667 Long. 38/30 = 1.266
= 1.15 fc x 2 = 2.30
Total footacndles at point "C" 2.52 fc

Maintained fc at point "B" = 1.605 x .97 x .70 x .96 = 1.05
Maintained fc at point "C" = 2.52 x .97 x .70 x .96 = 1.64 fc
Point "A" is low and produces a ratio of 2 avg. to 1 or a
2 to 1 ratio.

Problem No. 2

Using the same parameters as for problem no. 1 change the pole locations to opposite spacing for a 2 fc avg. maintained. See Fig. 8-9.

a. Determine spacing
   The values for coefficient of utilization, LDD, LLD, ITL, will remain the same.

b. Determine maintained fc for points "A" _____, "B" ______ and "C" ______.

c. Determine ratio for average maintained to minimum maintained ________.

Problem No. 3

Determine data for the following situation:

Roadway Width (W)	60'
Mounting Height (MH)	30'
Overhang (OH)	4'
Luminaire-See Fig. 8-8 (Opposite spacing)	
LDD	97%
LLD	70%
ITL	96%
Average maintained footcandles to be provided	2 fc

a. Determine Coefficient of Utilization (CU) ______
b. Determine opposite spacing ______
c. Determine maintained fc. at points "A", "B" and "C" ______ ______ ______
d. Determine average to minimum ratio.

Problem No. 4

Photometric Data - see Fig. 8-2, 8-3 and 8-6.
Luminaire, Medium, Semi-cutoff type II
Lamp; 400 watt clear mercury - H33-1CD (Ansi No. H33CD-400)
Test Lamp Lumens 20,500; Installed lamp lumens 19,667 - horizontal

Lamp Lumen Depreciation (LLD)	78%
Roadway Width (W)	42'
Overhang (OH)	6'
Required maintained fc	2
Luminaire Dirt Depreciation (LDD)	97%
Mounting Height	34'
Mounting Height factor (see table on data sheet)	78%
Installed - Test Lamp factor (ITL)	96%

a. Determine Utilization factor (CU)
b. Determine staggered pole spacing
c. Determine footcandle values maintained at Points "A", "B" and "C".
d. Determine average to minimum ratio.

Problem No. 5

The previous problem was on a clear mercury lamp, this one will be on a phosphor coated lamp of the same wattage, and will produce a different type of distribution.

Photometric Data - see Fig. 8-10
Luminaire, IES Type III Short, Cutoff (1972)
Lamp; 400 watt Phosphor coated H33GL-400/DX
Test Lamp Lumens 22,000
Installed Lamp Lumens, initial 21,780

Installed - Test lamp factor	.99
LLD	78%
Roadway width (W)	42'
Overhang (0)	6'
Mounting Height	34'
Mounting Height Factor	74%
LDD	97%
Footcandles maintained	2

a. Determine Coefficient of Utilization (CU)
b. Determine staggered pole spacing
c. Determine footcandles maintained at points "A", "B" and "C"
d. Determine average to minimum ratio

Problem No. 6

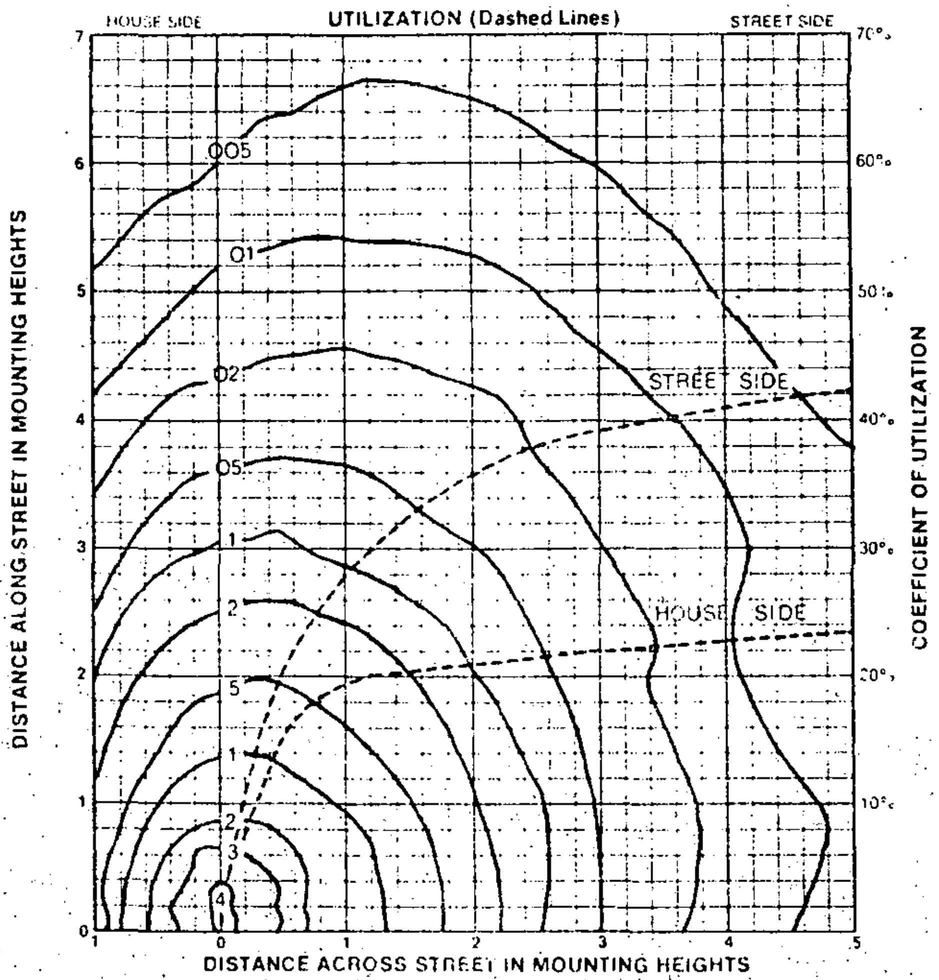
This problem has the same physical perameters as the two previous problems. The change is substituting a 400 watt sodium lamp fixture.

Photometric Data - See Fig. 8-11
Luminaire - IES type IV, medium, semi-cutoff
Lamp: LU-400 E-18

Test Lamp Lumens	42,000
Rated Lamp Lumens	50,000
Installed - test lamp lumen factor	1.19
LLD	.90%
Roadway Width (W)	42'
Overhang (0)	6'
Mounting Height	34'
Mounting height factor	78%
LDD	97%
Footcandles maintained	2

PHOTOMETRIC REPORT

LAMP H33 IGL DX — WATTS 400 LCL 7 — VOLTS LUMENS 22000	LUMINAIRE: **HORIZONTAL** SERIES: 25 000 WATTAGE: 400
TEST NO 25-6 — DATE 11-16-72 BY T.J.S. — REVISION 00 APPROVED BY [signature]	SOCKET POS. DWN. & FWD. III SHORT CUTOFF (1972) IES TYPE: III SHORT SEMI CUTOFF (1963)



ISOFOOTCANDLE AND UTILIZATION CURVES

TEST DISTANCE 30 FT.

Footcandle data is based on a luminaire mounting height of 30 feet. For other mounting heights, multiply the values of footcandles shown by the following table. The utilization curve (dashed) is correct for all mounting heights and does not require correction.

Mounting Ht.—Ft.	10	12	14	16	18	20	25	30	35	40	45	50	60	70
FACTOR						2 2 5	1 4 4	1	7 4	56	4 4	36		

This report is based on test methods in accordance with [illegible] to the degree that the tested sample is representative and that test conditions are duplicated. Voltage and [illegible] affect field performance.

LIGHT FLUX VALUES
(Test Distance Shown Above)

	Lumens	Percent of Lamp
DOWNWARD STREET SIDE	9840	43.1
UPWARD STREET SIDE		
DOWNWARD HOUSE SIDE	5200	23.6
UPWARD HOUSE SIDE		
Total	14680	66.7 %

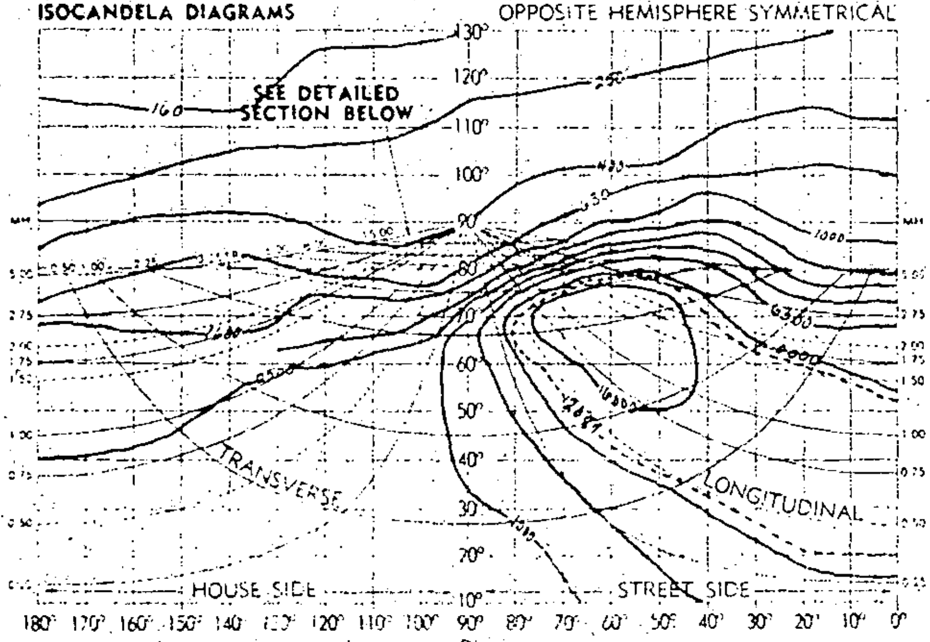
Values of isocandela, lumens and footcandles are based upon a lamp operated at 22000 lumens. If the data is desired for a different lumen rating, multiply all isocandela, lumen and footcandle values by the different lamp lumen rating divided by 22000.

Fig. 8-10.

PHOTOMETRIC DATA

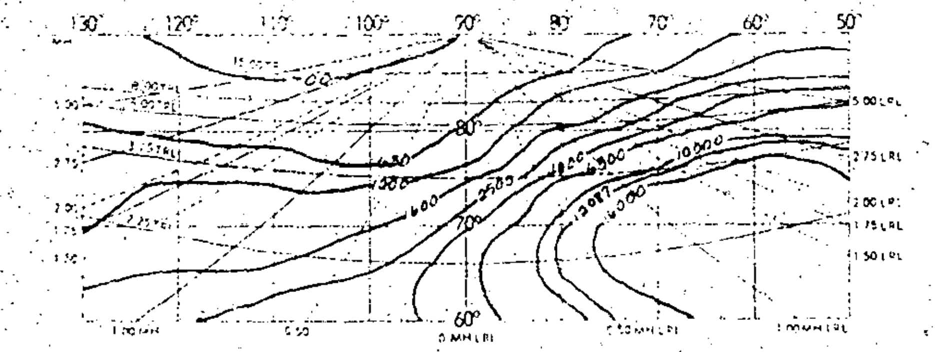
Fig. 8-11

ISOCANDELA DIAGRAMS OPPOSITE HEMISPHERE SYMMETRICAL



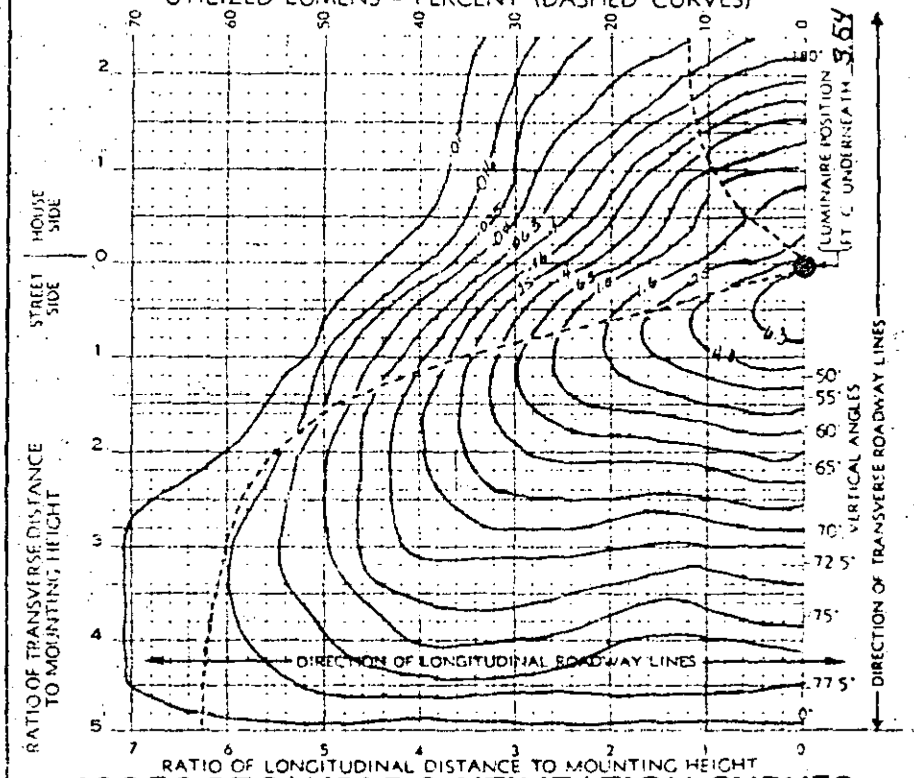
HALF MAX C.P. 12087
MAX C.P. 24174
NADIR C.P. 3186

MAX. CONE .79
MAX. VER. PLANE 62.5/74.5°



DETAILED SECTION: [illegible]

UTILIZED LUMENS - PERCENT (DASHED CURVES)



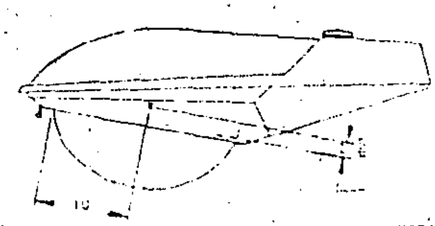
ISOFOOTCANDLE & UTILIZATION CURVES

FOOTCANDLE DATA IS BASED ON A LUMINAIRE MOUNTING HEIGHT OF 30 FEET. FOR OTHER MOUNTING HEIGHTS MULTIPLY THE VALUES OF FOOTCANDLES SHOWN BY THE FACTORS IN THE FOLLOWING TABLE. THE UTILIZATION CURVE (DASHED) IS CORRECT FOR ALL MOUNTING HEIGHTS AND DOES NOT REQUIRE CORRECTION.

MOUNTING HEIGHT - FT.	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
FACTOR	2.25	2.04	1.86	1.70	1.56	1.44	1.33	1.24	1.15	1.07	1	0.94	0.88	0.83	0.78	0.74

VALUES OF ISOCANDELA, LUMENS, AND FOOTCANDLES ARE BASED UPON A LAMP OPERATED AT [illegible] LUMENS. IF THE DATA IS DESIRED FOR A DIFFERENT LAMP LUMEN RATING, MULTIPLY ALL ISOCANDELA, LUMEN AND FOOTCANDLE VALUES BY THE RATIO DIFFERENT LAMP LUMEN RATING [illegible]

LIGHT FLUX VALUES	LUMENS	PERCENT OF LAMP
[illegible]	25620	64.5
[illegible]	[illegible]	[illegible]
[illegible]	5620	13.5
[illegible]	920	[illegible]
[illegible]	[illegible]	[illegible]



LUMINAIRE DESCRIPTION

Reflector 35-130301-11
Refractor #5[illegible]
[illegible] PDS. AL REAR/[illegible]

LAMP – 400 WATT
ASA No

[illegible]

NUMBER	REV. NO.
35-174846-00	03

a. Determine Coefficient of Utilization (CU)
b. Determine Staggered pole spacing
c. Determine footcandles maintained at points "A", "B" and "C"
d. Determine average to minimum ratio.

Problem No. 7

This problem is for a greater mounting height and a wider roadway.
Photometric Data Fig. 8-12
Luminaire IES type III, medium, semi-cutoff distribution.
Lamp: 1000 watts H36-15GV (Ansi - H36GV-1000) clear.

Test Lamp Lumens	57,000
Rated Lamp lumens initial horizontal	54,000
Installed- Test lamp lumen factor	94.74%
Roadway width (W) (Fig. 8-1)	72'
Overhang (OH)	5'
Mounting Height (MH)	50'
Footcandles maintained	2

a. Determine lamp lumen depreciation for 16,000 hours Fig. 5-24 page 5-
b. Determine luminaire dirt depreciation factor for a system of cleaning every 6 months in an avg. area.
c. Determine Coefficient of Utilization (CU)
d. Determine staggered spacing
e. Determine footcandles maintained at points "A", B" and "C"
f. Determine average to minimum ratio

Problem No. 8

To get a comparison of a clear and phosphor coated mercury lamp the same perameters will be used on this problem as in problem no. 7., except that a 1000 watt Deluxe white lamp will be used.
Photometric data - Fig. 8-13
Luminaire Ansi/IES Type IV, short, cut-off.
Lamp: 1000 watts H36-15GW/DX (Ansi -H36GW-1000/DX)

Test Lamp Lumens	63,000
Rated Lamp Lumens initial horizontal	60,000
Installed - Test lamp lumen factor	.9524
LLD	67%
LDD	95%
Roadway width (W)	72'
Overhang (O)	5'
Mounting Height (MH)	50'
Footcandles maintained	2
Mounting height factor	49%

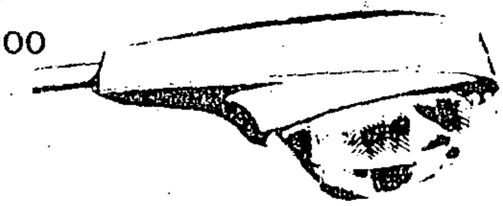
a. Determine Coefficient of Utilization
b. Determine staggered pole spacing
c. Determine maintained footcandles at points "A", "B" and "C"
d. Determine average to minimum ratio

PHOTOMETRIC REPORT

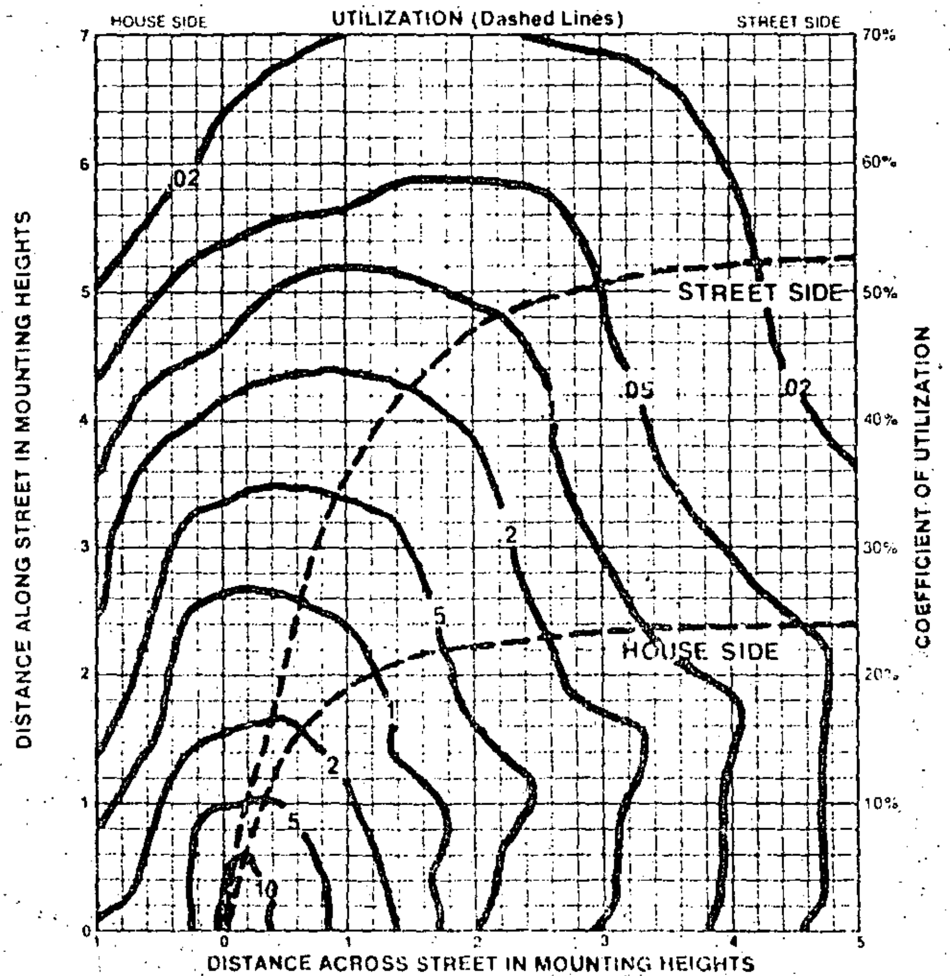
LAMP H36-15GV WATTS 1000
LCL 9.38 VOLTS ———
LUMENS 57000

TEST NO. 227-8 DATE 7-24-73
BY JSB REVISION 0
APPROVED BY [signature]

LUMINAIRE: "1000"
SERIES: 227
WATTAGE: 1000



IES TYPE: III MEDIUM SEMI-CUTOFF



ISOFOOTCANDLE AND UTILIZATION CURVES

TEST DISTANCE 25 FT.

Footcandle data is based on a luminaire mounting height of 30 feet. For other mounting heights, multiply the values of footcandles shown by the following table. The utilization curve (dashed) is correct for all mounting heights and does not require correction.

Mounting Ht.—Ft.	10	12	14	16	18	20	25	30	35	40	45	50	60	70
FACTOR	—	—	—	—	—	—	1.44	1.00	.74	.56	—	—	—	—

This report is based on test methods in accordance with IES Guides on Testing Procedures. Significance is limited to the degree that the tested sample is representative and that test conditions are duplicated. Voltage and characteristics of lamps and ballasts seriously affect field performance.

LIGHT FLUX VALUES
(Test Distance Shown Above)

	Lumens	Percent of Lamp
DOWNWARD STREET SIDE	31230	54.8
UPWARD STREET SIDE	———	———
DOWNWARD HOUSE SIDE	13897	24.4
UPWARD HOUSE SIDE	———	———
Total	45127	79.2 %

Values of isocandela, lumens, and footcandles are based upon a lamp operated at 57000 lumens. If the data is desired for a different lumen rating, multiply all isocandela, lumen, and footcandle values by the different lamp lumen rating divided by 57000

Fig. 8-12.

PHOTOMETRIC DATA

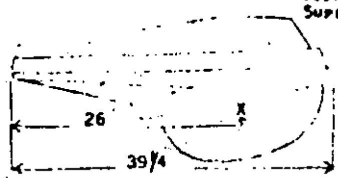
Luminaire
Refractor Cat. No. L088X1
Socket Setting A3
Lamp H36-15 GV/DX, 1000 Watts, 63,000 Lumens
BI-56, Deluxe White

ANSI IES Type IV, Short, Cut-off

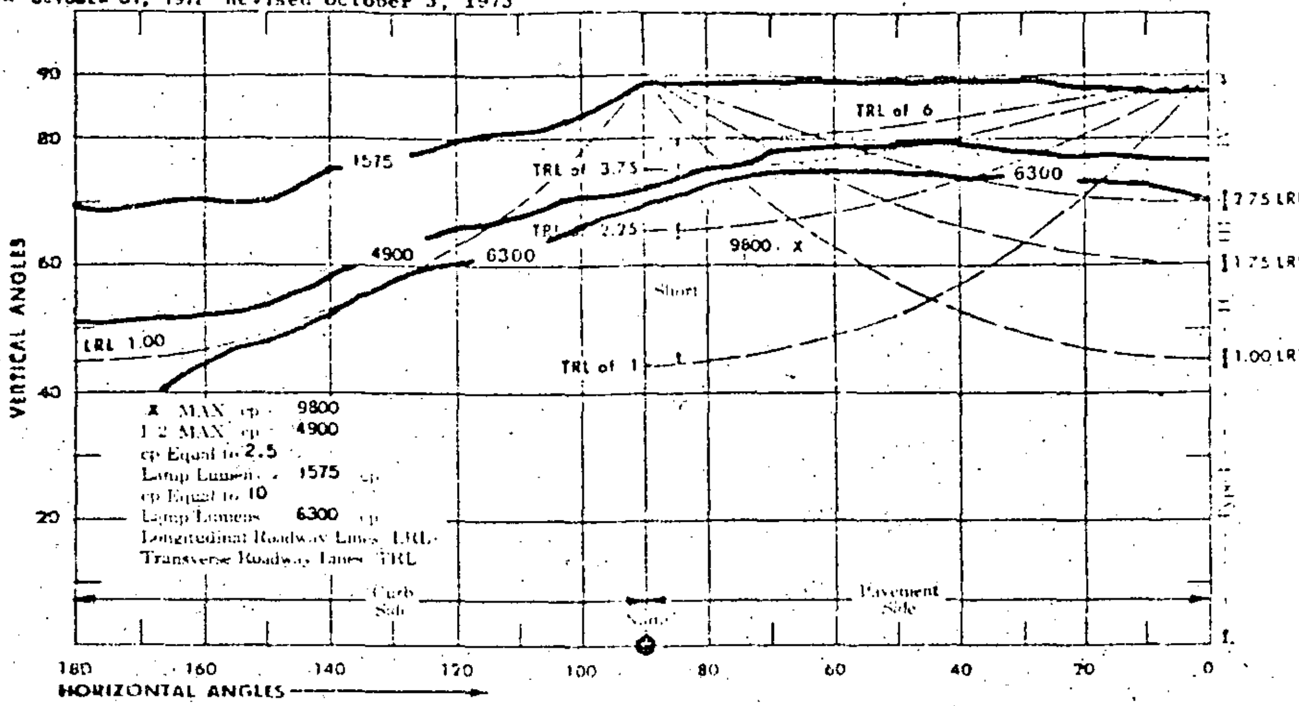
Approved By [signature]

Date October 31, 1972 Revised October 3, 1973

TEST No E373-51
Supersedes E373-15



ISOCANDELA DIAGRAM



5.55	Footcandles At Nadir

Footcandle "Multiplier"

Mounting Height in feet	Factor
30	1.36
31	1.27
32	1.20
33	1.12
34	1.06
35	1.00
36	0.95
37	0.89
38	0.85
39	0.81
40	0.77

Luminaire Efficiency Bare Lamp		
Direction	Pavement Side	Curb Side
Downward	34.2	23.1
Upward	1.8	1.7
Total	60.8	

Test distance 40 feet

Tested in accordance with IES recommendations for laboratory tests

Data reproduction contingent on duplicating test conditions.

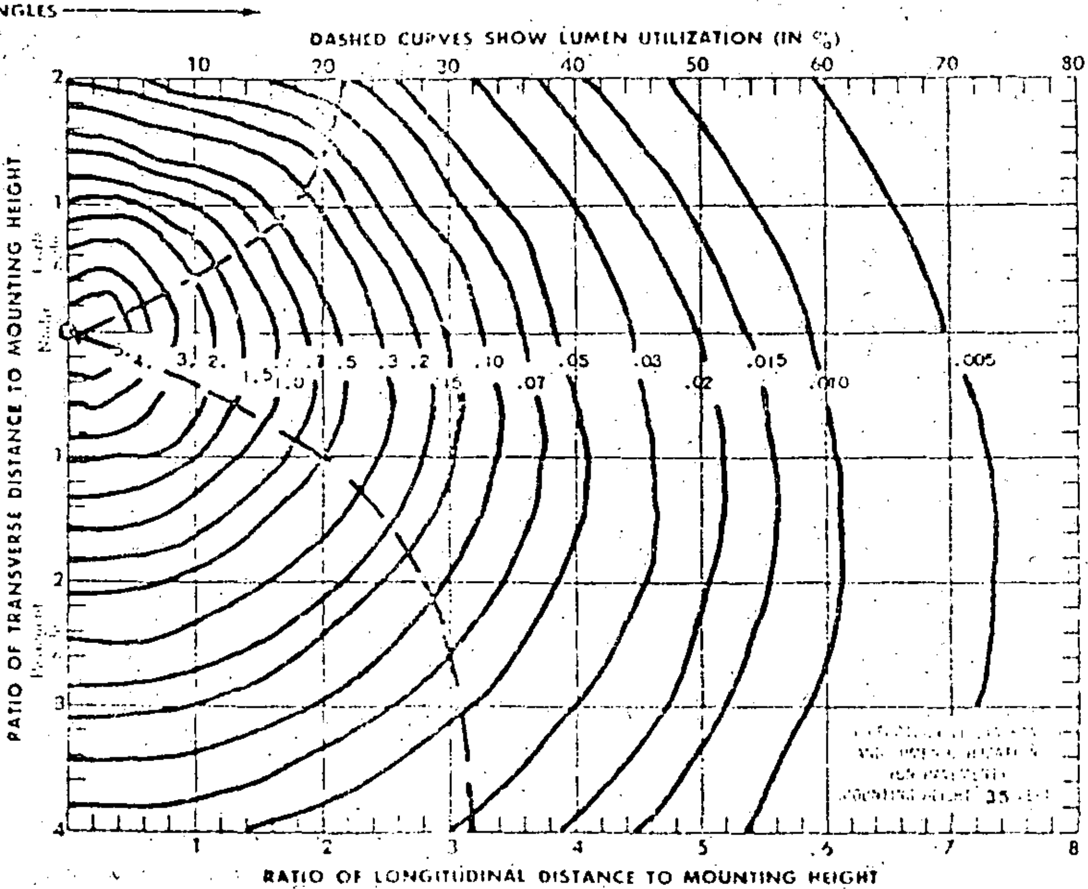


Fig. 8-13.

Problem No. 9

To compare different lamps we will take the same criteria as in problems no. 7 and 8 and now use a metal halide lamp. Photometric data Fig. 8-14 (Curve No. 630405).

Luminaire - IES type III, medium cutoff, distribution	
Lamp: MH-1000 1000 watts Bt-46.	
Test Lamp Lumens	90,000
Rated Lamp Lumens (Horizontal - initial)	95,000
Installed - Test lamp lumen factor	1.0555
LLD 7000 hours, 70% life	74%
LDD	95%
Roadway width (W)	72'
Overhang (O)	5'
Mounting Height (MH)	50'
Footcandle maintained	2
Mounting height factor	0

a. Determine Coefficient of Utilization (CU)
b. Determine staggered pole spacing
c. Determine maintained footcandles at points "A", "B" and "C"
d. Determine average to minimum ratio.

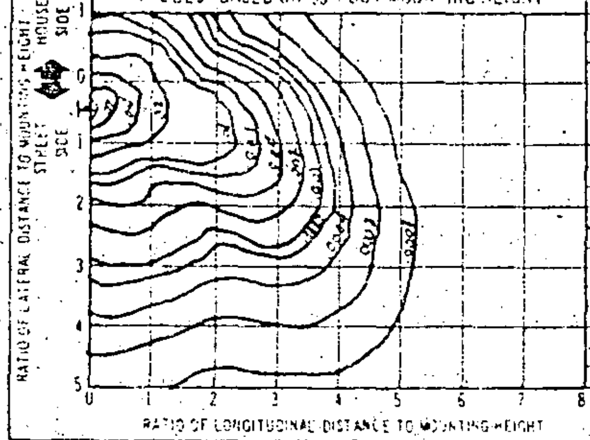
Problem No. 10

Many roadways are two separate roadways with a median between which may be from 2' to more than 20'. In this case we are using a 10' median and the luminaire is mounted over the edge of the roadway see Fig. 8-15. The lumens falling on the median will not be included in our calculations for CU. or footcandles.

Photometric Data Fig. 8-16	
Luminaire Ansi/IES type III medium, cutoff.	
Lamp; 1000 watts, M-1000/BD Bt-56 clear.	
Test Lamp Lumens 90,000	90,000
Rated Lamp Lumens Horizontal initial	95,000
Installed - Test Lamp lumen factor	1.0555
LLD (70% life - 7000 hours)	74%
LDD	95%
Roadway width Fig. 8-17 (2 strips 36' wide with 10' separation).	
Mounting Height (MH)	50'
Mounting height factor	49%
Mast arms	5' (Approx.)
Overhang (O) (center of fixture over curb)	0'
2 luminaires per pole.	

PHOTOMETRIC DATA

Fig. 8-14.



MH	CORREC. FACTOR
42	1.42
43	1.35
44	1.29
45	1.23
46	1.18
47	1.13
48	1.09
49	1.04
50	1.00
51	.96
52	.92
53	.89
54	[illegible]
55	[illegible]
56	[illegible]
57	[illegible]
58	.71
59	[illegible]

LAMP DATA	
SERVICE	Multiple
LUMENS	90,000
AMPS.	WATTS 1000 VOLTS
BULB BT-46	BASE Mog.Screw
DESIGNATION	MH-1000
LIGHT CENTER LENGTH	9-1/2 in.
BURNING POSITION	Horizontal

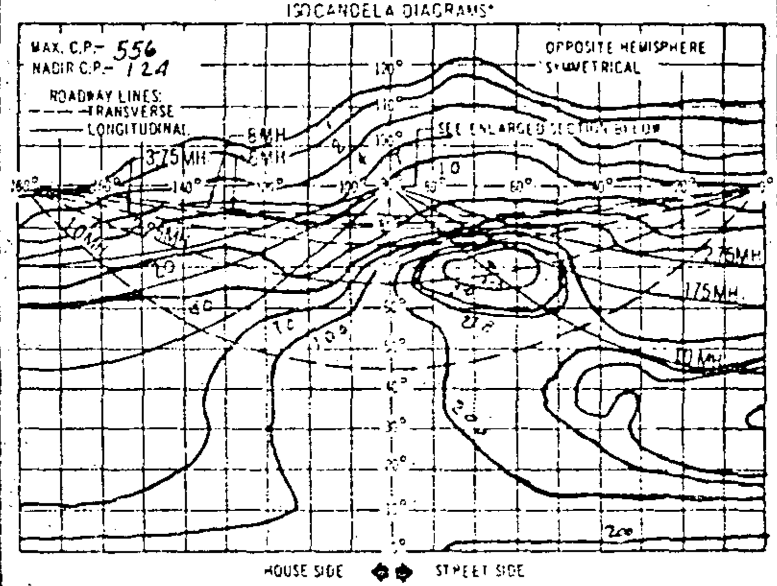
LIGHT FLUX VALUES*

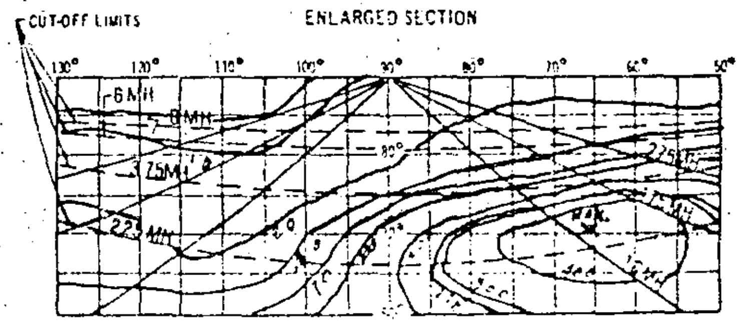
—	LUMENS	PERCENT OF LAMP
DOWNWARD STREET SIDE	582	58.2
UPWARD STREET SIDE	7	.7
DOWNWARD HOUSE SIDE	158	15.8
UPWARD HOUSE SIDE	1	.1
TOTAL	748	74.8

TESTED IN ACCORDANCE WITH THE IES GUIDE FOR PHOTOMETRIC TESTING OF STREETLIGHTING LUMINAIRES

TYPE* III	TEST NO K2517977	APP'D
DISTRIBUTION* Medium	TEST BY A. C. Sack	DATE 8-11-69
CLASSIFICATION** Cutoff		CURVE NO 630405

ISOCANDELA DIAGRAMS*





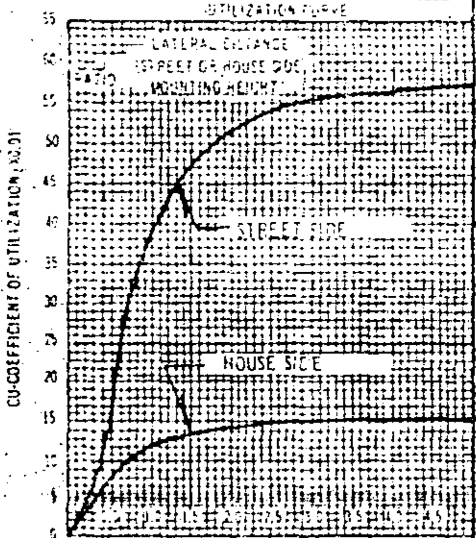
** CLASSIFICATION ...

CURVE NO 630405

TRANSFORMER FACTOR

HI-REACTANCE TYPE		
REGULATED OUTPUT TYPE		

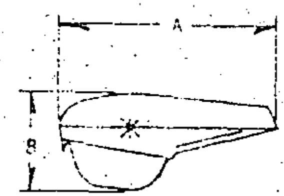
UTILIZATION CURVE



EFFECTIVE LUMENS = CU x BARE LAMP LUMENS
AVERAGE HORIZONTAL FOOT CANDLES ON STREET = $\frac{\text{EFFECTIVE LUMENS}}{\text{SPACING X WIDTH OF STREET}}$

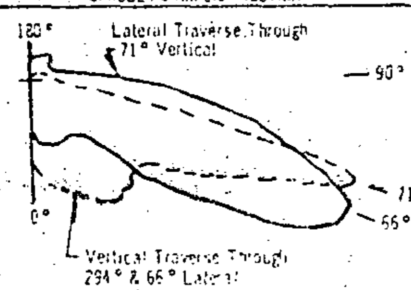
OUTLINE DIMENSIONS

A	39
B	16-1/8
C	
D	
E	
F	
G	



TEST DISTANCE 25 FEET
REFLECTOR — Specular Aluminum
SOCKET POSITION —

CANDLE POWER DISTRIBUTION



RESULTS ARE TYPICAL ONLY WHEN ALL TEST CONDITIONS, SUCH AS ... POSITION, LUMENS, ETC. ARE REPRODUCED.

*To obtain actual candela and footcandle values, multiply the values shown by the factors

a. Determine Coefficient of Utilization
b. Determine Spacing for double mounting
c. Determine maintained footcandles for points "A", "B", "C" and "D".
d. Determine average to minimum ratio.

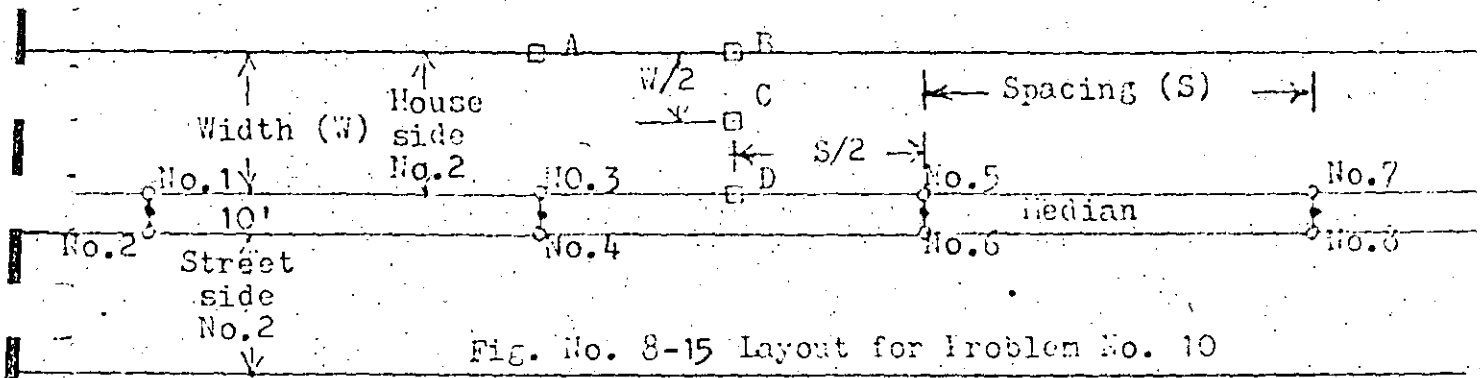


Fig. No. 8-15 Layout for Problem No. 10

Luminaire Refractor Catalog No. LO88X1
Socket Setting A3

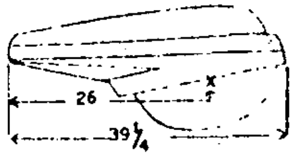
Lamp M-1000/60, 1000 watts, 90,000 lumens
BT-56, Clear

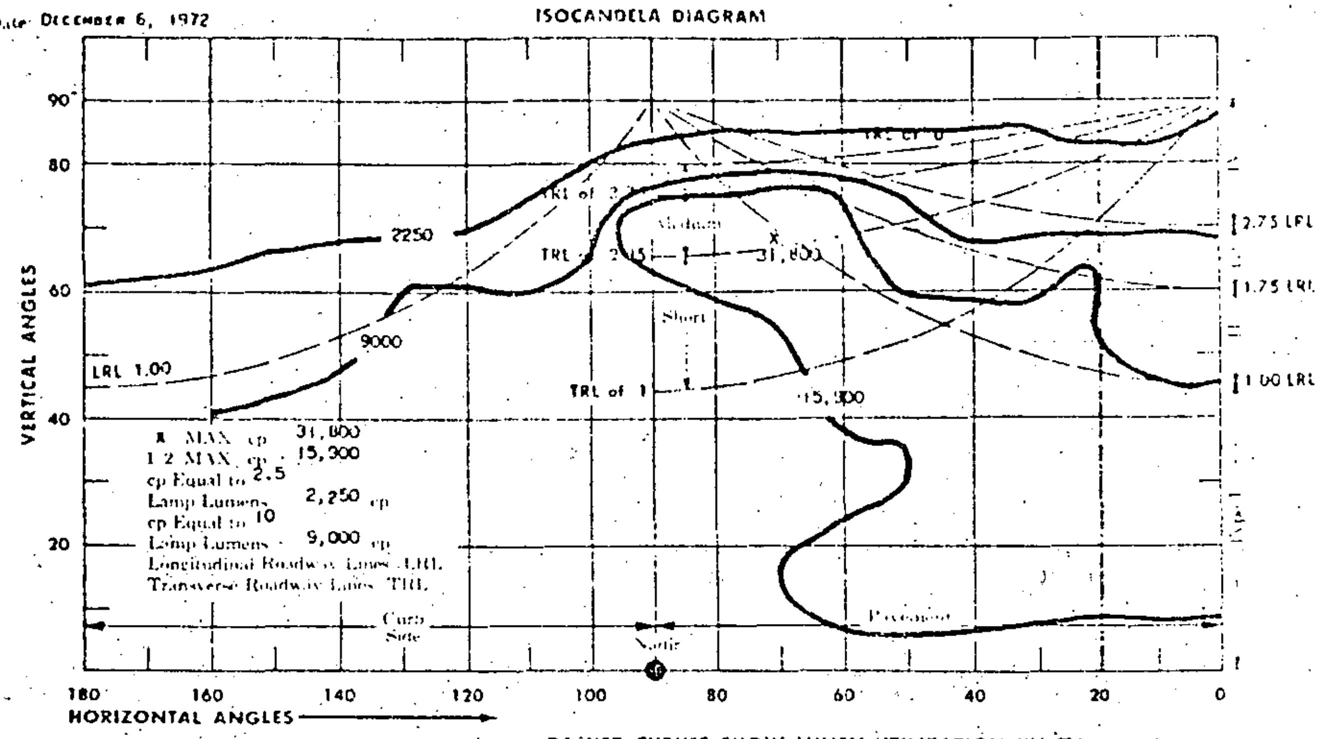
ANSI IES Type III, Medium, Cutoff

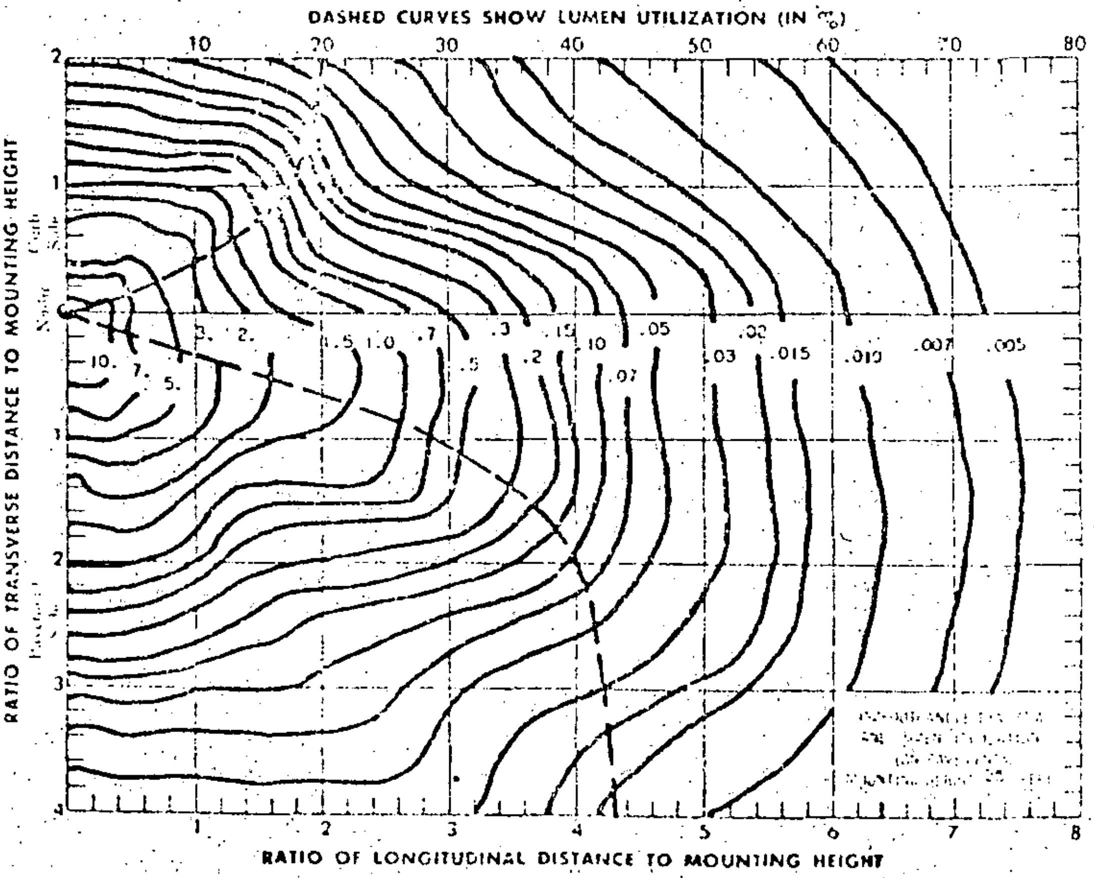
Approved By: [signature]

Date: December 6, 1972

Test No. C373-12
Supersedes C373-16







11.8 Foot-candles

Footcandle Multiplier

Mounting Height in feet	Factor
30	1.36
31	1.27
32	1.20
33	1.13
34	1.06
35	1.00
36	0.95
37	0.89
38	0.85
39	0.81
40	0.77

Luminaire Efficiency % Bare Lamp

Direction	Pavement Side	Curb Side
Downward	46.1	21.3
Upward	1.9	1.8
Total	71.1	

Test distance 60 feet

Tested in accordance with IES recommendations for laboratory tests.

Data reproduction contingent on duplicating test conditions.

Fig. 8-16.

APPENDIX A

Answers to Problems 2 through 10

Problem 2.

a.	Opposite spacing	154.8'
b.	Maintained footcandles at	
	Point A	2.57
	Point B	.71
	Point C	1.43
c.	Ratio average to minimum	2.8 to 1

Problem 3.

a.	Coefficient of Utilization	.57
b.	Opposite spacing	126.9'
c.	Maintained footcandles at	
	Point A	2.08
	Point B	.58
	Point C	1.84
c.	Ratio average to minimum	3.52 to 1

Problem 4.

a.	Coefficient of Utilization	.47
b.	Staggered spacing	83.6'
c.	Maintained footcandles at	
	Point A	1.15
	Point B	1.17
	Point C	2.51
d.	Ratio	1.72 to 1

Problem 5.

a.	Coefficient of Utilization	.351
b.	Staggered spacing	68.8
c.	Maintained footcandles at	
	Point A	1.3
	Point B	1.56
	Point C	1.98
d.	Ratio	1.54 to 1

Problem 6.

a.	Coefficient of Utilization	.391
b.	Staggered spacing	203.2'
c.	Maintained footcandles at	
	Point A	3.48
	Point B	.561
	Point C	.567
d.	Ratio	3.57 to 1

Problem 7.

a.	Determine lamp lumens depreciation (LLD)	.665
b.	Determine luminaire dirt depreciation (LDD)	.955
c.	Coefficient of Utilization	.415
d.	Staggered spacing	98.8'
e.	Maintained footcandles at	
	Point A	1.21
	Point B	1.7
	Point C	2.35
d.	Ratio	1.65 to 1

Problem 8.

a.	Coefficient of Utilization	.27
b.	Staggered spacing	70'
c.	Maintained footcandles at	
	Point A	1.33
	Point B	1.72
	Point C	2.08
d.	Ratio	1.5 to 1

Problem 9.

a.	Coefficient of Utilization	.47
b.	Staggered spacing	218'
c.	Maintained footcandles at	
	Point A	1.02
	Point B	.84
	Point C	1.14
d.	Ratio	2.27 to 1

Problem 10.

a.	Coefficient of Utilization	.335
b.	Spacing	310'
c.	Maintained footcandles at	
	Point A	3.46
	Point B	.447
	Point C	.524
	Point D	.567
d.	Ratio	4.47 to 1

Note: Where photometric data is difficult to interpret, answers within 5% of those given may be considered correct.

Luminaire Supporting Structures

1. Purpose

   To position the luminaire for optimum utilization, effectiveness and comfort of the illumination system. The supports usually consist of a pole with its associated appurtenances, but in some cases may consist only of a mast arm or bracket mounted on a structure such as a wall or bridge member.

2. Classification

   a. By location of electrical supply circuits

      (1) For overhead wiring
      (2) For underground wiring

   b. By composition

      (1) Wood
      (2) Steel
      (3) Aluminum
      (4) Concrete

   c. By functional requirements for luminaires

      (1) Mast arm (bracket) type
      (2) Davit or inclined shaft type
      (3) Post top type
      (4) Special types for high mast lighting

   d. By type of pole mounting

      (1) For bolt-down attachment to foundation
      (2) For imbedding in earth or concrete

Types of Electrical Supply Circuit

Almost all of the conventional luminaire mountings may be utilized for either overhead or underground lighting circuits. Wood poles lend themselves particularly well to overhead supply lines, while metal and concrete poles are more frequently used

ALUMBRADO PUBLICO
DISENO Y CALCULO

OBJETIVO:

EL OBJETIVO DEL ALUMBRADO PUBLICO ES EL DE PROPORCIONAR LA ILUMINACION ADECUADA EN CANTIDAD Y CALIDAD,PARA UNA VISION CONFORTABLE A LOS CONDUCTORES DE VEHICULOS Y PEATONES QUE LES PROPORCIONE SEGURIDAD Y PROTECCION, ADEMAS DE AYUDAR A EVITAR ACCIDENTES, REDUCIR EL VANDALISMO Y ESTIMULAR EL COMERCIO

METODO DE CALCULO

EL METODO ES APLICABLE PARA CALCULOS DE ILUMINANCIA EN CARRETERAS,CALLES, AVENIDAS,ANDADORES Y CICLOPISTAS.

LA ILUMINACION POR MEDIO DE POSTES ALTOS SE TRATA FUERA DE ESTE CAPITULO.

ES ESENCIAL EL DISPONER DE UN DIBUJO A ESCALA QUE MUESTRE TODOS LOS DATOS PERTINENTES,ADEMAS DE DEFINIR SU LOCALIZACION DE LA VIALIDAD,DENSIDAD DE TRAFICO,JURISDICCION,LOCAL,ESTATAL, NACIONAL Y CUALQUIER OTRO FACTOR UTIL.

PROCEDIMIENTO DE CALCULO

El procedimiento principal es para determinar por medio de cálculos y datos fotométricos, que combinación de lámpara-luminario se requiere para proveer una iluminación dada a una vialidad de dimenciones específicas y comprende dos partes principales:

A) OBJETIVOS Y ESPECIFICACIONES

B) FACTOR TOTAL DE PERDIDAS DE LUZ

) OBJETIVOS Y ESPECIFICACIONES

1) UN COMPLETO CONOCIMIENTO Y ENTENDIMIENTO DE LA LOCALIZACION Y TIPO DE VIALIDAD PARA DEFINIR SU CLASIFICACION

2) CALIDAD DE ILUMINACION.
CRITERIOS DE BRILLANTEZ Y DESLUMBRAMIENTO.

3) CANTIDAD DE ILUMINACION REQUERIDA
RECOMENDACIONES DE LA I.E.S. C.I.E.

4) ATMOSFERA DEL AREA.
ANALISIS DEL MEDIO AMBIENTE EN DONDE VA A OPERAR EL SISTEMA DE ILUMINACION POLVO EN LA ATMOSFERA PARA DEFINIR QUE GRUPO TIPICO DE AREA ATMOSFERICA.

