LIGHTING DESIGN

DATA COLLECTION

Office data collection is the first step in designing lighting. Collecting data, base mapping (obtaining or developing a base plan) and field review apply to any type of lighting. This is the time when the designer gathers information, collects existing data from outside sources, visits the project site and looks at potential design options.

Office Data Collection

Before preparing a design, the Designer should collect preliminary data and research existing records to develop the base plan and subsequently proceed with a conceptual design. For example, the Designer can research SHA files for as-built plans, highway design plans, right-of-way plats and utility plans. Although all of the as-built information may not be available or completely accurate, the Designer should do this research to gain information on the history of the location. The designer could also check with the District for existing plans.

The District office generally initiates the Design Request (DR) for lighting design projects, and thus may have some background information on the project. Again, although this information is shown in the DR the Designer can gain insight on the location, history, problems and recommendations by contacting the preparer of the DR.

Another element for collecting office data is any proposed work being done. If the project is an insert job to a highway project, then the proposed geometrics and area improvements should be obtained. This may be acquired through the SHA lead division or maybe a local authority.

Base Plan

The base plan is a key to the field work and design of lighting. It must be accurate and able to be used as a base for construction. In order to properly design the lighting, the designer needs a base plan showing existing topography, roadway geometrics, utilities, etc. The base plan should be in electronic format. One place to start is with the TEDD files (on MDS). Often there may be an existing electronic file with this information that can then be field verified. The designer should verify within TEDD that the obtained plan is the latest version. For an insert job the electronic base plan may be obtained from the lead division, usually Highway Division. Other options may include a professional survey or extensive field work to obtain all of the mapping information.

Information to Collect in the Field

Initial Site Visit

Most of the necessary information should be obtained during the initial site visit. This is the time to collect new information, verify existing information and prepare for the proposed and/or modified lighting design.

1. Collect existing information. This should include at a minimum:
   - Existing lighting – If there is any existing lighting then the control equipment, pole layout, pole types, luminaire types and sizes, etc. should all be gathered to be included with the plans. Determine what may be reused, what needs to be replaced.

     NEMA identification decals are placed on the outside of the ballast housing of each roadway luminaire. The color indicates the type of light source and the number indicates the lamp wattage:
     - Yellow = High Pressure Sodium
     - Red = Metal Halide
     - Light Blue = Mercury Vapor
     - The number multiplied by 10 designates the wattage. For example, a black on yellow “25” = 250 Watts HPS
   - Road geometrics (including diverging lanes, converging lanes, interchanges, intersections, structures, lane widths, etc.)
   - Drainage elements (structures and ditches)
   - Roadway alignment, vertical and horizontal
   - Driveways and entrances
   - Utilities, overhead and underground
   - Trees and vegetation
   - Existing power service (location and size)

2. Begin to prepare conceptual locations for the proposed lighting. Decide what is and is not going to be lit. Locate potential power feeds for service. Identify if there are any constraints for laying conduit and placing handholes.
3. Locate and measure the heights of overhead utilities, particularly at potential conflict locations. This will allow for meeting the NESC requirements of utility clearance and avoiding any conflicts between the proposed lighting and existing utilities. These measurements shall be documented.
4. Always take photographs while in the field. This may save another trip to the site.

Subsequent Site Visits

For most projects it will be necessary to do at least one subsequent site visit. This should include the verification of all proposed work. Things may change frequently without prior notice so it is important to verify that the design is constructible and optimal for the given location.

Field Data Collection Methods

The limits of the site review are usually determined by the limits of roadway or sign lighting. The methods used to collect field information may vary from a professional survey to simple tape and wheel techniques. The method will also vary dependent of the information required. Some or the following methodologies are explained further.

- Professional Survey – A professional survey is the hiring of an outside company or SHA survey forces to collect the field information and mapping. A professional topographically survey may be needed on a case-by-case basis. This is the most accurate, all encompassing method to collect field data, but is typically the most expensive.
- Tape and Wheel – The designer or designated person does a tape and wheel survey. This is the simple method of visiting the project site and using tape measures, wheels or other measuring devices to collect critical information. Using this method information may be collected on lane widths, distance between existing light poles, pole size, etc. This data collected shall be documented.
- Utility Heights – Measuring overhead utility heights is a critical element in the site visit, but it is also the most hazardous. Measuring the height of utilities is commonly done using an overhead cable measuring rod made of fiberglass. The rod is then used to measure the height of the different overhead utilities from the ground. DO NOT measure the primary electric lines with the rod due to hazardous high voltage. Further, do not attempt to measure any lines with rod unless with someone who is trained and experienced. Another method used for measuring utility heights is a teleheight or lock level. This is a safer method of measuring heights. See Figure 35 in the Signal Design Section.
- Photographs – Although photographs are not necessarily a formal method of collecting data, a picture can say a thousand words. Taking photographs will put the project site at arm's length once back in the office. Photos can be used to check signal configurations, signs, intersection layout, etc.
- Notes – Taking good field notes is a key when at the site. There are many things that a tape and wheel cannot measure. Taking notes to describe what is at the site is an excellent method of data collection. For example it is necessary to know the utility pole number for a potential power drop service, taking note of this number is the best way to communicate this information with the utility company to request location of a power source.

LIGHTING CONCEPT

Developing a Concept

The conceptual plan is developed before the final lighting plan is designed. It is the first milestone in which input is received from the parties involved including the designer, team leader and district traffic office at a minimum.

Prior to the conceptual plan being developed, the base mapping should have been obtained and verified in the field. All field information should be shown on the base mapping including utilities, intersection geometrics, pavement markings, etc.

The conceptual lighting design process can be broken down into several steps as follows:

1. Determine Function of Lighting
2. Determine Classification of Roadway
3. Select Luminaire and Lamp
4. Select Structure
5. Preliminary Photometrics
6. Define Design Criteria
7. Develop a Preliminary Layout

This is sometimes referred to as a post-it plan for lighting. The key is selecting the hardware, defining design criteria and developing a preliminary layout. Each of these steps will be discussed in depth further.

1. Function of Lighting

Lighting for SHA projects serves several different functions. At the beginning of the project the function of the lighting should be defined and agreed upon by all parties. On any given project there may be more than one function and all of these should be identified.

The most common application is roadway lighting. Other lighting functions include pedestrian/bicyclist lighting, sign lighting, parking lot lighting and aesthetic lighting. These five functions have similar design methods, but vary with criteria and function. Defining the function of the lighting allows the designer to determine the criteria to use for design. For example lighting a freeway will have different criteria than aesthetic lighting.

Roadway Lighting

The purpose of roadway lighting is to promote safety at night by providing illumination of the highway, vehicles, pedestrians and roadside objects.

Interchange Lighting

Partial Interchange

Partial interchange lighting is lighting only parts of an interchange that are considered critical for nighttime driving, i.e. merge-diverge areas of ramp connections, intersections and critical roadway features such as sharp curves, reverse curves etc. and the following:

- Generally works well for interchanges that can be readily visualized by motorists by viewing the critical decision points.
- Additional lights other than those minimally required should be installed where partial interchange lighting is used in conjunction with continuous freeway lighting or where full interchange lighting may otherwise be used.

Full Interchange

Full interchange lighting is the lighting of all roadways and ramps within an interchange and the following:

- Generally supplements continuous lighting along the mainline roadway.
- Also applied where substantial lighted commercial or industrial developments are located in the immediate vicinity of the interchange and where the crossroad is lit for at least ½ mile on each side of the interchange.
- May be used for lighting complex suburban or rural interchanges even when there is not a necessity to light the mainline.

Intersection Lighting

Intersection lighting is simply lighting only an intersection. It is Administration policy to light all signalized or ICB controlled intersection. Other intersections may be lit after an engineering study warrants due to safety concerns, high accident history, complex geometrics, etc.

Continuous Lighting

Continuous lighting illuminates a straight stretch of roadway between interchanges and/or intersections.

Freeway

Continuous lighting of freeways between interchanges consists of the following:

- Providing lighting along the mainline roadway where 3 or more successive interchanges are located with an average spacing of 1½ miles or less.
- Lighting from the beginning of the deceleration lane of the first interchange and ends at the end of the acceleration lane from the last interchange.
- Any gaps to the next lighting system of ¼ mile or less preceding or succeeding the continuous lighting system are filled in with additional lighting.

Other Highways

In general the Administration's practice is not to light continuous sections of the highway. However, sections of highways may be lit where combinations of sight distance, horizontal or vertical curvature, channelization or other factors contributing to a confusing or unsatisfactory condition exists.

Roundabout Lighting

It is the Administrations policy to light all roundabouts. See the FHWA 's *Roundabouts: An Information Guide* for more information. Lighting a roundabout follows the same process as lighting a roadway.

Tunnel and Underpass Lighting

Tunnel and underpass lighting is especially critical since this creates a "dark spot" during the day. Commonly if the length to height ratio of the underpass is greater than 10:1 then lighting the underpass is considered.

Transition Lighting

Transition lighting takes a driver from a high level of lighting to little or no roadway lighting gradually. Generally SHA doesn't use transition lighting for nighttime use, but uses transition lighting as needed for daytime use when entering and exit tunnels or underpasses.

Pedestrian Lighting

The Department of Transportation is committed to planning and constructing alternate forms of transportation i.e. walking and bicycle paths. Sidewalks that are located adjacent to the lighted roadways often do not have separate lighting provided for the safety and comfortable use by pedestrians and bicyclists. The incidental house side distribution of roadside luminaires is the only lighting afforded for the comfort of the pedestrian. Where a better quality of lighting for pedestrians is desired, the illumination design for the roadway can be modified to correct any deficiencies or supplemental lighting can be provided. Use the OOTS Pedestrian Lighting Policy for specifics on criteria for eligibility, financial responsibility and design standards.

