# CHAPTER 10

# HIGHWAY LIGHTING

# CONTENTS

## LIST OF FIGURES



## LIST OF TABLES

# CHAPTER 10

# HIGHWAY LIGHTING

## 10-01 GENERAL

This chapter provides details and guidance on the policies and standards of the Highway Authority on highway lighting including warrants on use, illumination design values, luminaire arrangements, lighting equipment, pole location, general illumination design procedure and plan requirements.

Lighting systems for Highway Authority projects shall be designed by qualified licensed electrical engineers. In addition to the requirements specified in this chapter, the lighting systems shall comply with all applicable standards and requirements of the Puerto Rico Water Resources Authority (PRWRA) and in particular their Public Lighting Standard Manual. The plans and specifications for lighting projects are subject to PRWRA approval.

## 10-02 HIGHWAY LIGHTING TERMS

The Illuminating Engineering Society (IES) has prepared a glossary of technical terms pertaining to roadway lighting. The following are brief definitions of several of the technical terms used in this chapter; most of these have been adopted from the IES glossary.

ASYMMETRIC DISTRIBUTION — A light distribution in which the curves of vertical distribution are not the same for all planes.

BALLAST — A device used with an electric-discharge lamp to obtain the necessary circuit conditions for starting and operating.

BRACKET (Mast Arm) — An attachment to a lamp post or pole from which a luminaire is suspended.

CANDELA (cd) — The unit of luminous intensity.

CANDLEPOWER (cp) — The luminous intensity of a light source in a specified direction expressed in candelas.

COEFFICIENT OF UTILIZATION (CU) — The ratio of the luminous flux (lumens) from a luminaire received on the roadway surface to the lumens emitted by the luminaire's lamps alone.

CONVENTIONAL LIGHTING — A highway lighting system in which the luminaires mounting heights do not exceed 50 feet.

FOOTCANDLES (fc) — The illumination on a surface one square foot in area on which there is a uniformly distributed flux of one lumen, or the illumination produced on a surface all points of which are at a distance of one foot from a directionally uniform source of one candela.

Average footcandles are calculated by dividing net lumens by the area over which they are distributed. They are also measured by averaging the individual footcandle readings along the center of each traffic lane at ten foot intervals.

Maintained footcandles values are determined for conditions when the luminaire is the most dirty and the lamp has reached its life replacement point.

FOOTLAMBERT (fl) — A unit of luminance (brightness). The uniform luminance of a perfectly diffusing surface emitting or reflecting light at the rate of one lumen per square foot. Footlamberts equals the product of footcandles multiplied by the coefficient of reflection (or refraction).

GLARE - The sensation produced by luminance within the visual field that is sufficiently greater than the luminance to which the eyes are adapted to cause annoyance, discomfort or visual loss. Glare is further defined as:

Direct – glare resulting from high luminances or insufficiently shielded light sources within the field of view.

Reflected – glare resulting from specular reflections of high luminances in polished surfaces in the field of view.

Discomfort – glare producing discomfort but which does not necessarily interfere with visual performance or visibility.

Disability – glare which reduces visual performance and visibility and which is often accompanied by discomfort.

HIGH-INTENSITY DISCHARGE LAMPS – A general group of lamps consisting of mercury, metal halide and high-pressure sodium lamps.

HIGH MAST LIGHTING –Lighting units consisting of a cluster of luminaires mounted on a pole or tower at heights of 60 feet or more.

ILLUMINATION – The density of the luminous flux incident on a surface.

ISOCANDELA LINE – A line plotted on any appropriate coordinates to show directions in space, about a source of light, in which the candlepower is the same.

ISOCANDELA LINE – A line plotted on any appropriate coordinates to show directions in all points of equal illumination on a surface.

LAMP – A generic term for a man-made source of light. Often called a "bulb" or "tube" if it is electrically powered.

LAMP LUMEN DEPRECIATION FACTOR (LLD) – The multiplier to be applied to the initial rated output of a light source to obtain the anticipated minimum rated output based on the relamping program to be used.

LIGHTING UNIT –The assembly of pole or post with bracket and luminaire.

LONGITUDINAL ROADWAY LINE (LRL) – Any line along the roadway parallel to the curb or pavement edge lines.

LUMEN (lm) – The unit of luminous flux. It is equal to the flux on a unit surface all points of which are at a unit distance from a uniform point source of one candela. The term by which the output of a light source is frequently expressed.

LUMINAIRE – A complete lighting device consisting of the lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps and to connect the lamps to the power supply. It does not include the post, pole or bracket.

LUMINAIRE DIRT DEPRECIATION FACTOR (LDD) – The multiplier to be applied to the initial illumination provided by clean, new luminaires to obtain the reduced illumination value that they will provide due to dirt accumulation on the luminaires at the time that cleaning is anticipated.

LUMINAIRE EFFICIENCY – The ratio of luminous flux (lumens) emitted by a luminaire to that emitted by the lamp or lamps used therein.

MAINTENANCE FACTOR (MF) – The product of the lamp lumen depreciation factor and the luminaire dirt depreciation factor (MF = LLD x LDD).

MOUNTING HEIGHT (MH) — The vertical distance between the roadway surface and the center of the apparent light source of the luminaire.

OVERHANG — The distance between a vertical line passing through the luminaire and the curb or edge of the traveled way.

REFERENCE LINE — Radial lines where the surface of the cone of maximum candlepower is intersected by a vertical plane parallel to the curb line and passing through the light center of the luminaire.

REFLECTANCE — The ratio of the light reflected by a surface to the light incident upon it.

REFLECTOR — A device used to redirect the luminous flux from a source by the process of reflection.

REFRACTOR — A device, such as a globe or glass band, used to redirect the luminous flux from a source, primarily by the process of refraction.

SPACING — The distance between successive lighting units measured along the center line of the highway.

SYMMETRICAL LIGHT DISTRIBUTION - A light distribution in which the curves of vertical distribution are substantially the same for all planes.

TRANSVERSE ROADWAY LINES (TRL) — Lines across the roadway perpendicular to the curb or pavement edge line.

UNIFORMITY OF ILLUMINATION — The ratio of average illumination level on the roadway to the minimum illumination level at any point on the roadway.

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

## 10—03 POLICY ON USE

It is not practical to establish specific conditions covering all cases as to when it is warranted to provide highway lighting. It is recognized that highway lighting will contribute to the safety, efficiency and comfort of vehicular and pedestrian traffic. On the other hand, the installation of lighting systems can involve a substantial investment of public funds and subsequent maintenance and power costs.