5) DESCRIPCION DEL AREA.
SE REQUIERE UNA COMPLETA DESCRIPCION DEL AREA A ILUMINAR QUE

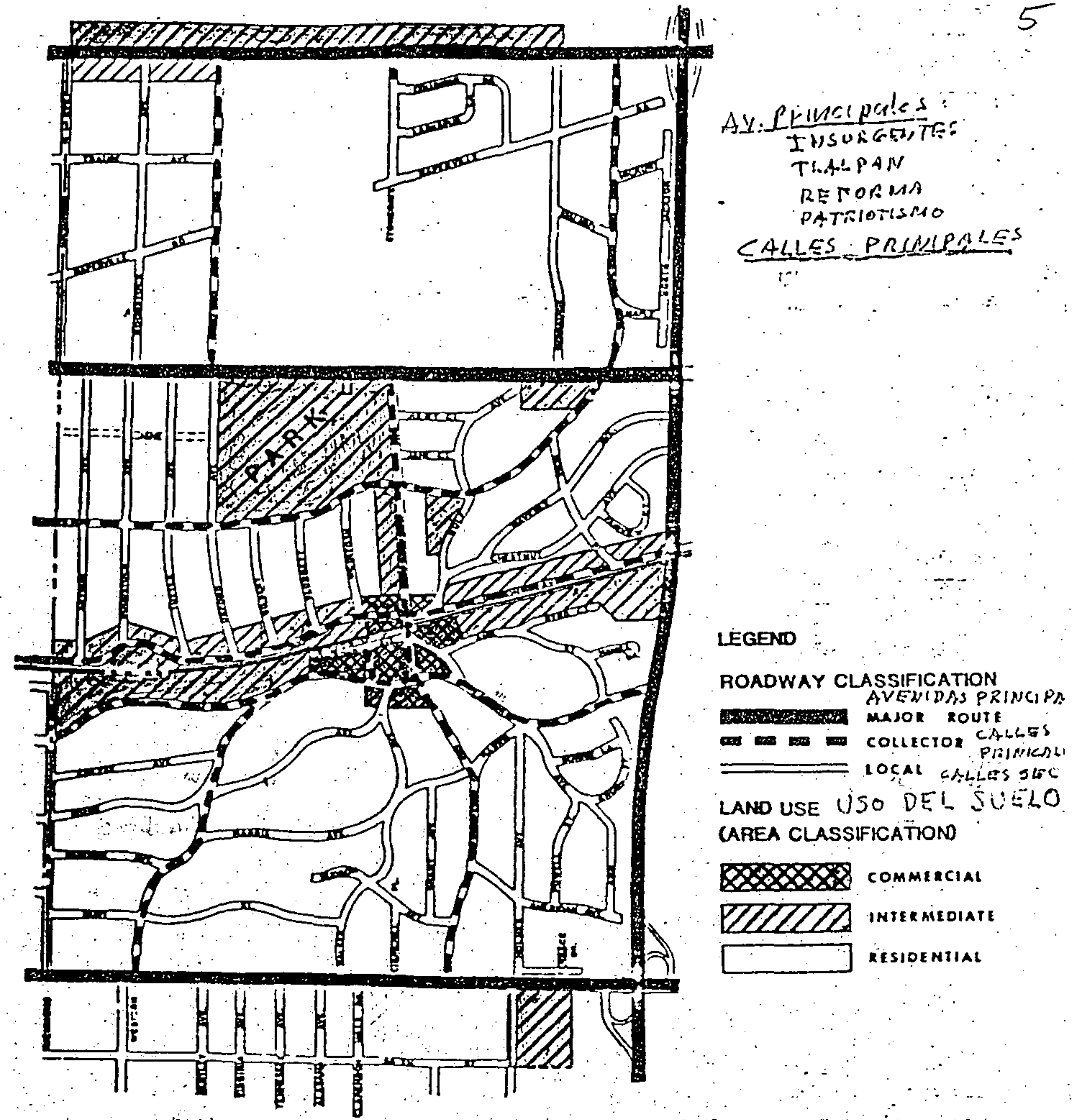


Figure 1. Example of roadway and area classification.

shared with other transportation modes.

(1) *Type A—Designated bicycle lane.* A portion of roadway or shoulder which has been designated for use by bicyclists. It is distinguished from the portion of the roadway for motor vehicle traffic by a paint stripe, curb, or other similar devices.

(2) *Type B—Bicycle trail.* A separate trail or path from which motor vehicles are prohibited and which is for the exclusive use of bicyclists or the shared use of bicyclists and pedestrians. Where such a trail or path forms a part of a highway, it is separated from the roadways for motor vehicle traffic by an open space or barrier.

2.2 Area classifications (abutting land uses).

(1) *Commercial.* A business area of a municipality where ordinarily there are many pedestrians during night-hours. This definition applies to densely developed business areas outside, as well as within, the central part of a municipality. The area contains land use which attracts a relatively heavy volume of nighttime vehicular and/or pedestrian traffic on a

Table 2 Cont'd

(a) Maintained luminance values

Road and Area Classification		Luminance L_{avg} (cd/m²)	Uniformity L_{avg} to L_{min}	Uniformity L_{max} to L_{min}	Maximum Ratio L_v to L_{avg}
Freeway Class A		0.6	3.5 to 1	6 to 1	0.3 to 1
Freeway Class B		0.4	3.5 to 1	6 to 1	0.3 to 1
Expressway	Commercial	1.0	3 to 1	5 to 1	0.3 to 1
	Intermediate	0.8	3 to 1	5 to 1	
	Residential	0.6	3.5 to 1	6 to 1	
Major	Commercial	1.2	3 to 1	5 to 1	0.3 to 1
	Intermediate	0.9	3 to 1	5 to 1	
	Residential	0.6	3.5 to 1	6 to 1	
Collector	Commercial	0.8	3 to 1	5 to 1	0.4 to 1
	Intermediate	0.6	3.5 to 1	6 to 1	
	Residential	0.4	4 to 1	8 to 1	
Local	Commercial	0.6	6 to 1	10 to 1	0.4 to 1
	Intermediate	0.5	6 to 1	10 to 1	
	Residential	0.3	6 to 1	10 to 1	

(b) Average maintained illuminance values (E_{avg}) in lux

Road and Area Classification		Pavement Classification R1	R2 and R3	R4	Illuminance Uniformity Ratio (E_{avg} to E_{min})
Freeway Class A } Autopistas		6	9	8	3 to 1
Freeway Class B		4	6	5	
Expressway (Periferico Anillos Radiales)	Commercial	10	14	13	3 to 1
	Intermediate	8	12	10	
	Residential	6	9	8	
Major (Avenidas Principales)	Commercial	12	17	15	3 to 1
	Intermediate	9	13	11	
	Residential	6	9	8	
Collector (Calles Primarias)	Commercial	8	12	10	4 to 1
	Intermediate	6	9	8	
	Residential	6	6	5	
Local (Calles Secundarias)	Commercial	6	9	8	6 to 1
	Intermediate	5	7	6	
	Residential	3	4	4	

Notes
L_v = veiling luminance

needs of night traffic (vehicular and pedestrian) and be expressed in terms clearly understandable by lighting designers, traffic engineers, and highway administrators.

The visual environmental needs along the roadway are described in this Standard Practice in terms of pavement luminance, luminance uniformity and disability veiling glare produced by the system light sources. Table 2(a) provides the recommended luminance design requirements, uniformity and the relationship between average luminance (L_{avg}) and veiling luminance (L_v).

The visual needs along the roadway may also be satisfied by the use of illuminance criteria. Table 2(b) provides the recommended illuminance design requirements, considering the differences in roadway reflectance characteristics. The designer should not expect that lighting systems designed under either criteria will correlate perfectly with each other.

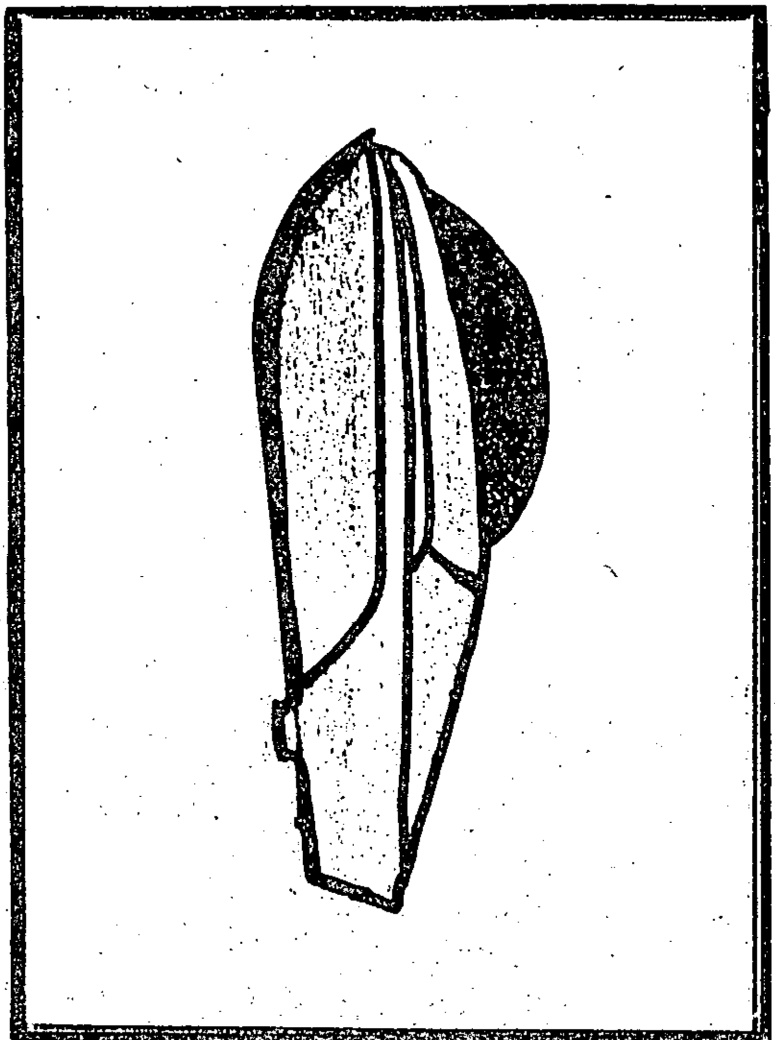
(2) Appendix D includes information for assessing the visibility conditions which also take into consideration the psychophysiological aspects of human

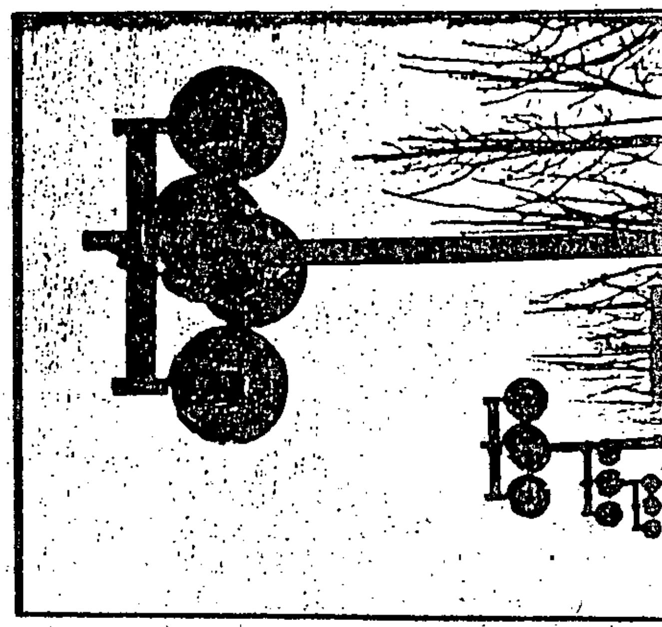
DEBERA INCLUIR LAS CARACTERISTICAS FISICAS DIMENSIONALES, COMO ANCHO DEL ARROYO, BANQUETA, CURVATURA, OBSTRUCCIONES (ARBOLES, POSTES DE OTROS SERVICIOS, CANALIZACIONES, ETC.), AREAS ADYACENTES.

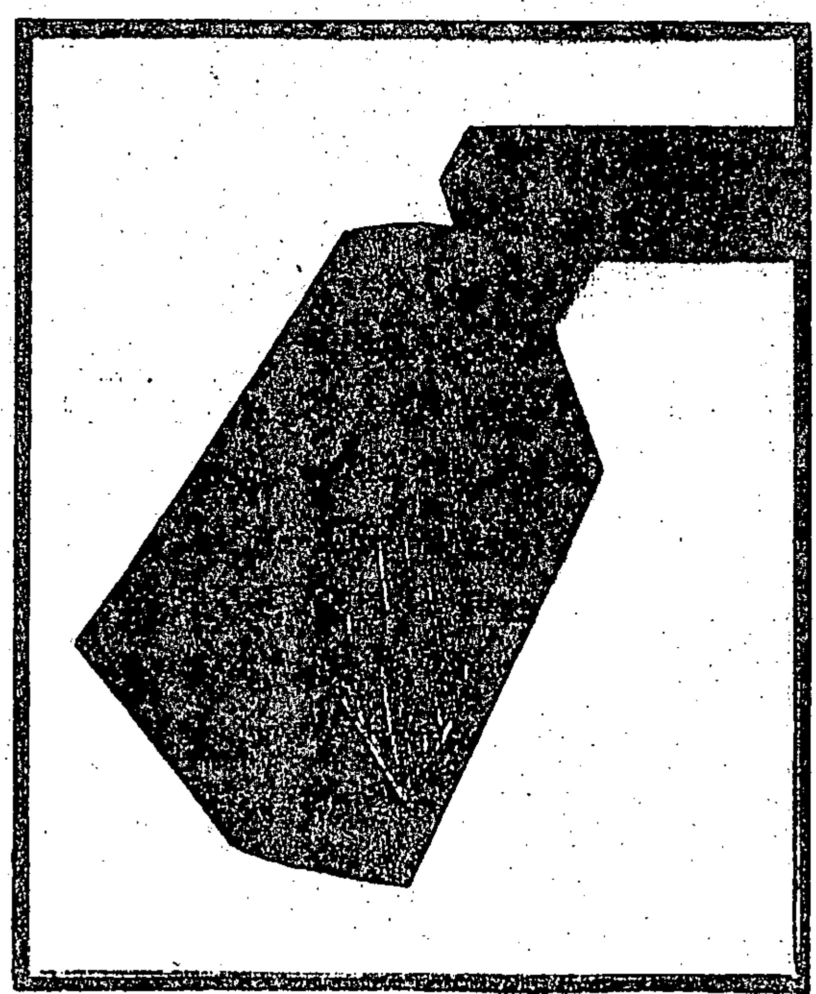
6) SELECCION DEL LUMINARIO

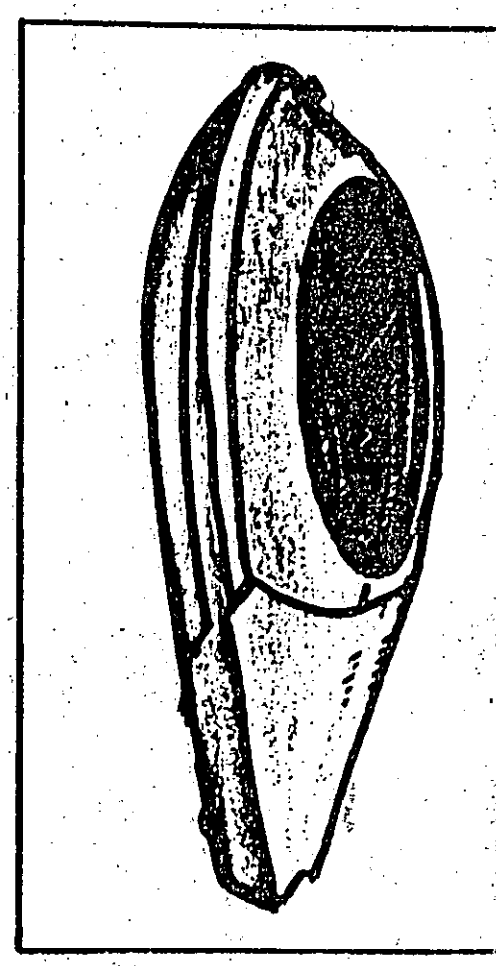
LA SELECCION DEL LUMINARIO ESPECIFICO REQUIERE CONSIDERAR SIMULTANEAMENTE VARIOS FACTORES ENTRE ELLOS:

DIMENSIONES Y TIPO DE VIALIDAD
LOCALIZACION EN QUE TIPO DE ZONA
CONDICIONES ATMOSFERICAS
ALTURA DE MONTAJE
DEPRECIACION POR POLVO
FUENTE LUMINOSA
CONSIDERACIONES DE MANTENIMIENTO
APARIENCIA
FACILIDAD DE MONTAJE
VANDALISMO









B) FACTOR TOTAL DE PERDIDA DE LUZ

-NO RECUPERABLES

1)TEMPERATURA AMBIENTAL

2)VOLTAJE DE LINEA

ES DIFICIL PREDECIR EL VOLTAJE DE LA LINEA EN SERVICIO,PERO ALTOS O BAJOS VOLTAJES AFECTARAN LA EFECIENCIA LUMINICA DE LA MAYOR PARTE DE LOS LUMINARIOS.

3)FACTOR DE BALASTRO

SI EL BALASTRO USADO EN EL LUMINARIO NO PROVEE EL WATTAJE REQUERIDO POR LA LAMPARA LA SALIDA DE LUZ SE AFECTARA PROPORCIONALMENTE Y UN FACTOR DE BALASTRO DEBERA CONSIDERARSE

4)DEPRECIACION DE LOS COMPONENTES.

LA DEPRECIACION DE LA SALIDA DE LUZ DE UN LUMINARIO ES DEBIDO AL RESULTADO DEL DETERIORO DEL METAL,VIDRIO, PLASTICO,PINTURA Y ACABADOS DEL REFLECTOR,QUE CAUSARAN UNA DISMINUCION DE LA SALIDA DE LUZ NO EXISTE FACTOR FIJO PARA ESTE PUNTO

) CAMBIOS FISICOS EN LOS ALREDEDORES.

EL DISENADOR DEBERA ENTERARSE DE QUE CAMBIOS SE PLANEAN, QUE PUEDAN AFECTAR LA EFECTIVIDAD DEL SISTEMA, TALES COMO AUMENTAR EL ANCHO DE LA VIALIDAD, MODIFICACION DE ACERAS, CAMBIO DE PAVIMENTOS, PLANTAR ARBOLES, CONSTRUCCION O DEMOLICION DE EDIFICIOS O CUALQUIER COSA QUE CAMBIE

6) MORTANDAD DE LAS LAMPARAS.

EL NO REEMPLAZAR LAS LAMPARAS FUERA DE OPERACION AFECTAN LA CALIDAD DEL SISTEMA DE ILUMINACION.

●ECUPERABLES

1)DEPRECIACION LUMINICA DE LA LAMPARA

2)DEPRECIACION POR POLVO EN EL LUMINARIO

LA ACUMULACION POR POLVO EN LA SUPERFICIE DEL LUMINARIO CAUSA UNA PERDIDA EN LA EFICIENCIA LUMINICA Y EN CONSECUENCIA MENOS LUZ SOBRE EL PAVIMENTO.

EL TOTAL DE LOS FACTORES DE PERDIDAS DE LUZ (FPTL) ES SIMPLEMENTE EL PRODUCTO DE MULTIPLICAR LOS FACTORES DESCRITOS

$$FPTL = F.B \times DSR \times FD \times FM \times CS$$

CUANDO LOS FACTORES NO SON CONOCIDOS O APLICABLES SE PUEDEN OMITIR LOS NO IMPORTANTES.

F.B - FACTOR DE BALASTRO - BF

DSR - DEPRECIACION DE LA SUPERFICIE DEL REFLECTOR - RD

FD - DEPRECIACION DE LUMENES DE LA LAMPARA - LLD

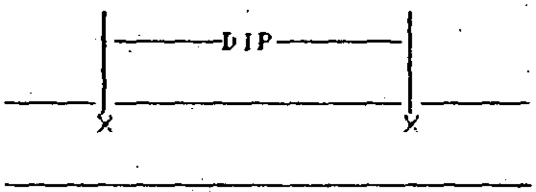
FM - FACTOR DE MORTANDAD- BCF

CS - DEPRECIACION POR POLVO EN EL LUMINARIO - LDD

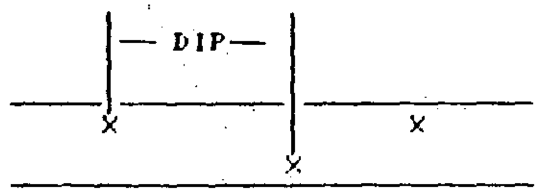
EMISION LUMINICA REAL DE
LAMPARAS DE VAPOR DE SODIO
ALTA Y BAJA PRESION

POTENCIA	TIPO	FABRICANTE	EMISION NOMINAL LUMENS	EMISION REAL LUMENS	DISMINUCION %
55 W	LPS	PHILIPS	8,000	7,888	1.4 %
135 W	LPS	PHILIPS	22,500	20,654	8.5 %
70 W	HPS	G.E.	6,300	6,016	4.5 %
150 W	HPS	G.E.	16,000	15,600	2.5 %
250 W	HPS	PHILIPS	27,500	26,317	4.3 %

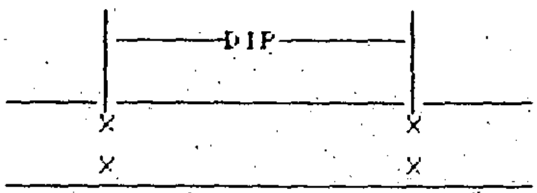
TIPO DE DISPOSICION



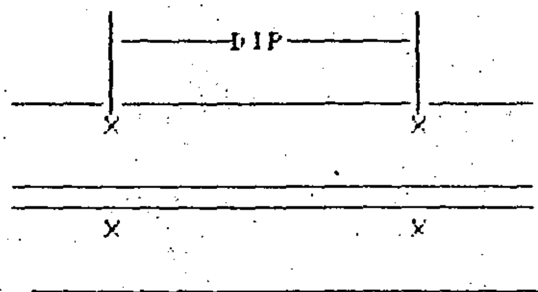
UNILATERAL



TRES BOLILLO



OPUESTO

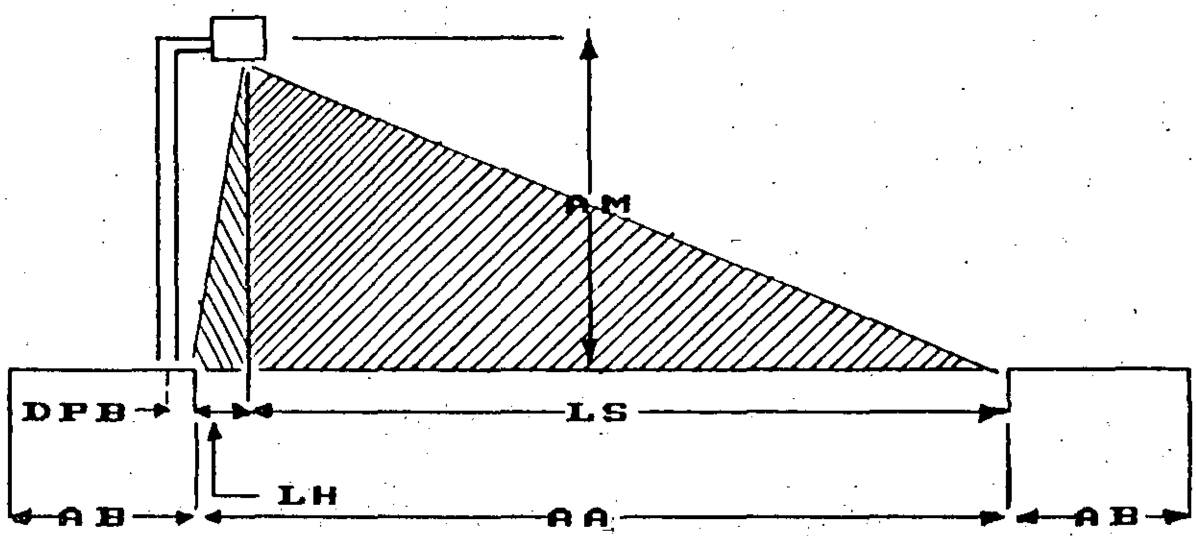


AL CENTRO

FORMULAS PARA EL CALCULO

$$E = \frac{O}{A} = \frac{\text{LUMENES DE LAMP} \times \text{CU} \times \text{FTPL}}{\text{ANCHO CALLE} \times \text{DIST. INTER POSTAL}}$$

$$\text{DIP} = \frac{\text{LUMENES DE LAMP} \times \text{CU} \times \text{FTPL}}{\text{ANCHO CALLE} \times \text{NIVEL DE ILUMINACION}}$$



AA: ANCHO DE ARROYO

AB: ANCHO DE BANQUETAS

DIP: DISTANCIA INTERPOSTAL

AM: ALTURA DE MONTAJE

LH: LADO CASA

LS: LADO CALLE

DPB: DISTANCIA CENTRO POSTE FIN BANQUETA

NI: NIVEL DE ILUMINANCIA MANTENIDO

CU: COEFICIENTE DE UTILIZACION

RECOMENDACIONES GENERALES

LONGITUD DEL BRAZO NO MAYOR 2.5 % DE LA ALTURA DE MONTAJE.

CUANDO EL RESULTADO DEL CALCULO NO CUMPLA CON LA RELACION DE UNIFORMIDAD ES POSIBLE QUE:

1.-ALTURA DE MONTAJE BAJA
2.-CURVA DE DISTRIBUCION INADECUADA
3.-MODIFICAR LONGITUD LADO CASA
4.-ESPACIAMIENTO EXCESIVO
5.-EXCESIVA POTENCIA LUMINICA

T-1 SELECCION DE TIPO DE DISPOSICION

TIPO DE DISPOSICION	RELACION ALTURA MONTAJE / ANCHO CALLE	
	VALOR MINIMO	VALOR RECOMENDABLE
UNILATERAL	0.85	1
TREBOLILLO	0.50	0.6
OPUESTAS	0.33	0.5

ALTURAS RECOMENDADAS EN FUNCION DE LA POTENCIA LUMINOSA INSTALADA

POTENCIA LUMINOSA INSTALADA (LM)	ALTURA DE MONTAJE (M)
3000 A 9000	6.5 A 7.5
9000 A 19000	7.5 A 9.00
> 19000	>= 9

EJEMPLOS DE CALCULOS PARA CALLES

DATOS:

ANCHO DE CALLE ———— 10.5 M

ANCHO DE BANQUETA ———— 3.0 M

DISTANCIA DEL POSTE AL BORDE DE LA BANQUETA ———— 0.6 M

CALLE PRINCIPAL EN ZONA COMERCIAL (NIZA)

DETERMINAR:

A.-NIVEL DE ILUMINANCIA REQUERIDA

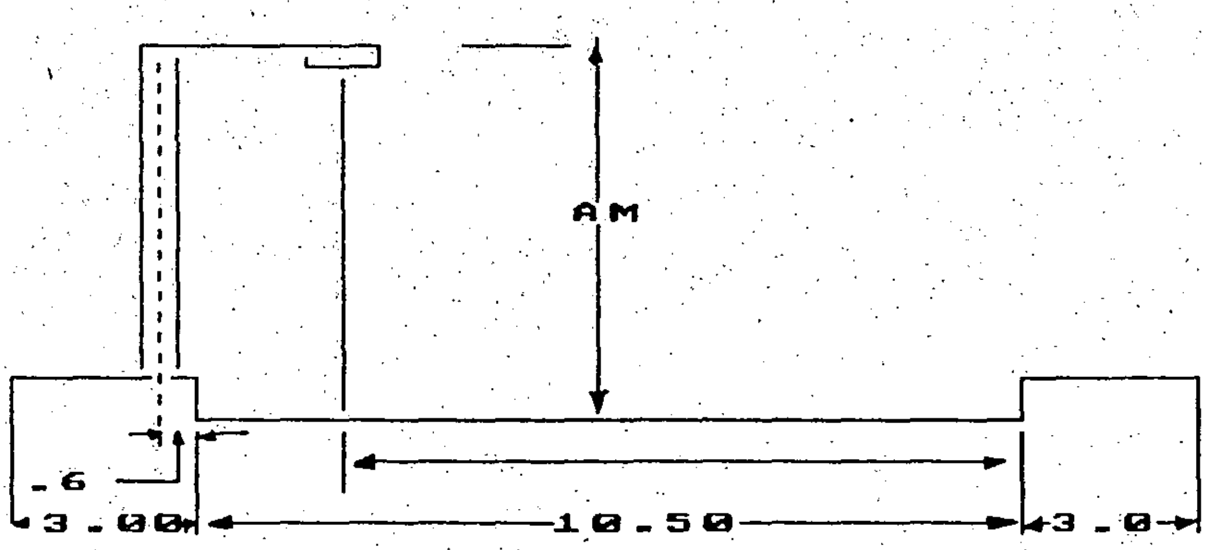
B.-ALTURA DE MONTAJE Y LONGITUD DEL BRAZO

C.-TIPO DE DISPOSICION

D.-DISTANCIA INTERPOSTAL

E.-NIVEL DE ILUMINANCIA EN BANQUETAS

F.-INDICE DE UNIFORMIDAD



SOLUCION:

A.- NIVEL DE ILUMINANCIA

DE LA TABLA 2 (b) DEL AMERICAN NATIONAL STANDARD PRACTICE FOR ROADWAY LIGHTING, CONSIDERANDO UNA CLASIFICACION DE PAVIMENTO R2-R3, ESPECIFICA PARA ESTE TIPO DE VIALIDAD 12 LUX.

B.- ALTURA DE MONTAJE

1.- DE LA TABLA 2 RECOMENDACIONES GENERALES TENEMOS QUE SUPONER QUE FUENTE LUMINOSA Y POTENCIA UTILIZAREMOS. EN ESTE CASO SUPONEMOS INICIALMENTE: LAMPARA DE VAPOR DE SODIO EN ALTA PRESION DE 150 WATTS. CON UN FLUJO LUMINOSO DE 16,000 LUMENS Y DE ACURDO A LA TABLA SE REQUIERE UNA ALTURA DE MONTAJE DE 8 METROS.

LAMP SPECIFICATION BULLETIN

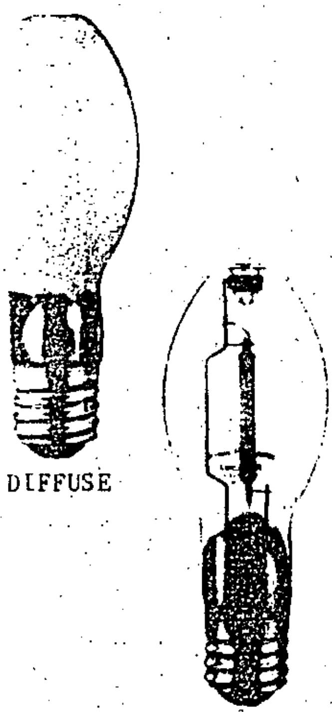
LUCALOX
LU150

LSB #220-6187R
4/21/78

LAMP TYPE: High Pressure Sodium

150-WATT LUCALOX®

ORDERING CODE: for operation in any position: LU150/D LU150



DIFFUSE CLEAR

Note:
All performance data shown are approximate values based on normal operating conditions with auxiliary equipment that meets current published specifications.
Data subject to change without notice.

PERFORMANCE DATA:		LU150/D	LU150
* Initial lumens (Avg.):	Horiz.	15,000	16,000
	Vert.	15,000	16,000
* Rated Average Life at 10 hrs/start		24,000	
Percent mean lumens at 10 hrs/start		90% est.	
Apparent color temperature		2100K	
Warm-up time		3-4 minutes	
Restart time		1 minute	
C.I.E. chromaticity		x=.522 y=.423	

PHYSICAL DESCRIPTION:		
Base designation	Mogul	
Bulb designation	E-23-1/2	
Bulb material	Lead borosilicate glass	
Bulb finish	Diffuse	Clear
Bulb diameter	2-5/16"	
Maximum overall length	7-3/4"	
Light center length	5"	
Arc length	1.6"	
Bulb temp. limitation (max.)	400°C	
Base temp. limitation (max.)	210°C	
Eccentricity:		
base to bulb	4°	
arc tube to lamp axis	5mm	

ELECTRICAL CHARACTERISTICS:	
Nominal lamp watts	150
Nominal lamp volts	55
Nominal lamp current	3.3 amps
Max. current crest factor	1.8
Max. starting current	5.0 amps
Ballast design open-circuit volts (min)	110**
Starting pulse requirements:	
pulse peak voltage (min)	2500
pulse peak voltage (max)	4000
pulse width	1 micro-sec. (min.) at 2250 v.
pulse repetition	50 per sec. (min.)
pulse peak current	.2 amp. (min.)

**Applicable for ballasts) operate lamps at rated performance. Lamps will operate at lower than the minim . ballast design OCV but performance values will change.
* Lumens at rated watts. Actual lamp watts may vary depending on the ballast characteristic curve.

2.- PODEMOS SUPONER COMO ALTERNATIVA INICIAL UN LUMINARIO " CROMALITE " CON LAMPARA DE 150 WATTS V.S.A.P. Y CURVA FOTOMETRICA No.35-175631 DE DONDE OBTENEMOS EL VALOR MAXIMO DE LA POTENCIA EN CANDELAS.

$$582 \times 16 = 9312 \doteq 10{,}000$$

CON ESTE VALOR SE ENTRA A LA GRAFICA DE LA FIGURA 3 DEL AMERICAN NATIONAL STANDARD PRACTICE FOR ROADWAY LIGHTING Y APROXIMADAMENTE NOS DA UNA ALTURA DE MONTAJE DE 8 METROS, VERIFICANDO EL CATALOGO DEL FABRICANTE, ESA DIMENSION ES COMERCIAL.

EL LARGO DEL BRAZO NO SERA MAYOR A UN 2.5 % DE LA ALTURA DE MONTAJE, DE DONDE SE SELECCIONA DE 1.8 METROS.

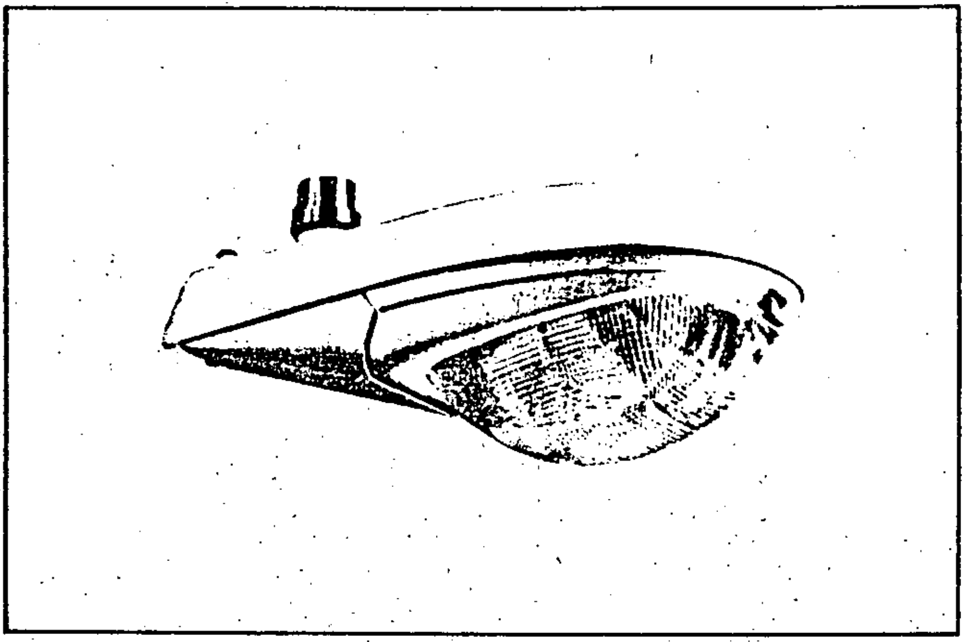
C.- TIPO DE DISPOSICION

DE LA TABLA 1 DE RECOMENDACIONES GENERALES SE ENTRA CON LA RELACION:

Luminario Cromalite*250

Los luminarios CROMALITE* 250 ofrecen la más elevada tecnología y la máxima eficiencia para la iluminación de calles y avenidas. El conjunto óptico hermético y filtrado (opcional) disminuye los costos de mantenimiento y da como resultado mayor cantidad de luz mantenida con mínimo costo total de operación.

El luminario CROMALITE* 250 puede utilizarse con lámparas de vapor de mercurio o aditivos metálicos de 250 watts y con lámparas de 70, 100, 150 y 250 watts de vapor de sodio de alta presión.



1.- **FACIL ACCESO A TODAS LAS COMPONENTES ELECTRICAS PRINCIPALES** : El MODULO exclusivo del luminario CROMALITE* 250 que contiene al balastro, facilita la instalación, reposición y mantenimiento.

2.- **FACIL REPOSICION DE LAMPARAS Y SERVICIO AL SISTEMA OPTICO** : La operación de un picaporte abre la puerta porta-refractor y permite el acceso al refractor, al reflector y la lámpara.

3.- **MINIMA PERDIDA DE LUZ DEBIDO A LA CONTAMINACION**: El filtro de carbón activado y el empaque de etileno propileno termopolímero del conjunto óptico (modelos CM), reducen enormemente las pérdidas que resultan de la contaminación por materiales gaseosos y partículas, eliminándose virtualmente la necesidad de limpieza del luminario entre períodos de cambio de lámpara.

4.- **ENSAMBLE SIMPLIFICADO EN LA TIERRA O EN EL AIRE** : Un adaptador deslizable con dos tornillos, permite a los instaladores colocar el brazo al luminario en la tierra o montar el luminario al brazo ya colocado en el poste, con un mínimo de esfuerzo y tiempo.

5.- **AMPLIA GAMA DE DISTRIBUCION** : El porta-lámpara de 12 posiciones en el caso de los modelos CM, se ajusta por medio de 2 tornillos para cumplir sus requerimientos.

6.- **OPERACION AUTOMATICA DE ENCENDIDO Y APAGADO** : El fotocontrol integrado al luminario (opcional para modelos CM y CI) permite la operación automática de encendido y apagado.

7.- **ELEVADA REFLECTANCIA DE LA LUZ** : El reflector de aluminio recubierto con Vitreflex* (vidrio flexible transparente) mantiene por largo tiempo sus características de reflectancia.

GUIA PARA ESPECIFICAR :

El luminario deberá ser modelo CROMALITE* 250 y debe consistir de un cuerpo de aluminio fundido a presión, un marco porta-reflector, un módulo de potencia y un control fotoeléctrico automático (opcional), el adaptador deslizable deberá tener dos tornillos, que podrán apretarse interna y externamente y deberá ser capaz de adaptarse a un brazo tubular de 38 a 50 mm. (1 1/2 a 2") sin requerir el reajuste de las partes de montaje.

El conjunto óptico consistirá de un reflector de aluminio, recubierto con Vitreflex* (vidrio flexible transparente), un porta-lámpara (ajustable a 12 posiciones para los modelos CM), colocado en un recipiente fundido a presión, un filtro de carbón activado (opcional), para filtrar tanto partículas como gases, un empaque que servirá como sello entre el reflector y el refractor, y un refractor de vidrio, acrílico o policarbonato (especificar). La distribución luminosa deberá ser IES (especificar), el MODULO de potencia deberá contener un balastro marca LUMICON* integrado y deberá ser fácil de remover y reemplazar, mediante el uso de clavijas de desconexión rápida. El balastro deberá estar pre-alambrado al porta-lámpara requiriendo solamente que se conecten los cables de alimentación.

El balastro deberá operar una lámpara de (especificar) watts de mercurio, aditivos metálicos o vapor de sodio de alta presión, desde una red de alimentación nominal de 127, 220, 254, 277 ó 440 volts, (especificar) 60 Hz., y ser capaz de encender y operar la lámpara dentro de los límites especificados por sus fabricantes.

*MARCAS REGISTRADAS

Fabricado Bajo Licencia de :
GENERAL ELECTRIC COMPANY, U.S.A.

exa Lumisistemas

PER 1000 LAMP LUMENS

DRAWING NO	SHEET	CONT ON	REVISION	
35-175G31			03	5-18-77 1-21-76 5-19-78

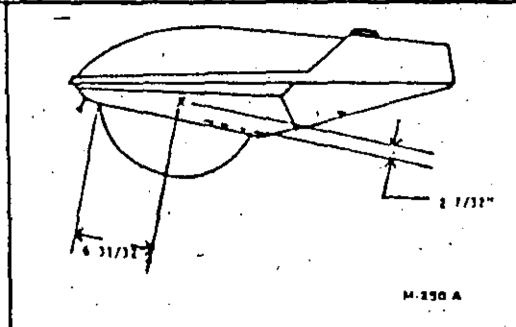
GENERAL ELECTRIC

PHOTOMETRIC DATA

APPROVED BY J.C. Alexander DATE Sept 25 73
DATE Sept 26 73

LIGHTING SYSTEMS BUSINESS DEPARTMENT
HENDERSONVILLE, N. C. U.S.A., 28739

RESERVED FOR INFORMATION ON SYMMETRICAL UNITS



LUMINAIRE DESCRIPTION

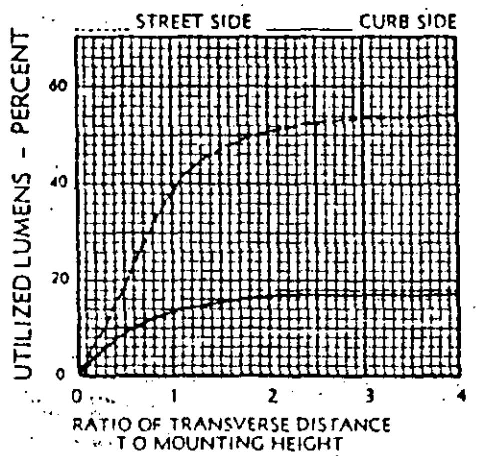
GENERAL ELECTRIC M250A LUMINAIRE
REFLECTOR #35-130568-01
REFRACTOR #518
SOCKET POSITION 5

LAMP:
70, 100, or 150 WATT HIGH PRESSURE SODIUM
G.E. NO. LU70/BD, LU100/BD, or LU150/BD (LUCALOX)
ANSI: S54 (LU100) or S55 (LU150)

ANSI/IES TYPE MEDIUM/CUTOFF/TYPE II (1963)
MEDIUM/SEMI-CUTOFF/TYPE II (1972)

CIE TYPE NON-CUTOFF

UTILIZATION CURVE



GENERAL INFORMATION

TEST NUMBER 73-0408
TEST DISTANCE 7 METERS
TEST LUMENS 1000

IF THE RATING OF THE LAMP USED DIFFERS FROM THE TEST RATING OF 1000 LUMENS, MULTIPLY ALL LUMEN, CANDELA (IF SHOWN) AND FOOTCANDLE VALUES BY THIS RATIO:

$$\text{RATIO} = \frac{\text{ACTUAL LAMP LUMENS}}{\text{TEST LUMENS}}$$

MAXIMUM CANDLEPOWER – 387
MAXIMUM CONE – 77.5°
MAXIMUM VERTICAL PLANE – 77.5°/282.5°
MAXIMUM CANDLEPOWER AT 90° – 30
MAXIMUM CANDLEPOWER AT 80° – 116
NADIR FOOTCANDLES – .13200
NADIR CANDLEPOWER – 119

PHOTOMETRIC TEST IN ACCORDANCE WITH IES GUIDE

ILLUMINATION DATA

RATIO OF LONGITUDINAL DISTANCE TO MOUNTING HEIGHT

Luminaire position: 180° / 270° / 0° / 90°. Contour lines: .0001, .001, .01, .1

RESERVED FOR INFORMATION ON SYMMETRICAL UNITS

RATIO OF TRANSVERSE DISTANCE TO MOUNTING HEIGHT

		7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0
CURB SIDE	2.0	.00005	.00008	.00013	.00025	.00050	.00107	.00241	.00391
	1.5	.00006	.00009	.00016	.00033	.00076	.00184	.00475	.01230
	1.0	.00007	.00011	.00021	.00045	.00131	.00427	.01050	.02820
	0.5	.00009	.00015	.00030	.00073	.00234	.01070	.02590	.03700
	0.0	.00011	.00020	.00046	.00143	.00692	.02320	.06710	.13200
STREET SIDE	0.5	.00014	.00027	.00069	.00264	.01670	.04330	.10900	.14800
	1.0	.00017	.00033	.00096	.00375	.01630	.03140	.06100	.07680
	1.5	.00019	.00040	.00107	.00150	.00697	.01070	.01970	.02000
	2.0	.00020	.00041	.00093	.00229	.00298	.00530	.00710	.00463
	2.5	.00019	.00036	.00070	.00119	.00179	.00277	.00335	.00294
	3.0	.00017	[illegible]	.00052	.00071	.00114	.00146	.00176	.00156
	3.5	.00015	.00015	.00037	.00055	.00074	.00089	.00099	.00090
	4.0	.00013	.00020	.00029	.00040	.00049	[illegible]	.00062	.00057

TO CONVERT ILLUMINATION DATA TO FT-C (ON HORIZONTAL SURFACE) MULTIPLY BY 1

LIGHT FLUX VALUES	LUMENS	PERCENT OF LAMP
DOWNWARD STREET SIDE	380	38
UPWARD STREET SIDE	20	2
DOWNWARD CURB SIDE	180	18
UPWARD CURB SIDE	20	[illegible]
TOTAL	790	79

CONVERSION FACTORS

1 FOOTCANDLE = 10.76 LUX
1 FOOT = 0.3048 METERS

ILLUMINATION DATA IS BASED ON A LUMINAIRE MOUNTING HEIGHT OF 30 FEET. FOR OTHER MOUNTING HEIGHTS MULTIPLY THE VALUES OF ILLUMINATION SHOWN BY THE FACTORS IN THE FOLLOWING TABLE.

MOUNTING HEIGHT FT.	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
FACTOR	1.44	1.33	1.23	1.15	1.07	1	.94	.88	.83	.78	.74	.69	.66	.62	.59	.56	.54	.51	.49	.46	.44	.42	.41	.39	.38	.36

this has been due to esthetic considerations. An example is the use of pole-top-mounted luminaires in residential areas, despite their reduced coefficient of utilization (CU) as related to conventional luminaires that overhang the roadways.

(3) When designing a system, mounting height must be considered in conjunction with spacing and lateral positioning of the luminaires, as well as the luminaire type and distribution. Uniformity and levels of luminance or illuminance must be maintained as recommended, regardless of the mounting height selected.

(4) Increased mounting height will usually (but not necessarily) reduce discomfort glare and disabling veiling luminance. It increases the angle between the luminaires and the line of sight to the roadway; however, luminaire light distribution and candlepower also are significant factors. Glare is dependent on the flux reaching the observer's eyes from all luminaires in the visual scene.

(5) Multi-level interchanges or highway sections with three or four separate roadways may be advantageously lighted with high mast-type units where high intensity sources are suspended in clusters at heights of over 20 meters. Such a design improves traffic safety by reducing the number of poles. High mast units also offer greater flexibility in pole location. (See Section 3.14.)

With the present state-of-the-art, the calculation method of luminance for high mast lighting is questionable. High mast lighting design should be based on illuminance. The method of calculation and high mast system layout principles are outlined in Appendix B, Section B5.

3.5 Luminaire spacing. The spacing of luminaires is often influenced by the location of utility poles, block lengths, property lines, and roadway geometry. It is generally more economical to use lamps with high lumen output at more reasonable spacings and mounting heights than to use lamps with lower lumen output at more frequent intervals with lower mounting heights. Higher mounting is usually in the interests of good lighting, provided the spacing-to-mounting height ratio is within the range of lighting distribution for which the luminaire is designed. The desired ratio of lowest luminance at any point on the pavement to the average luminance value should be maintained. Disregarding luminaire light distribution characteristics and exceeding maximum spacing-to-mounting height ratios can cause loss of visibility of objects between luminaires. Terminology with respect to luminaire arrangement and spacing is shown in Fig. 2.

Optimum luminaire location is best determined by reference to the photometric data showing lighting distribution and utilization. Other factors that must be considered are:

(*a*) Access to luminaires for servicing
(*b*) Vehicle-pole collision probabilities
(*c*) System glare aspects
(*d*) Visibility (both day and night) of traffic signs and signals
(*e*) Esthetic appearance

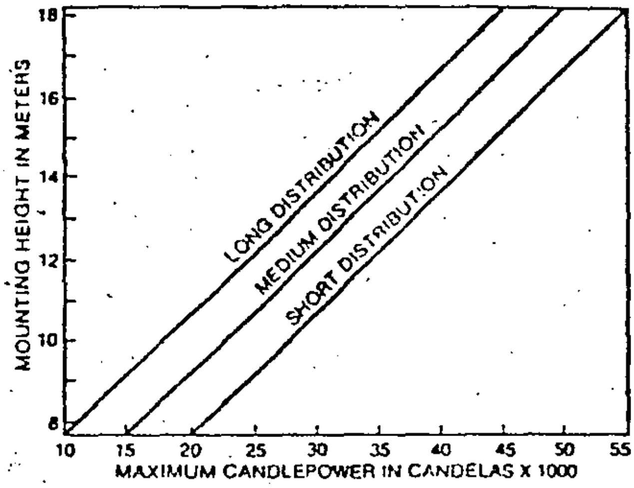


Figure 3. Minimum luminaire mounting heights based on current practice and DVB (Disability Veiling Brightness) calculations.

(*f*) Trees
(*g*) Locations of poles at intersections to allow joint use for traffic signals

3.6 Luminaire selection. (1) Luminaire light distribution classifications will help to determine the optical and economical suitability of a luminaire for lighting a particular roadway from the proposed mounting height and mounting location. A wide selection of light distribution systems are available (see Appendix E).

(2) Because a luminaire is assigned a particular classification is no assurance that it will produce the recommended quantity and quality of lighting for all roadway configurations and mountings shown in Fig. 2. The relative amount and control of light in areas other than the cone of maximum candlepower are equally important in producing good visibility in the final system, but are not considered in the classification system.

3.7 Lighting system depreciation. (1) The recommended values of Tables 2, 3, and 4 represent the lowest in-service luminance or illuminance values for the type of maintenance to be given to the system.

Prior to beginning the design of a lighting system it is necessary to determine the expected light losses.

Since the lighting values may depreciate by as much as 50 percent or more between relamping and luminaire cleaning cycles, it is imperative to use lamp lumen depreciation (LLD) and luminaire dirt depreciation (LDD) factors which are based on realistic judgment.

Pavement luminance values also may be changed by wear on the road surface, resulting in modifications of the reflectance coefficient. For example, asphalt tends to lighten due to exposure of aggregate, and Portland cement darkens due to carbon and oil deposits.

(2) There are eight general causes of luminaire light loss (see Appendix B, Section B3.2):

(*a*) Lamp lumen depreciation (LLD)
(*b*) Luminaire dirt depreciation (LDD)

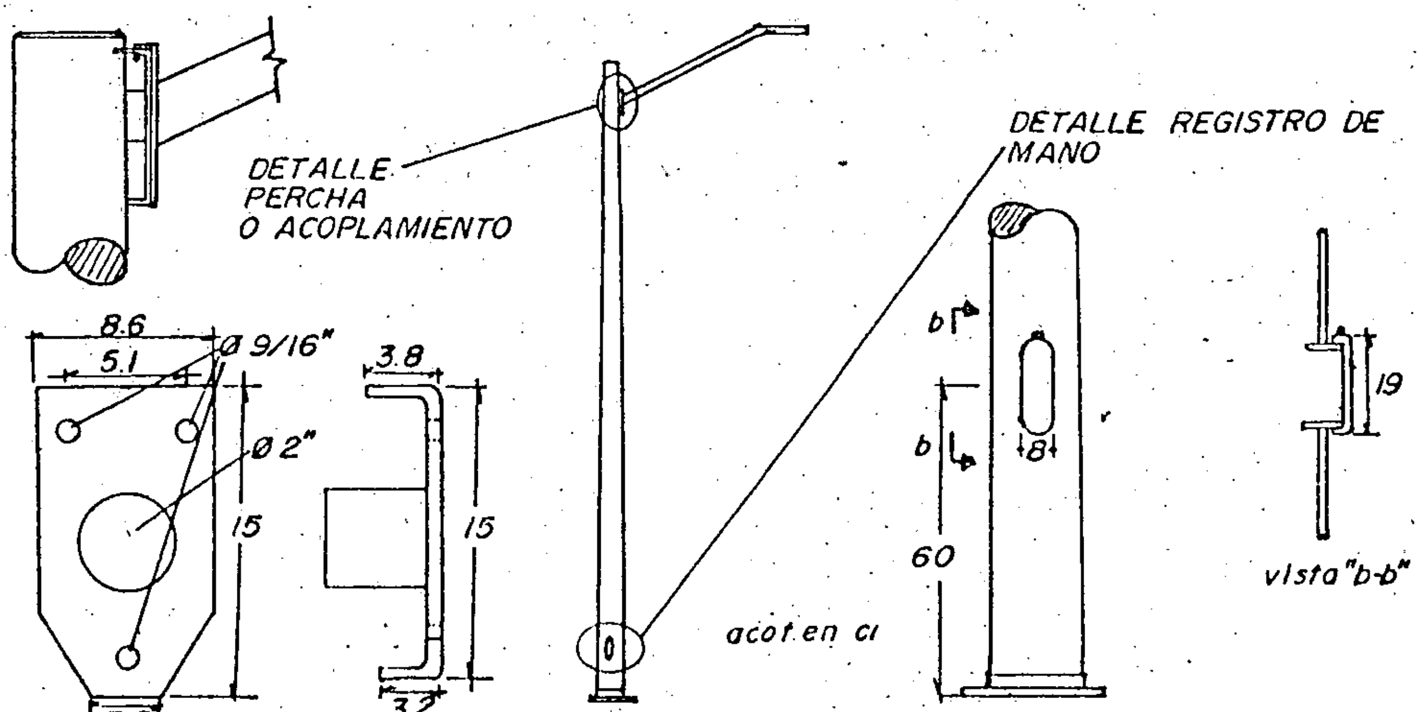
TUBO Y POSTES, S.A.

NAUTLA No. 7, ESQUINA CON CALZADA SAN LORENZO
COL. SAN NICOLAS TOLENTINO IZTAPALAPA A. P. 55-493
C. P. 09850 MEXICO, D. F.
TELEFONOS: 686-22-66 686-36-80

POSTE CHURUBUSCO CON BRAZO SENCILLO.(PAGINA 9).

ESPECIFICACIONES GENERALES.- FABRICADO CON LAMINA CALIBRE 11, LLEVANDO UN ACOPLAMIENTO PARA EL BRAZO DE TUBO RECTO EN SU EXTREMO SUPERIOR Y UN REGISTRO DE MANO A 60 CM DEL EXTREMO INFERIOR.

