DOCUMENT RESUME

ED 089 022 CE 001 062

TITLE	Short Course in Highway Lighting.
INSTITUTION	Federal Highway Administration (DOT), Washington, D.C.
PUB DATE	73
NOTE	67p.
EDRS PRICE	MF-$0.75 HC-$3.15 PLUS POSTAGE
DESCRIPTORS	*Curriculum Guides; Equipment Maintenance; *Illumination Levels; *Lighting Design; Lights; *Outdoor Lighting; Problem Solving; *Technical Occupations
IDENTIFIERS	*Highway Lighting

ABSTRACT

This course guide in highway lighting includes an overview of trends in highway lighting, illustrated information on three light sources for today's luminaires, a reference guide to lamp classification, specifications for highway lighting equipment, and instructions for calculating appropriate use. Maintenance notes on highway illumination and information on luminaire supports and illumination of highway signs are included, as well as class problems in highway lighting design, street lighting, and interchange illumination. Sample calculations, photometric data, isofootcandle and utilization curves, and drawings are provided with answer sheets and sample solutions to problems. The course guide is introduced by a glossary of terms. (AJ)

SHORT COURSE IN HIGHWAY LIGHTING

FEDERAL HIGHWAY ADMINISTRATION

1973

Conducted by
Office of Traffic Operations

THE LANGUAGE OF LIGHTING

NOMENCLATURE

INTRODUCTION

1. CANDELA - (Formerly Candle) The measuring unit of light.
2. CANDLEPOWER - The luminous intensity of a source in a specified direction.
3. FOOT CANDLE - The illumination at a point on a surface.
4. LUMEN - The quantity of light flux falling on a surface.
5. FOOT LAMBERT - A unit of brightness emitted from a surface.

A. RADIATION TERMS

1. LIGHT - Radiant energy traveling in the form of electromagnetic waves which can be visually evaluated. It is transferred by a transverse wave motion at a speed of 186,000 miles per second.
2. WAVE LENGTH - The distance between the two adjacent points of a wave and is measured in angstroms.
3. ANGSTROM - A unit of length equal to one ten-millionth of a millimeter.

B. LIGHTING TERMS

1. CANDELA - The unit of luminous intensity emitted by a light source in a given direction. It is the international basic physical quantity in all measurements of light; all other units are derived from it. The earliest standard actually was a burning candle of specified composition and thus referred to as "International Candle." It is now defined as the luminous intensity of one-sixtieth of one square centimeter of projected area of a blackbody radiator operated at the temperature of solidification of platinum.

2. CANDLE POWER - The luminous intensity of a light source in a single direction expressed in candelas.

   a. Mean horizontal candle power is the average in a horizontal plane.

   b. Mean spherical candle power is the average in all directions around the candle.

3. FOOTCANDLE - The illumination at a point on a surface which is one foot from and perpendicular to a uniform source of one candela.

   a. Average Footcandles (lumens per square) are calculated by dividing the net lumens by the area over which they are distributed. The net being the lumens generated by a source less those absorbed in the luminaire and those dissipated as spill light.

   b. Average Footcandles are measured by averaging the individual footcandle readings taken along the center of each traffic lane at ten foot intervals for the section of highway involved.

   c. Maintained Footcandle values for roadway lighting are determined for conditions when the luminaire is in its dirtiest state and the lamp has reached its life replacement point.

4. LUMEN - The quantity of light falling on a surface one square foot in area, every part of which is one foot from a point source having a luminous intensity of one candela in all directions. (Total lumens from source = 12.57)

5. FOOT LAMBERT - A unit of brightness from a source of one square foot emitting one lumen. The eye sees brightness (foot-lamberts) not illumination (footcandles).

6. INTERRELATION OF LIGHTING TERMS

a. Footcandles = candelas ÷ Distance squared (Known as the inverse square law)

b. Footcandles = Lumens ÷ Area

c. Corrected footcandles = incidence footcandles x cosine θ, where θ is the angle of incidence.

d. Foot lamberts = foot candles x coefficient of reflection (or refraction).

7. LIGHT METER - Instrument for measuring footcandle (incident or corrected).

8. BRIGHTNESS METER - Instrument for measuring foot lamberts.

C. <u>VISUAL TERMS</u>

1. VISABILITY - The quality or state of being preceivable by the eye.

2. VISUAL FIELD - All objects and points in space which can be preceived when head and eyes are kept fixed.

3. VISUAL TASK - Details and objects which must be seen.

4. GLARE - The sensation produced by brightness great enough to cause eye annoyance, discomfort, or visual loss.

a. Direct

b. Reflected

c. Discomfort

d. Disability

5. BRIGHTNESS - Luminance expressed in foot lamberts. (Not to be confused with glare but can produce glare).

D. LIGHT CONTROL TERMS

1. REFLECTION - Light that has had its direction changed by striking a surface.

   a. Specular (from a polished surface).

   b. Diffused (from a matt surface).

2. TRANSMISSION - Light that has passed through a solid or liquid material.

3. REFRACTION - Light that has its direction changed as it passes through solid or liquid material.

4. ABSORPTION - A process by which part of the incoming light is dissipated within the medium. (All light is accounted for by the process of reflection, transmission and absorption.)

TRENDS IN HIGHWAY LIGHTING

INTRODUCTION

During recent years we have witnessed a deepening awareness on the part of many individuals, agencies and organizations with respect to the need for adequate roadway lighting. Together with this awareness has gone the acceptance of new concepts and new methods of providing better quality and uniformity in our lighting installations, to the end that night visibility conditions are improved for both motorists and pedestrians. For roadway lighting applications in general and for highways in particular, the trend has been not so much toward greater levels of illumination, i.e., more footcandles, but rather toward making the lighting more comfortable for those who use the facilities. Concurrent with the trend toward quality illumination there has developed a widespread effort to make lighting poles as safe as possible for instances in which motorists accidentally collide with these appurtenances. Let us look at some of those developments which constitute trends in highway lighting.

QUALITY OF ILLUMINATION

For many years the majority of those responsible for designing and operating our street and highway lighting systems showed little concern for that somewhat elusive and difficult to define characteristic frequently referred to as quality of illumination. The main emphasis was usually placed on how many footcandles - the amount of illumination - were to be provided, with small consideration being given to the manner in which the light was to be controlled and distributed. Fortunately, we now find more attention being directed to the problems of proper light control, minimizing the negative effects of glare and striving for more acceptable uniformity. Horizontal surfaces and the light delivered to them were the basic consideration; now the importance of light on vertical and near-vertical surfaces is widely recognized.

Luminaire distributions as regards vertical light, lateral light and cutoff characteristics are scrutinized more carefully to insure that comfortable seeing conditions will be attained. Luminaire positioning with respect to the roadway receives consideration by designers in their attempts to provide optimum visibility and reduce glare effects. It is now generally agreed that some light on border areas beyond the roadway proper is desirable as a means of widening the visual field and improving the perspective impression of the road ahead. These and other factors contributing to quality lighting are being recognized in the design of our highway lighting systems.

UNIFORMITY OF ILLUMINATION

Prior to 1969 the AASHO criteria for highway lighting design stated that an average to minimum footcandle uniformity ratio up to 6:1 was considered satisfactory for freeways. Recognizing that there is considerable merit in providing better lighting uniformity for all principal streets and highways, AASHO has changed the existing criteria to call for a ratio between 3:1 and 4:1. The trend now is definitely to the better uniformity (lower numerical ratio). In many cases the 3:1 ratio is being used for design purposes rather than uniformity approaching the 4:1 ratio. Also, in some instances uniformity somewhat better than 3:1 has resulted from the necessity of a trade-off between the two parameters of average footcandles and uniformity.

Many engineers and researchers now believe that, in normal situations, lighting uniformity is of equal or perhaps greater importance than the level of illumination. Those who have been forced to drive on streets and highways with poor lighting uniformity know from experience how uncomfortable and visually tiring the alternate light and dark spots can make the night driving task.

Lighting criteria still retain the average to minimum footcandle ratio as a basic design element, but there is an increasing awareness that maximum to minimum ratios are also important and should receive equal consideration in the design process. Some highway departments have minimum footcandle requirements for longitudinal and transverse roadway grid points within a specified roadway area, a procedure which is intended to better assure the desired uniformity results from available equipment.

In keeping with the trend toward better uniformity we find an increasing acceptance and use of greater luminaire mounting heights, particularly for freeway locations. The better uniformities are, in general, more easily attained when higher mountings are employed.

LUMINAIRE MOUNTING HEIGHT

Mounting heights of luminaires have increased substantially during the past decade and the trend has been especially evident during the past five years. It was common practice for many years to use 400 watt mercury luminaires mounted at 30 feet above the roadway to light most of the main streets and highways throughout the country. Now it is fairly common to see these luminaires being installed at 35 and 40 foot heights, particularly on freeways and other heavily traveled facilities. Some highway agencies have established 40 feet as the *minimum* mounting height for all new lighting projects. The larger mercury lamps are normally used at mounting heights of 40 to 50 feet. As we see it, there are at least four advantages which accrue from higher mounting heights: (1) Improved lighting uniformities are more easily attained; (2) Glare may be reduced, provided candlepower values and vertical distributions remain constant; (3) The angle between the luminaire and the line of sight is increased; (4) Longer spacings with fewer poles and luminaires may be possible, thus reducing the number of roadside obstacles.

When we get into the realm of extra high mounting heights, otherwise known as high mast lighting or tower lighting, we note a very definite trend in many locations to this method of lighting highway interchanges. This subject will be discussed later.

LUMINAIRE SIZE

With the trend toward increased mounting heights we find that the larger wattage luminaires are being more widely used, particularly for highway sections having more than a total of 4 lanes. The 1,000 watt mercury luminaire has become proportionally more common in its application. This is a natural development in order to maintain a specified level of illumination under the conditions of higher mounting and greater spacing. Also, in some cases, the larger luminaires are necessary to furnish the increased levels of illumination required on certain urban streets. More widespread use of the high pressure sodium lamps may, with time, change this trend to some degree since considerably more lumens are obtained per unit of electrical energy.

HIGH INTENSITY DISCHARGE LAMPS

The advent of extra high mounted interchange lighting systems has brought with it a trend to the use of the 1,000 watt metal halide lamp for these installations. To develop the great amount of total lumens needed to cover relatively large areas at mounting heights of 100 to 175 feet a light source of high efficiency is needed. The metal halide lamp provides this better efficiency, with the added features of good color rendition and facility of light control when used in existing luminaires. The low wattage metal halide lamps may find application for sign illumination, where color rendition and light control are desirable attributes. While longer lamp life and some improvement in lumen maintenance would enhance the value of these lamps for street and highway applications, they nevertheless present features which make them worth considering for some situations.

Recently we have been witnessing a limited trend to the high pressure sodium lamp. So far the trend has been more pronounced at the city level, and State highway departments as a group have done relatively little with sodium. The Utah State Highway Department has made extensive use of sodium for freeways in the Salt Lake City area. The Illinois Division of Highways recently made a study of sodium application and are planning to use it for some projects now in the design stage. We are aware of one fairly large project in Alabama where the highway department intends to install sodium equipment. In regard to toll facilities there are extensive sodium lighting installations now in service on the Dallas North Toll Way and on the recently relighted San Francisco-Oakland Bay Bridge.

In the District of Columbia, sodium lighting is being used extensively, largely for converting and upgrading the existing mercury street lighting. Much of the effort here is directed toward reduction in the night crime rate and, in some locations, to improved traffic safety. Among other places, sodium has been widely used in Kansas City, Missouri, New York City, Baltimore and Cleveland.

Recent introduction of the 1,000 watt high pressure sodium lamp opens up possible applications for this large 130,000 lumen source. At this time it is probably premature to attempt a prediction of the extent to which this lamp will be used for roadway lighting. It is obvious, however, that the great amount of light produced by the lamp is a factor which will receive consideration for high mast interchange lighting and for other wide multi-lane facilities where very high mountings may be appropriate.

LUMINAIRE LIGHT CONTROL

In the discussion of Quality Illumination, mention was made of the fact that considerable attention is now given to proper light control and minimizing the negative effects of glare. The design features of the luminaire are of prime importance in attaining these objectives. Luminaire manufacturers accordingly devote much time and money to the many details necessary in arriving at a product to meet stringent photometric needs. The trend in luminaire design and construction continues to emphasize attention to those details which make modern light control components rather complex in their technical features.

HIGH MAST LIGHTING

The idea of using very tall structures to mount a cluster of luminaires has gained considerable acceptance by highway agencies for lighting interchanges. Consideration is also being given to the possibilities of using this method for continuously lighting highways having wide cross sections with a large number of traffic lanes. At this time it can safely be said that there exists a definite trend to high mast lighting. Information reaching us indicates that more than 50 installations are either in operation, under contract or in design stages in the United States. High mast has been used quite extensively in some parts of Europe for over ten years.

High mast lighting, also referred to as tower lighting, usually implies an area type of lighting with groups of luminaires mounted on free standing poles or reinforced towers at mounting heights of 100 feet or more. Some installations have used 150 foot mountings and at this time it appears that a range of 120 to 150 feet will become generally utilized. The deciding factor is principally one of economics, which, with presently available equipment, indicates that 150 feet is regarded as a practical limit.

Two types of luminaires have been used, namely, floodlights and conventional type roadway luminaires, in some cases modified slightly to adapt them for high mounted application. The roadway type luminaires are broken down into those which provide a symmetric or Type V light distribution and those delivering asymmetric distribution. At the present time the majority of existing installations utilize the roadway type luminaires. The 1,000 watt metal halide lamp has been normally used in the roadway luminaires, while 1,000 watt mercury lamps are ordinarily used in floodlights.

A number of developments have contributed to the successful application of high mast lighting. Among these are: (1) Improvements in the 1,000 watt metal halide lamps. (2) Availability of both symmetric and asymmetric roadway type luminaires. (3) Free standing poles, which are generally considered to be more aesthetic than other types of supporting structures. (4) Use of weathering steel poles. (5) Development of luminaire maintenance aids, consisting of mechanical lowering devices or elevator-type service cars. (6) Availability of better lighting design procedures.

The question has been asked as to whether any adjustment in prevailing recommended levels and uniformity of illumination may be acceptable when high mast lighting is employed. In the opinion of the writer, an answer cannot be given in terms of specific values which may or may not depart from criteria now contained in the American Standard Practice and the AASHO Lighting Guide. It should be noted that the draft of the proposed revision of the 1963 American Standard Practice provides no reduction in recommended minimum criteria for lighting levels when high mast systems are used. Appreciable differences exist in the amount of illumination prevailing at some of the installations now operating. The range seems to run from a low of about .3 average footcandle to a high of about .8 average footcandles. Some validity may be given to the theory that when excellent uniformity exists - which is frequently the case with high mast lighting - a reduction in average illumination may still give equivalent visibility. The fact that high mast lighting provides an expanded field of view and improved lighting on vertical and near-vertical surfaces may also contribute to satisfactory results with somewhat lower lighting levels. On the other hand, such factors as the complexity of the interchange, the existence of high brightness from extraneous competing light sources near the highway and the prevailing level of illumination on connecting roadways must be recognized in a rationalization of the lighting needs. In this connection, some reduction of lighting levels may be satisfactory in the case of a simple diamond rural interchange, whereas, the same philosophy may be inappropriate at a more complicated urban interchange location. To summarize, it would seem to be a dangerous premise to assume at this stage that lighting levels can automatically be reduced when high mast lighting is used. Until more experience has been gained we feel that a reduction in the normally recommended lighting values would not be in order.

We realize that high mast lighting is still in its infancy and that improvements may be expected in some equipment now being used. Our impression is that too much of the available light in many cases is now being delivered to areas within the interchange which are of secondary importance. The emphasis still should be on those areas on or close to the traveled way, where the seeing needs are most critical. It seems to be well within the realm of possibility to expect that, with further study and refinement, the ability of our lighting equipment to distribute light more efficiently to the areas of greatest concern will be substantially improved.

SIGN LIGHTING

There appears to be general agreement that overhead signs should normally have supplementary illumination for optimum effectiveness at night. For many years the accepted method of lighting was with fluorescent lamps and luminaires. The trend in many States now is to use the smaller and more compact mercury lamp for externally lighted signs. Specially designed mercury luminaires for this application are now available and are finding increased acceptance. Longer lamp life, good lamp lumen maintenance, freedom from changes in light output with variation of ambient temperature and accurate control of light output are factors favoring the mercury source. In addition, fluorescent luminaires are physically much larger and generally more difficult to maintain. While some State highway departments still continue to use fluorescent equipment we have observed a steady trend to mercury on the part of a great many States. Barring unforseen circumstances, we anticipate that the swing to mercury sign lighting will continue.

ROADSIDE SAFETY

The strong emphasis which has been placed on the "clear roadside" and "forgiving roadside" concepts as related to safety on high speed highways has found expression in a number of ways. Several concepts have been used, one of which is to minimize the number of poles being used and to locate them transversely as far away as possible from the traveled roadway usually a minimum of 30 feet. Where circumstances necessitate placing poles in exposed locations some form of "breakaway" feature is incorporated in the base portion of the pole to reduce the severity of a vehicular collision. Greater mounting heights and larger luminaires have permitted longer pole spacings, hence, less obstacles along the highway. High mast lighting, of course, makes it possible to largely do away with the pole hazard at interchange locations by virtue of the remote pole placement with respect to the roadway. Roadside safety is no longer just a trend; instead, it is now an essential part of the highway program in each State.

CONCLUSION

The foregoing are some of the more important trends which seem to give evidence of becoming accepted practice with the coming years. It would be ridiculous to assume, however, that these trends will not change as new methods are devised to meet the changing needs of night travel on our streets and highways. If past experience is a good basis for judging the future, highway lighting as we know it today will likely be regarded as obsolete by the end of this century.

Light Sources

The subject of Light Sources is pleasingly simplified when limited to the street and highway lighting field because of the relatively few types that are applicable. There are roughly 10,000 different types of lamps manufacturered while only three of these are generally used for highway illumination. These three, mercury vapor, metal halide, and high pressure sodium, are grouped as H.I.D. lamps - high intensity discharge. A brief description of these lamps is given in the attached article "Three Light Sources for Today's Luminaires," and their main characteristics are listed on the "Lamp Information" sheet.

The clear mercury vapor lamp produces light predominately in the blue-green section of the spectrum. It is used for street and highway lighting with mounting heights up to 50 feet, underpass lighting, some tunnel lighting and sign lighting where color is not a factor. When color rendition is important the phosphor lamp should be used. For example, the red of the Interstate shield will appear as dark brown under clear mercury. The phosphor coating will change the light pattern and should be taken into consideration with design work.

The mercury lamp requires a ballast which is designed for the proper size lamp and lowest ambient temperature under which the lamp will be required to operate. The ballast is normally part of the luminaire but can be remotely located. If there is a possibility of converting a mercury system to metal halide at a later time, consideration should be given to the use of a ballast for the halide lamp. The mercury lamp will operate on a halide lamp ballast but not the reverse. The light output of a mercury lamp will normally fall below an economical operating value long before it fails to operate at all.

The metal halide lamp has trade names of metallic additive, multi-vapor and metalarc. This lamp can be used to replace a mercury lamp in the same luminaire with a ballast change to produce 70 percent more light. It will not start on a mercury ballast but the mercury lamp will operate on a halide ballast. The color value of the lamp is good and phosphor is not required. There are two versions of the lamp, one designed for base-down operation and the other for base-up operation. The proper positioned lamp must be used for satisfactory use. The halide lamp is especially good for use with high mast installations and sign lighting.

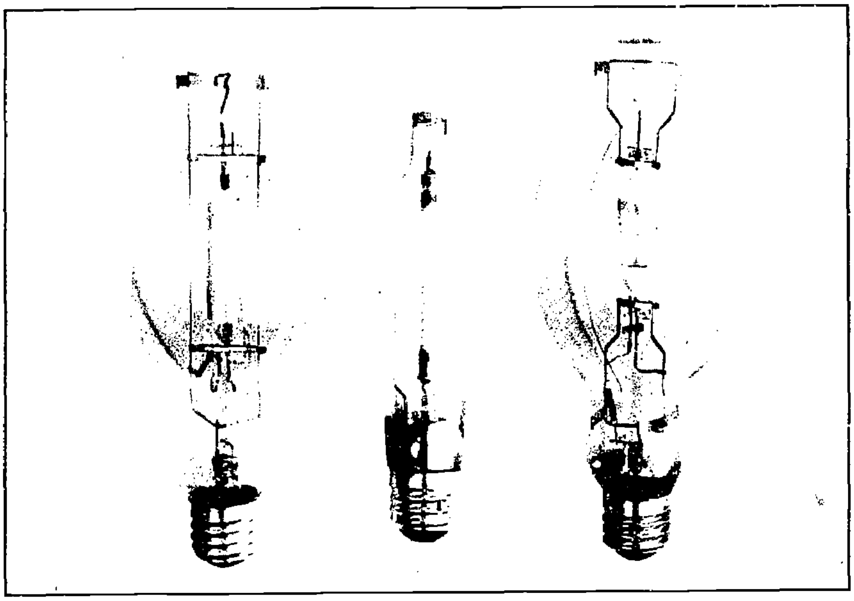
The high pressure sodium lamp emits light across the spectrum with a predominance in the orance-yellow region. The trade designations for the H.P.S. lamp are Lucalox and Ceramalux. It is the most efficient of the three H.I.D. sources and, in general, is suited for any of the uses applicable to the other two lamps. The visibility when used on signs is good but the color is not complimentary on the standard green sign. It is not recommended for this use. The lamp requires a ballast and special device to produce a very high voltage surge for starting. The ballast can be remotely located but the starter must be within 10 feet of the lamp. The high pressure sodium lamp usually cycles at the end of the normal life and should be checked before looking for other troubles.

The filament (incandescent) lamp is used for traffic signals but has almost been discontinued for street and highway service.

The fluorescent lamp is still used for tunnel and low rail lighting but not for street and highway lighting except in rare cases. Some agencies still use fluorescent lamps for sign lighting.

New sources and sizes of lamps are under test and expected to be announced soon. Among these are the 1000 watt high pressure sodium lamp and a new manufacture of the 400 watt high pressure sodium lamp.

Three Light Sources for Today's Luminaires



Left to right: mercury vapor, high pressure sodium, metallic additive lamps.

Installing a mercury vapor lamp.

In response to a number of questions relative to today's light sources, Clyde Gardner, Promotion and Application Manager of Lighting at the Central Plant, South Milwaukee has provided descriptions of the three primary sources used in today's luminaires.

Today's levels of brightness in lighting are higher than those in the good old days and permit daylight activities to be extended in an improved environment whether it is on a street or in a park. This improvement in lighting has developed through notable advances in illumination, light sources, and manufacturing technique.

In the old days, light sources were inefficient and dim. The incadescent lamp was the major source of artificial light producing an average of 15 lumens per watt and an average burning life of 1000 hours. A few years ago one of the most common street lights, for lighting major downtown streets, utilized a 405 watt bulb which produced 6000 lumens illumination.

Today, people are demanding more of everything. This includes more lighting. To produce more outdoor light at an economic level that is palatable to the general public, three major light sources are used. These are mercury vapor, metallic additive and high-pressure sodium lamps.

Mercury vapor lamps were introduced in the 1930's but did not become a significant light source until the early 1950's. Even though mercury vapor lamps are very efficient--having an efficacy of 55 lumens per watt and a rated burning life of 24,000 hours--many people were reluctant to use them. The color spectrum produced by this light source caused fingernals to appear purple and made it difficult to distinguish colors such as those of automobiles parked on the streets and in parking lots.

As the development of this light source progressed, phosphor coatings were developed. When these coatings are applied to the lamp envelope, color distortions almost disappear and a more natural color rendition is prevalent. These lamps available in 50, 75, 100, 175, 250, 400, 700 and 1000 watt sizes.

Metallic additive lamps were developed as a result of the need for still more efficient light sources. Attempts are made to obtain true color spectrums from light sources. Metallic additive lamps approach this, consequently, this is excellent as a light source for filming color television.

This lamp has an efficacy of 80-90 lumens per watt and is available in 175, 400 and 1000 watt sizes. Since this lamp is still in its infancy, it has a rated burnng life of 7500 hours.

The third, and perhaps most significant of the three high intensity discharge lamps, is the high pressure sodium lamp. This light source produces a golden color very similar to that produced by incandescent lamps. There has been a preference for the golden color of the incandessent lamp ever since Thomas Edison invented it. Consequently, the high pressure sodium source should prove to be acceptable. While this light source was not introduced in this country until the mid 1060's, it has been utilized for a number of years in Europe.