In this section general warrants are given for guidance in determining when lighting should be provided. These warrants are in conformance with the requirements of Highway Safety Program Standard No. 12 and generally follow the AASHTO "Informational Guide for Roadway Lighting" (1976).

### 10-03.01 AREA CLASSIFICATION

The following definitions apply to area classifications used in this chapter:

DOWNTOWN — That portion of a municipality in a business development where ordinarily there are large numbers of pedestrians and a heavy demand for parking space during periods of peak traffic or a sustained high pedestrian volume and a continously heavy demand for off-street parking space during business hours. This definition applies to densely developed business areas outside of, as well as those within, the central business district.

INTERMEDIATE – That portion of a municipality which is outside of a downtown are but generally within the zone of influence of a business or industrial development, characterized often by a moderately heavy nightime pedestrian traffic and a somewhat lower parking turnover than is found in a downtown area.

OUTLYING – A residential development, or a mixture of residential and commercial establishments, characterized by few pedestrians and a low parking demand or turnover at night.

## 10–03.02 WARRANTING CONDITIONS – FREEWAYS

1. CONTINOUS LIGHTING

Continous freeway lighting should normally be provided under any of the following conditions:

a. Sections 3 or more kilometers in lengthpassing through urbanized areas where the adjacent street system visible from the freeway is lighted.

b. Sections where three or more successive interchanges are located at an average spacing of 1 kilometer or less.

c. On sections where the ratio of night to day accidents experience is higher than the average for all similar unlighted sections and a study indicates that lighting may result in a substantial reduction in the night accident rate.

2. INTERCHANGE LIGHTING ON UNLIGHTED SECTIONS

Interchange lighting on unlighted freeways should normally be provided under any of the following conditions:

a. Complete lighting at interchanges where existing substantial commercial or industrial development in the immediate vicinity is lighted or where the crossroad approach legs are lighted for 0.5 kilometer or more on each side.

b. Complete lighting at interchanges where the current ADT on the crossroad, or the total ADT ramp traffic entering and leaving the freeway within the interchange, exceeds 5,000 vehicles.

c. Complete or partial interchange lighting where the ratio of night to day accident experience is higher than the average for similar unlighted interchanges and a study indicates that lighting may result in a significant reduction of the night accident rate.

## 10–03.03 WARRANTING CONDITIONS – OTHER HIGHWAYS

On highways other than freeways, including expressways with partial control of access, lighting should normally be provided under any of the following conditions.

1. All streets and highways in urbanized where the adjacent existing street system is lighted.

2. At junctions of major arterials in outlying or rural areas.

3. On sections in outlying and rural areas having ratios of night-to-day accidents higher than the average and where studies indicate the lighting may significantly reduce the night accident rate.

## 10—03.04 WARRANTING CONDITIONS – UNDERPASSES

1. SHORT UNDERPASSES (less than 30 meters)

Short underpasses along unlighted highways do not normally require illumination. However, when the highway is lighted the underpasses should also be lighted. For underpass lengths up to about 22 meters lighting can usually be provided from luminaires outside the underpass. For over 22 meters supplemental underpass lighting is usually required.

2. LONG UNDERPASSES (30 meters or longer)

All long underpasses require nightime illumination. They also normally require daytime illumination if their length exceeds 100 meters. Between 30 and 100 meters the possible need for daytime illumination should be analyzed. Daytime lighting is not required if the facility is straight, level and has a high width to length ratio which allows adequate daylight penetration.

## 10—04 ILLUMINATION DESIGN VALUES

1. HIGHWAYS

Recommended illumination values for the various highway classes through downtown, intermediate and outlying areas are shown in Table 10—1. The values given represent average footcandles on the traveled way when the lamp is at its lowest output and when the luminaire is in its dirtiest condition.

### TABLE 10—1

### RECOMMENDED ILLUMINATION VALUES FOR HIGHWAYS (1)

### AVERAGE MAINTAINED HORIZONTAL FOOTCANDLES (2)

| Highway Classification | Area Clasification (3) | | |
|---|---|---|---|
| | Downtown | Intermediate | Outlying |
| Freeways (4) | 0.6 | 0.6 | 0.6 |
| Other Arterials (5) | 0.8 | 0.8 | 0.8 |
| Collectors | 0.8 | 0.8 | 0.6 |
| Local | 0.8 | 0.6 | 0.2 |
| Uniformity Ratio: 0.6 fc or higher — 3:1 maximum<br>Less than 0.6 fc — 6:1 acceptable | | | |

Notes:

(1) These guide values apply to highway sections which are generally straight and nearly level.

(2) Average illumination on the traveled way after applying the LLD (Lamp Lumen Depreciation) and (Luminaire Dirt and Depreciation).

(3) See Section 10—03 for definitions.

(4) Both mainline and ramps.

(5) Includes expressways with partial control of access.

The values in Table 10-1 are considered adequate for the safe and efficient flow of pedestrian and vehicular traffic under normal conditions. However, there may be specific conditions under which somewhat greater illumination may be warranted as indicated by the notes. In addition, there may be other conditions under which somewhat higher values may be desirable such as at sections with restrictive geometric features and intersections with introduced raised medians or channelizing islands. The lighting designer should consider all pertinent information in determining the lighting level to be provided for any specific highway or street section.

To insure effective visibility it is necessary to provide an adequate uniformity of illumination. The uniformity ratio, which is the ratio of the average illumination of the roadway design area between two adjacent luminaires to the lowest value at any point in the area should not exceed 3 to 1. The only exception is when an average illumination level of less than 0.2 fc is authorized when a uniformity ratio as high as 6:1 is acceptable.

2. TRANSITION LIGHTING

Where adaptation lighting is required when passing from a lighted section to an unlighted section, a transition section of about 300 meters should be provided with an illumination level of one-half the design level of the lighted section but the terminal illumination should be not less than 0.25 fc nor more than 0.5 fc.

3. UNDERPASSES

When underpass illumination is required the following should be used as a guide.

a. Short Underpasses (less than 30 meters)

If lighting is warranted, the illumination on the roadway should be no more than two times that on the roadway outside the underpass unless additional illumination is required for pedestrian and policing purposes.

b. Long Underpasses (30 meters or longer)

(1) Nightime — The average maintained illumination on the walls should be in the range of 0.7 to 2.0 fc. These values are based on a wall reflectance factor of at least 70 percent. When the reflectance factor is less than 70% the designed footcandles should be increased accordingly.