When specific lighting is provided for pedestrians, the quality of lighting provided is dependent on whether the lighting is installed for illuminating the sidewalk or walkway, or if there is an additional requirement for special pedestrian security. Lighting for security purposes has an additional requirement for providing the specified vertical illumination 5' above the walkway for pedestrian identification at a distance.

Pedestrian lighting is usually classified into three levels: high, medium and low.

- High: This is high nighttime pedestrian volume with expected crosswalks and sidewalks such as downtown retail areas, near theaters, stadiums, transit terminals, etc.
- Medium: This is a lower nighttime pedestrian volume such as near office buildings, libraries, apartments, industry, etc.
- Low: This is a very low nighttime pedestrian volume such as rural areas, low density residential areas, etc.

Sign Lighting

It is the Administration's standard practice to light all overhead signs. New signs installations are constructed using a retro-reflective material that is designed to glow under headlight illumination.

Some believe this eliminates the need for sign lighting. However, when dew or condensation forms on the sign face the retro-reflectivity is lost and if the sign is not illuminated, it becomes illegible at night. A second disadvantage to relying solely on retro-reflectivity is that it uses the vehicle headlights to illuminate the sign. However, the trend in new headlight design is to significantly reduce the illumination above the horizontal to reduce glare to oncoming drivers. Unfortunately, this can also be expected to reduce the luminance and legibility of overhead signs.

Sign lighting is usually accomplished by lighting the signs from the bottom for the following reasons:

- By having the lights pointed in an upward direction any light, which misses the sign, tends to shine into the sky and not provide a severe glare source for the drivers.
- Having the light point up tends to reduce the amount of light shining on adjacent properties and reduces the light trespass.
- Sign lighting is currently being placed on a track system that must be mounted on the bottom of the sign that allows all of the lights to be serviced from the side of the road. Older installations, which do not have this system, require lanes to be closed to service the lights. This increases the hazard to the workers and the drivers, and the maintenance cost significantly. Servicing the lights on a sign with a track system may now cost $60.00 per bulb, or $240.00 for the typical sign. In some cases direct MOT cost have been in excess of several thousand dollars, and intangible costs such as inconvenience and delay significantly add to the costs.

Parking Lot Lighting
Typically any given parking lot will be lit. For SHA the most common application will be for Park & Ride facilities. Lighting for a parking lot will utilize different criteria for illuminance, but the design process is the same.

Aesthetic Lighting
Aesthetic lighting is lighting designed to enhance existing or proposed surrounding features such as buildings, landscaping, structures, community signs etc. This is becoming more common with streetscape projects. For a typical roadway, aesthetic lighting will not be used.

2. Classification of Roadway
The roadway classification will determine the photometrics required for lighting as well as guide the designer to the proper lighting. These are basically the same as any other roadway classification for highway projects. The classifications are as follows:

- Freeway: A freeway is a divided roadway with full control of access. Freeway classification is further subdivided into A and B. Freeway A has greater visual complexity and high volumes. This is common in urban areas. Freeway B represents all other freeways with full control of access.
- Expressway: An expressway is a divided roadway with partial control of access. This commonly includes parkways as well.
- Major: A major roadway is a principle arterial for through flow of traffic.
- Collector: A collector roadway services between major and local roadways.
- Local: A local roadway is direct access to residential, commercial, industrial or other property.

3. Luminaire and Lamp
The luminaire is the housing unit for the lamp, along with the distribution and power elements such as reflectors, refractors, socket, wiring terminals, etc. The lamp is the actual light source. Selecting a luminaire and lamp is a key element in the illumination design of lighting. There are several variables with in the luminaire to be determined: shape, distribution, lamp, ballast and depreciation.

Shape
The shape of the luminaire is primarily for aesthetics although the shape may influence the distribution. SHA typically uses a cobra head luminaire for roadway projects. Often parking lots will incorporate a square or rectilinear head for aesthetics. There are numerous other shapes typically used for aesthetics.

Distribution
Roadway luminaires are classified by the way they transmit and distribute light. The use of various types of reflectors and refractors permits the

lighting designer to produce an efficient and aesthetic design. Luminaire classifications are defined in terms of vertical light distribution, lateral light distribution and the control of distribution above nadir, known as cutoff.

Vertical Distribution

The vertical distribution of light is divided into three categories; short, medium and long. Vertical distributions are classified by the candlepower along the transverse roadway lines (TRL) measured in lengths of the pole mounting height (MH). A shorter vertical distribution will reduce glare, but will require a tighter spacing to maintain uniformity. A longer vertical distribution will increase glare, but reduce spacing. SHA commonly uses a medium vertical distribution.

Horizontal/Lateral Distribution

The lateral distribution of lighting is essentially the shape that the luminaire distributes on the pavement. There are five basic types of horizontal distribution, Type I through Type V. Types I and II have two subgroups for two-way and four-way distribution. Figure 66 illustrates types I-IV.

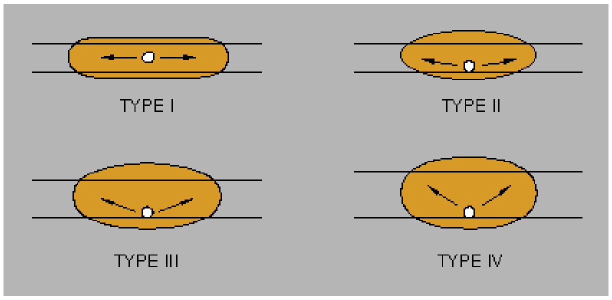

Figure 66 - Horizontal Distribution

Control of Distribution above Nadir

The control of lighting distribution above nadir is known as cutoff. (The nadir is a reference of point in the line of the pole.) Lighting 90° above nadir leads to “sky glow,” glare and often an overflow of light where no light is needed.

Full Cutoff

A full cutoff luminaire allows no light above an angle 90° above nadir. For an angle 80° above nadir, the intensity can be no more than 10% of the total lumens. It has become common practice on highway projects to use the full cutoff luminaries.

Cutoff

A cutoff luminaire allows less than 2.5% of the total lumens above an angle 90° above nadir. For an angle 80° above nadir, the intensity can be no more than 10% of the total lumens.

Semicutoff

A semicutoff luminaire allows less than 5% of the total lumens above an angle 90° above nadir. For an angle 80° above nadir, the intensity can be no more than 20% of the total lumens.

Noncutoff

A non-cutoff roadway fixture typically has a dropped lens (a refractor). This allows the light to be easily distributed from the fixture to an area larger than the section being lighted. This type of fixture may be appropriate for area lighting such as wide intersections along divided highways, at grade railroad crossings, parking lots, maintenance yards and urban streets where some house-side lighting is desirable for pedestrians. There are no intensity limits for a noncutoff luminaire. The Administration typically does not use these types of luminaries.

Lamps

The lamp is housed inside the luminaire and is the artificial source of light. There are many different types of lamps. Lamps may be selected based on their efficiency, depreciation, color, life, cost and/or restrike time. There are two basic categories for lamps, low pressure sodium and high intensity discharge.

Low Pressure Sodium

Low pressure sodium (LPS) lamps are monochromatic and have no color rendition. They have good initial efficiency however, the efficiency decreases and the current draw increases with aging. The lamps also tend to be much larger and require larger fixtures making them prohibitive for roadway lighting applications.

High Intensity Discharge

High Pressure Sodium

High pressure sodium (HPS) lamps are the standard light source for the Administration's roadway lighting. HPS is used because they give the optimum mix of a long life and low maintenance with a high efficiency (lumen output per watt). The primary draw- backs are that it has a pinkish orange color, which some people find objectionable and tends to mute some colors.

Mercury Vapor

Mercury vapor lamps have a very good color rendition with a green tint. They have a lower efficiency but a longer service life than metal halides. They are primarily used for sign lighting where color recognition is required and by utility companies for roadway lighting along local roads.

Metal Halide

Metal halide lamps have a blue white color that provides a very good color rendition. They have a good energy efficiency however, a relatively shorter service life. They are primarily used for old high mast lighting applications and by local jurisdictions that need a better color rendition with their pedestrian or roadway lighting.

Ballasts

Ballasts are used for high intensity discharge lamps. The ballast is an interface between the electric current and the lamp. It allows the lamp to obtain the necessary circuit conditions for starting and operating. For application with SHA projects, a high power factor ballast is housed in the luminaire.

Depreciation

Another factor in the selection of a luminaire and lamp is depreciation. The depreciation of the luminaire and lamp directly effect the illuminance calculations. Depreciation is measured as a light loss factor and is a combination of several factors. The two main factors are maintenance and equipment. Both of these elements combine to form a total light loss factor. Depreciation is defined by a percentage of loss. The factor will vary greatly depending on the elements discussed below.

Maintenance Factor

Maintenance factors are time dependent depreciations and include lamp lumen depreciation (LLD), luminaire dirt depreciation (LDD) and burnouts. The largest most common factors are the LLD and LDD. The LLD is based on the average life of the lamp per start. The LDD is based on the accumulation of dirt in the luminaire from the surrounding environment.

Equipment Factor

Equipment factors are not time dependent, but are related to the specific equipment in use. These include ambient temperature, voltage, ballast and lamp factor, luminaire component depreciation and change in physical surroundings.

4. Lighting Structures

Book of Standards References
Lighting Structure
Lighting Arm and Luminaire Placed on Traffic Signal Poles
Breakaway Lighting Transformer Base / Typical Lighting Structure Foundation on Slope

The light structure is the support of the luminaire. Most commonly the luminaire is attached to a bracket arm in turn connected to a pole that sits on a base. Luminaires can also be attached to walls, bridges. It includes the pole, base and typically the bracket arm.