No. CATALOGO	ALTURA DE CAÑA (M)	ALTURA DE MONTAJE (M)	DIAMETRO DE LA BASE (CM)	DIAMETRO DE LA CORONA (CM)	DIMENSION DE PLACA-DE BASE (CUADRADA) (CM)	ESPESOR DE LA - PLACA DE BASE. (CM)	DISTANCIA ENTRE CENTROS AGUJERO BASE. (CM)
PCH- 5.00/CBS	5.00	6.00	14.0	7.5	28 X 28	1.27	19.0
PCH- 6.00/CBS	6.00	7.00	16.0	7.5	28 X 28	1.27	19.0
PCH- 6.50/CBS	6.50	7.50	18.0	7.5	28 X 28	1.27	19.0
PCH- 7.00/CBS	7.00	8.00	18.0	7.5	28 X 28	1.27	19.0
PCH- 7.50/CBS	7.50	8.50	18.0	7.5	28 X 28	1.27	19.0
PCH- 8.00/CBS	8.00	9.00	18.0	7.5	28 X 28	1.27	19.0
PCH- 8.50/CBS	8.50	9.50	18.0	7.5	28 X 28	1.27	19.0
PCH- 9.00/CBS	9.00	10.00	18.0	7.5	28 X 28	1.27	19.0
PCH- 9.50/CBS	9.50	10.50	18.0	7.5	28 X 28	1.27	19.0
PCH-10.00/CBS	10.00	11.00	18.0	7.5	28 X 28	1.27	19.0
PCH-10.50/CBS	10.50	11.50	18.0	7.5	28 X 28	1.27	19.0
PCH-11.00/CBS	11.00	12.00	18.0	7.5	28 X 28	1.27	19.0
PCH-11.50/CBS	11.50	12.50	18.0	7.5	28 X 28	1.27	19.0
PCH-12.00/CBS	12.00	13.00	18.0	7.5	28 X 28	1.27	19.0



Lumisistemas — INFORMACION FOTOMETRICA

Numero de Curva	Hoja	Fecha	Revisión
91-001			

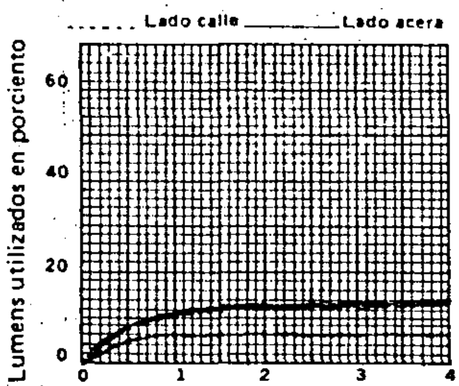
Probado por M A M fecha 24/1/91
Aprobado por ______ fecha ______
Número de Catálogo CR57F35
Descripción: CROMALITE 400
Reflector CR.
Refractor CR.
Posición del Portalámpara 1
Tipo de Lámpara LU400/U
Ansi No. S51/U

PARA 1000 LUMENS DE LAMPARA

SUCIO INTERIOR Y EXTERIOR

TIPO ANSI/IES MEDIA SEMI CUTOFF III
TIPO CIE NO CUTOFF

CURVA DE UTILIZACION



Información General
Prueba No.
Distancia de Prueba (metros) 10
Lumens de Prueba 1000
Si el número de Lumens que proporciona la lámpara es diferente de 1000 Lumens, multiplique todos los Lumens, Candelas y Luxes por el siguiente Factor :

Factor = Lumens reales de Lámpara / Lumens de Prueba

Candelas máximas	-180
Cono máximo	-72
Plano vertical máximo	-74
Candelas máximas a 90	-36
Candelas Máximas a 80	-124
Luxes en el Nadir	-34
Candelas en el Nadir	-34

Prueba Fotometrica según procedimientos de la IES

Lumenes Norm
620 - 168
Disminuyó un 73%

CURVAS ISOLUX

Relación de Distancia Longitudinal entre Altura de Montaje (180° / 90° / 270° / 0°; Posición del Luminario)

Relación de Distancia Transversal entre Altura de Montaje

		7.0	6.0	5.0	4.0	3.0	2.0	1.0	0.0	
Lado acera	2.0	00030	00040	00060	00090	00120	00220	00550	00720	
	1.5	00030	00050	00090	00160	00310	00620	01620	02070	
	1.0	00050	00070	00130	00250	00610	01790	03700	05100	
	0.5	00070	00120	00210	00450	01360	05130	08290	13020	
	0.0	00090	00170	00340	00810	02720	08680	19660	34380	
Lado calle	0.5	00120	00240	00530	01350	04250	10420	20370	2604	
	1.0	00160	00320	00680	01650	04430	07840	09150	08580	.1
	1.5	00190	00360	00730	01600	03160	04040	03460	04140	
	2.0	00210	00370	00690	01300	01740	01830	01580	02350	
	2.5	00210	00340	00570	00920	00960	00910	00980	01240	.01
	3.0	00140	00290	00450	00590	00560	00480	00530	00580	
	3.5	00160	00230	00340	00380	00350	00270	00300	00290	
	4.0	00140	00140	00250	00250	00210	00170	00190	00170	

.001

2.5 cm. / 1.25 / 0

VALORES DE FLUJO LUMINOSO

	LUMENS	PORCIENTO DE LAMPARA
LADO CALLE HACIA ABAJO	168	17
LADO CALLE HACIA ARRIBA	6	.6
LADO ACERA HACIA ABAJO	57	6
LADO ACERA HACIA ARRIBA	1.4	.1
TOTAL	232	23

Factores de Conversión

1 Lux 0.093 Footcandles
1 Metro 3.28 Pies (feet)

Los datos de Luxes estan basados en un luminario montado a diez metros de altura, para otras alturas de montaje multiplique los valores de Luxes por el Factor de corrección dado en la siguiente tabla:

Altura de montaje (m)	7.5	8.0	8.5	9.0	9.5	10	11	12	13	14	15
Factor de corrección	1.78	1.56	1.38	1.23	1.11	1.00	0.83	0.69	0.59	0.51	0.44

Número	Hoja	Revisión
91-001		

PARA LA BANQUETA DEL LADO DEL LUMINARIO

DISTANCIA LADO CASA
ALTURA DE MONTAJE

$$\frac{OD}{AM}=\frac{1.2+3}{8}=\frac{4.7}{8}=0.525 \text{ PARA UN CU}=0.09$$

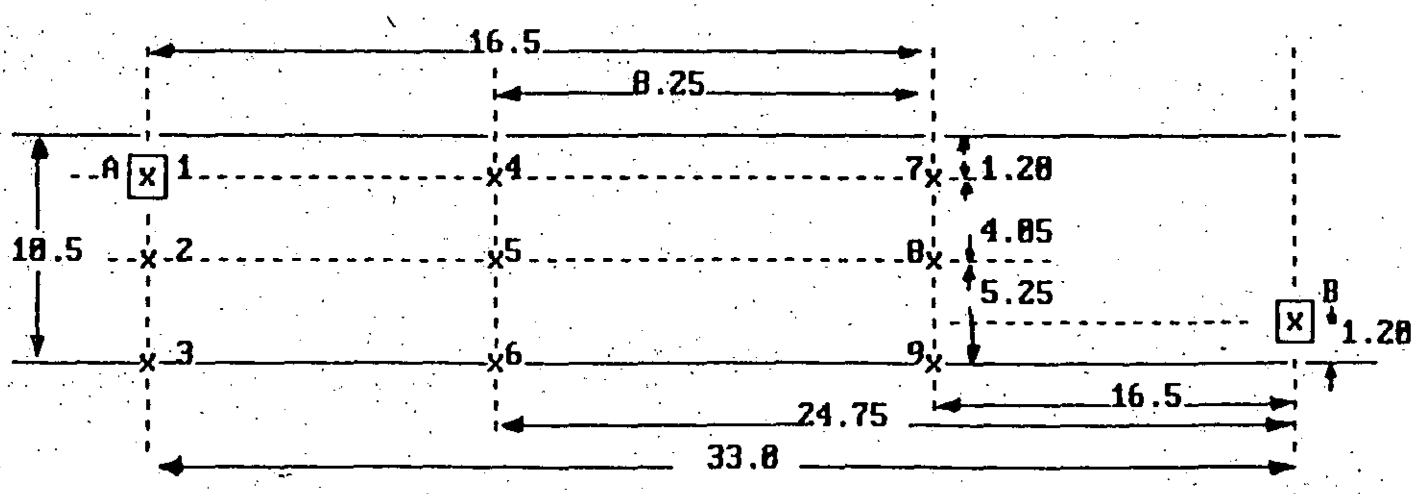
$$\frac{OC}{AM}=\frac{1.2}{8}=0.15 \text{ PARA UN CU}=0.03$$

CU NETO EN BANQUETA=0.09-0.03=0.06

POR LO TANTO EL NIVEL DE ILUMINACION EN BANQUETAS SERA:

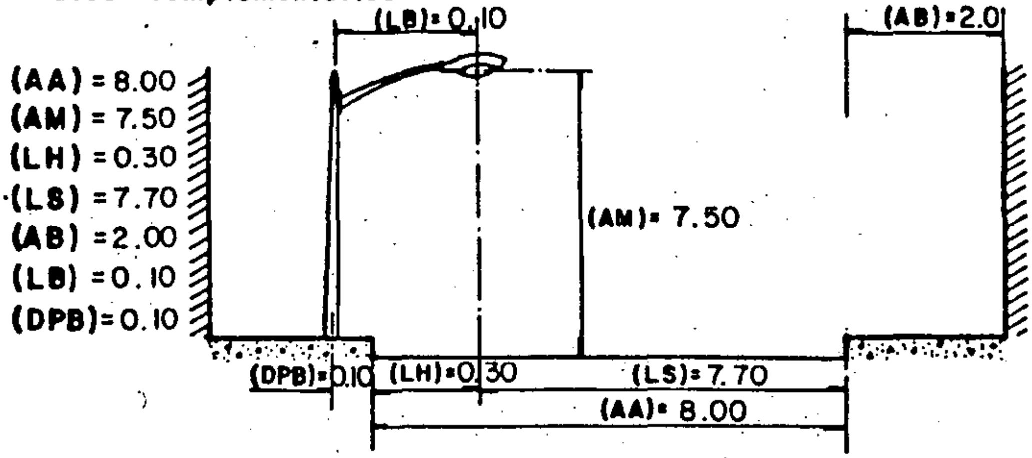
$$NIB=\frac{16000\times 0.06\times 0.62}{33\times 3}=\frac{595.2}{99}=6 \text{ LUX}$$

F.- INDICE DE UNIFORMIDAD



CIA. DE LUZ Y FUERZA DEL CENTRO S. A.
GERENCIA DE CONSTRUCCION
CALCULO DE NIVEL DE ILUMINACION

1.4 Datos Complementarios



2.- CALCULO DEL NIVEL PROMEDIO.

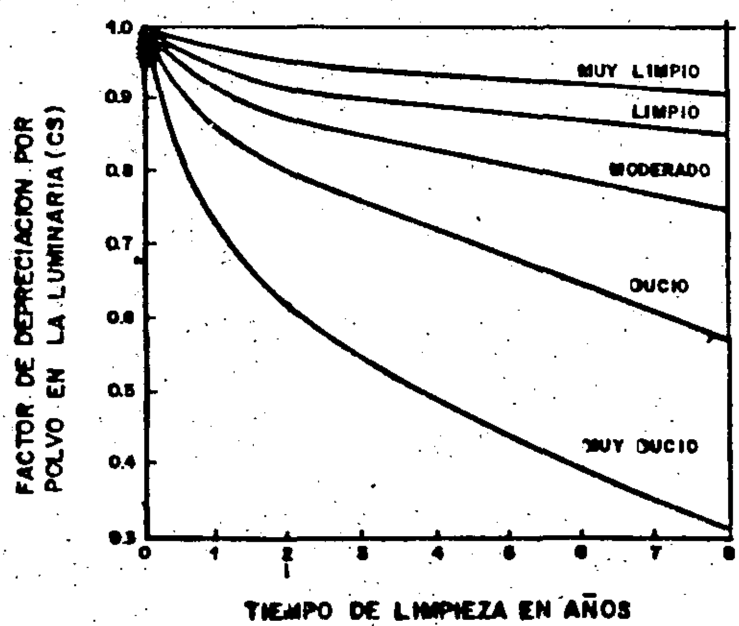
(Método de lumen)

2.1 Cálculo del factor de pérdidas totales de luz. (FPTL)

(FD) Depreciación lumínica de la lámpara al 50% de su vida (ver curvas del fabricante de lámparas) 0.9

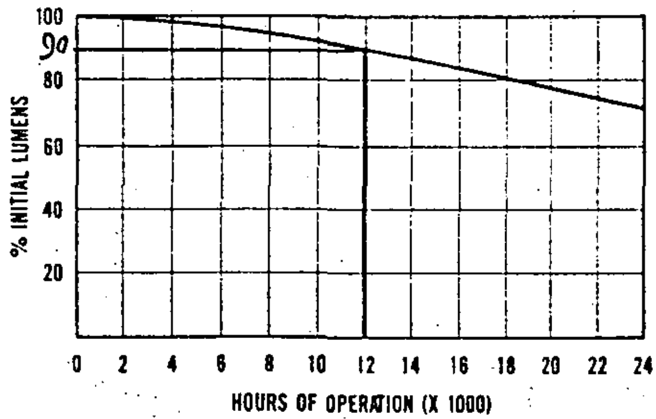
(FM) Mortandad de lámparas al 50% de su vida (ver curvas del fabricante de lámparas) 0.9

(CS) Coeficiente de depreciación (se necesitan los datos de tipo de ambiente (TA) y tiempo de limpieza (TL) para entrar a la curva. ver inciso 1.2 0.92

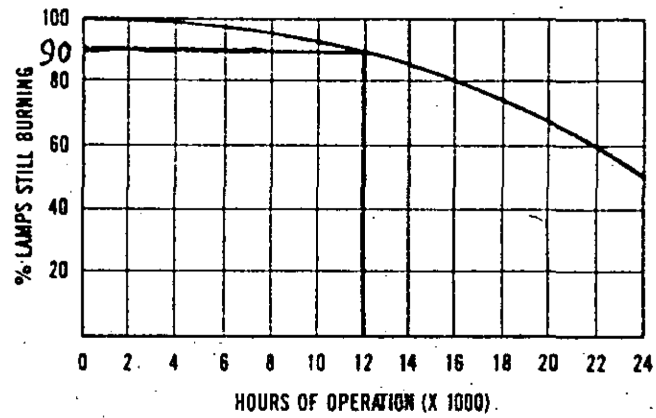


LU150

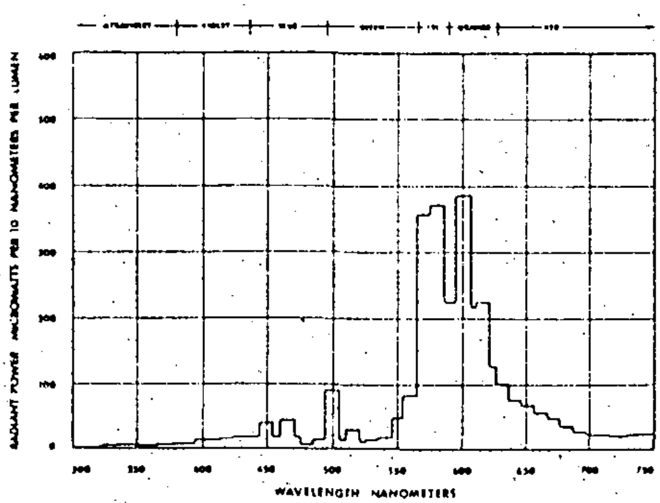
LUMEN MAINTENANCE



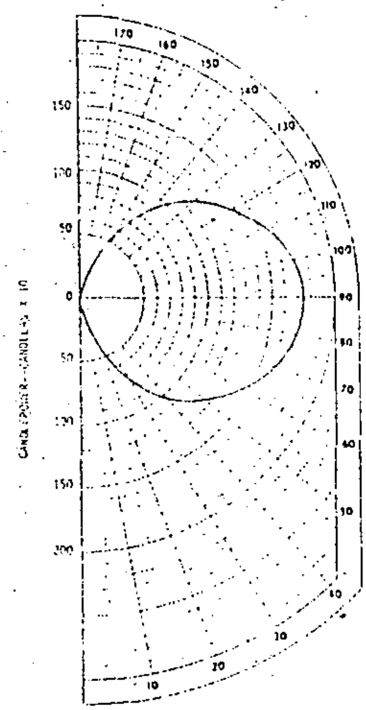
LAMP MORTALITY



SPECTRAL DISTRIBUTION



PHOTOMETRIC CHARACTERISTIC



CLEAR LAMP
PHOTOMETRIC DATA

ZONE	LUMENS	% TOTAL
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	26.9	.45
[illegible]	9.3	.15
[illegible]	[illegible]	57.8
[illegible]	[illegible]	42.2
[illegible]	[illegible]	[illegible]

CANDLEPOWER DATA AND TABULATED LUMENS ARE INITIAL [illegible]

LIGHTING B ;INESS GROUP
NELA PARK CLEVELAND, OHIO 44112

GENERAL ELECTRIC

PARA LA BANQUETA DEL LADO DEL LUMINARIO

DISTANCIA LADO CASA
ALTURA DE MONTAJE

$$\frac{OD}{AM}=\frac{1.2+3}{8}=\frac{4.7}{8}=0.525 \text{ PARA UN CU}=0.09$$

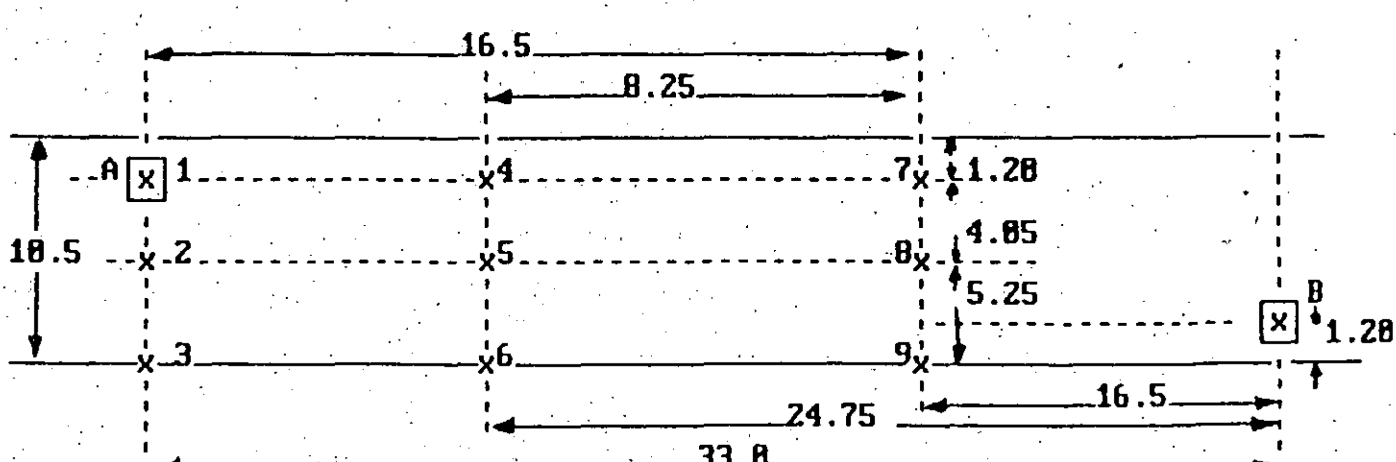
$$\frac{OC}{AM}=\frac{1.2}{8}=0.15 \text{ PARA UN CU}=0.03$$

CU NETO EN BANQUETA=0.09-0.03=0.06

POR LO TANTO EL NIVEL DE ILUMINACION EN BANQUETAS SERA:

$$NIB=\frac{16000\times0.06\times0.62}{33\times3}=\frac{595.2}{99}=6 \text{ LUX}$$

F.- INDICE DE UNIFORMIDAD



DETERMINACION DEL CU

EL COEFICIENTE DE UTILIZACION ES LA RELACION ENTRE LOS LUMENES UTILIZADOS EN EL ARROYO DE LA CALLE Y LOS LUMENES TOTALES PRODUCIDOS POR LA LAMPARA.
EL FABRICANTE DE LUMINARIOS PROPORCIONA LA CURVA DE UTILIZACION.
PARA QUE LA INFORMACION SEA USADA SE UTILIZA PARA ENTRAR A LA CURVA, LA RELACION DE DISTANCIA LATERAL O TRASVERSAL A LA ALTURA DE MONTAJE.

RELACION LADO CALLE

$$LS = \frac{\text{DISTANCIA TRASVERSAL}}{\text{ALTURA DE MONTAJE}}$$

$$= \frac{10.5-1.2}{9} = \frac{9.3}{9} = 1.033$$

$$LH = \frac{\text{DISTANCIA TRASVERSAL}}{\text{ALTURA DE MONTAJE}} = \frac{1.2}{9} = 0.133$$

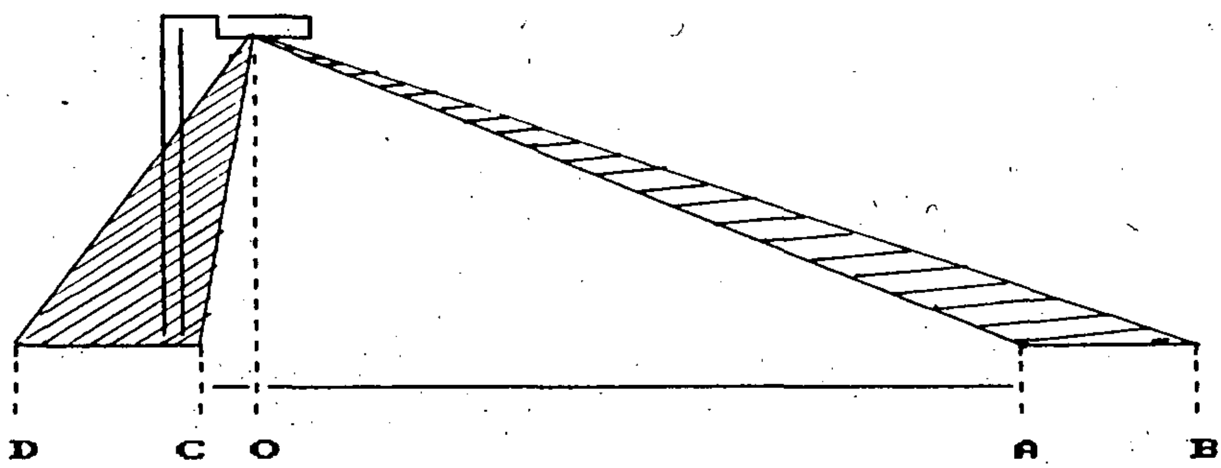
CON ESTOS DATOS ENTRAMOS A LA CURVA

RELACION 1.033 LADO CALLE CORRESPONDE UN
CU = 0.40
RELACION 0.133 LADO CASA CORRESPONDE UN
CU = 0.03
POR LO TANTO EL CU TOTAL ES "CU = 0.43"

ESPACIAMIENTO REQUERIDO

$$DIP = \frac{16000 \times 0.43 \times 0.62}{10.5 \times 12} = \frac{42656}{126} = 33.85$$

CONSIDEREMOS 33 METROS
LA DISTANCIA INTERPOSTAL



UTILIZACION EN LAS BANQUETAS

CON POSTE EN LA BANQUETA, PARA LA BANQUETA DE ENFRENTE

$$= \frac{\text{DISTANCIA LADO CALLE}}{\text{ALTURA DE MONTEJE}}$$

$$\frac{OB}{AM} = \frac{9.3+3}{8} = \frac{12.3}{8} = 1.537$$

CORRESPONDE UN CU = 0.48

$$\frac{OA}{AM} = \frac{9.3}{8} = 1.162$$ CORRESPONDE UN CU =0.42

CU NETO EN BANQUETA 0.48-0.42=0.06

NIVEL DE ILUMINACION DEBIDO A LUMINARIO "A"

PUNTO	DIST LONG	DIST. TRANS	DIST.LONG / AM	DIST.TRAN / AM	LECTURA GRAFICA	FACTOR CORRIENTE	NIVEL DE ILUMINACION
1	0	0	0	0	.132	139.4	18.4
2	0	4.05	0	0.5	.148		20.63
3	0	9.3	0	1.16	.06544		9.12
4	8.25	0	1.03	0	.06710		9.35
5	8.25	4.05	1.03	0.5	.1080		15.05
6	8.25	9.3	1.03	1.16	.05274		7.35
7	16.5	0	2.06	0	.02320		3.23
8	16.5	4.65	2.06	0.5	.04180		5.83
9	16.5	9.3	2.06	1.16	.02726		3.80

CALCULO DEL FACTOR DE CORRECCION : FC

(FL)FOOTCANDEL A LUX = 10.76

(RAM)ALTURA DE MONTAJE DE GRAFICA A ALTURA DE MONTAJE EN CAMPO

$$RAM = \frac{(AM\ GRAFICA)^2}{(AM)^2} = \frac{9.144^2}{8^2} = \frac{83.16}{64} = 1.306$$

(LL) FACTOR DE CORRECCION DE LUMENES DE LA GRAFICA (1000) A LUMENES DE LA LAMPARA UTILIZADA

16000 / 1000 = <u>16</u>

(FPTL) EN ESTE CASO FUE DE 0.62

FC=FLxRAMxLLxFPTL

FC=10.76x1.306x16x0.62

" FC = 139.4 "

NIVEL DE ILUMINACION DEBIDO A LUMINARIO "B"

PUNTO	DIST LONG	DIST. TRANS	DIST.LONG / AM	DIST.TRAN / AM	LECTURA GRAFICA	NIVEL DE ILUMINACI	TOTAL
1	33	8.10	4.1	1.01	.00375	0.522	10.92
2	33	4.05	4.1	0.506	.00264	0.368	21.00
3	33	1.2	4.1	0.15	.001234	0.172	9.29
4	24.75	8.1	3.09	1.01	.01630	2.27	11.62
5	24.75	4.05	3.09	0.506	.01670	2.32	17.37
6	24.75	1.2	3.09	0.15	.00561	0.78	8.23
7	16.5	8.10	2.06	1.01	.03140	4.377	7.61
8	16.5	4.05	2.06	0.506	.04180	5.826	11.65
9	16.5	1.2	2.06	0.15	.01945	2.71	6.51

CON UN FACTOR DE CORRECCION DE 139.4

SUMA TOTAL = 112.1

$$\frac{112.1}{9} = 12.45$$

NIVEL DE ILUMINACION POR PUNTO

" 12.45 LUX "

NIVEL DE ILUMINACION INICIAL $\frac{12.45}{0.62} =$

" 20 LUX "

NIVEL DE ILUMINACION DEL PUNTO MENOR

" 6.51 LUX "

NIVEL DE ILUMINACION DEL PUNTO MAYOR

" 21.00 LUX "

ILUMINACION ORNAMENTAL

INTRODUCCION:

Los efectos visuales de la luz solar en edificios, fachadas y monumentos, han sido de considerable importancia en el desarrollo de un proyecto arquitectónico. Las relaciones entre volumenes, planos y detalles arquitectónicos son estudiadas por los arquitectos en relación a la luz cambiante del día. La luz solar varía tanto en dirección como en calidad, dependiendo de la hora del día, temporada y condiciones climatológicas.

Durante la noche los efectos dinámicos de la luz del día no existen, resultando que la identidad de una obra se pierde a menudo, o esta resulta un conjunto de ventanas iluminadas. A veces otros elementos luminosos, tales como anuncios, alumbrado público, luz de otros edificios se reflejan en elementos no iluminados de una construcción.

Con técnicas modernas de iluminación, así como con equipos adecuados, la situación anterior no debe suceder. De hecho con iluminación que pueda ser controlada en dirección, intensidad y color, una estructura puede ser ornamentada con luz para destacar sus características arquitectónicas. Sus elementos pueden ser resaltados o disminuidos, sus detalles pueden ser enfatizados para crear diseños y texturas que normalmente no son vistas durante el día o que son dependientes de la posición del sol.

Con el énfasis actual en actividades nocturnas, recreacionales, comerciales o turísticas, la iluminación ornamental ofrece una oportunidad para crear impresiones agradables.

La iluminación ornamental se aplica tambien en los alrededores de los edificios o un grupo de ellos y más importante aún, a áreas completas de una ciudad (Centro Histórico de la Ciudad de México, por ejemplo). Se deberán establecer puntos focales por medio de las edificaciones más importantes y las edificaciones secundarias servirán de guías a estos puntos. También se pueden acusar patrones de circulación y unificar toda un área a traves de su alumbrado público y ornamental. Una iluminación bien planeada puede ser una contribución muy importante al éxito de un proyecto urbano.

Los exteriores de un edificio y sus alrededores se iluminan por dos aspectos, el utilitario y el decorativo. Esta sección se dedica únicamente al aspecto ornamental de edificios, funetes exhibiciones, jardines o cualquier aspecto que decore a un edificio.

FACTORES ECONOMICOS.

Con el alto costo de la energía eléctrica y la tendencia a optimizar su uso, la iluminación ornamental no debe descuidar los factores que pueden afectar su diseño, tales como el uso de fuentes luminosas y luminarios que sirvan a este propósito de la manera más eficiente y económica. Se debe considerar tambien los códigos eléctricos existentes y de una forma muy especial la selección de los equipos adecuados ya que la iluminación ornamental o decorativa requiere la iluminación en dos planos, el vertical en edificios y el horizontal en sus alrededores, sin descuidar el confort visual _ y la brillantez que producen los equipos sleccionados, ya que __ una mala selección, puede arruinar el efecto deseado.

La iluminación ornamental es escencialmente un arte, _ más que una ciencia y los cálculos de luminancia o iluminancia _ son necesarios, pero el éxito depende primordialmente de la ___ habilidad del diseñador para manipular relaciones de brillantez, textura, volumen y colores, de tal suerte que la iluminación ornamental ayude a crear el efecto deseado.

RECOMENDACIONES PARA EL DISEÑO

Para desarrollar un proyecto de iluminación ornamental es necesario contar con los siguientes elementos:

1.- Plano de la zona a iluminar, así como de sus alrededores.

2.- Si es posible, tarjetas postales, fotos diapositivas, perspectivas tomadas a diferentes ángulos.

3.- Alturas de los diferentes elementos (monumentos, edificios, árboles, caidas de agua etc.)

4.- Tipo color de los árboles, flores, piedras, estructura, relieve del terreno.

5.- Sentido de circulación (peatonal, vehicular)

6.- Posibilidades para la instalación de los equipos de iluminación sobre los edificios vecinos, en el piso o sobre postes.

7.- Tensión de utilización y potencia eléctrica disponible.

8.- Nivel de iluminancia de las zonas circunvecinas.

La iluminación ornalmental es un espectáculo que el observador puede ver de cerca, o de lejos, o desplazándose. Entonces es conveniente estudiar cada caso, según principios diferentes, así mismo hacer en ciertos proyectos importantes una síntesis de todos estos elementos, teniendo en cuenta el conjunto de puntos de observación.

TABLA 1

ILUMINANCIA PARA ORNAMENTO (NIVELES RECOMENDADOS)

MATERIALES DEL EDIFICIO	REFLECTANCIA DEL MATERIAL EN %	ALREDEDORES ILUMINADOS O BRILLANTES (LUX)	ALREDEDORES OBSCUROS (LUX)
MARMOL CLARO, YESO BLANCO, ZARPEO BLANCO O CREMA, MORTERO O PASTA-CLARA	70 - 85	150	50
CONCRETO O CEMENTO NATURAL, YESO PINTADO, SILLAR DE AGUA, TEPETATE O LADRILLO CLARO VITRIFICADO.	45 -70	200	100
ACABADOS DE CEMENTO GRIS, AGREGADOS DE ARENA OBSCURA, BLOCK DE CONCRETO GRIS.	25 - 45	300	150
LADRILLO ROJO COMUN, PIEDRA CAFE O GRIS OBSCURO, MADERA ENTINTADA, BLOCK DE CONCRETO GRIS OBSCURO O LADRILLO DE COLOR OBSCURO.	10 - 20*	500	200

* EN EDIFICIOS O AREAS CON REFLECTANCIAS DE MENOS DE 20%, GENERALMENTE NO PUEDEN SER ILUMINADOS DE UNA FORMA ECONOMICA, A MENOS DE QUE TENGAN UN ALTO CONTENIDO DE AGREGADOS ALTAMENTE REFLEJANTES.

EN LUGARES DE ALTA LUMINANCIA AMBIENTAL, DOBLAR LOS VALORES DE ESTA TABLA.

THE FLOODLIGHTING OF BUILDINGS

PHILIPS

Lighting Division - Market Group Outdoor Lighting

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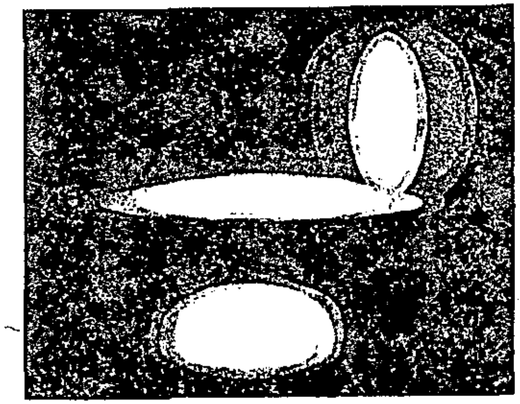

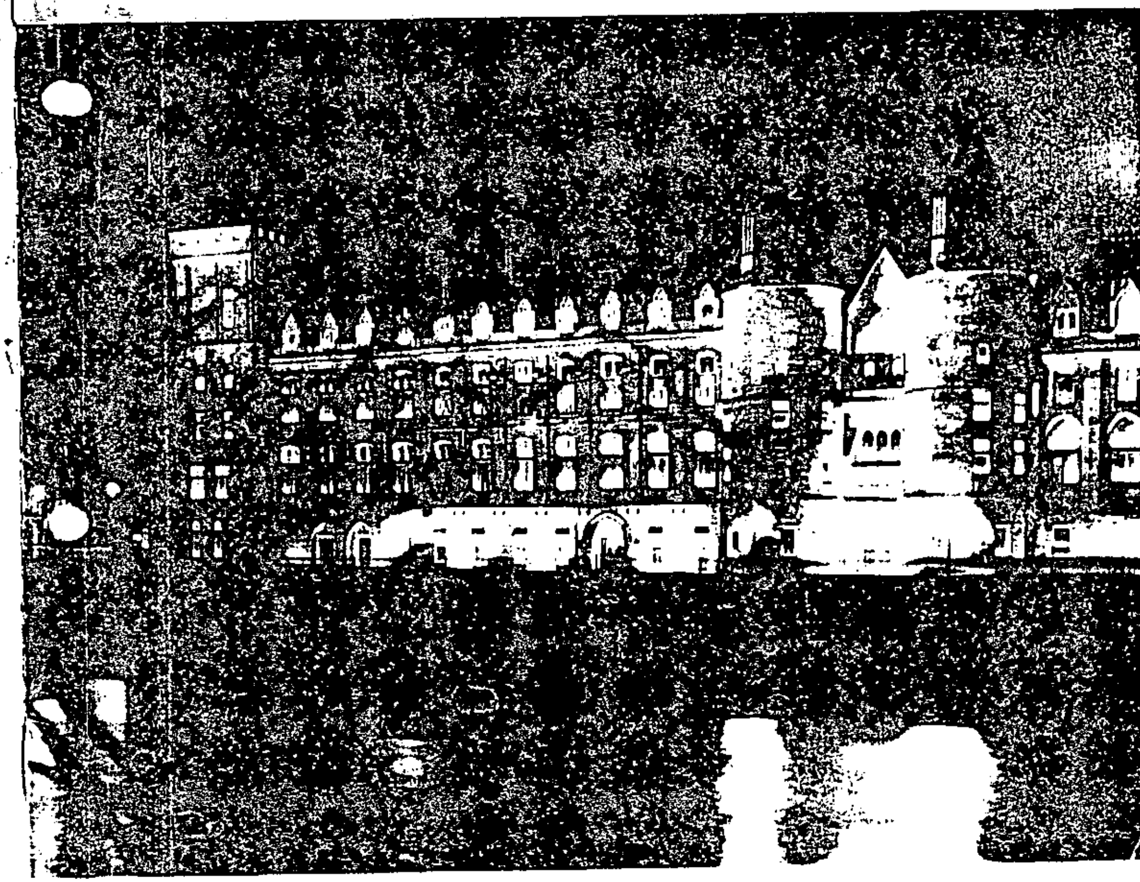

THE FLOODLIGHTING OF BUILDINGS

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TABLA 6

LUMINANCIAS RECOMENDADAS PARA LOS ANUNCIOS LUMINOSOS

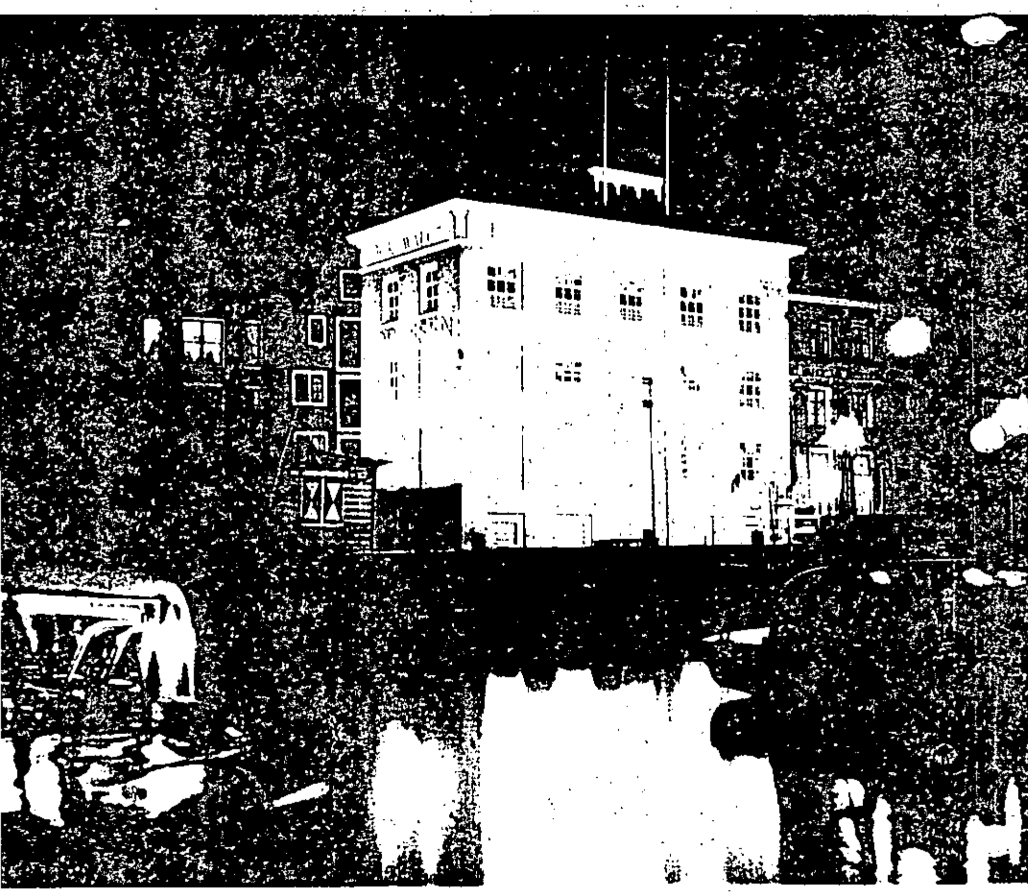
RANGO DE LUMINANCIA DEL ANUNCIO		AREAS POTENCIALES DE APLICACION
Candelas/ metro duadrado	Footlam- berts	
70 a 350	20 a 100	Fachadas y anuncios iluminados.
250 a 500	75 a 150	Anuncios brillantez iluminados como en los centros comerciales.
450 a 700	125 a 200	Areas de baja brillantez, donde anuncios son relativamente aislados, o tienen alrededores obscuros.
700 a 1000	200 a 300	Anuncios comerciales normales, tales como los de identificación de estaciones de gasolina.
1000 a 1400	300 a 400	Alto rango de anuncios y anuncios en areas de gran competencia.
1400 a 1700	400 a 500	Para control de tráfico de emergencia, donde la comunicación es crítica

FRENTES O FACHADAS DE EDIFICIOS LUMINOSOS

El mismo principio básico para el diseño de elementos luminosos se aplican en general para iluminar porciones frontales de edificios. Sin embargo las iluminancias necesarias no deben diseñarse mayores a 350 candelas por metro cuadrado (100 footlambert) de luminancia superficial.

En un área de bajo nivel de iluminación ambiental, 85 candelas por metro cuadrado (25 footlambert) de luminancia superficial será adecuada.

Fig. 1. The fine houses that line Amsterdam's canals are an unfailing attraction for thousands of tourists every year. The illuminated façades lend a special charm to evening cruises in the city's water buses. A carefully chosen and properly installed floodlighting system can give added emphasis to the special architectural or historical significance of certain buildings.



THE FLOODLIGHTING OF BUILDINGS

Introduction

There is no doubt that floodlighting a building is one of the most spectacular achievements in lighting engineering. A floodlit building is a focal point in a town, when it is dark and colours are blurred.
Formerly it was mostly buildings of historic interest that were floodlit.
Floodlighting of these old buildings, which often boast rich, ornate façades and beautiful architecture, is still very effective. Such wonderful results can be achieved that often these buildings are reinvested in this way with some of their former glory.

In addition to being used for aesthetic purposes, floodlighting nowadays can be simply functional.
This is especially true of industrial and commercial buildings where floodlighting is used for advertising and security reasons. In general, floodlighting of industrial and commercial buildings can be said to have a threefold purpose:

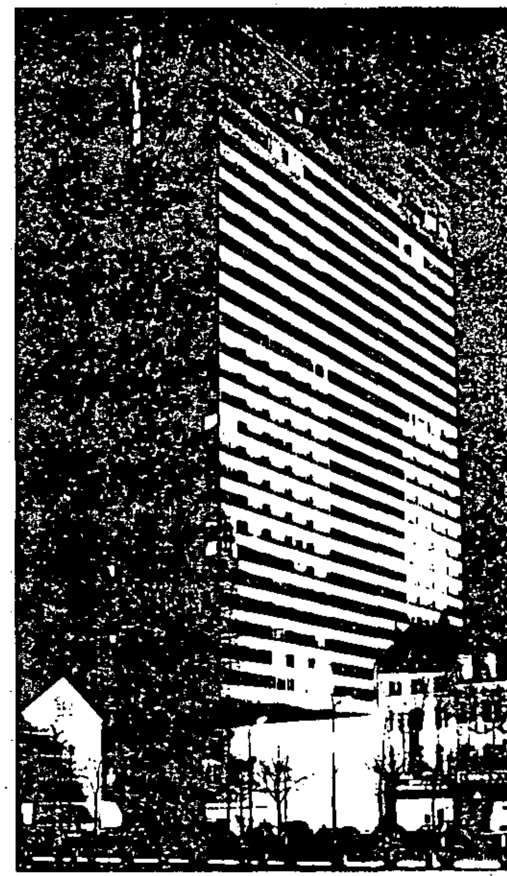
- **As a relatively inexpensive means of advertising**
  A building which at night would otherwise be completely invisible or inconspicuous, will immediately attract attention when it is floodlit.
  If the name of the firm or the trade mark is floodlit on the façade, advertising is possibly made even more effective.

- **Prestige.**
  In many cases the reason for wanting a building to be as spectacular as possible is that it is of local or national importance or has particular architectural qualities.
  After sunset, floodlighting is consequently an effective means of impressing visitors.

- **Increased security around buildings.**
  Nowadays it is unfortunately necessary to take elaborate precautions in order to prevent illegal entry, theft or wilful destruction of factory and other industrial buildings. Floodlighting in the areas around buildings enables night watchmen and police to have a clear view of the scene.

The different uses to which floodlight is put, whether they are primarily aesthetic or purely functional to achieve commercial ends, does not alter the fact that the quality of the end product should be as high as possible. Even a modern office block with a bare frontage can be made attractive by means of artificial lighting. However, it must be said that, whatever the reason, it is better to abandon the idea of a floodlight installation than to be satisfied with a mediocre result.

Fig. 2. Many cities owe much of their characteristic appearance to the high, impressive façades of office buildings, blocks of flats, hotels, etc. The impressiveness of these buildings can be accentuated during the hours of darkness by a well-planned floodlighting installation.



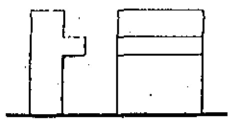


Fig 8
Left side view of section of building
Right front view of building

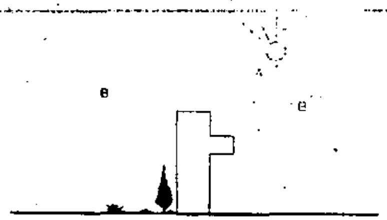


Fig 9 A Sun Point light source, small dimensions, high brightness. Creates hard shadows. B Sky Diffusor, large dimensions, low brightness. Creates soft shadows

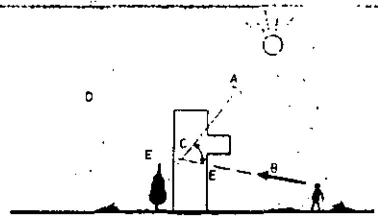
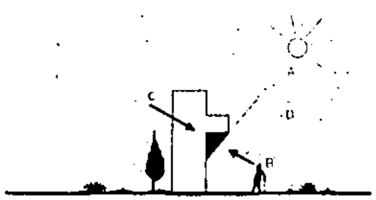


Fig 10 A Direction of sunlight. B Direction of view. C Angle between direction of light and direction of view. D Light from the sky softens sun shadow. E Shadows caused by sunlight

Fig 11. A Direction of sunlight. B Direction of view. C Shadow part opposite direction of view. D Direction of shadow.



Note

The difference in the effects which can be obtained with daylight and with artificial light are demonstrated in this brochure with a building of simple form. The front and side views are given in Fig. 8. Throughout the brochure this building is mainly used as an example in each of the figures.

DAYLIGHT

The composition of daylight

Daylight can be regarded as comprising both direct sunlight and the diffuse light of the sky (Fig. 9). Looked at from this point of view the sun is a point light source of small dimensions and great brightness. The sky, on the other hand, behaves like a very large diffuser of much lower brightness.

Daylight effects

Assuming that there is a cloudless sky and bright sunshine, two natural sources of light can thus be said to be present at one and the same time.

As a result hard shadows falling under projections on the façade and caused by direct sunlight are softened by the diffused light from the sky (Fig. 10). Fundamentally, illumination by sunlight is the ideal form of floodlighting. Sunlight streaming down on a building causes shadows to form under façade projections on the side facing the viewer (Fig. 11). The result is a never ending interplay of light and darkness on the façade, emphasizing the architectural features. For the ever available direct sunlight, the bas relief of the ancient Greek temples was already sufficient to create an interesting pattern of light and shadow on that type of sculpture. In Western Europe, however, with its often dull weather and cloudy diffuse sky, more relief was needed in the façades of the gothic cathedrals found there, in order to create the same interplay of light and shadow. This phenomenon reveals one of the first principles of floodlighting, which is that the direction of the light and the direction of view should be at an angle to one or other, preferably between 45° and 135°.

In one of the following sections this aspect will be looked at more closely.

Fig. 12 The main facade of the Old Town House, Cape Town [illegible] floodlit by narrow beam fittings from a very high office building [illegible] on the facades are similar to those caused by normal sunlight

The contrast between the façade and the background

The contrast between the façade and its background changes continuously with changes in weather conditions. When, for example, the rays of the sun fall directly on the façade and there is a cloudless sky, the façade will be brighter than the background because of the greater reflection. Sunlight falling directly on the building causes hard shadows (Fig. 13).

When the sky is cloudless but the façade receives no direct rays from the sun (a situation which may be found if the façade is facing north or if there is a skyscraper close to the building, shutting out the direct sunlight) the sky is brighter than the façade. The sky radiates light in all directions, while the façade merely reflects the light. Since the light is diffuse only soft shadows appear (Fig. 14). If the sky is clouded over, diffuse light falls on the building.

In such light a façade is less bright than the background, in that the light comes from the sky; moreover practically no shadows are seen. The façade therefore looks flat and uninteresting (Fig. 15).

In practice, of course, all kinds of combinations of the cases, which have been considered above, are possible.

It is not only the changing weather conditions and the varying contrasts between the façade and its background that are important in "daylight studies", but also the changing aspects of the building over a given period of time. For example, during the course of the day, the shadows move from one part of the façade to another owing to the continuously changing position of the sun. Generally a building is at its best in the early hours of the morning and just before sunset.

This is because the sun is low in the sky at these times and we see the contrast in colour between the sunlight, which contains much red light, and the diffused light from the sky, which contains a great deal of blue.

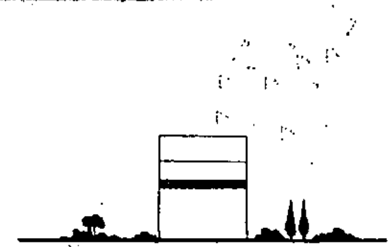


Fig 13

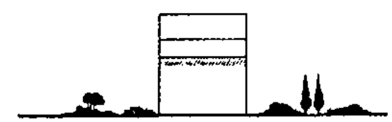


Fig 14

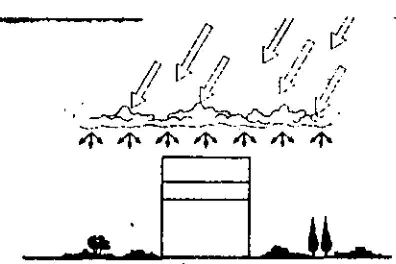


Fig 15

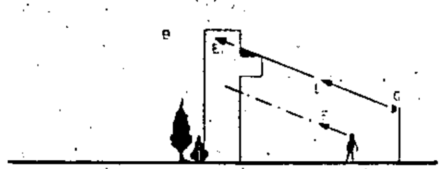


Fig. 16
A. Dark background
B. Brightness of the building is greater than the brightness of the black sky
C. Artificial light source.
D. Direction of light.
E. Direction of shadow
F. Direction of view.

Fig. 17. The manner in which an important monument, like this church, is illuminated depends on such factors as the direction and distance from which the building is viewed, the building's background and the presence of trees, gates, stretches of water, etc., in the vicinity.

Mental image

It is possible to imagine, that, in studying a building, the lighting expert may be attracted at a given moment by a certain striking effect and that this mental image sticks in his mind as the effect he would like to retain.

This "mental image", i.e. the lighting expert's conception of the building when floodlit, is in many cases the initial point of departure for a floodlighting design. Proceeding from this mental image he must translate the natural lighting effect, which he has seen, into an artificial lighting effect. One of the first things to be noted is that at night the position of the light sources is completely different from the daytime situation. Whereas the natural light sources illuminate the building from above, artificial light sources are generally placed low down near the building or a little higher on an adjacent building.

A comparison of Fig. 11 and Fig. 16 will make this abundantly clear. Thus a clear idea of how the installation is to be carried out may be gained by methodically collecting all details relevant to the possible positions of light sources, the appropriate fittings and lamps, the reflecting properties of the surface material of the façade, the various points from which the building can be observed, etc.

CARRYING OUT A FLOODLIGHTING PROJECT

The following points should be considered when planning a floodlight installation.

Direction of view

Decide on the main direction from which the building is viewed. Generally there will be several, but often one can be decided upon as the main direction of view.

Distance

Decide on the normal distance between the viewer and the building, based on the main direction of view. Whether one can see all or none of the architectural details on the façade will depend on the distance chosen.

Surroundings and background

Obtain a clear idea of the background against which the building will be seen. If the surroundings and background are dark a relatively small amount of light is needed to make the building lighter than the background (Fig. 18).

If there are other buildings in the close vicinity in which interior lighting is left on at night, the lighted windows will give an even greater impression of brightness and therefore more light will be needed for floodlighting the building if it is to have an impact (Fig. 19). The same is true if, in addition, the background is bright. In such cases a maximum amount of light is needed to achieve the contrast between the building and its background (Fig. 20). The actual values of the lighting intensities to be used will be dealt with in the following chapters. Another solution for the two last-mentioned cases can be found in the creation of a colour contrast instead of a brightness contrast. The colours of the light already present in the background of the building, even street lighting, must then be taken into consideration.

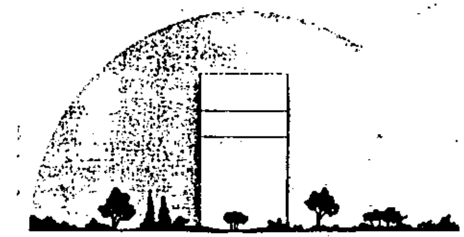


Fig. 18

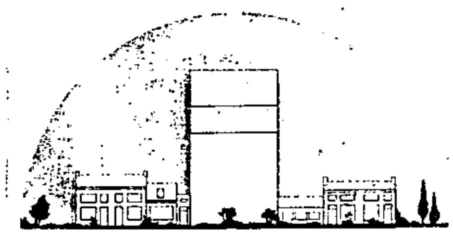


Fig. 19

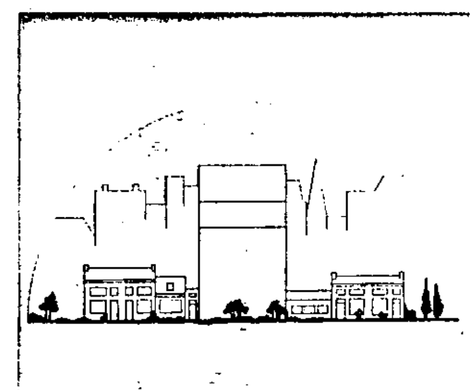


Fig. 20

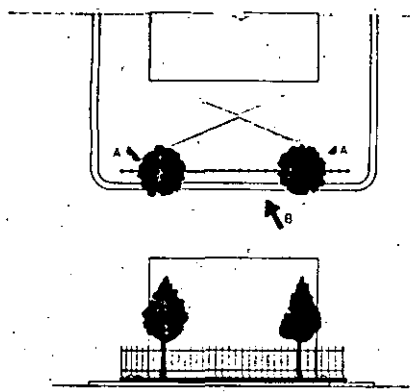


Fig. 21.
A Light sources.
B Direction of view.

Obstacles

Trees and fences around the building can form a decorative part of an installation. An attractive way of dealing with these is to place the sources of light behind them.
Two advantages are gained: firstly the light sources are not seen by the viewer, and secondly the trees and fences are silhouetted against the light background of the façade. The impression of depth is therefore heightened (Fig. 21).

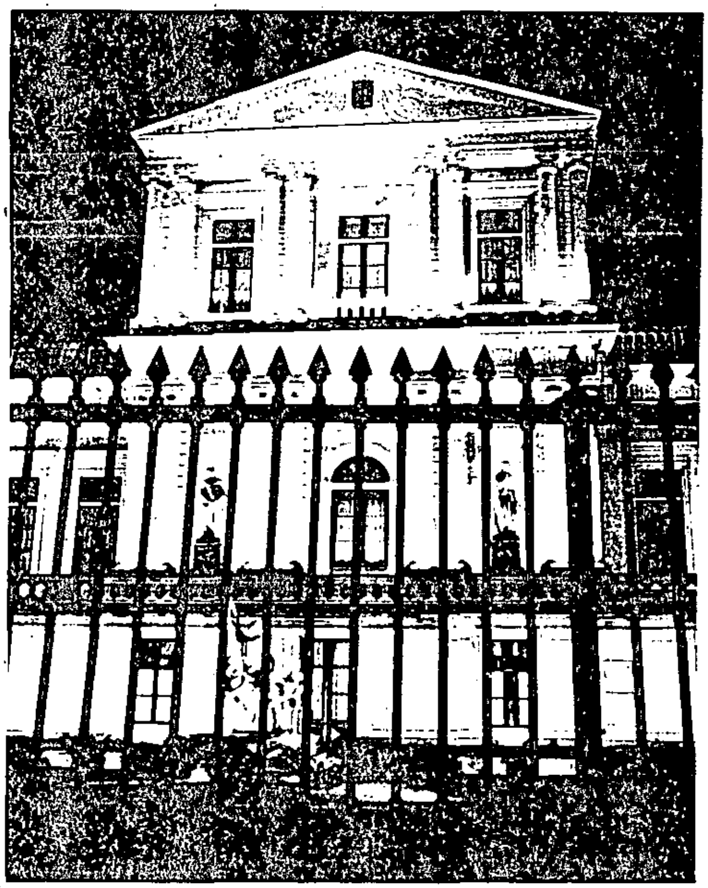


Fig. 22

Fig. 22. Attractive contrasts and a pleasing effect of depth can be achieved by locating the light sources between the façade and, for example, a decorative gate or railings.