(2) Daytime — When daytime lighting is required the interior average maintained illumination on the walls should be in the range of 30 to 60 fc provided the wall reflectance factor is 70% or better.

## 10-05 LUMINAIRE LIGHT DISTRIBUTIONS

Luminaire light distributions are classified on the basis of three criteria by the IES. These include vertical light distribution, lateral light distribution and control of light distribution above maximum candlepower. Classification of light distribution is made on the basis of an isocandela diagram which on its rectangular coordinate grid has superimposed a series of Longitudinal Roadway Lines (LRL) identified by multiples of Mounting Height (MH) and a series of Transverse Roadway Lines (TRL) also in multiples of Mounting Height. This is illustrated in Figure 10—A.

### 10-05.01 VERTICAL LIGHT DISTRIBUTION

Vertical light distribution is by three groups as follows:

1. SHORT (S) – A luminaire for which the maximum candlepower point on the roadway lies between the 1.0 and the 2.25 MH-TRL grid zone.

2. MEDIUM (M) — A luminaire for which the maximum candlepower point on the roadway lies between the 2.25 and the 3.75 MH-TRL grid zone. See Figure 10—A.

3. LONG (L) — A luminaire for which the maximum candlepower point lies between the 3.75 and the 6.0 MH-TRL grid zone.

## 10—05.02 LATERAL LIGHT DISTRIBUTION

The various patterns of lateral light distribution are illustrated in Figure 10—B. Types I, I-4-way, and V are normally used for luminaires located near the center of the roadway and have a similar light distribution on both the house side and the street side of the reference line. These types are not normally used by the Highway Authority except for Type V which may be used on high mast designs.

Types II, II-4-way, III, and IV are used for luminaires located near the edge of the traveled way. Types II and III are the most frequently used in Highway Authority designs for conventional lighting systems.

The EIS definitions of lateral distribution types are related to the location of the 1/2 maximum candlepower isocandela trace with respect to the LRL grid and the location of the point of maximum candlepower, except for Type V, as follows:

TYPE I — Its 1/2 max. cp. isocandela trace lies within the Type I width range (See Fig. 10—A) on both sides of the reference line which is bounded by the 1.0 MH house side LRL and the 1.0 MH street side LRL within the longitudinal distribution range (S, M or L) where the point of max. cp. falls.

TYPE I — 4-way — It has four beams of the width as defined for Type I.

TYPE II — the street side segment of the 1/2 max. cp. isocandela trace within the longitudinal range (S, M or L) in which the point of max. cp. falls does not cross the 1.75 MH street side LRL. (Illustrated in Fig. 10—A)

TYPE II ⊥ 4-way — It has four beams each of the width on the street side as defined for Type II.

TYPE III — The street side segment of the 1/2 max. cp. isocandela trace within the longitudinal range (S, M or L) in which the point of max. cp. falls lies partly or entirely beyond the 1.75 MH street side LRL but does not cross the 2.75 MH street side LRL.

TYPE IV — The street side segment of the 1/2 max. cp. isocandela trace within the longitudinal range (S, M or L) in which the point of max. cp. falls lies partly or entirely beyond the 2.75 MH street side LRL.

TYPE V — Its pattern has a circular symmetry of candlepower distribution which is essentially the same at all lateral angles.

## 10—05.03 CONTROL ABOVE MAXIMUM CANDLEPOWER

The control of the candlepower in the upper portion of the beam above maximum candlepower is classified into three categories as follows:

CUTOFF — When the candlepower per 1000 lamp lumens, at any lateral angle around the luminaire, does not exceed 25 (2—1/2%) at an angle of 90° and 100 (10%) at a vertical angle of 80°. (See Fig. 10—A).

SEMI-CUTOFF — When the candlepower per 1000 lamp lumens, at any lateral angle around the luminaire, does not exceed 50 (5%) at an angle of 90° and 200 (20%) at a vertical angle of 80°.

# LUMINAIRE LIGHT DISTRIBUTION

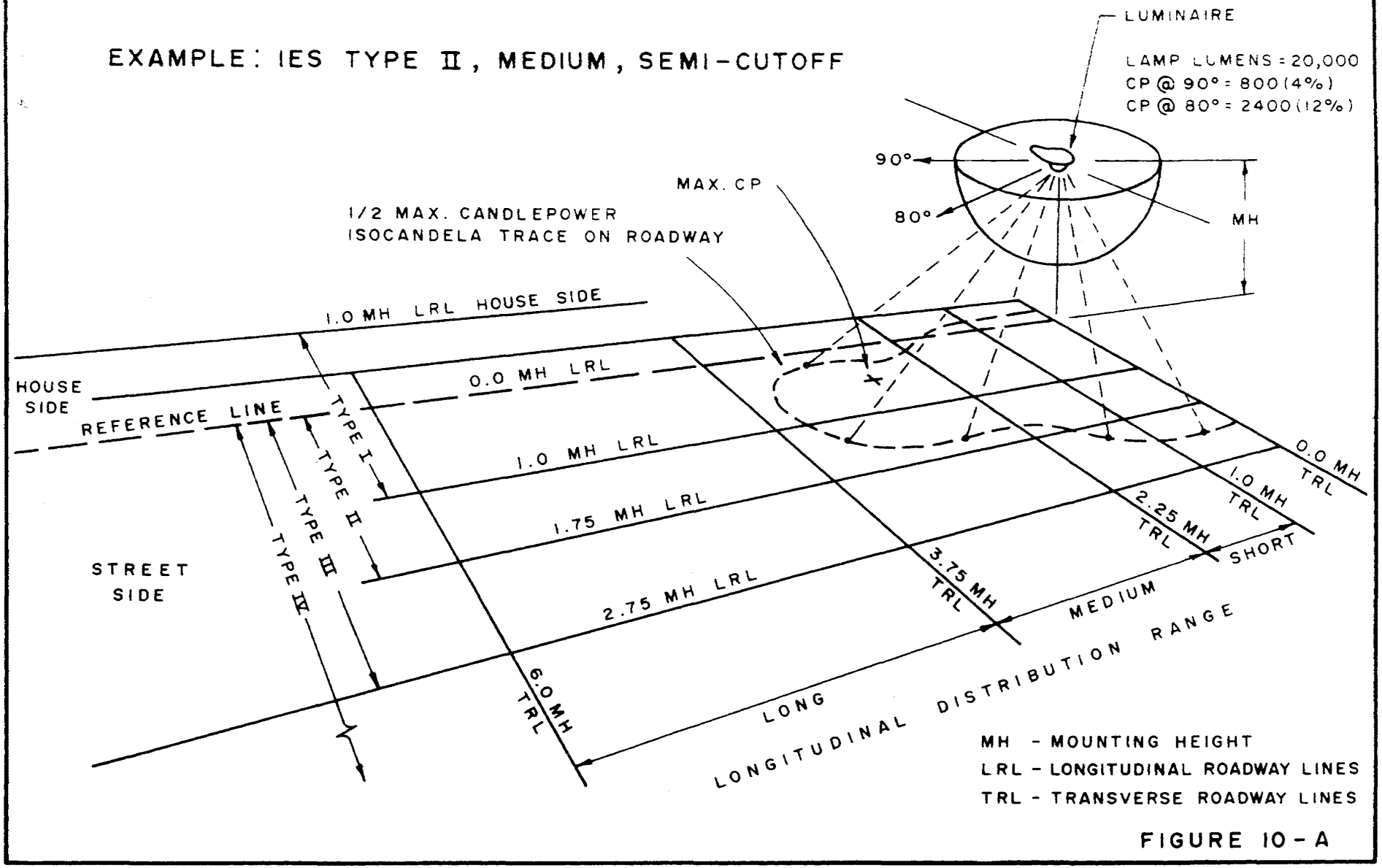
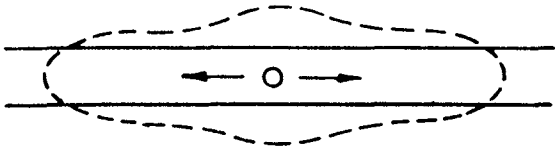
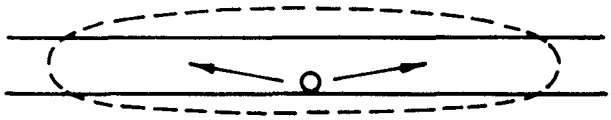