This lamp is currently available in 250 and 400 watt sizes and has an efficacy of 100 and 115 lumens per watt, respectively. This light source is also considered to be in its infancy. It currently has a rated burning life of 10,000 hours.

Since these are high intensity discharge lamps, ballasts are required for their operation. In the mercury vapor lamp, the ballast maintains the proper starting voltage and limits the current to the lamp.

The metallic additive lamp is similar to mercury vapor lamp but has a halogen additive in the arc tube. Therefore, a higher RMS voltage is required. It is possible to operate a mercury vapor lamp on a metallic additive lamp ballast but at the present time, lamp design does not allow the opposite combination.

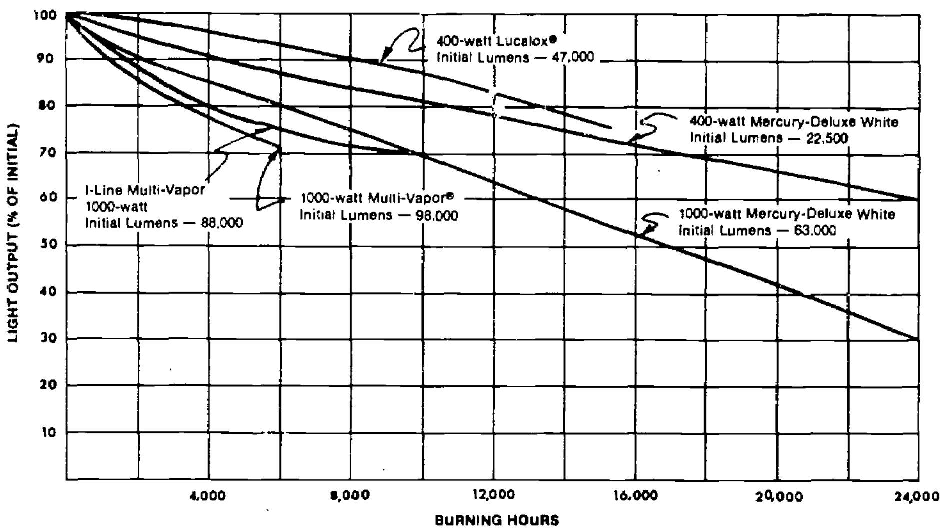
Due to the length of the arc tube in high pressure sodium lamps, a voltage pulse between 2500 and 4000 volts is required for starting the lamp. A solid state starting circuit is used to provide this pulse. After the lamp is started the ballast operates similar to a mercury vapor ballast.

Coordination of light source and luminaire produce improved downtown illumination for South Milwaukee, Wisconsin.

HIGH-INTENSITY DISCHARGE LAMP CHARACTERISTICS

(For More Detailed Information, Refer to OLP-1296 or GEA-9666)

HID LAMP LUMEN DEPRECIATION (VERTICAL OPERATION)



HID LAMP COMPARATIVE DATA

Based on Lamp Manufacturer's Published Data††	Mercury	Metal Halide‡ ▼	Lucalox ▼
Approximate Lumens per watt	42 — 63	76 — 102	102 — 130
Rated Life—(10 hours/start)			
100-175 watt	24,000+ hrs.	....	....
250-watt	24,000+ hrs.	....	15,000 hrs.
400-watt	24,000+ hrs.	8,000 hrs. 15,000□ hrs.	15,000 hrs. ....
1000-watt	24,000+ hrs	6,000 hrs. 10,000□ hrs.	10,000 hrs ....
1500-watt	2,000▽ hrs	1,500 hrs. (at 5 hrs. per start)	....
Warm-up time — minutes (Time from energize to 80% light output)	5 — 7	3 — 5	3 — 4
Re-start time — minutes (Time for lamp to re-ignite after it has been extinguished)	3 — 6	10 — 15	1 min.

†† Above data was current at time of bulletin publication.
‡ Values vary between manufacturers.
▽ 1000-watt Mercury Lamp operated at 1500-watts.
▼ Check lamp position in luminaire specifications — Base up or base down — and specify correct lamp.
□ I-Line Multi-Vapor lamp.

HID Re-strike Characteristics

All HID lamps will deionize when there is a power interruption or if the lamp socket voltage drops below the amount required to sustain the arc for more than a few cycles. Because it takes greater voltage to ionize the arc tube vapors while they are hot and under higher pressure, the lamp will not re-start immediately. Thus a period of time is required for the arc tube to cool down and internal pressure to drop sufficiently to permit the arc to restrike and warm up to full output again. Because Lucalox ballasts produce a starting pulse when there is no lamp current, Lucalox re-strike time is shorter than for mercury and metal halide lamps.

LAMP INFORMATION

ALL LAMP INFORMATION PRINTED HERE IS SUBJECT TO CHANGE. LAMP PRICES ARE FOR ESTIMATING PURPOSES ONLY. FOR EXACT LAMP PRICES FOR YOUR APPLICATION, CONSULT YOUR LARGE LAMP DEPARTMENT REPRESENTATIVE.

MERCURY LAMP DATA — BONUS LINE

GE Ordering Abbreviation	ASA Code	Finish	Light Center Length Inches	VERTICAL					HORIZONTAL					List Price Each
				Initial Lumens	Light Output Factor		Suggested[a] Maintenance Factor		Initial Lumens	Light Output Factor		Suggested[a] Maintenance Factor		
					Mean Factor	End of Relamping Period Factor	Mean Factor	End of Relamping Period Factor		Mean Factor	End of Relamping Period Factor	Mean Factor	End of Relamping Period Factor	
100-Watt—Life 24,000+ hours—Mogul Base														
H100A38-4 H100DX38-4	H38-4HT H38-4JA/DX	Clear Deluxe white	5 5	3850 4200	0.81[y] 0.84[y]	0.64[y] 0.70[y]	0.73 0.76	0.58 0.63	3650 4000	0.77[y] 0.79[y]	0.57[y] 0.61[y]	0.69 0.71	0.51 0.55	**10.10** **11.00**
175-Watt—Life 24,000+ hours—Mogul Base														
H175A39-22 H175DX39-22	H39-22KB H39-22KC/DX	Clear Deluxe white	5 5	7450 8150	0.92[y] 0.86[y]	0.85[y] 0.74[y]	0.83 0.77	0.77 0.67	7100 7750	0.88[y] 0.82[y]	0.77[y] 0.68[y]	0.79 0.74	0.69 0.61	**8.00** **8.85**
250-Watt—Life 24,000+ hours—Mogul Base														
H250A37-5 H250DX37-5	H37-5KB H37-5KC/DX	Clear Deluxe white	5 5	11,200 12,100	0.92[y] 0.86[y]	0.85[y] 0.74[y]	0.83 0.77	0.77 0.67	10,700 11,500	0.88[y] 0.82[y]	0.77[y] 0.68[y]	0.79 0.74	0.69 0.61	**13.20** **14.95**
400-Watt—Life 24,000+ hours—Mogul Base														
H400A33-1 H400DX33-1	H33-1CD H33-1GL/DX	Clear Deluxe white	7 7	21,000 22,500	0.91[y] 0.85[y]	0.83[y] 0.72[y]	0.82 0.77	0.75 0.65	20,000 21,500	0.87[y] 0.80[y]	0.75[y] 0.63[y]	0.78 0.72	0.68 0.57	**10.50** **12.00**
700-Watt—Life 24,000+ hours—Mogul Base														
H770A35-18 H700DX35-18	H35-18NA H35-18ND/DX	Clear Deluxe white	9½ 9½	39,000 42,000	0.89[y] 0.80[y]	0.79[y] 0.63[y]	0.80 0.72	0.71 0.57	36,500 39,500	0.85[y] 0.75[y]	0.72[y] 0.54[y]	0.77 0.68	0.65 0.49	**24.40** **26.60**
1000-Watt—Life 24,000+ hours—Mogul Base														
H1000A36-15 H1000DX36-15	H36-15GV H36-15GW/DX	Clear Deluxe white	9⅜ 9⅜	57,000 63,000	0.85[y] 0.75[y]	0.72[y] 0.54[y]	0.77 0.68	0.65 0.49	54,000 60,000	0.85[y] 0.80[y]	0.72[y] 0.63[y]	0.77 0.72	0.65 0.57	**21.05** **23.65**
1500-Watt Operation (h) of 1000 watt lamps—2,000 hour life														
H1000A36-15 H1000DX36-15	H36-15GV H36-15GW/DX	Clear Deluxe white	9½ 9½	85,500[h] 87,000[h]	0.85[v] 0.75[v]	0.67[v] 0.57[v]	0.77 0.68	0.60 0.51	(c) (c)	(c) (c)	(c) (c)	(c) (c)	(c) (c)	**21.05** **23.65**

LUCALOX® LAMP DATA

GE Ordering Abbreviation	ASA Code	Finish	Light Center Length Inches	VERTICAL					HORIZONTAL					Life	List Price Each
				Initial Lumens	Light Output Factor		Suggested[a] Maintenance Factor		Initial Lumens	Light Output Factor		Suggested[a] Maintenance Factor			
					Mean Factor	End of Relamping Period Factor	Mean Factor	End of Relamping Period Factor		Mean Factor	End of Relamping Period Factor	Mean Factor	End of Relamping Period Factor		
250-WATT — LUCALOX															
LU-250/BU[w] LU-250/BD[w]	(c)	Clear	5¾	25,500	0.91[b]	0.77[b]	0.82	0.69	25,500	0.91[b]	0.80[b]	0.82	0.72	15,000 hrs. 10 hrs/ Start	**53.00**
400-WATT — LUCALOX															
LU-400/BU[w] LU-400/BD[w]	(c)	Clear	5¾	47,000	0.90[b]	0.77[b]	0.81	0.69	47,000	0.90[b]	0.77[b]	0.81	0.69	15,000 hrs. 10 hrs/ Start	**55.00**
LU-400/BU[w] LU-400/BD[w]	(c)	Clear	5¾	47,000	0.90[u]	0.77[u]	0.81	0.69	47,000	0.90[u]	0.77[u]	0.81	0.69	20,000 hrs./ Continuous Burning	**55.00**
1000-WATT — LUCALOX															
LU-1000/BU[w] LU-1000/BD[w]	(c)	Clear	8¾	130,000	0.92[J]	0.85[J]	0.83	0.77	130,000	0.92[J]	0.85[J]	0.83	0.77	10,000 hrs. 10 hrs./ Start	**125.00**

MULTI-VAPOR® LAMP DATA

400-WATT: MV400/BU/I, MV400/BD/I > 15,000 Hours Life (10 burning hours per start).
MV400/HV/E = 8000 Hours Life (10 burning hours per start). 20,000 Hours Life (continuous burning).

1000-WATT: MV1000/BU/I = 10,000 Hours Life (10 burning hours per start).
MV1000/HBU/E, MV1000/HBD/E > 6000 Hours Life (10 burning hours per start).

GE Ordering Abbreviation	ASA Code	Finish	Light Center Length Inches	VERTICAL Initial Lumens	Vertical Light Output Factor Mean Factor	Vertical Light Output Factor End of Relamping Period Factor	Vertical Suggested Maintenance Factor[a] Mean Factor	Vertical Suggested Maintenance Factor[a] End of Relamping Period Factor	HORIZONTAL Initial Lumens	Horizontal Light Output Factor Mean Factor	Horizontal Light Output Factor End of Relamping Period Factor	Horizontal Suggested Maintenance Factor[a] Mean Factor	Horizontal Suggested Maintenance Factor[a] End of Relamping Period Factor	Life	List Price Each
400-WATT — MULTI-VAPOR															
MV400/BU/I‡	(c)	Clear	7	34,000	0.78[b]	0.60[b]	0.70	0.54						See 400W above	**26.80**
MV400/BD/I‡	(c)	Clear	7	34,000	0.78[b]	0.60[b]	0.70	0.54							**26.80**
MV-400/HV/E*	(c)	Clear	7	32,000	0.79[s]	0.65[s]	0.71	0.59	30,500	0.79[s]	0.65[s]	0.71	0.59		**26.80**
1000-WATT — MULTI-VAPOR															
MV1000/BU/I‡	(c)	Clear	9⅜	88,000	0.80[j]	0.70[j]	0.72	0.63						See 1000W above	**59.50**
MV-1000/HBU/EΔ*	(c)	Clear	9⅜	98,000	0.83[z]	0.70[z]	0.75	0.63	85,500	0.83[z]	0.70[z]	0.75	0.63		**59.50**
MV-1000/HBD/EΔ*	(c)	Clear	9⅜	98,000	0.83[z]	0.70[z]	0.75	0.63	85,500	0.83[z]	0.70[z]	0.75	0.63		**59.50**
1500-WATT — MULTI-VAPOR															
MV-1500/HBU/EΔ*	(c)	Clear	9⅜	153,000	0.93[x]	0.87[x]	0.84	0.78	132,000	0.93[x]	0.87[x]	0.84	0.78	1500 hrs. 5 or More hrs./Start	**65.00**
MV-1500/HBD/EΔ*	(c)	Clear	9⅜	153,000	0.93[x]	0.87[x]	0.84	0.78	132,000	0.93[x]	0.87[x]	0.84	0.78		**65.00**

MULTIPLE FILAMENT LAMP DATA (120V EXCEPT AS NOTED)

Rated Watts	Bulbs	Lamp Ordering Abbreviation	Light Center Length	Max. Overall Length	Filament	Base	Burning Position	Life Hours	Initial Lumens	Mean Lumens	End of Life Lumens	Suggested Factor[a] Maintenance Based on Mean Lumens	Maintenance Based on End of Life Lumens	List Price Each
500	PS-40	500/RS	7	9-3/4	C-9	Mog.	Any	1000	9400[m]	8350[m]	7426[m]	0.80	0.71	**2.10**
500	G-40	500G/FL	4-1/4	7-1/16	C-5	Mog.	BDH	800	9300	8370	7560	0.81	0.73	**5.40**
500	T3	Q500T3/CL[r]	2-1/4	4-11/16	C-8	RSC	Horiz.	2000	10,950	10,600	10,293	0.87	0.85	**10.90**
1000	PS-52	1000/7	9-1/2	13	C-7A	Mog.	Any	1000	21,600[m]	18,400[m]	15,700[m]	0.77	0.65	**3.85**
1000	G-40	1M/G40FL	5-1/4	7-1/8	C-5	Mog.	BDH	800	20,000	17,000	14,500	0.77	0.65	**14.00**
1500	PS-52	1500	9-1/2	13	C-7A	Mog.	Any	1000	34,400	28,900	24,200	0.75	0.63	**5.50**
		1500	9-1/2	13	C-7A	Mog.	Any	300[k]	47,470[k]	40,250[k]	34,300[k]	0.75	0.62	**5.50**
1500	G-48	1500G48/6	5-1/4	8-9/16	C-5	Mog.	BDH	800	32,200	26,600[m]	19,600[m]	0.71	0.52	**27.50**
1500	T3	Q1500T3/CL(240V)[p]	6-3/4[i]	10-1/16	C-8	RSC	Horiz.	2000	35,800	34,200	33,650	0.87	0.84	**15.70**

FLUORESCENT LAMP DATA — RECESSED DOUBLE CONTACT BASE

GE Ordering Abbreviation	Nominal Length Feet	Lamp Current Amperes	(e) Rated Life Hours	Nominal Lamp Watts	(d) Rated Initial Lumens	Light Output Factor (g) Mean Factor	Light Output Factor End of Relamping Period Factor	Suggested Maintenance Factors[a] Mean Factor	Suggested Maintenance Factors[a] End of Relamping Period Factor	List Price Each
F48T12/CW/HO	4	1.0	12,000	70	4700	0.77	0.62	0.69	0.56	**$2.90**
	4	0.8	17,000	60	4300	0.85	0.76	0.77	0.68	
F72T12/CW/HO	6	1.0	12,000	98	7350	0.77	0.62	0.69	0.56	**3.30**
	6	0.8	17,000	85	6650	0.85	0.76	0.77	0.68	
F96T12/CW/HO	8	1.0	12,000	130	10,000	0.83	0.70	0.75	0.63	**2.95**
	8	0.8	17,000	110	9200	0.85	0.76	0.77	0.68	
F48PG17/CW	4	1.5	12,500	110	7000	0.76	0.60	0.68	0.54	**5.85**
F72PG17/CW	6	1.5	12,500	160	11,500	0.76	0.60	0.68	0.54	**6.25**
F96PG17/CW	8	1.5	12,500	215	16,000	0.76	0.60	0.68	0.54	**6.45**
F96T12/CW/1500	8	1.5	12,500	215	14,500	0.78	0.64	0.70	0.57	**5.85**
F48T10J/CW	4	1.5	10,500	105	5900[n]	0.77	0.60	0.69	0.54	**8.85**
F72T10J/CW	6	1.5	10,500	150	9400[n]	0.77	0.60	0.69	0.54	**9.90**
F96T10J/CW	8	1.5	10,500	205	12,900[n]	0.77	0.60	0.69	0.54	**9.70**

a Maintenance factor = (Light Output Factor) x 0.9 where 0.9 is suggested "dirt factor" for an enclosed, filtered, luminaire utilized in a system which enjoys a regular cleaning program. "End of Relamping Period Factor" recommended for use in roadway lighting calculations. "Mean Factor" recommended for use in most other cases.

b Group "relamping period" assumed to be 15,000 hours and "mean factor" computed for 15,000 hour period.

c Information not available on current design at time of printing.

d Light output data for High Output and Power Groove apply for bare-lamp operation with 77°F ambient temperature, still air. Data for All-Weather lamps (T-10J) are maximum values. On all fluorescent lamps, refer to photometric data to obtain correction factors for other ambient temperatures.

e 12 hours per start.

g Equivalent to lumen output factor at 40% of relamping period. Relamping period assumed to be at 80% of rated life.

h Ratings at 45° Base Down and 2000-hour life.

i Approximate lighted length.

j Group "relamping period" assumed to be 10,000 hours and "mean factor" computed for 10,000 hour period.

k Operation at 10% above rated voltage. Actual watts consumed: 1755.

m Estimated, actual data not available.

n Peak values.

r Also available in 130-volt rating. However, initial lumens are 10,350.

p Also available in 208 and 220 volt rating (35800 Lumens) and 277 volts (34400 Lumens).

s Group "relamping period" assumed to be 8000 hours and "mean factor" computed for 8000 hour period.

u Group "relamping period" assumed to be 20,000 hours and "mean factor" computed for 20,000 hour period.

v Group "relamping period" assumed to be 2000 hours and "mean factor" computed for 2000 hour period.

w BU=Base up to horizontal.
BD=Base down to horizontal.

x Group "relamping period" assumed to be 1500 hours and "mean factor" computed for 1500 hour period.

y Group "relamping period" assumed to be 16,000 hours and "mean factor" computed for 16,000 hour period.

z Group "relamping period" assumed to be 6000 hours and "mean factor" computed for 6000 hour period.

* This lamp is to be used in an enclosed fixture only.

‡ BU=Vertical base-up to 15° of VBU.
BD=Vertical base down to 15° of VBD.

Δ HBU=Base-up to 15° below horizontal.
HBD=Base-down to base 15° above horizontal.

BDH Base Down Horizontal.

All data subject to change without notice. Consult your local Lamp Department representative for latest information.

TYPICAL LIGHT SOURCES
(FOR HIGHWAY LIGHTING)

LAMP	HOURS LIFE	MF	LUMENS	COST
400 W. CL. MERCURY	24,000	70	20,000	6.00
1000 W. CL. MERCURY	24,000	63	54,000	12.00
400 W. HALIDE	10,000	60	32,000	15.00
1000 W. HALIDE	10,000	63	95,000	33.00
400 W. HP SODIUM	15,000	69	47,000	30.00
1000 W. HP SODIUM	8,000	85	130,000	69.00

MF - MAINTENANCE FACTOR AT RELAMPING (LLD & LDD)

COST - CONTRACTORS PRICE (NOT LIST) SEPT. 1972

Outdoor lighting application data and sample calculations

WHAT IS A LUMINAIRE?

A luminaire is a complete lighting unit consisting of a lamp, or lamps, together with those components designed to distribute light, to position and protect the lamps, and to connect the lamps to the necessary power supply.

A luminaire can be likened to a garden-hose nozzle. Lumens "squirt" out of it in a beam spread determined by the nozzle design and adjustment. The candlepower is analogous to the water pressure in that it is the force that gives motion to the lumens. Neither all the lumens nor all the water reaches the area at which the luminaire or nozzle is directed. In Figure 1, utilization factor of the water is determined by dividing the quantity of water entering the barrel by the total gallons in the main portion of the stream for any given length of time. Likewise, the utilization factor of a luminaire installation is:

$$UF = \frac{\text{USEFUL LUMENS}}{\text{BEAM LUMENS}}$$

In luminaire types other than floodlights, UF is usually expressed as a ratio of utilized lumens to generated lumens.

After the nozzle becomes old and corroded, the friction loss increases and a smaller quantity of water can pass through, for a given pressure, because of these losses. In lighting, the factor used to compensate for losses due to reduced lamp output and dirt collection is known as the maintenance factor.

The density of water collected over the area of the barrel bottom can be measured in gallons per square foot. In a like manner, light can be measured in lumens per square foot. One lumen per square foot is equivalent to one footcandle.

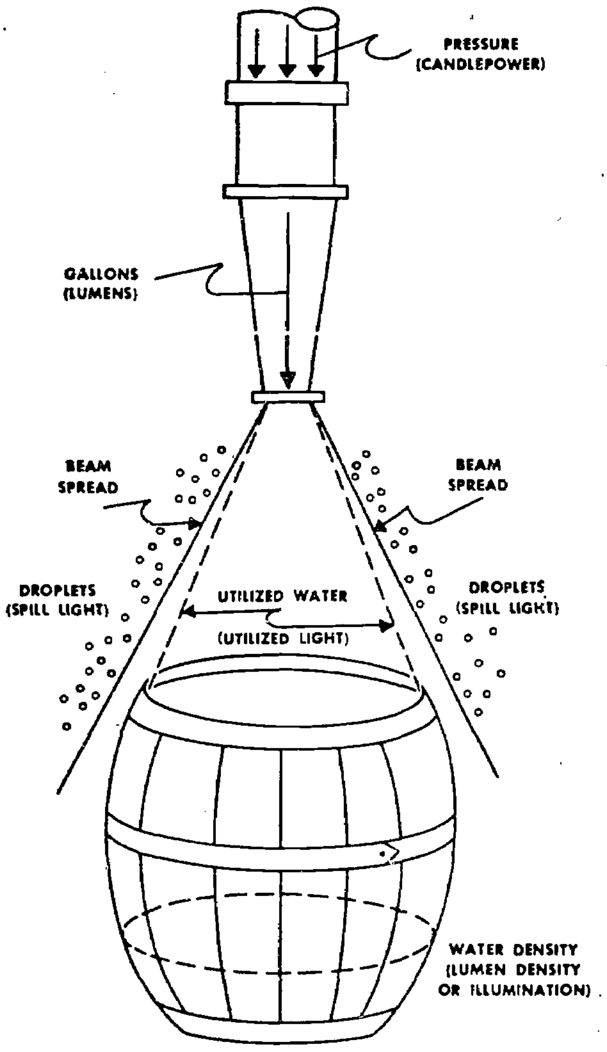


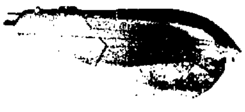
Figure 1. Luminaire-Nozzle Analogy

ANALOGY	
Nozzle	**Luminaire**
Nozzle	Luminaire
Gallons/Min.	Lumens
Pressure	Candlepower
Beam Spread	Beam Spread
Droplets	Spill Light
Utilized Water	Utilized Light
Water Density	Lumen Density (illumination)

M-400 LUMINAIRE

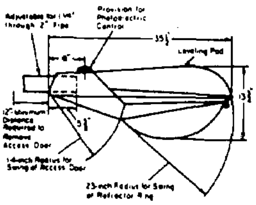
WHERE TO USE

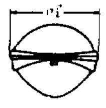
- Traffic streets
- Business streets
- Highways
- Industrial plants
- Parking lots



M-400 luminaire

DIMENSIONS





M-400 luminaire

ACCESSORIES

External Shield—
Cat. No. 35-962490-36, external shield for use with M-400 luminaires

REFRACTORS

Refractor	Cat. No.
Lexan	35-130015-02
Self-shielded (2-way)	35-130559-03

FEATURES

• **Ease of installation**—Adjustable two-bolt slip-fitter for quicker installation, capable of accepting 1¼ through 2-inch standard pipe size; drop-down access door makes wiring connections easy; ballast components pre-wired to terminal board.

• **Choice of light distributions** — Lamp socket adjustable for variety of settings for clear and phosphor coated mercury.

• **Maintenance ease**—Refractor door latch large and easy to open while wearing lineman's gloves. Refractor easily removed without tools.