Pole

Low Level Lighting

Low level lighting is most commonly used in Maryland. It refers to poles that are lower than 50' in height.

Bracket Arm

The bracket arm connects the pole to the luminaire. The arm may range is size from none to 30'. The bracket arm length is dependent on the luminaire and the offset of the pole from the roadway and desired place to be lit.

Bases

The first element to define for the base is the use of a breakaway base versus anchor base. A breakaway base is a safety feature that breaks the pole from its foundation when impacted. An anchor base does not offer this safety feature and can be a hazard if not protected. Breakaway bases should be used when the structure is not protected from errant vehicles such as with guardrail or barrier wall.

High Mast Lighting

High mast lighting is typically installed at large complex interchanges within predominantly business or industrial areas. It is associated with mounting heights that require special lowering gears to maintain the lights. The lights typically require higher wattage lamps to produce the desired illumination levels on the pavement. The light output usually provides an improved visual field negating the tunnel effect usually associated with low-level lighting, improved uniformity and reduced veiling glare. The poles can be placed further away from the travel lanes, which decrease the possibility of off-the-road accidents. Light trespass into surrounding neighborhoods however, is a usual source of complaints associated with high mast lighting.

Roadside Placement

During the conceptual plan it may not be necessary to finalize an offset location of the lighting structures, but it should be considered. Lighting structures are like any other roadside hazard and should be placed based on AASHTO's Roadside Design Guide. Look for obstacles that may limit placement such as bridges, signs, signals, utilities, etc. Some of these elements may help to define where poles may or may not be placed.

Other Structures

In addition to simple pole structures, luminaries may be attached to walls, bridges to other special features. These often require a special design.

5. Preliminary Photometrics

After selecting the luminaire, lamp and structure to be used, the process of designing the layout begins. Placing the lights is an iterative process that depends heavily on several factors such as roadway geometrics, roadway classification, and pavement surface. Some of the other factors that are considered when determining the design are traffic accident experience, severe grades and curves, type and location of high use driveways, underpasses, overpasses, trees and whether surrounding areas are residential or commercial/industrial.

The prevailing design criteria for highway lighting are based on the "Illuminating Engineering Society of North America - American National Standard for Roadway Lighting IES RP-8." There are three methods for designing a lighting system. They are illuminance, luminance and Small Target Visibility (STV). Currently the Administration design practice utilizes illuminance for roadway lighting and veiling luminance for glare reduction. The calculations involve an iterative process for predicting the quality of lighting and are usually performed using commercially available software.

Design Software and Establishing Lighting Criteria

There are numerous design software programs available to use when calculating lighting photometrics. They allow for ease and efficiency of computations. Most software packages require several inputs from the user. This may vary with the software, but below is a general list of inputs that should be established during preliminary design:

- Roadway geometrics
- Luminaire selected
- Lamp
- Depreciation factors
- Orientation
- Distribution
- Mounting height

- Bracket arm length
- Pavement classification

Illuminance

Illuminance is generally described as the amount of light falling on a surface or as "incident light" and is measured in footcandles (fc) (or lux (lx) in the metric system). This method is the simplest to calculate using an integration of all the light falling on a spot on the pavement surface from all adjacent light point sources. An additional calculation is done to determine the uniformity of lighting based on the ratio of the average and minimum illumination.

The recommended values of illuminance and veiling luminance for various roadway classifications and pedestrian classifications are found in the ANSI/IESNA RP-8, American National Standard Practice for Roadway Lighting.

Luminance

Luminance is a method of predicting effective brightness of an object that a driver sees based on light, which is reflected back to the eye after having struck the surface. The luminance of the object depends on its material characteristic and reflectance. Luminance is usually expressed in candelas per square meter (cd/m2). Additional calculations are done to determine the uniformity of lighting and the veiling luminance (glare) to determine the comforting level of lighting.

Veiling Luminance

Also known as disability glare, veiling luminance is a stray light that is produced within the eye.

Pavement Classification

Pavement classifications for the purpose of pavement luminance and lighting design is classified as follows (Source is the ANSI/IESNA RP-8, American National Standard Practice for Roadway Lighting):

1. R1: Portland cement concrete road surface. Asphalt road surface with minimum of 12 percent of the aggregates composed of artificial brightener aggregates.
2. R2: Asphalt road surface with an aggregate composed of a minimum 60 percent gravel. Asphalt road surface with 10 to 15 percent artificial brightener in aggregate mix.
3. R3: Asphalt road surface with dark aggregates; rough texture after some months of use.
4. R4: Asphalt road surface with very smooth texture.

SHA uses the R3 classification all roads.

Small Target Visibility

Small target visibility is a theoretical method for predicting how well objects can be perceived to the human eye and the time available to view the object. The detection of the objects depends on the contrast of the object to the background. Since, there are too many unpredictable variables such as the cognitive abilities of the driver, size and color of objects, luminance of the pavement, ambient lighting from external light sources, etc., this method is difficult to apply for real situations.

6. <u>Defining the Design Criteria</u>

Defining the design criteria is the most critical step in the design process for lighting. During this step it is essential to put it writing each piece of the design. This should include at a minimum:

- Lighting Function
- Classification
- Luminaire
- Lens
- Vertical Distribution
- Lateral Distribution
- Cut-Off
- Lamp Type
- Lamp Wattage
- Mounting Height
- Bracket Arm Type
- Type of Pole
- Pole Base
- Average Maintained Illuminance
- Uniformity Ratio

- Veiling Luminance
- Operating Voltage

Figure 65 shows an example of a list of design criteria definitions.

7. Preliminary Layout

The preliminary layout is the first opportunity to start to layout structure locations. This may be based on:

- Previous experiences
- Preliminary analysis with design software
- Engineering judgment

Using previous experience is a good way to develop an initial spacing. If using the same luminaire, lamp, mounting height and design criteria it may be possible to use previous experience as a starting point. Experience also allows the designer to be familiar with certain types of luminaire distribution and the designer becomes familiar with specific capabilities.

Many software programs for lighting design incorporate a “pre” program to allow for preliminary layout.

Engineering judgment and studies is a last way to develop a preliminary layout of luminaires. The preliminary layout will determine if luminaries will be placed on one side of the road, both sides of the road, in the median, will they be staggered. This layout should also define a preliminary spacing of the luminaries.

Reviewing the Concept

The conceptual plan is the time for all interested parties to agree and finalize the major decision making components of the lighting design. At this point the designer should receive input from the District Traffic Office and the Team Leader. This conceptual plan will govern the other elements of design to follow. Resolving any conflicts or issues at this point will eliminate the need for change after final design.

A reviewer should consider the following items when viewing a conceptual lighting plan:

1. Check that the lighting meets the requirements of the Design Request.
2. Check for any special design considerations such as underpasses, roundabouts, signing, and pedestrians.
3. Check that the design criteria is well defined and that the criteria is met within the design.
4. Check for overall concurrence with Federal and SHA standards.

Design Criteria for Lighting
US 29 / MD 216

Highway Lighting Assumptions and Conditions

Lighting Function

- partial interchange lighting
- lighting for both roundabouts
- add lighting to the expanded Park & Ride
- complete lighting of loop ramps

Luminaire and Lamp

- high pressure sodium lamps
- flat glass lens
- full cut off
- medium vertical distribution
- type III lateral distribution
- light loss factor = 0.64
- HPF reactor or lag ballast
- GE luminaires (M250A2)

Lighting Structure

- 40 ft poles
- galvanized steel poles
- galvanized steel bracket arm
- breakaway transformer base

Illuminance

- uniformity ratio (avg:min) - 3:1
- minimum maintained illuminance - > 0.2 fc
- US 29, freeway classification; average maintained illumination between 0.6 fc and 0.8 fc
- for MD 216, expressway classification; average maintained illumination between 0.8 fc and 1.2 fc
- used ALADAN software to calculate illumination

Electrical

- 120/240 operating voltage
- single phase, three wire
- duct cable

Sign Lighting Assumptions and Conditions

- all overhead signs shall be lighted
- mercury vapor luminaires
- die-cast aluminum housing
- sign lighting maintenance system

Figure 67: Example of Design Criteria

ROADWAY LIGHTING DESIGN

Once the lighting concept plan has been developed, reviewed and approved the next step is to formally evaluate the photometrics and finalize the layout. By now all criteria to be used, pole selection, luminaire and lamp selection and a preliminary layout have been determined.

Photometrics

Computing photometrics is a complex process. Most designers use computer software to evaluate the necessary photometrics to design the lighting layout. This is typically the most efficient and effective method of computation. For most SHA projects, the average maintained illuminance, uniformity and veiling luminance should be computed.

Using Design Software

At this time, SHA doesn't require a specific type of software. Since most manufacturers of luminaries and lamps have their own design software, the results of any given software will vary. For this reason, the software used should be specified to allow for quality review and comparison to other software applications.

Some applications will only consider straight line roadways and the designer will need to apply general engineering practices to account for special geometrics such as curves. Other applications have preliminary calculations, which allow the user to develop a preliminary spacing.

Special Geometrics

Depending on the software used to design the lighting photometrics, special consideration may need to be given to some situations. For example a horizontal curve may need the spacing of the poles tightened to compensate for the effect that the curve has on the illumination.