Fig. 24. Buildings situated beside water are rewarding subjects for a floodlighting arrangement. Care must be taken to ensure that the floodlight fittings are not installed directly in the field of vision, where they are liable to produce unwanted brightness and reflections.

Water

The design can also take advantage of any expanse of water in the vicinity, such as a pond or canal. The lighted building will be reflected in the water, which serves as a "black mirror" (Fig. 23). The following points should however be borne in mind when setting up the light sources in such a case:

- the rays of light must not strike the surface of the water; this must be left totally dark
- it is advisable to place the light sources as low down as possible; the rays are then either horizontal or slanting upwards
- the water must be clean; slime or weeds floating on the surface of the water will weaken and distort the reflection.

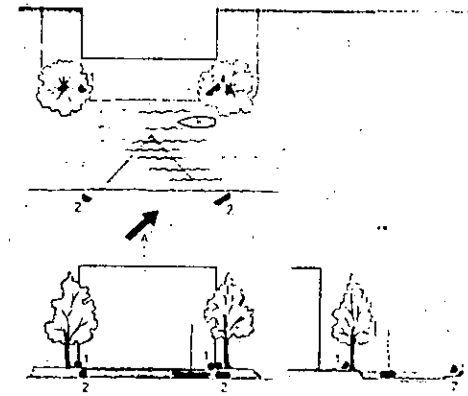


Fig. 23. 1. Light sources, 2. Light sources, A. Direction of view.
With arrangement 1, care should be taken to ensure that no light strikes the surface of the water or trees.

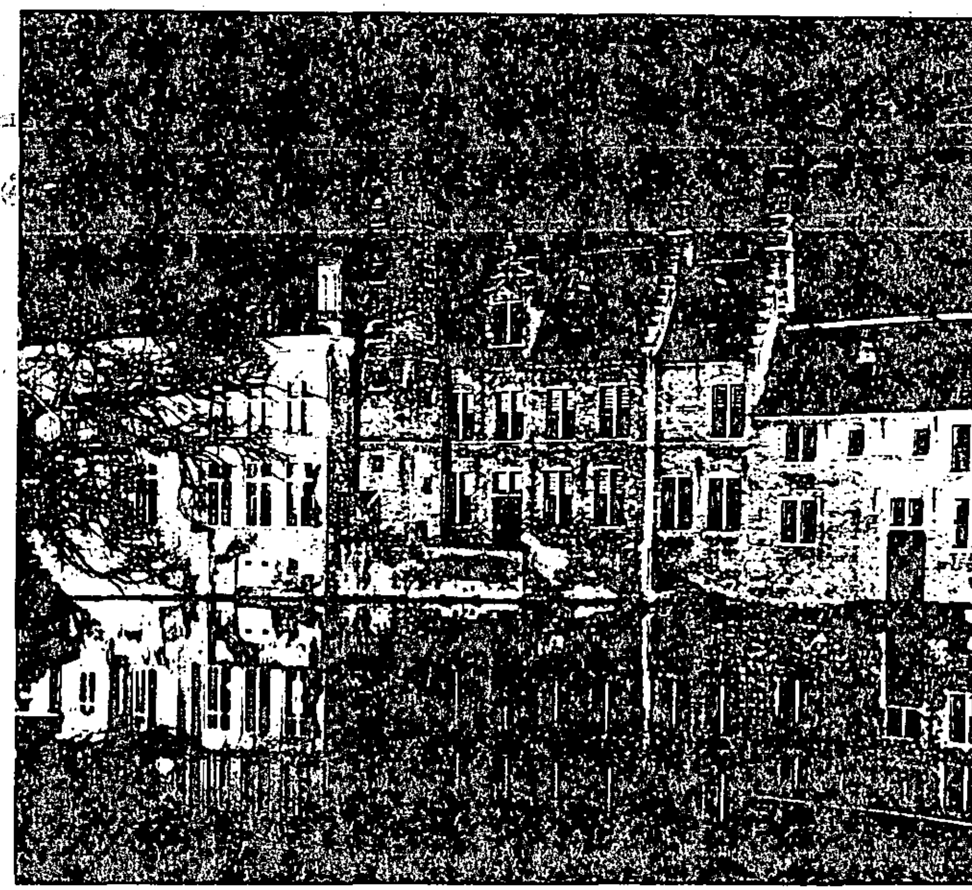


Fig. 24

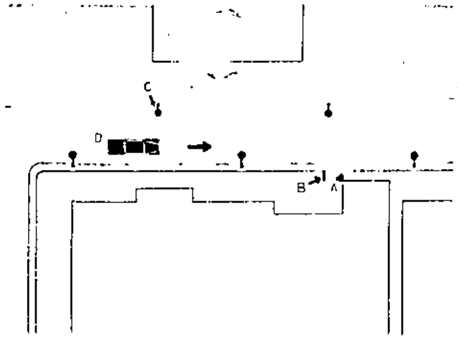


Fig. 25
A Floodlight fittings.
B Screen to prevent glare in the direction of drivers
C Street lighting
D Traffic.

Fig. 26 To illuminate tall factory chimneys, floodlight fittings with highly concentrated beams are needed. The fittings shown here are installed within easy access, on a steel frame, thus permitting accurate adjustment of the beam and simplifying maintenance.

Figs. 27 and 28 The floodlight fittings must be set up in such a way that they are as unobtrusive as possible in the daytime. The installation has to be readily accessible for ease of maintenance.

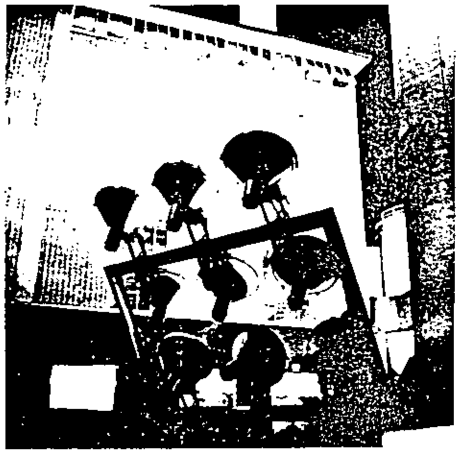


Fig. 26

Setting up the light sources

One of the most important points in designing a floodlight installation is to investigate all the possible ways of setting up the light sources. There are many alternatives for mounting, for example:

- on street lamps or other posts specially erected for the purpose
- on a penthouse roof
- on brackets on the house front
- on the ground behind flower-beds, bushes or copses etc.

If the building is located along a main road it must be borne in mind that the lighting must not hinder the traffic. Fittings should be well screened from the drivers of oncoming vehicles (Fig. 25). In order to set up the light sources in the most advantageous position it may be necessary, in certain cases, to call in the help of the town council or the owner of the adjacent or opposite property where, for instance, local conditions may prevent the light sources from being set up on the actual site.

Fig. 27

Fig. 28

The form of the building

Once the main direction of view has been chosen, the choice of direction of the light depends on the shape of a building or rather the form of its ground plan or horizontal section.

The position of the light sources which are to cover the building may then be more or less fixed.

In theory it is possible to reduce all ground plans of buildings to simple geometrical figures: square, rectangular or round. In the case of complex structures, the ground plan can be thought of as a group of such figures. For buildings with a square, rectangular or circular ground plan a basic lay-out exists which, in virtually all cases, leads to good results. It has been found that the best light-source lay-out for a square building is that shown in Fig. 29.

The main direction of view is indicated by line A-A, the position of the light sources by the points B-B. If the light sources are placed to one side of the diagonal, perpendicular to A-A, the effect achieved is a good contrast in brightness between the two adjacent sides of the building, resulting in good perspective. The slanting beams between the floodlight also make the most of the texture of the surface material. The arrangement described for a square building is also applicable to a building with an oblong or rectangular ground plan (Fig. 30).

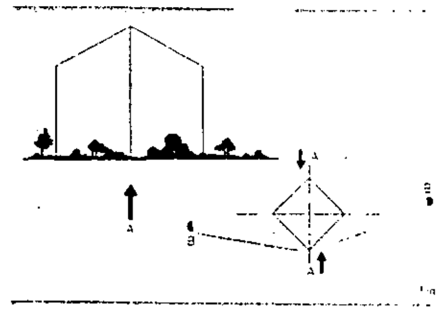


Fig. 29

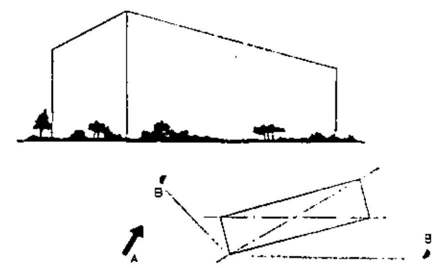
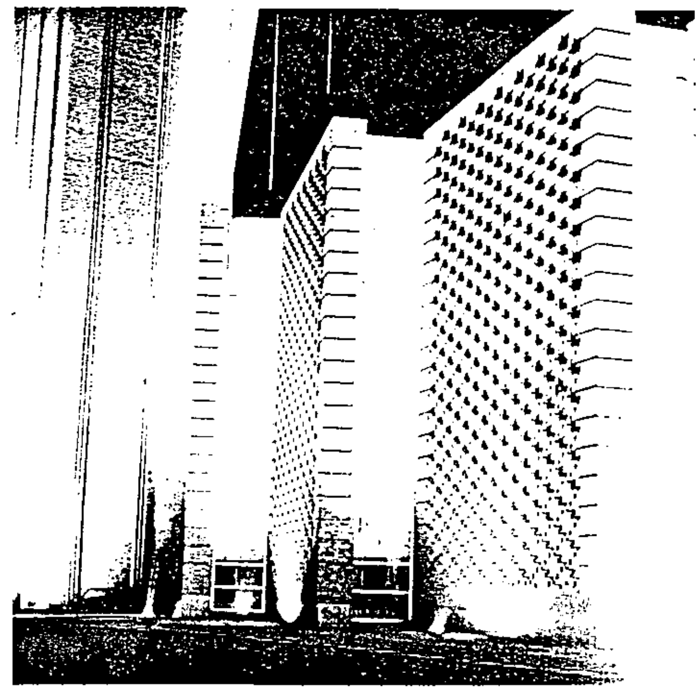


Fig. 30

Fig. 31. Some façades are set off with a special pattern in relief on the masonry. A pleasing interplay of light and shadow can be achieved by lighting from one side with concentrated beams of light.



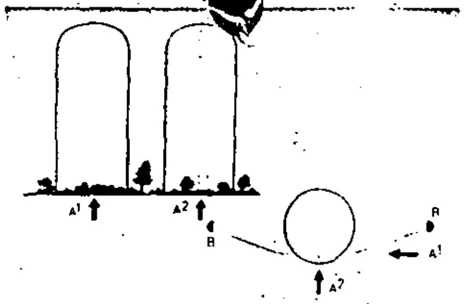


Fig. 32

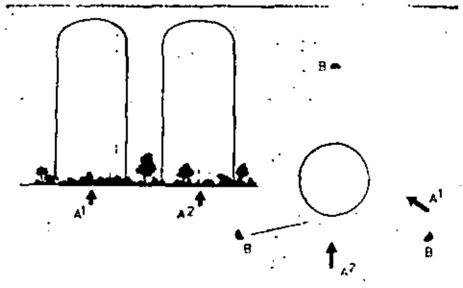


Fig. 33

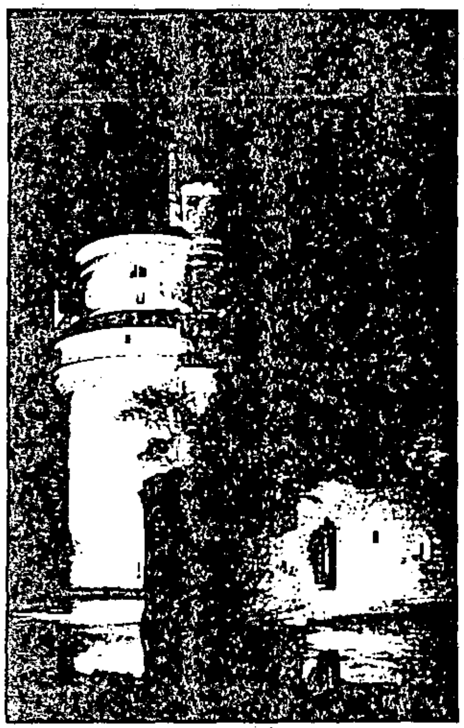


Fig. 34

Figs. 34 and 35. The rounded forms of towers are only visible as such if, in addition to highlights, shadow effects are achieved. These can be obtained by installing the floodlights to the side of the main direction of view. The glancing light of the beams then produces a widening pattern of brightness which clearly brings out the rounded form.

Fig. 35

The examples described here stress the principle already stated, namely that the direction of the light and the direction of view must be at a certain angle to each other, so that the illuminated front of the building looks as attractive as possible.

The characteristics of the façade show to best advantage when the incident light is at an angle smaller than 90°. No definite angle can be given; on the horizontal and vertical planes the angle may vary between 0° and 90°, calculating from the vertical to the façade. For a deep profile the angle should be between 0° and 60°, for a flat profile between 60° and 85°. In order to show the structural details of the façade to advantage scattered light should be used, incident at an angle of 80° to 85° to the vertical.

The situation is somewhat different in the case of round buildings, such as round towers or chimneys; here it is not so much a matter of accentuating the texture or the profile of the façade but more of emphasizing its rounded form. This effect can be achieved by means of narrow-beam or medium-beam floodlights set up at two or three points around the tower, the beams directed upwards as high as possible. It may then be assumed that the narrow beams of light reach the tower as more or less parallel rays, forming a strip of light over its entire height.

Because of the roundness of the tower, the angle of incidence varies between 0° and 90°, calculated from the middle outwards to the edges. Consequently the direction of the reflection and also the brightness of the tower wall are both affected. Thus a variation in brightness is effected around the circumference of the tower-wall and this impression of depth emphasizes the roundness. Fig. 32 illustrates the positioning of two batteries of floodlights, B; the directions of view, A1 and A2, can either be taken parallel or perpendicular to the direction of the light.

Fig 38. Office building with clear-cut vertical lines. The tall façade calls for floodlight fittings that give a narrow beam. An excellent glancing-light effect is obtained with an asymmetrical location of the light sources.

Fig 39. The use of floodlights with broad beams for illuminating low buildings has the advantage that high luminance and a very even light distribution can be obtained with fewer fittings located a short distance away from the building.

Fig 36. A Wide-beam floodlights

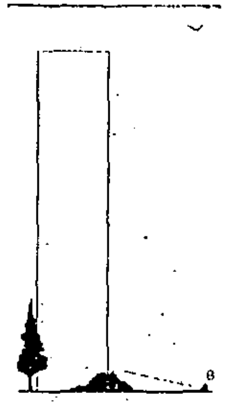


Fig 37. B Narrow and medium-beam floodlights

The installation set up for three batteries of floodlights, B, is given in Fig. 33. Here two main directions of view, A1 and A2, are possible: one parallel to the direction of light of one of the batteries of floodlights and one from a point between the two batteries. If the positioning of the floodlight batteries principally depends upon the shape of the ground plan of a building, the type of fitting to be used, in particular the width of the beam is mainly determined by the height. Wide-beam floodlights are the most appropriate light sources for low buildings with one or two storeys (Fig. 36).

In the case of high buildings, with 8 to 12 or even more storeys, the best results are obtained with a number of narrow-beam and medium-beam floodlights (Fig. 37).

Uniform brightness is achieved by careful distribution of the beams over the façade and proper adjustment of the floodlights.

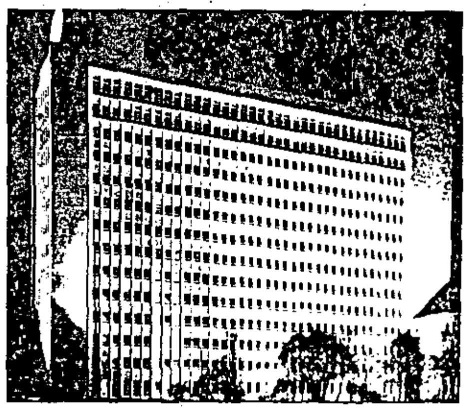


Fig. 38

Fig. 39.

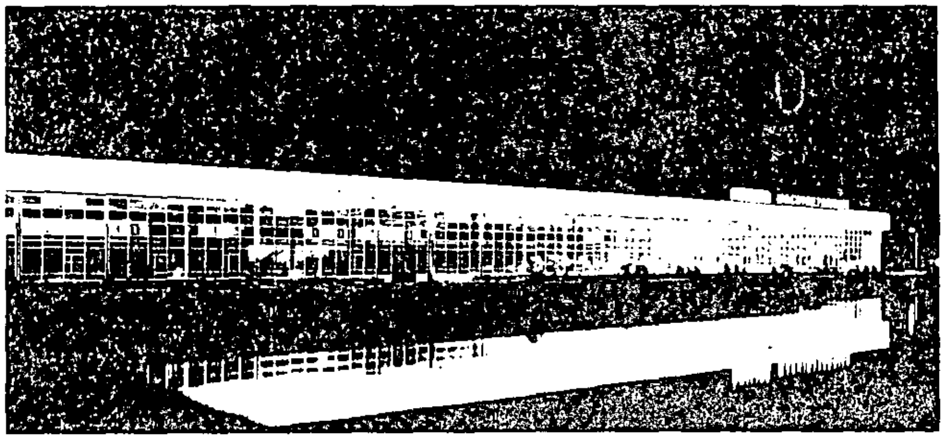


Fig. 50. The halogen floodlights used to illuminate this church tower in Berne, Switzerland, are set up on the balustrades of the tower itself. The decorative profiling is given extra emphasis by the powerful glancing light from narrow-beam light sources installed against the tower, while each segment of the tower receives an attractive widening pattern of brightness.

Figs. 51, 52, 53 and 54. The great variation in architectural forms of buildings makes standard floodlighting installations practically impossible. Apart from the general principles of lighting engineering, every building presents its own specific requirements. A specialized knowledge of the entire subject of floodlighting and of the equipment available is therefore essential before reliable advice can be given.

Fig. 50

SURFACE MATERIAL OF THE FAÇADE

In determining the illumination level needed for a façade, in order to obtain the required brightness, the reflection factor and the way the building surface material reflects the light are important factors to be borne in mind. The table below indicates the reflection factors of a number of different materials.

Material	State	Reflection factor
White marble	fairly clean	0.60 - 0.65
Granite	fairly clean	0.10 - 0.15
Light concrete or stone	fairly clean	0.40 - 0.50
Dark concrete	fairly clean	0.25
or stone	very dirty	0.05 - 0.10
Imitation concrete paint	clean	0.50
White brick	clean	0.80
Yellow brick	new	0.35
Red brick	dirty	0.05

The total reflection from a façade depends on the following points:

- the material of the façade
- the incident angle of the light
- the position of the observer in relation to the reflecting material (specular reflections).

The colour of the material is also an important factor.
The colour of the surface material is accentuated if light of the same colour is used.

A distinction can be made between diffuse reflection and specular reflection and of variations between the extremes. These different types of reflection are due to the particular surface textures of the different materials. Four classes of surface may be distinguished (see page 22).

Fig. 51

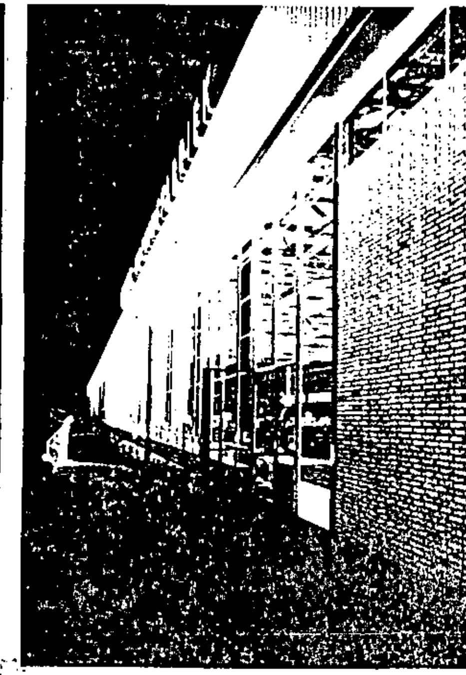


Fig. 52

Fig. 53

Fig. 54

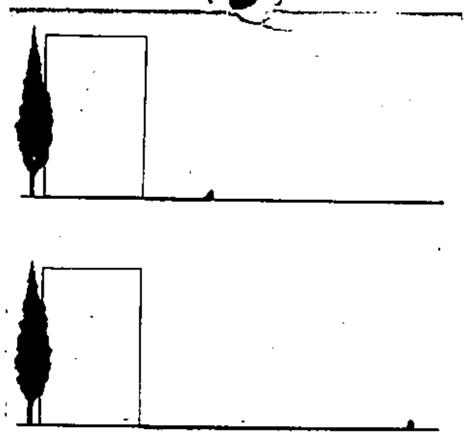


Fig. 60

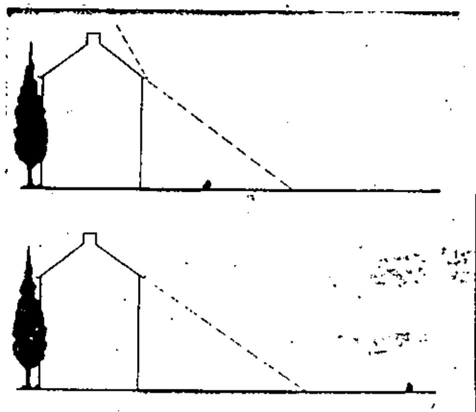


Fig. 61

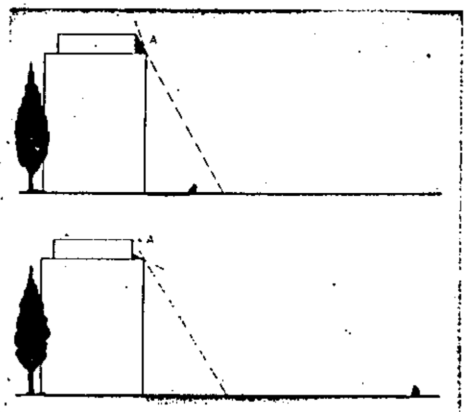
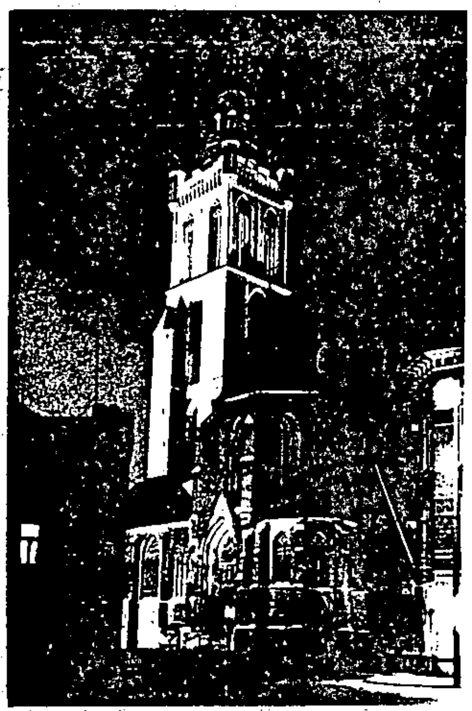


Fig. 62

Fig. 63. To accentuate the sharp corner lines of this tower and achieve a good contrast effect between the various surfaces, different sized groups of floodlight fittings have been directed at the tower. A very attractive sensation of depth is achieved with a clear difference of brightness between the tower and the church building.



SELECTION OF THE LEVEL OF ILLUMINATION

The lighting level needed on a façade to effect a certain brightness contrast depends upon such factors as the reflection factor of the surface building material, the location of the building in relation to its surroundings, the general brightness of these surroundings and the dimensions of the building. The table below presents some recommended illumination levels for various surface building materials used on buildings in either poorly lit, well lit or brightly lit surroundings.

Type of surface	State	Illumination in lux: poorly lit surroundings	well lit surroundings	brightly lit surroundings
White marble	fairly clean	25	50	100
Light concrete	fairly clean	50	100	200
Imitation concrete paint	fairly clean	100	250	400
White brick	fairly clean	20	40	80
Yellow brick	fairly clean	50	100	200
White granite	fairly clean	150	300	600
Concrete or dark stone	fairly clean	75	150	300
Red brick	fairly clean	75	150	300
Concrete	very dirty	requires at least 150 - 300		
Red brick	dirty	requires at least 150 - 300		

Methods of calculation

There are two possible ways of calculating the types and numbers of floodlights needed to achieve the desired illumination; the lumen method and the luminous intensity method. For a large façade the lumen method should be used. This is based upon a certain average luminous efficiency. For high and small objects, church steeples, chimneys, etc., the luminous intensity method should be used. This is based on the luminous intensity radiation in a certain direction.

Lumen method

As the name suggests, this method consists in calculating the number of lumens to be directed on to a façade in order to obtain a certain illumination level.

The number of lumens can be calculated by means of the formula:

$$\Phi_t = \frac{F \times E}{\eta}$$

where Φ_t is the total number of lamp-lumens, i.e. the total luminous flux produced by all lamps,

F is the surface of the façade to be illuminated in m^2,

E is the desired illumination in lux on that façade, and

η is a factor which takes into account the efficiency of the fitting and the light losses (luminous efficiency).

The presence of a utilization factor in this formula indicates that not all the lamp lumens contribute to the illumination level on the façade. The lumens produced by the lamps are concentrated by reflectors, in which process some loss is involved. If the initial output is 100 % lamp lumens, 60 to 75 % are projected through the lighting equipment and 40 to 25 % are lost in the fitting itself through interreflection in the reflector and absorption by other parts of the fitting.

After the floodlight has been in operation for some time, a further percentage of the actual number of lamp lumens is lost because of the decrease in luminous flux due to the ageing of the lamp and dirt which collects on the lamp and fitting.

Finally a percentage of the losses is accounted for by wasted light, that is light not incident to the building façade. In practice an average utilization factor varying between 0.25 and 0.35 may be reckoned with. Using this figure in the formula given above, the total luminous flux needed, Φt, can be calculated. Once the total number of lumens is known, the number of fittings (N) needed can be calculated by dividing this amount by the number of lumens installed per fitting:

$$N = \frac{\Phi\ total}{\Phi\ fitting}$$

Note: If fittings are equipped with two lamps, Φ fitting is twice Φ lamp.

A more accurate determination of the required luminous flux calls for more extensive and complicated calculations. These are carried out by computer with the aid of photometric data on the fittings used.

Luminous intensity method

In this method the starting point is the luminous intensity, in candela, radiated by a light source in a particular direction. This luminous intensity may be derived from the luminous intensity diagram or from a table. This data can usually be found in the appropriate catalogue and brochures.

The calculation is made with the formula (Figs. 64 and 65):

$$E = \frac{I}{h^2} \cdot \sin^2 \alpha \cdot \cos \alpha \text{ and } tg\,\alpha = \frac{h}{D}$$

where E is the vertical illumination on the façade,

I is the luminous intensity at the angle α,

h is the height of the object above the level on which the fittings are arranged, and

α is the angle at which the light beam strikes the normal on the plane to be illuminated.

Fig. 64

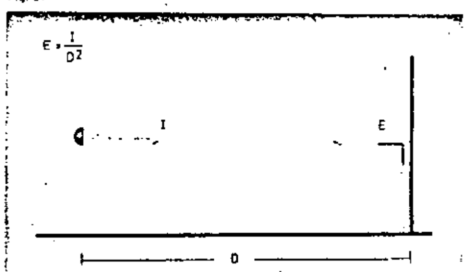
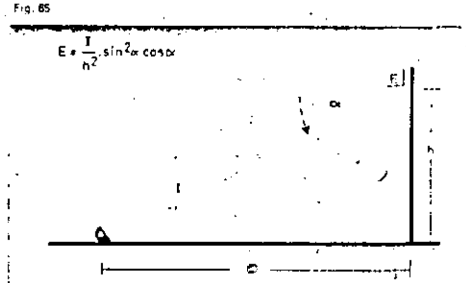


Fig. 65



2

APENDICE 2

NORMAS DEL D.D.F.

- Normas para levantamientos topográficos y localización de postes y arbotantes para alumbrado público/Dirección General de Servicios Urbanos/Sección de Normas y Especificaciones/Octubre de 1973.

- Normas de Obra Civil/Dirección General de Servicios Urbanos/Sección de Normas y Especificaciones/Octubre de 1963–Noviembre de 1974.

• NORMAS PARA LEVANTAMIENTO TOPOGRAFICO Y LOCALIZACION DE POSTES Y ARBOTANTES PARA ALUMBRADO PUBLICO.

I. LEVANTAMIENTO PARA POSTES DE ALUMBRADO PUBLICO

1. GENERALIDADES

1.1 Información preliminar

Al topógrafo designado para el levantamiento topográfico de una Red de Alumbrado Público, se le deberá proporcionar la información completa, acerca de la localización general de los puntos iniciales y terminales de la Red de Alumbrado Público, del tipo de postes, levantamiento de primera o de segunda importancia, según párrafos 2.1 y 2.2, datos que serán comunicados por la Ofna. de Alumbrado Público.

1.2 Reconocimiento de terreno

El topógrafo procederá junto con un representante de la Ofna. de Alumbrado Público un reconocimiento del posible trazo, teniendo en cuenta los siguientes puntos:

1.2.1 Tipo de levantamiento por efectuar.

1.2.2 Fijación de puntos obligados.

1.2.3 Evitar en lo posible accidentes topográficos.

1.2.4 Considerar la localización que parezcan convenientes por razones técnicas o por facilidades de paso.

1.2.5 Indicar las alternativas que parezcan convenientes por razones técnicas o por facilidades de paso.

1.3 Trazo preliminar

Realizado el reconocimiento general del terreno, se efectuará un trazo preliminar sin detalles, que permitan a la Oficina de Alumbrado Público formarse una idea aproximada, de la localización, dirección y longitud de la futura red de Alumbrado Público.

El trazo se indicará en un croquis que contenga además:

1.3.1 Los terrenos atravesados y dificultades encontradas.

1.3.2 Las calles que toca el trazo y la cercanía a otras.

1.3.3 Líneas eléctricas, de telecomunicación, cruzadas o paralelas al trazo a una distancia menor de 100 mts. a cada lado de la red de alumbrado público.

1.3.4 Obstáculos que condicione el trazo (casas, canteras propiedades cerradas, etc.).

382 El croquis se elaborará a una escala de 1:______* para redes de alumbrado público de ______Km. de longitud y 1: ______ para mayores.

1.4 Recomendaciones para el trazo.

Durante el reconocimiento y el estudio para el trazo, el topógrafo deberá tener presente las recomendaciones siguientes:

1.4.1 Realizar alineamientos lo más largo posible y evitar ángulos grandes.

1.4.2 Al localizar los vértices, es importante tener presente el tipo de poste con objeto de dejar el espacio necesario para las bases, y evitar interferencias con cercas líneas, de fuerza, caminos, etc.

1.4.3 Todos los cruzamientos de la red de alumbrado con las líneas de comunicación de potencia, FF.CC., carreteras y caminos se deben efectuar en ángulo recto o tan cerca del ángulo recto como sea posible y evitar hacerlo a menos de 45°.

1.4.4 No implantar postes en cruzamientos con las vías férreas, caminos y calles a una distancia inferior a la altura de poste que se estime instalar.

1.4.5 Se deberá evitar en lo posible localizar el trazo en laderas que pueda deslizarse o en terrenos de relleno o blando. En caso contrario deberá anotar en los planos respectivos.

* En todos los casos en que figure Escala 1:, ésta es a especificar.

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2. LEVANTAMIENTO DEFINITIVO

2.1 Levantamientos de primera importancia.

Se ejecutará el levantamiento con tránsito y cinta por lo que respecta a planimetría y con nivel fijo o el tránsito utilizándolo como nivel, por lo que respecta a altimetría.

2.2 Levantamiento de segunda importancia

Se usará el método estadimétrico, comprobando las lecturas hacia atrás y hacia adelante, para cerciorarse de que las distancias no se exceden de las tolerancias marcadas por el mismo método y las permitidas por la aproximación del aparato usado.

2.3 El método de caminamiento será:

2.3.1 Azimutes astronómicos directos, referidos a un meridiano fijo que pasa por el punto de partida.

2.3.2 Caminamientos por deflexiones.

De estos dos métodos se recomienda el primero, por ser más sencillo y tener menos probabilidades de su error.

2.4 Trazo definitivo.

La disposición del trazo se hará con ayuda de estacas de estación numerada y centradas en cantidad de cinco por cada 200 metros cuando menos. La cabeza de la estaca se pintará de amarillo para su fácil identificación. En caso de que el terreno sea de pavimento se ejecutará una marca en el mismo color rojo, marcando el centro del mismo.

2.4.1 La red de alumbrado deberá pasar por los puntos del trazo preliminar, excepto con las modificaciones que en su caso indique la Ofna. de Alumbrado Público.

2.5 Linderos de propiedades.

Los linderos de las propiedades se deben de localizar en el punto del cruce, debiendo de registrar la siguiente información:

2.5.1 Distancia del lindero a la estación más cercana del trazo.

2.5.2 Rumbo del lindero.

2.5.3 Nombre y dirección del propietario.

2.6 Edificio y obstrucciones.

Se deben describir completamente y ligar topográficamente todos los edificios árboles de altura considerable y obstrucciones similares, que estén dentro de 5 metros de la red de alumbrado público.

2.7 Vértices y deflexiones.

La línea del levantamiento en el plano, se debe mostrar interrumpida en los vértices y señalar con una flecha apuntando a derecha o izquierda, según el giro del ángulo.

En todos los vértices en el plano se debe indicar la estación número que le corresponda, así como la magnitud del ángulo en grados y minutos y el kilometraje correspondiente.

Se deberá determinar el rumbo de las redes.

2.8 Datos adicionales en el perfil.

A lo largo del caminamiento, se tomarán puntos intermedios entre las estaciones consecutivas, de preferencia en los lugares en que cambie la pendiente del terreno, y con menor detalle en los puntos prominentes, así como en las hondanadas.

Estas observaciones, se harán con detalles de consideración en calles, carreteras, vías férreas, líneas de energía eléctrica telefónica, o telegráficas, etc.

2.9 Cruzamientos

2.9.1 Ferrocárriles.

a) Nombre del ferrocarril y su sentido.
b) Estación y kilometraje en el eje de las vías.
c) Angulo de intersección.
d) Elevación de los rieles.
e) Kilometraje de la vía férrea en el punto cruzado.
f) Altura de los conductores telegráficos cruzados superior e inferior.
g) Distancia a la estructura de telégrafos en cada lado de la intersección.
h) Cuando la red sigue paralela al ferrocarril, se debe dar la distancia desde el eje del levantamiento, hasta los linderos de los derechos de vía. En troncal o espuela, se deberá indicar el kilometraje de la vía principal en el entronque y la longitud del entronque o espuela al cruce con el trazo.

2.9.2 Calles y carreteras.

Se deben localizar todos los cruzamientos con calles y carreteras, registrando la siguiente información:

a) Nombre de la carretera.
b) Estación en el eje de la calle.

c) Angulo de intersección.
d) Ancho del derecho de vía.
e) Tipo de la superficie de rodamiento (asfalto, terracería, tierra, etc.).
f) Ancho entre los acotamientos.
g) Elevación tanto del centro como de los acotamientos.
h) Se debe indicar si la carretera es primaria, secundaria o camino vecinal.
i) Cuando el trazo vaya paralelo a la calle o carretera, se debe dar la distancia del eje del levantamiento a las cercas de los derechos de vía.

2.9.3 Líneas de energía y comunicación.

En los planos generales de localización del trazo, se deben mostrar todas las líneas de energía, de teléfono, de telégrafo y de señales, incluyendo las líneas de comunicación de los ferrocarriles, que queden dentro de 5 metros a los lados de la red de alumbrado.

Se deben localizar todos los cruzamientos de las líneas de energía y de comunicación registrándose la siguiente información:

a) Nombre de la Línea.
b) Estación en la intersección del eje.
c) Angulo de intersección.
d) Distancia del eje de la red en cada lado de la intersección.
e) Número de alambres que se cruzan.
f) Voltaje, tipo de servicio (teléfono, energía, telégrafo, etc.).

2.9.4 Canales.

Se deben localizar todos los canales, y drenes, registrándose la siguiente información:

a) Estación a la altura de la superficie del canal.
b) Estación en las orillas del canal.

2.10 Levantamiento de alternativas o modificaciones

Cuando se tengan que elaborar levantamientos para modificaciones o alternativas, se deberá registrar la siguiente información:

a) Estación del trazo definitivo con el kilometraje exacto en el punto de partida y llegada de la modificación.
b) Angulo y dirección de la deflexión de los puntos de partida y llegada.
c) Elevación de las estaciones de los puntos de partida y llegada.

La diferencia de cotas entre el levantamiento original y la modificación deberán ser las mismas.

5. SE EVITARA INSTALAR POSTES EN LOS SIGUIENTES PUNTOS:

a) Dentro de los derechos de vía de los FF.CC., carreteras y calles.

b) En lugares de acceso difícil.

6. ANTES DE EFECTUAR LA LOCALIZACION DE POSTES SE VERIFICARA QUE EL PERFIL DEL TERRENO COINCIDA EN TODOS SUS DETALLES CON LO INDICADO EN LOS PLANOS.

DE ENCONTRARSE CUALQUIER DISCREPANCIA SE REPORTARA AL SUPERVISOR DE LA OFICINA DE ALUMBRADO PUBLICO, QUIEN DECIDIRA LO PROCEDENTE.

NOTA IMPORTANTE

Por ningún motivo se aceptarán trabajos topográficos que no hayan sido ejecutados de conformidad con lo anterior, no planos que no contengan la información indicada en éstas normas y sus anexos.

TABLA 1

SIMBOLOS CONVENCIONALES

SIGNO	NOMBRE	SIGNO	NOMBRE
	ARBOTANTE ESFERICO		POSTE SEMI ORNAMENTAL
	ARBOTANTE COLONIAL		POSTE TIPO JARDIN
	CABLES		POSTE TIPO COLONIAL
	COMBINACION CENTRO DE CARGA CONTROL		POSTE TIPO CUADRADO
	DUCTO DE CONCRETO EN BANQUETA		POSTE HEXAGONAL 20000
	2 DUCTOS DE CONCRETO EN ARROYO		POSTE TIPO VISTA III
	FLUORESCENTES 40 / 60 (Watts)		POSTE ORNAMENTAL DOBLE MENSULA
	FLUORESCENTES 80 (Watts)		REFLECTOR DE CUARZO
	FLUORESCENTES 110/120 (Watts)		REFLECTOR TIPO CAÑON
	FLUORESCENTES 150 (Watts)		REFLECTOR DE MERCURIO
	INCANDESCENTE 15 (Watts)		REFLECTOR DE SODIO
	INCANDESCENTE 25 (Watts)		REGISTRO DE CAMBIO DE DIRECCION
	INCANDESCENTE 40 (Watts)		REGISTRO PARA CRUCE EN ARROYO
	INCANDESCENTE 60 (Watts)		SODIO BAJA PRESION 135 (Watts)
	INCANDESCENTE 75 (Watts)		SODIO BAJA PRESION 250 (Watts)
	INCANDESCENTE 100 (Watts)		SODIO ALTA PRESION 1000 (Watts)
	INCANDESCENTE 150 (Watts)		VAPOR DE MERCURIO 175 (Watts)
	INCANDESCENTE 200 (Watts)		VAPOR DE MERCURIO 250 (Watts)
	INCANDESCENTE 300 (Watts)		VAPOR DE MERCURIO 400 (Watts)
	INCANDESCENTE 500 (Watts)		VAPOR DE MERCURIO 700 (Watts)
	INCANDESCENTE 1000 (Watts)		VAPOR DE MERCURIO 1000 (Watts)
	INCANDESCENTE 2000 (Watts)		
	LAMPARA PAR		
	MUFA DE CIA. DE LUZ Y FUERZA		
X / Y	NUMERO DEL CIRCUITO / NUMERO DE LAMPARAS		
	POSTE ORNAMENTAL SENCILLO		

(CONTINUA)

TABLA 1

SIGNO		NOMBRE
		LINEAS BAJA TENSION 3 HILOS
		LINEAS BAJA TENSION 4 HILOS
o		POSTE DE CONCRETO DE 30' O MENOS
o		POSTE DE CONCRETO DE 35' O MAS
ø		POSTE DE MADERA DE 35' O MAS
		TRANSFORMADOR EN POSTE DE ACERO
		FUSIBLE
		FUSIBLE DESCONECTADOR
		TRANSFORMADOR C 20/6

ALUMBRADO PUBLICO MULTIPLE

SIGNO			NOMBRE
AEREO	SUBTERRANEO		
			2 HILOS ALIMENTACION
			3 HILOS 2 ALIMENTACIONES 1 CONTROL

ALUMBRADO PUBLICO SERIE

SIGNO			NOMBRE
AEREO	SUBTERRANEO		
			1 HILO 6.6 AMP
			2 HILOS 6.6 AMP

• NORMAS DE OBRA CIVIL.

I. DUCTOS *(Figura 1)*

1. INSTALACION

1.1 En banqueta

Se instalará con el eje una distancia entre ejes de 930 mm (36-5/8") con respecto al paño exterior de la guarnición cuando se instalen arbotantes tipo ornamental, látigo o jardín y 760 mm (14-31/32") con relación a la corona de la guarnición.

1.2 En arroyo

Se instalarán dos vías en un solo lecho con el eje a una profundidad de 1040 mm (40-61/64") con respecto a la corona de la guarnición y con una separación en planta entre ejes de 240 mm (9-29/64").

1.3 Especial

La especificada en el inciso 1.1 con la siguiente variante:
Este tipo de ducto irá instalado en los lugares donde haya entradas para vehículos.

2. CEPA PARA INSTALACION

2.1 En banqueta

2.1.1 Tipo

Sección rectangular, con un trazo recto en la planta y una pendiente igual a la de la banqueta en corte longitudinal.

2.1.2 Dimensiones

300 mm (11-13/16") de ancho por 500 mm (19-11/16") de profundidad.

2.1.3 Características de construcción

En caso de que la banqueta estuviera recubierta con losa de concreto, se hará un corte con sierra previo a la ruptura de la misma. El corte tendrá una profundidad mínima de 2/3 del espesor de la losa. Una vez hecha la cepa se procederá a apisonar y nivelar el fondo en toda su longitud.

2.2 En arroyo

2.2.1 Tipo

Sección rectangular, con un trazo en planta y con una pendiente igual a la existente entre las guarniciones de las banquetas por donde pasará el ducto, en corte longitudinal.

2.2.2 Dimensiones

500 mm (19-11/16") de ancho por 1160 mm (45-43/64") de profundidad.

2.2.3 Características de construcción

Una vez hecha la cepa se procederá a nivelar el piso y a colocar una cama de 50 mm (1-31/32") de espesor con concreto de f'c = 150 Kg/cm² a los 28 días con agregado máximo de 20 mm (25/32").

2.3 Especial

2.3.1 Tipo

El especificado en el inciso 2.1.1.

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2.3.2 Dimensiones

300 mm (11-13/16") de ancho por 550 mm (21-21/32") de profundidad.

2.3.3 Características de construcción

En caso de que la banqueta estuviera con losa de concreto, se hará un corte con sierra previo a la ruptura de la misma. El corte tendrá una profundidad mínima de 2/3 del espesor de la losa. Una vez hecha la cepa se procederá a nivelar el piso y a colocar una cama de 50 mm (1-31/32") de espesor con concreto de f'c = 150 Kg/cm² a los 28 días con agregado máximo de 20 mm (25/32").

3 DUCTO

3.1 En banqueta

3.1.1 Tipo

De sección circular

3.1.2 Dimensiones y características

102 mm (4") de diámetro interior por 133 mm (5–15/64") de diámetro exterior y 200 mm (7–7/8") de diámetro en la campana. Deberá ser de concreto, con un recubrimiento interior asfáltico de 3 mm (1/8") de espesor.

3.1.3 Instalación

La instalación del ducto en la cepa deberá efectuarse de forma tal que siempre quede paralelo a la guarnición de la banqueta y perfectamente nivelado. La alineación de los ductos será verificada con un cordel como referencia.

3.1.4 Junteado

El ducto irá junteado, con mortero de cemento proporción 1:3, debiendo ser colocada una cama de dicho mortero de 25 mm (1") de espesor en la campana del ducto al proceder a su colocación. Previamente se humedecerá la zona de junteado.

3.2 En arroyo

3.2.1 Tipo

De sección circular

3.2.2 Dimensiones y características

Las especificadas en el inciso 3.1.2.

3.2.3 Instalación

La instalación de ductos en las cepas deberá efectuarse de forma tal que siempre queden perfectamente nivelados y alineados. La alineación de los ductos será verificada con un cordel como referencia.

3.2.4 Revestimiento

Previamente al colado, los ductos deben ser humedecidos. El revestimiento de los ductos se hará con concreto de $f'_c = 150$ kg/cm² a los 28 días con agregado máximo de 20 mm (25/32"), con una cama sobre lecho de 150 mm (5–29/32").

3.3 Especial

3.3.1 Tipo

De sección circular.

3.3.2 Dimensiones y características

Las especificadas en el inciso 3.1.2.

3.3.3 Instalación

Igual a la especificada en el inciso 3.1.3.

3.3.4 Revestimiento

Igual al del inciso 3.2.4 con la diferencia de que la cama sobre lecho será de 120 mm (4–3/4").

4. RELLENO

4.1 En banqueta

El relleno se hará, con una capa del material producto de la excavación de 320 mm (12–19/32") de espesor debidamente compactada. No deberá dejarse abierta la cepa de un día para otro y del mismo modo el retiro de escombro tendrá que hacerse en el mismo turno de trabajo en que se haya excavado la cepa.

4.2 En arroyo

El relleno se hará, con material de subbase, que se compactará con agua y pisón en capas de 200 mm (7–7/8") hasta una altura de 400 mm (15–3/4") abajo del nivel del piso. La altura restante se construirá con material de base compactado con agua y pisón en capas de 100 mm (3–15/16") de espesor.
No deberá dejarse abierta la cepa de un día para otro así como el escombro deberá ser retirado en el mismo turno de trabajo en que se haya excavado la cepa.

5. REPARACION

5.1 En banqueta

Cuando se proceda a la reparación de la banqueta se colocará una capa de relleno debidamente apisonado de 100 mm (3–15/16") de espesor de grava cementada antes del colado de la losa. El concreto que se emplee para colar la losa de 80 mm (3–5/32") de espesor, será de $f'_c = 150$ kg/cm² a los 28 días con agregado máximo de 20 mm (25/32") y dando un acabado semejante e integral al existente en toda la banqueta afectada.

5.2 En arroyo

Se reconstruirá el pavimento del corte con una capa de concreto asfáltico compactado de 75 mm (2–61/64") de espesor.

5.3 Especial

Igual al inciso 5.1 con la advertencia de que no deberá dejarse abierta la cepa de un día para otro y del mismo modo el retiro del escombro tendrá que hacerse en el mismo turno de trabajo en que se haya excavado la cepa.

II. REGISTROS

1. INSTALACION

1.1 Deflexión

Se instalará al pie del poste de la Cía. suministradora donde se instale el equipo de control de los circuitos, también donde el ducto en banqueta cambie de dirección y en aquellos lugares donde por necesidades debe existir registro de candelabro al pie del poste.

1.2 Paso

Como su nombre lo indica, este registro se instalará en los lugares donde haya necesidad de pasar arroyos.

1.3 Especial

Cuando se vaya a colocar en banqueta, una de sus caras debe estar paralela a la guarnición y a un mínimo de 200 mm (7–7/8") de su paño interior. Cuando vaya a ser colocado en zona jardinada su instalación será en el lugar donde se juzgue conveniente.

2. CEPA PARA INSTALACION

2.1 Deflexión

2.1.1 Tipo

Sección rectangular

2.1.2 Dimensiones

Lado menor 700 mm (27–9/16"), lado mayor 850 mm (33–15/32") y con una profundidad de 638 mm (25–1/8").

2.2 Paso

2.2.1 Tipo

Sección rectangular

2.2.2 Dimensiones

Lado menor 800 mm (31–1/2"), lado mayor 1000 mm (39–3/8") y con una profundidad de 1238 mm (48–3/4").

2.3 Especial de 1250 mm (49–7/32") por lado.

2.3.1 Tipo

Rectangular de sección cuadrada.

2.3.2 Dimensiones

1730 mm (68–7/64") por lado y 1870 mm (73–5/8") de profundidad.

2.4 Especial de 1500 mm (59–3/64") por lado.

2.4.1 Tipo

Rectangular de sección cuadrada.

2.4.2 Dimensiones

2260 mm (88–31/32") por lado y 2170 mm (85–7/16") de profundidad.

3. CARACTERISTICAS DE CONSTRUCCION DE LA CEPA

3.1 Deflexión

En caso de que la banqueta, estuviera recubierta con losa de concreto, se hará un corte con sierra prèvio a la ruptura de la misma, debiendo quedar el lado mayor paralelo a la guarnición. El corte tendrá una profundidad mínima de 2/3 del espesor de la losa.
Al efectuar la excavación se tomarán las precauciones necesarias para evitar que al encontrarse con tuberías o ductos de otros servicios públicos, estos resulten dañados.

3.2 Paso

Las especificadas en el inciso 3.1 de registros.

3.3 Especial

Las especificadas en el inciso 3.1 de registros.
El escombro que resulte de la excavación para la cepa será retirado en el mismo turno de trabajo de su excavación.

4. REGISTROS COMO TALES

4.1 Deflexión *(Figura 2)*

4.1.1 Tipo

Sección rectangular

4.1.2 Dimensiones

Lado menor de 500 mm (19–11/16") lado mayor de 650 mm (25–19/32") y una profundidad que incluye el marco de fierro ángulo de 368 mm (25–1/8").

4.1.3 Características de construcción

El registro deberá ser precolado y las paredes tendrán 50 mm (1–31/32") de espesor y serán de concreto $f'_c = 150$ kg/cm² a los 28 días con agregado máximo de 20 mm (25/32") y reforzados con una malla de alambrón de 6.3 mm (1/4") de diámetro con la distribución que se señala en la *figura 2.* El marco será de fierro ángulo de 38.1 x 38.1 x 4.8 mm (1–1/2") x (1–1/2") x (3/16") el cual quedará integralmente empotrado al registro inmediatamente después de vaciado el concreto y antes de que se inicie el fraguado inicial del mismo, mediante seis anclas de varilla No. 3. La cimbra interior deberá ser metálica y la exterior similar o de madera a criterio del contratista. La varilla irá soldada al fierro ángulo con doble cordón.

4.1.4 Instalación

Al ser instalado el registro cuyas caras interiores deben estar al plomo, escuadras y bien pulidas, el lado mayor quedará paralelo a la guarnición, se le dará la pendiente de la banqueta y en ningún caso deberá quedar arriba o abajo del nivel de la misma. El ducto será entroncado y emboquillado debidamente con las paredes del registro.

4.2. Paso *(Figura 3)*

4.2.1 Tipo

Sección rectangular

4.2.2 Dimensiones

Lado menor 600 mm (23–5/8"), lado mayor de 800 mm (31–1/2") y una profundidad que incluye el marco de fierro ángulo de 1238 mm (48–3/4").

4.2.3 Características de construcción

Las especificadas en el inciso 4.1.3 de registros a diferencia de que el número de anclas de varilla No. 3 es de ocho.

4.2.4 Instalación

La especificada en el inciso 4.1.4 de registros.

4.3 Especial de 1250 mm (49–7/32") por lado.

4.3.1 Tipo

Rectangular de sección cuadrada.

4.3.2 Dimensiones

1,250 mm (49-7/32") por lado en la parte interior, y 1,500 mm (59-3/64") de profundidad entre lecho bajo de la losa especificada en el inciso 7.1 y lecho superior de la plantilla especificada en el inciso 5.3.

4.3.3 Características de construcción

Los muros serán de tabique recosido de 140 mm (5-33/64") de espesor con aplanado interior de mortero de cemento de proporción 1:3 con impermeabilizante integral.

4.4 Especial de 1,500 mm (59-3/64") por lado

4.4.1 Tipo

Rectangular de sección cuadrada.

4.4.2 Dimensiones

1,500 mm (59-3/64") por lado en la parte interior y 1,800 mm (70-7/8") de profundidad entre lecho bajo de la losa especificada en el inciso 7.2 y lecho superior de la plantilla especificada en el inciso 5.4.

4.4.3 Características de construcción

Los muros serán de tabique recocido de 280 mm (11-1/32") de espesor con aplanado interior de mortero de cemento de proporción 1:3 con impermeabilizante integral.

5. PLANTILLA

5.1 Deflexión

Una vez instalado el registro se procederá a colar una plantilla de 50 mm (1-31/32") de espesor de mortero de cemento proporción 1:3 con un dren central de 140 mm (5-2/2") de diámetro y una profundidad de 200 mm (7-7/8").

5.2 Paso

Igual al inciso anterior.

5.3 Especial de 1,250 mm (49-7/32") por lado.

5.3.1 Tipo

Rectangular de sección cuadrada.

5.3.2 Dimensiones

1,530 mm (61-15/64") por lado y 80 mm (3-9/64") de espesor.

5.3.3 Características de construcción

Sera construída con concreto de f'_c = 150 Kg/cm^2 a los 28 días con agregado máximo de 20 mm (25/32") armado con varilla de 9.5 mm (3/8") de diámetro a cada 300 mm (11-13/16") en ambos sentidos, con un dren central de 140 mm (5-1/2") de diámetro y 200 mm (7-7/8") de profundidad. La plantilla tendrá una pendiente de 2% hacia el dren.

5.4 Especial de 1,500 mm (59-3/64") por lado

5.4.1 Tipo

Rectangular de sección cuadrada.

5.4.2 Características de construcción 401

Las especificadas en el inciso 5.3.3 de registros.

6. TAPA

6.1 Deflexión

6.1.1 Tipo

Rectangular.

6.1.2 Dimensiones

630 mm (24-13/16") lado mayor, 480, mm (18-29/32") lado menor y 51.7 mm (2-1/32") lado menor y 51.7 mm (2-1/32") de espesor total. Para mayores detalles ver *figura 2*.

6.1.3 Características de construcción

Será construída de concreto f'_c = 200 Kg/cm^2 a los 28 días con agregado máximo de 20 mm (25/32") con fierro ángulo de 31.7 x 4.8 mm (1-1/4" x 1 1/4" x 3/16") y con refuerzo de varilla corrugada No. 3 distribuída según *figura 2* utilizando cimbra metálica. La varilla irá soldada al fierro ángulo con doble cordón. Las llaves para levantar las tapas serán construídas con placa de acero de 4.76 mm (3/16") de espesor llevando la placa central una perforación de 12.7 mm (1/2") de diámetro. Para obtener la forma y dimensiones de las llaves ver detalle a y b de la *figura 2.*

6.2 Paso

6.2.1 Tipo

Rectangular.