• **Long life** — Durable precision die-cast aluminum housing; Alzak† finished reflector; optical assembly well gasketed for integrity of refractor-to-reflector and socket seal.

[illegible]

ORDERING INFORMATION (Prices, see GEA-9666)

Watts	BALLAST§ Volts	Type	Lamp□ (Not Included)	Luminaire Cat. No. (less lamp)▼ [illegible]	[illegible]	Approx. Net Wt. lbs.
400	120×240††	Mercury (Regulator)	H33	[illegible]	[illegible]	40
	208	Mercury (Regulator)	H33	[illegible]	[illegible]	40
	277	Mercury (Regulator)	H33	[illegible]	[illegible]	40
	240×480‡	Mercury (Regulator)	H33	[illegible]	[illegible]	40
	240	Mercury (Reactor (NPF))	H33	[illegible]	[illegible]	37
	240	Mercury (Reactor (HPF))	H33	[illegible]	[illegible]	38
	120	Mercury (Lag)	H33	[illegible]	[illegible]	39
		Externally Mounted	H33	[illegible]	[illegible]	30

§ For ballast electrical data, see pages 42-43.

†† Dual voltage ballasts rated 120 × 240-volts are factory-wired for 120-volt operation of ballast (and photoelectric control where applicable). These units can easily be converted to 240-volt operation in the field.

‡ Dual voltage ballasts rated 240 × 480-volts are factory-wired for 480-volt operation of ballast. These can be easily converted to 240-volt operation in the field.

▽400-watt reactor ballasts shown are factory-wired for 3-wire, 120/240-volt supply. 120-volts to photoelectric control and 240-volts to ballast.

▼The M-400 luminaires listed above are shipped with socket set in *Position 1. Socket can be easily adjusted to other positions to obtain other light distributions. See photometric data table.*

□ Lamp is mounted base down 10° below the horizontal.

OPTIONS

The options below can be made available on order. Order similar to Cat No. CxxxGxxx except (specify option).

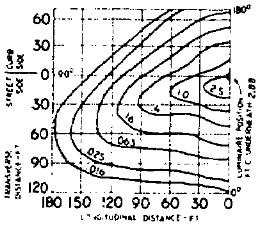
1. **Ballasts.** Reactor (400-watt only) 277-volts, high or normal power factor. Minimum quantity of ten of any one Cat. No.
2. **Refractors.** Lexan® or self-shielded glass refractors (2-way). Minimum quantity of ten of any one Cat. No.

PHOTOMETRIC DATA

Distribution Type	Lamp	Socket Position	Curve Number
S-S-III	400-w phosphor	1	35-174454
S-S-II	400-w phosphor	2	35-174455
M-S-III	400-w clear	1	35-174450
M-C-III	400-w clear	5	35-174451
M-S-II	400-w clear	2	35-174452
M-C-II	400-w clear	6	35-174453

[illegible]

ISOFOOTCANDLE CURVE (Typical)



Curve Reference: 35-174450

Luminaire: M-400/M-400A
Distribution: M-S-III
Lamp: 400-watt Clear Mercury
Luminaire height: 30 feet

†Proprietary term of Aluminum Co. of America

MOUNTING CONSIDERATIONS

Recommended Poles

Suggested mounting height — 30'. For 30' round, tapered, anchor base poles including anchor bolts and bolt circle templates:

Arm Arrangement	Pole Catalog Number: Aluminum	Steel: Prime Painted	Steel: Galvanized
Single 6' arm	C690H19X	C790H36X	C790H37X
Twin 6' arms at 180°	C690H20X	C790H38X	C790H39X
Four 6' arms at 90°	C690H21X	C790H40X	C790H41X

These systems will withstand winds up to at least 100 mph velocity. Additional information about the above poles is given on page 45. Other poles are shown on pages 46, 47 (aluminum) and 48 (steel).

Brackets and Adapters for Above Poles

Poles above and on pages 46, 47, and 48 include bracket arms. No additional brackets or adapters are required to mount the luminaires.

M-400A POWR/DOOR® LUMINAIRE

FEATURES

• **Installation ease** — Adjustable two-bolt slip-fitter easily tightened from outside or inside, capable of accepting 1¼ through 2-inch standard pipe size; pre-wired Powr/Module* ballast assembly can be easily removed.

• **Choice of light distributions** — Readily accessible adjustable lamp socket (twelve positions) permits use of HID clear-arc sources (*mercury*, metal halide and Lucalox®) and phosphor-coated mercury lamps.

• **Lower light loss** — Unique, sealed and activated-charcoal filtered optical assembly reduces intake of both particulate and gaseous contaminants.

• **Ease of maintenance** — Hinged Powr/Module contains multiple ballast and Astrodome® photoelectric controller, easily lowered for installation, service, or replacement when upgrading to newer light sources. Easy-to-use refractor door latch, refractor easily removed without tools.

• **Long life** — Trouble-free Maxalum ballast; Alzak† finished aluminum reflector; durable precision die-cast aluminum housing.

GUIDE FORM SPECIFICATIONS

The luminaire shall be Type M-400A Cat. No. (specify) consisting of a cast aluminum upper housing and refractor holder, a Powr/Module to which are mounted the major electrical components for multiple operation, including ballast, capacitors (and Astrodome control). For series operation, major electrical components are mounted in top housing. The luminaire shall have a slipfitter capable of adapting to 1¼ inch through 2-inch IPS brackets, an Alzak finished aluminum reflector, and a borosilicate glass refractor with gasketing between the reflector and refractor. The optical assembly shall contain a socket adjustable to 12 positions capable of producing IES Type (specify) distribution with a (specify lamp number) lamp and an activated charcoal filter.

(Optional) The luminaire shall contain a locking-type mounting receptacle for photoelectric control.

ORDERING INFORMATION (Prices, see GEA-9666)

Ballast§			Lamp□ (Not Included)	Luminaire Cat. No. (less lamp)▼					Approx. Net Wt. lbs.
Watts	Volts	Type		With Astrodome Control Rated 120 Volts	With Astrodome Control Rated 240 Volts	With PE Receptacle Rated 120 Volts	With PE Receptacle Rated 240 Volts	Without Astrodome or PE Receptacle	
400	120×240††	Mercury (Regulator)	H33	C723G001	....	C724G002	....	C724G001	40
	240×480‡	Mercury (Regulator)	H33	....	....	....	....	C724G004	40
	240	Mercury (Reactor [NPF])	H33	C723G003▽	C723G005#	C724G010▽	C724G012#	C724G003	37
	240	Mercury (Reactor [HPF])	H33	C723G009▽	C723G004#	C724G021▽	C724G022#	C724G020	38
	120	Mercury (Lag)	H33	C723G006	....	C724G013	....	C724G015	39
250	120	Lucalox (Regulator)	LU250/BD	C723G561	....	C724G570	....	C724G571	53
	240	Lucalox (Regulator)	LU250/BD	....	C723G562#	....	C724G572#	C724G573	53
	480	Lucalox (Regulator)	LU250/BD	....	....	....	....	C724G574	53
400	120	Lucalox (Reactor)	LU400/BD	C723G524	....	C724G545	....	C724G530	46
	240	Lucalox (Reactor)	LU400/BD	C723G525▽	C723G526#	C724G546▽	C724G547#	C724G548	46
	480	Lucalox (Reactor)	LU400/BD	....	....	....	....	C724G520	46
	120	Lucalox (Regulator)	LU400/BD	C723G563	....	C724G580	....	C724G581	53
	240	Lucalox (Regulator)	LU400/BD	....	C723G564#	....	C724G578#	C724G575	53
	480	Lucalox (Regulator)	LU400/BD	....	....	....	....	C724G564	53
400	120	Metal Halide (Auto-reg.)	Metal Halide	C723G014	....	C724G029	....	C724G030	44
	240	Metal Halide (Auto-reg.)		C723G021▽	C723G019#	C724G047▽	C724G048#	C724G049	44
	480	Metal Halide (Auto-reg.)		....	....	....	....	C724G050	44
400		Externally Mounted	H33	....	....	....	....	C722G001	28

§ For ballast electrical data, see pages 42-43

†† *Luminaires listed above with regulator ballast rated 120 × 240-volts* are factory-wired for 120-volt operation of ballast (and photoelectric control where applicable). If units with photoelectric control are changed to 240-volt operation of ballast in the field, then photoelectric control must also be changed to 240-volt rating

‡ Luminaires listed above with regulator ballast rated 240 × 480-volts are factory-wired for 480-volt operation of ballast. These units can be easily converted to 240-volt operation in the field.

▽ For use on 3-wire 120 × 240-volt supply — 240-volt to ballast and 120-volts to photoelectric control.

For use on 2-wire 240-volt supply — 240-volts to ballast and 240-volts to photoelectric control.

▼ The M-400A luminaires listed above are shipped with socket set in Position 1 for mercury vapor, Position 2 for Lucalox, and Position 5 for metal halide. Socket can be easily adjusted to other positions to obtain other light distributions. See photometric data table.

□ Lamp is mounted base down 10° below the horizontal.

OPTIONS

The options below can be made available on order. Order **similar to** Cat. No. CxxxGxxx except (specify option).

1. Refractors. Lexan* or self-shielded glass refractors (2-way). Minimum quantity of ten of any one catalog number.

2. Ballasts.
A. Mercury *regulator* 208- and 277-volt.
B. Mercury *reactor* 277-volt, HPF or NPF. Min. quantity of ten of any one Cat. No.
C. Mercury *series* 6.6 amp and 20 amp. Minimum quantity (20 amp) ten of any one Cat. No.

EFFECTIVE PROJECTED AREA (see discussion pg 45)

M-400A Side 1.4 sq. ft. [illegible]

MOUNTING CONSIDERATIONS

Recommended Poles

Suggested mounting height — 30'. For 30' round, tapered, anchor base poles including anchor bolts and bolt circle templates:

Arm Arrangement	Pole Catalog Number		
	Aluminum	Steel	
		Prime Painted	Galvanized
Single 6' arm	C690H19X	C790H36X	C790H37X
Twin 6' arms ● 180°	C690H20X	C790H38X	C790H39X
Four 6' arms ● 90°	C690H21X	C790H40X	C790H41X

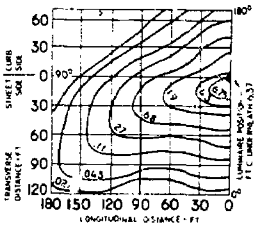
These systems will withstand winds up to at least 100 mph velocity. Additional information about the above poles is given on page 45. Other poles are shown on pages 46, 47 (aluminum) and 48 (steel).

Brackets and Adapters for Above Poles

Poles above and on pages 46, 47 and 48 include bracket arms. No additional brackets or adapters are required to mount the luminaires.

*Trademark of General Electric Company   †Proprietary term of Aluminum Co. of America

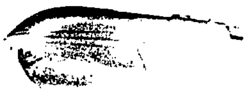
ISOFOOTCANDLE CURVE (Typical)



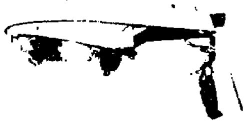
Curve Reference, 35-174486
Luminaire: M-400A
Distribution: M-S-III
Lamp: 400-watt Lucalox
Luminaire height: 30 feet

WHERE TO USE

- Traffic streets
- Business streets
- Highways
- Industrial plants
- Parking lots

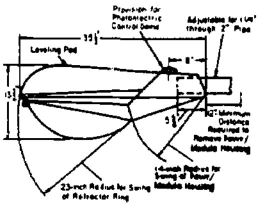


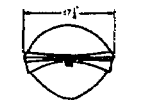
M-400A Luminaire



M-400A with Powr/Module housing in open position

DIMENSIONS





M-400A Luminaire

ACCESSORIES

External Shield —
Cat. No. 35-962490-36 external shield for use with M-400A luminaire

REFRACTORS

Refractor	Cat. No.
Lexan	35-130015-02
Self-shielded (2-way)	35-130559-03

PHOTOMETRIC DATA

IES Type	Socket Position	Lamp	Curve Number
M-S-III	1	Clear mercury	35-174450
M-C-III	5	Clear mercury	35-174451
M-S-II	2	Clear mercury	35-174452
M-C-II	6	Clear mercury	35-174453
S-S-III	1	Phosphor coated	35-174454
S-S-II	2	Phosphor coated	35-174455
M-N-IV	1	Lucalox (400 watt)	35-174490
M-S-III	2	Lucalox (400 watt)	35-174486
S-S-II	10	Lucalox (400 watt)	35-174467
M-N-IV	1	Lucalox (250 watt)	35-175134
M-S-III	2	Lucalox (250 watt)	35-175135
M-S-II	3	Lucalox (250 watt)	35-175136
M-S-I	4	Lucalox (250 watt)	35-175137
M-S-III	5	Metal Halide	35-174492
M-S-II	6	Metal Halide	35-174493

 21.

M-1000 LUMINAIRE

WHERE TO USE

- Downtown business
- High level traffic
- Highways
- Intersections
- Parking lots

M-1000 luminaire

FEATURES

- **Ease of Installation** — Adjustable two-bolt slip-fitter for quicker installation, capable of accepting 1¼ through 2-inch standard pipe size; ballast components pre-wired to terminal board.
- **Choice of light distribution** — Lamp socket adjustable, permits use of all HID light sources — mercury, metal halide or Lucalox®.
- **Maintenance ease** — Refractor door latch large and easy to open while wearing lineman's gloves. Refractor easily removed without tools.
- **Long life** — Durable precision die-cast aluminum housing; Alzak† finished reflector; optical assembly well gasketed for integrity of refractor-to-reflector and socket seal.

GUIDE FORM SPECIFICATIONS

The luminaire shall be Type M-1000 Cat. No. (specify) [illegible] and the refractor and the socket [illegible] entry, an adjustable socket capable of producing IES Type (specify) distribution with the (specify lamp number) lamp and a refractor.

The luminaire shall contain a ballast designed for use on (specify voltage) circuit. The ballast shall be pre-wired to the lamp socket and terminal board.

(Optional) The luminaire shall include a locking-type mounting receptacle for photoelectric control.

ORDERING INFORMATION (Prices, see GEA-9666)

BALLAST§			Lamp□ (Not Included)	Luminaire Cat. No. (less lamp)▼		Approx. Net Wt. lbs.
Watts	Volts	Type		With Photoelectric Receptacle	Without Photoelectric Receptacle	
1000	120×240††	Mercury (Regulator)	H36 ∇	C796G016	C796G015	59
	208	Mercury (Regulator)		C796G018	C796G017	59
	277	Mercury (Regulator)		C796G022	C796G021	59
	240×480‡	Mercury (Regulator)		....	C796G023	59
	480	Mercury (Reactor (HPF))		....	C796G025	52
700	120×240††	Mercury (Regulator)	H35	C796G004	C796G003	59
	208	Mercury (Regulator)		C796G006	C796G005	59
	277	Mercury (Regulator)		C796G010	C796G009	59
	240×480‡	Mercury (Regulator)		....	C796G011	59
	480	Mercury (Reactor (HPF))		....	C796G013	52
1000	120×240††	Metal Halide (Auto-regulator)	MV1000/HBD/E	C796G028	C796G027	59
	208	Metal Halide (Auto-regulator)		....	C796G029	59
	277	Metal Halide (Auto-regulator)		....	C796G031	59
	480	Metal Halide (Auto-regulator)		....	C796G033	59
1000	120	Lucalox (Auto-regulator)	LU1000/BD	C796G171	C796G146	60
	208	Lucalox (Auto-regulator)		C796G174	C796G147	60
	240	Lucalox (Auto-regulator)		C796G164	C796G145	60
	277	Lucalox (Auto-regulator)		C796G180	C796G148	60
	480	Lucalox (Auto-regulator)		....	C796G149	60
....	....	Externally Mounted	....	C796G002	C796G001	36

§ For ballast electrical data, see pages 42 and 43.

†† Dual voltage ballasts rated 120 × 240-volts are factory-wired for 120-volt operation of ballast (and photoelectric control where applicable). These units can easily be converted to 240-volt operation in the field. If units with photoelectric control are changed to 240-volt operation of ballast in the field then photoelectric control must also be rated for 240-volts.

‡ Dual voltage ballasts rated 240 × 480-volt are factory-wired for 480-volt operation of ballast. These can be easily converted to 240-volt operation in the field.

∇ H34 mercury lamp cannot be used.

▼ The M-1000 luminaires listed above are shipped with socket set in Position S. Socket can be easily adjusted to other positions to obtain other light distributions. See photometric data table.

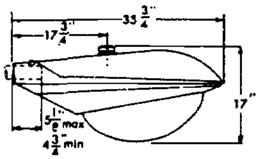
□ Lamp is mounted base down 10° below the horizontal.

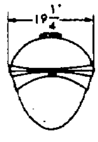
[illegible]

PHOTOMETRIC DATA TYPE M-1000

Distribution Type	Lamp	Socket Position	Curve Number
M-S-IV	1000-w clear mercury	S	35-175039
M-C-III	1000-w clear mercury	T	35-175040
M-C-II	1000-w clear mercury	F	35-175041
S-S-IV	1000-w phosphor mercury	S	35-175045
S-S-III	1000-w phosphor mercury	T	35-175046
S-S-III	1000-w phosphor mercury	F	35-175047
M-C-IV	700-w clear mercury	S	35-175044
M-C-III	700-w clear mercury	T	35-175043
M-C-II	700-w clear mercury	F	35-175042
S-S-IV	700-w phosphor mercury	S	35-175050
S-S-III	700-w phosphor mercury	T	35-175049
S-S-III	700-w phosphor mercury	F	35-175048
M-C-II	1000-w metal halide	S	35-175059
M-C-I	1000-w metal halide	T	35-175060
M-C-I	1000-w metal halide	F	35-175061
M-S-IV	1000-w Lucalox	S	35-175180

DIMENSIONS





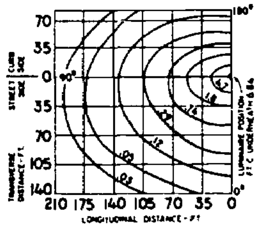
M-1000 luminaire

ACCESSORIES

External Shield

Cat. No. 35-961570-89, external shield for use with M-1000 luminaire.

ISOFOOTCANDLE CURVE (Typical)



Curve Reference: 35-175045
Luminaire: M-1000
Distribution: S-S-IV
Lamp: 1000-watt Deluxe White Mercury
Luminaire height: 35 feet

†Proprietary term of Aluminum Co. of America

MOUNTING CONSIDERATIONS

Recommended Poles

Suggested mounting height — 35'. For 35' round, tapered, anchor base poles including anchor bolts and bolt circle templates:

Arm Arrangement	Pole Catalog Number		
	Aluminum	Steel	
		Prime Painted	Galvanized
Single 6' arm	C690H22X	C790H42X	C790H43X
Twin 6' arms at 180°	C690H23X	C790H44X	C790H45X
Four 6' arms at 90°	C690H24X	C790H46X	C790H47X

These systems will withstand winds up to at least 100 mph velocity. Additional information about the above poles is given on page 45. Other poles are shown on pages 46, 47 (aluminum) and 48 (steel).

Brackets and Adapters for Above Poles

Poles above and on pages 46, 47, 48 include bracket arms. No additional brackets or adapters are required to mount the luminaires.

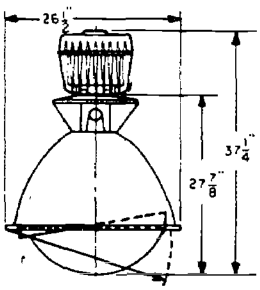
HM-1000 ASYMMETRICAL LUMINAIRE

WHERE TO USE

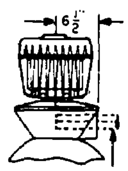
- Interchanges
- Intersections
- Roadways

HM-1000 Asymmetrical luminaire

DIMENSIONS

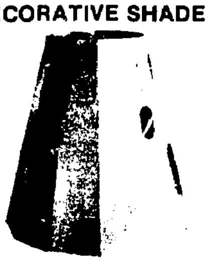


26" Rod For Swing Of Door Glass



HM-1000 Asymmetrical luminaire

DECORATIVE SHADE



Cat. No. 35-221481-01

FEATURES

• **Precision light control** — Optical assembly with Alzak† aluminum reflector and glass refractor provides various distributions; entire optical assembly can be rotated 360° about slipfitter housing for proper orientation with roadway.

• **Ease of installation** — Slipfitter with four easily accessible bolts mounts to 2" standard pipe with ± 3° leveling adjustment; slipfitter housing has terminal board pre-wired to optical assembly; pre-wired quick-disconnect plug between ballast housing and optical assembly.

• **Long life construction** — Die-cast aluminum ballast housing, cast aluminum slipfitter housing, aluminum housing over optical assembly; heat- and shock-resistant tempered borosilicate glass refractor, stainless steel latches.

• **High light output** — Gasketed and activated charcoal filtered optical assembly helps maintain light output.

• **Choice of light source** — Mercury, metal halide or Lucalox®.

ORDERING INFORMATION (Prices, see GEA-9666)

BALLAST§			Lamp▽ (Not Included)	Luminaire Cat. No. (less lamp)	IES Light Dist.	Photometric Curve No.	Approx. Net Wt. lbs.
Watts	Volts	Type					
400	120	Lucalox (Regulator)	LU400/BD	C741G030	S-S-II	35-175235	80
	240	Lucalox (Regulator)	LU400/BD	C741G031	S-S-II	35-175235	80
	480	Lucalox (Regulator)	LU400/BD	C741G032	S-S-II	35-175235	80
1000	120	Mercury (Regulator)	H1000A36-15	C741G027	S-S-II‡	35-175236	80
	240	Mercury (Regulator)	H1000A36-15	C741G028	S-C-II‡	35-175236	80
	480	Mercury (Regulator)	H1000A36-15	C741G029	S-S-II‡	35-175236	80
	120	Metal Halide (Auto-regulator)	MV1000/HBD/E	C741G021	M-C-II	35-175169	80
	240	Metal Halide (Auto-regulator)	MV1000/HBD/E	C741G022	M-C-II	35-175169	80
	480	Metal Halide (Auto-regulator)	MV1000/HBD/E	C741G023	M-C-II	35-175169	80
	120	Lucalox (Auto-regulator)	LU1000/BD	C741G045	S-S-III	35-175251	81
	240	Lucalox (Auto-regulator)	LU1000/BD	C741G047	S-S-III	35-175251	81
	480	Lucalox (Auto-regulator)	LU1000/BD	C741G049	S-S-III	35-175251	81
...	....	Externally Mounted	....	C742G012	... .	....	45

§ For ballast electrical data see pages 42-43.

‡ Data shown is for clear lamp. Do not use H-34 lamp

▽ Lamp is mounted base down, 10 degrees below the horizontal.

OPTION

The option below can be made available on order. Order similar to Cat. No. CxxxGxxx, except (specify option).

Ballasts. 208- and 277-volt ballasts.

DECORATIVE SHADE

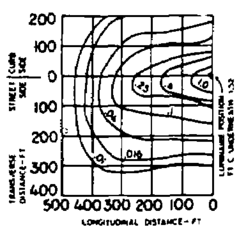
Sturdy — Construction is of 0.040-inch sheet aluminum.
Easy to Assemble — Shipped in two vertical halves; secured together with stainless-steel screws.

ORDERING INFORMATION

Cat. No.	Description	Net Weight (lbs.)
35-221481-01	12-sided shade—no finish□	11

□ Specify paint finish required; standard gray or one of the eight decorator colors. See back cover.

ISOFOOTCANDLE CURVE (Typical)



Curve Reference: 35-175169

Luminaire: HM-1000 Asymmetrical
Distribution: M-C-II
Lamp: 1000-watt Metal Halide
Luminaire Height: 100 feet

†Proprietary term of Aluminum Co. of America.

MOUNTING CONSIDERATIONS

Recommended Poles

See page 49

Mounting Rings and Lowering Devices

Careful consideration should be given to maintenance of the luminaires — particularly above 60' mounting heights which restrict the use of service and maintenance vehicles.

Luminaire mounting rings are available, for 2 through 12 HM-1000 luminaires. Lowering devices include the necessary stainless steel lift cables, power cables, winch and winch cable, as well as power drive units to facilitate raising and lowering the luminaire and mounting ring assembly for servicing. Complete details for these components, see page 49.

SYMMETRICAL HM-1000 LUMINAIRE

FEATURES

• **Choice of light distribution** — Adjustable socket permits selection of three beam angles, from either mercury, metal halide or Lucalox® light sources.
• **Ease of Installation** — Slipfitter with four easily accessible bolts, mounts to 2" standard pipe with ± 3° leveling adjustment; slipfitter housing has terminal board pre-wired to optical assembly; pre-wired quick-disconnect plug between ballast housing and optical assembly.
• **Long life construction** — Die-cast aluminum ballast housing, cast aluminum slipfitter housing, Alzak† finished aluminum reflector, heat- and shock-resistant tempered borosilicate glass globe, stainless steel latches.
• **High light output** — EPT door gasket, activated charcoal filtered optical assembly helps maintain light output.