Roundabouts

When illuminating roundabouts, FHWA's *Roundabouts: An informational Guide* should be used as a reference. This guide emphasizes the following recommendations:

- The illumination of the intersection should approximately equal the sum of the illumination levels of the intersecting roadway.
- Lights should be located so that they provide good illumination on the approach nose of splitter islands, the conflict area where traffic enters the circulating stream and at places where traffic streams separate at points of exit.
- Particular attention should be given to the lighting of the pedestrian crossing areas at sites where the pedestrian/bicycle/vehicle conflicts are likely to be significant.
- Poles should not be placed within splitter islands, on the central island directly opposite an entry roadway, or on the left-hand perimeter immediately downstream of an entry point.

Lighting of roundabouts in local streets should be individually designed to suit site considerations. Aesthetic lighting may be a consideration for the type and placement of poles in roundabouts. As a general guide SHA lights each leg of a roundabout.

The risk of an errant vehicle colliding with a pole should always be considered when designing the lighting system and the use of breakaway type poles should be encouraged.

Vertical and Horizontal Curves

The visual problems in driving increase on horizontal and vertical curves. In general, gradual, large radius curves and gently sloping grades when lighted are treated as straight level roadway surfaces. Sharper radius curves and steeper grades, especially at the crest of hills require closer spacing of luminaires in order to provide higher pavement luminance and improved uniformities. The spacing ratio between poles may vary from 0.55 to 0.90 to provide adequate and uniform levels of lighting.

The geometry of abrupt horizontal curves, such as those found on traffic interchanges and many roadway areas, also requires special consideration. Headlighting is not as effective in these situations and silhouette seeing cannot be provided in some instances. Luminaires should be located to provide light on vehicles, road, curbs, traffic barriers and other fixed objects. It is generally found in national guidelines that poles are more likely to be involved in fixed object type accidents if placed on the outside of curves. Many vehicle operators may be unfamiliar with these areas and lighting the surroundings greatly helps their discernment of the roadway path.

Proper horizontal orientation of luminaire supports and poles on curves is important to assure balanced distribution of the light flux on the pavement. Furthermore, when luminaires are located on steep grades, it is desirable to orient the luminaire so that the light beams reach the pavement equidistant from the luminaire. This assures maximum uniformity of light distribution and keeps glare to a minimum.

Interchanges

Since SHA prefers partial interchange lighting over continuous lighting, it may be desirable to light critical conflict areas such as intersections, points of access and egress, horizontal curves, crest curves and similar areas of geometric and traffic complexity. In these cases, lighting should be extended beyond the critical areas.

Aesthetically pleasing lighting structures and pole colors may be required under some projects to coordinate with existing structures or other special design applications. Usually, these requirements are defined by the SHA and are documented in the Design Request.

Intersections

Grade intersections may have unrestricted traffic flow on both roadways, restriction by means of stop signs on one or both of the roadways and control by traffic signals. Some are complicated by pedestrian activities as well as vehicular traffic. The lighting task on all of these, however, is fundamentally the same. The luminance level in these areas should generally be higher than the level of either intersecting road.

Luminaires should be located so that lighting will be provided on vehicles and pedestrians in the intersection area, on the pedestrian walkways, and on the adjacent roadway areas. Of particular importance is the amount of light falling on the vertical surfaces of such objects that differentiate them from the pavement background they are seen against.

With channelized intersections, the Designer should examine the frequency and location of nighttime accidents so that an adequate design can be prepared to address the problem.

Acceleration and Deceleration Lanes

Acceleration lanes refer to entrance ramps; they frequently have all the challenges of abrupt curves. Vehicle headlighting in acceleration lanes may be ineffective and silhouette seeing cannot be provided for many of the situations. It is thus desirable to provide good direct side lighting on the vehicles entering the main traffic lanes. Generally, lighting is provided within 100 feet after the physical gore in the safety clearance, and ending at a point where the full width acceleration lane begins to taper into full transitioning.

Deceleration lanes warrant careful consideration because these are areas where motorists are reducing speeds and looking for exit/turn information. Luminaires should be placed to provide illumination on curbs, abutments, traffic barriers and vehicles in the area of traffic divergence. Poles should be located to provide adequate safety clearance for vehicles that may cross the gore area. Lighting also should be provided in the deceleration zone. Starting at the full width of the deceleration lane and ending approximately 100 feet past the gore area, i.e. the safety clearance.

With acceleration and deceleration lanes it may be necessary to use transitional lighting when the mainline roadway is not lit. The transitional lighting allows the driver to adapt from no lighting to significant lighting in a slower manner. On the other hand, where there is ¼ mile or less between lit areas, then continuous lighting should be considered. Otherwise, install partial lighting.

Underpasses and Overpasses

An underpass is defined as a portion of a roadway extending through and beneath some natural or manmade structure, which because of its limited length to height ratio requires no supplementary daytime lighting. Length to height ratios of approximately 10:1 or lower will not, under normal conditions, require daytime underpass lighting. Underpasses of multiple highway structures, where the space between these structures permits good penetration of daylight on the underpass roadways, will normally be treated separately, rather than as one single, composite length. In cases where the overhead structure results in one or more sides of the roadway beneath being open to relatively direct daylight, the structure may be of considerable length but yet does not require daytime lighting.

When the length to height ratio exceeds 10:1, it is necessary to analyze the specific geometry and roadway conditions, including vehicular and pedestrian activity, to determine the need for daytime lighting.

Long underpasses, where adequate lighting from the street luminaires cannot be accomplished, require special treatment. Long underpasses also greatly reduce the entrance of daylight and, therefore, may warrant lighting during the daytime.

For nighttime lighting, luminaires on the lower roadway should be positioned so that there are not large dark spots in the pavement lighting from that on either side of the overpass. These luminaires should also provide adequate vertical illumination on the supporting structures.

A roadway which is not continuously lighted may warrant underpass lighting in areas having frequent nighttime pedestrian traffic through the underpass, or where unusual or critical roadway geometry occurs under or adjacent to the underpass area.

Roadways having continuous lighting will generally warrant the use of underpass illumination. Favorable positioning of luminaires adjacent to the underpass can often provide adequate lighting of relatively short underpass areas without the need for supplemental lighting.

Underpass lighting levels and uniformities should duplicate, to the extent practical, the lighting values on the adjacent roadways. Because of luminaire mounting height and spacing limitations in an underpass, it may be necessary to provide somewhat higher levels of lighting in the underpass to achieve the required underpass uniformity values. Such increased levels should not exceed approximately twice that of the roadways adjacent to the underpass.

For further information of tunnel and underpass lighting see IES's *RP-22 Tunnel Lighting*.

Final Layout

Book of Standards References
Lighting Structure Placement

After the photometric computations have been completed the final layout should be designed. Using the results of the photometrics as well as good engineering judgment the poles should be located in their final location.

Placement of Poles

The horizontal placement of the pole is the placement in relation to the roadway. Most horizontal placements are defined by an offset distance from the baseline, face of curb or edge of pavement. Lighting structures are should be placed based on AASHTO's Roadside Design Guide.

The physical roadside conditions may restrict the placement of lighting poles. Therefore, it is important that the Designer consider limitations in the design. Sign structures, overpasses, traffic barriers, roadway curvature, gore clearances and lighting equipment limitations are factors which must be taken into account during design. The Designer must evaluate all judgment factors including safety, aesthetics, economics and environmental impact while accounting for the physical limitations.

Some safety considerations for lighting pole locations include the following:

- It is desirable to place poles outside the roadside clear zone, but this isn't often possible in order to meet the photometric needs. When placed inside the clear zone, breakaway bases should be used.

- Pole locations should consider the hazards and convenience in servicing the lighting equipment.
- Poles should be located to provide adequate safety clearance in the gore areas of exit and entrance ramps. For exit ramps it shall be at least 100' from the physical gore.
- Forty foot or fifty foot poles with an arm length of 25 feet or greater cannot be equipped with breakaway bases due to the heavier poles required. Therefore, they must be protected or placed beyond the clear zone.
- Poles should be placed to minimize interference with the driver's sight distance and the luminaire brightness should not seriously detract from night driving.
- Poles should not be placed within 50 feet of an overhead sign. Violating this could cast distracting shadows on the roadway surface at night and/or wash out the message on the sign.
- Poles on the inside radius of superelevated roadways should have sufficient clearance to avoid susceptibility of being struck by trucks.
- Poles should not be placed on the traffic side of traffic barrier or any natural or man-made deflecting barrier.
- Where poles are located in exposed areas, they should be designed to have a suitable breakaway or yielding feature. The safety feature shall comply with all applicable AASHTO requirements for structural supports.
- Poles behind traffic barriers should be so located to provide the necessary clear distance for the railing or barrier deflection as defined in the SHA Book of Standards.
- Poles should be placed to avoid conflict with utilities, inlets and other underground or overhead items that must be cleared.
- Median pole locations should be considered where the width is appropriate on open roadways or median barriers are to be used. Median pole locations provide several lighting and economic advantages. The number of poles necessary may be reduced to approximately one-half; amount of cable may be reduced; house side lighting could be utilized and the visibility on the high speed lanes also may be improved.

Other design considerations also include:

- The installed lighting system should have a pleasant daytime appearance. The design should reflect aesthetic considerations.
- Provisions for present or future lighting may be included with the roadway and structural work. Such provisions include under pavement conduit, junction boxes and conduit, and pole anchorage in structures.
- Annual cost of energy and maintenance, maintenance capability, and responsibility for the maintenance of the lighting system are some of the items, which should be considered as part of the system design. All items should be weighed for their importance on any specific design.

SPECIAL LIGHTING DESIGN

Rest Areas

Rest areas incorporate both vehicular and pedestrian usage, and constitute an important highway feature to the traveling public. They are available for use at night as well as by day, and their general appearance should generate a feeling of safety and security. This condition can exist only if the facility is adequately lit for nighttime use. According to AASHTO, any rest area offering complete rest facilities should be lit.