FIGURE 10-A

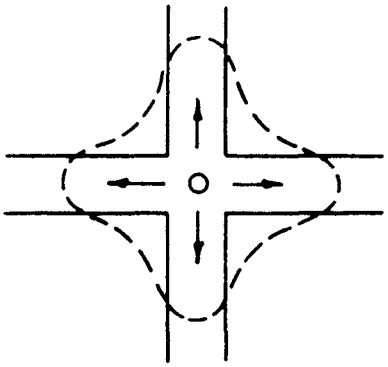
# ROADWAY COVERAGE BY LUMINAIRE TYPES



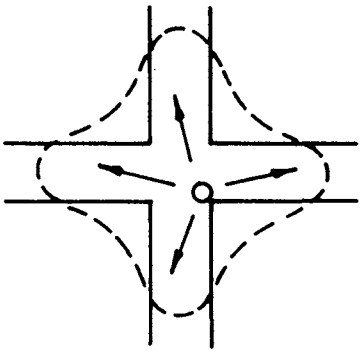
TYPE I



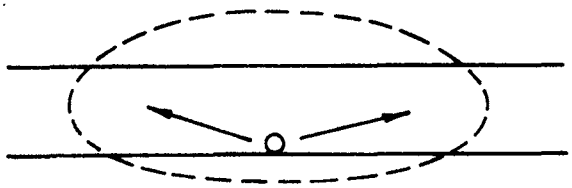
TYPE II



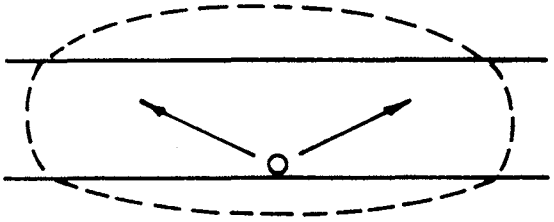
TYPE I - 4-WAY



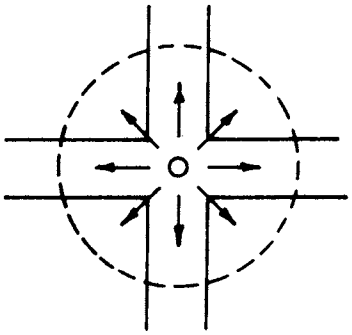
TYPE II - 4-WAY



TYPE III



TYPE IV



TYPE V

FIGURE 10 - B

NON-CUTOFF – When there is no candlepower limitation in the zone above maximum candlepower.

## 10-06 CONVENTIONAL LIGHTING SYSTEMS

Many alternate configurations are possible to meet the lighting requirements for a highway. This section includes a discussion of the arragements of luminaries, spacing of poles, mounting heights, luminaire types and other equipment currently in use by the Highway Authority for the design of conventional overhead lighting systems.

### 10-06.01 LUMINAIRE ARRANGEMENTS

The four basic types of luminaire arrangements most commonly used by the Highway Authority for conventional overhead lighting include one side, both sides-opposite, both sides-staggered and median as shown in Figure 10—C. The type of arrangement and spacing selected for a given highway section will depend primarily on the highway class, roadway width, desired level of illumination, mounting height, light source and luminaire type.

1. ONE SIDE – This arrangement is used mainly with Types II or III luminaires on ramps, frontage roads and undivided local roads and streets.

2. OPPOSITE – Used mainly with Type III or IV luminaires on multilane divided highways with wide medians.

3. STAGGERED – Used mainly with Type III or IV luminaires on multilane undivided highways or streets, and on multilane divided highways with narrow medians. This is the preferred type of arrangements for most expressways.

4. MEDIAN – Used on multilane divided urban highways, with curbed medians up to 6.0 meters in width, but on which operating speeds are normally under 35 mph. May also be used on urban expressways in special cases (see Section 10—06.03).

### 10-06.02 LUMINARE MOUNTING HEIGHT

The current standard mounting height of the Highway Authority for conventional lighting systems is 30 feet. However, the P.R.H.A. is considering the use of increased mounting heights to obtain increased pole spacing, better uniformity of illumination, and generally more economical and effective lighting systems.

### 10-06.03 POLE LOCATION AND SAFETY CONSIDERATIONS

Lighting poles constitute roadside obstacles and should be so placed and constructed as to minimize their potential hazard to out-of-control vehicles. Ideally they should be located outside of the clear roadside area, desirably at least 9 meters from the edge of the traveled way. However, this separation is not normally attainable in most installations.