[illegible]

ORDERING INFORMATION (Prices, see GEA-9666)

BALLASTS§			Lamp▽ (Not Included)	Luminaire Cat. No. (less lamp)	Maximum Beam Angle (Degrees)▼	Photometric Curve No.	Approx. Net Wt. lbs.
Watts	Volts	Type					
400	120	Lucalox (Regulator)	LU400/BU	C741G007	57.5	35-175074	65
	240	Lucalox (Regulator)	LU400/BU	C741G008	57.5	35-175074	65
	480	Lucalox (Regulator)	LU400/BU	C741G009	57.5	35-175074	65
1000	120	Mercury (Regulator)	H1000A36-15	C741G001	50‡	35-175067	65
	240	Mercury (Regulator)	H1000A36-15	C741G002	50‡	35-175067	65
	480	Mercury (Regulator)	H1000A36-15	C741G003	50‡	35-175067	65
	120	Metal Halide (Auto-regulator)	MV1000/BU/I	C741G004	55	35-175057	65
	240	Metal Halide (Auto-regulator)	MV1000/BU/I	C741G005	55	35-175057	65
	480	Metal Halide (Auto-regulator)	MV1000/BU/I	C741G006	55	35-175057	65
	120	Lucalox (Auto-regulator)	LU1000/BU	C741G041	57.5	35-175227	66
	240	Lucalox (Auto-regulator)	LU1000/BU	C741G040	57.5	35-175227	66
	480	Lucalox (Auto-regulator)	LU1000/BU	C741G044	57.5	35-175227	66
		Externally Mounted		C742G003			30

§ For ballast electrical data see pages 42-43
‡ Data shown is for clear lamp. Do not use H-34 lamp

▼ Socket position 2 for all catalog numbers shown except 1000-watt Lucalox which is position 1. For other socket settings and resulting beam angles see table below
▽ Lamp is mounted vertical base up.

OPTION

The option below can be made available on order. Order **similar to** Cat. No. CxxxGxxx, except (specify option).

Ballasts. 208- and 277-volt ballasts.

DECORATIVE SHADE

Sturdy — Construction is of 0.040-inch sheet aluminum
Easy to Assembly — Shipped in two vertical halves; secured together with stainless-steel screws.

ORDERING INFORMATION

Cat. No.	Description	Net Weight (lbs.)
35-221481-01	12-sided shade—no finish□	11

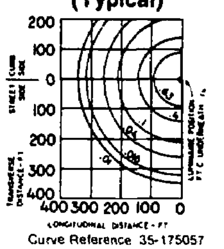
□Specify paint finish required; standard gray or one of the eight decorator colors. See back cover.

[illegible]

PHOTOMETRIC DATA

Watts	Lamp	Socket Position	Max Beam Angle (Degrees)	Photometric Curve No.
400	LU400/BU	1	65	35-175073
	LU400/BU	2	57.5	35-175074
	LU400/BU	3	55	35-175075
1000	MV1000/HBU/E	1	60	35-175056
	MV1000/HBU/E	2	55	35-175057
	MV1000/HBU/E	3	55	35-175058
1000	H1000A36-15	1	60	35-175066
	H1000A36-15	2	50	35-175067
	H1000A36-15	3	45	35-175065
1000	H1000DX36-15	1	55	35-175076
	H1000DX36-15	2	45	35-175077
	H1000DX36-15	3	45	35-175078
1000	LU1000/BU	1	57.5	35-175227
	LU1000/BU	2	45	35-175372

ISOFOOTCANDLE CURVE (Typical)



Curve Reference 35-175057
Luminaire: HM-1000 Symmetrical
Distribution: Type V
Lamp: 1000-watt Metal Halide
Luminaire height: 100 feet

MOUNTING CONSIDERATIONS

Recommended Poles

See page 49

Mounting Rings and Lowering Devices

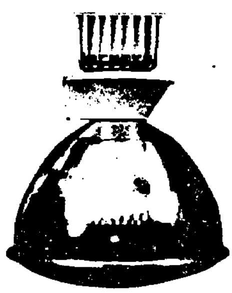
Careful consideration should be given to maintenance of the luminaires — particularly above 60' mounting heights which restrict the use of service and maintenance vehicles.

Luminaire mounting rings are available, for 2 through 12 HM-1000 luminaires. Lowering devices include the necessary stainless steel lift cables, power cables, winch and winch cable, as well as power drive units to facilitate raising and lowering the luminaire, and mounting ring assembly for servicing. Complete details for these components, see page 49.

†Proprietary term of Aluminum Co. of America

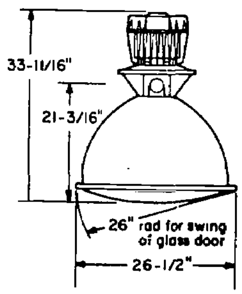
WHERE TO USE

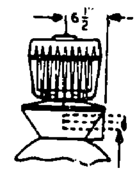
- Interchanges
- Intersections
- Large parking lots
- Material handling
- Railroad yards



HM-1000 Symmetrical luminaire

DIMENSIONS





HM-1000 Symmetrical luminaire

DECORATIVE SHADE

Cat. No. 35-221481-01

QUICK REFERENCE GUIDE TO AMERICAN IES AND CIE CLASSIFICATION OF ROADWAY LIGHTING LUMINAIRES

I. VERTICAL LIGHT DISTRIBUTION: "LONG", "MEDIUM", or "SHORT"
Vertical light distribution classifications are determined by the areas bounded by the following transverse roadway lines (TRL). These areas are defined as the transverse zones of max. cd.

"SHORT" Distribution	1.0 MH TRL to 2.25 MH TRL
"MEDIUM" "	2.25 MH TRL to 3.75 MH TRL
"LONG" "	3.75 MH TRL to 6.0 MH TRL

The location of the max. cd. point in these transverse zones of max. cd determines the vertical light distribution classification.

II. VERTICAL CONTROL: "CUTOFF", SEMI-CUTOFF" or "NON-CUTOFF"

The 90° and 80° vertical angles are used for classifying the vertical control as tabulated:

Luminaire Vertical Control	Maximum Permissible Intensity Permitted	
	90°	80°
Cutoff	25 cd/1000 lm (2.5%)	100 cd/1000 lm (10%)
Semi-Cutoff	50 cd/1000 lm (5%)	200 cd/1000 lm (20%)
Non-Cutoff		

III. LATERAL LIGHT DISTRIBUTION: IES "TYPE" CLASSIFICATION
Locate the 1/2 max. cd line on the Isocandela Diagram and note its position relative to specified longitudinal roadway lines (LRL). "Type" is determined from the location of the 1/2 max. cd isocandela line for all except Type V.

Type I: 1/2 max. cd line enters the area on both sides of reference line (zero MH LRL) and remains within the area bounded by 1.0 MH LRL on both house and street sides in the transverse zone of max. cd.

Type II: 1/2 max. cd line does not cross the 1.75 MH LRL on the street side in the transverse zone of max. cd.

Type III: 1/2 max. cd line enters area bounded by the 1.75 MH LRL to the 2.75 MH LRL on the street side in the transverse zone of max. cd.

Type IV: 1/2 max. cd line crosses the 2.75 MH LRL in the transverse zone of max. cd.

Type V: When the pattern has circular symmetry of cd distribution and is essentially the same at all lateral angles.

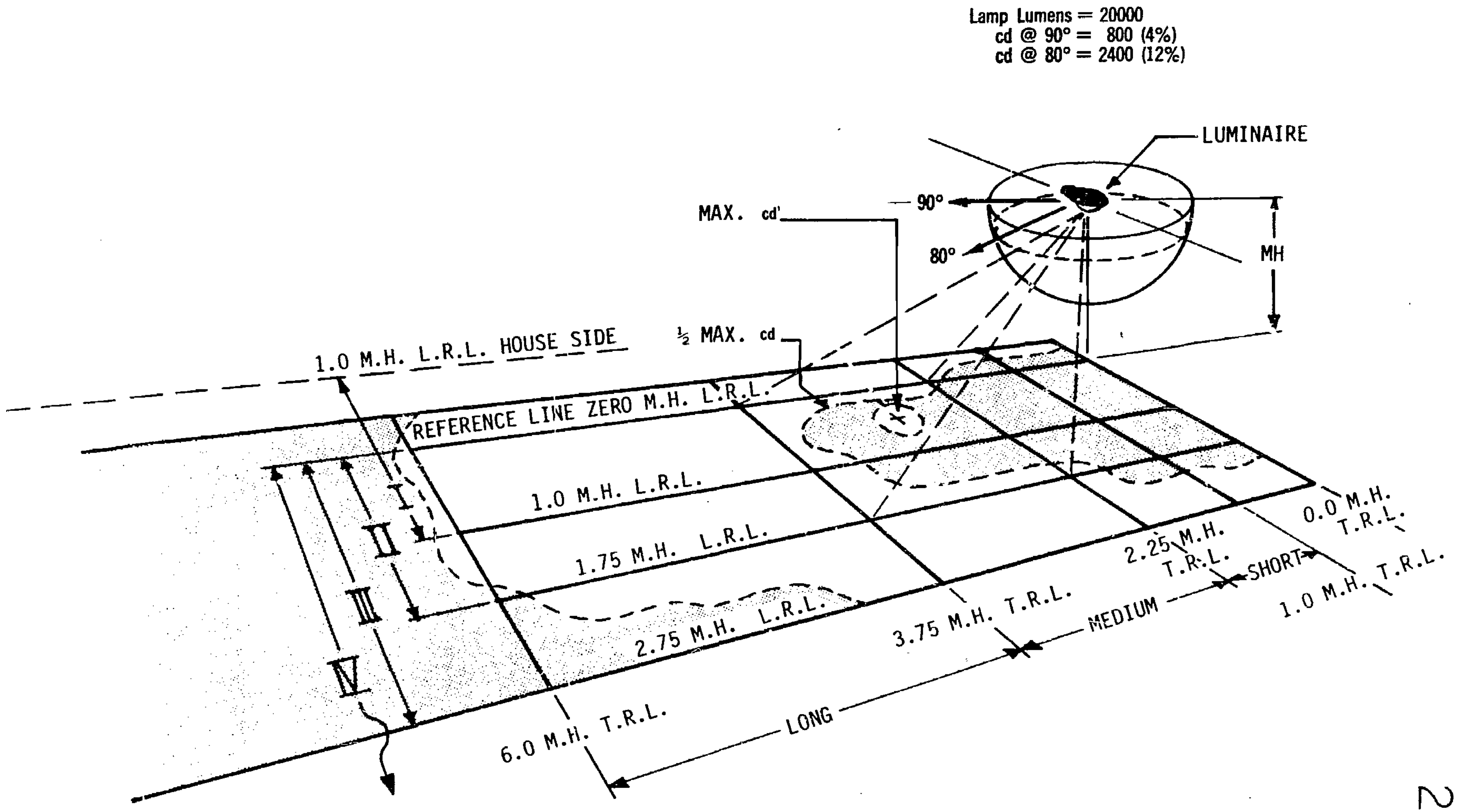
IV. The CIE (Commission Internationale De L'Eclairage) classification is relatively simple since it is based primarily upon the Vertical Control. Criteria are tabulated:

Luminaire Type	Location of Vertical Angle of Maximum cd	Maximum Permissible Intensity Emitted	
		90°	80°
Cut-off	0-65°	*10 cd/1000 lm (1%)	30 cd/1000 lm (3%)
Semi-cut-off	0-75°	*50 cd/1000 lm (5%)	100 cd/1000 lm (10%)
Non-cut-off	— —	1000 cd	— —

*A maximum of 1000 cd is permitted regardless of the lamp lumens.

GENERAL ELECTRIC COMPANY
Lighting Systems Business Department, Hendersonville, N. C.

IES CLASSIFICATION: TYPE II, MEDIUM, SEMI CUTOFF
CIE CLASSIFICATION: NON CUTOFF



HIGHWAY LIGHTING DESIGN
Coefficient of Utilization

Determine the Coefficient of Utilization (CU) with the luminaire at the outside edge of the traveled way and include the median.

Ratio Transverse (RT) = 96/50 = 1.92 (Street side)
CU = 0.44 (Photometric Curve 35 - 175039 - 00)
Note: Use roadway width of 96" in calculating illumination

* *

Determine the CU with the luminaire over the traveled way, 6' from the outside edge.

Total CU = CU of "B" + CU of "C" + CU of "E"

RT of "B" = 6/50 = 0.12 (House Side)
CU of "B" = 0.05

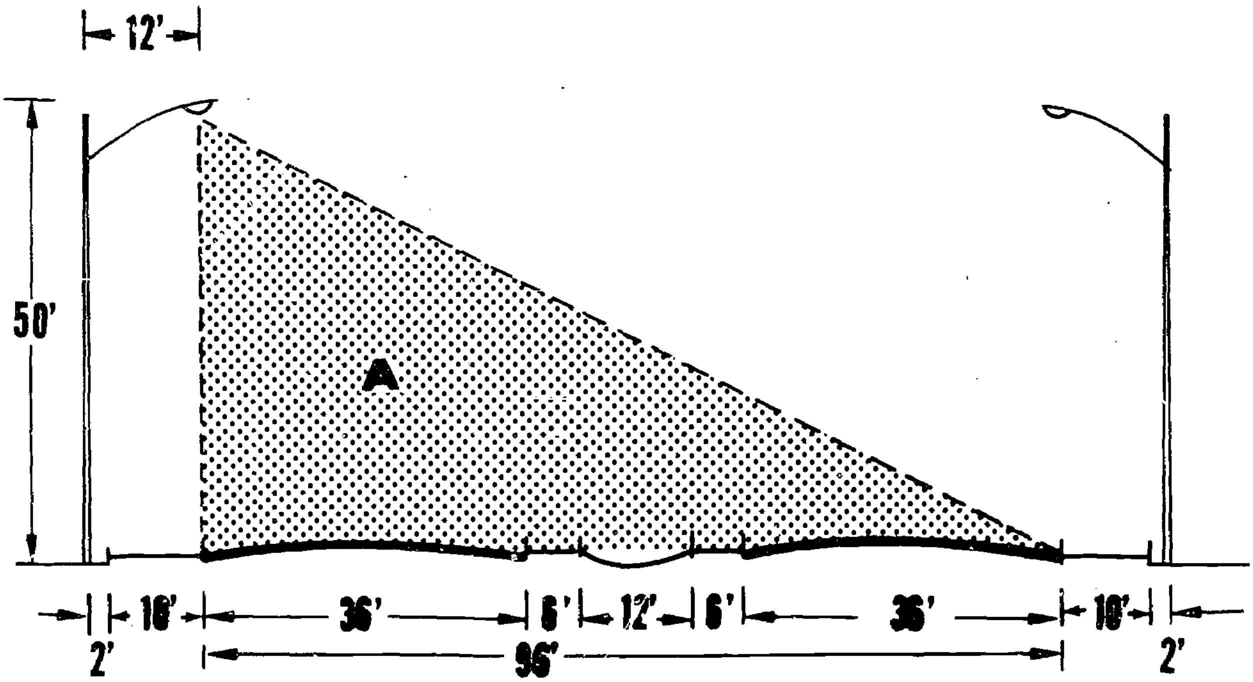
RT of "C" = 30/50 = 0.6 (Street Side)
CU of "C" = 0.24

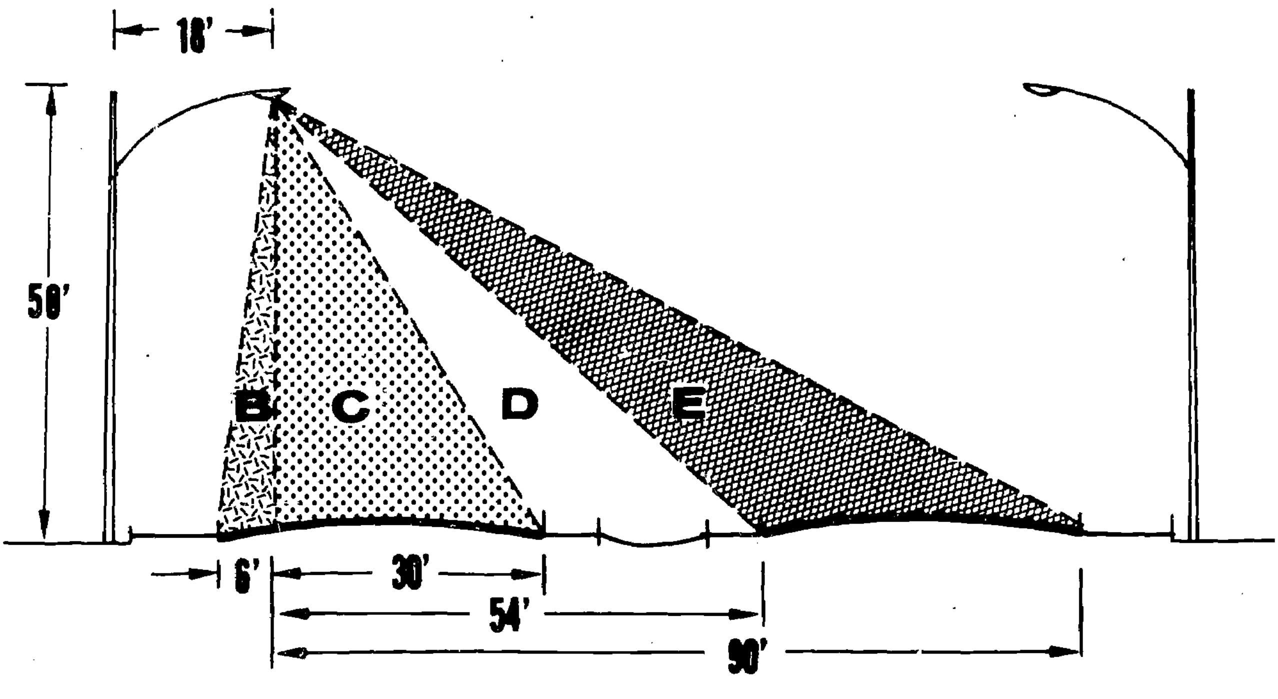
CU of "E" = CU (C + D + E) - CU (C + D)
RT of (C + D + E) 90/50 = 1.8
CU of (C + D + E) = 0.43
RT of (C + D) = 54/50 = 1.08
CU of (C + D) = 0.35
CU of "E" = 0.43 - 0.35 = 0.08

Total CU = 0.05 + 0.24 + 0.08 = 0.37

Note: Use roadway width of 36' + 36' = 72' in calculating illumination

COEFFICIENT OF UTILIZATION





OUTDOOR LIGHTING DEPARTMENT
HENDERSONVILLE, N. C.
ISSUED BY H.F. Huisman DATE 10 NOV. 69

GENERAL ELECTRIC

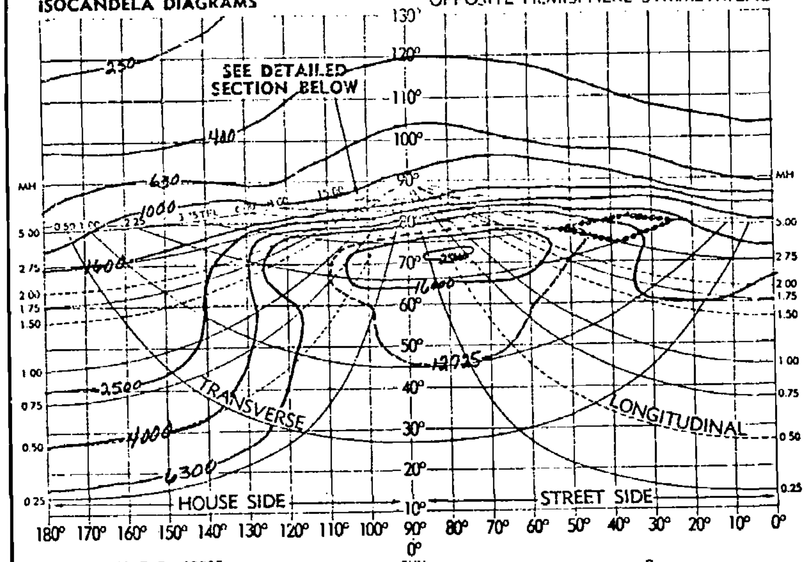
PHOTOMETRIC DATA

DESIGN CODE 955

69-0336

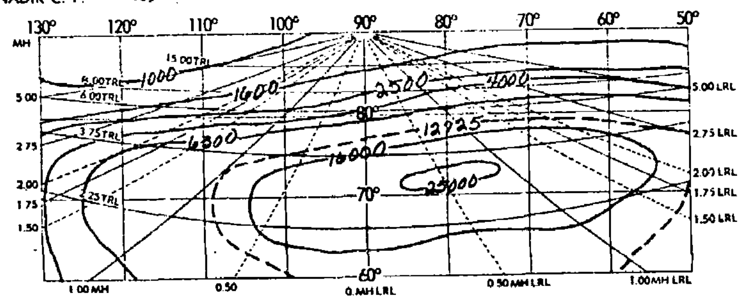
ISOCANDELA DIAGRAMS

OPPOSITE HEMISPHERE SYMMETRICAL



HALF MAX. C. P. 12725
MAX C. P. 25450
NADIR C. P. 10980

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

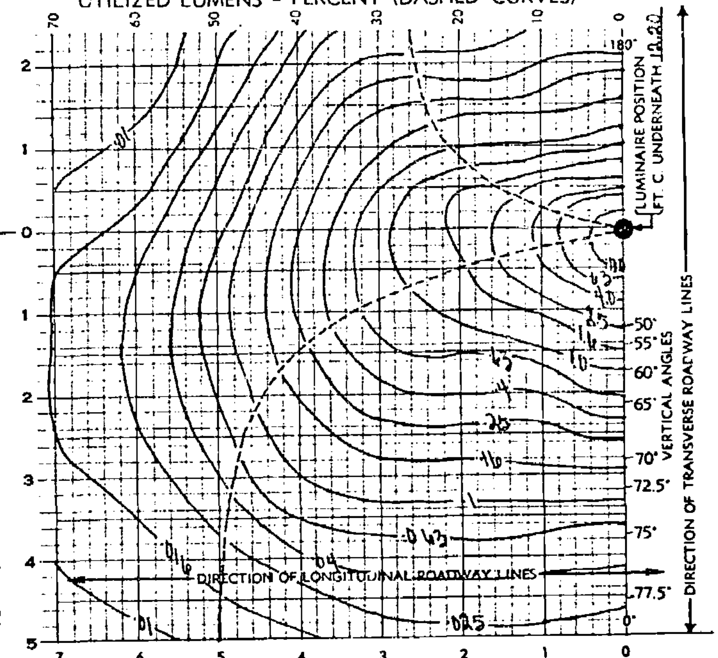


DETAILED SECTION: Based upon data taken at closer intervals than used for main diagram.

CANDELA, FOOTCANDLE AND LUMEN DATA ARE SHOWN FOR 56000 LUMENS AT THE SOURCE AS TESTED IN ACCORDANCE WITH THE IES APPROVED METHOD FOR TESTING STREET LIGHTING LUMINAIRES. EXPECTED PERFORMANCE VALUES FOR A LUMINAIRE IN SERVICE CONDITIONS MAY BE DETERMINED BY MULTIPLYING GIVEN VALUES BY AN APPROPRIATE FACTOR SUCH AS ACTUAL LAMP LUMENS X EQUIPMENT OPERATING FACTOR DIVIDED BY 56000.