Properly designed lighting, conventional or high mast, will enhance the architectural and landscape features of the facility, promote safety by easing the task of policing, and contribute to the rest and relaxation of the motorist by completely delineating the driving, parking and walking areas of the facility.

One of the prime concerns in consideration is that the motorists traveling along an unlighted main highway do not have their vision adversely affected by glare or by spill light from luminaires placed adjacent to the roadway within the rest area. Adverse glare within all interior areas should also be given consideration. As the motorist on the main roadway traverses the entire length of the adjacent rest area, the motorist should be able to discern any vehicle leaving the rest area, as well as the traffic traveling along the main roadway.

The overall design of the lighting is divided into four general areas as follows:

- Entrance and exit
- Interior roadways
- Parking areas
- Activity areas

Parking Facilities

Parking facility lighting is vital for traffic safety, for protection against assault, theft and vandalism, for convenience and comfort to the user. Typical parking facilities include park-n-ride lots, train stations, building parking lots and other types of commuter lots.

The illumination requirements of an open parking facility depend on the amount of usage it receives. According to the IES three levels of activity have been established and are designated as *high, medium* and *low*. For SHA projects, the design of lighting for parking lots is for transportation parking such as airports, commuter lots, train stations lots, etc. This is considered a medium activity. Use the *IESNA Lighting Handbook* and *RP-20 Lighting for Parking Facilities* as a guide for the photometric design of these facilities

If the level of nighttime activity involves a large number of vehicles, then the examples above for low and medium activity properly belongs in the next higher level.

In open parking facilities, a general parking and pedestrian area is defined as one where pedestrian conflicts with vehicles are likely to occur. A vehicular use area (only) is defined as one where conflicts with pedestrians are not likely to occur. These are areas such as service areas or access roads.

Special consideration should be given to lighting of access roads to all types of parking facilities and lighting levels should match the local highway lighting, as much as possible. The average maintained illuminance should be compatible with local conditions. The average-to-minimum uniformity ratio should not exceed 3:1. In all parking facilities, consideration should be given to color rendition, uniformity of lighting and minimizing glare. Users sometimes have trouble identifying their cars under light sources with poor color rendering characteristics. Uniformities less than recommended can detract from safety and security. Glare can affect the ability to perceive objects or obstructions clearly.

Vandalism is an important consideration with open parking facilities. Damage can generally be reduced by mounting luminaires at least 3 m (10 ft) above grade. However, greater mounting heights are recommended.

Pedestrian Lighting

When properly designed and installed, pedestrian lighting has benefits that include enhancing revitalization projects, increasing nighttime pedestrian use and commerce, increasing safety and security, improving aesthetics, and adding to the sense of pride of a community. In some instances, however, it may be preferable not to install pedestrian lighting due to environmental or other considerations.

Specific criteria for eligibility is as follows:

- Within ½ mile of a transit center or ¼ mile of a major transit stop or along connection between two or more transit centers
- Within a designated urban revitalization area
- Within ½ mile of an educational or similar facility
- High volume of pedestrians at nighttime
- Within a commercial area with significant nighttime activity
- Pedestrian safety and security issues

See the Pedestrian Lighting Policy for specifics on warranting, funding, design, construction, and maintenance of pedestrian lighting systems in which the Administration will be involved.

Sign Lighting

Book of Standards References
Sign/Luminaire Supports and Mounting
Sign/Luminaire Mounting

Motorists may stop or reduce their speed at roadway signs that are difficult to read, and thus create a hazardous condition. Proper sign lighting can aid rapid and accurate recognition of the sign shape, color and message. SHA lights all overhead signs and prefers to use a Sign Lighting Maintenance System no matter what type of roadway. The Administration has developed sign lighting design schedules for various types and sizes of lamp wattages and sign panels.

Lighting for roadway signs becomes more significant as the volume of traffic increases, the complexity of highway design increases, the likelihood of adverse weather increases and the ambient luminance increases.

The background luminance against which a motorist will view a sign is called its ambient luminance. Three categories of ambient luminance (high, medium and low) can be identified:

- High: Areas with high street lighting levels and brightly lighted advertising signs
- Medium: Areas with small commercial developments and lighted roadways and interchanges
- Low: Rural areas without lighting or areas with very low levels of lighting

SHA illuminates all overhead signs from the bottom of the sign rather than the top due to easier maintenance and better uniformity of lighting.

When selecting the light source for sign lighting, energy consumption is a major consideration that must be balanced by other factors, such as color rendering, ambient temperature and maintenance. Selection should be based on efficacy and lamp life in addition to careful evaluation of color rendering abilities. Lighting must maintain the color rendering as close as practical to that seen under daylight conditions.

There are three types of lighted signs: externally lighted signs, internally lighted signs, and luminous source message signs (where the message is formed by lamps).

High Mast Lighting

High mast lighting is only used for special cases and implies an area type of lighting with groups of luminaires mounted on free standing poles or towers, at mounting heights varying from approximately 80 feet to 180 feet or more. At these mounting heights, several high output luminaires develop a highly uniform light distribution. High mast lighting is used principally on interchange lighting, lighting of toll plazas, rest areas and parking areas, general area lighting and for continuous lighting on highways having wide cross sections and a large number of traffic lanes, such as Interstate 95.

The principal benefits of high mast lighting applications are the ability to provide excellent uniformity of illumination and reduce glare with a substantially smaller number of pole locations. This is especially true in interchange and other complex road areas.

While utilization efficiency is low on individual roadways, several roadways can usually be illuminated from the luminaires on a single pole. The off-road surrounding areas receive sufficient illumination to provide the motorist with an exceptionally wide illuminated field of vision compared to the "tunnel of light" effect provided by the conventional system. Performance of the system under adverse weather conditions such as rain, fog, etc., is good.

High mast lighting generally provides its own adaptation (transition) lighting to and from unlighted roadways.

High mast lighting makes a contribution to safety and aesthetics by reducing the number of poles that would be required for a conventional system and through locating poles out of the recovery area adjacent to the driving lanes. Also, their remote location eliminates the need for maintenance vehicles obstructing traffic on the roadway, or the requirement for maintenance personnel to be near the high speed traffic lanes.

The design and installation of high mast lighting equipment is more complex than conventional lighting. Poles or towers, with lowering devices or other methods of luminaire servicing, require special design and maintenance considerations.

The most common type of luminaire used in high mast lighting is the area type, which is usually offered having symmetric or asymmetric distribution. Both types of distribution are frequently used to adequately fit the area to be lighted, and to minimize spill light.

Due to the lack of satisfactory experience in designing high mast installations to the luminance system, use of the luminance system is not encouraged when designing a high mast installation. Higher levels of illuminance on the roadway may be required after consideration of such factors as the complexity of the interchange, the existence of high brightness from competing light sources near the roadway, and the prevailing level of lighting on connecting roadways. In addition to the level of light on the roadway, the Designer must also consider objectionable spill light and discomfort glare beyond the right of way and the visibility of vertical surfaces of the roadway system, i.e., traffic barriers, bridge columns, abutments, drainage headwalls, and the like.

For the design of a high mast installation it may be assumed that all symmetric distribution luminaires on a given mast form a point source and have the same orientation and photometric display. All asymmetric distribution luminaires are usually oriented in groups with the principal axis of each luminaire in the group having the same orientation and having the same photometric pattern. Two methods available for formulating a design for high mast lighting are:

1. Utilized Lumens Method (Templates): By use of isofootcandle curve transparencies overlaid on drawings of the area to be lighting, pole locations are established and design values are then computed from standard utilized lumens formula. This method can also be accomplished by using direct calculations made from the coefficient of utilization charts.

2. Average Point Method: Readings are determined at points designated in an established grid pattern on the roadway and then averaged. Pole spacing, size of luminaire, and mounting height are usually determined by the Designer based on economics, illumination levels, and lighting area. Typically, the size of luminaire may vary from 600W HPS to 1000W HPS and spacing of poles also may range from 400 to 600 feet.

LIGHTING ELECTRICAL SYSTEM

This section presents guidelines and procedures that may assist the Designer in selecting the type and size of an electrical service for a lighting system. It also presents guidelines for sizing Traffic Control Device Cabinets and equipment (as described in Spec. Section 816), determining the size of lighting cables, determining the voltage drop on lighting circuits, and determining the type and number of connector kits used.

The electrical system for lighting is designed after the lighting is fully designed. The luminaires are selected and the poles have been laid out in their final locations. Following is a list of the basic steps to follow when designing the electrical system for lighting.

1. Determine Power Source
   a. Location
   b. Size
2. Define Lighting Cabinet
   a. Location
   b. Size
3. Define Luminaire Electrical Requirements
4. Circuit Layout, Wire Size and Voltage Drop
5. Connector Kits

Power Source

Book of Standards References
Roadway Lighting Voltage Connections
Embedded Service Pedestal

Power source refers to the power company's standard supply of electricity at secondary distribution systems, i.e. the system voltage supplied by the power company. Generally, a lighting system for an isolated intersection requires a single phase, 120/240 volts, 3-wire service. The first number, that is 120V, refers to the phase to neutral voltage in the transformer. The second number, that is, 240 volts refers to the phase-to-phase voltage. SHA prefers to use the 120/240 V service.

For larger projects such as interchanges and continuous roadway lighting, electrical services may be via either a single phase, 120/240 volts, 3-wire service or a 3-phase, 277/480 volts, 4-wire service. Three-phase circuits are composed of three single-phase circuits where the source voltages for each phase are 120° apart. SHA prefers to split interchanges into smaller systems and use multiple 120/240 volts service if possible.