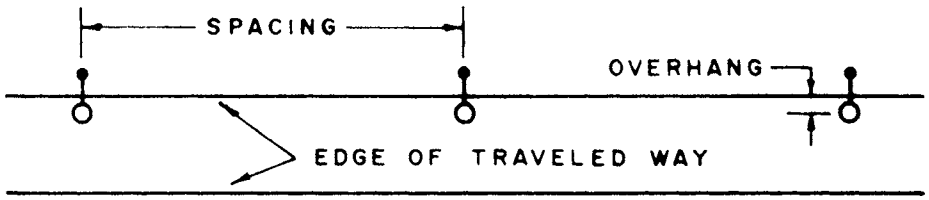
1. EXPRESSWAYS AND MULTILANE RURAL HIGHWAYS

Figure 10—D shows the normal pole locations for conventional lighting used by the Highway Authority for all expressways and rural multilane highways. These locations are also applicable to other high-speed highways where lighting is to be provided.

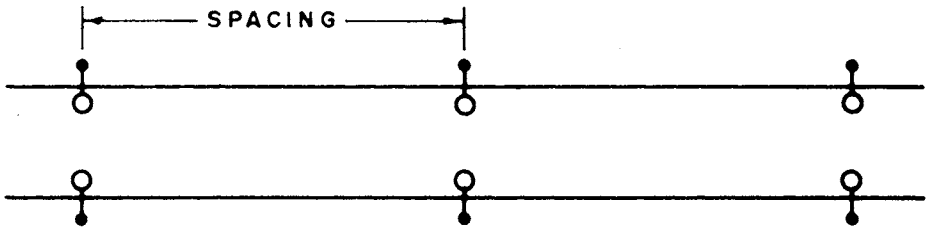
a. Mainline

Along the mainline the preferred pole location is on the right side in the direction of traffic a distance of 4.2 meters from the edge of the traveled way as shown in Figure 10—D (1). Where the shoulders are less than 3.0 meters in width and the highway section is restricted, the poles may be located closer but not less than 1.2 meters outside the normal shoulder width.

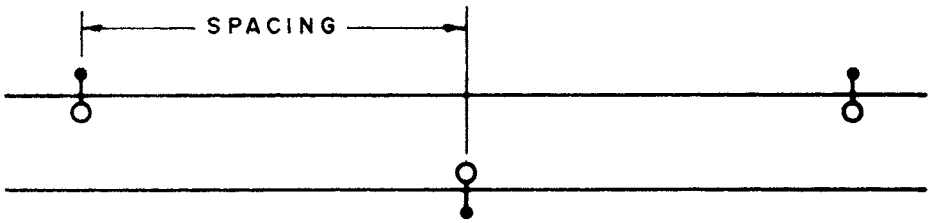
# LUMINAIRE ARRANGEMENTS



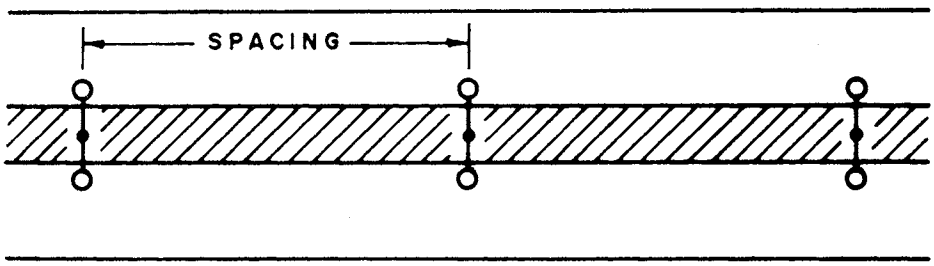

(1) ONE SIDE




(2) OPPOSITE




(3) STAGGERED

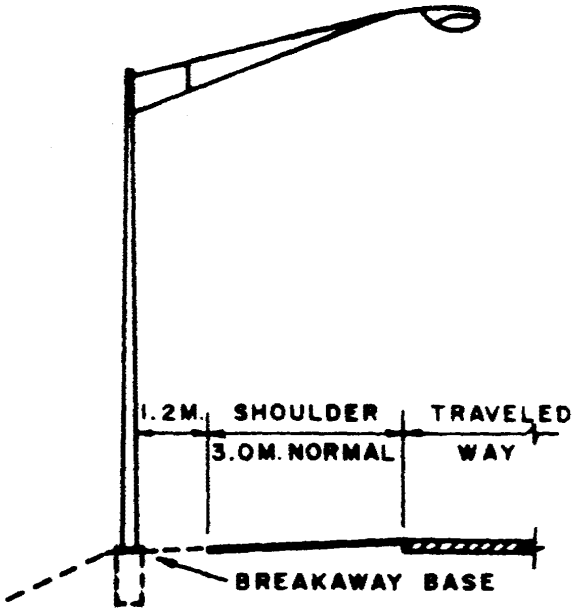



(4) MEDIAN

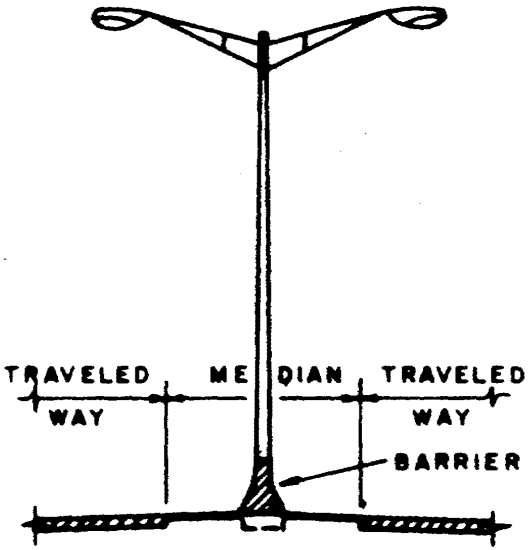
FIGURE 10-C

# LOCATION OF CONVENTIONAL LIGHTING UNITS

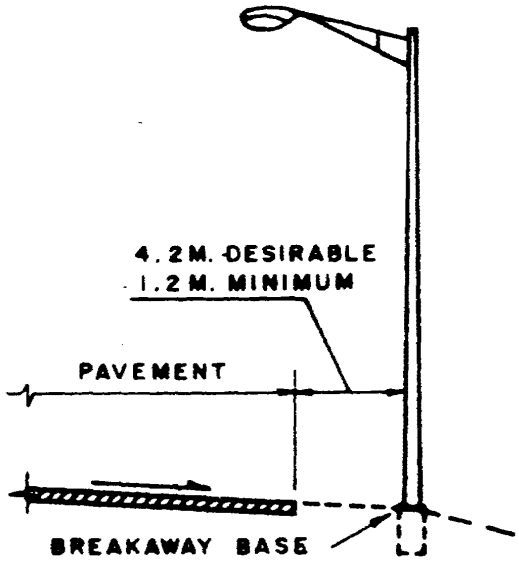
## ALL EXPRESSWAYS AND OTHER MULTILANE RURAL HIGHWAYS




(1) MAINLINE
NORMAL INSTALLATION




(2) ALTERNATE FOR
NARROW MEDIAN
WITH BARRIER




(3) RAMPS

FIGURE 10-D

Although median pole location, Figure 10—D (2), normally results in lower initial construction costs, this location shall not be used unless the highway design calls for a median barrier for other safety reasons. When median location is used, the pole design must be coordinated with the barrier design to insure that the effectiveness of the barrier is not jeopardized.