LIGHT FLUX VALUES	LUMENS	PERCENT OF LAMP
DOWNWARD STREET SIDE	28448	50.8
UPWARD STREET SIDE	952	1.7
DOWNWARD HOUSE SIDE	15176	27.1
UPWARD HOUSE SIDE	784	1.4
TOTAL	45360	81.0

UTILIZED LUMENS - PERCENT (DASHED CURVES)

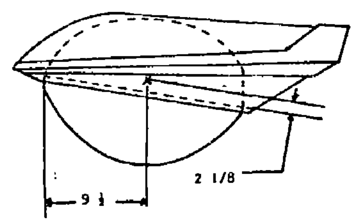


RATIO OF LONGITUDINAL DISTANCE TO MOUNTING HEIGHT

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.	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	1.00	0.94	0.88	0.83	0.78	0.73	0.69	0.66	0.62	0.59	0.56	0.54	0.51	0.49	0.46	0.44	0.43	0.41	0.39	0.37	0.36



LUMINAIRE DESCRIPTION

General Electric M 1000 Luminaire
Reflector # 35-130169-01
Refractor # 558
Socket Position "S"

LAMP – 1000 WATT CLEAR MERCURY
ANSI No H36-15GV
G.E. No. H1000A36-15

ANSI/IES TYPE MEDIUM, SEMICUTOFF, TYPE IV
CIE TYPE NONCUTOFF

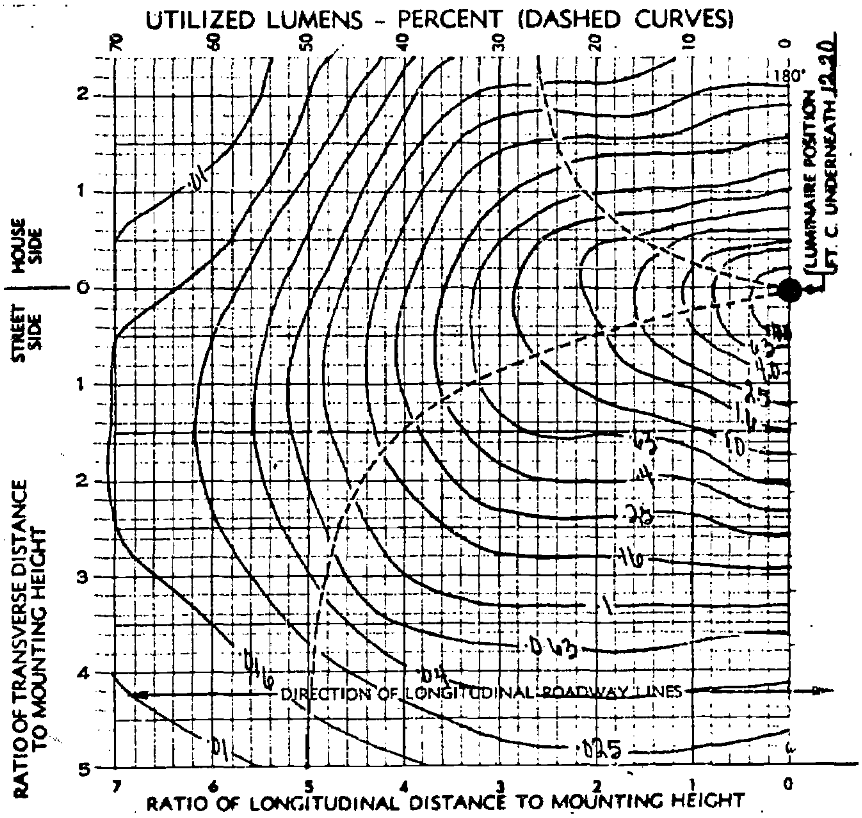
NUMBER 35-175039-00

REV. NO. 2

NUMBER 35-175039-00

PHOTOMETRIC DATA

ISOFOOTCANDLE & UTILIZATION CURVES



CANDELA, FOOTCANDLE AND LUMEN DATA ARE SHOWN FOR 56000 LUMENS
FOOTCANDLE DATA IS BASED ON A LUMINAIRE MOUNTING HEIGHT OF 30 FEET

ANSI/IES TYPE MEDIUM, SEMICUTOFF, TYPE IV

LAMP – 1000 WATT CLEAR MERCURY
ANSI No. H36-15GV

NUMBER
35-175039-00

GENERAL APPLICATION

Many different luminaires are available for outdoor lighting. Their choice is usually dictated by appearance, cost and the type of lighting to be done. Regardless of the luminaire chosen, there are several guidelines that should be followed when planning a lighting installation:

(1) Light level—The light levels suggested by the Illuminating Engineering Society are listed in the table on page 61. These are minimum values. Higher levels are frequently used for better appearance and added safety.

(2) Uniformity—Parking areas should be lighted to a uniformity of 4:1 average to minimum. For architectural floodlighting uniformity is not very critical unless the structure consists of large areas of uniform brick or marble. For most structures 10:1 maximum to minimum uniformity will provide good results.

(3) Beamspread—Select fixtures with beamspreads greater than the subtended angle of the area being lighted. Good lighting overlap occurs when the edge of the beam of one fixture coincides with the aiming point of the adjacent fixture.

(4) Aiming—When a fixture is aimed at a surface at an angle other than perpendicular the maximum lighting level will always occur behind the aiming point, or point of maximum candela. This is important to know when the fixtures are placed close to the base of a tall structure. In this case the highest light level will normally occur at the base even though the fixtures are aimed at the top.

Good Installation Practice

For best results the fixture brightness should be concealed or controlled so it does not dominate the area. Normal fixture brightness can be several thousand times brighter than the area lighted. Fixtures should not be aimed in the direction of the observer. Better comfort is obtained by increasing the mounting height of the fixture and lowering the angle of maximum candela. In general, where the fixture can be seen maximum candela should be kept below 60 degrees.

Special attention is needed for architectural treatments when luminaires are mounted on top of the structure being lighted. Unless the fixtures are well shielded and concealed by additional structure at the parapet they will not do a satisfactory job due to the fixture brightness. The fixture location must also be keyed to the dominant features of the building. Fixture spacing will also have to be closer since the scallop of light produced between fixtures will be very prominent. Lighting from the top of the structure should only be considered for special effects. Lighting from the base of the structure will usually produce better results.

Architectural foodlighting should consider the dominant architectural features of the structure. Co-ordinating the lighting design with the architect will produce the best results since he better than anyone will know the effect he is trying to achieve both during the day and at night.

Installation & Mechanical Considerations

(1) Line voltage—Incandescent lamps are very sensitive to changes in line voltage. Approximately 3% *loss of lamp life* will result for each percent line voltage increases above lamp rating. *Light output* will vary about 3½% with each percent change in lamp voltage. HID fixtures are not affected as much but rely on a given voltage at the ballast to insure starting of the lamp and generation of rated light output.

(2) Metal poles are preferred over wood since there is less chance of the fixtures changing position as the system ages. This is especially critical on sports fields where close tolerances must be maintained on the fixture aiming.

(3) All mounting and service hardware should be corrosion resistant. Position locks on luminaires are required to return the fixture to its original position following servicing.

(4) When vandalism is a problem heavy duty fixtures with tempered glass lenses should be used. Lexan* globes and shields can also be provided for added durability.

(5) Sealed and filtered luminaires improve the maintained light level. Today's longer life HID lamps have extended relamping periods which results in less frequent luminaire cleaning and maintenance. The filtering concept reduces the light degradation due to contaminants in the optical system.

LIGHTING MAINTENANCE

Lighting maintenance factors (properly called "light loss factors") are made up of the following:

(1) Lamp Lumen Depreciation (LLD)
(2) Luminaire Dirt Depreciation (LDD)
(3) Temperature, voltage and ballast performance
(4) Aging of luminaire finish and material
(5) Burned-out, unreplaced lamps.

Of these, the first two are generally considered in determining the reduction of light output throughout life of both luminaire and lamp. Lamp lumen depreciation (LLD) results from lamp aging and can be determined from the lamp manufacturer's data based on actual lamp tests. LLD values are published for "mean" lumen output. For HID lamps the mean lumen output is measured at 50% of relamping period. For calculation of minimum light levels the "end of relamping" lamp lumens are used. This can be based on the lamp lumens produced when the lamp reaches its end of life or at an economic life selected by the user to fit his maintenance program. "End of relamping" lumen values are obtained from curves published by the lamp manufacturers.

The luminaire dirt depreciation (LDD) can only be determined by experience. Field tests on actual installations are the best guide. For unfiltered fixtures the luminaire dirt depreciation can vary widely depending on atmospheric conditions. For a sealed and filtered fixture a value of .9 has been determined to be a reasonable LDD.

The luminaire dirt depreciation (LDD) is not determined simply by whether the installation is in a clean or a dirty atmosphere but, rather, upon how much dirt is allowed to accumulate before it is cleaned. It is necessary then to consider the time interval between cleanings, as well as the environment.

There are three primary methods of minimizing luminaire dirt depreciation (LDD):

—Regular cleaning of the luminaire
—Complete sealing of the luminaire (hermetic sealing)
—Allowing only clean air to enter the luminaire (sealed and filtered).

Regular cleaning can produce good results; however, this method is becoming more and more costly, especially when cleaning programs are separate from the relamping periods.

Hermetic sealing is a good technique for applications such as reflector incandescent lamps but is impractical for larger HID luminaires.

Sealed-filtered luminaires incorporate a low resistance path for the air to flow into the optical assembly. The filter permits only clean air to flow during the "breathing" cycle when the fixture is turned on or off. Activated charcoal filters keep out dirt particles, as well as vapors and gases which could corrode the reflector or deposit opaque films that are subsequently baked on by lamp heat.

Maintenance factors for typical lamps used in outdoor lighting are tabulated in "Outdoor Lighting Systems Price Catalog GEA-9666".

MAINTENANCE NOTES
HIGHWAY ILLUMINATION

The questionnaire used at the close of each Regional Highway Lighting Course asks for comments. Here is the comment made by a State Engineer at the course conducted in August 1971. "The typical highway department designs, lets a contract, supervises construction, and forgets the lighting installation. We have a gap when it comes to evaluating and maintenance of our systems. This area needs to be given more attention."

The primary reason for lack of maintenance is the slow depreciation of the illumination. For example, a mercury lighting system does not stop functioning at the end of so called lamp life. It depreciates gradually until it reaches a point below the designed minimum and where the production of light is not economical. This is normally six years and the illumination is down about 40%. The loss is not visually realized until the luminaires are cleaned and relamped. The fact that the lamp continues to produce some light and that maintenance is hazardous, often requiring lane closing, makes lighting maintenance an easily deferred and neglected item. Maintenance is usually done on a group replacement plan or on an as-reported basis. Group replacement plan suggests that the mercury luminaires to be washed annually and all lamps in a group replaced every four years, which is two thirds of the rated life. With other than mercury lamp, the replacements are determined by the rated lamp life. The as-reported basis does not include a time schedule and usually results in sub-standard illumination after the initial lamp-life period.

High mast lighting is new and better attention is given to maintenance. The three means of reaching the luminaires are; 1. steps, requiring personnel to climb the pole, 2. service car, to transport the worker to the pole top, and 3. lowering device, to bring the luminaire to ground level. The lowering device is the most accepted at this time. The clear mercury lamp is the most accepted for conventional highway illumination. Its color is blue-green light that does not die but just fades away at 24,000 hours. This lamp will operate on a mercury or halide ballast.

The metal halide lamp is generally used for high mast installations. Some trouble is being experienced in color balance of the temperamental action of the halides. Lamp of the same production may have a pink or green tint. This does not effect the resultant light. It does however indicate near end of 10,000 hour life when it changes to a noticeable green. This lamp may not operate satisfactorily unless used with a ballast of the same manufacturer. This lamp will not operate on a mercury ballast.

The high pressure sodium lamp, strong in yellow, is being used for conventional and high mast lighting. The States using this lamp are well pleased while some States are heistant because of its yellow trend. The lamp shows good possibilities for increased usage. The ballast pack includes a high voltage starter required for the lamp. The life of the 400 watt lamp is now 15,000 hours while the new 1000 watt is only 8,000 hours. Failure of the lamp is noted by cycling.

These comments are only a few of the facts regarding highway lighting maintenance. Its purpose is to alert you to the maintenance needs and to exchange your experiences with others. An Area Engineer in the Iowa Division put his thoughts in a very good article for last December's issue of Public [illegible]is.

CALCULATIONS PHOTOMETRIC DATA METHOD

BEAM LUMEN METHOD — Using Floodlight Performance Data

Most floodlights are rated in beam lumens. Beam lumens include only the lumens in that part of the beam in which the candela values are 10% or more of the average maximum candela.

Beam lumens = Lamp Lumens × Beam Efficiency.

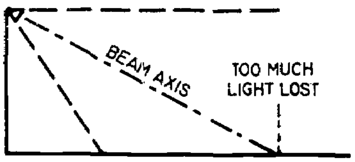
UF (utilization factor) is the ratio of the lumens effectively lighting an area to the total available beam lumens, expressed as a decimal.

The basic equation for calculating average illumination to be expected from any given number of luminaires is:

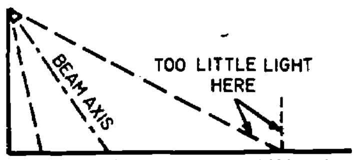
$$fc = \frac{N(BL)(UF)(MF)}{A} \quad \text{or} \quad N = \frac{fc(A)}{(BL)(UF)(MF)}$$

where:

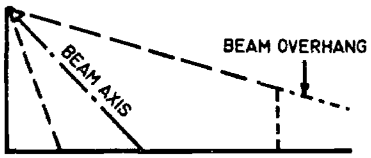
- **fc** illumination in footcandles
- **N** number of luminaires
- **BL** beam lumens of each luminaire
- **UF** utilization of beam lumens
- **MF‡** maintenance factor
- **A** size of area to be lighted in square feet



When a floodlight is pointed so that its axis is aimed at the far boundary, considerable light is lost.

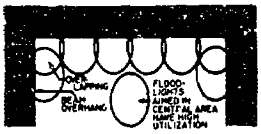


If the top of the beam is aimed at the field boundary, too little light reaches the area at the perimeter.



Pointing the floodlight somewhere between these two extremes is a practical compromise.

Floodlights aimed toward the center of an area as shown have 100% (beam lumen) utilization since all of their beam lumens fall on the area. Those aimed toward the perimeter may vary from 0.40 to 0.90 in utilization depending upon their position.



From this the following approximations can be made:

1. If half, or more than half, of the floodlights are aimed so that all their lumens fall within an area, the overall utilization factor will be about 0.75.
2. If from one-quarter to one-half of the floodlights are aimed so that all their beam lumens fall within an area, the overall utilization factor will be about 0.60.
3. If less than one-quarter of the floodlights can be aimed so that their beam lumens fall within an area, the overall utilization factor is likely to be not more than 0.40.

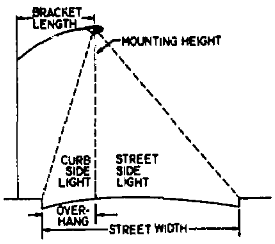
Most roadway luminaires have performance data expressed in terms of a **coefficient of utilization.** The cu takes into account the light distribution curve of the luminaires, its efficiency of light output and conditions of use. The coefficient of utilization curve is plotted as a percentage of usable light for various ratios of lateral distance (street and curb side) to the mounting height.

The basic equation for calculating average illumination to be expected from any given number of luminaires is:

$$fc = \frac{N\,(LL)\,(cu)\,(MF)}{L \times W} \quad \text{or} \quad N = \frac{fc\,(L \times W)}{(LL)\,(cu)\,(MF)}$$

where:

- **fc** illumination in footcandles
- **N** effective number of luminaires contributing
- **LL** rated initial lamp lumens
- **cu** coeffecient of utilization
- **MF‡** maintenance factor
- **L** length of area being lighted (in feet)
- **W** width of area being lighted (in feet)



GUIDE FOR LUMINAIRE LATERAL LIGHT DISTRIBUTION TYPE SELECTION AND PLACEMENT ▽

The American National Standard Practice for Roadway Lighting published by the Illuminating Engineering Society classifies luminaires according to their light distribution pattern. In an attempt to assist the practicing application engineer the following table has been prepared as a guide for "Type" selection and placement of luminaires.

Rectangular Roadway Area					
Side of the Roadway Mounting			**Center of the Roadway Mounting**		
One Side or Staggered	**Staggered or Opposite**	**Grade Intersections□**	**Single Roadway**	**Twin Roadways (Median Mtg.)**	**Grade Intersections□**
Width up to 1.5 MH	Width beyond 1.5 MH	Width up to 1.5 MH	Width up to 2.0 MH	Width up to 1.5 MH (each pavement)	Width up to 2.0 MH
Types II-III-IV	Types II & IV	Type II 4-Way	Type I	Types II & III	Types I 4-Way & V

□ Local Category Intersection.

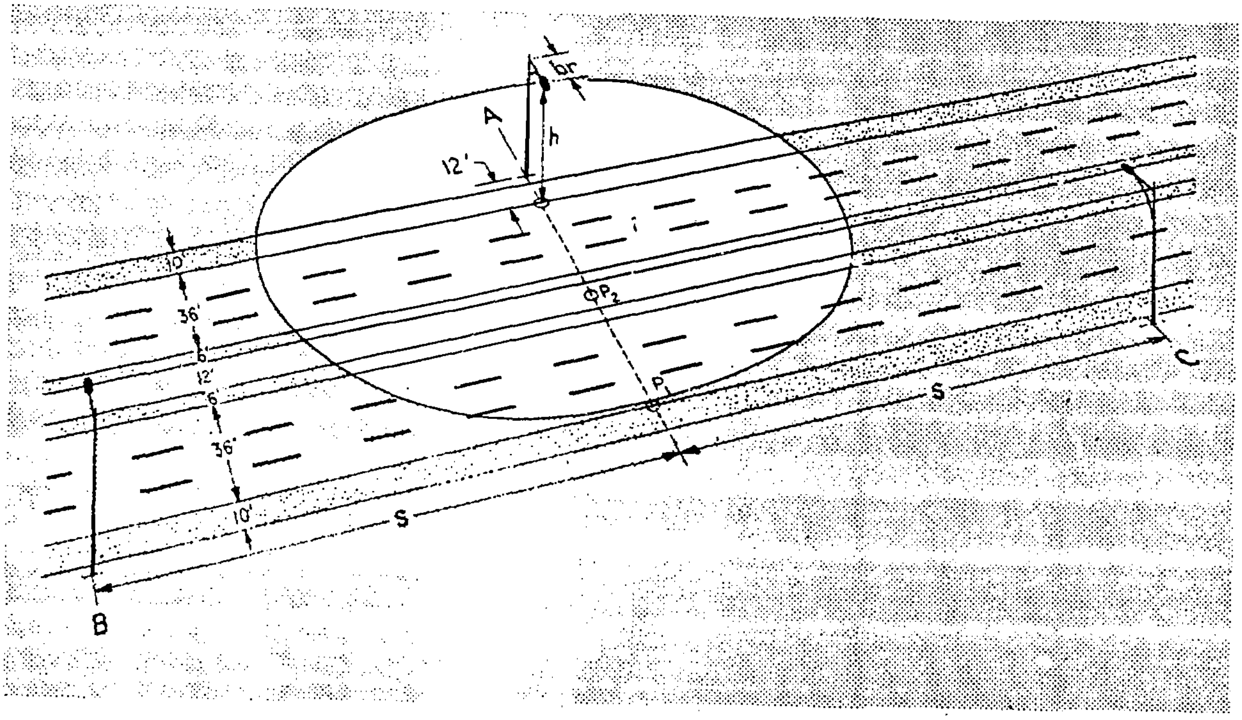
▽The user of this table is cautioned that it is only a guide to be used for preliminary design and trial calculations. Often times the designer will discover that a distribution different than the one suggested by the table will accomplish the design criteria better. This is quite often the case in borderline situations. This occurs because all luminaires carrying the same classification are not identical in performance when applied to a particular situation. System performance is of prime importance. Generally, skilled engineering judgment must be exercised when comparing different luminaire light distributions for a specific system. It may not be judicious to specify only one Type distribution when it is obvious that several Types will provide equivalent performance for a specific application.

‡ MF (maintenance factor) is an allowance for lamp lumen depreciation (LLD) with life, and luminaire dirt depreciation (LDD) due to the collection of dirt on lamp, reflector, and cover glass. (Refer to page 60.)

HIGHWAY ILLUMINATION DESIGN

SAMPLE CALCULATIONS
CONVENTIONAL FREEWAY LIGHTING

TYPICAL SECTION



A. PROBLEM: Design the illumination of an Interstate highway located in an urban area. The section has six 12 foot lanes, a 24 foot medium, two 10 foot shoulders and is without entrance or exit ramps.

B. DETERMINE: First, the level of illumination and the uniformity required. Second, the light source, luminaire, mounting height, pole location, bracket length, and spacing to meet the requirements.

C. AIDS:
1. AASHO Guide for Roadway Lighting.
2. IES Recommended Practice (ANSI)
3. Manufacturer's Photometric Data.

D. CALCULATION:

1. Level of illumination and uniformity -

   0.6 fc (footcandles) average maintained horizontal with uniformity ratio of 3:1 to minimum point. (1969 AASHO Guide, page 7, recommends 0.6 to 0.8 average footcandles with 3:1 to 4:1 ratio as reasonable)

2. Light source -

   1000 watt clear mercury vapor (56,000 lumens)
   400 watt high pressure sodium vapor (47,000 lumens)

3. Luminaire -

   Medium, semi-cutoff, Type IV (Mfg. Photometrics)

4. Mounting height -

   MH = 50 feet above the traveled way (IES Recommended Practice - 1972)

5. Pole location -

   12' from edge of traveled lanes with appropriate safety provisions. (Preferably 30' when practicable)

6. Bracket Length -

   Adequate to position luminaire approximately at edge of traveled lanes.

7. Spacing and Uniformity -

   a. <u>1000 Watt Mercury</u>

   Photometric data, reference curve: 35-175039-00
   Maintenance Factor:
   Lamp Lumen Depreciation LLD = 70%
   Luminaire Dirt Depreciation LDD = 90%
   Combined Maintenance Factor MF = 63%

   Ratio Transverse distance to mounting height:

   $$RT = \frac{\text{width}}{\text{height}} = \frac{96}{50} = 1.92$$

   Coefficient of Utilization:
   CU = 0.44 (Photometric Curve)

   Spacing:

   $$S = \frac{\text{Lumens x Depreciation x Utilization}}{\text{Level of illumination x Width}}$$

   $$= \frac{56000 \times .70 \times .90 \times .44}{0.60 \times 96} = 270 \text{ feet}$$

Uniformity:

Try point P_1 for minimum illumination with light from luminaires A, B, and C.