For information on the existing service, the Designer could obtain data on the service type, circuits, and cable sizes either from as-built plans, the SHA District Office for Maintenance, or by coordinating a field visit to the electrical distribution cabinet.

Selecting Power

Selecting the electrical service size and type is the responsibility of the Designer. Generally, a higher operating voltage will allow the design of a more efficient and cost effective system, but for simplicity and consistency SHA's preference is to use the 120/240 voltage service with a 60 amp cabinet.

Luminaires are generally supplied in two types: a multitap which can operate on 120, 207, 240, or 277 voltage systems and secondly a 480 volt luminaire. If a 480 volt luminaire is used in an area that historically uses a lower voltage, then maintenance personnel must have a larger inventory of spare parts, or may accidentally install an inappropriate luminaire. Historically, 480 volts luminaires have typically been used along I-495, while the rest of the State operates at a lower voltage, such as 120/240 volts. The Designer should always specify a multitap system in order to avoid problems with wrong luminaires installed in wrong systems.

A 120/207 or 277/480 volt 3-phase supply is generally considered an industrial service, and may not be available in a rural or suburban area. In these areas 120/240 volts may be the only option.

Lighting associated with traffic signals is wired at 120 volts.

For servicing non-signalized intersections, an underground 120/240 volts, 3-wire, single phase service should be selected. An embedded metered service pedestal is normally specified for a project with less than 8 luminaires. This is a typical design for Areawide lighting projects, and requires each luminaire to have its own photocell.

A pole mounted lighting control cabinet, using a single phase 120/240 volts electrical service, is also accepted by SHA for Areawide contracts where eight or more luminaires but less than 15. The post mounted lighting control cabinet has a 3-circuit panel and a photocell for all circuits. Separate photocells on each luminaire are not required with this type of control and distribution.

Selecting the Service Connection

The Designer is responsible for the coordination with the power company on the availability of service within the proximity of the proposed installation location. Coordination with the power company should begin in the preliminary stages and should continue throughout the project. The Designer should initiate the coordination activity with a telephone call and a follow-up letter with a preliminary concept layout of the lighting design. All correspondence should be documented and kept for reference throughout the project.

Determining Service Load

The electrical service required is dependent on several things, but the key item is the current required for the luminaires to operate. Each type of luminaire for each wattage size requires a different operating current at any given operating voltage. For example a 250 watt high pressure sodium luminaire with a line voltage of 277 operates at a current of 1.2 amps. A 400 watt mercury vapor luminaire with a line voltage of 240 operates at a current of 2.1 amps. **Table 9** shows some of the standard operating voltages of commonly used luminaries in Maryland.

Table 9 - Typical Operating Current for Common Lamps and Ballasts

Type of Lamp	Bulb Watts	Line to Line Voltage				Line Watts
		120 V	240 V	277 V	480 V	
HPS	100	1.2	0.6	0.5	0.3	127
HPS	150	1.6	0.9	0.7	0.5	189
HPS	200	2.1	1.0	0.9	0.8	253
HPS	250	2.6	1.3	1.2	0.7	312
HPS	400	3.9	2.0	1.7	1.0	475
MV	175	1.8	0.9	0.8	0.5	206
MV	250	2.6	1.3	1.1	0.7	288
MV	400	4.1	2.1	1.8	1.1	458

In order to determine the required load of a proposed system, the Designer may follow two steps.

1. Identify the total number of luminaires and the types of lamp such as 250 High Pressure Sodium or Mercury Vapor. Include any luminaire within the system, signing and roadway.
2. Calculate the total load of the lighting system, based on the desired line voltage and operating current data as shown in **Table 9**. The total amperage may be determined as follows:

$$\sum \left({}^{\#lamps}\!/_{type} \right) \times (current)$$

Equation 1 - Minimum Total Amperage

Following is an example of this calculation.

<u>Given:</u>

Operating Voltage: 277 V

Roadway Lighting Lamps: 12 luminaires with 250 Watt High Pressure Sodium Lamps

Sign Lighting: 4 luminaires with 250 Watt, Mercury Vapor Lamps

Based on the above given information the results are shown in **Table 10.**

Table 10 - Example of Calculating Total Load of Lighting System

No of Luminaires	Type of Lamp	Lamp Power (watts)	Operating Current (amp)	Total Load (amp)
12	HPS	250	1.2	14.4
4	MV	250	1.1	4.4
TOTAL				**18.8**

This example results in a total minimum load required of 18.8 amps. Under these circumstances, the Designer could either request from the power company a 60 amp service or may consider future expansion of the lighting system and request either a 100 amp or 200 amp service.

In general, the SHA uses a minimum of 100 amp service for a typical application of 15 to 20 lighting standards. A 277/480V service will be more expensive to provide than a 120/240V service.

Another consideration in selecting the power source and size is the voltage drop on the circuits. A typical circuit would have less of a voltage drop with the same number of lighting standards under a 277/480 volts service than with a 120/240 volts system because of the higher operating voltage with a 277/480 volt system.

Lighting Control Cabinet

Book of Standards References
Lighting Control Cabinet Foundation
Lighting Control Cabinet

The lighting control cabinet is either Base Mounted or Pole Mounted and refers to the control cabinet itself and the equipment within the cabinet including the meter socket, external disconnect switch and circuits panel. Control equipment is usually housed in an aluminum cabinet enclosure and is installed on the side of the road where it can be easily accessed for maintenance. It performs the following functions:

1. Distributes electrical energy (current) to individual luminaires via lighting circuits.

2. Powers on and powers off the lighting system via switching equipment such as photoelectric cells.

The number of circuits on a panel should not exceed 42.

Circuit Layout, Wire Size and Voltage Drop

After determining the service to be used for the lighting system, the next step is to layout the circuits, determine wire to be used and calculate voltage drops. These three items are dependent upon each other meaning that this process is an iterative process to achieve an optimal system. There are also several methodologies to determine the same results. This section is directed toward the NEC equations and applications of calculations.

Circuit Layout

Circuits are run from the control and distribution equipment to the lights. Each circuit has a unique number in that panel. Following are some general guideline for laying out circuits in a lighting system:

- Odd circuit numbers run together and even circuit numbers run together

- For a 120/240V single phase, 3 wire system circuits are run together in groups of two circuits (e.g. circuits 1 and 3 will run together or 2 and 4 will run together)

- For a 277/480 V three phase, 4 wire system circuits are run together in groups of three circuits (e.g. circuits 1, 3, 5 will run together or 2,4,6 will run together)

- Luminaires should always have alternating circuits so that if one circuit goes out, the one next to it will still be operating

- For sign lighting, run dedicated circuits for only the sign lighting.

The maximum number of luminaires allowed per circuit is a function of the line voltage, voltage drop, operating current of luminaire, circuit breaker trip size, and the length of the circuit run. All of these variables are interrelated to each other.

The number of luminaires per circuit can preliminarily be determined by:

As a matter of safety, the Designer should not load the circuit to more than 80 percent of its capacity.

Optimal Cable Size

Generally, underground wiring for lighting is either #6 AWG or #4 AWG. Number 4 AWG cables are used for larger installations with longer circuit runs that may have higher voltage drop. The resistance of a larger size cable is lower than the resistance of a smaller size cable and, therefore, will have a lower voltage drop.

Number #12 AWG cables are used for luminaires in conjunction with traffic signals. For intersections where few lights are anticipated, and there is a potential for the intersection to be signalized, a #12 AWG cable may be used to insure expandability for a future signal. Smaller size cables are more susceptible to damage during construction, and are more susceptible to damage from environmental causes when buried.

Generally only one size cables should be used on a project. Requiring multiple cable sizes leads to constructability problems and increases the potential for error. If a project requires #8 AWG cables in one area and #4 AWG cables in another area, then it is possible for the contractor to install the #8 cables where the #4 cables are required. This will cause improper system operation, and may lead to critical failures. The exception is when #4 cables are used underground and #6 cables are used in bridges and walls. The NEC has different requirements for cables that are #4 AWG or larger than it does for cables that are #6 AWG or smaller. Generally, #4 AWG cables should not be run through bridges or in barrier walls. In these applications, only #6 AWG cables should be used.

Theoretically, determining the optimum cable size depends largely on the luminaire operating secondary voltages and the anticipated load of the luminaires. Some things to remember when selecting the wiring:

- Use multiple 2 conductor duct cables instead of 4 or 6 conductor duct cables. This allows for circuits not being used in a given pole to bypass the pole underground instead of running into the pole with connector kits.

- For sign lighting go ahead and use the 4 or 6 conductor duct cable since sign lighting uses more than one circuit and it isn’t possible to fit 2 duct cables into the 4 inch conduit in the sign foundation.

- For cable runs in bridges and/or parapets, the designer must use #6 AWG wiring.

- Ensure that all plans are clearly marked to the size of wiring, number of conductors, duct cable and/or conduit.

Voltage Drop Calculations

In order to assure that the luminaires on the lighting system have the proper operating current delivered to them it is critical to determine the voltage drop on each circuit including all branches. A branch circuit is any subsection of a circuit that may be diverged in a non-linear path to service other lighting devices on the same circuit. Branch circuits begin at the splice point in electrical manholes.

Voltage drops should be computed at each lighting pole or sign luminaire in an incremental order. For planning, however, the Designer may also check the voltage drop at the last pole with the longest circuit run with the assumption that all loads occur at the last pole location. This procedure is only used for a quick checking of the most critical voltage drop on a circuit. SHA requires pole-by-pole voltage drop computations on each of the lighting circuits, for all roadway and interchange projects. The maximum allowed voltage drop for any given circuit should not exceed 5 percent of the operating voltage.