Where the roadway design calls for guardrail installation adjacent to the outside shoulders, the poles shall be located at least 0.6 M. back of the guardrail. However, guardrail or other type barrier shall not be installed solely for the protection of motorists against collision with lighting poles.

All lighting poles located adjacent to the outside shoulders shall have breakaway bases. This does not permit the use of the current standard concrete poles at such locations. This requirement applies regardless of the presence of guardrail between the pole and the traveled way unless the offset between the guardrail and the post is sufficient to allow for the full deflection of the rail element under impact.

Lighting poles located in narrow medians within the barrier system should be of the rigid type since a post falling on the roadway after impact can be a great hazard to traffic.

b. Ramps

Along ramps, lighting poles should desirably be located at least 4.2 M. from the edge of the traveled way as shown in Figure 10—D (3) but where space limitations or the configuration of the roadway section do not permit it, they may be placed closer but not less than 1.2 meters from pavement (shoulder) edge. If there is guardrail provided, the poles shall be offset at least 0.6 M. back of the rail.

On tangent alignment or on curved alignment where the ramp curve radius exceeds 250 M. the lighting poles should be placed on the right side in the direction of traffic. However, along loops or curves less than 250 M. in radius, the poles should be located on the inside of the curve.

At exit ramp terminals at interchanges no lighting poles should be placed in the gore area within 15 meters of the approach nose.

c. Structures

Lighting poles on bridges and overpasses should be located either on or preferably behind the railings or parapets.

Where there are retaining walls parallel to the roadway, the lighting units should be placed either on top or on the side of the walls as appropriate for the design. Lighting poles in front of such walls should be avoided since they could increase the severity of an accident for a vehicle sliding along the wall.

2. OTHER URBAN HIGHWAYS AND STREETS

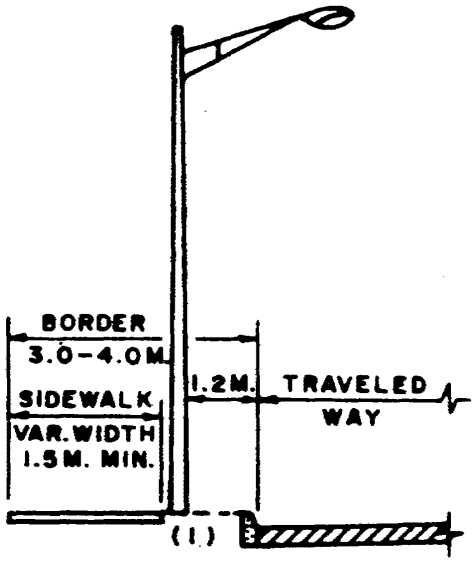
Figure 10—E shows the normal lighting pole locations on avenues, principal and local streets.

On avenues and principal streets the preferred location is along the border or house side with the pole placed at least 1.2 M. from the curb line. On avenues and divided principal streets with a median width of 4.25 M. or more, the lighting poles may be placed in the median without a barrier if normal operating speeds will not exceed 35 mph.

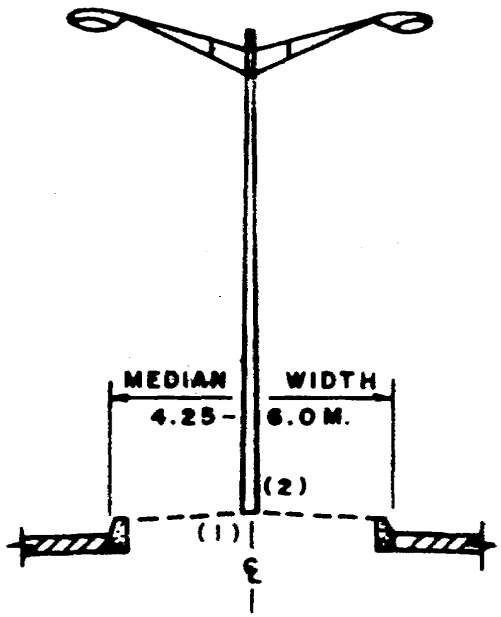
Median pole locations without a barrier are objectionable because they are exposed to the total two-way traffic flow, a pole may fall in the oppossite traffic lanes after impact, the poles are closer to the higher speed traffic of the inner lanes, maintenance operations are more hazardous, and the poles may conflict with median lanes.

# LOCATION OF CONVENTIONAL LIGHTING UNITS

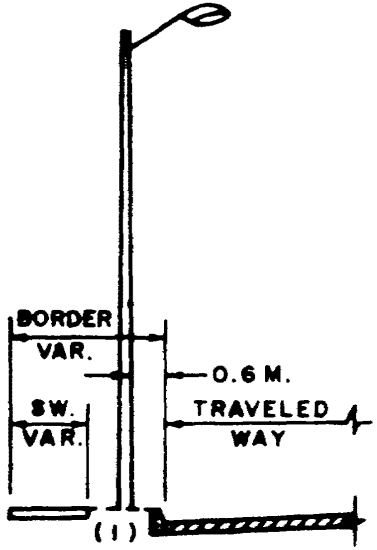
## AVENUES, PRINCIPAL AND LOCAL STREETS




PREFERRED LOCATION
HOUSE SIDE




ALTERNATE LOCATION
MEDIAN




LOCAL STREETS

AVENUES AND DIVIDED PRINCIPAL STREETS

NOTES: (1) USE NON-BREAKAWAY SUPPORTS.
(2) USE BARRIER PROTECTION WHEN WARRANTED BY TRAFFIC VOLUMES AND/OR OPERATING SPEEDS.