Isofootcandle curve correction for lamp lumens and mounting height.

$$CF = \frac{\text{actual lamp lumens}}{\text{lumens shown on curve}} \times \frac{(\text{MH on curve})^2}{(\text{actual MH})^2}$$

$$= \frac{56000}{56000} \times \frac{(30)^2}{(50)^2} = 0.36$$

E = fc (curve for RT & RL) x CF x MF

From luminaire A -

RT - Ratio Transverse = 96/50 - 1.92
RL - Ratio Longitudinal = 0/50 = 0
Reading 0.8 fc (curve)
E_{PA} = 0.8 x 0.36 x 0.63 = 0.1814 fc

From luminaire B -

RT = 0/50 = 0

RL = 270/50 = 5.4

Reading 0.035 fc (curve)

E_{PB} = 0.035 x 0.36 x 0.63 = 0.0079

E_{PC} = Same as E_{PB}

$E_P = E_{PA} + E_{PB} + E_{PC}$

= 0.1814 + 0.0079 + 0.0079

= 0.197

U = 0.6/0.197 = 3.04 to 1

b. <u>High Pressure Sodium</u> - 400 watts

Photometric data, reference curve 35-174846-00(02)
Maintenance Factor:

$MF = 0.69$

Ratio Transverse:

$RT = 96/50 = 1.92$

Coefficient of Utilization:

$CU = 0.54$ (curve)

Spacing:

$$S = \frac{47,000 \times 0.69 \times 0.54}{0.6 \times 96} = 304 \text{ (use 300)}$$

$$E = 0.6 \times \frac{304}{300} = 0.607$$

Correction Factor:

$$CF = \frac{47000}{42000} \times \frac{(30)^2}{(50)^2} = 0.403$$

Illumination at P_1

From luminaire A -

$RT = 96/50 = 1.92$
$RL = 0/50 = 0$
$E_{PA} = 0.8 \times 0.403 \times 0.69 = 0.222$

From luminaire B -

$RT = 0$
$RL = 300/50 = 6.0$
E_{PB} & $E_{PC} = 0$

$E_{P1} = 0.222$

Illumination at P_3 (Edge of traveled way and shoulder halfway between luminaires)

From luminaire A -
$RT = 96/50 = 1.92$
$RL = 150/50 = 3.00$
$E_{PA} = 0.4 \times 0.403 \times 0.69 = 0.111$

From luminaire B -
$RT = 0/50 = 0$
$RL = 150/50 = 3.00$
$E_{PB} = 0.1 \times 0.403 \times 0.69 = 0.028$
$E_{P3} = 0.111 + 0.028 = 0.139$
U.R. = 0.607/0.139 = 4.4 to 1 (<u>NOT</u> acceptable)

c. High Pressure Sodium - 400 watts

Photometric data reference curve 35-174846-00(02)
(level of illumination 0.7 fc, average maintained)

MF = 0.69
RT = 96/50 = 1.92
CU = 0.54 (curve)

$$S = \frac{47{,}000 \times 0.69 \times 0.54}{0.7 \times 96} = 260$$

$$CF = \frac{47000}{42000} \times \frac{(30)^2}{(50)^2} = 0.403$$

Illumination at P_1

From luminaire A -
RT = 96/50 = 1.92
RL = 0/50 = 0
E_{PA} = 0.8 x 0.403 x 0.69 - 0.222

From luminaire B -
RT = 0/50 = 0
RL = 260/50 = 5.2
E_{PB} & E_{PA} = 0
E_{P1} = 0.220

Illumination at P_3 (Edge of traveled way and shoulder half way between luminaires)

From luminaire A -
RT = 96/50 = 1.92
RL = 130/50 = 2.6
E_{PA} = 0.5 x 0.403 x 0.69 = 0.135

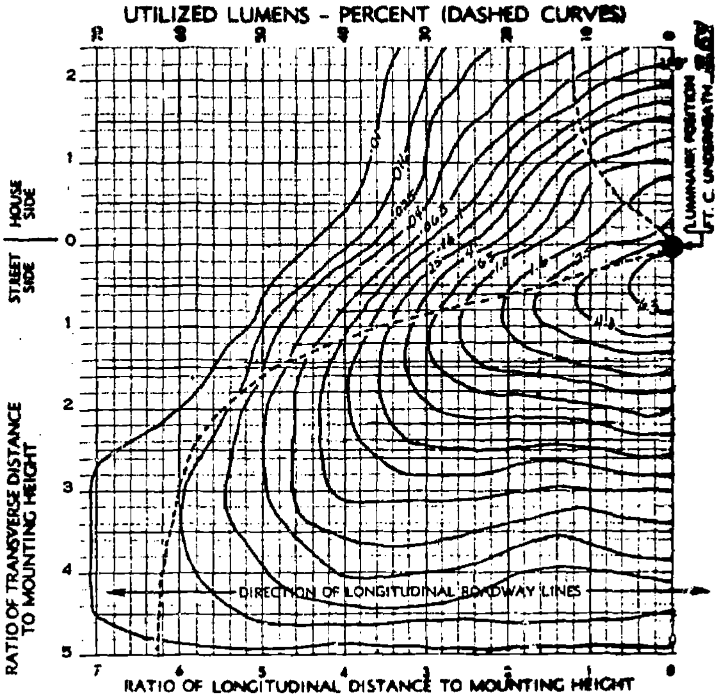
From luminaire B -
RT = 0/50 = 0
RL = 130/50 = 2.6
E_{PB} = 0.23 x 0.403 x 0.69 = 0.0635
E_{PC} = 0

E_{P3} = 0.135 + 0.0635 = 0.1985

U = 0.7/0.1985 = 3.5 to 1

PHOTOMETRIC DATA

ISOFOOTCANDLE & UTILIZATION CURVES



VALUES OF ISOCANDELA, LUMENS, AND FOOTCANDLES ARE BASED UPON A LAMP OPERATED AT 42,000 LUMENS.

FOOTCANDLE DATA IS BASED ON A LUMINAIRE MOUNTING HEIGHT OF 30 FEET.

ASA/IES TYPE MEDIUM, SEMI-CUTOFF, TYPE IV

LAMP – 400 WATT LUCALOX
ASA No.

NUMBER 35-174846-00 | REV NO 02

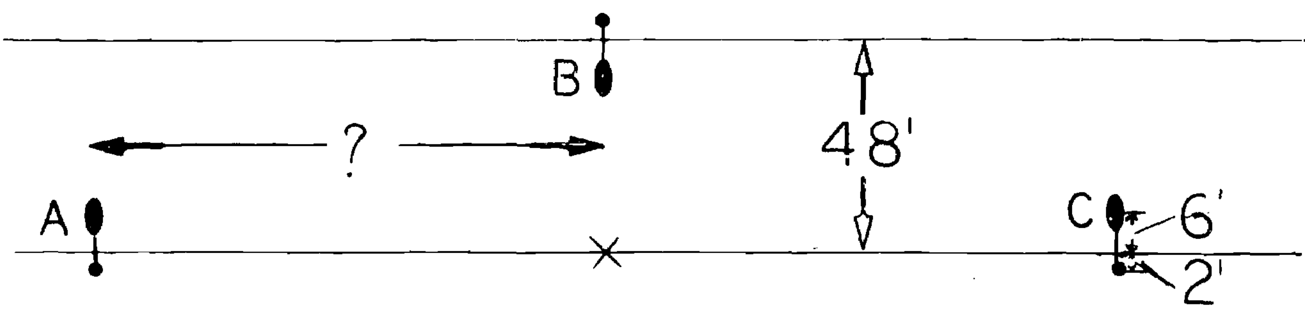
Highway Lighting Design
Class Group Problem
Major Street Lighting

Problem: Design the illumination of a four lane major street on an intermediate traffic area.

The recommendation for average maintained horizontal footcandles, illumination shall be 1.2 foot candles and the lowest foot candle value at any point on the pavement shall not be less than one-third the average value. (Page 11, "American Standard Practice for Roadway Lighting")

Other conditions are:
8 foot brackets
2 foot set back
48 foot curb to curb street width
30 foot mounting height
400 watt H33-1-CD clear mercury lamp (20,500 lumens)
Maintenance Factor = (LLD x LDD) = .70 x .90 = .63

Calculate (a) Staggered spacing required to provide 1.2 foot candles maintained.
(b) Ratio of average to minimum illumination.



Highway Lighting Design
Class Group Problem
Major Street Lighting
Answer Sheet

$$\text{Spacing} = \frac{(\text{Lamp Lumens}) \times (\text{Utilization Factor}) \times (\text{Maintenance Factor})}{(\text{Foot Candles}) \times (\text{Width})}$$

(a) Determine the coefficient of utilization for the "Street" side of the luminaire

$$R_S = \frac{48\text{ Feet} - 6\text{ Feet}}{30\text{ Feet}} = \frac{42\text{ Feet}}{30\text{ Feet}} = 1.4$$

Coefficient of utilization from curve is 0.48

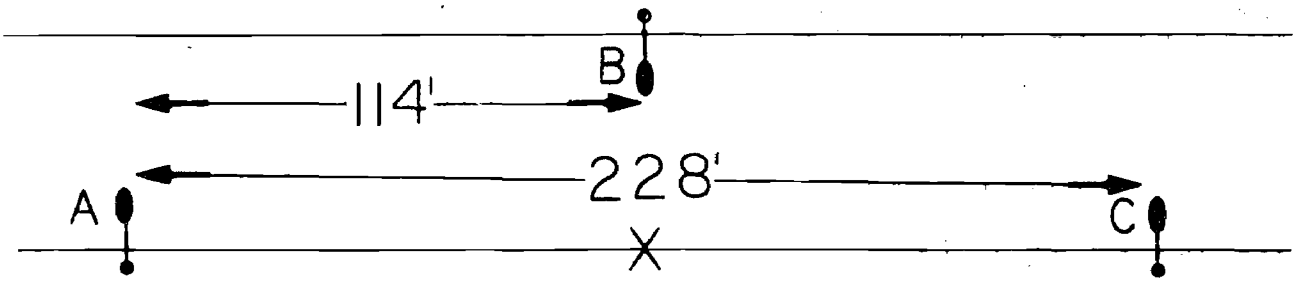
Determine the coefficient of utilization for the house side of the luminaire

$$R_H = \frac{6\text{ Feet}}{30\text{ Feet}} = 0.2$$

Coefficient of utilization from curve is 0.03

Total coefficient for street side plus house side is 0.48 plus 0.03 or 0.51

$$\text{Spacing} = \frac{20.500 \times 0.51 \times 63}{1.2 \times 48} = 114\text{ Ft.}$$



(b) Ratio of average to minimum maintained (illumination assuming point x is minimum point)

Luminaire	Trans. Ratio Point X	Long Ratio Point X	Foot-Candles Point X
B	$\frac{42}{30} = 1.4$	0	0.5
A	$\frac{6}{30} = 0.2$	$\frac{114}{30} = 3.82$	0.04
C	Same	Same	0.04
			0.58 Total

Illumination at x - 0.58 x .63 = 0.37 (maintained)
Uniformity = 1.2/0.37 = 3.25 to 1
Both design criteria are satisfied

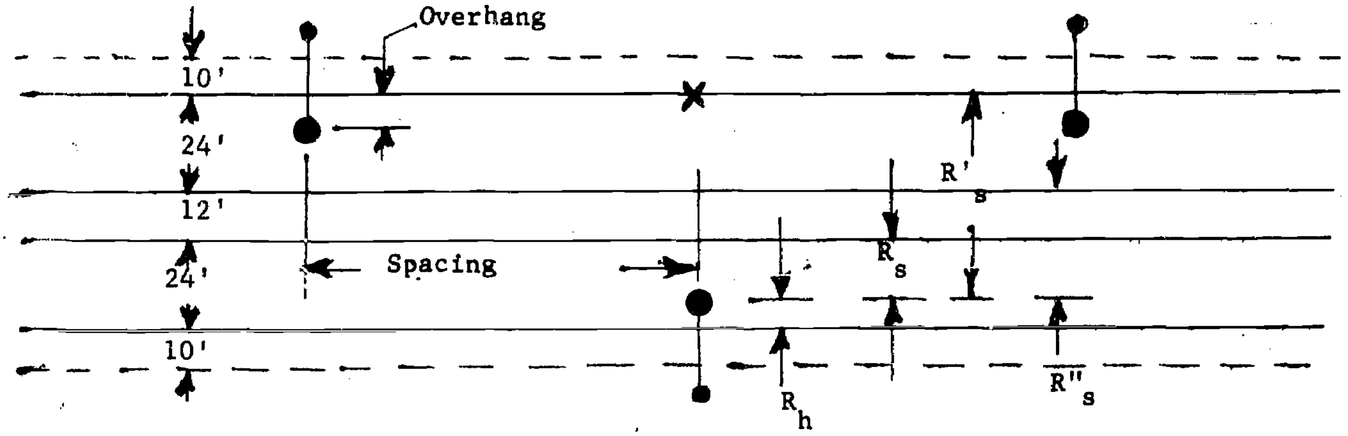
Highway Lighting Design
Class Group Problem
Highway Lighting

PROBLEM: Design the illumination of a four-lane highway with a 12-ft. median. Other conditions are:

- 10-ft. shoulders
- 15-ft. brackets
- 2-ft. setback off shoulder
- 400-watt H33-1CD mercury lamp (19,500 lumens)
- 40-ft. mounting height
- Photometric Data - page 2
- Maint. factor = (LLD x LDD) = (.70) x (.90) = 0.63

CALCULATE:

(a) Staggered spacing required to provide 0.6 fc maintained (include light falling on median)
(b) Staggered spacing required to provide 0.6 fc maintained (DO NOT include light falling on median)
(c) Opposite spacing required to provide 0.6 fc maintained
(d) Illumination at a point half-way between adjacent luminaires on one side at pavement-and-shoulder junction shown by X in the sketch.
(e) Ratio of average to minimum illumination



Highway Lighting Design
Class Group Problem
Answer Sheet

Average fc = $\frac{\text{(lamp lumens)} \times \text{(utilization factor)} \times \text{(Maint. factor)}}{\text{(spacing)} \times \text{(width)}}$

R_h = 3/40 = 0.075	UF_h = 1%
R_s = 21/40 = 0.525	UF_s = 23%
R'_s = 57/40 = 1.425	UF'_s = 48%
R''_s = 33/40 = 0.825	UF''_s = 35%

Part (a)

Utilization factor = $UF_h + UF'_s$ = 1 + 48 = 49%

Spacing = $\frac{\text{(LL)} \times \text{(UF)} \times \text{(MF)}}{\text{(fc)} \times \text{(W)}} = \frac{19{,}500 \times .49 \times .63}{0.6 \times 60}$ = 167 feet

Part (b)

Utilization factor = $(UF_h + UF_s) + (UF'_s - UF''_s)$

= (1 + 23) + (48 - 35) = 37%

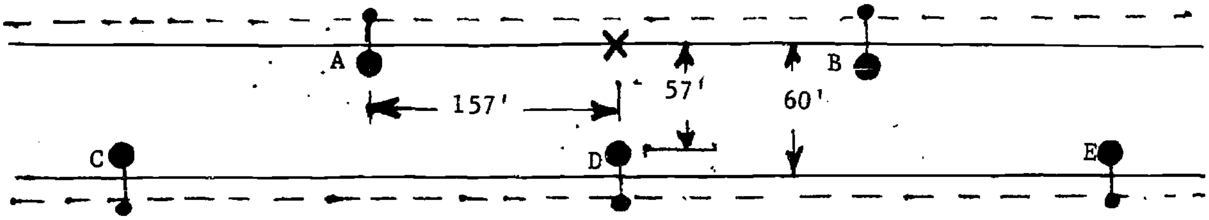
Spacing = $\frac{\text{(LL)} \times \text{(UF)} \times \text{(MF)}}{\text{(fc)} \times \text{(W)}} = \frac{19{,}500 \times .37 \times .63}{0.6 \times 48}$ = 157 feet

Part (c)

Opposite Spacing = 2 x staggered = 314 feet

Part (d)

Staggered arrangement

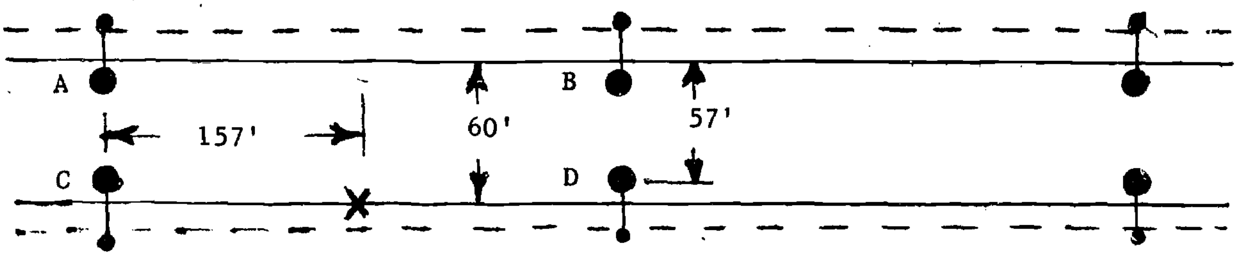


Luminaire	Trans. Ratio Point X	Long Ratio Point X	FC Point X
A	-3/40 = -.075	157/40 = 3.925	0.05
B	Same		0.05
C	57/40 = 1.425	314/40 = 7.85	.01
D	1.425	0	.48
E	1.425	7.85	.01
			.60

Correction for 40 ft. MH = $(30/40)^2$ = .56

Correction Lamp Factor (19,500/20,500) = .953

Illumination at X = .56 x .953 x .63 x .60 = 0.202 fc



Luminaire	Trans. Ratio Point X	Long Ratio Point X	FC Point X
A	57/40 = 1.425	157/40 = 3.95	.15
B	Same		.15
C	-3/40 = -0.075	157/40 = 3.95	.05
D	Same		.05
			.40

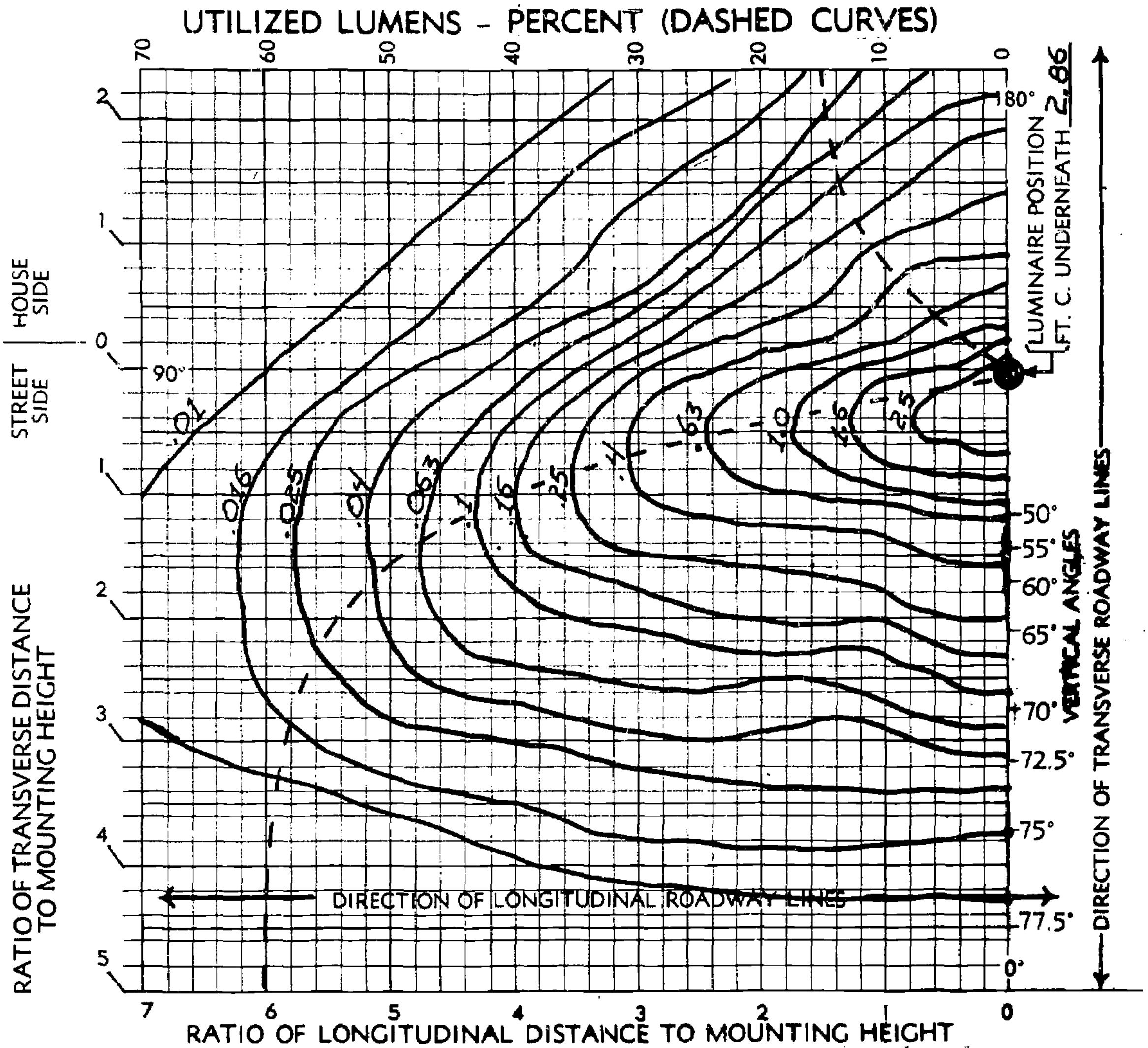
Illumination at X = .56 x .953 x .63 x .40 = 0.134

Part (e)

Ratio of average to minimum, maintained illumination (Assuming point X is minimum point -- this may not be the case)

Uniformity staggered arrangement = 0.6/0.202 = 3.0
Uniformity opposite arrangement = 0.6/.134 = 4.4

ISOFOOTCANDLE & UTILIZATION CURVES



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

LIGHT FLUX VALUES		
	LUMENS	PERCENT OF LAMP
DOWNWARD STREET SIDE	12480	60.9
UPWARD STREET SIDE	330	1.6
DOWNWARD HOUSE SIDE	3380	16.5
UPWARD HOUSE SIDE	210	1.0
TOTAL	16400	80.0

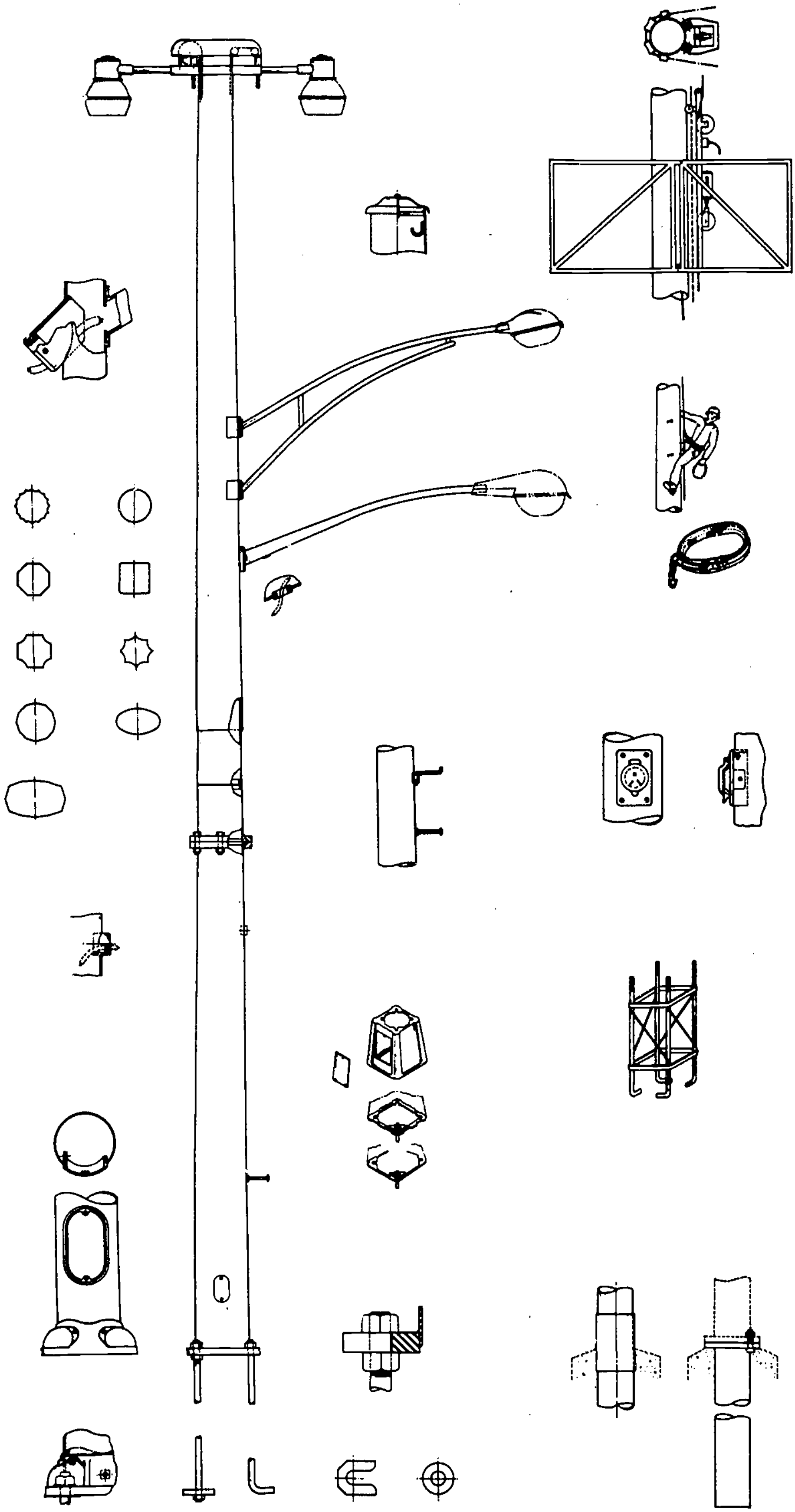
LAMP – 400 WATT CLEAR MERCURY
ASA No. H33-ICD
G.E. No. H400A33-1
20500 LUMENS.

ASA/IES TYPE
MEDIUM-SEMICUTOFF- TYPE III

Lighting Guides, Standards and Directives

The following items are the principle references which deal with street and highway lighting:

1. An Informational Guide for Roadway Lighting, 1969, AASHO.
2. IM 40-2-71, Participation in Highway Lighting. This Instructional Memorandum supersedes IM 40-2-65, issued October 1, 1965, and provides a basis for determining Federal-aid fund participation in the cost of installing lighting for all projects on Federal-aid highway systems.
3. PPM 40-2 designates the AASHO Informational Guide for Roadway Lighting as acceptable for application in the design of Federal-aid highways and in connection with traffic operating on these highways.
4. PPM 21-18 and other applicable directives relating to TOPICS projects.
5. A 1972 ANSI Standard Practice for Roadway Lighting, superseding the 1963 edition, is a design guide for roadway lighting. The recommended levels of illumination and uniformity in the new Standard Practice are largely the same as the criteria in the earlier issue. The same fact is true with respect to information in the AASHO Guide.
6. Highway Safety Programs Standard No. 12, Highway Design, Construction and Maintenance.
7. IM 21-6-66, Safety Provisions for Roadside Features and Appurtenances.
8. IM 21-11-67 and IM 21-11-67(1). Same subject as item 7.
9. IM 21-14-67, Application of Highway Safety Measures.
10. CM dated June 5, 1968, Application of Highway Safety Measures - Breakaway Luminaire Supports.
11. FHWA Notice dated November 16, 1970. Same subject as item 10.
12. IM 30-4-71, Federal-Aid Participation - Utility Installations Serving a Highway Purpose.
13. FHWA Notice dated May 17, 1972, High Mast Lighting. This Notice removes high mast lighting from the experimental category and it transmits a summary of available reports on high mast installations. It provides procedures for approval of high mast lighting as a standard construction item.