6.2.2 Dimensiones

780 mm (30-45/64") lado mayor, 580 mm (22-53/64") lado menor y 51.7 mm (2-1/32") de espesor total. Para mayores detalles ver *figura 3.*

6.2.3 Características de construcción

Las especificadas en el inciso 6.1.3 de registros ver *figura 3.*

6.3 Especial de 1,250 mm (49-7/32") por lado

Su tipo, dimensiones y características de construcción serán las especificadas en el inciso 5.2.

6.4 Especial de 1,500 mm (59-3/64") por lado

Su tipo, dimensiones y características de construcción serán las especificadas en el inciso 6.2.

7. LOSA

7.1 Especial de 1,250 mm (49-7/32") por lado

7.1.1 Tipo

Cuadrado de acuerdo con especificaciones de la CLyFC

7.1.2 Dimensiones Interiores

Base: 1,250 x 1,250 mm, altura 1,000 mm.

7.1.3 Características de construcción

Será de concreto armado de 80 mm (3-5/32") de espesor siendo el concreto de $f'_c = 200$ Kg/cm^2 a los 28 días con agregado máximo de 20 mm (25/32") y el armado, de varilla corrugada de acero estructural No. 3.

7.2 Especial de 1,500 mm (59-3/64") por lado

7.2.1 Tipo

Cuadrado, de acuerdo con especificaciones de la CLyFC

7.2.2 Dimensiones

Base: 1,500 x 1,500 mm, altura 1,500 mm.

7.2.3 Características de construcción

Las especificadas en el inciso 7.1.3.

8. CONTRAMARCO

8.1 Especial de 1,250 mm (49-7/32") por lado

8.1.1 Tipo

Rectangular.

8.1.2 Dimensiones

600 mm (23-5/8") por 800 mm (31-1/2") de dimensiones exteriores.

8.1.3 Características de construcción

Construído de fierro ángulo de 38.1 x 38.1 x 4.8 mm (1-1/2" x 1-1/2" x 3/16") y 8 anclas de varilla No. 3 irá instalado sobre un brocal de tabique de 150 mm (5-29/32") de espesor y de 210 mm (8-17/64") de altura entre el nivel de la banqueta y el lecho superior de la losa. El marco deberá quedar nivel de banqueta y con la pendiente de la misma.

8.2 Especial de 1,500 mm (59-3/64") por lado

Deberá cumplir con las especificaciones dadas en el inciso 8.1.

9. ESCALERA

9.1 Especial de 1,250 mm (49-7/32") por lado.

9.1.1 Tipo

Marina.

9.1.2 Características de construcción

Formada por 4 escalones de varilla redonda del No. 6.

9.2 Especial de 1,500 mm (59-3/64") por lado

9.2.1 Tipo

Marina.

9.2.2 Características de construcción

Formada por 5 escalores de varilla redonda del No. 6.

10. PINTURA

10.1 Deflexión, Paso y Especial

El fierro ángulo del registro o marco y la tapa o contramarco serán pintados con dos manos de pintura anticorrosiva.

11. RELLENO

11.1 Deflexión y Paso

El relleno alrededor del registro se hará con grava cementada debidamente compactada, hasta una profundidad de 80 mm (3-5/32) medida del nivel de la banqueta hacia abajo.

11.2 Especial

Cuando el registro sea construído en banqueta el relleno alrededor del registro se hará con grava cementada o material de subbase debidamente compactada, hasta una profundidad de 80 mm (3-5/32") medida del nivel de la banqueta hacia abajo.
Cuando el registro sea construído en zona jardinada el relleno alrededor del registro se hará con grava cementada o material de subbase debidamente compactada, hasta el nivel de tierra.

12. REPARACION DE BANQUETA

12.1 Deflexión, Paso y Especial

El concreto que se emplee para colar la losa de 80 mm (3-5/32") de espesor, será de f'_c = 150 Kg/cm^2 a los 28 días con agregado máximo de 20 mm (25/32").

sierra previo a la ruptura de la misma, debiendo quedar un lado, paralelo y razante a la cara interior de la guarnición. El corte tendrá una profundidad mínima de 1/3 del espesor de 1/3 del espesor de la losa.

Al efectuarse la excavación se tomarán las precauciones necesarias para evitar que el encontrarse con tuberías ó ductos de otros servicios públicos, estos resulten dañados. Una vez hecha la cepa se procederá a apisonar y nivelar el fondo.

2.2 Para arbotantes tipo Colonial o San Angel

2.2.1 Tipo

Sección cuadrada.

2.2.2 Dimensiones

900 mm (35-7/16") por lado y 900 mm (35-7/16") de profundidad.

2.2.3 Características de construcción

Las especificadas en el inciso 2.1.3 de cimiento de concreto.

2.3 Para postes de 12000 mm

2.3.1 Tipo

Sección cuadrada.

2.3.2 Dimensiones

700 mm (27-9/16") por lado y 1500 mm (59") de profundidad.

2.3.3 Características de construcción

La especificada en el inciso 2.1.3 de cimientos de concreto, con la salvedad de que el lado paralelo a la guarnición debe quedar a 150 mm (6") de la carta interior de la misma.

2.4 Para postes de 16000 mm

2.4.1 En banqueta

2.4.1.1 Tipo

2.4.1.1 Tipo

Rectangular de sección cuadrada.

2.4.1.2 Dimensiones

800 mm (31–1/2") por lado y 1800 mm (70–7/8") de profundidad.

2.4.1.3 Características de construcción.

La especificada en el inciso 2.1.3 de cimientos de concreto, con la salvedad de que el lado paralelo a la guarnición debe quedar a 50 mm (2") de la cara interior de la misma.

2.4.2 En área libre.

2.4.2.1 Tipo

Rectangular de sección cuadrada.

2.4.2.2 Dimensiones

2000 mm (78–3/4") por lado y 1220 mm (48") de profundidad.

2.4.2.3 Características de construcción.

La excavación se hará en la posición que más se acomode para el fin que se persigue, de acuerdo con el supervisor de la Oficina de Alumbrado y se tomarán las precauciones necesarias para evitar que al encontrarse con tuberías o ductos de otros servicios públicos, estos resulten dañados. Una vez hecha la cepa se procederá a apisonar y nivelar el fondo.

2.5 Parapostes de 20000 mm.

2.5.1 Tipo

Rectangular de sección cuadrada.

2.5.2 Dimensiones

2500 mm (98–27/64") por lado y 1500 mm (59") de profundidad.

2.5.3 Características de construcción.

Igual a las indicadas en el inciso 2.4.2.3 de cimientos de concreto.

2.6 Para postes de 25000 mm.

2.6.1 Tipo

Rectangular de sección cuadrada.

2.6.2 Dimensiones.

3600 mm (141–13/16") por lado y 1900 mm (74–13/16") de profundidad.

2.6.3 Características de construcción.

Igual a las indicadas en el inciso 2.4.2.3 de cimientos de concreto.

2.7 Para postes de 30000 mm.

2.7.1 Tipo

Rectangular de sección cuadrada.

2.7.2 Dimensiones

4500 mm (177–5/32") por lado y 2080 mm (81–57/64") de profundidad.

2.7.3 Características de construcción.

408 Igual a las indicadas en el inciso 2.4.2.3 de cimientos de concreto.

3. CIMIENTOS

3.1. Para arbotantes tipo Ornamental, Látigo y Jardín.

3.1.1 Tipo

Tronco–Piramidal

3.1.2 Dimensiones

600 x 600 mm (23–5/8" x 23–5/8") en la base superior, 1000 x 1000 mm (39 x 39") en la base inferior y 1000 mm (39") de altura.

3.1.3 Características de construcción

Una vez apisonado el piso de la cepa se procederá a colocar la cimbra metálica con una de sus aristas de la cara superior paralela a la guarnición, a una distancia de 200 mm (7–7/8") con respecto a su paño interior y a una altura de 15 mm (19/32") con relación a su corona.
Esta cimbra deberá ser construída con lámina No. 18 de 1.27 mm (1/20") de espesor y refuerzos necesarios para obtener que sus caras laterales queden planas y las aristas de las caras superiores e inferiores a escuadra. La cimbra deberá troquelarse a fin de que no se mueva durante el colado y vibrado del concreto. Integralmente se colocarán 4 anclas de varilla redonda de 25.4 mm (1") de diámetro y 600 mm (25–5/8") de longitud. En un

extremo las anclas llevarán 100 mm (3–15/16") de cuerda standard de 8 hilos/pulg y en el otro un dobléz o regatón de 100 mm (3–15/16") de longitud, debiendo ser galvanizadas la zona de cuerdas. La separación entre anclas será de 270 mm (10–5/8") de centro a centro y sobresaldrán del cimiento 60 mm (2–23/64") debiendo quedar centradas con relación a las aristas de las caras superior y completamente verticales. Para asegurar lo anterior se empleará un escantillón metálico. También integralmente se colocará una pieza de concreto en forma de "Y" y los niples necesarios tal como se muestra en la *figura 4*.
Cuando el cimiento esté localizado en zona jardinada se colocará a una altura de 50 mm (1–31/32") con relación al nivel de tierra. El colado se hará con concreto de $f'_c = 150$ kg/cm² a los 28 días de agregado máximo de 40 mm (1–37/64") debidamente vibrado. Terminado el colado y verificada la posición de las anclas y la "Y" conforme a lo señalado anteriormente y lo establecido en la *figura 4*, se pulirá la cara superior dejándola a nivel, se bolearán sus aristas y se emboquillará a la salida de la pieza en "Y" de concreto.
Si se empleó concreto de resistencia normal se descimbrará a las 9 horas si se empleó resistencia rápida a las 4 horas. Una vez descimbrado el cimiento se entroncará el ducto en banqueta.

3.2 Para arbotante tipo Colonial o San Angel.

3.2.1 Tipo

Tronco–Piramidal.

3.2.2 Dimensiones

400 x 400 mm (15–3/4" x 15–3/4") en la base superior, 800 x 800 mm (31–1/2" x 31–1/2") en la base inferior y 900 mm (35–7/16") de altura.

3.2.3 Características de construcción.

Las especificadas en el inciso 3.1.3 con la diferencia de que la separación entre anclas será de 190 mm (3–35/64") de centro a centro.

3.3 Para postes de 12000 mm

3.3.1 Tipo

Rectangular de sección cuadrada.

3.3.2 Dimensiones

700 mm (27–9/16") por lado y 1500 mm (59") de altura.

3.3.3 Características de construcción.

Una vez apisonado el piso de la cepa se procederá a colocar el armado, el cual llevará ama-

rrado en cada esquina inferior un dado de concreto de 50 x 50 x 50 mm (2" x 2" x 2") para evitar el contacto directo del armado con el piso de la cepa. Ver *figura 5*.
Una vez colocado el armado se procederá a colocar una cimbra metálica de 500 mm (19–11/16") de altura, la cual irá desde 15 mm (19/32") arriba de la corona de la guarnición hacia abajo y con uno de sus lados paralelo a la guarnición.
Esta cimbra deberá ser construída con lámina No. 18 de 1.27 mm (1/20) de espesor y refuerzos necesarios para obtener que las aristas, formadas por las caras laterales y la superior queden a escuadra. La cimbra deberá acuñarse lateralmente a fin de que no se mueva durante el colado y vibrado del concreto. Integralmente se colocarán 4 anclas que deben cumplir con la especificación AP/AFR-1000. La separación entre anclas será de 270 mm (10–5/8") de centro a centro y sobresaldrán del cimiento 60 mm (2–23/64") debiendo quedar alineadas con los vértices de la cara superior, con centros sobre una circunferencia de 380 mm (15") de diámetro y completamente verticales. Para asegurar lo anterior se empleará un escantillón metálico. También integralmente se colocará una pieza de concreto en forma de "Y" y los niples necesarios, tal como se muestra en la *figura 5*. El colado se hará con concreto de $f'_c = 200$ kg/cm² a los 28 días con agregado máximo de 40 mm (1–37/64") debidamente vibrado. Terminado el colado y verificada la posición de las anclas y la "Y" conforme a lo señalado anteriormente, se pulirá la cara superior, dejándola a nivel, se bolearán sus aristas y se emboquillará la salida de la pieza en "Y" de concreto.
Si se empleó concreto de resistencia normal se descimbrará a las 9 horas y si se empleó resistencia rápida a las 4 horas. Una vez descimbrado el cimiento se entroncará el ducto en banqueta.

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3.4 Para postes de 16000 mm

3.4.1 En banqueta

3.4.1.1 Tipo

Rectangular de sección cuadrada.

3.4.1.2 Dimensiones

800 mm (31–1/2") por lado y 1800 mm (70–7/8") de profundidad.

3.4.1.3 Características de construcción.

Una vez apisonado el piso de la cepa se procederá a colocar el armado, el cual llevará amarrado en cada esquina un dado de concreto de 50 x 50 x 50 mm (2" x 2" x 2") para evitar el contacto directo del armado con el piso de la cepa. Ver *figura 6*.
Una vez colocado el armado se procederá a colocar una cimbra metálica de 500 mm (19–11/16") de altura, la cual irá desde 15 mm (19/32") arriba de la corona de la guarnición hacia abajo y con uno de sus lados paralelo a la guarnición.

Esta cimbra deberá ser construída con lámina No. 18 de 1.27 mm (1/20") de espesor y refuerzos necesarios para obtener que las aristas, formadas por las caras laterales y la superior queden a escuadra. La cimbra deberá acuñarse lateralmente a fin de que no se mueva durante el colado y vibrado del concreto. Integralmente se colocarán 4 anclas que deben cumplir con la especificación AP/AFR 1220. La separación entre anclas será de 270 mm (10–5/8") de centro a centro y sobresaldrán del cimiento 60 mm (2–23/64") debiendo quedar alineadas con los vértices de la cara superior, con centros sobre una circunferencia de 380 mm (15") de diámetro y completamente verticales. Para asegurar lo anterior se empleará un escatillón metálico. También integralmente se colocará una pieza de concreto en forma de "Y" o codo según sea el caso y los niples necesarios.

El colado se hará con concreto de $f'_c = 200$ kg/cm² a los 28 días con agregado máximo de 40 mm (1–37/64") debidamente vibrado. Terminado el colado y verificada la posición de las anclas y la "Y" o el codo conforme a lo señalado anteriormente, se pulirá la cara superior dejándola a nivel, se bolearán sus aristas y se emboquillará la salida de la pieza "Y" o el codo de concreto.

Si se empleó concreto de resistencia normal se descimbrará a las 9 horas y si se empleó resistencia rápida a las 4 horas. Una vez descimbrado el cimiento se entroncará el ducto.

3.4.2 En área libre

3.4.2.1 Tipo

Dado tronco–cónico de sección cuadrado con zapata cuadrada. Ver *figura 7.* 411

3.4.2.2 Dimensiones

Las mostradas en la *figura 7.*

3.4.2.3 Características de construcción.

Una vez apisonado el piso de la cepa se procederá a colocar una cama de 80 mm (3–5/32") de espesor con concreto de $f'_c = 100$ kg/cm² a los 28 días con agregado máximo de 20 mm (25/32"). Una vez colocada y fraguada la cama de concreto se procederá a realizar el armado del cimiento en la forma indicada en la figura e inmediatamente después de terminado este, se procederá a colocar una cimbra metálica tanto en los lados de la zapata como en las caras laterales del dado tronco-cónico.

Esta cimbra deberá sobresalir del nivel del piso 80 mm (3–5/32") y se deberá construir con lámina No. 18 y refuerzos necesarios para obtener que las caras laterales queden planas y las aristas de la cara superior a escuadra. La cimbra deberá troquelarse a fin de que no se mueva durante el colado y vibrado del concreto. Integralmente se colocarán 4 anclas que deben cumplir con la especificación AP/AFR–1220. La separación entre anclas será de 270 mm (10–5/8") de centro a centro y sobresaldran del cimiento de 60 mm (2–23/64") debiendo quedar alineadas con los vértices de la cara superior, con centros sobre una circunferencia de 380 mm (15") de diámetro y completamente verticales. Para asegurar lo anterior se empleará un escantillón metálico. También integralmente, se colocará una pieza de concreto en forma de "Y" o codo según sea el caso y los niples necesarios.

El colado se hará con concreto $f'_c = 200$ kg/cm² a los 28 días con agregado máximo de 40 mm (1–37/64") debidamente vibrado. Terminado el colado y verificada la posición de las anclas y la "Y" o el codo conforme a lo señalado anteriormente, se pulirá la cara superior dejándola a nivel, se bolearán sus aristas y se emboquillará la salida de la pieza "Y" o el codo de concreto.
Si se empleó concreto de resistencia normal se descimbrará a las 9 horas y si se empleó resistencia rápida a las 4 horas. Una vez descimbrado el cimiento se entroncará el ducto.

3.5 Para postes de 20000 mm.

3.5.1 Tipo

Dado tronco cónico de sección cuadrada con zapata cuadrada. Ver *figura 8.*

3.5.2 Dimensiones

Las mostradas en la *figura 8.*

3.5.3 Características de construcción

412 Una vez apisonado el piso de la cepa se procederá a colocar una cama de 80 mm (3-5/32") de espesor con concreto de $f'_c = 100$ kg/cm² a los 28 días con agregado máximo de 20 mm (25/32"). Una vez colocada y fraguada la cama de concreto se procederá a realizar el armado del cimiento en la forma indicada en la *figura 8*, e inmediatamente después de terminado éste, se procederá a colocar una cimbra metálica tanto en los lados de la zapa como en las caras laterales del dado tronco-cónico. Esta cimbra deberá sobresalir del nivel del piso 80 mm (3-5/32") y se deberá construir con lámina No. 18 y refuerzos necesarios para obtener que las caras laterales queden planas y las aristas de la cara superior a escuadra. La cimbra deberá troquelarse a fin de que no se mueva durante el colado y vibrado del concreto. Integralmente se colocarán 6 anclas que deben cumplir con la especificación AP/AFR-1220 distribuídas uniformemente sobre una circunsferencia de centros de 508 mm (20"), debiendo quedar completamente verticales. Para asegurar lo anterior se emplearán escantillón metálico. También integralmente se colocará una pieza de concreto en forma de "Y" o codo según sea el caso y los niples necesarios. El colado se hará con concreto $f'_c = 200$ kg/cm² a los 28 días con agregado máximo de 40 mm (1-37/64") debidamente vibrado. Terminado el colado y verificada la posición de las anclas y la "Y" o el codo conforme a lo señalado anteriormente, se pulirá la cara superior dejándola a nivel, se bolearán sus aristas y se emboquillará la salida de la pieza "Y" o el codo de concreto.
Si se empleó concreto de resistencia normal se descimbrará a las 9 horas y si se empleó resistencia rápida a las 4 horas. Una vez descimbrado el cimiento se entroncará el ducto.

3.6 Para postes de 25000 mm

3.6.1 Tipo

Dado tronco-cónico de sección cuadrada con zapata cuadrada. Ver *figura 9.*

3.6.2 Dimensiones

Las mostradas en la *figura 9.*

3.6.3 Características de construcción

Una vez apisonado el piso de la cepa se procederá a colocar una cama de 80 mm (3-3/32") de espesor con concreto $f'_c = 100$ kg/cm² a los 28 días con agregado máximo de 20 mm (25-/32"). Una vez colocada y fraguada la cama de concreto se procederá a realizar el armado del cimiento en la forma indicada en la *figura 9*, e inmediatamente después de terminado éste, se procederá a colocar un cimbra metálica, tanto en los lados de la zapata como en las caras laterales del dado tronco-cónico. Esta cimbra deberá sobresalir del nivel del piso 80 mm (3-5/32") y se deberá construir con lámina No. 18 y refuerzos necesarios para obtener que las caras laterales queden planas y las aristas de la cara superior a escuadra. La cimbra deberá troquelarse a fin de que no se mueva durante el colado y vibrado del concreto. Integralmente se colocarán 8 anclas que deben cumplir con la especificación AP/AFR-1220, distribuídas uniformemente sobre una circunsferencia de centros de 762 mm (30") debiendo quedar completamente verticales. Para asegurar lo anterior se empleará un escantillón metálico. También integralmente se colocará una pieza de concreto en forma de "Y" o codo según sea el caso y los niples necesarios. El colado se hará con concreto de $f'_c = 200$ kg/cm² a los 28 días con agregado máximo de 40 mm (1-37/64") debidamente vibrado. Terminado el colado y verificada la posición de las anclas y la "Y" o el codo conforme a lo señalado anteriormente se pulirá la cara superior, se bolearán sus aristas y se emboquillará la salida de la pieza "Y" o el codo de concreto.
Si se empleó concreto de resistencia normal se descimbrará a las 9 horas y si se empleó resistencia rápida a las 4 horas. Una vez descimbrado el cimiento se entroncará el ducto.

3.7 Para postes de 30000 mm

3.7.1 Tipo

Dado tronco-cónico de sección cuadrada con zapata. Ver *figura 10.*

3.7.2 Dimensiones

Las mostrada en la *figura 10.*

3.7.3 Características de construcción

Una vez apisonado el piso de la cepa se procederá a colocar una cama de 80 mm (3-5/32") de espesor con concreto $f'_c = 100$ kg/cm² a los 28 días con agregado máximo de 20 mm (25/32"). Una vez colocada la cama de concreto se procederá a realizar el armado del cimiento en la forma indicada en la *figura 10*, e inmediatamente después de terminado éste, se procederá a colocar una cimbra metálica tanto en los lados de la zapata como en las caras laterales del dado tronco-cónico. Esta cimbra deberá sobresalir del nivel del piso 150 mm (6") y se deberá construir con lámina No. 18 y refuerzos necesarios para obtener que

las caras laterales queden planas y las aristas de la cara superior a escuadra. La cimbra deberá troquelarse a fin de que no se mueva durante el colado y vibrado del concreto. Integralmente se colocarán 8 anclas que deben cumplir con la especificación AP/AFR-1220, distribuídas uniformemente sobre una circunsferencia de centros de 762 mm (30") debiendo quedar completamente verticales. Para asegurar lo anterior se empleará un escantillón metálico. También integralmente se colocará una pieza de concreto en forma de "Y" o codo según sea el caso y los niples necesarios. El colado se hará con concreto de $f'_c = 200$ Kg/cm^2 a los 28 días con agregado máximo de 40 mm (1-37/64) debidamente vibrado. Terminado el codo conforme a lo señalado anteriormente, se pulirá la cara superior dejándola a nivel, se bolearán sus aristas y se emboquillará la salida de la pieza "Y" o el codo de concreto.
Si se empleó concreto de resistencia normal se descimbrará a las 9 horas y si se empleó resistencia rápida a las 4 horas. Una vez descimbrado el cimiento se entroncará el ducto.

4. RELLENO

4.1 Para cualquier tipo de arbotante

414 El relleno alrededor del cimiento se hará con material de sub-base debidamente compactado, hasta una profundidad de 80 mm (3-5/32"). medida del nivel de la banqueta o piso hacia abajo.

5. REPARACION DE LA BANQUETA O PISO

5.1 Para cualquier tipo de arbotante

El concreto que se emplea para colar la losa de 80 mm (3-5/32") de espesor será de $f'_c = 150$ Kg/cm^2 a los 28 días con agregado máximo de 20 mm (25/32").

IV. VESTIDO Y PARADO DE POSTES

1. EL POSTE SE DEBERA VESTIR ANTES DE INSTALARLO SOBRE LA BASE, Y ESTO IMPLICA LO SIGUIENTE:

1.1 Colocarle el o los brazos; en caso de ser atornillables, en el punto de unión, se le debe colocar una junta resistente o la intemperización como el neopreno.

1.2 Colocarle la luminaria, sin foco, de tal manera que el plano longitudinal del poste, con brazos, y el de la luminaria, coincidan.

1.3 La luminaria al colocarse sobre los brazos, deberá estar conectada según su tipo y los cables de conexión deben quedar con holgura de 1500 mm (59-1/16"), para sus conexiones a las bases de alimentación.

1.4 El tapón superior del poste, si lo llevara, deberá quedar perfectamente sellado.

2. LA SECUELA DEL PARADO DEL POSTE, DEBE SEGUIR LAS FASES SIGUIENTES:

2.1 Colocar la base del poste sobre la cimentación pasados cuando menos 7 días de su colado.

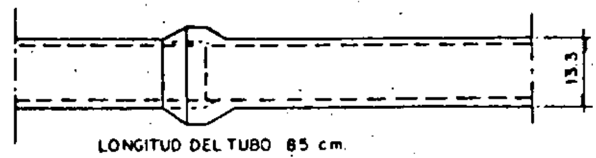
2.2 La base del poste, deberá quedar nivelada en sus dos ejes sobre la cimentación y paralela a la guarnición de la banqueta, para posteriormente fijarla por medio de las 4 anclas colocadas en la cimentación.

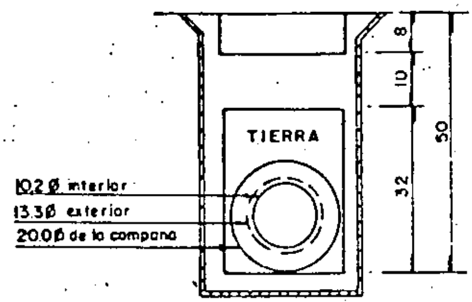
De ser necesaria la colocación de calzas para la nivelación de la base deberá ser galvanizada.

2.3 Se colocará el poste vestido sobre su base, teniendo cuidado en que los cables de conexiones no queden entre el poste y la base. El poste deberá quedar plomado y nivelado, y los brazos con las lámparas deberán quedar perpendiculares a la guarnición de la banqueta. Los tornillos se deberán colocar con la tuerca hacia arriba.

2.4 La maniobra de parado del poste, se deberá realizar con cables flexibles, tales como manila o polipropileno para no lastimar la pintura del mismo. En caso de hacerlo el contratista deberá resanar el área lastimada. 415

2.5 Todos los tornillos, deberán llevar arandela plana y de presión todo esto galvanizado por inmersión en caliente.





EN BANQUETA

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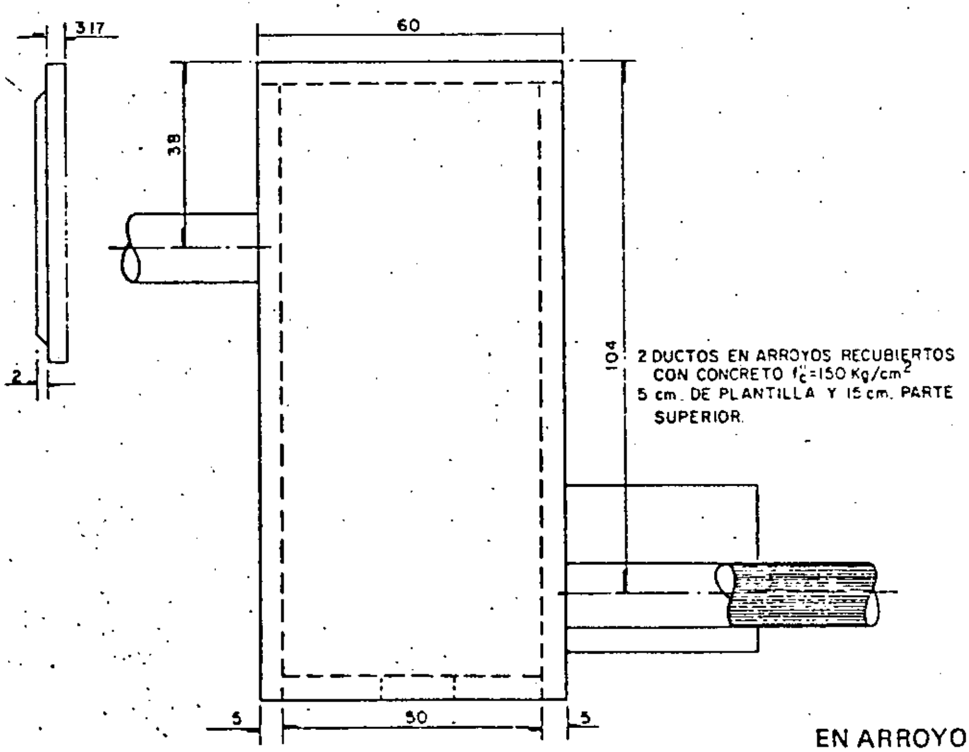
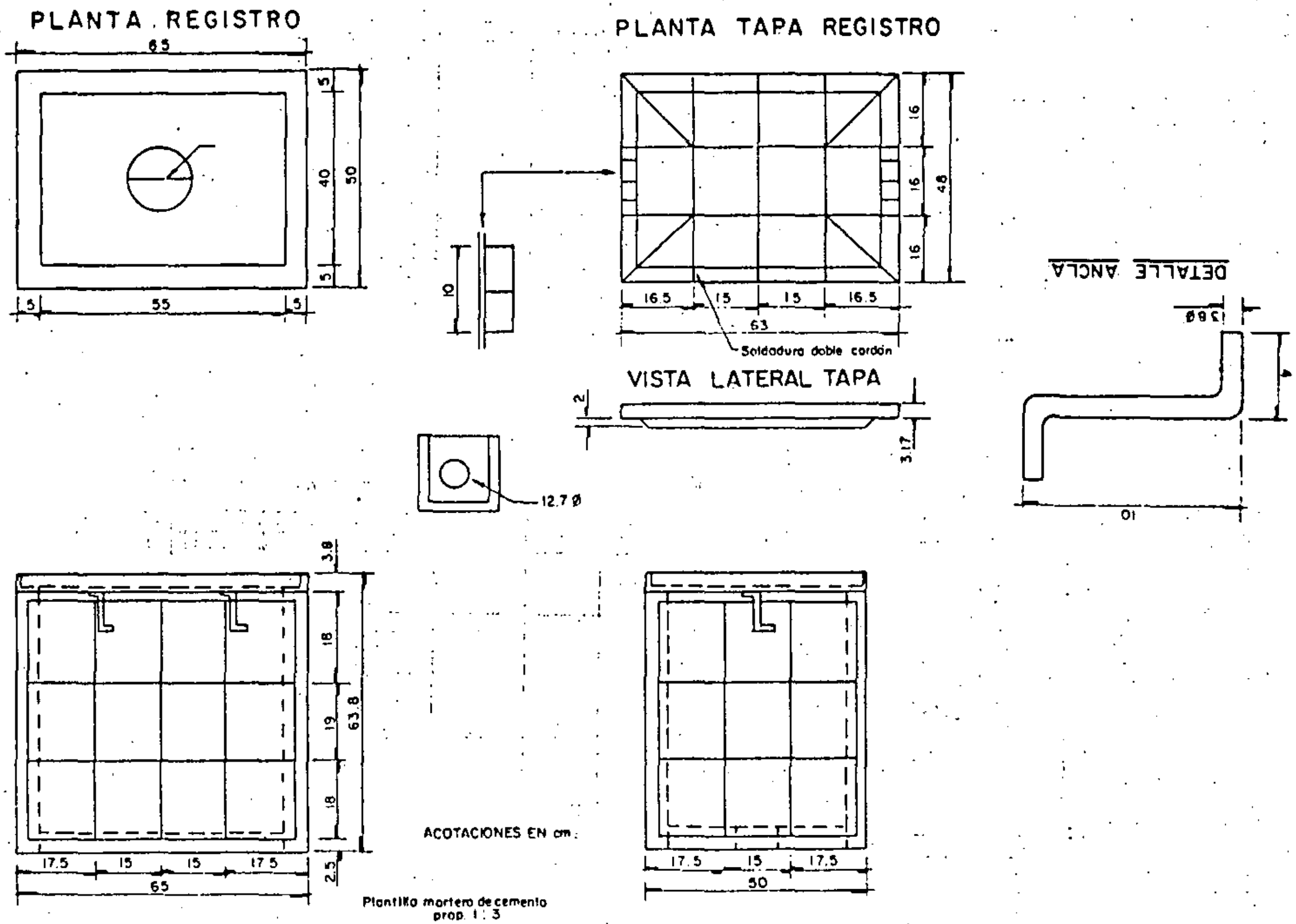


EN ARROYO

Figura 1
INSTALACION DE DUCTOS

Figura 2
REGISTRO AUXILIAR



15 05 80

418

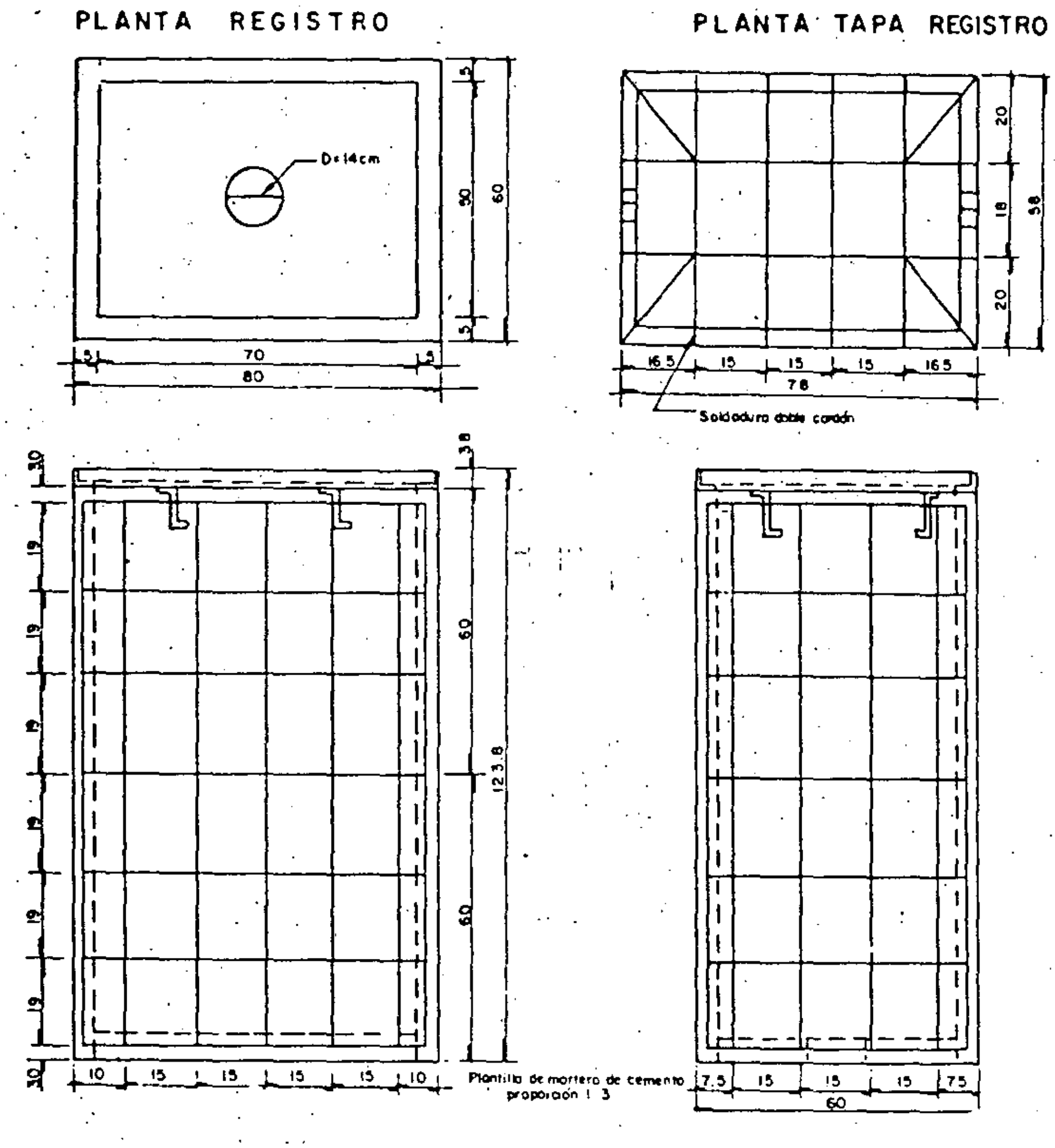
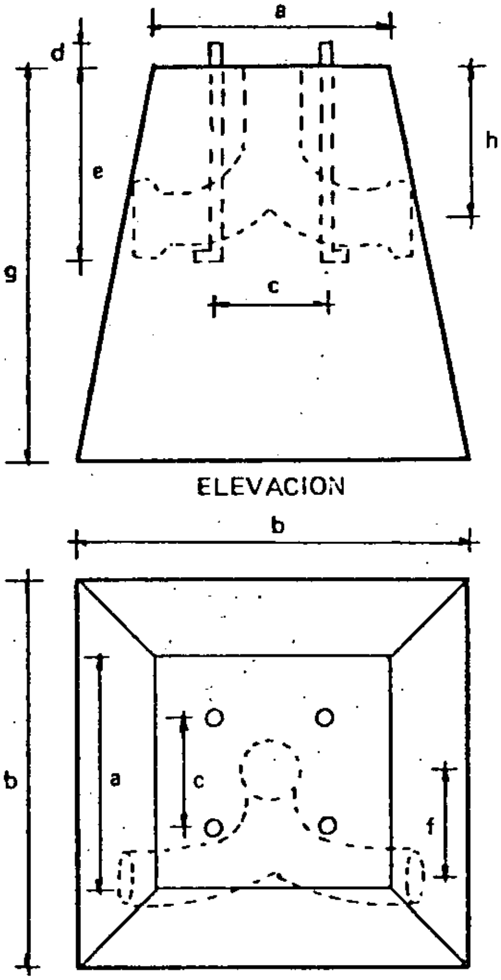


Figura 3
REGISTRO DE PASO



Concreto de f'_c – 150 kg/cm² con agregado máximo de 40 mm. Doble codo 90° de concreto de 10 cm de diámetro interior. Anclas de 25.4 mm (1") de diámetro y 55 cm de longitud con doblez de 10 cm.

CIMIENTO	a	b	c	d	e	f	g	h
para arbotante churubusco y jardín	60	100	27	6	49	28	100	38
para arbotante colonial	40	80	19	6	49	28	90	38

Acotaciones en cm

Figura 4
CIMENTACION DE CONCRETO TRONCO PIRAMIDAL

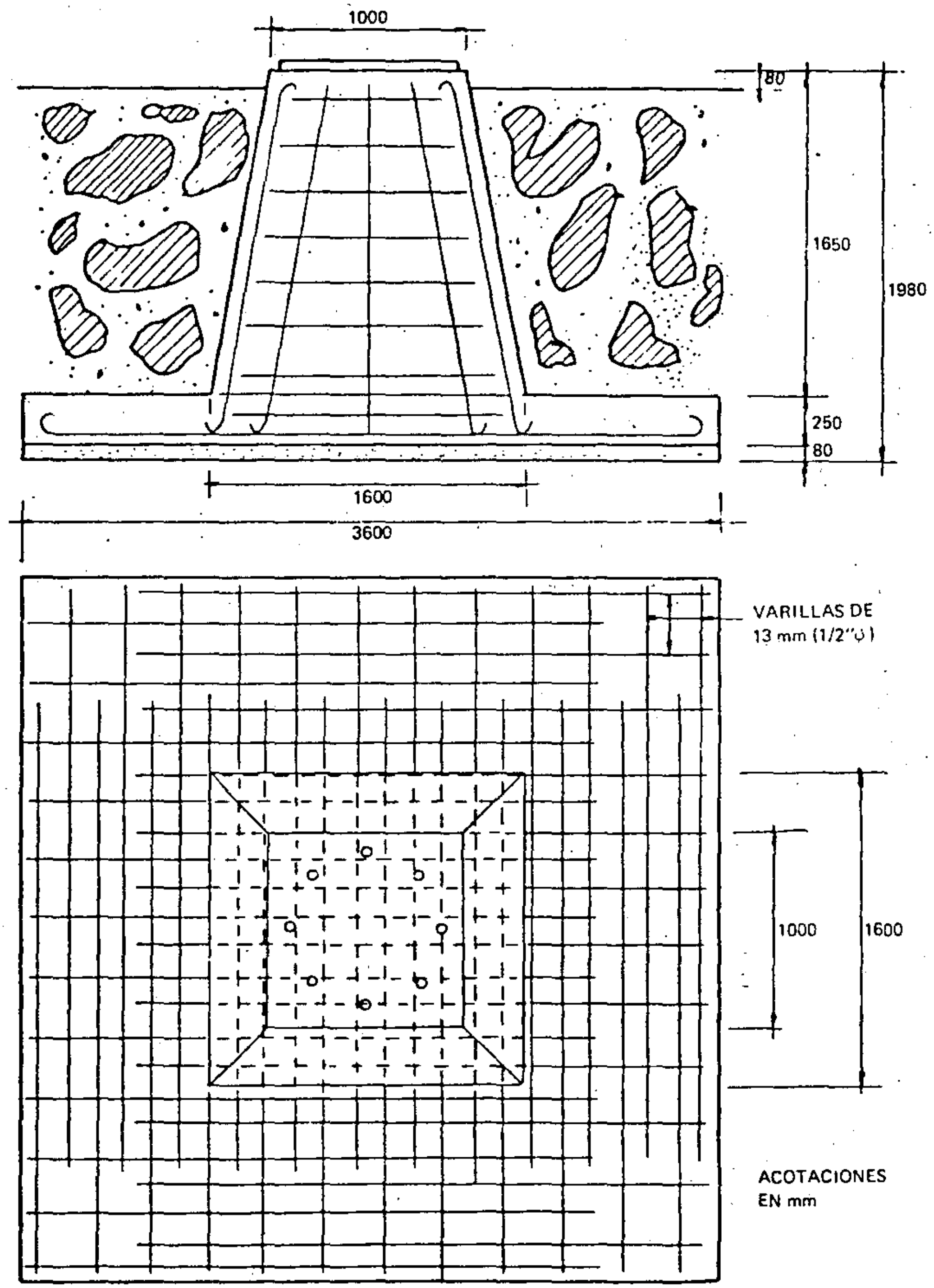


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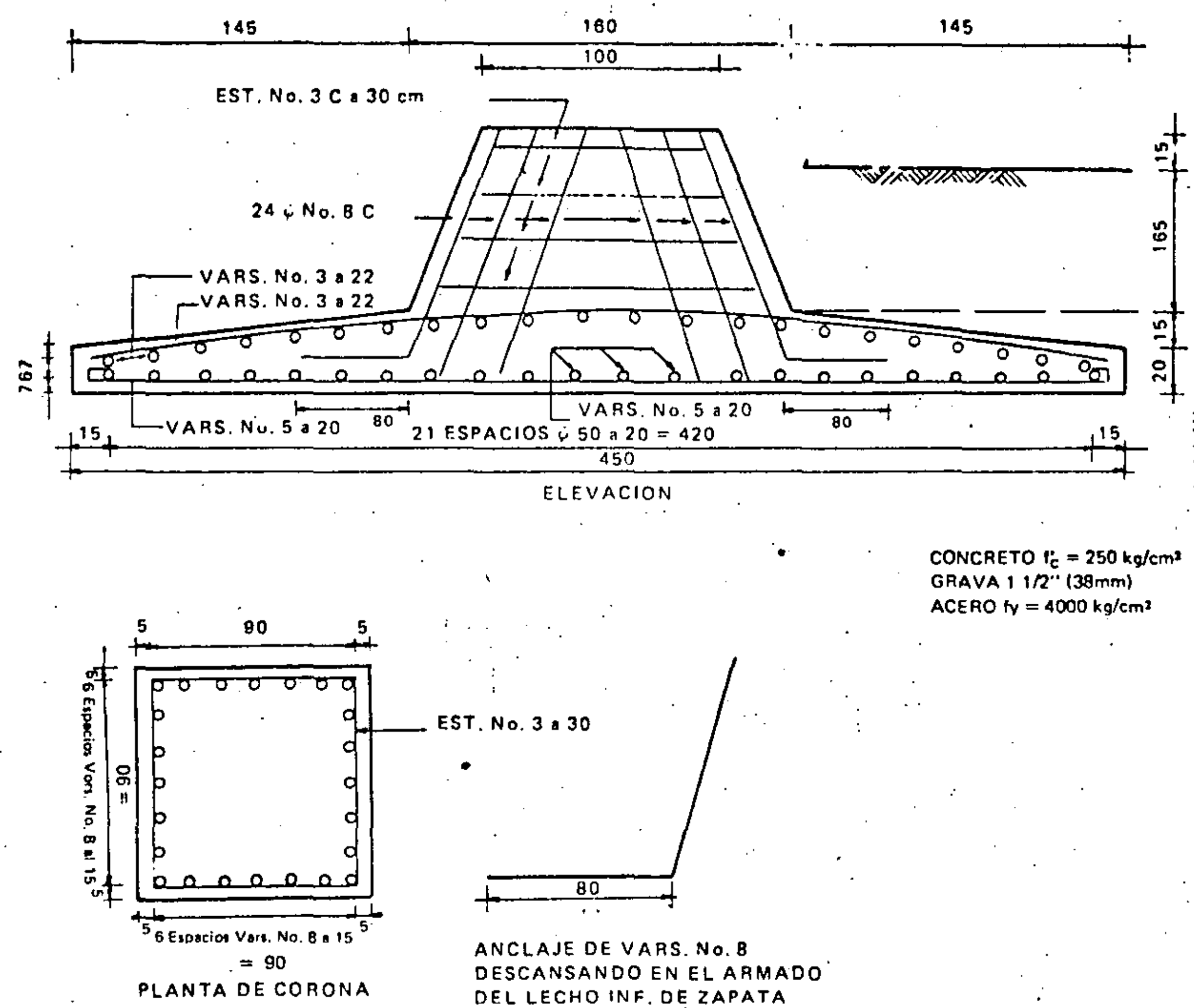
Figura 9
CIMENTACION PARA POSTES DE 25000 mm

Figura 10
CIMENTACION PARA POSTES DE 30000 mm



15 05 80

45

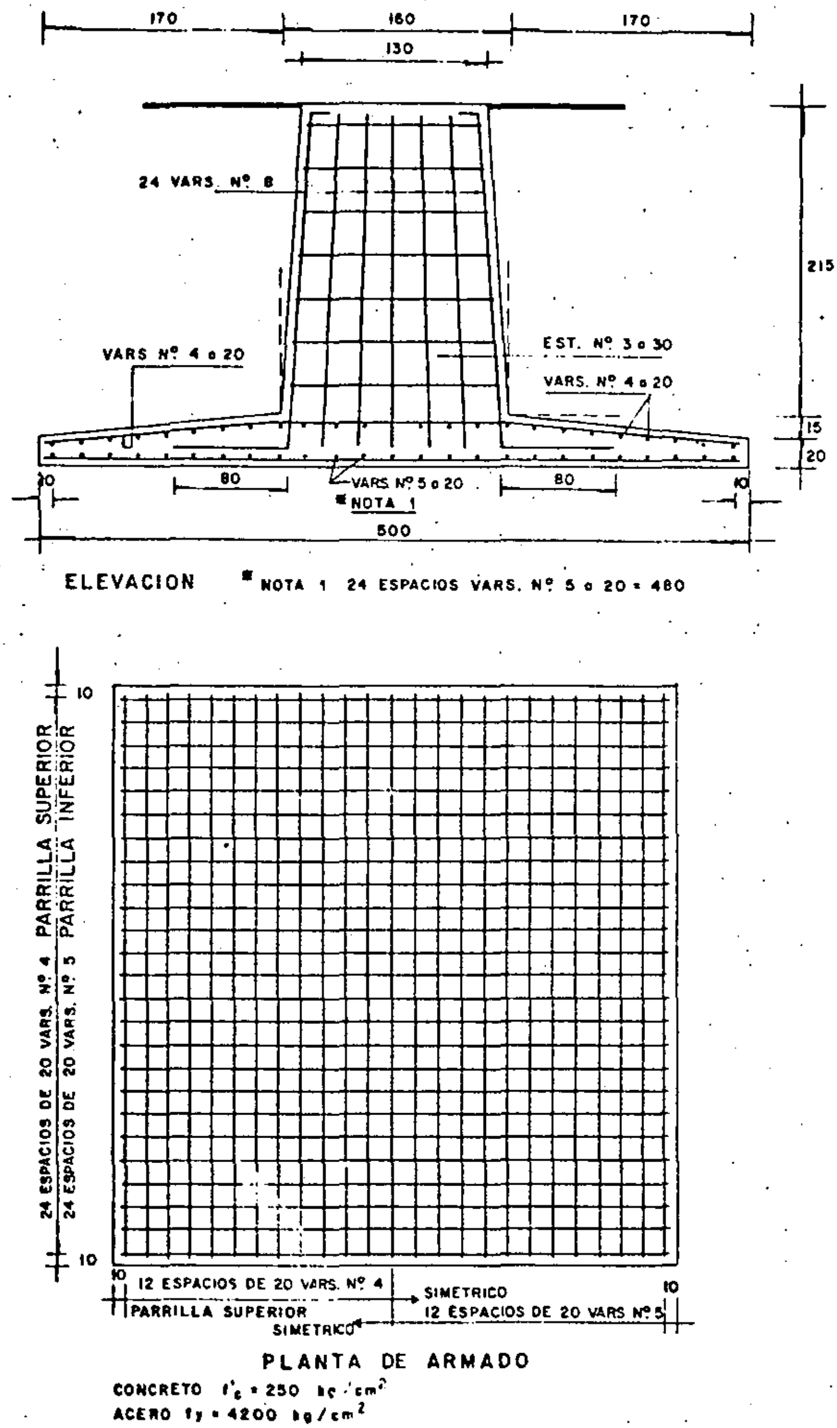


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Figura 11

CIMENTACION PARA POSTES DE 35000 mm

(1 de 2)

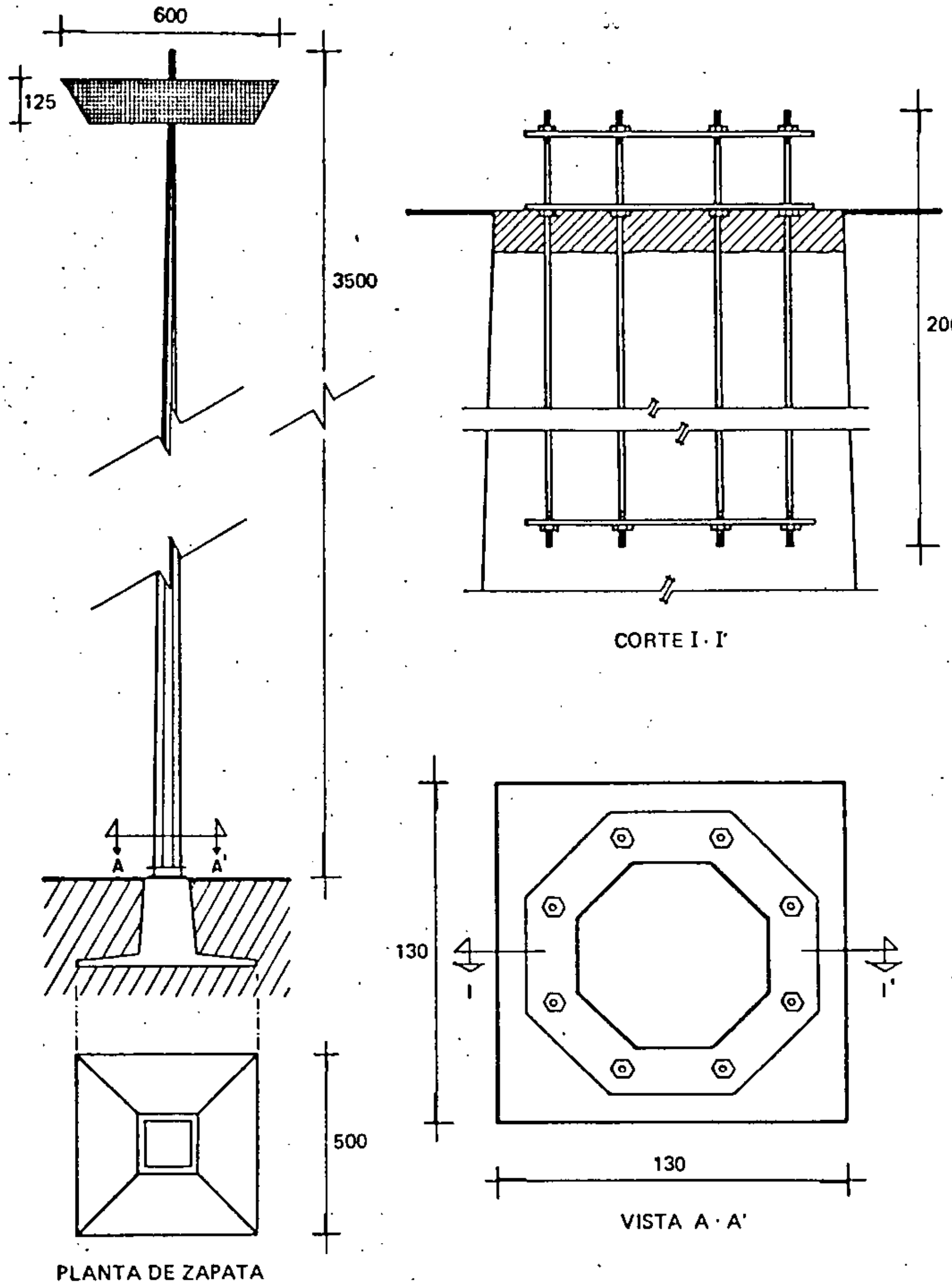

Figura 11
CIMENTACION PARA POSTES DE 35000 mm
(2 de 2)

1.5.4 Postes

Las luminarias para alumbrado público se montan generalmente en postes, ya sean propios o de la red eléctrica. Cualquiera de estos soportes deberán cumplir con las siguientes funciones:

- Resistir los impactos de viento
- Resistir los agentes corrosivos de la atmósfera
- Ser lo suficientemente ligeros para su manejo
- Proveer espacio suficiente para los accesorios que deban alojarse en ellos, tales como: conductores, balastros o equipos de control
- Requerir el mínimo de mantenimiento.

En la *figura III-63* se muestran las principales características geométricas de la unidad poste-luminaria, que son definidas por el poste mismo.

1.5.4.1 *Componentes*

Los postes son en sí columnas verticales instaladas con el fin de soportar una o varias luminarias y constan de varias partes:

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Poste o columna vertical que permite alcanzar la altura de montaje requerida, en combinación con el brazo, si se requiere.