FIGURE 10-E

On local streets the poles shall be placed at least 0.6 M. from the curb line.

All lighting poles in these facilities shall be of the non-breakaway type since a falling pole may strike pedestrians, fall on the roadway or on a building, and cause property damage.

## 10 06.04 LIGHTING EQUIPMENT AND INSTALLATIONS

The requirements and details on poles, brackets, luminaires, lamps, ballasts, conductors, transformers and other equipment and materials for lighting systems are covered in the specifications and standard plans of the Highway Authority and in the Public Lighting Standards Manual of the Puerto Rico Water Resources Authority.

All highway lighting systems shall be designed for underground distribution. Overhead lighting distribution will only be allowed for temporary lighting systems to illuminate detours or temporary relocations of existing lighting systems.

On all expressways the transformers should be pad mounted and installed at protected locations at least 9.0 meters from the edge of the nearest traveled way. On other streets and highways, the transformers may be pole mounted.

## 10-07 HIGH MAST LIGHTING

High mast lighting is the systems preferred by the Highway Authority for the illumination of major interchanges and toll plazas.

The pole or mast in current use is a weathering steel type for 80-foot mounting height. It shall be provided with a circular ring for mounting the luminaire cluster. The ring shall be provided with a suitable raise-lower device to allow the lowering of the cluster for luminaire maintenance.

High mast units should be located at not less than 9.0 meters from the edge of the nearest traveled way. If because of space limitations if becomes necessary to place them closer to the pavement, guard rail protection shall be provided. The guard rail shall be placed at a sufficient distance from the pole base to allow for the full deflection under impact of the particular guard rail design used. Normally this distance should be about 2.5 meters.

The transformers or power centers shall be pad mounted and should be placed at protected locations, at least 9.0 meters from the nearest traveled way.

## 10-08 UNDERPASS LIGHTING

For underpass lighting, where required, the Highway Authority normally uses clear mercury vapor wall type luminaires of 175 or 250 watts as required to provide the illumination level desired. Normal mounting height is 15 feet above the pavement.

For underpass lengths of up to 22 meters, adequate illumination can usually be provided by the outside roadway luminaires when a conventional system is used. The outside luminaires adjacent to the underpass must be properly positioned for maximum light penetration into the underpass area. This is attained by selecting a location at which the vertical angle of maximum candle power will just miss the overhead portal structure.

## 10-09 GENERAL ILLUMINATION DESIGN PROCEDURE

A basic guide for the design of highway lighting systems is provided by the "American National Standard Practice for Roadway Lighting" published by the Illuminating Engineering Society (IES). In addition, the leading manufacturers of highway lighting equipment provide technical data and publications that facilitate the design process.

## 10—09.01 CONVENTIONAL LIGHTING SYSTEM

The following general procedure may be followed to arrive at a satisfactory design for any specific highway section.

1. Determine the initial controlling factors which include:
   a. Level of illumination and uniformity required. See Section 10—04 and Table 10—1.
   b. Width of roadway to be illuminated.
   c. Width of shoulders or sidewalk.

2. Select a mounting height. Current Highway Authority practice is to use 30 feet.

3. Select a lamp type and wattage, and determine from manufacturer's data its initial lamp lumens and lamp lumen depreciation factor (LLD). The Highway Authority is normally requiring 400 watt lamps, HPS Code H—51.

4. Select a compatible luminaire with a light distribution type appropriate for the ratio of roadway width to mounting height of the highway section. See Section 10—05.

5. Select an appropriate luminaire arrangement. See Section 10—06.01.

6. Specify pole location. See Section 10—06.03.

7. Select bracket length to position luminaire approximately at edge of traveled way. Standard bracket lengths used by the Highway Authority are 4, 8, 12 and 15 feet.

8. Calculate the street side and house ratios for use with the utilization curves as follows:

$$\text{Street Side Ratio} = \frac{\text{Pavement Width} - \text{Luminaire overhang}}{\text{Mounting Height}}$$

$$\text{House Side Ratio} = \frac{\text{Luminaire Overhang}}{\text{Mounting Height}}$$

9. Using the above ratios determine coefficients of utilization (CU) from the utilization curve (photometric data) supplied by the manufacturer for the particular luminaire type previously selected.

10. Calculate the longitudinal spacing as follows:

$$\text{Spacing (S)} = \frac{\text{lm x CU x MF}}{\text{Average fc x Width}}$$

where lm = initial lamp lumens
CU = total coefficient of utilization (street side + house side)
MF = Maintenance factor ( = LLD x LDD) Normally use values suggested in the PRWRA manual.
Average fc = level of illumination desired
Width = width to be lighted

Roundout the calculated value of S as appropirate.

11. After locating the lighting units, determine the minimum illumination at representative points using the isofotcandle diagrams for the particular luminaire type selected.

12. Adjust the minimum illumination value by the MF to correct for the effects of aging and dirt and, if necessary, by a correction factor for mounting height.

13. In determining the minimum illumination at any point be sure to add up the light contributed by the various lighting units in the vicinity of the point.

14. Calculate the uniformity ratio by dividing the average illumination by the minimum illumination.

15. If the maximum uniformity ratio allowed is exceeded, try a new spacing and compute the average illumination by the equation:

$$\text{Average fc} = \frac{\text{lm x CF x MF}}{\text{S x Width}}$$

Then repeat steps 11 through 14.

16. If a satisfactory configuration is not obtained, if may be necessary to try with a different type luminaire and/or lamp.

## 10—09.02 HIGH MAST LIGHTING

For high mast lighting design it is necessary to obtain the photometric data (isofootcandle and utilization curves) from the lumaire/lamp manufacturers. The following general design procedure may be followed:

1. Determine the initial controlling factors which include:

   a. Level of illumination and maximum uniformity ratio. See Table 10—1

   b. Area to be illuminated, from project plans.

2. Select the light source and mounting height. The Highway Authority is currently using 1000 W. metal halide or mercury vapor luminaires at 80-foot mounting heights.

3. Assume a number of luminaires per pole. Design a template, at the same scale as project plan, with all points on the perimeter representing the minimum initial illumination which is required from one luminaire. Use the appropriate photometric data and MF to arrive at the size of the template.

4. Cut out a number of templates. Place some first at critical areas such as gores and structures, then fill in the rest of the area so that all traveled ways are covered. Use a minimum number of templates. Make sure that the center of each, representing the lighting unit, is located no less than 9 meters from any traveled way.