The procedure to determine the voltage drop is as follows:

1. Layout the preliminary circuits
2. Define a preliminary wire size
3. For each circuit, determine the length of a circuit run between the electrical source

and the load, i.e. the lighting standard or overhead sign.

4. Compute the voltage drop for each circuit based on the following equations

$$\frac{2 \times L \times R \times I}{1000}$$

Equation 2 – NEC Voltage Drop for Single Phase, 3 Wire Circuit

$$\frac{0.866 \times 2 \times L \times R \times I}{1000}$$

Equation 3 – NEC Voltage Drop for 3-Phase, 4 Wire Circuit

OR

$$\frac{11.2 \times 2 \times L \times I}{CM}$$

Equation 4: SHA Voltage Drop

Where,

L = one way length of circuit (feet)
R = conductor resistance (ohms per thousand feet). This is dependent on the wire size and is looked up in tables from the NEC handbook.
I = load current (amps)
CM = area of the wire being used (circular mils)

Equation 2 and **Equation 3** are based on the NEC Handbook. **Equation 4** is the common equation used by SHA. Either method is acceptable.

5. Once the preliminary run of the voltage drop is computed, if the drop is unacceptable then it is necessary to rerun through this process again with either a new circuit layout or a different wire size or possibly both until an acceptable efficient system is reached.

Figure 68 provides a side-by-side comparison of the relationship that conductor size has with equations 2 and 4. **Figure 69** also shows the comparison of conductor size with equations 2 and 4 but shows converted Conductor Resistance values that are based on a temperature of 40°C rather than 75°C. **Figure 70** is an example of a spreadsheet used to calculate voltage drops using the NEC equations. **Figure 71** is an example of a spreadsheet used to calculate voltage drops using the SHA equation. The circuit number, conductor size, area, resistance, operating voltage, from/to, length between and operating current are all inputs from the designer.

The difference in results between the NEC equations and the SHA equation is based on the relationship between resistance and temperature as follows:

- Resistance increases as conductor temperature increases

The NEC voltage drop equation is based on a conductor temperature of 75°C while the SHA assumes a conductor temperature of 40°C based on their experience. Since resistance will increase with a temperature increase, the NEC equation will produce a higher, more conservative voltage drop.

Further, SHA generally uses #6 AWG or #4 AWG wiring for lighting since conductor lengths are usually long. With a larger conductor size, the resistance will decrease and result in a lower voltage drop.

Conductor Size (AWG)	Conductor Resistance* (ohm/kFT)	Area (Circular mils)	**NEC Method** R/1000**	**SHA Method** 11.2/CM**	Difference
18	7.95	1620	0.00795	0.00691	0.00104
16	4.99	2580	0.00499	0.00434	0.00065
14	3.14	4110	0.00314	0.00272	0.00042
12	1.98	6530	0.00198	0.00171	0.00027
10	1.24	10380	0.00124	0.00107	0.00017
8	0.778	16510	0.000778	0.000678	0.0001
6	0.491	26240	0.000491	0.000427	0.000064
4	0.308	41740	0.000308	0.000268	0.00004
3	0.245	52620	0.000245	0.000212	0.000033
2	0.194	66360	0.000194	0.000169	0.000025
1	0.154	83690	0.000154	0.000134	0.00002

Figure 68 – Comparison of Conductor Size and the Voltage Drop Equations

*Conductor Resistance is based on Direct-Current Resistance at 75°C (167°F). This example uses Uncoated Copper conductors with 7 strands for all conductor sizes except 1 AWG; 19 strands were used for this example.

**Values for R/1000 and 11.2/CM represent the conductor properties related components in the Voltage Drop Equations and are considered in this comparison.

Conductor Size (AWG)	Converted Conductor Resistance* (ohm/kFT)	Area (Circular mils)	**NEC Method** R/1000**	**SHA Method** 11.2/CM**	Difference
18	7.05	1620	0.00705	0.00691	0.000141
16	4.43	2580	0.00443	0.00434	0.000085
14	2.79	4110	0.00279	0.00272	0.000065
12	1.76	6530	0.00176	0.00171	0.000046
10	1.10	10380	0.00110	0.00107	0.000029
8	0.690	16510	0.000690	0.000678	0.000012
6	0.435	26240	0.000435	0.000427	0.0000085
4	0.273	41740	0.000273	0.000268	0.0000052
3	0.217	52620	0.000217	0.000212	0.0000053
2	0.172	66360	0.000172	0.000169	0.0000031
1	0.137	83690	0.000137	0.000134	0.0000026

Figure 69 – Comparison of Conductor Size with Converted Temperatures and the Voltage Drop Equations

*Conductor Resistance is based on Direct-Current Resistance at 40°C (104°F). This example uses Uncoated Copper conductors with 7 strands for all conductor sizes except 1 AWG; 19 strands were used for this example.

**Values for R/1000 and 11.2/CM represent the conductor properties related components in the Voltage Drop Equations and are considered in this comparison.

Example Voltage Drop Computations, NEC Method						
	Circuit Number:	1				
	Conductor Size:	4	AWG			
	Conductor Resistance:	0.31	ohm/kFT			
	Operating Voltage:	277	Volts			
From / To	Length	Operating	Total	Section Volt	Total Volt	Vd %
control to mh1	10		12	0.07	**6.20**	**2.24**
mh1 to P47	40	1.2	12	0.30	6.13	2.21
mh1 to mh2	60		10.8	0.40	5.83	2.11
mh2 to P38	200	1.2	10.8	1.34	5.43	1.96
P38 to mh3	60		9.6	0.36	4.09	1.48
mh3 to mh4	80		9.6	0.48	3.73	1.35
mh4 to P39	15	1.2	9.6	0.09	3.26	1.18
P39 to P41	200	1.2	8.4	1.04	3.17	1.14
P41 to P42	100	1.2	7.2	0.45	2.13	0.77
P42 to P43	80	1.2	6	0.30	1.68	0.61
mh1 to mh6	100		4.8	0.30	1.38	0.50
mh6 to mh7	80		4.8	0.24	1.09	0.39
mh7 to P49	15	1.2	4.8	0.04	0.85	0.31
P49 to P4	120	1.2	3.6	0.27	0.80	0.29
P4 to P53	280	1.2	2.4	0.42	0.54	0.19
P53 to mh29	30		1.2	0.02	0.12	0.04
Mh29 to mh5	80		1.2	0.06	0.10	0.03
mh5 to 44	50	1.2	1.2	0.04	0.04	0.01

Figure 70 - Example of Voltage Drop Calculations, NEC Method

Example Voltage Drop Computations, SHA Method						
Circuit Number:	1					
Conductor Size:	4	AWG				
Cross Sectional Area:	41740	CM				
From / To	Length	Operating	Total	Section Volt	Total Volt	Vd %
control to mh1	10		12	0.064	**5.371**	**1.94**
mh1 to P47	40	1.2	12	0.258	5.306	1.92
mh1 to mh2	60		10.8	0.348	5.049	1.82
mh2 to P38	200	1.2	10.8	1.159	4.701	1.70
P38 to mh3	60		9.6	0.309	3.542	1.28
mh3 to mh4	80		9.6	0.412	3.233	1.17
mh4 to P39	15	1.2	9.6	0.077	2.821	1.02
P39 to P41	200	1.2	8.4	0.902	2.743	0.99
P41 to P42	100	1.2	7.2	0.386	1.842	0.66
P42 to P43	80	1.2	6	0.258	1.455	0.53
mh1 to mh6	100		4.8	0.258	1.198	0.43
mh6 to mh7	80		4.8	0.206	0.940	0.34
mh7 to P49	15	1.2	4.8	0.039	0.734	0.27
P49 to P4	120	1.2	3.6	0.232	0.696	0.25
P4 to P53	280	1.2	2.4	0.361	0.464	0.17
P53 to mh29	30		1.2	0.019	0.103	0.04
Mh29 to mh5	80		1.2	0.052	0.084	0.03
mh5 to 44	50	1.2	1.2	0.032	0.032	0.01

Figure 71: Example of Voltage Drop Calculations, SHA Method

Control Panel

The Lighting Control Cabinet and associated equipment is determined based on the combined load on all circuits.

Connected Load

The connected load refers to the total current and power in each circuit. It is defined by power (kilowatts KW) and current (amps).

The power is determined by summing the line wattage of each luminaire on the circuit.

Poles

Poles is the number of electrical connection points of the circuit breaker. A two-pole connection system is normally used on all SHA lighting projects for 120V/240V. A single pole connection is used for 277V/480V systems.

Frame Size

The frame size refers to the amperage size of the main circuit breaker. A frame size of 100 or 200 amps is normally used on highway lighting projects.

Trip Size

The trip size refers to the amperage size of each branch circuit breaker. It is primarily used to safely disconnect the circuit in the event of an overload on the circuit breaker. For lighting, the normal operating load shall not exceed 80% of the trip size. A trip size of 20 ampere is normally used on SHA lighting projects.

Connector Kits

Book of Standards References
Roadway Lighting Voltage Connections

Connector kits serve two purposes in a typical lighting design. First, connector kits are used for making a serviceable waterproof splice connection of lighting cables for each conductor or duct cable in electrical junction devices such as electrical manholes. Secondly, connector kits are used to connect branch circuit conductors to the luminaire (ballast circuit) conductors in the handhole or transformer base of lighting and sign structures.

There are four types of connector kits, Types I, II, III and IV. Some of the connector kits are used for fused or unfused applications. Fused connectors provide safety measures against knockdown of lighting poles, which causes the cables in the splice box to be disconnected without exposing any of the internal cable wiring.