Brazo o columna horizontal que permite ubicar la luminaria en el punto deseado, en el plano transversal de la calle a iluminar

Punta o pieza de montaje, colocada en el extremo superior del poste o del brazo, según sea el caso y que permite el montaje de la(s) luminaria(s). Puede ser lisa o roscada

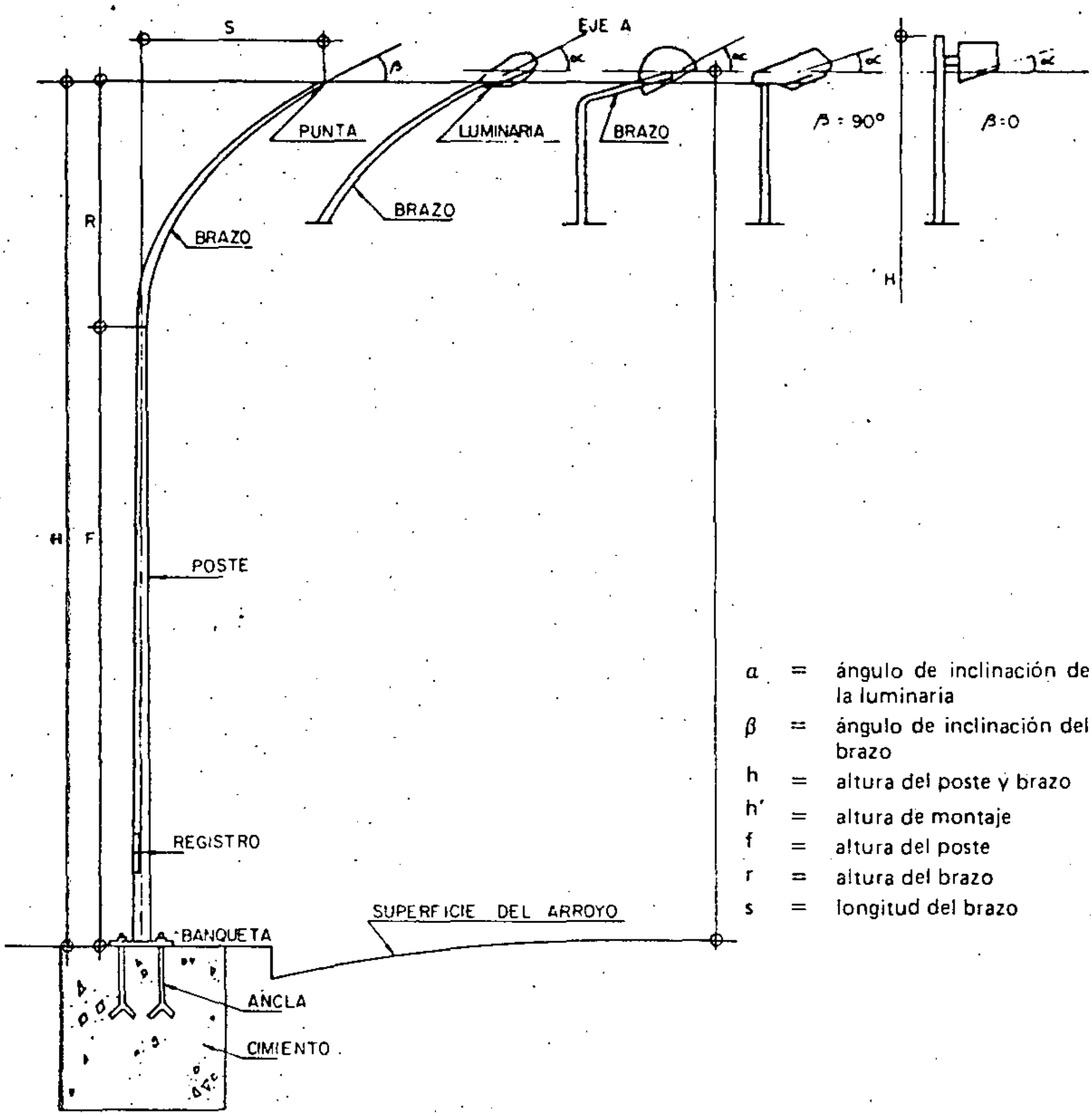
Placa base sólidamente fija a la base del poste para recibir las anclas de fijación al cimiento

Registro puesto cerca de la base del poste para permitir el alcance a los accesorios dentro del poste

Pedestal pieza que tiene el doble propósito de servir para el anclaje del poste y alojar el balastro

Anclas pernos metálicos empotrados en la cimentación de concreto para sujetar la base (placa o pedestal) al cimiento

En las *figuras III-64* a *III-66* se muestran los componentes anteriormente descritos, en diferentes modalidades de montaje.



α = ángulo de inclinación de la luminaria
β = ángulo de inclinación del brazo
h = altura del poste y brazo
h' = altura de montaje
f = altura del poste
r = altura del brazo
s = longitud del brazo

Figura III-63

1.5.4.2 *Construcción*

Los postes se fabrican con lámina de fierro rolado, en sus presentaciones más comunes y, se pueden encontrar también fabricados de concreto, madera o aluminio.

Uso

Por su uso, se clasifican como "punta de poste" cuando la luminaria va montada directamente al extremo superior del poste o "con brazo", estando en este caso preparados para

PUNTA DE POSTE

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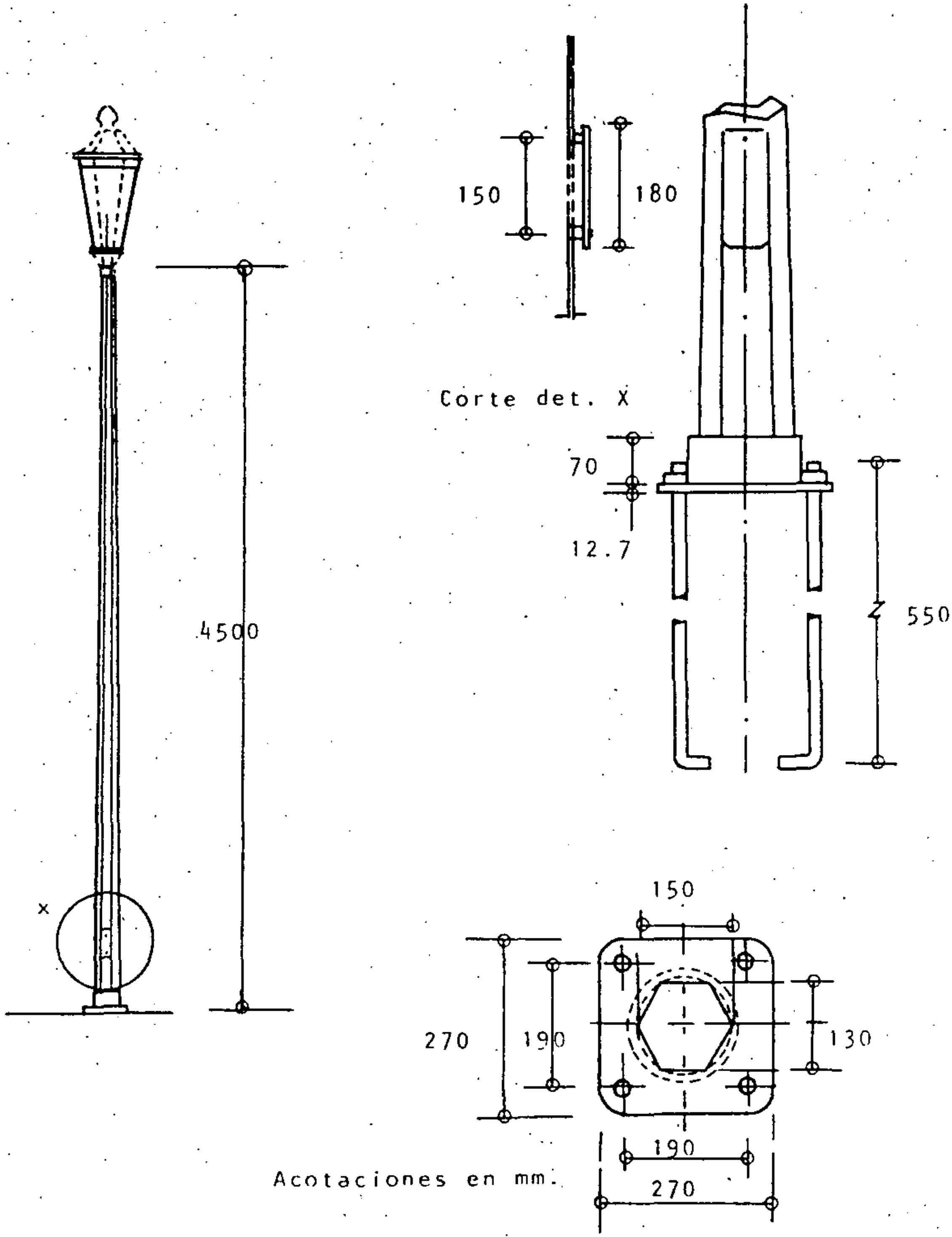


Figura III-64

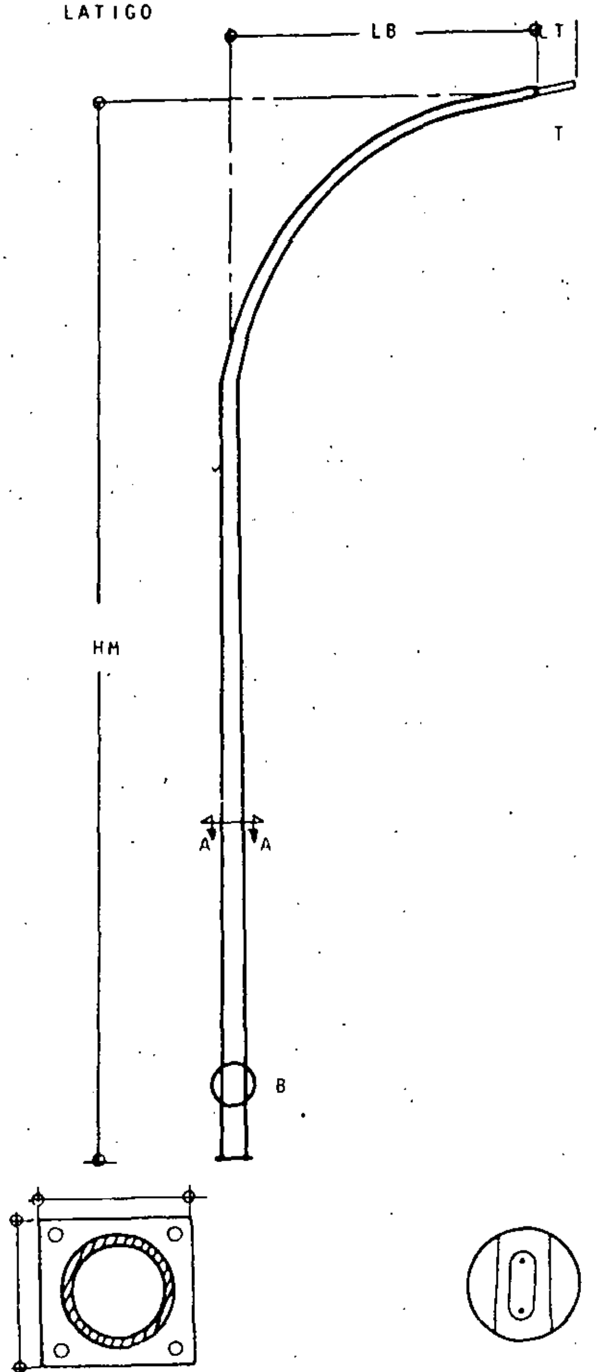
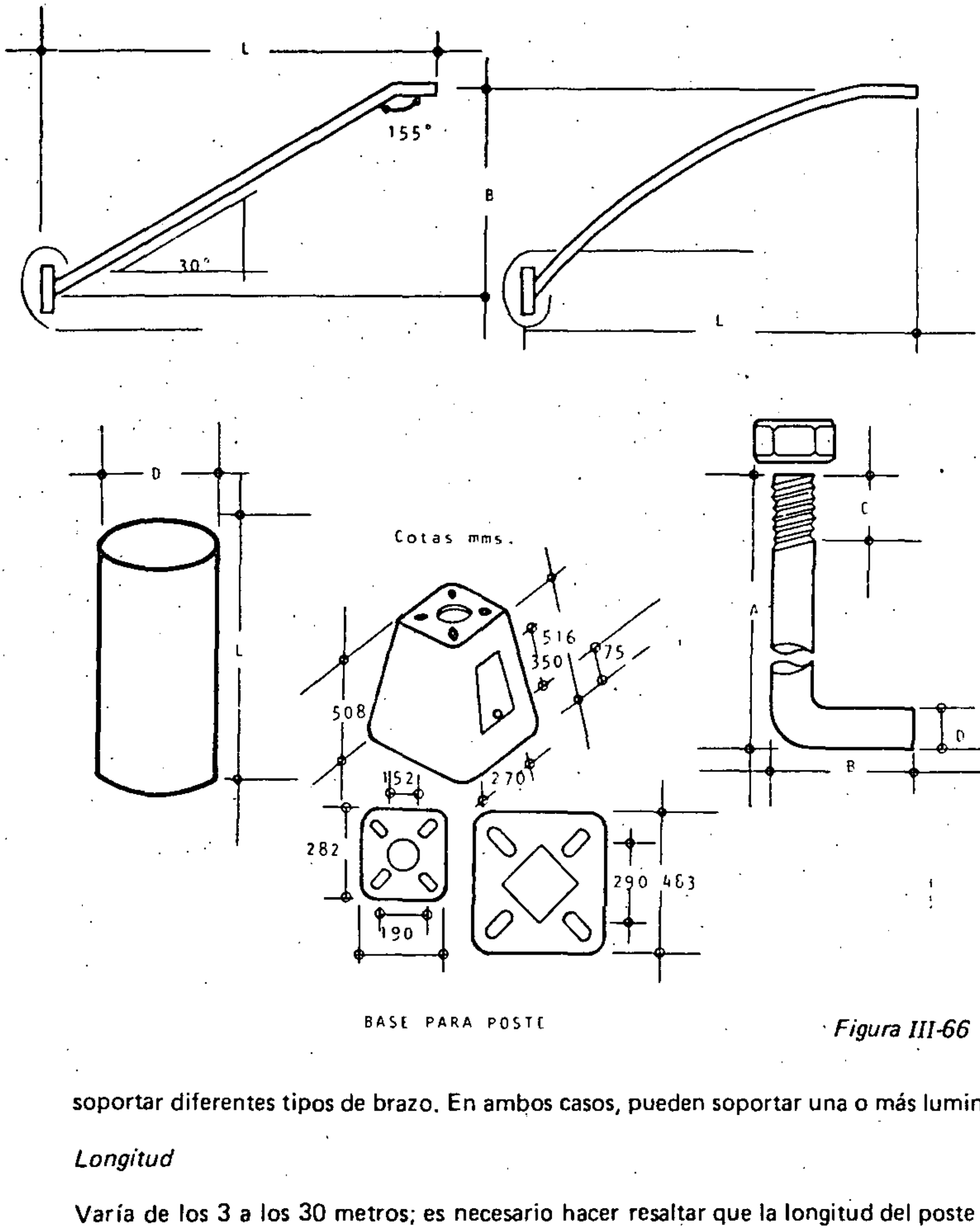


Figura III-65

Brazos metálicos



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BASE PARA POSTE

Figura III-66

soportar diferentes tipos de brazo. En ambos casos, pueden soportar una o más luminarias.

Longitud

Varía de los 3 a los 30 metros; es necesario hacer resaltar que la longitud del poste no necesariamente corresponde a la altura de montaje, ya que se debe de combinar con el brazo y en algunos casos con la longitud de poste que se empotra en el terreno para su montaje. Los fabricantes los ofrecen rectos o curvados (látigo).

Sección transversal

Es costumbre definirla por la forma, el material y el espesor del mismo, pero es recomendable especificarla por los esfuerzos a que estará sometido el poste, tales como: empuje del viento, impactos, flexión, peso originado por la luminaria y el brazo, etc. Las formas más comunes en el mercado son: circular, cuadrada, exagonal y octogonal.

Características estéticas

En el párrafo III.1.5.2.8, se menciona la necesidad de adecuar la luminaria al paisaje urbano, tanto diurno como nocturno. El poste deberá ser seleccionado en forma tal que armonice con dicho paisaje urbano.

En la *tabla III-13* se resumen los tipos de poste (con sus nombres comerciales) ofrecidos por los fabricantes y que puede servir como una guía inicial para su selección.

1.5.4.3 *Postes de la red eléctrica*

Tanto desde el punto de vista económico como estético, es conveniente usar los postes de la red eléctrica para soportar luminarias para alumbrado público.

Desde el punto de vista estético, al disminuir el número de postes se reducen los obstáculos al paisaje urbano.

Desde el punto de vista económico, la inversión inicial disminuye por:

1. No se requiere de postes ni de su instalación.
2. No se requiere la red subterránea ni la obra civil (excavaciones, ductos, registros, bases, etc.).
3. En caso de instalarse una red aérea de alimentación exclusiva para el servicio de alumbrado público, el costo de los conductores se reduce al usarse desnudos y de longitud menor.

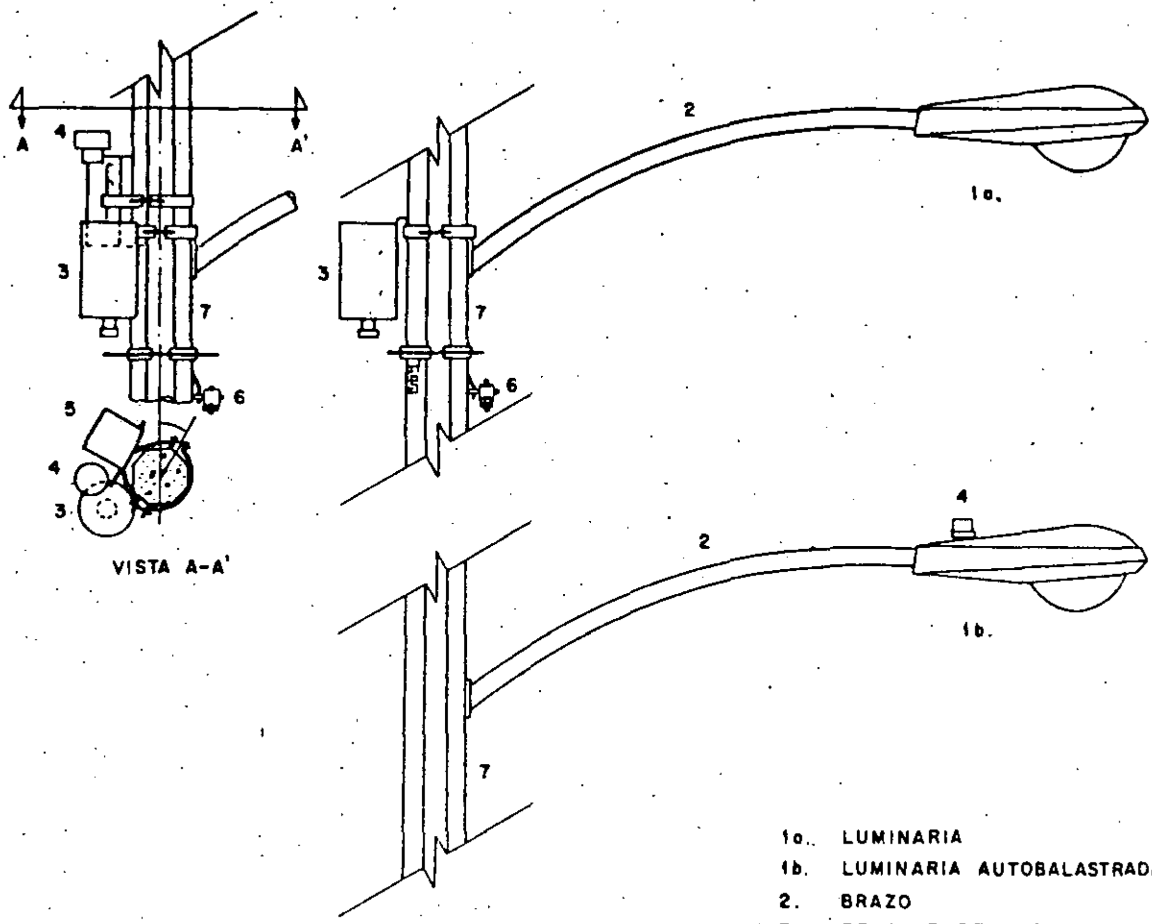
Por otra parte, la inversión aumenta por:

1. La posibilidad de instalar controles de encendido y apagado para cada lámpara.
2. La posibilidad de requerir que algunas operaciones de montaje y/o mantenimiento tengan que ser realizadas por la empresa suministradora.

Obviamente, esta solución sólo se puede considerar en aquellos casos en que la red eléctrica sea del tipo aéreo.

Deberá consultarse la oficina más próxima de la CFE, a fin de elaborar el proyecto en forma conjunta, ya que las alturas de montaje permitidas en este caso, así como la distancia interpostal, están definidas por la geometría de la red eléctrica.

La *figura III-67* muestra una instalación típica en poste de la red eléctrica.



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1a. LUMINARIA
1b. LUMINARIA AUTOBALASTRADA
2. BRAZO
3. REACTOR REMOTO
4. FOTOCONTROL
5. INTERRUPTOR
6. LINEA DE ALIMENTACION
7. POSTE DE CONCRETO

NOTA : LA COLOCACION EXACTA DE LA LUMINARIA DEBERA DETERMINARSE DE ACUERDO CON EL PERSONAL TECNICO DE CFE.

FIGURA III - 67

a) MONTAJE DE LUMINARIA CON BALASTRO Y FOTOCONTROL REMOTOS EN POSTE DE CFE

b) MONTAJE DE LUMINARIA AUTOBALASTRADA EN POSTE DE CFE

Figura III-67

Tabla III-13 POSTES

TIPO	MODELO	MATERIAL	ALTURA (m)	DIAMETRO BASE (cm)	DIAMETRO CORONA (cm)	MONTAJE	LONGITUD BRAZO (m)	ALTURA MONTAJE (m)
CUADRADO	Cónico	Lámina de acero	4 y 4.5	12	6.35	Sobrepuesto	1.8 a 2.5	5.2 y 5.7
		Lámina de acero	5 a 7	15.24	7.62	Sobrepuesto	1.8 a 2.5	6.2 a 7.2
		Lámina de acero	7.5 a 9.5	18.73	8.9	Sobrepuesto	1.8 a 2.5	8.7 a 10.7
		Lámina de acero	10 a 15	24.13 a 30.5	10.16 a 14	Sobrepuesto	1.8 a 2.5	11.2 a 16.2
	Con base metálica	Concreto (ligero)	6 y 7.5	15 y 16.3	10	Con pedestal	2.4	7 y 8.5
		Concreto (normal)	7 a 13	23.1 a 30	15	Con pedestal	2.4	8 a 14
	Para empotrarse	Concreto (ligero)	6 y 7.5	15 y 16.3	10	Empotrado	2.4	7 y 8.5
		Concreto (normal)	7 a 13	23.1 a 30	15	Empotrado	2.4	8 a 14
PUNTA DE POSTE	Tipo de jardín	Lámina de acero	7	15.2	5.1	Sobrepuesto	Sin	7
	Circular	Lámina de acero	4 a 7.5	15.25	10.16	Sobrepuesto	Sin	4 a 7.5
		Lámina de acero	8 a 12	16.51 a 26.67	10.6 a 15.25	Sobrepuesto	Sin	8 a 12
		Lámina de acero	3 a 8	15	5	Sobrepuesto	Sin	3 a 8
	Alameda para 1	Lámina de acero	5 a 7	15.24	7.62	Sobrepuesto	Sin	5 a 7
	bombillo	Lámina de acero	7.5 a 9	18.73	8.9			7.5 a 9
	San Angel	Lámina de acero	4.5	13	5.1	Sobrepuesto	Sin	4.5
	Cuadrado	Lámina de acero	12	28	10	Sobrepuesto	Sin	12
	Recto hexagonal	Lámina de acero	4.5 y 5	N. R.	N. R.	Con pedestal	Sin	5.6 y 6.1
	Tubo recto para	Lámina de acero	4 a 5	7.62	7.62	Sobrepuesto	Sin	4 a 5
	niple sin registro	Lámina de acero	5.5 a 6.5	10.16	10.16	Sobrepuesto	Sin	5.5 a 6.5
OCTAGONAL	Cónico para niple	Lámina de acero	4 y 4.5	11.8	6.35	Sobrepuesto	1.8 a 2.5	5.2 y 5.7
	con y sin registro	Lámina de acero	5 a 7	15.6	7.62	Sobrepuesto	1.8 a 2.5	6.2 a 8.2
		Lámina de acero	7.5 a 9.5	19	8.9	Sobrepuesto	1.8 a 2.5	8.7 a 10.7
		Lámina de acero	10 y 10.5	23.1	10.16	Sobrepuesto	1.8 a 2.5	11.2 y 11.7
	Tipo Insurgente	Lámina de acero	6 a 9	27.7	N.R	Con pedestal	1.8 y 2.4	6.5 a 9.5
	Cónico para 1	Lámina de acero	6 a 7	15.6	7.62	Sobrepuesto	1.8 a 2.5	7.2 a 8.2
	brazo con y sin	Lámina de acero	7.5 a 9.5	19	8.9	Sobrepuesto	1.8 a 2.5	8.7 a 10.7
	registro	Lámina de acero	10 y 10.5	23.1	10.16	Sobrepuesto	1.8 a 2.5	11.2 y 11.7
	Recto con y sin	Lámina de acero	7 a 8	N. R.	N. R.	Con pedestal	2.4	7.6 a 8.6
	pedestal	Lámina de acero	7 a 8	19	10	Sobrepuesto	1.8 y 2.5	8 a 9
	Arbotante	Concreto (ligero)	8.5 y 10.5	21 y 24.5	13.5	Con pedestal	2.4	9.5 y 11.5
	Con base metálica	Concreto (normal)	7 a 13	25 a 35	15	Con pedestal	2.4	8 a 14
	Para empotrarse	Concreto (ligero)	8.5 y 10.5	21 y 24.5	13.5	Empotrado	2.4	9.5 y 11.5
		Concreto (normal)	7 a 13	25 a 35	15	Empotrado	2.4	8 a 14

Tabla III-13 (Continuación)

TIPO	MODELO	MATERIAL	ALTURA (m)	DIAMETRO BASE (cm)	DIAMETRO CORONA (cm)	MONTAJE	LONGITUD BRAZO (m)	ALTURA MONTAJE (m)
CIRCULAR	Cónico tipo churubusco	Lámina de acero	N.R.	19	N.R.	Con pedestal	1.8 y 2.4	N.R.
	Ligero para reflectores	Lámina de acero	6 a 10.5	19	9	Sobrepuesto	1.8 y 2.4	6 a 10.5
		Lámina de acero	12 a 21	25 a 40	10	Sobrepuesto	1.8 y 2.4	12 a 21
	Pesado para reflectores	Lámina de acero	12 a 18	30 a 36	16	Sobrepuesto	1.8 y 2.4	12 a 18
		Lámina de acero	24 y 30	40 y 48	30	Sobrepuesto	1.8 y 2.4	24 y 30
	Troncónico	Lámina de acero	10.3 a 14.7	25.8 a 32.7	12	Empotrado	1.8 y 2.4	N.R.
	Recto sin pedestal	Lámina de acero	6.5 a 8	N.R.	N.R.	Sobrepuesto	2.4	7.5 a 8.6
	Recto con pedestal	Lámina de acero	6.5 a 8	N.R.	N.R.	Con pedestal	2.4	8 a 9.1
	Redondo para sobreponer	Lámina de acero	4 a 5.5	N.R	N.R.	Sobrepuesto	2.4	4.5 a 6
	sin pedestal	Lámina de acero	6 a 7.5	N.R.	N.R.	Sobrepuesto	2.4	6.5 a 8
	Redondo para sobreponer	Lámina de acero	4 a 5.5	N.R.	N.R.	Con pedestal	2.4	5 a 6.5
	con pedestal	Lámina de acero	6 a 7.5	N.R.	N.R.	Con pedestal	2.4	7 a 8.5
	Cónico	Lámina de acero	7 a 8	19	10	Sobrepuesto	1.8 y 2.5	8 a 9
	Cónico para un brazo	Lámina de acero	5 a 9.5	15.6 a 19	7.6 a 8.9	Sobrepuesto	1.8 a 2.5	6.2 a 10.7
	sin registro	Lámina de acero	10 y 10.5	23.1	10.1	Sobrepuesto	1.8 a 2.5	11.2 a 11.7
	Cónico para niple	Lámina de acero	4 a 7	11.8 a 15.6	6.35 a 7.6	Sobrepuesto	1.8 a 2.5	5.2 a 8.2
		Lámina de acero	7.5 a 9.5	19	8.9	Sobrepuesto	1.8 a 2.5	8.7 a 10.7
		Lámina de acero	10 a 12	23.1	10.16	Sobrepuesto	1.8 a 2.5	11.2 a 13.2
		Lámina de acero	15	30	14	Sobrepuesto	1.8 a 2.5	16.2
LATIGO	Forma parabólica	Lámina de acero	6 a 8	N.R.	N.R.	Sobrepuesto	1.8 a 2.8	6 a 8
	Circular tipo olímpico	Lámina de acero	5.3 a 7.3	15	4.5 a 6.9	Con pedestal	1.6 a 2.15	7 a 9
	Circular sin pedestal	Lámina de acero	7 a 8	N.R.	N.R.	Sobrepuesto	1.8 y 2.4	7 a 8
	Cónico circular para	Lámina de acero	7 a 9.5	15.6 a 19	7.6 a 8.9	Sobrepuesto	1.8 a 2.5	8.2 a 10.7
	1 brazo sin registro	Lámina de acero	10.5 a 12	23.1	10.16	Sobrepuesto	1.8 a 2.5	11.7 a 13.2
	Cónico circular para	Lámina de acero	4 a 7	11.8 a 15.6	6.35 a 7.6	Sobrepuesto	1.8 a 2.5	5.2 a 8.2
	niple sin registro	Lámina de acero	7.5 a 9.5	19	8.9	Sobrepuesto	1.8 a 2.5	8.7 a 10.7
		Lámina de acero	10 a 15	23.1 a 30	10.16 a 13.4	Sobrepuesto	1.8 a 2.5	11.2 a 16.2
	Cuadrado tipo olímpico	Lámina de acero	5.3 a 7.3	27	4.5 a 6.9	Con pedestal	1.8 y 2.4	7 a 9
	Octagonal sin pedestal	Lámina de acero	7 a 8	N.R.	N.R.	Sobrepuesto	1.8 y 2.4	7 a 8
HEXAGONAL	Cónico para niple	Lámina de acero	4 y 4.5	11.43	6.35	Sobrepuesto	1.8 y 2.5	5.2 y 5.7
		Lámina de acero	5 a 6	15.24	7.62	Sobrepuesto	1.8 y 2.5	6.2 a 7.2

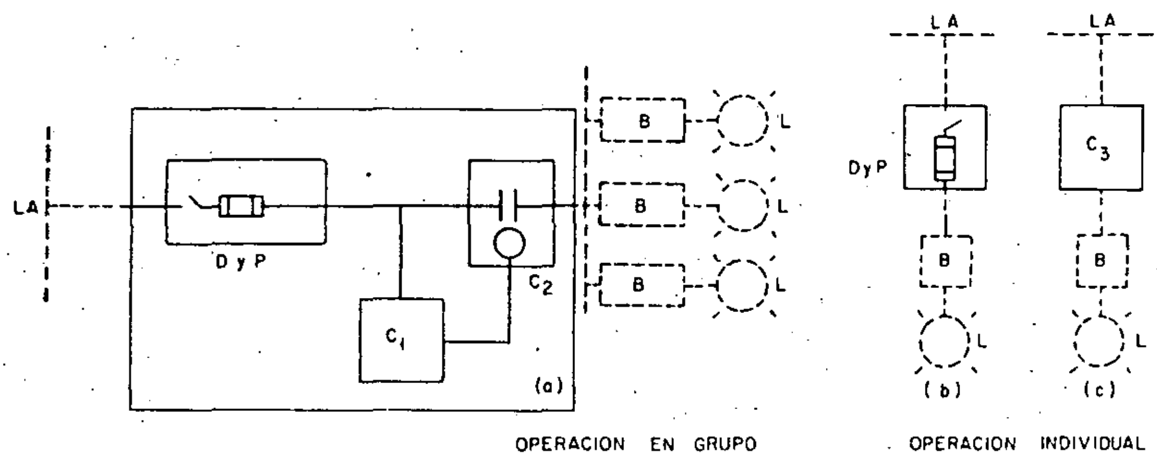
Altura de montaje = Altura del poste más longitud del brazo, de acuerdo al ángulo en que se fabrico el mismo.

N.R. = No reportado por el fabricante.

1.5.5 Equipos de control y protección

El control y la protección de los sistemas de alumbrado público puede ser individual o en grupo, manual o automático y se analiza en detalle en la sección III-2.1.

Los equipos que intervienen en las funciones de control y protección se muestran en la *figura III-68*.



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D	Desconexión de la red (interruptor de cuchillas o termomagnético)
P	Protección contra cortocircuito (y sobrecarga si se desea)
C_1	Sensor del control (fotocontrol, reloj, apagador manual, etc.)
C_2	Control del encendido y apagado (relevador o contactor)
C_3	Fotocontrol con fusible para operación y control de una lámpara
B	Balastro
L	Lámpara
LA	Línea de alimentación

Figura III-68

1.5.5.1 *Fotocontroles*

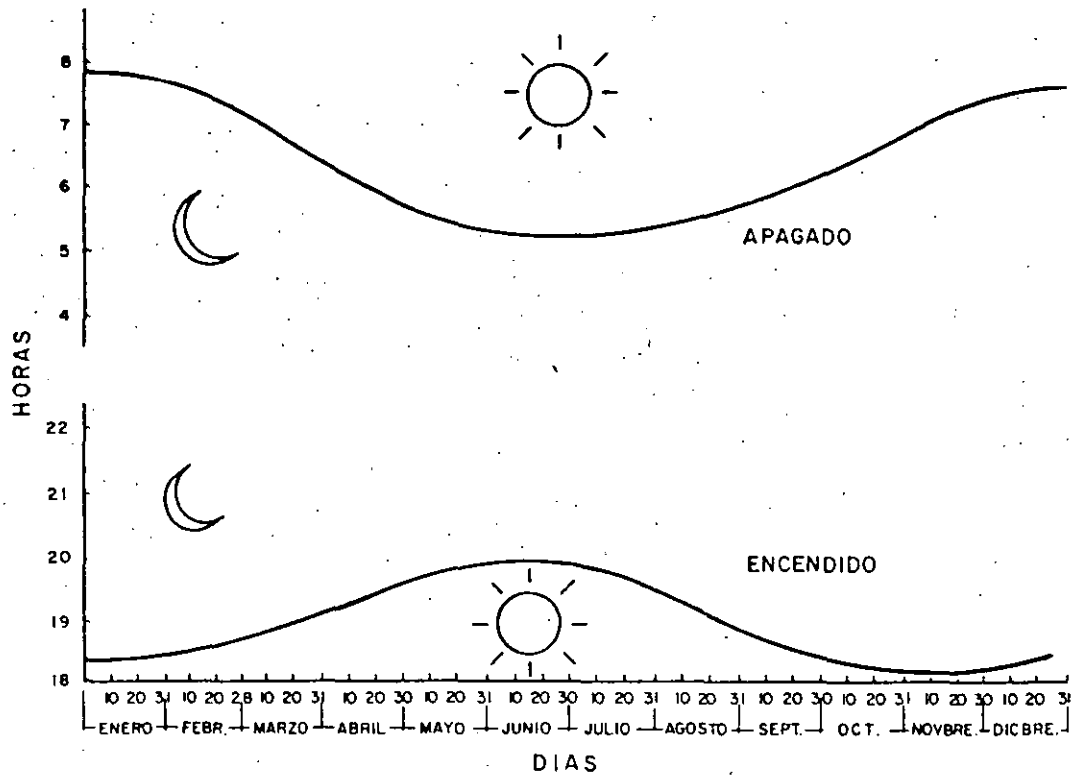
Son dispositivos sensibles a la luz natural, por lo que permiten encender y apagar las lámparas de un sistema de alumbrado público cuando se alcanza un nivel de iluminación natural prefijado. El fotocontrol puede tener incorporados circuitos o elementos que le permitan complementar su operación:

- Ajuste de los límites de operación en función de la iluminación natural.
- Retardos en la operación para evitar operaciones indebidas por la influencia de la luz proveniente de fanales de automóviles, rayos, oscurecimiento temporal por nubes espesas, etc.

Funcionamiento

A fin de familiarizar al lector con el funcionamiento de los fotocontroles, es conveniente explicar la llamada curva astronómica (*Figura III-69*).

El fotocontrol se ajusta a un valor tal que opere a valores cercanos a los obtenidos para el trazo de la curva astronómica del lugar.



CURVAS ASTRONOMICAS

Figura III-69

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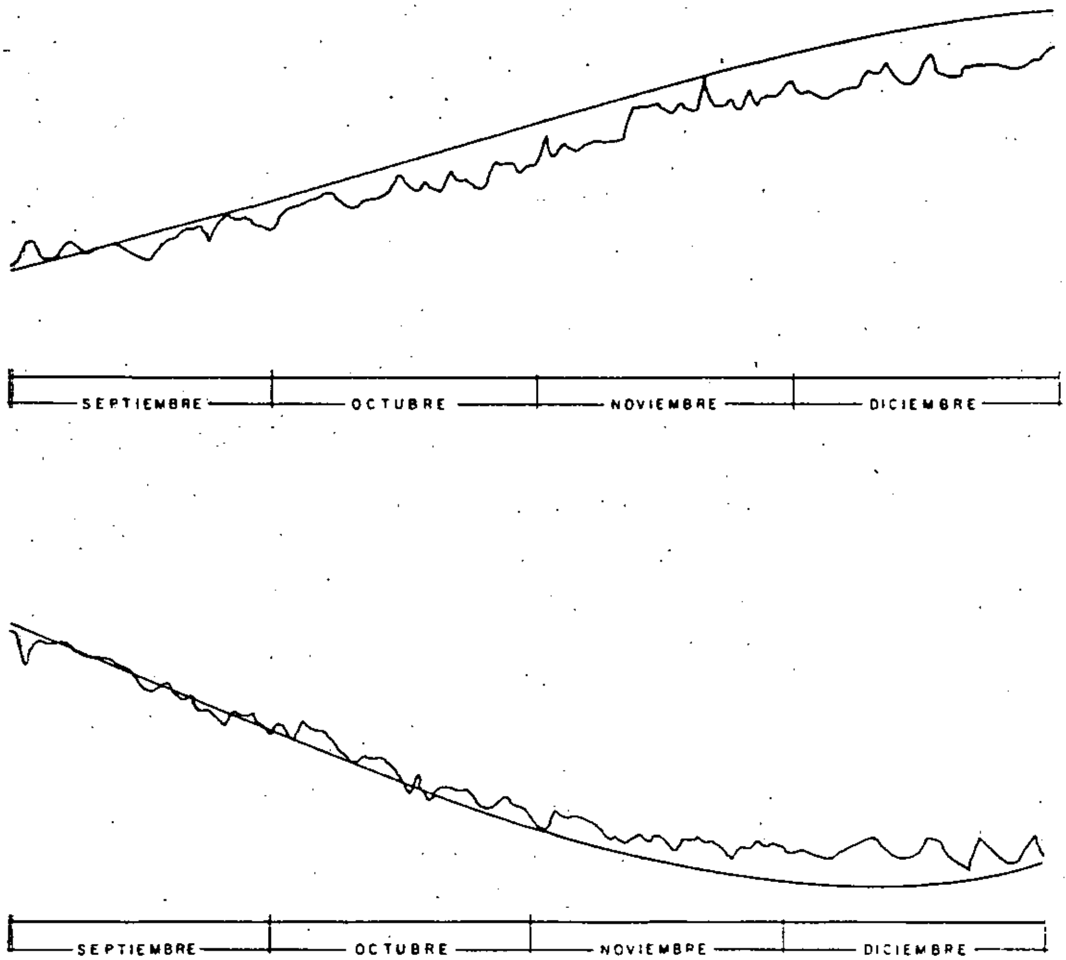
La luz del sol no empieza en el momento mismo de salir el sol ni se apaga súbitamente cuando se pone. Así, al orto y ocaso del sol precede y antepone una iluminación variable por momentos, denominada crepúsculo.

Teniendo en cuenta lo anterior, se puede trazar la curva de este comportamiento durante el año; a esto se le denomina curva astronómica.

En la *figura III-70* Electricité de France graficó el comportamiento de un fotocontrol comparado con la curva horaria, correspondiente a la Ciudad de París. Se observa que el fotocontrol tiene una respuesta muy aproximada a las necesidades de encendido-apagado, por lo que es el medio más adecuado para control de sistemas de alumbrado público.

Existen tres tipos de fotocontroles: fotoconductores, que funcionan por el efecto de la luz



D I A S

EJEMPLO COMPARATIVO DEL ENCENDIDO SEGUN CELULA FOTOELECTRICA Y SEGUN CURVA ASTRONOMICA.

Figura III-70

sobre el valor de la resistencia de determinados elementos, como el selenio y el sulfuro de cadmio; autogeneradores, en los cuales se produce una pequeña diferencia de potencial entre sus bornes cuando el elemento sensible es iluminado, como el selenio y óxido de cobre; los fotoemisores, en los cuales el cátodo emite electrones al iluminarse, utilizando para ello litio o sodio.

Todos los fotocontroles tienen el inconveniente de que con el transcurso del tiempo se van insensibilizando, por lo cual deben sustituirse o regularse periódicamente (este período puede estar comprendido entre dos y cinco años, lo que depende del fabricante).

El fotocontrol se debe situar normalmente en el centro de mando de la instalación, en tal forma que sólo pueda recibir luz diurna; orientado hacia el norte, cuidando que no incida sobre él la luz producida por las lámparas que controla o alguna otra fuente. El fotocontrol también puede instalarse en la parte superior de la luminaria si ésta está diseñada para dicho objetivo.

Es necesario hacer resaltar que dada la velocidad con que varía la iluminancia en los momentos en que se enciende o apaga el alumbrado, no tiene importancia decisiva la localización del fotocontrol, siempre que se tomen las medidas necesarias para que no incida sobre él luz artificial.

Un mismo fotocontrol puede accionar diversos centros de mando, aunque es conveniente que los circuitos correspondan a características similares.

En la *figura III-71* se representa físicamente un fotocontrol y en la *figura III-72* un esquema típico. La *tabla III-14* presenta los diferentes valores característicos disponibles en el mercado.

FOTOCONTROL

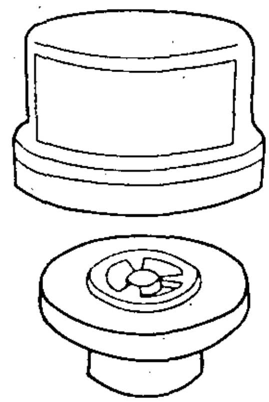


DIAGRAMA BASICO DE CONEXION

Figura III-71

CARACTERISTICAS DE SELECCION

1. Contactos.

   Deberán estar protegidos en el interior del fotocontrol, se suministran para una potencia entre 1,000 y 2,000 W, dependiendo de la utilización, con acción instantánea de cierre para evitar cualquier posibilidad de cebado del arco o chisporroteo.

2. Tiempo de retardo.

Deberá tener un tiempo de retardo entre 10 y 50 segundos en el accionamiento del fotocontrol, con el fin de evitar que éste funcione debido a una luz momentánea o a un ensombrecimiento.

3. Orientación direccional.

Para que la máxima respuesta se alcance colocando el fotocontrol hacia el norte (no todas las fotoceldas la requieren).

4. Nivel de ajuste.

Los fotocontroles se suministran con el ajuste realizado en fábrica, que puede variar entre 10 y 45 luxes al encender, pero lo importante es verificar que conserven la relación entre el encendido y apagado de 1 a 3.

1 – CHISPEADOR
2 – RDV (REGULADOR DE VOLTAJE
3 – RESISTENCIA LIMITADA
4 – FOTOCELULA
5 – BOBINA RELEVADOR
6 – CONTACTO DE OPERACION
7 – TERMINALES EXTERNAS

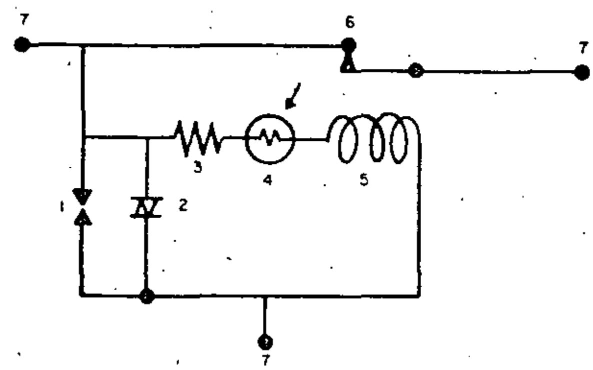


Figura III-72

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Calibración nominal, relación encendido-apagado y consumo propio de los fotocontroles nacionales

Tensión de operación, en volts	Calibración nominal, en luxes	Relación encendido apagado	Consumo propio, en watts
127	10.767	1:3	1.5
127	15 ± 20%	< 1:5	0.6
220	10.767	1:3	1.5
220	15 ± 20%	< 1:5	1.5
105 – 130	45	1:3	s/d
100 – 280	15 ± 20%	< 1:5	s/d
105 – 285	21.5	s/d	0.3
208 – 277	45	1:3	s/d
440	10.767	1:3	1.5

Tabla III-14

1.5.6 Relojes

El contactor puede ser accionado por medio de relojes de diversas características.

En el alumbrado público se deben utilizar los de operación eléctrica, con reglaje astronómico y escape de áncora.

Los interruptores horarios con reglaje astronómico varían diariamente, en forma automática y continua, la hora en que efectúan el anganche y desenganche del alumbrado, realizando esta operación a lo largo del año en el momento en que se indica en la curva astronómica correspondiente.

En los interruptores horarios sin reglaje astronómico es necesario ajustar a las curvas astronómicas la hora a la cual accionan el apagado y encendido de la instalación de alumbrado; este ajuste debe efectuarse en períodos comprendidos entre 10 y 20 días como máximo, lo que hace resaltar el problema y costo de esta operación y justifica ampliamente que no se utilicen en alumbrado público los interruptores horarios sin reglaje astronómico. co.

Cuando se interrumpe la corriente, es necesario que el reloj continúe funcionando, lo que se logra con un dispositivo de resorte para mantener el control. El resorte reserva debe enrollar eléctrica y automáticamente al retornar la corriente, sin necesidad de enrollamiento manual.

1.5.7 Combinaciones para alumbrado

Integran en una unidad dos elementos básicos para la protección y el control de circuitos de alumbrado público.

1.5.7.1 *Aplicación*

Cuando se requiera proteger y controlar desde un punto, uno o varios circuitos de alumbrado, en combinación con algún dispositivo de operación: fotocontrol, reloj, interruptor manual, etc.

1.5.7.2 *Características*

La *figura III-73* muestra los diagramas de conexión típicos de las combinaciones usadas. Las características eléctricas son:

Corriente (Amperes)	No. de Polos	Tensión Volts C. A.
30	2 a 4	120 a 600
60	2 a 4	120 a 600
100	2 a 4	120 a 600
200	2 a 4	120 a 600
300	2 a 4	120 a 600

La capacidad del interruptor termomagnético y de los contactos del contactor está dimensionada para soportar una corriente de arranque de 150 % de la corriente nominal.

La bobina de operación del contactor, generalmente opera a 127 V C.A. y puede estar conectada por medio de una clavija en la parte superior de la caja al fotocontrol.

En ocasiones se ofrecen algunos accesorios opcionales, tales como, contactos auxiliares normalmente abiertos o cerrados, apartarrayos, tablillas de conexión, etc.

También se pueden usar contactores para cargas de motores, teniendo la precaución de no sobrepasar su capacidad y se originen daños en los contactos.

1.5.7.3 *Construcción*

El conjunto interruptor-contactor debe alojarse en una caja metálica para uso intemperie y a prueba de lluvia (NEMA 3R), son dispositivos para su montaje en poste y si se especifica, con el fotoncontrol montado en su parte superior. Debe ser suficientemente robusto para soportar los esfuerzos que le transmita la vibración que se produzca en el poste por efecto de impactos o la acción del viento.

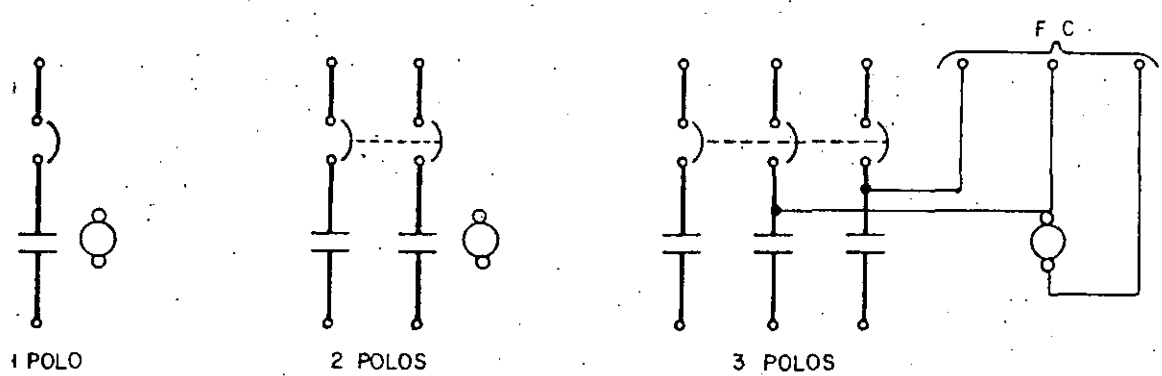

Figura III-73

1.5.8 Interruptores

Los interruptores son aparatos que sirven para interrumpir una corriente eléctrica, con objeto de proteger los equipos que se instalan a continuación de ellos, de sobrecorrientes que pudieran presentarse en las líneas de alimentación.

Para alumbrado público, se utilizan interruptores de navajas con fusibles, o termomagnéticos.

Al encontrarse normalmente a la intemperie, se utilizan cajas o gabinetes con denominación NEMA 3R, los cuales son a prueba de lluvia, ya que fueron diseñados para usarse en exteriores y para proteger al equipo que encierran contra precipitaciones pluviales; al mismo tiempo son resistentes a la corrosión ocasionada por la humedad.

a) Interruptores de navajas con fusibles (Figura III-74).

Las capacidades en las que se fabrica este tipo de interruptor son:

Capacidad, en amperes	Fusible tipo	Número de polos	Tensión, en C.A.	Gabinete Nema
30	Tapón	2	240	3R
30	Tapón	3	240	3R
30	Tapón	2	240	3R
30	Cartucho	3	240	3R
60	Cartucho	2	240	3R
60	Cartucho	3	240	3R
100	Cartucho	3	240	3R
200	Cartucho	3	240	3R

b) Interruptores termomagnéticos en gabinete (Figura III-75).

Se pueden conseguir de las siguientes capacidades:

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Capacidad, en amperes	Número de polos	Tensión, en C. A.	Gabinete Nema
15	1	120	3R
15	2	240	3R
15	3	240	3R
15	3	600	3R
20	1	120	3R
20	2	240	3R
20	3	240	3R
20	3	600	
30	1	120	3R
30	2	240	3R
30	3	240	3R
30	3	600	3R
40	1	120	3R
40	2	240	3R
40	3	240	3R
40	3	600	3R
50	1	120	3R
50	2	240	3R
50	3	240	3R
50	3	600	3R
70	2	240	3R
70	3	240	3R
70	3	600	3R
100	2	240	3R
100	3	240	3R
100	3	600	3R

INTERRUPTOR
TERMOMAGNETICO
EN GABINETE

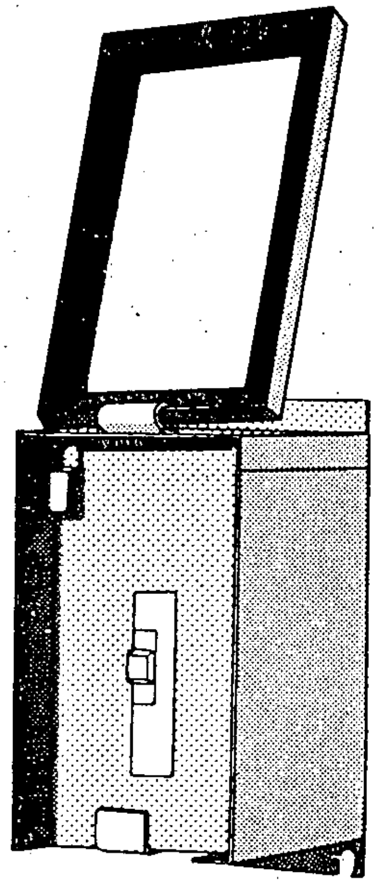


Figura III-75

INTERRUPTOR
DE NAVAJAS
CON FUSIBLES

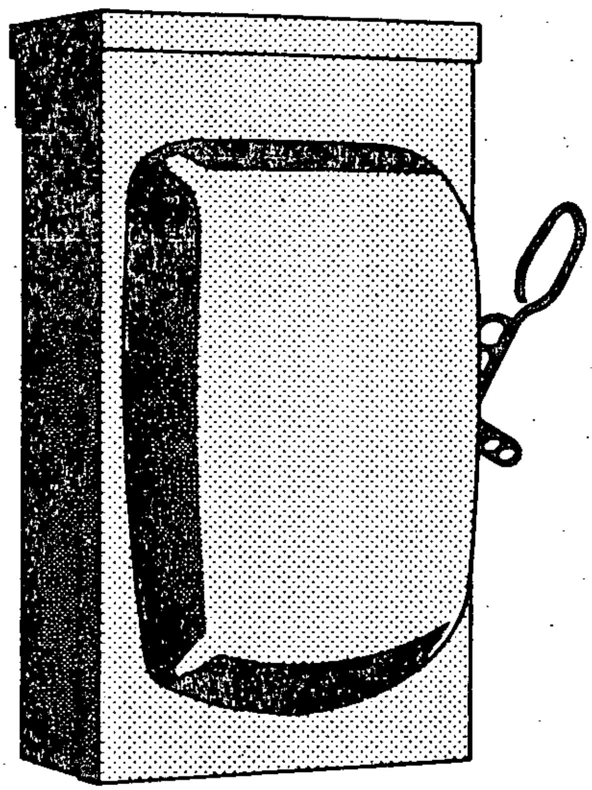


Figura III-74

CALCULO DE CONDUCTORES

Se va a iluminar una calle donde la compañía suministradora de energía eléctrica proporciona una línea trifásica de 13,200V, tipo aerea, con transformadores monofásicos de 10 KVA.