Union Metal Outdoor Lighting Lithograph 9/27/71

LUMINAIRE SUPPORTS
HIGHWAY ILLUMINATION

BREAKAWAY FEATURES

The first direct safety order concerning roadside signs and light poles following the President's Safety Message of March 1966 is IM 21-14-67. It states in affect "no rigid fixed sign supports or light poles are to be authorized along a Federal-aid route for installation in exposed areas where it would be practical to utilize a yielding or breakaway type of design." This requirement made the need apparent for guidelines to determine the yielding or breakaway characteristics of sign or luminaire supports.

Circular Memorandum of June 5, 1968 "Application of Highway Safety Measures - Breakaway Luminaire Supports" acknowledged the need for guidelines and noted that detail criteria for this was lacking. Based on TTI and U. of Miami full-scale tests specific steel and aluminum poles with cast aluminum transformer or shoe base were considered to meet the requirements of IM 21-14-67. The CM determined generally that if a State is satisfied from available data that a pole will yield or breakaway with a change in momentum less than 1100 pound seconds and submit such conclusion with a request for approval, such pole can be considered as having breakaway features. This was interim procedure based on full scale tests.

A dynamic laboratory test was developed to reduce testing costs. This showed the change in momentum to be substantially lower than in full-scale tests. FHWA Notice of November 16, 1970, was issued to take this into account for guidelines. The Notice made no change in criteria for full-scale tests but permitted dynamic tests in lieu of full scale tests for poles not exceeding 50 feet or 700 pounds. This test required a 2000 pound pendulum, or equivalent means, to strike a pole at 20 MPH and at an impact point of 20" from the mounting base. Poles producing a change in momentum of 400 pound-seconds or less shall be considered evidence of acceptable breakaway features. Supports not meeting the dynamic test may be accepted if they meet the full-scale test requirements. This FHWA Notice is the guide at this time.

HRB Report 77 evaluates "safe" luminaire supports in the broad classifications of: (1) aluminum shoe base, (2) progressive-shear base, (3) frangible insert base, and (4) the slip joint. These are ranked in order of most severe to least severe in vehicle collisions.

The aluminum shoe base is with an aluminum shaft and is considered the most severe in collisions. The failure of the support often occurs in the shaft and at the hand-hole as well as pulling from the base or fracturing the base.

The first configuration of the progressive -- shear base was a complete assembly, base and shaft of stainless steel riveted to a base plate with stainless steel rivets. The latest design replaces the rivets with button welds.

Frangible insert bases include a large variety of types, the most general and second in safety to the slip-joint is the cast aluminum transformer base. The base itself is usually struck by the vehicle bumper and little if any damage is done to the shaft. A modification of this is the cast aluminum insert which differs in its height being a quarter to a third of that of the transformer base.

The notched bolt and notched coupling come in the frangible classification. These are simply inserts placed on each anchor bolt and notched down to approximately half diameter of the insert. The advantage of these is in conversions to safety features without disturbing the existing electrical wiring. Other methods require a wiring conversion kit to lengthen or break the cable.

The slip joints in both the 3-bolt and 4-bolt types are the most reliable and result in the least severity damage of the safety bases. The two precautions with the use of the slip joint is the need for a keeper plate to hold the bolts in place with vibration and not using excessive torque on the nuts holding the plates together. These are the most important maintenance considerations.

Both the frangible insert type and slip-joint type can be used with either steel or aluminum shafts. Breakaway standards should not be used where they may cause a secondary accident more severe than the primary collision. This applies to heavy pedestrian traffic areas and where there is a possibility of the support or luminaire coming to rest in a traffic lane. Low velocity collisions (35 MPH or less) are the most hazardous with breakaway concepts.

Finally, the priority for providing safe roadside supports is (1) Remove all standards, (2) move 30 feet from traveled way, (3) use breakaway standards, and last (4) provide guardrails.

HIGHWAY SIGNS
ILLUMINATION

There are 251 sections in the MUTCD dealing with highway signs. These sections provide uniform standards for the appropriate message, the proper letters, the related symbols, the best color combinations, the proportionate size, the sign locations, and the sign supports. This is all essential for day time when there is three-fourths of the total traffic on the roads. There are only 2 of these 251 sections that deal with illumination, the added need for the night fourth of the total traffic.

The requirement of one of the illumination sections is "Regulatory and warning signs, unless excepted in the standards covering a particular sign or group of signs, shall be reflectorized or illuminated to show the same shape and color both by day and night. All overhead sign installations should be illuminated where an engineering study shows that reflectorization will not perform effectively." The other related section gives the means of illumination as: 1. a light behind the sign face, 2. a light directed to the sign face, and 3. the luminous tubing on the sign face.

So far so good, but there are no uniform standards, here or elsewhere, for the amount of light needed and how to provide the light. A few of the States have specifications that vary widely while others depend on the headlights of automobiles. A great deal of research has been done in this field and now the IES Highway Sign Lighting Subcommittee is attempting to put this together in a "Recommended Practice." The Committee has made a good start in sending a resume' of highway sign illumination to its members for review. The paper even quoted figures that could be used as preliminary standards. This was done to provoke discussion and it did. The result was the chairman assigning certain sections to individual members and gave them a dead-line for their work.

The Illinois Division of Highways is conducting experiments dealing with the amount of light needed as standard requirements. The result will show the amount of light that is reflected from various sign surfaces, brightness in foot lamberts, when subjected to a know illumination in foot-candles. This is needed since the process in seeing is by reflected light, luminance, and not incident light, illumination. The difference between the two is known as the reflection factor. When the reflection factor is known, the illumination, footcandles, can be calculated to provide adequate lighting. The experiment will be continued by installing standard highway signs at several locations along highways and lighted themto varying brightnesses. A qualified team will observe these signs and visually decide on the best brightness.

The major lamp manufacturers have devised means of showing the color shift when the standard highway sign colors are viewed under various light sources. A paper presented at the July IES National Conference explained a method of establishing a Munsell designation to describe the appearance of a sign color under sodium light as compared with the same color under natural light. This means that two Munsell chips can be selected and one will show the color under natural light while the other will give the appearance of the same color under sodium light. This method can be used for any light source as well as sodium.

With the research that has been completed and the progress of the experiments now underway, it is believed that a preliminary draft of a "Recommended Practice for Highway Sign Lighting" will be completed for approval by the IES National Conference in July 1973 at Philadelphia.

HIGHWAY LIGHTING DESIGN

HIGH MAST ILLUMINATION CALCULATIONS

PROBLEM: Design the illumination of an Interstate highway interchange located near an urban area using the high mast system. (See Figure A)

DESIGN DATA: Maintained illumination - 0.6 f.c.
Uniformity - 3:1 to 4:1, average to minimum
Light source - 1000 watt metal halide (90,000 lumens)
Photometric Data - Use curve for Type V
Mounting height - 100 feet
Maintenance Factor (MF) - 59%

SOLUTION:

Step 1 - Assume that there will be 4 luminaires per pole. Design a template with all points on perimeter representing the minimum initial illumination that is required from 1 luminaire.

a. Min. maintained from 4 luminaires with overlap from adjacent pole = E/R=0.6/3 = 0.2 f.c.

b. Same for 1 pole = 0.2/2 = 0.1 f.c.

c. Initial illumination = Min./MF - 0.1/0.59 - 0.17 f.c.

d. Correction for MH - (none)

e. Initial min. 1 luminaire = 0.17/4 = 0.0425 f.c.

f. Photometric curve for 0.0425 = 3.0 (RT)

g. Distance transverse = RT x MH = 3 x 100 = 300 feet

h. A circle with a radius of 300 feet will cover an effective area of one pole.

Step 2 - Locate 300 foot radius circles at critical points, gore areas. Position to assure light on gore and not in direct line of drivers vision. (Overlay Figure B on Figure A using matching points △).

Step 3 - Fill-in interchange area by overlapping 300 foot radius circles using spacing between masts of approximately 500 feet. Higher intensities should be provided on gores and overpass while minimum intensities are permitted on interconnections (Overlay Figure C and then Figure D on Figure B. Figure D gives the better arrangement)

Step 4 - Calculate **average illumination** (f.c.)

$$\text{Illumination} = \frac{\text{Total lumens x CU x MF}}{\text{Area covered}}$$

Total lumens = 90,000 x 12 poles = 108 x 10^4

CU (Coefficient of Utilization) from curve = 60%

Area covered by circles =
(1330 x 1330) + 4 (π x 300^2) = 290 x 10^4

Area is determined by area of the 4 gore circles (4 π x 300^2) plus area of a square equal to remaining area covered by overlapping circles (1330' x 1330'). Overlay Figure E on Figure D and note that areas not covered, areas covered twice, and open areas will balance.

$$\text{Av. Illum.} = \frac{(108) \times (10^4)\ (0.60)\ (0.59)}{290 \times 10^4} = 0.132 \text{ f.c.}$$

Step 5 - Calculate illumination at random points.

Point P_1

From mast #1 (120')	- 0.316 (Curve V)
From mast #5 (370')	- 0.019
From mast #11 (460')	- 0.009
Total	- 0.344 x 0.59 = 0.203 f.c.

Point P_2

From mast #7 (250')	- 0.076
From mast #8 (240')	- 0.082
From mast #9 (240')	- 0.082
Total	- 0.240 x 0.59 = 0.142 f.c.

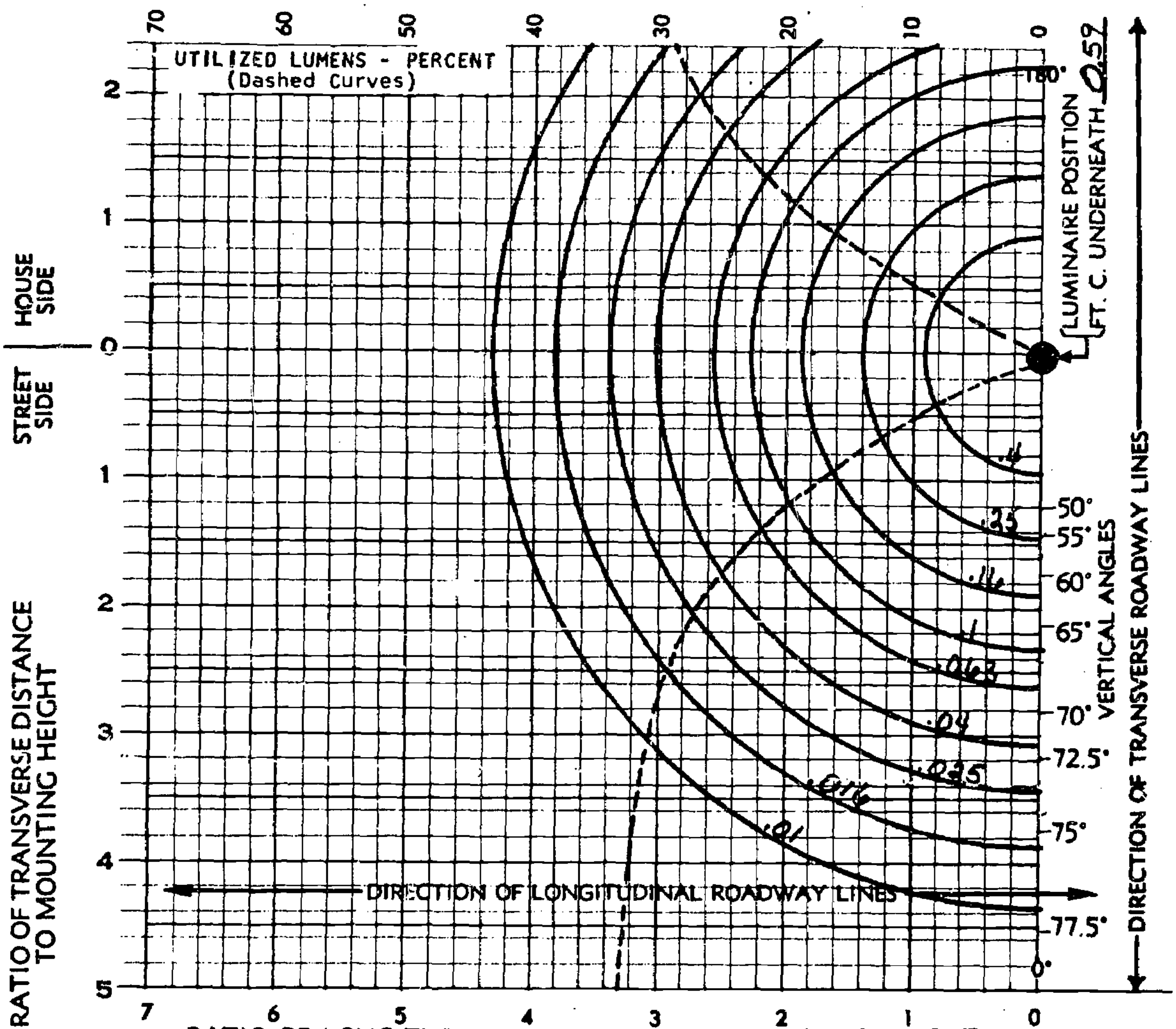
Point P_3

From mast #8 (320')	- 0.034
From mast #9 (320')	- 0.034
Total	- 0.068 x 0.59 = 0.04 f.c.

Step 6 - $\text{Uniformity} = \frac{\text{Average Illumination}}{\text{Minimum Illumination}} = \frac{0.132}{0.040}$

= 3.3 to 1

Step 7 - If 1 luminaire per mast will provide illumination of 0.132 f.c. then 5 luminaires per mast will be required to produce 0.66 f.c.



ISOFOOTCANDLE & UTILIZATION CURVES

90,000 LUMENS

FOOTCANDLE DATA IS BASED ON A LUMINAIRE MOUNTING HEIGHT OF 100 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.	60	70	80	90	100	110	120	130	140	150	175	200
FACTOR	2.78	2.04	1.56	1.23	1.00	0.83	0.69	0.59	0.51	0.44	0.33	0.25

PHOTOMETRIC DATA

TYPE - V

1000 WATT METAL HALIDE

HIGHWAY LIGHTING DESIGN

TYPICAL CLOVERLEAF INTERCHANGE

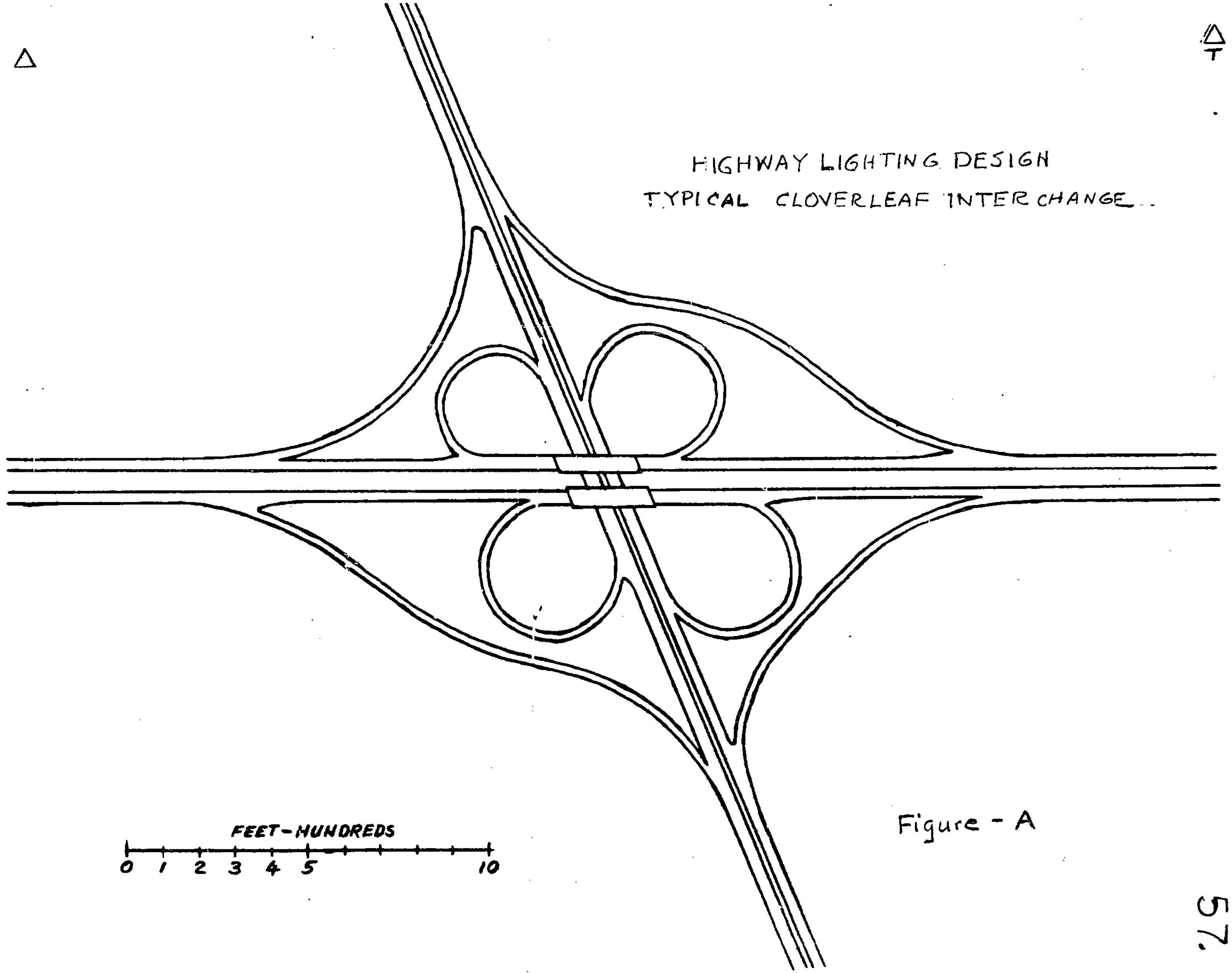
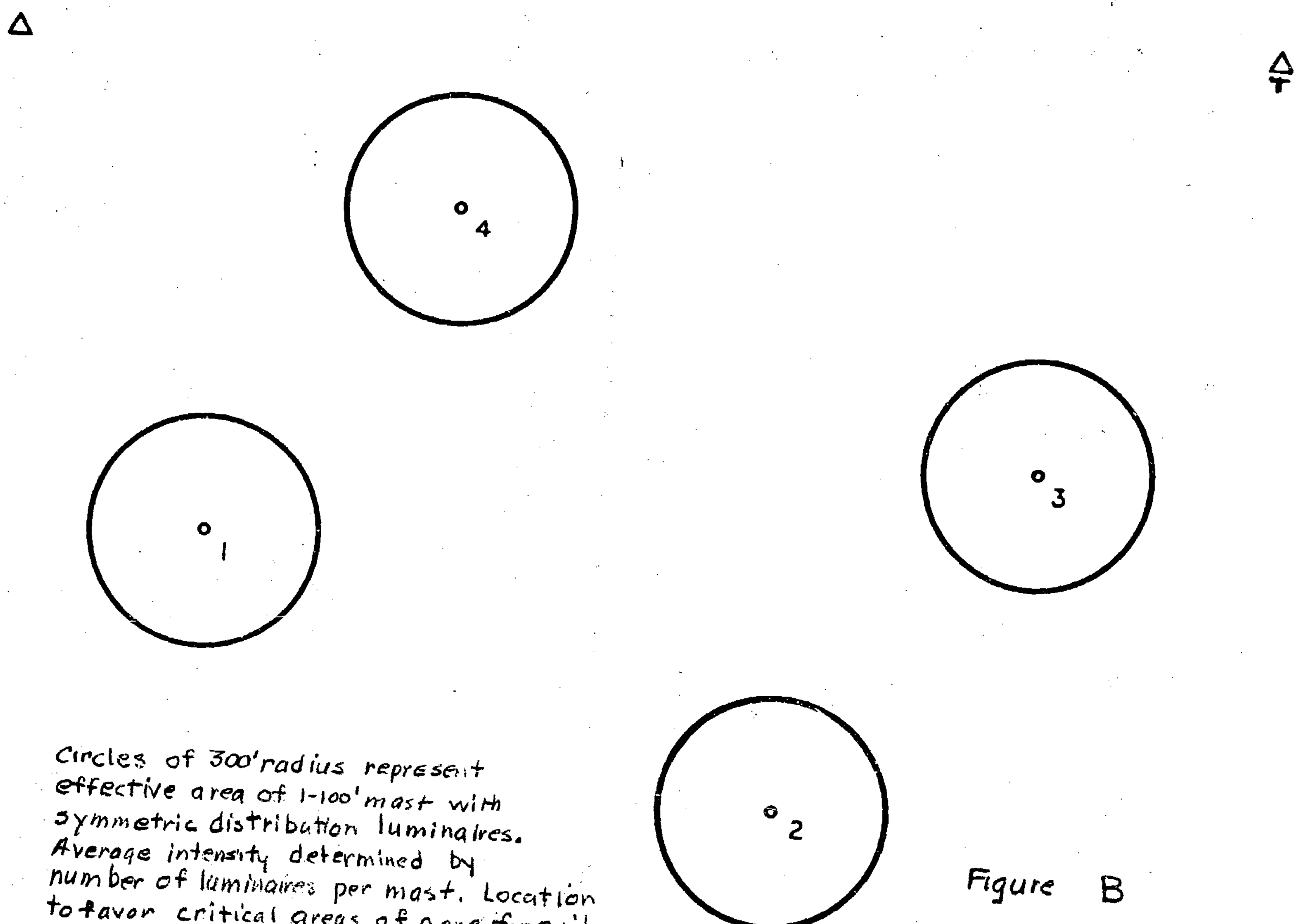
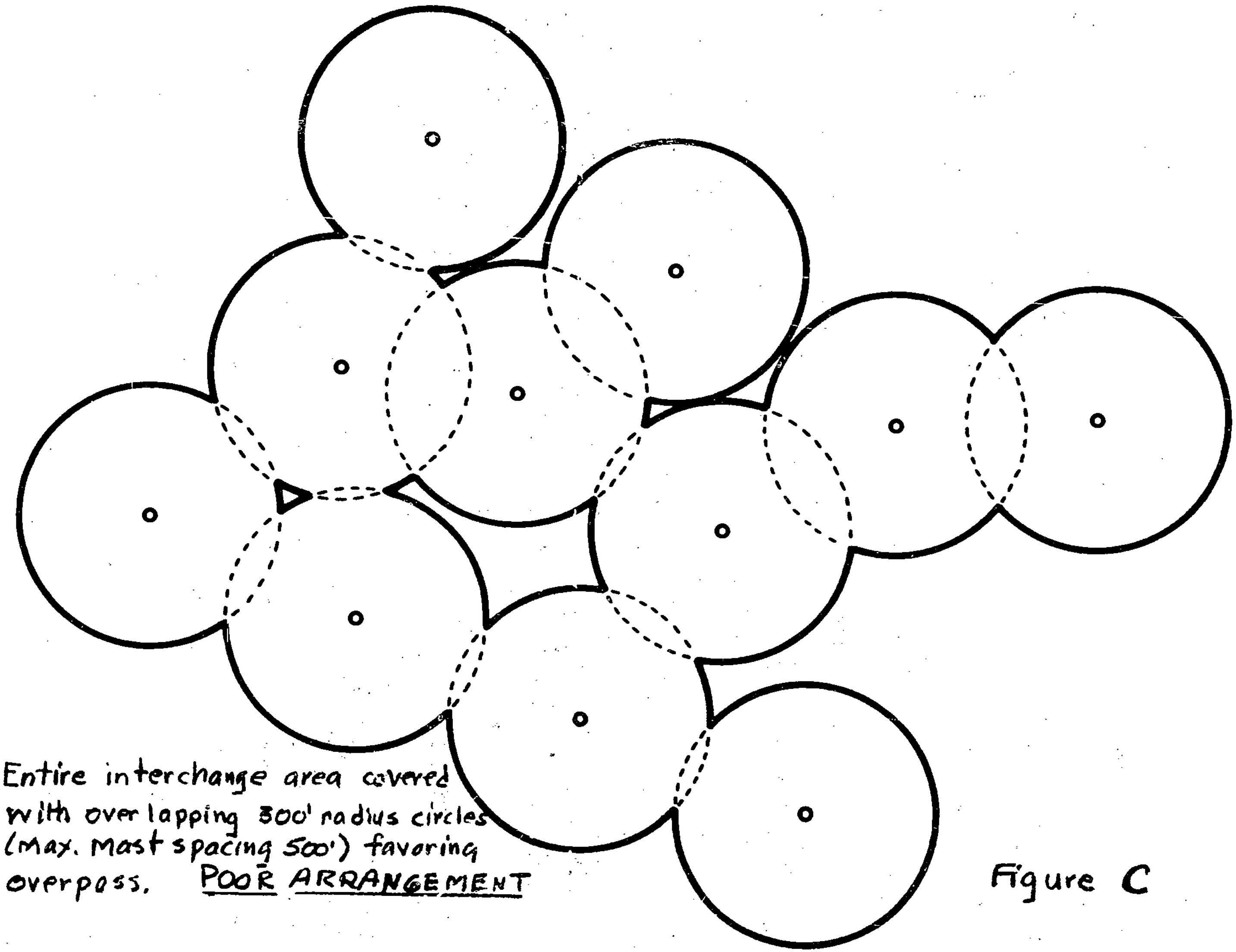


Figure - A



Circles of 300' radius represent effective area of 1-100' mast with symmetric distribution luminaires. Average intensity determined by number of luminaires per mast. Location to favor critical areas of qore for exit and entrance ramps.