Fused vs. Unfused

When a branch circuit conductor must be connected to the luminaire a *fused* connector shall be used. If a branch circuit conductor is being spliced in a junction device (such as in a manhole or a handhole) an unfused connector should be selected. Neutrals are never fused.

In-line vs. "Y" Connection

In-line connector kits are used in manholes for continuous runs of duct cables. In-line connectors may be unfused when used in underground handholes and fused when used in pole bases. "Y" connector kits are used in handholes where a single duct cable must be spliced and branched in multiple directions.

The applications for each connector kit are shown in Table 11:

Table 11 - Connector Kits

Application →	Unfused In-line	Fused In-Line	Fused Y	Unfused Y
Connector Type →	I	II	III	IV

Number of Connector Kits

Typically, each conductor cable requires a connector kit. Determining the total number of connector kits needed for connection in a lighting system design is based on two factors:

1. The type of service being used (single or three phase system), and
2. The pattern of splices in a junction point either at the pole base or in a handhole.

The SHA Book of Standards shows a typical schematic for using all four types of connector kits, under a 120/240 volt lighting system for 240-volt luminaire connections. Likewise, the Book of Standards shows a schematic for typical pole connections under a 277/480 volt system, with 277-volt luminaire connections.

Lighting Legend

The lighting legend includes symbols and detail callouts that provide the following information for each proposed pole and luminaire: type of luminaire and mounting detail, type and size of cable or wires required, the number and type of connector kits, the station number and offset, the pole number, the mounting height and mast arm length and the circuit number. A detail callout is also provided for each handhole which provides: the handhole ID number, the handhole ID tag, the number of inline splices – type 1, and the number of 'Y' splices – type 4. Figure 72 on the following page shows these detail callouts as well as other typical symbols found on a lighting plan.

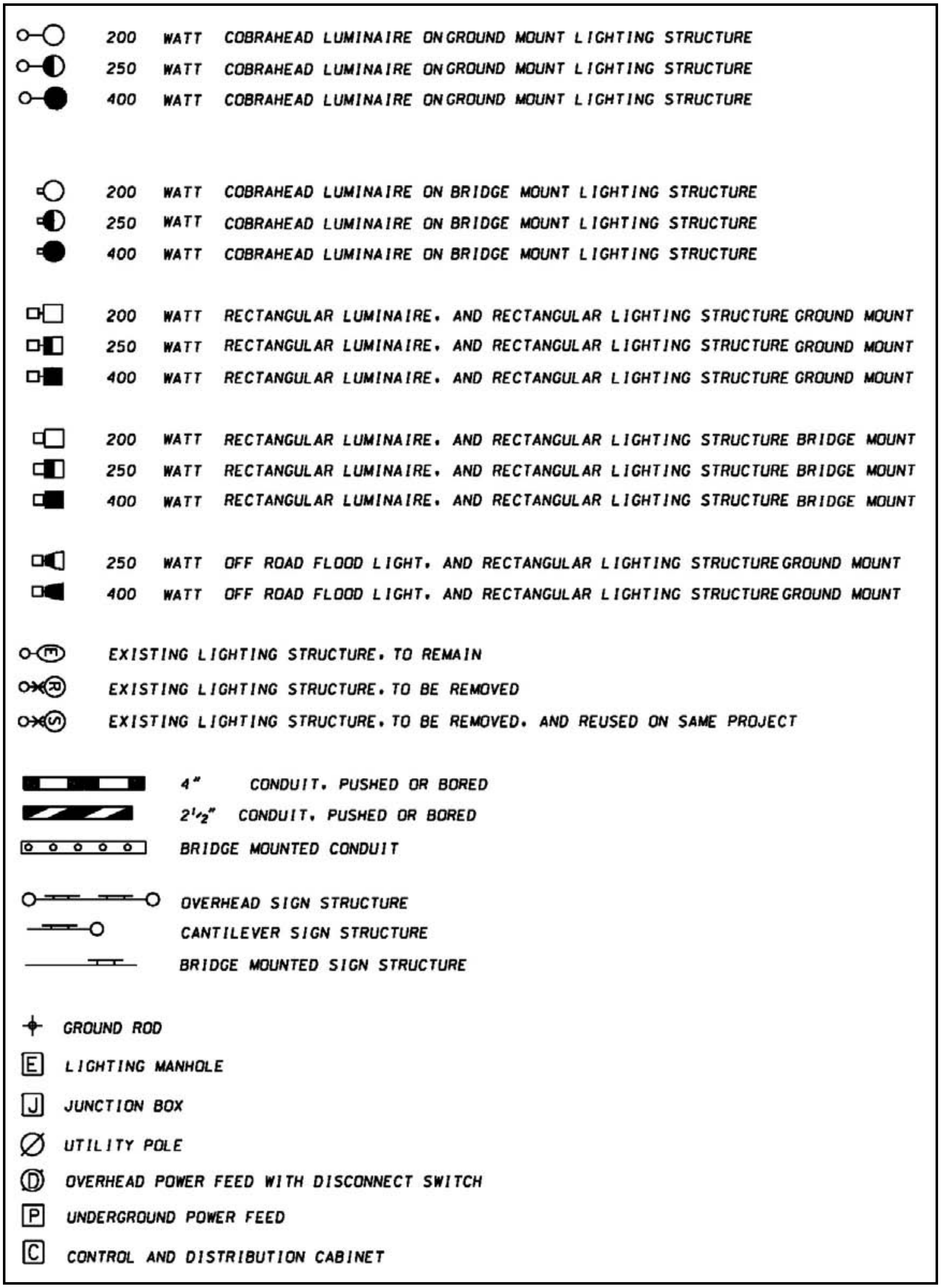

Figure 72a – Lighting Legend

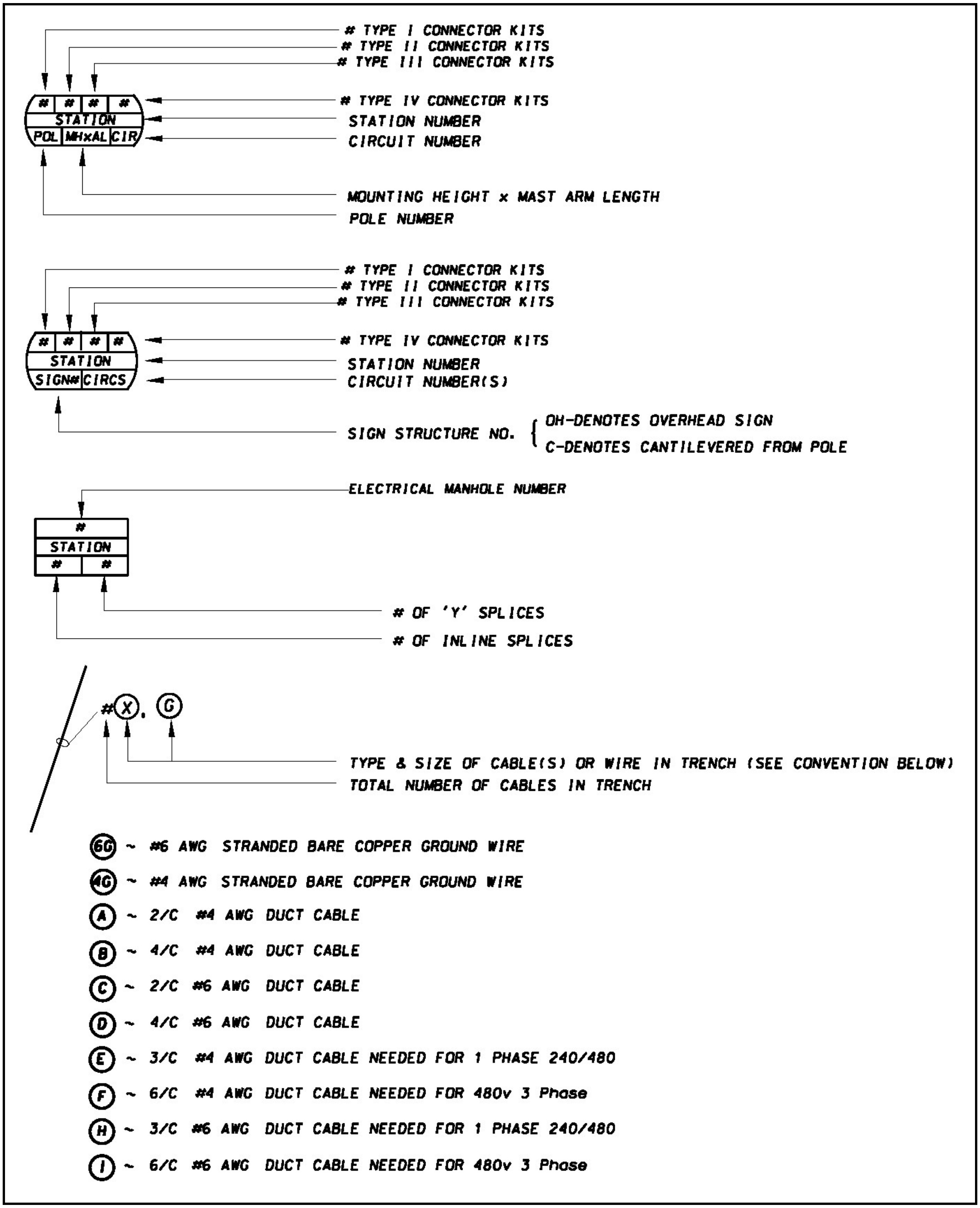

Figure 72b – Lighting Legend