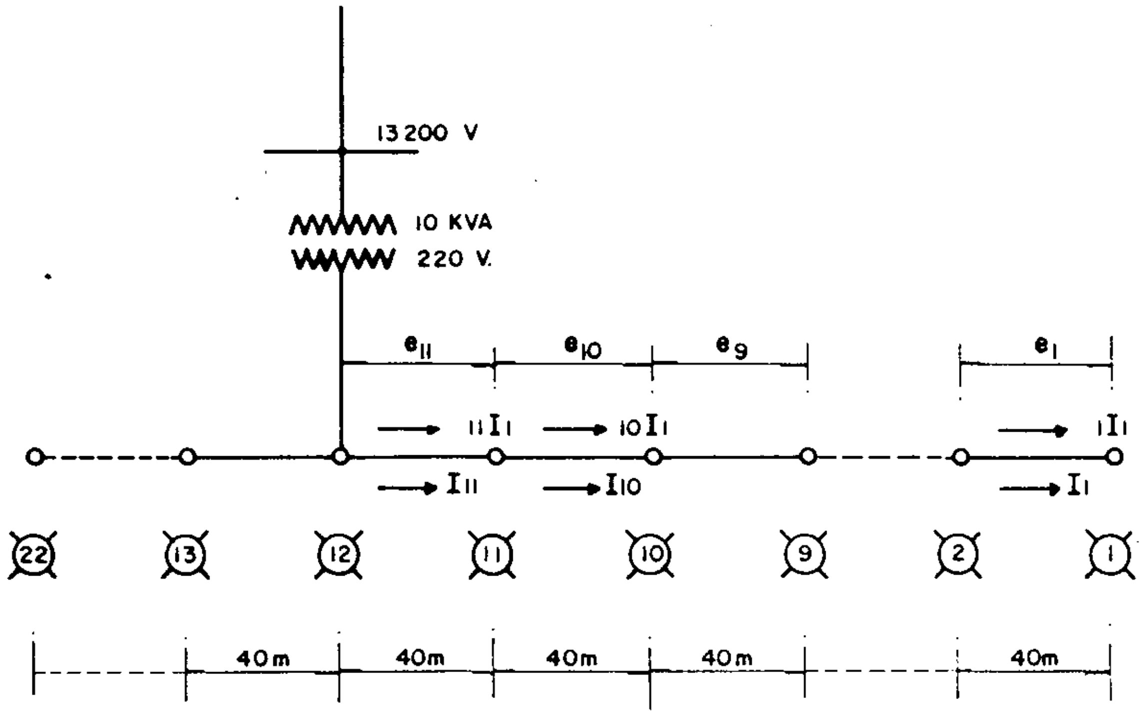
Los luminarios se instalarán en los mismos postes de la compañía suministradora, los cuales están espaciados regularmente a 40m, por lo tanto; se tiene un arreglo lateral y se colocará una luminaria por poste. El control y la alimentación se hará por grupo para un máximo de 23 luminarios.

DATOS:

No. de luminarios -	198
Tipo de lámpara -	Sodio A.P.
Potencia -	250 W
Pérdidas- -	50 W
Factor de potencia -	0.9 (-)
Balastro autorregulado - - - - - - - - - - - - - - - - -	60 Hz, 220V

DESARROLLO:

1°. Verificar si un transformador de 10 KVA, puede llevar la carga de 23 luminarios.


13200 V
10 KVA
220 V.
e11
e10
e9
e1
11I1
10I1
1I1
I11
I10
I1
22
13
12
11
10
9
2
1
40m
40m
40m
40m
40m

$$\frac{\text{(No. luminarios) x (Potencia del luminario)}}{\text{FACTOR DE POTENCIA}} = \frac{(23)\ (300)}{0.9} = 7.66 \text{ KVA.}$$

2°. Determinar el No. de transformadores requeridos.

$$\frac{\text{198 Luminarios}}{\text{23 LUM/TRANSFORMADOR}} = 8.6$$

No. de transformadores = 9

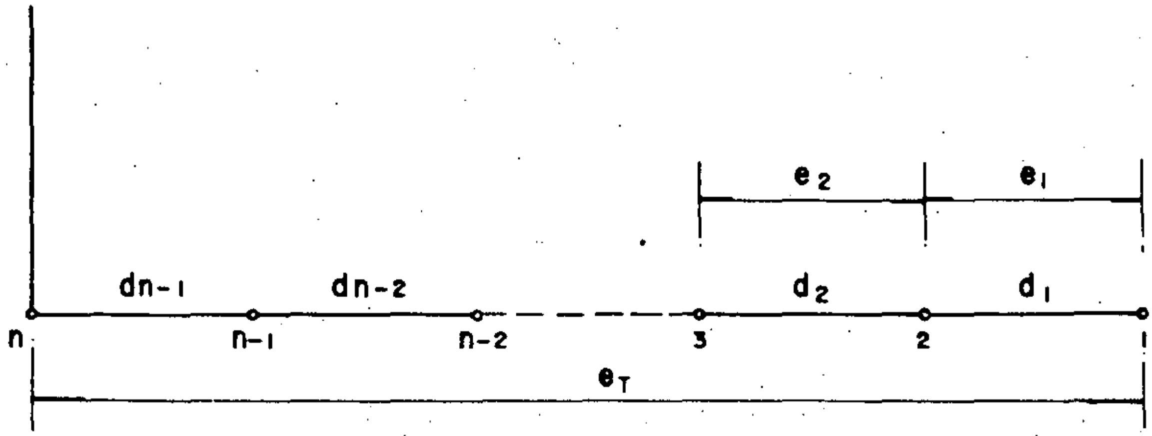
3°. Reagrupar el No. de luminarios por transformador.

$$\frac{\text{198 Luminarios}}{\text{9 Transformadores}} = \text{22 Luminarios/Transformador}$$

4°. Localización de transformadores.

La localización del transformador se hará al centro de cada grupo de 22 postes ∴ la alimentación a cada luminario se hará de acuerdo al siguiente arreglo.

5ª CALCULO APROXIMADO DE CONDUCTORES.



CONSIDERANDO LA MISMA POTENCIA PARA TODAS LAS LAMPARAS:

$$e_2 = \frac{e_1 d_2}{d_1} + e_1 \frac{d_2}{d_1} = 2e_1 \frac{d_2}{d_1}$$

$$e_3 = 3e_1 \frac{d_3}{d_1}$$

$$e_n = ne_1 \frac{d_n}{d_1}$$

$$e_T = \sum_{i=1}^{n} e_i = \sum_{j=1}^{n} \frac{j e_1 dj}{d_1} = \frac{e_1}{d_1} \sum_{j=1}^{n} j\ dj \quad \therefore$$

$$\frac{e_T\ d_1}{\sum_{j=1}^{n} j\ dj} = e_1 \qquad A_1 = f(e_1, I_1, V, d_1)$$

Si $d_1 = d_2 = \ldots\ldots\ldots = dn \quad \therefore$

$$e_T = \frac{e_1}{d_1} \sum_{j=1}^{n} j\ dj = e_1 \sum_{j=1}^{n} j = e_1 \frac{n(n+1)}{2}$$

$$e_1 = \frac{(e_T)(2)}{(n)(n+1)}$$

PARA NUESTRO CASO EN QUE LA DISTANCIA INTERPOSTAL ES LA MISMA, TENEMOS:

$$e_1 = \frac{2\,e_T}{n(n+1)}$$

e_T = MAXIMA CAIDA DE TENSION PERMITIDA A LO LARGO DE LAS 11 LUMINARIAS.

$e_T = 5\ \%$

$$e_1 = \frac{10}{11(12)} = 0.07575\ \%$$

$$e_n = n\,e_1\,\frac{dn}{d1} \quad \therefore$$

$$e_{11} = 11\,e_1\,\frac{40}{40} \quad \therefore$$

$$e_{11} = 0.833\ \%$$

PARA CALCULAR LA SECCION DE UN CONDUCTOR QUE NOS PERMITA LAS CAIDAS DE TENSION ESPECIFICADAS, PARA CADA TRAMO DE ALIMENTACION DE LUMINARIAS, SE PUEDEN APLICAR DIFERENTES METODOS ENTRE ELLOS:

$$A = \frac{4IL}{Vn\,e}$$ PARA CIRCUITOS MONFASICOS 2 HILOS.

DONDE: A = AREA DEL CONDUCTOR EN mm^2

I = CORRIENTE NOMINAL EN EL TRAMO QUE SE ANALIZA.

L = LONGITUD DEL TRAMO DE CONDUCTOR QUE SE ANALIZA

Vn = VOLTAJE NOMINAL DE LA LAMPARA.

e = PORCIENTO DE CAIDA DE TENSION DEL TRAMO QUE SE ANALIZA.

O BIEN APLICANDO EL FACTOR DE CAIDA DE TENSION UNITARIA

$$Fc = \frac{e \times 10 \times V}{L \times I}$$

DONDE :

Fc = FACTOR DE CAIDA DE TENSION UNITARIA
e = PORCIENTO DE CAIDA DE TENSION PERMITIDA EN EL TRAMO QUE SE ANALIZA
V = TENSION DE LA LAMPARA
L = LONGITUD INTERPOSTAL DEL TRAMO QUE SE ANALIZA
I = CORRIENTE QUE PASA POR EL TRAMO QUE SE ANALIZA

PARA DESARROLLAR CUALQUIERA DE LAS FORMULAS ANTERIORES, ES NECESARIO CONOCER LAS CORRIENTES EN CADA TRAMO $\therefore$

$$I_1 = \frac{\text{POTENCIA DE LAMPARA + PERDIDAS EN BALASTRO}}{\text{VOLTAJE NOMINAL DE LUMINARIO POR FACTOR DE POT. DEL LUM.}}$$

$$I_1 = \frac{250+50}{(220)(0.9)} = 1.515 \text{ A.}$$

$$I_n = nI_1$$

$$I_{11} = 11(1.515) = 16.66 \text{ A}$$

$$\text{SI } A = \frac{4IL}{Vne} \quad \therefore$$

PARA EL LUMINARIO 1 TENEMOS : $A_1 = \dfrac{4 I_1 L_1}{Vn \; e_1} \quad \therefore$

$$A = \frac{4(1.515)(40)}{220(0.07575)} = 14.5 \text{ mm}^2.$$

DE TABLA 1.4 TENEMOS QUE EL CONDUCTOR QUE SELECCIONADO SERA EL No. 4 AWG.

PARA EL LUMINARIO No. 11 TENEMOS :

$$A = \frac{4(11)(1.515)(40)}{220\ (0.833)} = 14.5\ mm^2$$

APLICANDO LA FORMULA DE FACTOR DE CAIDA DE TENSION UNITARIA TENEMOS:

PARA EL LUMINARIO 1

$$Fc = \frac{e_1 \times 10 \times V}{L_1 \times I_1} = \frac{(0.07575)(10)(220)}{(40)(1.515)} = 2.75$$

CONSULTANDO LA TABLA "A" TENEMOS UN CONDUCTOR CALIBRE No. 4 AWG.

PARA EL LUMINARIO 11

$$Fc = \frac{10\, e_{11} \times V}{L_{11} \times I_{11}} = \frac{10(0.833)(220)}{40\,(16.66)} = 2.75$$

SI CONSIDERAMOS EL CONDUCTOR CALIBRE 4 AWG., SE CALCULA EL PORCIENTO DE CAIDA DE TENSION REAL EN CADA TRAMO.

$$e_1 = \frac{Fc\ L_1\ I_1}{10\ V} = \frac{1.919 \times 40 \times 1.515}{(10)(220)} = 0.0528$$

$$e_T = \frac{n(n+1)}{2}\ e_1 = 3.488\ \%$$

ESTOS METODOS SON MUY APROXIMADOS, SI SE DESEA TENER CALCULOS MAS EXACTOS, SE PARTE DE ESTE CONDUCTOR PARA APLICAR LA SIGUIENTE FORMULA

$$e = I\,(R\cos\theta + X\,\text{sen}\,\theta) \times 2$$

$$e_1 = 2 I_1\,(R_1\cos\theta + X_1\,\text{sen}\,\theta)$$

$R_1 = ? = 0.04037\ \Omega$

$X_1 = ?$

$\theta = ?$

DE TABLA 1.4 $R = 0.83\ \Omega/\text{Km}$ a 20° C

ENTRE EL LUMINARIO 1 y 2 HAY UN TRAMO DE 40 m. ∴

$$R_1 = 0.83\ \frac{\Omega}{\text{Km}} \times \frac{1\,\text{Km}}{1000\,\text{m}} \times 40\,\text{m}$$

$R_1 = 0.0332\ \Omega$ a 20° C

CORRIGIENDO A 75° C $\qquad R_{1N} = R_1\,\dfrac{T_N + 234.5}{T + 234.5}$

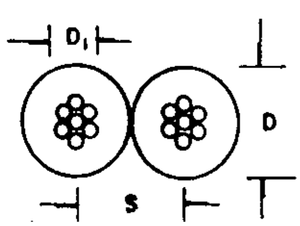
$$R_{1N} = 0.0332\ \frac{75 + 234.5}{20 + 234.5}$$

$$\boxed{R_{1N} = 0.04037\ \Omega}$$

$X = 2\pi f L$ PERO L DE TABLA B TENEMOS :

$$L = 2 \times 10^{-4}\ \text{Ln}\,\frac{DMG}{RMG}$$

ARREGLO DE CONDUCTORES.



S = DMG = DISTANCIA MEDIA GEOMETRICA

D = DIAMETRO EXT. DEL CONDUCTOR C/AISLAMIENTO

D_1 = DIAMETRO EXT. DEL CONDUCTOR S/AISLAMIENTO

$D = 9.4$ mm.

$D_1 = 5.41$ mm.

$S = D = 9.4$ mm. (DE TABLA B)

r = RADIO DEL CONDUCTOR

$$r = \frac{D_1}{2} = \frac{5.41}{2} = 2.705 \text{ mm.}$$

DE TABLA D

$RMG = 0.726\, r = 0.726 \times 2.705 = 1.9638$ mm.

APLICANDO LA FORMULA

$$L = 2 \times 10^{-4} \text{Ln} \frac{DMG}{RMG} = 2 \times 10^{-4} \text{Ln} \frac{9.4}{1.9638}$$

$$L = 2 \times 10^{-4} \text{Ln } 4.7866 \ \frac{\text{HENRIOS}}{\text{KM.}}$$

PARA 40 m TENEMOS: $L = 2 \times 10^{-4} \text{ Ln } 4.7866 \ \frac{H}{KM} \ \frac{1 \text{ KM}}{1000 \text{ M.}} \times 40 \text{ m}$

$$L = 2 \times 10^{-4} \text{ Ln } 4.7866 \times 0.04 \text{ H}$$

$$L = 2 \times 10^{-4} \times 1.5658 \times 0.04 \text{ H}$$

$$\boxed{L = 0.2526 \times 10^{-5} \text{ H}}$$

$$X = 2 \pi f L = 2 (3.1416)(60)(1.2526 \times 10^{-5})$$

$$X = 472.219 \times 10^{-5}$$

$$\boxed{X = 0.00472219 \ \Omega}$$

CALCULO DEL ANGULO DE DEFASAMIENTO

FACTOR DE POTENCIA DE LUMINARIO = 0.9

ANG. cos (0.9) = θ = 25.84° ∴

$\cos\theta = 0.9$

$\operatorname{sen}\theta = 0.4358$

SUSTITUYENDO EN LA ECUACION

$$e_1 = 2 I_1 (R \cos\theta + X \operatorname{sen}\theta)$$

$$e_1 = 2 (1.515)(0.04037 \times 0.9 + 0.00472219 \times 0.4358)$$

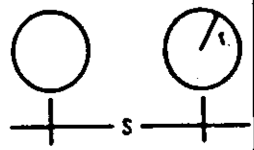
e_1 = 0.116 VOLTS

$$e_T = \frac{n(n+1)}{2} e_1 = 7.66 \text{ V.}$$

$$e_T(\%) = \frac{7.66}{220} \times 100 = 3.48\ \%$$

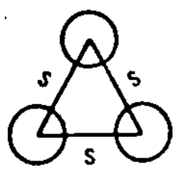
TABLA B CASO 1

FORMULAS DE CALCULO DE LA INDUCTANCIA TOTAL (H/Km)



$$L_m = 2\times10^{-4} \ \ln \frac{S}{RMG} \quad (6.3)$$

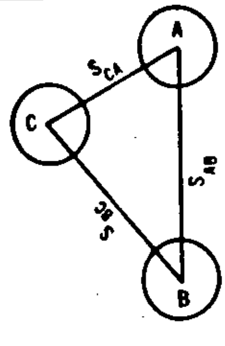
Formación triangular equidistante



$$L = L_A = L_B = L_C$$

$$L = 2\times10^{-4} \ \ln \frac{S}{RMG}$$

(6.4)



$S_{AB} \neq S_{BC} \neq S_{CA}$

Formación triangular

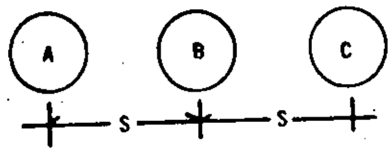
El valor medio de la inductancia total del sistema es:

$$L = 2\times10^{-4} \ \ln \frac{DMG}{RMG} \quad (6.5)$$

donde DMG es la distancia media geométrica y queda definida como:

$$DMG = \sqrt[3]{S_{AB} \times S_{BC} \times S_{CA}}$$

(6.5')



Formación plana

El valor medio de la inductancia total es:

$$L = 2\times10^{-4} \ \ln \frac{DMG}{RMG}$$

donde $DMG = \sqrt[3]{2} \times S$ (6.6)

TABLA C

CONSTRUCCIONES PREFERENTES DE CABLE DE COBRE CON CABLEADO REDONDO COMPACTO

Designación mm²	AWG o MCM	Área de la sección transversal, mm²	Número de alambres	Diámetro exterior nominal, mm	Peso nominal kg/km
—	8	8.37	7	3.40	75.9
—	6	13.30	7	4.29	120.7
—	4	21.15	7	5.41	191.9
—	2	33.6	7	6.81	305
—	1	42.4	19	7.59	385
50	—	48.3	19	8.33	438
—	1/0	53.5	19	8.53	485
—	2/0	67.4	19	9.55	612
70	—	69.0	19	9.78	626
—	3/0	85.0	19	10.74	771
—	4/0	107.2	19	12.06	972
—	250	126.7	37	13.21	1149
150	—	147.1	37	14.42	1334
—	300	152.0	37	14.48	1379
—	350	177.3	37	15.65	1609
—	400	203	37	16.74	1839
240	—	239	37	18.26	2200
—	500	253	37	18.69	2300
—	600	304	61	20.6	2760
—	750	380	61	23.1	3450
—	800	405	61	23.8	3680
—	1000	507	61	26.9	4590

TABLA D

RADIO MEDIO GEOMETRICO DE CONDUCTORES USUALES

Construcción del conductor	RMG
Alambre sólido	0.779r
Cable de un solo material	
7 hilos	0.726r
19 hilos	0.758r
37 hilos	0.768r
61 hilos	0.772r
91 hilos	0.774r
127 hilos	0.776r
r = Radio del conductor	

TABLA 1.4

RESISTENCIA ELECTRICA DE CONDUCTORES DE COBRE

	CALIBRE AWG MCM	AREA DE LA SECCION TRANSVERSAL (mm2)	NUMERO DE HILOS	RESISTENCIA ELECTRICA C.D. 20°C (OHMS/KM)
ALAMBRES	18	0.823	–	21.0
	16	1.308	–	13.2
	14	2.08	–	8.27
	12	3.31	–	5.22
	10	5.26	–	3.28
CABLES	18	0.823	7	21.3
	16	1.308	7	13.42
	14	2.08	7	8.45
	12	3.31	7	5.32
	10	5.26	7	3.35
	8	8.37	7	2.10
	6	13.30	7	1.322
	4	21.15	7	0.830
	2	33.6	7	0.523
	1/0	53.5	19	0.329
	2/0	67.4	19	0.261
	3/0	85.0	19	0.207
	4/0	107.2	19	0.1640
	250	126.7	37	0.1390
	300	152.0	37	0.1157
	350	177.4	37	0.0991
	400	202.7	37	0.0867
	500	253.3	37	0.0695
	600	304.1	61	0.0578
	750	380.0	61	0.0463
	1000	506.7	61	0.0348
	1250	633.3	91	0.0278
	1500	760.1	91	0.0232

FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

C U R S O S   A B I E R T O S

ILUMINACION EXTERIOR:
PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

PROCEDIMIENTOS PARA MEDICIONES EN CAMPO

ING. JUAN JOSE QUEZADA R.

PALACIO DE MINERIA

Palacio de Minería   Calle de Tacuba 5   Primer piso   Deleg. Cuauhtémoc 06000   México, D.F.   Tel.: 521-40-20   Apdo. Postal M-2285

AREAS DEPORTIVAS

PUNTOS DE PRUEBA

Espaciados de acuerdo al area.

Lecturas al centro.

Dividir cuadros aprox. 5% del area total.

Puntos especiales de prueba.

(Campos de tiro, Golf, patinaje, etc..)

Cuadros con mas del 50% dentro del area se Incluyen al calculo, menores no se incluyen.

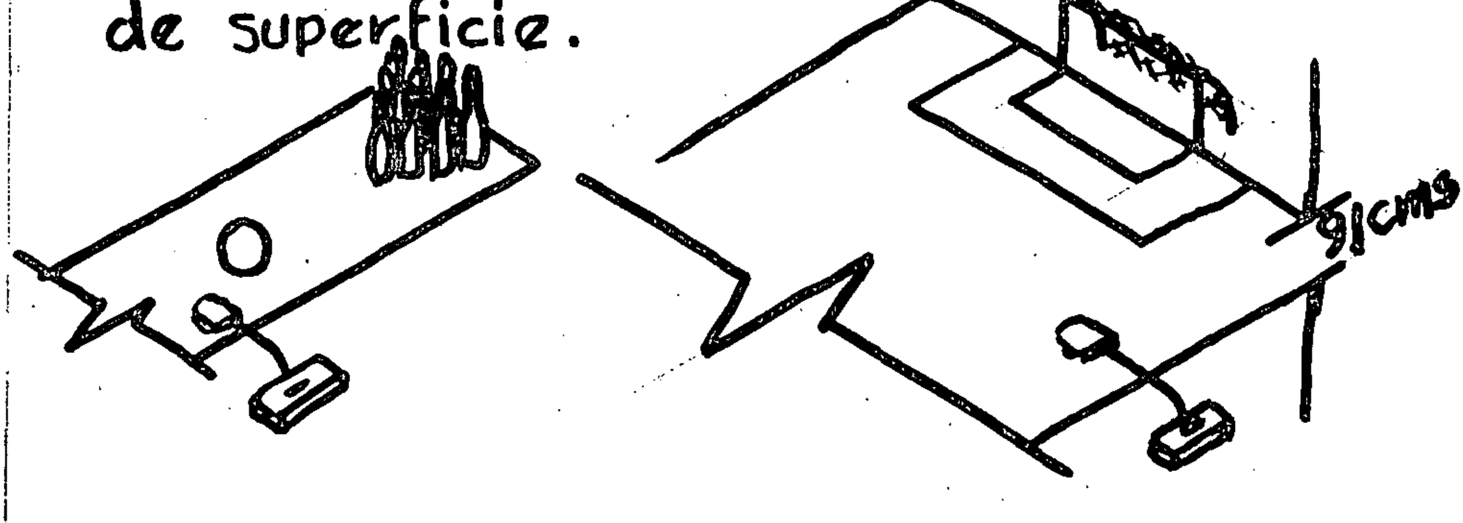
PROCEDIMIENTO DE PRUEBA

Nivelar celda.

Mediciones en cada punto (diagramas)

Promediar Iluminancia.

Celda en superficie de juego ó 91 cms. (36 pulgs) de superficie.



CARRETERAS

PUNTOS DE PRUEBA

Espacios de rectángulos.

Lecturas al centro.

Medir en longitud (3 postes por lo menos)

Puntos de prueba (centro del tráfico)

Arreglos característicos (figura)

Intervalos entre puntos 10 pies aprox.

PROCEDIMIENTO DE PRUEBA

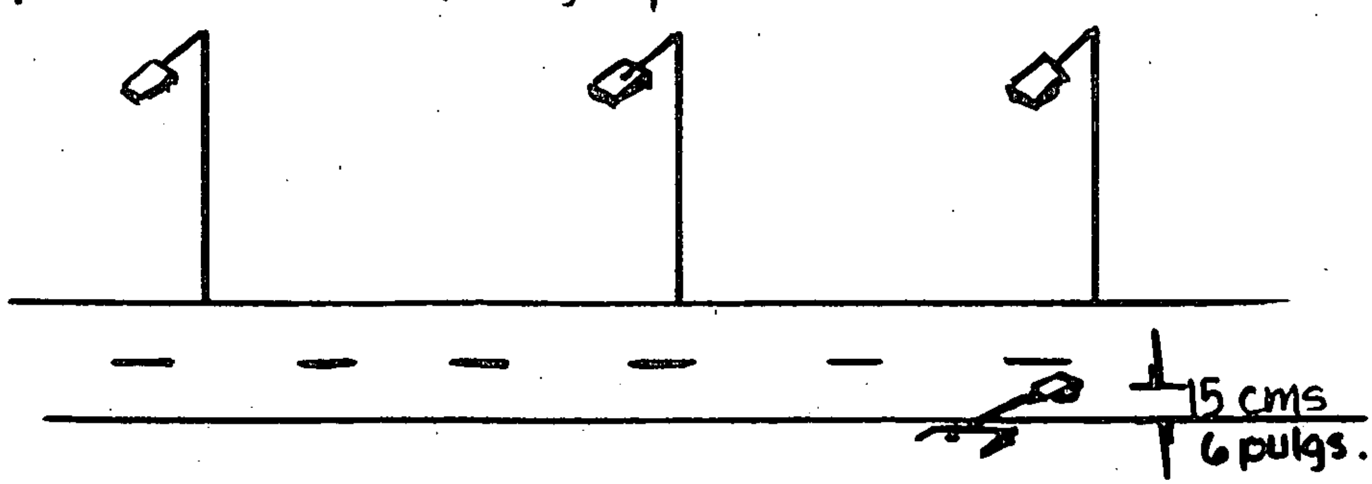
Mediciones en cada punto.

Nivelar celda.

Promediar iluminancia

Celda a 0.15 mts. (6 pulgs) de superficie de la carretera.

Pavimento seco (no agua, no nieve)



REPORTES DE DATOS

1) Locación (avenida, cancha, estadio, etc..)
2) Descripción del equipo (Lúminario)
3) Fecha de mediciones.
4) Diagrama de puntos de prueba (dimensiones)
5) Condiciones eléctricas (V, I y P)
6) Condicion de luminarios (Limpieza, duración etc.)
7) Condiciones climaticas.
8) Tabulación de datos de prueba.
9) Registro de mediciones de prueba (brillo, etc..) especiales.
10) Relación máximo/minimo (prom. de ilum.)
11) Altura de montaje, espaciamiento, arreglo.
12) Datos de instrumentos de prueba.
13) Tiempo de instalación.
14) Datos de probadores.

INSTALACIONES ANTIGUAS

Para instalaciones de este tipo los luminarios deben checarse sin limpiarlos y tomar mediciones, posteriormente se limpian y se toman mediciones. o sea que se hacen 2 series de mediciones.

INSTALACIONES NUEVAS

Con el objeto de checar rendimiento a las condicio. nes iniciales; se limpian, acondicionan y ajustan los luminarios.

Fotometros: coseno, y color corregido, portátil y calibrado

Condiciones electricas: checar (lampara, luminario etc)

V = Voltajes

I = Corriente

P = Potencia

TIPO DE LAMP. HID, FLUOR. ó INCAND.

EXTERIORES

En instalaciones de alumbrado en exteriores donde el flujo luminoso es dirigido a zonas, formando un angulo de incidencia con la superficie dl ser iluminada; debe

→ AJUSTARSE CUIDADOSAMENTE ←

para que esa iluminación sea UTIL y de CALIDAD

I.E.S. desarrolla métodos con el objetivo de normalización en la medición y registro de caracteristicas principalmente para:

- CARRETERAS

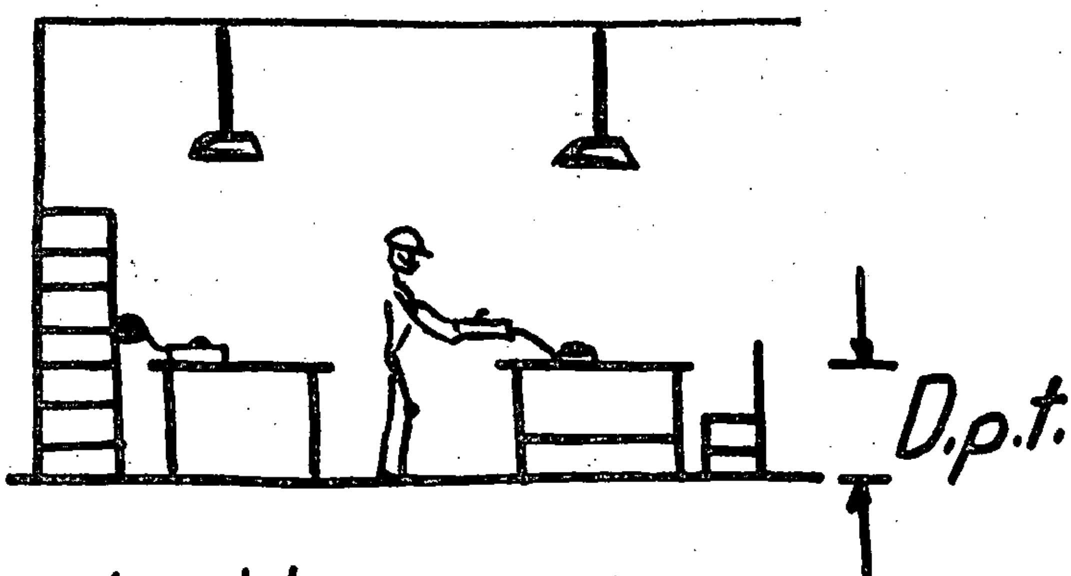
- AREAS DEPORTIVAS

La precisión es menor a la obtenida en laboratorio, debido a las condiciones adversas inherentes,

(voltaje, temperatura, polvo y otros factores.)

Medición de Iluminancia

La iluminancia en las areas definidas debe medirse en el momento del trabajo en puntos específicos.
la celda debe colocarse en el plano de trabajo 760 mm. (30 pulgs.) = Dpt.



Inspecciones de instalaciones.

Donde se utilize el día y la noche, la inspección debe hacerse en ambos turnos (*) y donde se utilize solamente en el día, debe inspeccionarse en el día.

(*) Se puede una inspección nocturna realizarse en el día, bloqueando ventanales o toda fuente de luz externa a la inspeccionada.

INTERIORES

EN LA EVALUACION DE INSTA_
LACIONES DE ALUMBRADO ES
NECESARIO:

- MEDIR ILUMINACION
- REGISTRAR DATOS

I.E.S. DESARROLLA UN METODO DE
INVESTIGACION UNIFORME DE ME_
DICION Y REGISTRO DE DATOS.
LOS RESULTADOS SE USAN COMPARA_
TIVAMENTE CON ESPECIFICACIONES PARA
DETERMINAR NECESIDADES DE:

MANTENIMIENTO
MODIFICACION
REEMPLAZO

Medición de iluminancia

- Instrumento de celda (coseno y color corregidos) celda expuesta a luz 5 a 15 mins. antes de las mediciones.
- Probadores: no causan sombras, reflejos leer en 2ª ó 3ª parte de la escala (mayor precisión, menor error)
- Lamparas HID tiempo encendido ≥ 30 mins.
- Lamparas fluorescentes 1 hora y tiempo vida encendido ≥ 100 horas de operación.
- Lamparas incandescentes tiempo acondicionamiento ≥ 20 horas de operación.

ILUMINANCIA PROMEDIO

El método se utiliza para un plano horizontal con 10% de valores aprox. tomando lecturas en cuadros de 0.6 m (2 fts) y PROMEDIANDO:

$$\text{Iluminanc. prom.} = \frac{\sum_{i=1}^{i=n} P_i}{n} \qquad \begin{array}{l} P = \text{lecturas} \\ n = \#\text{ de lect.} \end{array}$$

AREAS

- Regular con luminarios simétricamente espaciados en dos ó mas filas.
- Regular con un luminario localizado simetricamente.
- Regular con una fila individual de luminarios.
- Regular dos ó mas filas continuas de luminarios.
- Regular con una fila continua de luminarios.
- Regular con techo luminoso.

Fig. 4-25. Form for Tabulation of Luminance Measurements

Work Point Location*	Luminance					
	A	B	C	D	E	F
Luminaire at 45° above eye level						
Luminaire at 30° above eye level						
Luminaire at 15° above eye level						
Ceiling, above luminaire						
Ceiling, between luminaires						
Upper wall or ceiling adjacent to a luminaire						
Upper wall between two luminaires						
Wall at eye level						
Dado						
Floor						
Shades and blinds						
Windows						
Task						
Immediate surroundings of task						
Peripheral surroundings of task						
Highest luminance in field of view						

* Describe locations A thru F.

these times. Nighttimes surveys should be made with shades drawn. Daytime surveys should be made with shades adjusted for best control of daylight.

On a floor plan sketch of the area, an indication should be made of which exterior wall or walls, if any, were exposed to direct sunlight during the time of the survey by writing the word "Sun" in the appropriate location. Readings should be taken, successively, from the worker's position at each work point location A, B, C, etc. and luminance readings from each location recorded as shown in Fig. 4-25.

FIELD MEASUREMENTS—OUTDOOR

In roadway and many floodlight installations light is projected in a direction forming a large angle of incidence with the surface to be lighted, and each unit must be adjusted carefully to produce the best utilization and quality of illumination. For an accurate evaluation of this type of installation, special care must be taken in the measurement of the resultant illumination. A summary of the IES guides for Roadway Illumination Measurements and Sports Illumination Measurements follows, but the full guides should be consulted before making an actual survey.[89-91]

Preparation for the Survey. (1) Inspect and record the condition of the luminaires (globes, reflectors, refractors, lamp positioning, etc.). In the case of roadway lighting, make sure luminaires are level and their lateral placement is correct. Unless the purpose of the test is to check depreciation or actual in-service performance, all units should be cleaned and new lamps installed. New lamps should be seasoned properly.[77] While inoperative lamps are readily noticed in roadway installations, they can easily be overlooked in large floodlighting systems. If these lamps are not replaced for the field survey, proper consideration must be given when evaluating the test. (2) Record the mounting height of the luminaires. (3) Record the location of the poles, the number of units per pole, the wattage of the lamps and other pertinent data. Check these data against the recommended layout; a small change in the location or adjustment of the luminaires may make a considerable difference in the resultant illuminance. (4) Determine and record the hours of burning of the installed lamps. (5) Record the atmospheric conditions. Because of the effect of adverse atmospheric conditions, the survey should be made only when the atmosphere is clear. Extraneous light produced by a store, service station, or other lights in the vicinity, requires careful attention in street lighting tests. (6) Because of the influence of the electrical circuit operating conditions on lamp light output, it is usually necessary to know precisely the electrical circuit operating conditions at the luminaires in the system at the time the photometric measurements are being made. At night, during the hours when the luminaires will normally be used, record the voltage at the lamp socket with all of the lamps operating. The voltage at the main switch may be measured provided allowance is made for the voltage drop to the individual units. If discharge lamps are installed, record the input voltage to the ballast at the ballast terminals. Discharge lamps should be operated at least one half hour to reach normal operating conditions before measurements are made.

Survey Procedures. Measurements should be made with a recently calibrated, color- and cosine-corrected photometer capable of being leveled for horizontal measurements or positioned accurately for other measurement planes as required. The photometer should be selected for its portability and repeatability of measurements at any point of the scale which is used. If required by the spectral characteristic of the light source in the system being measured, appropriate corrections should be made to each reading.

1. For roadways, divide the distance between poles into an even number of divisions (as near 3-meter (10-foot) intervals as possible) and take

a reading in the center of each rectangle formed by the above divisions and the lanes of the roadway. Additional measurements may be taken at points of special significance, but these readings should not be used in calculating the average horizontal illuminance. In some instances, luminance measurements may also be desirable.

2. For sports installations, the sports area, or that portion of the area under immediate consideration, should be divided into test areas of approximately 5 per cent of the total area and readings should be taken in the center of each area. Where illuminance for color television is involved,[92] multiple readings should be taken at each station: one reading with the meter cell tilted 15 degrees from vertical in the direction of each camera location, and 0.9 meters (36 inches) above ground level, unless otherwise specified for the particular sports activity, and a final reading with the cell in the horizontal position.

3. Readings should be made at each test station with repeat measurements at the first station frequently enough to assure stability of the system and repeatability of results. Readings should be reproducible within 5 per cent. Enough readings should be taken so that additional readings in similar locations will not change the average results significantly. Care should be exercised while taking readings to avoid casting shadows on the receptor of the measuring instrument, and also by standing far enough away from the receptor, especially when wearing light colored clothes, to prevent light from the source from being reflected onto it.

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RECOMENDACIONES PARA LA MEDICION DE ILUMINACION DE AREAS E INSTALACIONES DEPORTIVAS

1.- INTRODUCCION

1.1.- Aspectos Generales.- El objeto de estas recomendaciones es proporcionar un procedimiento de la medición y reporte de las características fotométricas en instalaciones deportivas. Considerando los factores que intervienen, se procurará determinar las condiciones del sistema de iluminación.

1.2.- Condiciones de la Prueba.- Generalmente las pruebas de iluminación efectuadas en campo son diferentes a las que se pueden obtener en un laboratorio fotométrico, esto se explica por la influencia de factores incontrolables (fuentes externas, posibles sombras, etc), que estan afectando el sistema. En consecuencia habrá de procurarse eliminarlos (en lo posible) y evitar con esto que interfieran en los resultados de la prueba.

Cuando se trate de instalaciones nuevas, antes de la prueba, deberá procurarse que los luminarios se encuentren limpios. Las lámparas deberán ser "curadas" y tanto la lámpara como el luminario deberán estar bien ajustados en su conjunto óptico.

Si la prueba es hecha con própositos de una verificación de la instalación después de una depreciación en servicio; el número de horas de operación de las lámparas, así como las que se encuentran en falla, deberá ser registrado en el reporte. A continuación se efectuará una prueba al sistema en estas condiciones, realizando enseguida un mantenimiento compleo; para concluir con una nueva medición al sistema en óptimas condiciones.

Es recomendable que en sistemas que tengan lámparas de alta intensidad de descarga (HID), estas deberán tenerse en operación normal por un lápso de media hora como mínimo, a fin de estabilizar su temperatura de operación antes de efectuar la prueba del sistema.

Debido a la influencia que el circuito eléctrico tiene sobre el flujo luminoso de las lámparas, es recomendable determinar los parámetros de corriente, voltaje y potencia de los luminarios en operación, lo anterior es con el propósito de establecer una comparación con los datos originales del fabricante del luminario y con esto determinar si se encuentran en condiciones normales para efectuar la prueba fotométrica del sistema. Generalmente es suficiente con lecturas de voltaje y corriente de línea, pero si se sospechara una condición anormal en el funcionamiento del (os) luminario (s), es conveniente hacerle pruebas más exhaustivas al equipo del cual se tenga duda.

En instalaciones grandes, las lecturas de voltaje deberán tomarse en un buen número de luminarios (de ser posible en el socket de la lámpara) para asegurarse que el valor es el apropiado para la lámpara o para el conjunto lámpara-balastro que se esté utilizando.

La prueba de medición fotométrica deberá hacerse preferentemente en condiciones ambientales despejadas y cuando la aportación de luz de fuentes externas sea mínima.

Un especial cuidado deberá tenerse, por parte del personal que opere los instrumentos de prueba, a fin de evitar que la sombra de su cuerpo interfiera la luz procedente del sistema corriendo el riesgo de obtener lecturas completamente alteradas. Igual cuidado se tendrá en verificar que la luz incidente en la celda del instrumento que detecte las lecturas, no se vea influenciado por reflejos muy acentuados. En general el evitar sombras o luz extraña requiere siempre una actitud alerta del personal de prueba, con el propósito de detectar estos inconvenientes.

1.3.- Equipo de prueba.- Se utilizará un fotómetro que sea portátil con el propósito de poder efectuar las lecturas en cualquier punto del área que se esté probando. Deberá estar bien calibrado y corregido en color y en coseno. La celda del fotómetro podrá ser llevada a diferentes niveles sobre el plano horizontal y también podrá ser colocado en cualquier plano que se requiera. No deberá ser sensible a variaciones de temperatura y en caso de serlo, se harán las correcciones correspondientes para compensar las lecturas. Cuando se utilice un instrumento de escalas múltiples, asegúrese que la lectura se obtenga en la porción superior de la escala del aparato. Para más información refiérase al "IES General Guide to Photometry" (4).

2.- PROCEDIMIENTO DE LA PRUEBA.

2.1.- Puntos de prueba.- Los puntos para la medición de la iluminación deberán localizarse y espaciarse de tal forma que las mediciones sean representativas del área que se este midiendo; constituyendo un conjunto de lecturas que permitan calcular la iluminación promedio.

Recomendaciones especificas para la localización de puntos de prueba de la mayoría de areas deportivas se dan en las figuras 1 a la 16 que se anexan más adelante.

Para áreas irregulares, como el caso de canchas de golf, o cualquiera que no tenga dimensiones regulares, se recomienda hacer divisiones en cuadrados iguales o rectángulos que no excedan del 5% (cinco por ciento) del área total considerada y las mediciones se procurarán hacer al centro de este cuadrado o rectángulo.

Las áreas que esten diseñadas con diferente nivel de iluminación con el mismo sistema o instalación se tratarán de manera individual. Hágase la consideración, al dividir las zonas de prueba, de eliminar los cuadros que participen con menos de la mitad de su área en el campo y en el caso que su área sea mayor de la mitad, entonces deberá incluírsele como punto de prueba.

Cuando se den recomendaciones en puntos específicos, definiendo valores de iluminación para ellos, tales como líneas de salida en campos de golf, lugar del blanco en campos de tiro de rible y pistola, etc., se tomarán diferentes lecturas de tal manera que se cubra el total de puntos que involucren el lugar objeto de mediciones fotométricas.

2.2.- Medición de iluminancia.- A menos que no se especifique otra cosa, se harán las lecturas fotométricas posesionando la celda del instrumento directamente en la supérficie del campo de prueba cuando se trate de juegos sobre piso, en tanto que en el caso de juegos áéreos la celda se colocará a una altura de 91 centímetros (36 pulgadas). Las lecturas se efectuarán en cada punto de prueba, repitiendo frecuentemente la del primer punto a fin de asegurarse que exista una estabilidad del sistema, cuando no exista una variación mayor del 5% de la lectura se considera estable.

2.3.- Medición de luminancia.- En instalaciones deportivas y recreativas, cuando hablamos de equipo de iluminación, el control de la luminancia indeseable producida por los proyectores, o bién los reflejos producidos por superficies especulares, deben ser evitados mediante el posesionamiento adecuado de los proyectores que constituyen el sistema. Se recomienda ver "IES Current Recommended Practice for Sports and Recreational Area Lighting" (2).

En ocasiones es deseable determinar la magnitud de __ deslumbramientos causados por el sistema de ilumina-- ción en ciertos puntos de visión crítica, con el propósito de tomar alguna acción correctiva. Un camino a sugerir sería efectuar un recorrido por diferentes puntos de observación que pudieran considerarse crí-- ticos (generalmente son los directamente frontales a los proyectores) y con esto procurar determinar la __ corrección aefectuar, siempre y cuando esta sea posible y no afecte el comportamiento de iluminación en el área.

3.- REPORTE DE PRUEBAS

El reporte deberá integrar los datos más significativos, de manera que permita un manejo fácil de ellos. Es recomendable que incluya los siguientes aspectos:

REPORTES DE DATOS

1).- Locación (Avenida, Cancha, Estacio, etc.)

2).- Descripción del equipo (Lúminario)

3).- Fecha de mediciones

4).- Diagrama de puntos de prueba (dimensiones)

5).- Condiciones eléctricas (V, I y P)

6).- Condición de luminarios (Limpieza, Duración etc.)

7).- Condiciones climaticas

8).- Tabulación de datos de prueba

9).- Registro de mediciones de prueba (Brillo, etc.) especiales

10).- Relación máximo/minimo (Prom. de Ilum).

11).- Altura de montaje, espaciamiento, arreglo.

12).- Datos de instrumentos de prueba.

13).- Tiempo de instalación

14).- Datos de probadores

REPORTE DE PRUEBAS

Promedio de lecturas en campo ______________________________

Relación máximo a mínimo ______________________________

Promedio de ____________ Lecturas fuera de campo ____________

Relación máximo a mínimo ______________________________

Voltaje en proyectores con el total de lámparas en operación

____

DATOS DE LA INSTALACION

Tipo de luminario ______________________________

Número de unidades ______________________________

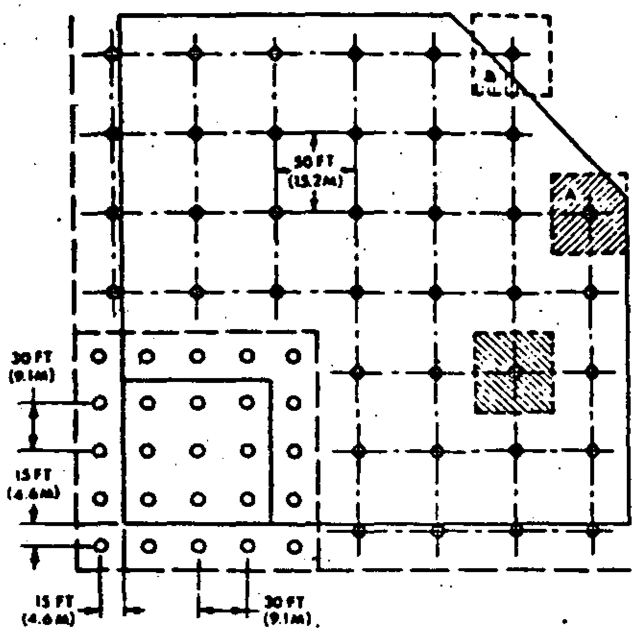
Fuentes de luz ______________________________

Número de torres ______________________________

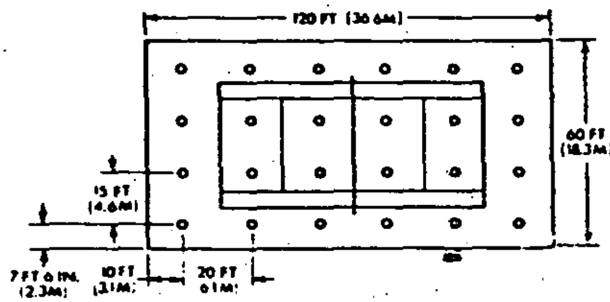
Altura de torres ______________________________

Distancia de las torres a la línea de "foul" o a extremos de la cancha ______________________________

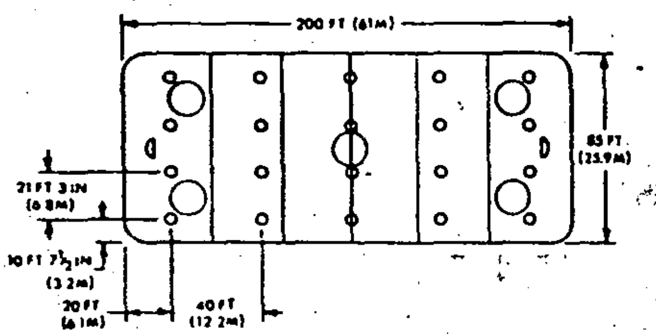
3. Baseball Fields



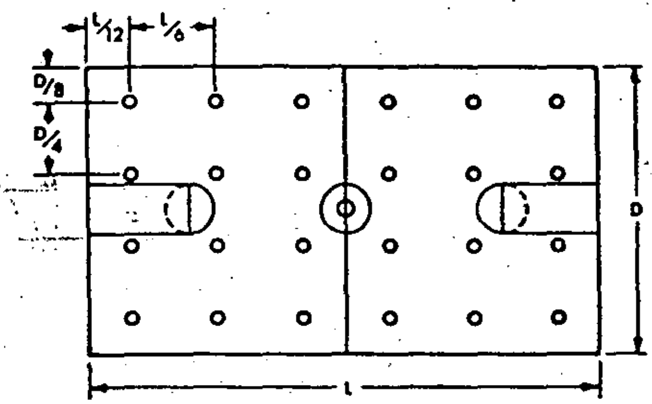
1. Tennis



4. Hockey—Ice

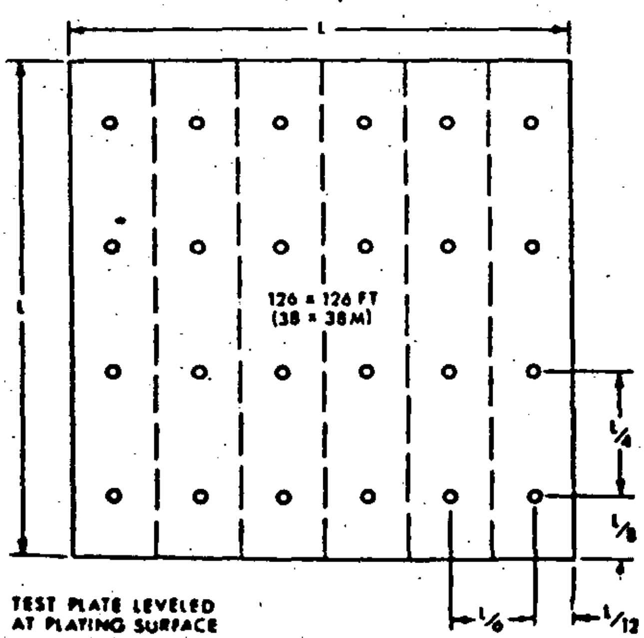


6. Basketball Courts



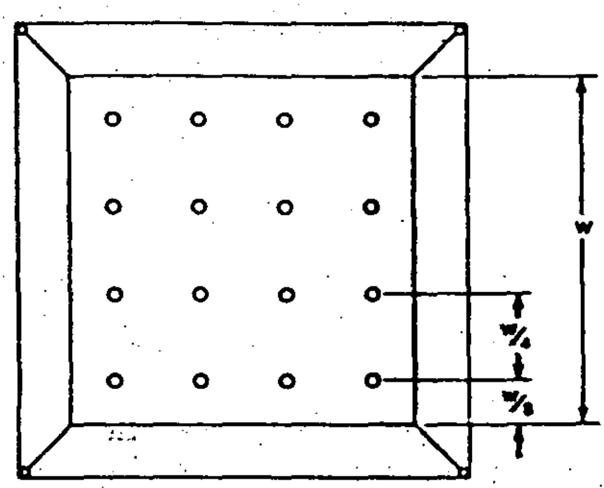
L = 74–94 FT (22.6–28.7M)
D = 42–50 FT (12.8–15.2M)

5. Bowling Greens



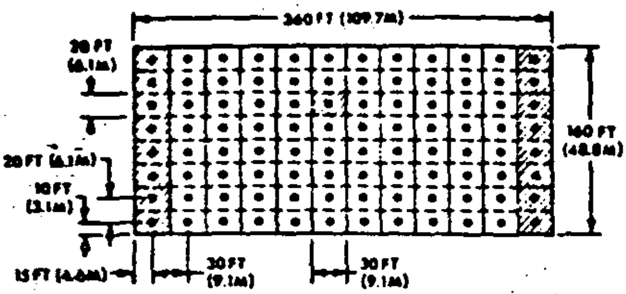
TEST PLATE LEVELED
AT PLATING SURFACE

7. Boxing Rings



W = 16–20 FT (4.9–6.1M)

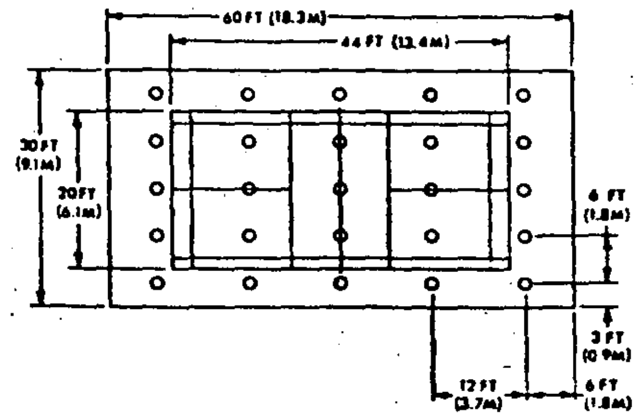
8. Football Fields—Regulation



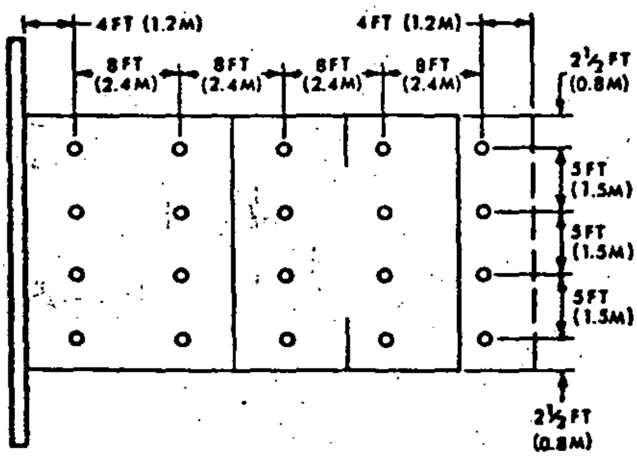
Notes

(1) Crosshatching at ends indicates end zones.
(2) Small cross hatched rectangle indicates typical test area with reading station in center.

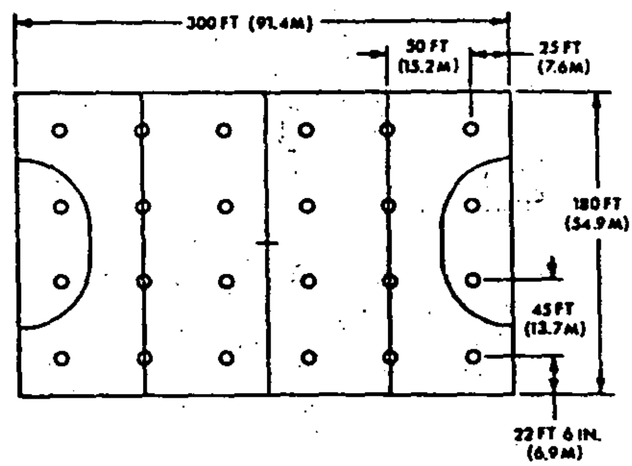
2. Badminton Courts



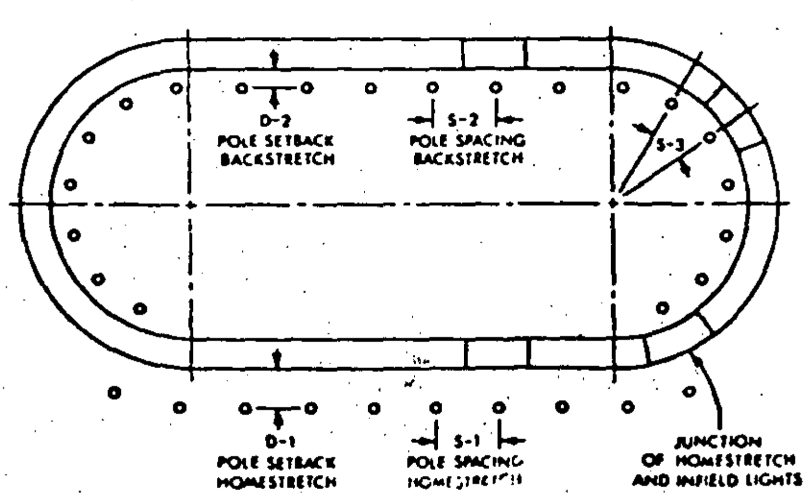
9. Handball—One Wall



11. Hockey—Field



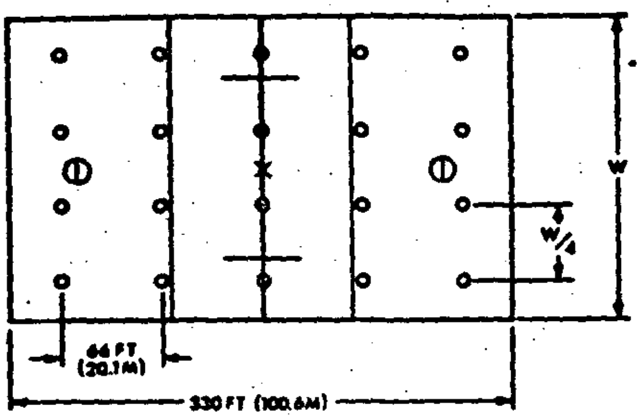
10. Race Tracks



Notes:

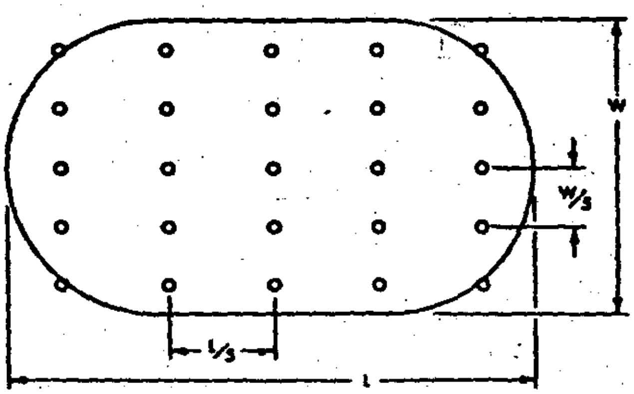
(1) Select areas typical of each lighting condition of mounting height, floodlight quantity and distribution per location, setback, spacing and design footcandle (lux) level.
(2) Divide each are into equal and approximately symmetrical test stations not exceeding five per cent of the test area.
(3) Take readings at the center of each station.