Figure B



Entire interchange area covered with overlapping 300' radius circles (Max. Mast spacing 500') favoring overpass. POOR ARRANGEMENT

Figure C

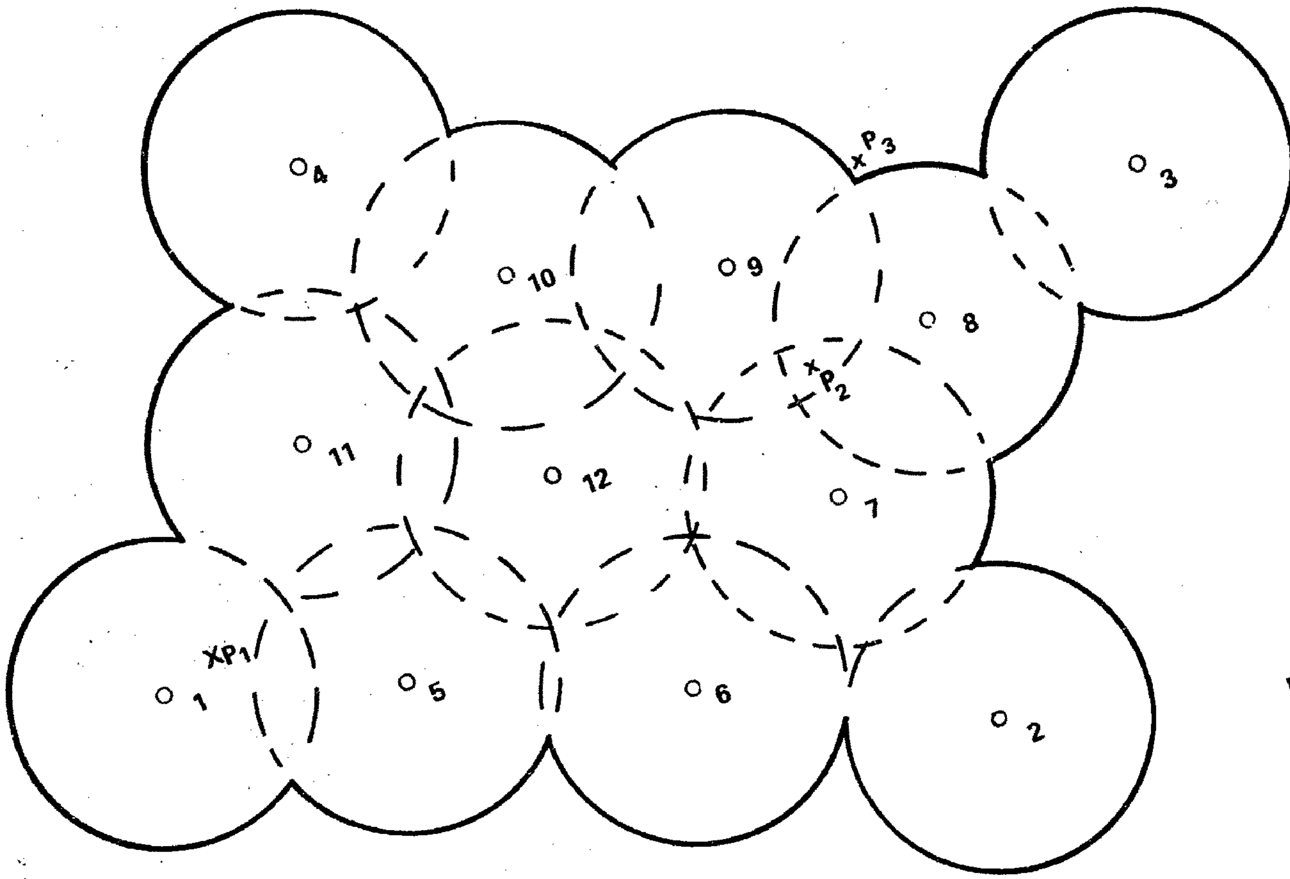


Figure D

Entire interchange area covered with overlapping 300 radius circles (Average mast spacing 500) favoring overpass. Acceptable Arrangement

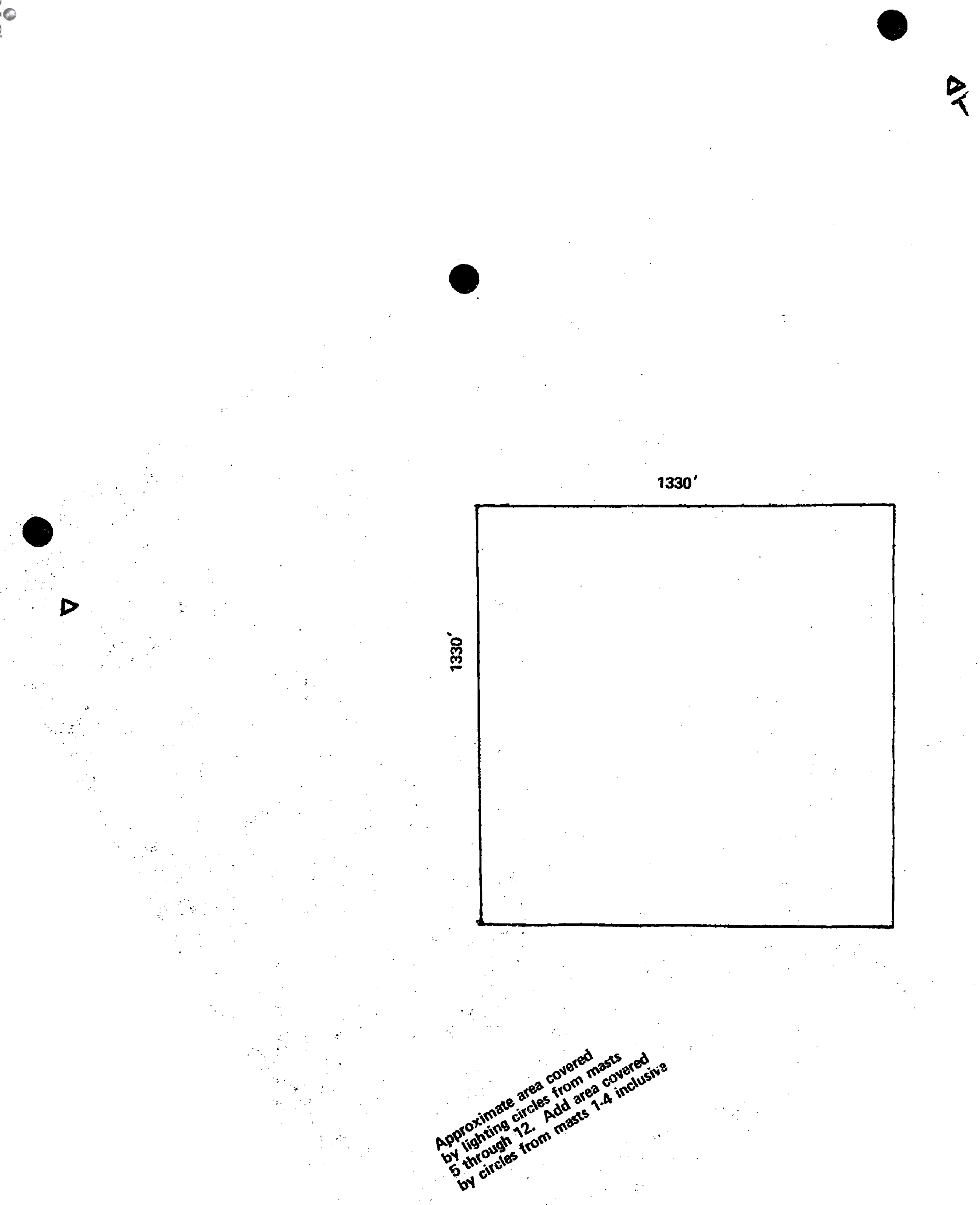

1330′
1330′
Approximate area covered
by lighting circles from masts
5 through 12. Add area covered
by circles from masts 1-4 inclusive

Figure E

Highway Lighting Design
Class Group Problem
High Mast Interchange Lighting

PROBLEM:

Design the illumination of an Interstate highway interchange using the high mast system.

DESIGN DATA:

a. Geometrics - Plan showing traveled way and ramps of a modified clover-leaf.

b. Maintained illumination (E) - 0.7 footcandles

c. Uniformity (R) - 3.5 to 1, average to minimum

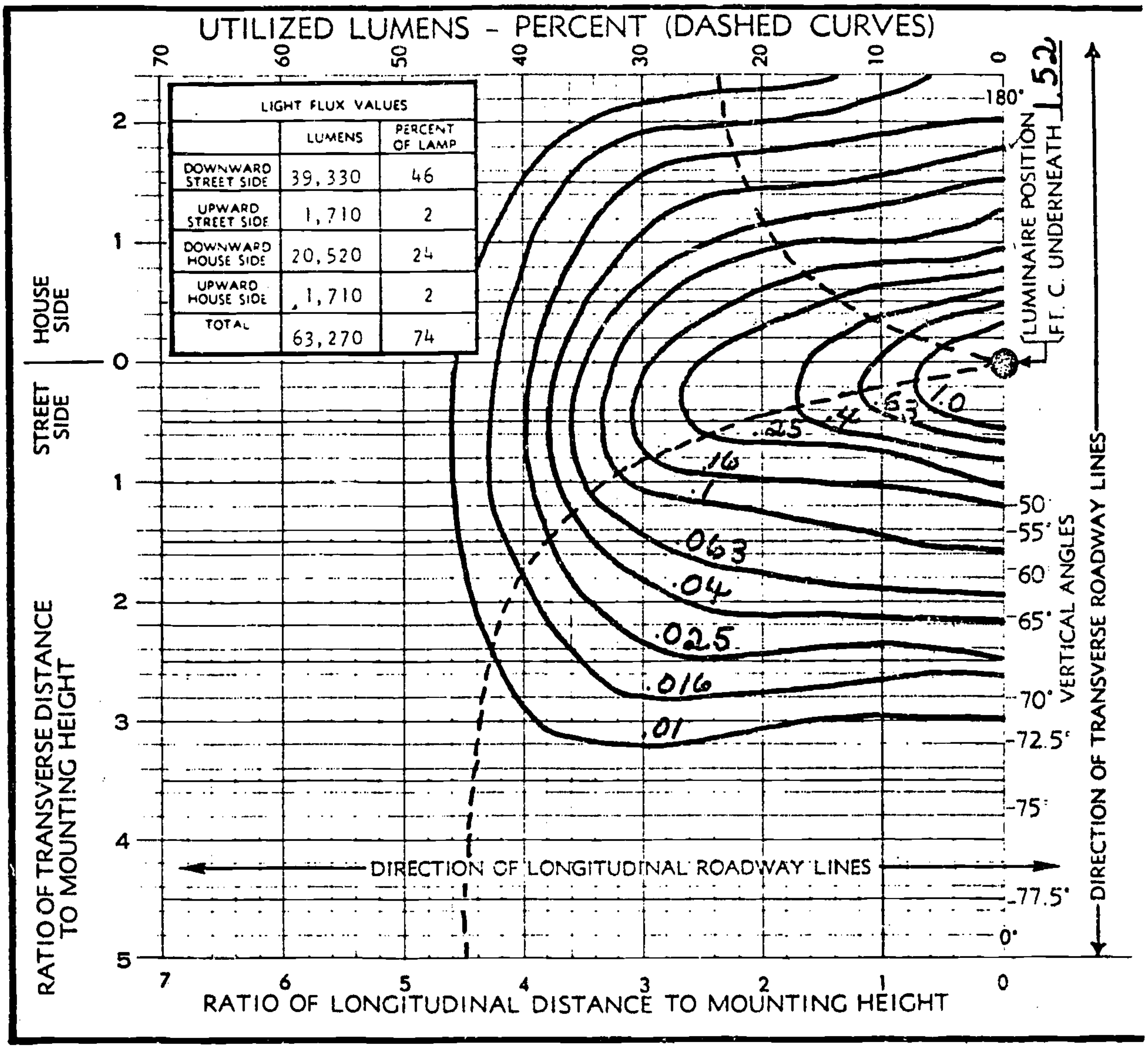
d. Light source - 1000 watt metal halide (91,500 lumens)

e. Photometric data - **Figure 3**

f. Mounting height (MH) - 150 feet

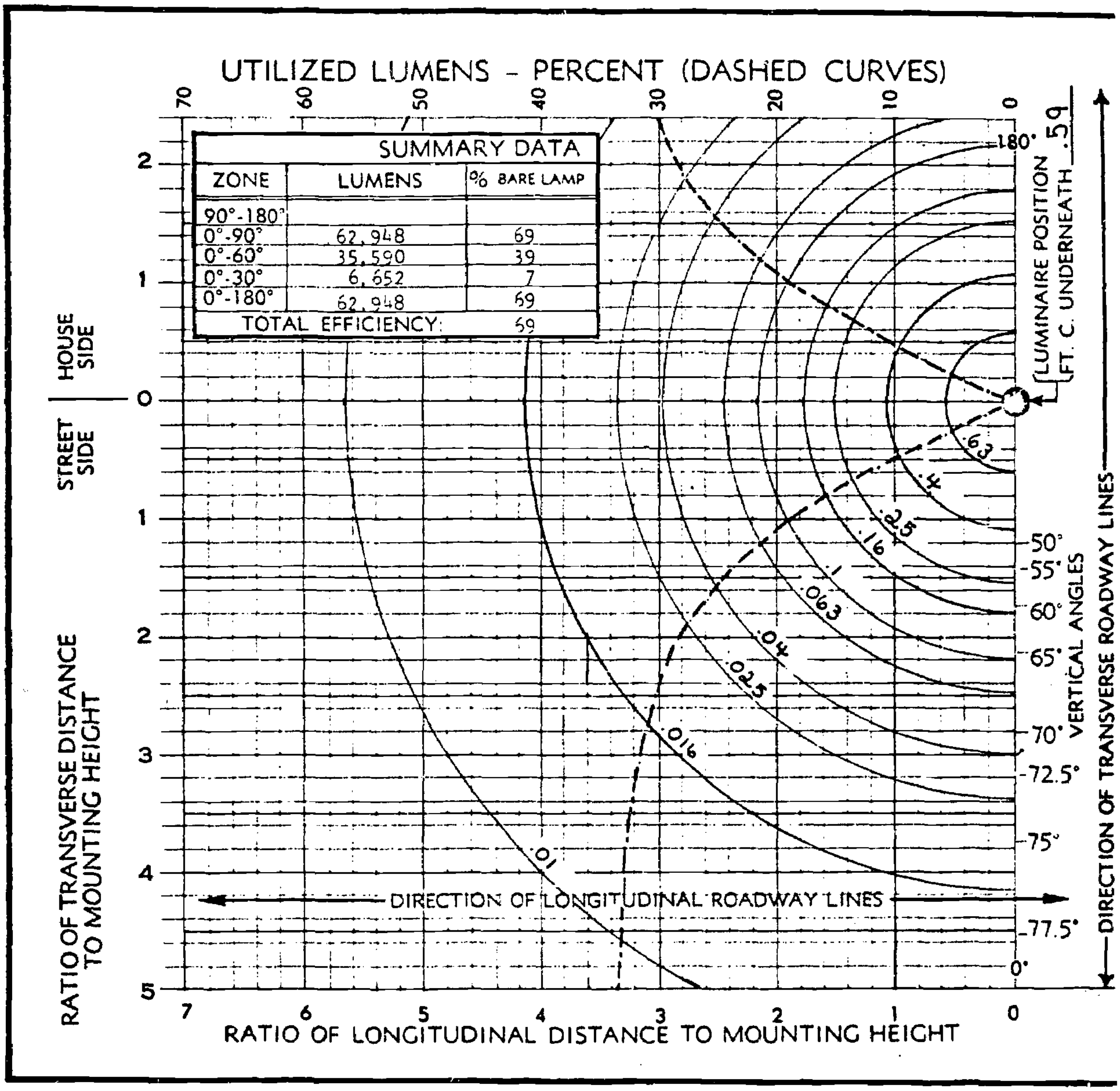
g. Maintenance factor (MF) 70% x 90% = 0.63

8/15/72



LIGHT FLUX VALUES	LUMENS	PERCENT OF LAMP
DOWNWARD STREET SIDE	39,330	46
UPWARD STREET SIDE	1,710	2
DOWNWARD HOUSE SIDE	20,520	24
UPWARD HOUSE SIDE	1,710	2
TOTAL	63,270	74

Fig. 2 Isofootcandle lines and coefficient of utilization for oval pattern light distribution. Lamp: 1000 watt metal halide, 85500 lumens (horizontal operating position), 100 ft. mounting height.



SUMMARY DATA		
ZONE	LUMENS	% BARE LAMP
90°-180°		
0°-90°	62,948	69
0°-60°	35,590	39
0°-30°	6,652	7
0°-180°	62,948	69
TOTAL EFFICIENCY:		69

Fig. 3 Isofootcandle lines and coefficient of utilization for circular pattern light distribution. Lamp: 1000 watt metal halide, 91500 lumens (vertical operating position); 100 ft. mounting height.

Answer Sheet
Highway Lighting Design
Class Group Problem
High Mast Interchange Lighting

Step 1 - Assume that there will be 8 luminaires per pole. Design a template with all points on the perimeter representing the minimum initial illumination (E) that is required from 1 luminaire.

a. Maintained minimum from 8 units with overlap from adjacent pole = E/R = 0.7/3.5 = 0.2 f.c.

b. Maintained minimum from 8 units without overlap = 0.2/2 = 0.1 f.c.

c. Initial minimum from 8 units on only one pole = E min./MF = 0.1/0.63 = 0.16 f.c.

d. Initial minimum from 8 units on one pole corrected for MH = 0.16/0.44 = 0.363 f.c.

e. Initial minimum from one unit = 0.363/8 = 0.0453 f.c.

f. Photometric Curve for 0.0453 f.c. indicates a ratio transverse (RT) = 2.9

g. Distance transverse = RT x MH = 2.9 x 150 = 435 feet

h. A circle with a radius of 435 feet will cover an effective area of one mast.

Step 2 - Construct templates to the scale of the plan and with a radius of 435 feet.

Cut-out 20 templates. Place these first at all critical areas such as exit gores. Next fill-in the remaining interchange area so that all traveled ways are covered using a minimum number of templates. The center of each should be at least 30' from any traveled way for safety.

Step 3 - Determine the number of templates required and the total area covered by all of these templates.

One arrangement required 14 locations covering an equivalent rectangle 2400 x 2500 feet.

Step 4 - Calculate the average illumination using the formula

a. $E = \frac{(\text{Total lumens}) \times (\text{CU}) \times (\text{MF})}{\text{Area}}$

b. Total lumens = (Lumens/lamp) x (Number of poles)

c. Find CU from photometric curve for ratio transverse (RT) of 2.9 as determined for constructing templates
CU = 0.31 (St. Side) + 0.31 (house side) = 0.62

d. E (1 luminaire) $\frac{91500 \times 14 \times 0.62 \times 0.63}{2400 \times 2500} = 0.083$

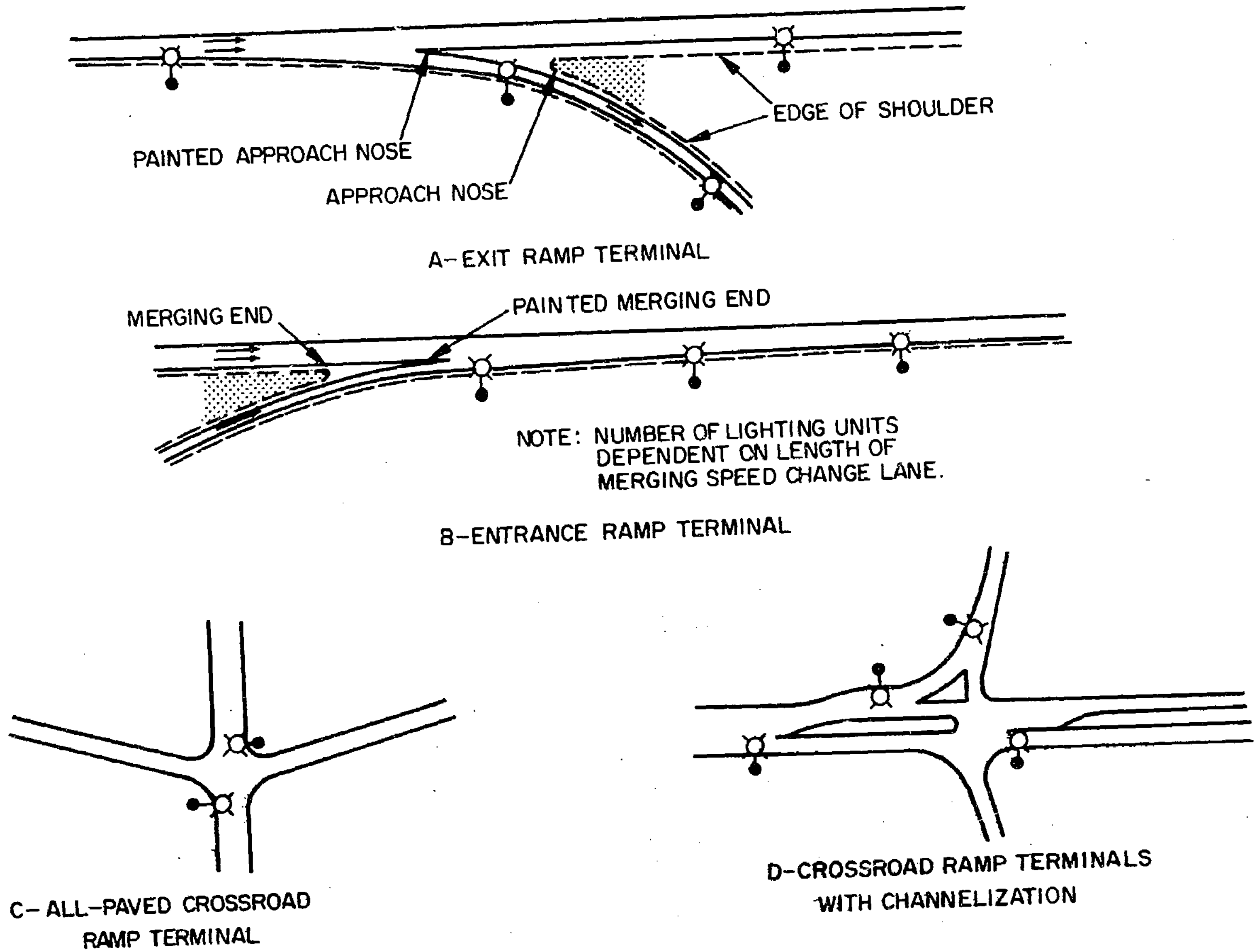
e. E (8 luminaires) = 0.083 x 8 = 0.665

Step 5 - Determine the uniformity ratio as the average maintained illumination divided by the minimum maintained illumination =

$$\frac{0.665}{0.2} = 3.35 \text{ to } 1$$

Step 6 - Conformity with AASHO Guide. The average maintained intensity of 0.665 footcandles falls between the recommended limits of 0.6 and 0.8 footcandles. The uniformity of 3.35: 1 falls between the limits recommended limits of 3:1 and 4:1.

8/15/72



TYPICAL LUMINAIRE ARRANGEMENT
PARTIAL INTERCHANGE LIGHTING
FIGURE 1