5. Determine the number of templates required and the total area covered by these templates.

6. Calculate the average illumination as follows:

$$\text{Average fc} = \frac{\text{(Total Lumens) x CU x MF}}{\text{Area}}$$

where Total Lumens = (no. of Luminaires/Pole) x (Lumens/Lamp) x (no. of Poles)

7. Determine the uniformity ratio.

8. Check for conformance with required average maintained illumination and uniformity ratio. Requirements are not met, the number of luminaires per pole may have to be increased or the distribution patterns modified. Several configurations may need to be tried before arriving at the most satisfactory design. Some configurations may call for varying numbers of luminaires rather than a uniform number on all poles. Also, although symmetric (circular) distribution patterns are normally used for interchanges, some layouts may be better served by an asymmetric (elongated) design.

### 10—09.03 SPECIAL CONDITIONS

Whenever the construction or alteration of a highway lighting system in the vicinity of an airport is proposed, the design must be coordinated and cleared with the airport authorities to insure that the lighting installation does not violate the required airway-highway clearances and that the illumination does not interfere with the safe night operations of aircraft.

## 10—10 PLAN REQUIREMENTS

The construction plans for a highway lighting system shall include the following:

1. Layout of the complete system on a plan of the roadway showing the location of each lighting unit, conductors, conduits, power centers, tie to power systems, and other system appurtenances. The location of the lighting units with respect to the traveled ways shall be identified by giving the station and offset.

2. The design criteria shall be shown on the first sheet and shall include:

   a. Luminaire and lamp type and wattage
   b. Lumens
   c. Design illumination levels
   d. Uniformity ratio
   e. Luminaire mounting height
   f. Maintenance factor
   g. Photometric curve number
   h. Circuit type

3. The legend of symbols used shall also be included in the first sheet. Figure 10—F shows suggested standard plan symbols.

4. All necessary details, not covered by standard plans, of poles, brackets, pole foundations, transformers or power centers, wiring diagrams, underpass luminaire installations, and other system appurtenances.

5. Appropriate notes needed to clarify the design and installation details.

6. Signature, name and license number of the electrical engineer responsible for the design.

## 10—11 REFERENCES

The highway lighting designer should be familiar with and have access to the following references.

1. "American Standard Practice for Roadway Lighting", D 12.1 — 1972, Illuminating Engineering Society.

2. "An Informational Guide for Roadway Lighting", 1969, American Association of State Highway and Transportation Officials.

3. "Public Lighting Standards Manual", 1974, P.R. Water Resources Authority.

4. "Lighting of Tunnels", 1972, Illuminating Engineering Society.

5. "IES Lighting Handbook", 1972, Illuminating Engineering Society.

6. "Specifications for the Design and Construction of Structural Supports for Highway Luminaires", 1970, AASHTO. (This will be superseded by the "Standard Specification for Structural Supports for Highway Signs, Luminaires, and Traffic Signals" when approved and published by AASHTO.)

7. "Handbook of Highway Safety Design and Operating Practices", 1973, Federal Highway Administration, USDOT.

# STANDARD ILLUMINATION PLAN SYMBOLS

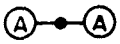

LIGHTING UNIT. LETTER DENOTES THE POLE TYPE, MOUNTING HEIGHT, LENGTH AND TYPE OF BRACKET, AND LUMINAIRE DATA AS PER NOTES.
EXAMPLE :
TYPE A- ALUMINUM POLE WITH 12 FT. BRACKET, 30 FT. MOUNTING HEIGHT, 400 W. MERCURY VAPOR LUMINAIRE - TYPE III.

EXISTING LIGHTING UNIT TO BE REMOVED.

EXISTING LIGHTING UNIT TO REMAIN.


EXISTING LIGHTING UNIT TO BE RELOCATED AS INDICATED ON PLANS.

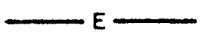
RELOCATED EXISTING LIGHTING UNIT.



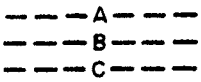

LIGHTING UNIT WITH TWO BRACKETS. LETTER DENOTES POLE TYPE, MOUNTING HEIGHT, LENGTH AND TYPE OF BRACKETS, AND LUMINAIRE DATA AS PER NOTES.


HIGH MAST LIGHTING UNIT. LETTER IDENTIFIES POLE TYPE, HEIGHT, AND LUMINAIRE DATA AS PER NOTES. ARROWS INDICATE LIGHT DISTRIBUTION ARRANGEMENT FOR ORIENTATION OF LUMINAIRES.
EXAMPLE :
TYPE A- WEATHERING STEEL POLE, 80 FT. MOUNTING HEIGHT, SIX 1000 W. TYPE IV METAL HALIDE LUMINAIRES.

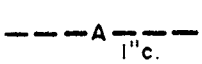
UNDERPASS LUMINAIRE. PROVIDE PERTINENT DATA ON LUMINAIRE TYPE AND MOUNTING HEIGHT.



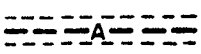

EXISTING UNDERGROUND CONDUCTOR CABLE.




UNDERGROUND CONDUCTOR CABLE TO BE INSTALLED. USE A DIFFERENT LETTER TO IDENTIFY EACH CONDUCTOR TYPE AND SHOW APPLICABLE DATA IN NOTES.




CONDUCTOR IN CONDUIT IN STRUCTURES. IDENTIFY SIZE AND TYPE OF CONDUIT.




CONDUCTOR IN CONDUIT UNDER ROADWAY. IDENTIFY SIZE AND TYPE OF CONDUIT.


JUNCTION BOX. LETTER ABOVE SYMBOL DENOTES TYPE AS PER NOTES.

POLE MOUNTED TRANSFORMER. SHOW APPLICABLE DATA.

PAD MOUNTED TRANSFORMER. SHOW APPLICABLE DATA.

FIGURE 10-F

8. Manufacturers technical literature on poles, brackets, luminaires, lamps and other lighting hardware and equipment.

Other references and guides may be found in publications of the National Cooperative Highway Research Program of the Transportation Research Board, the Federal Highway Administration, and research reports of the Texas Transportation Institute at Texas A & M University. In addition, the lighting equipment manufacturers such as General Electric, Westinghous, McGraw-Edison, and Holophane, publish reports and manuals on various aspects of highway lighting design and equipment.

This chapter is in conformance with FHWA requirements for Federal-aid projects. However, on projects that will be partly financed with Federal-aid funds the designer should consult the latest directives of the Federal Highway Administration pertaining to lighting installations.