12. Lacrosse

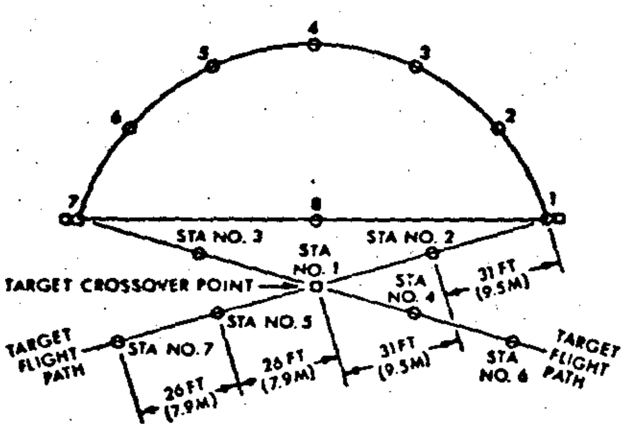


W = 180-210 FT (54.9-64M)

13. Horse Show Ring



14. Skeet



Notes:

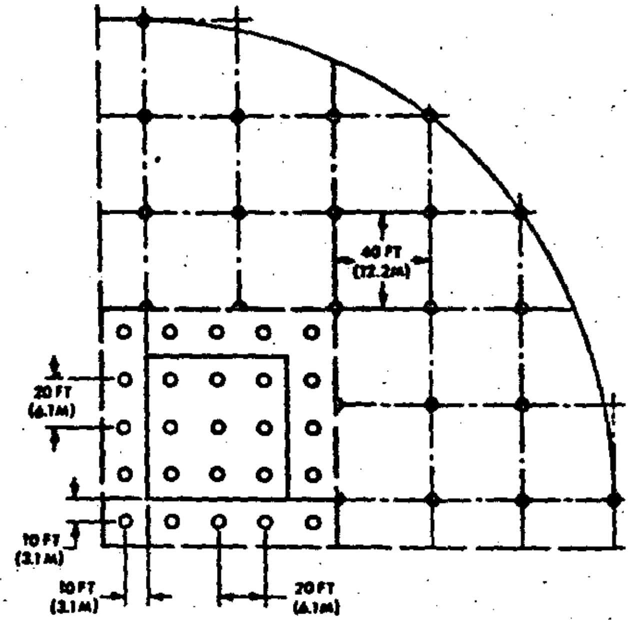
(1) Take horizontal reading at each firing point.

(2) Take vertical readings normal to shooting position number, as follows:

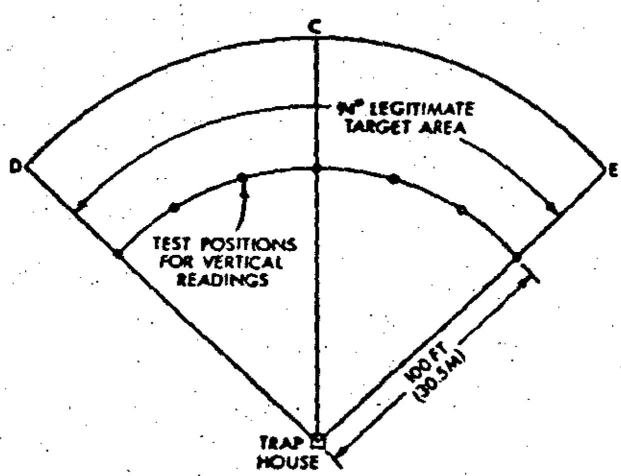
Test Station	Shooting Position
1	1–7
2 & 3	4
4	3
5	5
6 & 7	8

Test stations are approximately 60 feet (18.3 meters) from firing point indicated.

15. Softball Fields



16. Trap Shooting



Notes:

(1) Measure horizontal illumination at each firing point test station. Test plate 36 inches (91 centimeters) above surface.

(2) Measure vertical illumination at a distance of 100 feet (30.5 meters) from trap house at an elevation of 20 feet (6.1 meters)—seven readings equally spaced within 94° legitimate target area.

MEDICION FOTOMETRICA DE INSTALACIONES DE ALUMBRADO PUBLICO

1.- LOCALIZACION

CALLE ______________________ ENTRE ______________________

COLONIA ______________________ DELEGACION ______________________

2.- FECHA

______________________ DE ______________________ DE 198

HORA ______________________

3.- DESCRIPCION DE LA INSTALACION Y EQUIPO.

3.1.- LAMPARA

3.1.1.- MARCA ______________________

3.1.2.- TIPO ______________________

3.1.3.- WATTS ______________________

3.1.4.- ACABADO ______________________

3.1.5.- POSICION ______________________

3.1.6.- HORAS DE USO ESTIMADAS ______________________

3.2.- BASTRO

3.2.1.- MARCA ______________________

3.2.2.- TIPO ______________________

3.2.3.- FACTOR DE POTENCIA ______________________

3.2.4.- INTEGRAL ____________ REMOTO ____________

3.3.- LUMINARIO

3.3.1.- MARCA ______________________

3.3.2.- TIPO ______________________

3.3.3.- CURVA ______________________

3.3.4.- CERRADO ______________ ABIERTO __________

3.3.5.-

3.4.- POSTES

3.4.1.- ARREGLO ______________________________
____
____

3.4.2.- ALTURA DE MONTAJE ______________________

3.4.3.- TIPO ______________________________

3.4.4.- DISTANCIA INTERPOSTAL ____________________

3.4.5.- LONGITUD DE BRAZO ______________________

3.4.6.- DISTANCIA POSTE A LA ACERA ________________

3.5.- CALLE

3.5.1.- LONGITUD A MEDIR ______________________

3.5.2.- ANCHO DE CALLE ______________________

3.5.3.- ANCHO DE ACERA ______________________

4.- CIRCUNSTANCIAS ESPECIALES

4.1.- INTERFERENCIAS ______________________________
____
____
____
____

4.2.- CONDICIONES AMBIENTALES (NO DE TIEMPO) ______________
____
____
____

4.3.- FUENTES DE LUZ EXTRAÑAS ______________________
____
____
____

5.- CONDICIONES ELECTRICAS DE LA INSTALACION

5.1.- VOLTAJE ENTRE FASES			
5.2.- VARIACION DE VOLTAJE			
5.3.- CORRIENTE DE LINEA			
5.4.- WATTS DE LINEA			
5.5.- WATTS DE LAMPARA			

5.6.- HORAS DE ENCENDIDO __________ HR. DE OP. POR ENCENDIDO

6.- CONDICIONES DE LUMINARIO

6.1.- MESES APROXIMADOS DE USO ____________________

6.2.- CONDICIONES DE LIMPIEZA

6.2.1.- BUENAS ____________________

6.2.2.- REGULARES ____________________

6.2.3.- MALAS ____________________

ESTACION	CARRIL	CARRIL	CARRIL	CARRIL	CARRIL	CARRIL
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
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7.- CONDICIONES DEL TIEMPO

7.1.- NUBLADO ____________

7.2.- DESPEJADO ____________

15

ESTACION	CARRIL	CARRIL	CARRIL	CARRIL	CARRIL	CARRIL
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
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14						
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27						

ESTACION	CARRIL	CARRIL	CARRIL	CARRIL	CARRIL	CARRIL
28						
29						
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33						
34						
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41						
42						
43						
44						
45						
46						
47						
TOTAL POR CARRIL						
PROMEDIO						
MAXIMO						
MINIMO						

10.- MEDICIONES ESPECIALES

ESTACION	LOCALIZACION	LECTURA OBTENIDA

11.- RELACIONES

PROMEDIO	
PROMEDIO A MINIMA	
PROMEDIO A MAXIMA	
MAXIMA A MINIMA	

LA RELACION DE PROMEDIO A MINIMA NO DEBE EXCEDER DE 3 A 1 PARA CUALQUIER CALLE, EXCEPTO PARA CALLES RESIDENCIALES LOCALES, EN TAL CASO PODRA SER HASTA 6 A 1.

12.- INSTRUMENTOS UTILIZADOS

CLASE	MARCA	MODELO	OBSERVACIONES

13.- PRUEBAS EFECTUADAS POR:

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FACULTAD DE INGENIERIA U.N.A.M.
DIVISION DE EDUCACION CONTINUA

C U R S O S   A B I E R T O S

ILUMINACION EXTERIOR:
PRINCIPIOS, DISEÑO Y APLICACIONES

30 DE MARZO AL 10 DE ABRIL DE 1992

MANTENIMIENTO

ING. CARLOS GARCIA ROMERO

PALACIO DE MINERIA

PROGMA DE MANTENIMIENTO PARA SISTEMAS DE ALUMBRADO PUBLICO.

1.- INTRODUCCION. El mantenimiento adecuado de cada instalación es la única forma de continuar proporcionando un alumbrado público efectivo. El mantenimiento del alumbrado incluye todos los medios que puedan utilizarse para mantener la cantidad de luz en el pavimento, tan cerca de su valor inicial como sea práctico.

Los objetivos del mantenimiento del alumbrado público son el mantener el nivel deseado de iluminación con un costo mínimo y un uso efectivo de la energía.

¿ Porqué es importante el mantenimiento del alumbrado público?

Primero, porqué el propósito primordial de una instalación de alumbrado público es el reducir la criminalidad, mantener las calles seguras al tráfico peatonal y vehícular durante la noche y ayudar al desarrollo de la comunidad.

Segundo, porqué se debe proporcionar tanta luz como sea económicamente posible. Por lo que se debe minizar la depreciación de los lúmenes de las lámparas y las lámparas apagadas.

El uso de factores de pérdida de luz, en el diseño de toda instalación de alumbrado público es un reconocimiento necesario de que no hay un programa de mantenimiento capaz de mantener los parámetros iniciales de una instalación. Los valores de los factores de pérdida de luz usados, indican la cantidad esperad de depreciación incontrolable y a la vez la cantidad de esfuerzo necesario para contrarrestar esta depreciación.

2.- FACTORES QUE AFECTAN LA ILUMINACION. Es importante conocer los factores que afectan la iluminación proporcionada por un sistema de alumbrado público, estos factores son:

1) Temperatura ambiente del luminario.
2) Voltaje de alimentación al luminario.
3) Factor del balastro.
4) Depreciación de las superficies del luminario.
5) Lámparas apagadas.
6) Depreciación de los lúmenes de las lámparas.
7) Depreciación por polvo en el luminario.

El efecto individual de cada uno de estos factores varia con las condiciones atmosféricas que se tienen en cada lugar.

2.1 Temperatura ambiente del luminario. La temperatura puede ser un grave problema cuando por alguna causa la lámpara permanece encendida durante el día ya que esta se puede elevar a valores que dañen los aislamientos o algunas otras partes del luminario. Se debe corregir lo antes posible cualquier falla que provoque que la lámpara permanesca encendida durante el día.

2.2 Voltaje de alimentación al luminario. Cuando el voltaje de alimentación al luminario no está dentro de los valores nominales de operación del balastro o lámpara, se pueden tener variaciones sensibles en el flujo emitido. Las variaciones grandes de voltaje de alimentación se deben evitar ya que reducen considerablemente la vida de las lámparas y equipos auxiliares. El sobrevoltaje puede dañar rápidamente los aislamientos, mientras que un bajo voltaje puede provocar que las lámparas no enciendan ó estén encendiendo y apagando. Adicionalmente, cuando se presenta alguno de los casos anteriores, la iluminación no tie ne el valor para el cual fué diseñada la instalación, por lo anterior, se debe revisar periodicamente este parámetro y corregirse en caso necesario.

2.3 Factor del balastro. Cuando el factor del balastro utilizado en un luminario difiere del balastro usado en la fotometría, la emisión de luz diferirá en la misma cantidad. Se debe consultar a los fabricantes sobre estos factores.

2.4 Depreciación de las superficies del luminario. Los materiales usados en la construcción de luminarios difieren en su resistencia al deterioro. El aluminio procesado tiende a depreciarse poco, pero por otro lado el esmalte es mas fácil de limpiar. Con respecto al uso de plásticos en la construcción de luminarios este se ha incrementado en los ultimos años. Los tipos mas comunmente utilizados para la transmisión y control de luz son los acrílicos y poliestirenos. Despues de un periodo de tiempo de estar expuestos a las radiaciones ultravioletas, estos materiales cambian su color y transmitancia. Los acrílicos son los mas resistentes a estos cambios. El grado de cambio en el color y transmitancia depende de la aplicación; tipo de lámpara, distancia del plástico a la lámpara y temperatura del plástico durante la operación del luminario. Cuando estos materiales son limpiados, se debe tener especial cuidado en utilizar materiales y técnicas adecuadas de limpieza ya que se puede cambiar la transmitancia del material por la acción de productos químicos ó maltrato.

2.5 Lámparas apagadas. Las lámparas apagadas contribuyen a la pérdida de luz. Si las lámparas no son cambiadas rápidamente despues de que fallan, la iluminación promedio disminuirá proporcionalmente. Cuando existen tramos con lámparas apagadas y encendidas se disminuye notablemente la capacidad de detectar obstáculos o peatones en las vialidades, ya que al estar el obstáculo o peatón en una zona obscura el contraste disminuye, impidiendo al --

ojo humano detectarlo.

2.6 Depreciación de los lúmenes de las lámparas. La emisión lumínica de las lámparas disminuye conforme la lámpara se va envejeciendo. Esta disminución es llamada depreciación de lúmenes y es una ca-- característica inherente de todas las lámparas. Las pérdidas debido a este factor se reducen con los programas de reemplazo de lámparas en grupo.

2.7 Depreciación por polvo en el luminario. Una cantidad significante de la pérdida de luz puede atribuirse generalmente a la cantidad de polvo acumulado en las superficies internas del luminario, el humo de los escapes de los vehículos automotores en especial, se adhiere a las superficies de los luminarios depreciando rápidamente la emisión de estos. En adición a la clase y cantidad de polvo en el ambiente, la cantidad de pérdida de luz depende del diseño del luminario, forma y tipo de lámpara y acabados del luminario.
Adicionalmente a los factores mencionados anteriormente existen - otros dos que son: Vandalismo y la obstrucción de árboles. El -- Vandalismo es un problema que se presenta con mas frecuencia en - zonas Suburbanas , y da como resultado un costo muy elevado el -- mantenimiento de estas instalaciones.
Las soluciones mas ampliamente utilizadas son; el aumentar la altura de montaje cuando es posible, utilizar luminarios fabricados con materiales resistentes a los impactos y colocar guardas a -- los refractores de los luminarios. Por lo que respecta a la obs-- trucción de ramas de árboles, este problema se presenta principalmente en avenidas en las cuales existen árboles en la misma acera en que se encuentran los postes de alumbrado público, la única solución es podar las ramas de árboles que interfieren con el cono de candelas máximas de cada luminario.

3.-LA NECESIDAD DE IMPLEMENTAR PROGRAMAS DE MANTENIMIENTO. Todo sistema de alumbrado público puede mantenerse en perfecto estado de trabajo tanto mecánica como eléctricamente y aún así puede estar proporcionado a la superficie de la calle solo un tercio ó menos de la iluminación para la cual se diseñó el sistema.

En un caso típico, un luminario que estuvo en servicio durante cinco años sin limpieza, se depreció hasta un 29% de su emisión inicial. Se lavó el exterior del refractor y se obtuvo una ganancia significativa. Posteriormente se lavó el interior del refractor y se obtuvo una ganancia mucho mayor. El exterior estaba tan sucio que la curva de distribución se había modificado. Con objeto de tratar de obtener una ganancia de luz mayor, el reflector se lavó varias veces, se cambió la lámpara por una nueva y tambien se instaló un refractor nuevo, con esto solo se logró recuperar la emisión hasta un 84% de la inicial, lo cual indica claramente que puede ocurrir un daño irreparable y permanente debido a la falta de un mantenimiento adecuado.

Un programa adecuado de mantenimiento de un sistema de alumbrado público permite obtener el máximo beneficio de la instalación y evita que esta sufra daños irreparables.

Este programa debe estar basado en el número de horas que trabaja la instalación, el tipo de lámpara y luminario, las condiciones ambientales y de tráfico, inspecciones períodicas, reportes de los usuarios, magnitud de la instalación, etc.

3.1 Sistemas para el mantenimiento del alumbrado público. Existen tres tipos de sistemas de mantenimiento que son:

1) Reemplazo individual
2) Reemplazo en grupo
3) Reemplazo en grupo combinado con reemplazo individual intermedio.

Reemplazo individual. El reemplazo individual es un sistema utilizado ampliamente sobre todo en instalaciones de mediana y baja importancia. Consiste en el reemplazo de lámparas apagadas cada vez que esto sucede esto generalmente se lleva a cabo con una inspección períodica de las instalaciones la cual genera reportes para ser atendidos de inmediato. Este trabajo se facílita utilizando un vehículo con canastilla con mandos hidráulicos. En casos particulares la escalera remolcada es de gran utilidad, sobre todo cuando los vehículos motorizados no pueden intervenir.

Este sistema de reemplazo de lámparas apagadas, combinado con la limpieza simultánea de los luminarios correspondientes, da buen resultado para las fuentes luminosas de corta y mediana vida del orden de:

Lámparas incandescentes	1000 horas
Lámparas incandescentes con halógeno	2000 horas
Lámparas de luz mixta	4000 horas

Reemplazo en grupo. Teniendo en cuenta, por una parte el aumento de las vias de circulación y por otra la larga vida de las lámparas de descarga, es cada vez mas importante el reducir las inspecciones períodicas para localizar y cambiar lámparas apagadas. El sistema de reemplazo en grupo, consiste en cambiar al cabo de un cierto número de horas de funcionamiento, todas las lámparas de una misma vialidad o de un cierto sector.

En los intervalos de reemplazo en grupo, las lámparas apagadas no serán cambiadas, pero al cabo de cierto tiempo de horas de funcionamiento, se efectuará una inspección para localizar y cambiar lámparas que hallan fallado prematuramente. Las visitas para limpieza de luminarios se deben mantener, así como la verificación de los equipos de encendido y apagado.

Este sistema es válido y económico, pero da lugar a algunas observaciones:

- Cuando no se reemplazan las lámparas apagadas, se tiene que atender a las reclamaciones (a veces muy acaloradas) de autoridades y del público, que se incomodan por el no funcionamiento de las lámparas.

- La existencia de lámparas apagadas puede provocar que aumenten los casos de accidentes y los actos de delincuencia debido a condiciones inseguras por haber zonas iluminadas y zonas obscuras. Esto puede generar dificultades y la responsabilidad moral puede ser empañada.

  Pero este sistema tiene ventajas ya que al mismo tiempo que se efectúa el reemplazo en grupo se puede dar el mantenimiento necesario, particularmente:

- Limpieza del luminario y sobre todo del sistema óptico.
- Posicionamiento correcto de la lámpara en el foco del sistema óptico.
- Mantenimiento mecánico y eléctrico del luminario, equipo auxiliar y soportes.

Las condiciones de funcionamiento de las lámparas en cualquier sistema de alumbrado son diferentes de las condiciones en que son probadas las lámparas en un laboratorio. Las lámparas en sistemas de alumbrado público están sujetas a vibraciones, variaciones de voltaje, variaciones de temperatura, intemperie, variaciones en el ciclo de encendido-apagado, etc. La duración de la vida práctica, no puede determinarse en base a valores obtenidos en condiciones diferentes. La experiencia conduce a determinar el número de horas después de las cuales las lámparas deben ser reemplazadas en grupo. El número aproximado de horas es el siguiente:

- Lámparas de vapor de mercurio	8000 a 12000 horas.
- Lámparas fluorescentes	8000 horas.
- Lámparas de vapor de sodio baja presión	8000 a 12000 horas
- Lámparas de vapor de sodio alta presión	8000 a 12000 horas

Los valores que se establezcan para una instalación dependen de las condiciones locales de operación, el costo de la mano de obra, disponibilidad de material, etc.

En general, y particularmente en zonas con mucha contaminación y en vialidades con alta densidad de tráfico, no se puede efectuar la limpieza únicamente en el momento del reemplazo en grupo. Se debe adoptar un calendario de limpieza adecuado a las condiciones locales, la periodicidad de limpieza varía generalmente entre 6 y 18 meses.

Reemplazo en grupo combinado con reemplazo individual intermedio. Este sistema es el mas completo y que dá, desde el punto de vista técnico los mejores resultados, pero tambien es el más costoso.

Las inspecciones para detectar y cambiar lámparas apagadas se mantienen, aunque menos frecuentes. El reemplazo trata de efectuarse al día siguiente de su localización y puede ser acompañado con la acción de limpieza y mantenimiento mecánico y eléctrico del luminario.

Aunque este sistema de mantenimiento es el más metódico y el más cuidadoso, la instalación no vuelve a proporcionar la misma cantidad de luz que proporcionó inicialmente. Esta pérdida anual de flujo puede ser importante.

La gráfica siguiente mustra para un caso típico el porcentaje de flujo inicial despues de hacer la limpieza cada año y reemplazo en grupo cada 2 años.

4.- MANTENIMIENTO DE INSTALACIONES DE ALUMBRADO PUBLICO. El mantenimiento de instalaciones de alumbrado público lo dividiremos en tres grupos:

- Limpieza
- Cambio de lámparas
- Regulación de voltaje y verificación de equipos de encendido-apagado

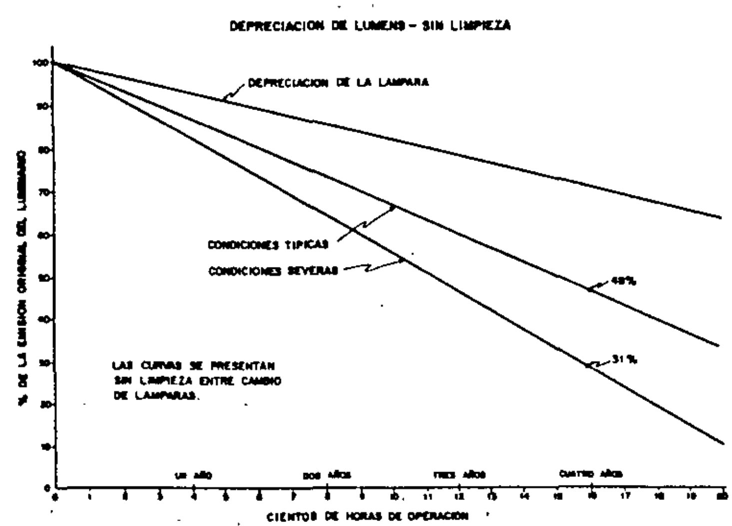
4.1 Limpieza.

4.1.1 Generalidades.

a) La acumulación de suciedad fuera y dentro de los luminarios causa absorción de luz, reduciendo la iluminación en algunos casos a una fracción de su valor original.

b) La depreciación debido a la suciedad varía con los tipos de luminarios ; por ejemplo, los luminarios, cerrados modernos de buena calidad requieren menos mantenimiento y gran parte de la suciedad acumulada en el exterior es limpiada en algún grado - por la lluvia.

c) Los humos industriales y de escapes de vehículos en vías -- con mucho tráfico crean áreas dònde las condiciones quiza re-- quieran de un programa de limpieza mas corto. (ver figura 4.1)



La acumulación excesiva de contaminantes dentro ó fuera del refractor puede provocar un calentamiento anormal que puede ocacionar fracturas, causadas por una condición llamada choque -- térmico.

d) Las superficies reflectoras comunmente fabricadas de aluminio anodizado en los luminarios modernos, pueden oxidarse ó - mancharse por la acción química de contaminantes en el aire ó por insectos los cuales se introducen dentro del conjunto --- óptico.

e) El vidrio es un material inerte, pero debe ser limpiado regularmente. De otro modo la acumulación contínua de contaminantes, se adherirá a la superficie del cristal, debido al calor de la lámpara. Esta cubierta no puede ser limpiada por metodos ordinarios.

f) La depreciación debe tomarse en cuenta en los cálculos de diseño, para que el promedio de iluminación en servicio, coincída con el nivel especificado de iluminación. Esto significa que la iluminación inicíal excedera el nivel de diseño en una cierta cantidad.

g) Todo diseño asume condiciones promedio y requiere que el programa de limpieza recupere al sistema lo mas cerca posible de su eficiencia original, al menos cada vez que se cambie la lámpara. Esto puede ser satisfactorio para luminarios incandescentes, pero es completamente insatisfactorio para luminarios que utilizan las fuentes modernas de luz que tienen una vida económica mucho mayor, que la de las incandescentes. Este equipo debe lavarse entre cambios de lámparas con objeto de obtener los valores de emisión lumínica previamente mencionados.

h) Por supuesto que las condiciones locales varían grandemente, y en lugares muy sucios el lavar con intervalos de un año puede ser inadecuado. Se deben estudiar las condiciones de cada localidad y obtener un programa de limpieza que proporcione buen servicio y proteja su inversión en el sistema de alumbrado público.

i) Un manejo meticuloso puede hacer necesario el tener un inventario por localización, cantidad y tipo de todos los luminarios del sistema, si es posible en un mapa. Se puede determinar la frecuencia de limpieza de varios luminarios por medio de un estudio, el cual muestre las pérdidas de iluminación en un intervalo dado de tiempo.

4.1.2 METODOS DE LIMPIEZA.

a) En ciertos tipos de luminarios antiguos no se cuenta con la facilidad de retirarlo facílmente, por lo que el equipo debe limpiarse en el lugar. En tales circunstancias - utilize un detergente que elimine la suciedad rápidamente y a fondo y que no requiera enjuagarse. Elimine ---- el exceso de humedad con un trapo limpio. Los trapos sucios ensucian nuevamente la superficie limpiada. Nunca - se deben utilizar materiales abrasivos para limpiar las superficies metálicas ó de vidrio, particularmente los - reflectores de aluminio y refractores de vidrio, los cuales, pueden dañarse permanentemente , destruyendo su eficiencia óptica y proporcionando superficies rugosas mas suceptibles de acumulación de polvo. Estas superficies - pueden cambiar los patrones de distribución de luz.

b) la mayoria de refractores de los luminarios modernos son removibles por medio de un seguro, permitiendo bajar el refractor a donde sea apropiadamente lavado, enjuagado y secado, un procedimiento es tener refractores de repuesto ó ensambles completos, los cuales puedan ser instalados para que los sucios sean retirados para limpieza, la cual puede efectuarse en el vehículo de mantenimiento, - si cuenta con facílidades diseñadas para este proposito.

d) Sumerja totalmente el conjunto óptico ó parte de él en - una solución detergente, utilizando una esponja ó cepillo suave para quitar la suciedad adherida. Existen muchos polvos de limpieza particularmente adecuados para - lavar equipo de iluminación. Sin embargo, los agentes de limpieza acidos ó alcalinos no deben usarse para el mantenimiento de partes de aluminio.

Despues de limpiadas las unidades deben ser enjuagadas con agua limpia y tibia y dejarlas escurrir hasta secarse. El proceso de secado puede ser acelerado con un chorro de aire caliente reduciendo el costo de mantenimiento por unidad.

d) Hay dos tipos claramente diferentes de luminarios abiertos, que son los llamados no ventilados y ventilados. En el diseño abierto no ventilado, el control de la luz depende del refractor --- prismático. El llamado marco metálico ó porta refractor no interviene casi nada en el control de la luz por lo que solo es - necesario limpiarlo con el fín de evitar el deterioro mecánico. Contrariamente a lo que se piensa, este tipo de luminario necesita limpiarse con la misma frecuencia que el tipo cerrado.

e) El luminario abierto ventilado depende tanto del refractor como el reflector para el control de luz. El efecto venturi producido por el calor de la lámpara y las corrientes de aire, asegura un movimiento contínuo de aire hacia arriba, a través del -- conjunto óptico. Este principio a sido usado para interiores industriales especialmente en atmósferas sucias tales como fundidoras.

f) Los luminarios fluorescentes son usados actualmente para la iluminación de pasos a desnivel, túneles y para iluminar puentes. El gran perímetro con empaque entre la cubierta transparente y el cuerpo del luminario hace necesario asegurarse que las fugas de aire sean mínimas. Las condiciones de polvo en el ambiente - varían grandemente y afectarán los programas de limpieza. La - baja altura de montaje de los luminarios puede hacer necesario_ lavarlos exteriormente en forma muy frecuente debido al agua sucia que salpica sobre ellos. Por la circulación de vehículos.

4.2 Cambio de lámparas.

a) Una fase importante del mantenimiento del alumbrado público (iluminación)es la adopción de un programa eficiente y efectivo de reemplazo de lámparas de acuerdo con el diseño del sistema y otras circunstancias. Este programa tiene dos propositos: Primero, el más obvio, mantener las lámparas encendidas y segundo, mantener los niveles de iluminación.

b) Cuando las lámparas estan apagadas:

1.- Las calles estan obscuras, presentando el peligro de crimenes y accidentes.

2.- El departamento responsable tiene una mala imagen.

3.- Los viajes especiales son costosos.

4.- La pérdida de luz es importante para el público.

c) Los viajes especiales requeridos para cambiar lámparas son caros. Cuando las lámparas están encendidas con baja eficiencia, la pérdida de luz es más seria, pero más sutíl. - Cualquier persona puede observar cuando una lámpara se ha apagado, pero pocas pueden decir si la iluminación tiene su valor nominal. Por esta razón las personas que tienen conocimiento especial de la depreciación de luz, así como la responsabilidad de proporcionar un buen servicio de alumbrado público, deben estar pendientes no solo de mantener las lámparas encendidas, sino también de cambiarlas cuando se han depreciado hastá su valor determinado.

¿ Que límite de depreciación es aceptable en un caso dado? Depende del tipo de lámpara, criterio de diseño y otras condiciones locales.

d) La vida nominal de la lámpara es publicada por el fabricante basado en pruebas de vida de la lámpara en particular, cuando es operada a voltaje y corriente nominal. No es posible fabricar lámparas que trabajen durante un número ---

exacto de horas y despues fallen.
Sin embargo con los métodos modernos de fabricación, es posible producir grupos de lámparas las cuales se aproximen mucho a la vida de diseño. Hay lámparas que fallan prematuramente, pero esto se compensa con algunas lámparas que fallan despues de finalizada su vida de diseño. El comportameinto de las lámparas actuales se muestra en gráficas llamadas curvas de mortalidad.

La curva típica de mortalidad es una gráfica de sobrevivientes de un grupo de lámparas contra una base de tiempo, por ejemplo; el número de horas que han estado encendidas desde el inicio de la prueba. La vida nominal de una lámpara es el punto en la curva de mortalidad donde la mitad de las lámparas se han apagado.

e) Reducir el número de lámparas fundidas entre reemplazos en grupo, naturalmente reduce el costo de mantenimiento. El restaurar el nivel de iluminación a su valor inicial en intervalos regulares es un beneficio directo al público.

f) En un sistema adecuadamente programado de reemplazo de lámparas en grupo es posible reducir los cambios individuales ó cambios intermedios a un 5% o menos.

4.3 Regulación de Voltaje y verificación de equipos de encendido-apagado.

4.3.1 Regulación de voltaje. Como se mencionóanteriormente el voltaje de suministro a una instalación de alumbrado público debe mantenerse dentro del rango de operación nominal de los equipos.

Las lámparas de descarga de alta y baja intensidad están conectadas a los circuitos a través de balastros.

Algunos balastros son auto-regulados, otros no tienen capacidad -- para regular el voltaje, ya que tanto un alto como un bajo voltaje afecta la vida de la lámpara, se debe mantener el voltaje nominal.

El que el voltaje nominal se proporcione o nó depende en gran -- parte de la etapa del diseño. Cuando se diseña un sistema de alumbrado público se debe poner especial cuidado en seleccionar los -- conductores de alimentación para evitar caídas de tensión excesivas, también es importante investigar la regulación de la fuente de suministro, ya que puede ser mala y afectar constantemente al sistema de alumbrado público. Se debe inspeccionar periódicamente el valor del voltaje de todo sistema de alumbrado público y en caso de no ser el adecuado se debe corregir lo antes posible.

4.3.2 Verificación de equipos de encendido-apagado.

4.3.2.1 Relevadores contactores. Los relevadores contactores utilizados - en alumbrado público son de construcción robusta para asegurar una larga vida sin la necesidad de inspecciones frecuentes. Se recomienda una inspección anual a los siguientes puntos.

a) Contactos. Se debe revisar si hay flameo excesivo y si las caras de los contactos estan erosionadas, y si es así, habrá que desconectarlo del circuito y arreglar los contactos o cambiarlos si es necesario.

b) Circuito magnético. Compruebe su operación silenciosa.
Los ruidos magnéticos pueden ser resultado de bajo voltaje en las terminales de la bobina, materiales extraños en la superficie del núcleo o corrosión. Se recomienda limpiar y eliminar la corrosión.

.3.2.2 Controles fotoeléctricos . Los controles fotoeléctricos requieren de poco mantenimiento, como puede ser limpiar la ventana de la cubierta y recalibrarlos. Las cubiertas sucias provocan que las -- lámparas permanescan encendidas más tiempo del necesario.

Se recomienda limpiarlos cada vez que se haga limpieza a los luminarios. Los controles fotoeléctricos usualmente fallan en la posición de encendido. Esto provoca que la lámpara permanezca encendida hasta que el control es cambiado. El calor generado por la lámpara y balastro al ser operados en un gabinete cerrado durante -- las horas de luz diurna, mas el calor del sol pueden causar un -- aumento excesivo de temperatura dentro del luminario. Esto puede causar una falla prematura del balastro y otros componentes. Por otro lado al permanecer las lámparas encendidas en horas en que - no son necesarias, se está desperdiciando energia eléctrica y se envejecen las lámparas innecesariamente, estos controles fallados deben ser reemplazados tan pronto como sea posible.

5.- SISTEMATIZACION DEL MANTENIMIENTO DE ALUMBRADO PUBLICO

Las instalaciones de alumbrado publico están creciendo constantemente, debido al aumento de población urbana que demanda es por esto que se hace cada día mas dificil proporcionar un buen serbi buen servicio de mantenimiento a estas instalaciones.

Con objeto de obtener el máximo provecho al menor costo posible de nuestras instalaciones de alumbrado publico, se- han desarrollado una serie de programas de computadora que facilitan el control de personal, equipo y material, necesarios para el mantenimiento de instalaciones de alumbrado-- publico. Adicionalmente se ha desarrollado un programa que nos permite evaluar en forma economica que sistema de ---- mantenimiento es el más adecuado. Este programa está ----- basado en las siguientes consideraciones:

El costo por reemplazo unitario es:

$$Cu = L+S$$

El costo por reemplazo en grupo es:

$$Cg = \frac{L + S}{I}$$

El costo por reemplazo en grupo(usando reemplazos intermedios):

$$Cg_I = \frac{L+G+(B \times S)}{I}$$

Siendo:

C = Costo total del reemplazo por lámpara

L = Precio neto de la Lámpara

S = Costo de la mano de obra por reemplazar una lámpara (una a la vez)

G = Costo de la mano de obra por reemplazo de una lámpara (reemplazo en grupo)

B = % de lamparas fuera de servicio en el momento de efectuar el reemplazo en grupo.

I = % de la vida promedio de la lámpara en el momento de efectuar el reemplazo en grupo.

EJEMPLO:

DETERMINAR EL PERIODO OPTIMO DE REPOSICION EN GRUPO DE LAS LAMPARAS DE VAPOR DE SODIO EN ALTA PRESION DE 250 WATTS DE UNA-- INSTALACION DE ALUMBRADO PUBLICO EN LA QUE EL COSTO DE REEMPLAZO INDIVIDUAL DE UNA LAMPARA ES DE $ 69,798.95, EL COSTO DE REEMPLAZO EN GRUPO DE UN LAMPARA ES DE $ 8,934.26, Y EL PRECIO DE LA LAMPARA ES DE $ 13,750.80.

PARA EL CALCULO DEL PERIODO DE REEMPLAZO EN GRUPO UTILIZAREMOS LA SIGUIENTE FORMULA:

$$C_{Gi} = \frac{L + G + (B \times S)}{I}$$

DONDE:

CGi = COSTO DE REEMPLAZO EN GRUPO (CON REPOSICION INTERMEDIA DE LAMPARAS)

L = PRECIO DE UNA LAMPARA ($ 13,750.80)

G = COSTO DE MANO DE OBRA DE REPOSICION DE UNA LAMPARA CUANDO SE UTILIZA REEMPLAZO EN GRUPO ($ 8,934.26)

S = COSTO DE MANO DE OBRA DE REPOSICION DE UNA LAMPARA CUANDO SE UTILIZA REEMPLAZO INDIVIDUAL ($ 69.798.95)

B = % DE LAMPARAS FUERA DE SERVICIO EN EL MOMENTO DE EFECTUAR EL REEMPLAZO EN GRUPO (VER TABLA ADJUNTA).

I = % DE LA VIDA PROMEDIO DE LA LAMPARA EN EL MOMENTO DE EFECUAR EL REEMPLAZO EN GRUPO (VER TABLA ADJUNTA).

DE LA CURVA DE MORTANDAD PROPORCIONADA POR LOS FABRICANTES DE LAMPARAS TENEMOS

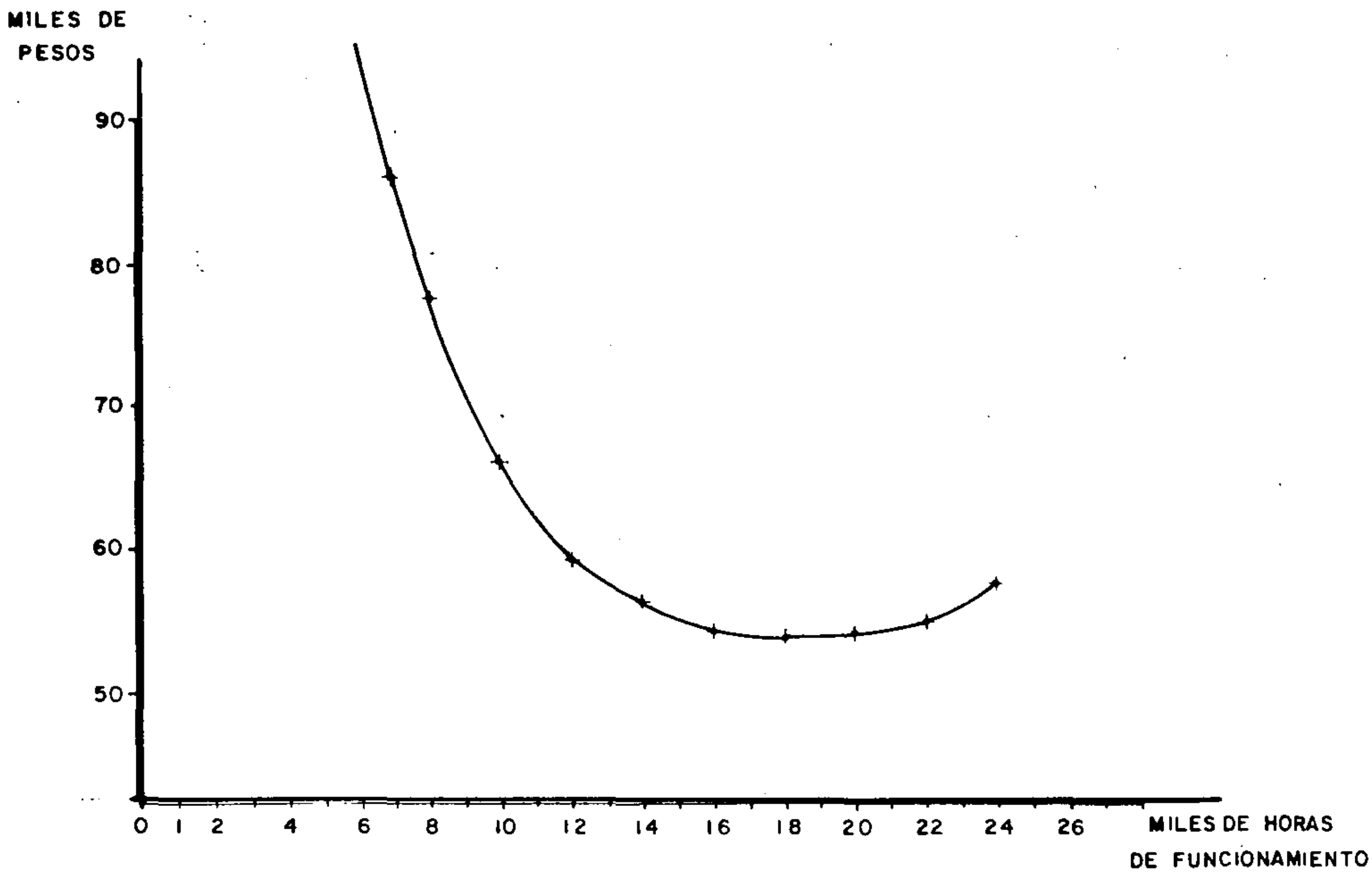
DATOS DE CURVA DE MORTANDAD		DATOS PARA LA FORMULA		RESULTADOS	
HORAS DE FUNCIONAMIENTO (EN MILES DE HORAS)	% DE LAMPARAS ENCENDIDAS	% HORAS DE VIDA ENTRE CIEN (I)	% LAMPARAS FUERA DE SERVICIO ENTRE CIEN (B)	COSTO DE REEMPLAZO EN GRUPO CON REEMPLAZO INDIVIDUAL INTERMEDIO (Cgi)	
0	100	0	0	—	
1	99.9	.0417	.001	$ 545680	
2	99.7	.083	.0035	276257	
3	99.5	.125	.0050	184272	
4	99.0	.167	.0095	139809	
5	98.3	.208	.0165	114599	
6	97.4	.250	.0260	97999	
7	96.4	.292	.0375	86652	
8	95.3	.333	.0465	77870	
9	94.2	.375	.0580	71289	
10	92.8	.417	.0720	66452	
11	91.4	.458	.0860	62637	
12	89.9	.5	.1010	59469	
13	88.0	.542	.1200	57308	
14	85.8	.583	.1420	55911	
15	83.4	.625	.1655	54778	
16	80.8	.667	.1920	54102	
17	78.0	.708	.2200	53723	
* 18	75.0	.750	.2500	53513	*
19	71.7	.792	.2830	53583	
20	68.5	.833	.3150	53627	
21	64.6	.875	.3540	54164	
22	60.6	.917	.3940	54728	
23	55.3	.958	.4465	56211	
24	50.0	1.0	.5000	57584	

COSTO DE REEMPLAZO INDIVIDUAL

$$C_I = L + S = 13\,750.80 + 69\,798.95 = \$\,83\,549.75$$

COSTO DE REEMPLAZO EN GRUPO SIN REPOSICION DE LAMPARAS FALLADAS

$$C_g = L + G = 13\,750.80 + 8934.26 = \$\,22\,685.06$$



COSTO DE REEMPLAZO EN GRUPO CON REEMPLAZO INDIVIDUAL INTERMEDIO.

DETECCION DE FALLAS EN BALASTROS HID

Ya que las lámparas de alta intensidad de descarga producen un corto e intenso arco y porque llegan a consumir más potencia que una sola lámpara fluorescente, el conjunto lámpara-balastro de alta intensidad de descarga, puede proporcionar una variedad de guías visuales para detectar su mal funcionamiento.

Un balastro para lámpara HID origina un calor considerable cuando está en operación y normalmente recibe algo de calor de la lámpara que está alimentando. Por esta razón el material aislante se deteriora y puede causar un corto en los devanados de la bobina. El calor puede causar tambien daños a los conductores o falla al capacitor en cualquiera de las dos formas corto o abierto.

Un balastro HID puede verificarse de manera similar al balastro fluorescente usando un multímetro. Nuevamente el aspecto seguridad debe observarse con cuidado en todos los casos, porque existen muchos balastros diseñados que proporcionan alto voltaje en circuito abierto. Cuidado especial se debe tener cuando se está trabajando con luminarios de vapor de sodio en alta presión, porque usan un voltaje especial alto en el circuito de arranque para iniciar el arco de conducción. El voltaje de arranque en lámparas de 50 hasta 400 Watts es mínimo de 2500 volts y para lámparas de 1000 Watts el mínimo es 3000 volts. (ver fig.1)

Dos mediciones se pueden efectuar en cualquier tipo de balastro energizado tipo HID y compararlas con las publicadas por los fabricantes, respecto al valor del voltaje a circuito abierto y el valor de la corriente de corto circuito.

Se usa un vóltmetro para valores RMS preciso, para medir el voltaje proporcionado en el portalámpara (Socket) sin lámpara en el socket (Voltaje a ciruito abierto). Para realizar esta operación en luminarios con lámpara de sodio en alta presión, se debe desconectar los pulsos de alto voltaje del circuito de arranque (ignitor) ya que pueden dañar los multímetros comunes.

Un método para medir la corriente de corto circuito, es poner en corto el balastro en el socket y después medir el flujo de corriente. Una pieza de alambre grueso o un conductor se puede usar para conectar el centro del contacto del portalámpara al casquillo, la medición puede hacerse con un ampérmetro de gancho.

El capacitor de balastro se puede probar con un óhmetro analógico, puesto en una escala de resistencia muy alta. Al principio el óhmetro está apagado y el capacitor desconectado del circuito, un desarmador o una pieza de metal se pone uniendo las terminales para descargar el capacitor, una punta de prueba del medidor se sujeta a cada terminal del capacitor, se pone en operación el instrumento y si se obtiene una lectura muy alta, el capacitor está abierto y se debe reemplazar. Si el ohmetro mide cero o una muy baja resistencia, entonces el capacitor está en corto y se debe reemplazar. Si el ohmetro mide cero o muy baja resistencia

inicialmente y la resistencia se incrementa lentamente entonces el capacitor esta bien.

GUIA DE FALLAS

I.- LA LAMPARA NO ENCIENDE

CAUSA PROBABLE	ACCION CORRECTIVA
1.- Falla del portlámpara.	Revisar el portalámpara y reemplazarlo si está dañado. (flameado oxidado).
	Atornillar la lámpara hasta que haga buen contacto. Sin descuidar que un torque excesivo puede romper el bulbo.
2.- Lámpara incorrecta.	Revisar que las características eléctricas de la lámpara sean compatibles con las del balastro.
3.- Fin de la vida normal de la lámpara	Determinar las horas de uso de la lámpara, para compararlo con el rango de vida especificado por el fabricante de lámparas.
4.- Soldaduras abiertas.	Inspeccionar las soldaduras y puntos de contacto eléctrico en los conductores internos de la lámparas.

	CAUSA PROBABLE	ACCION CORRECTIVA
5.-	Fin de la vida del balastro	Revisar las bobinas del balastro sobre todo en los puntos negros, capacitores hinchados o perforados. Medir tensión de circuito abierto y corriente de corto circuito, reemplazar el balastro si las mediciones estan fuera de las especificadas.
6.-	Alambrado incorrecto o deteriorado	Terminales sin energía, revisar el alambrado contra el diagrama. Revisar conexiones o aislamien-- tos raros probar continuidad.
7.-	Perdida del suministro o bajo voltaje de entrada	Medir tensión de suministro y de salida del balastro.
8.-	Temperatura ambiente muy alta o muy baja	Revisar la temperatura dentro del luminario.
9.-	Falla de ignitor (En balastros para lámparas de sodio alta presión)	a) Para lámparas de 250 W y 400W Sustituirlas por lámparas de mercurio de la misma potencia, sí la lámpara enciende la parte magnética del balastro esta en buen estado (El ignitor es el fallado) b) Para lámparas de 35W a 150W sustituir las lámparas de sodio

CAUSA PROBABLE	ACCION CORRECTIVA
	por focos (lámparas incandescentes) de 120 V. y potencia similar a la sustituida; si enciende con un brillo entre 1/2 a 2/3 de su brillantes normal la parte magnética esta en buen estado, si brilla con más o menos, la parte magnética del balastro esta averiada.

II BAJA EMISION LUMINICA

10.-	Bajo voltaje de suministro	Medir voltaje de suministro con la lámpara encendida.
11.-	Bajo voltaje de salida del balastro	Medir voltaje de salida con la lámpara encendida.
12.-	Capacitor en corto circuito	Medir voltaje de circuito abierto y corriente de corto circuito.
13.-	Conexiones corroidas u oxidadas	Revisar corrosión en terminales de la portalámpara, tablillas, etc.

III CICLEO DE LA LAMPARA

(La lámpara enciende y se apaga continuamente)

CAUSA PROBABLE	ACCION CORRECTIVA
14.- Bajo voltaje de suministro	Medir voltaje de suministro y compararlo con los rangos de voltaje de entrada del balastro.
15.- Balastro incorrecto	Revisar que las características eléctricas de la lámpara sean compatibles con las del balastro.
16.- Alto voltaje de suministro (solo lámparas de sodio)	Medir voltaje de suministro y compararlo con los rangos de voltaje de entrada del balastro.
17.- Bajo voltaje de salida del balastro.	Medir voltaje de circuito abierto y corriente de corto circuito. Compararlos con los datos publicados por los fabricantes.
18.- Fin de la vida de la lámpara	Determine las horas de uso de la lámpara para compararlo con el rango de la vida esperada.
19.- Voltaje de operación de la lámpara alto	Determinar las horas de uso de la lámpara para compararlo con el rango de la vida esperada y confirmarlo con la medición de voltaje y potencia de lámpara.

LAMPARA MUY BRILLANTE

CAUSA PROBABLE	ACCION CORRECTIVA
20.- Lámpara incorrecta	Revisar que las características eléctricas de la lámpara sean compatibles con las del balastro.

PROBLEMAS DE BALASTROS

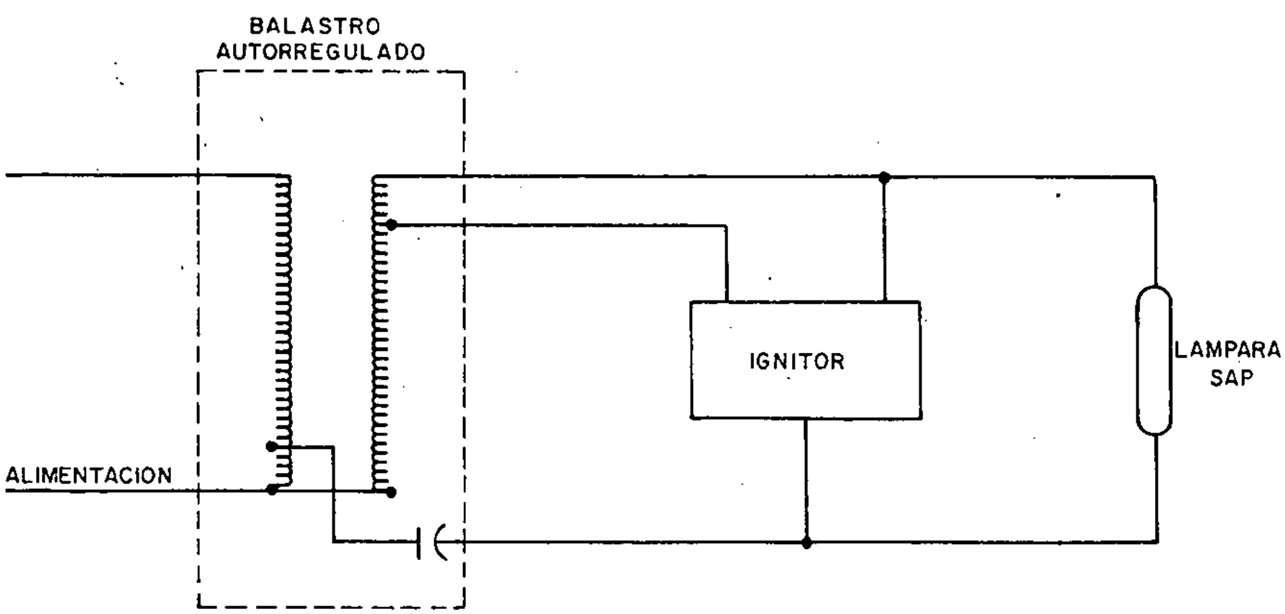


Fig. 1

Fig. 1

DE LA FIGURA No. 1

El balstro para una lámpara de vapor de sodio en alta presión incluye un ignitor con un circuito magnético y un capacitor. La falla del ignitor que suministra alto voltaje, alta frecuencia de pulsación para empezar el encendido del arco, es la mayor causa de deterioro de la lámpara en uso.

Para determinar si el ignitor ha fallado:

a).- Si con una lámpara probada inicialmente y que se encuentra en buenas condiciones la instalamos en el conjunto bajo prueba y la lámpara trata de arrancar y no se establece el arco, entonces el ignitor es el problema.

b).- Para una prueba rápida, se sustituye la lámpara de sodio en alta presión, por una lámpara de mercurio del mismo wattaje (para lámparas de 150 a 400 watts), si la lámpara arranca, la parte magnética está buena, pero el ignitor está malo.

c).- Para lámparas de 35 a 150 watts de alta presión de sodio, se inserta una lámpara incandescente. Si la lámpara se prende a 1/2 o 2/3 de su brillantez normal, eso nos indica que el circuito magnético esta correcto y el ignitor está fallado. Si la lámpara brilla totalmente o es muy obscura, nos indica mal circuito magnético del balastro.

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DEL CURSO: ILUMINACION EXTERIOR: PRINCIPIOS, DISEÑO Y APLICACIONES

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