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Version History


Version 2 – July 2008

Revised to accommodate NTTA conversion from tolling plazas to all Electronic Toll Collection (ETC) including revised electrical loads and revised three phase to single phase system design. Chapter 7 was rewritten to include Bridge Electrical Systems design. All appendix material was replaced by one appendix to show a typical design for a section of NTTA roadway.

Version 3 – August 2011

Revised manual to revert back to three phase system design based on custom equipment costs and availability from utility providers. Revised manual includes chapters on bridge, tunnel and sand stockpile electrical design and includes an additional chapter for equipment and material selection. Version 2 Appendix was replaced with full detailed appendix covering all aspects of system design.

Version 4 – June 2015

Revised manual to down size ESC Centers from 400 amps to 200 amps. This involves the recalculation of all loads. This is reflected in the panel schedules and one-line diagrams in the appendix. Included in this revised manual are lessons learned.
About the Roadway Electrical System Manual (RESM)

The information contained in this Manual is a compilation of: hands-on experience, research and observation of the existing Texas Tollway Authority (TTA) and North Texas Tollway Authority (NTTA) electrical systems, lessons learned from existing NTTA electrical installations, various additional components requested by NTTA Departments, and a desire to create a system that would be easy to maintain, operate and function with minimal problems over a 30+ year lifespan.

If any portion of the RESM content, methodology or intent is unclear contact the NTTA Maintenance Department for clarification.

The NTTA roadway electrical system is the backbone for all of the Authority’s various systems including: revenue producing equipment; data collection; security and system alerts; roadway illumination; and irrigation control. It is therefore imperative that the electrical system be designed to withstand a multitude of various issues ranging from adverse weather conditions, environmental impacts, utility brown-outs, and physical impacts.

Thoroughly reading and understanding the RESM including the associated appendices and approved NTTA Electrical Standards, and subsequently creating design plans which reflect the standardization required by the Authority, effectively reduces electrical downtime associated with any damage caused by the above scenarios.

This document was created to standardize NTTA Roadway Electrical Systems. The wording, descriptions, examples and appendixes were created to show a minimum level of design and to give an expectation of electrical system consistency.
Chapter 1 - Introduction

1.1 Purpose of Manual

1.1.1 This manual is to provide NTTA Electrical system design philosophy and information concerning power distribution and infrastructure as it pertains to tolling electrical systems serving Mainlane Gantry (MLG) and Ramp Gantry (RG), roadway illumination, and power supplies for communication huts, ITS elements and irrigation controllers. It does not cover power or illumination inside of buildings or other facilities.

1.1.2 NTTA facilities cover a large geographic area and not every design contingency can be accounted for. It shall be the responsibility of a qualified member of the NTTA Electrical Maintenance staff who serves as the electrical plan reviewer within the Operations sub-division of the Maintenance Department, the Program Management Consultant (PMC), the General Engineering Consultant (GEC) and the Maintenance Management Consultant (MMC), if under contract, to ensure the individual design engineer meets the intent of this manual and the NTTA Standards. It is the further intent of this manual to ensure standardization of equipment to reduce the cost of inventory and ease of replacement.

1.1.3 The NTTA requires all electrical designs be signed and sealed by a professional engineer licensed to practice in the State of Texas.

1.1.4 This manual is for use by electrical engineers and designers during the preparation of plans for NTTA projects. It is not for the direct use of contractors or construction personnel during the actual construction of roadways. However, this manual may be beneficial if reviewed by field personnel to understand the placement of various pieces of equipment and the reasoning behind the electrical system layout.

1.1.5 Prior to preliminary or detailed design, the designers should review any Inter-Local Agreement (ILA), this Roadway Electrical Systems Manual (RESM), NTTA Standards, NTTA Standard Guidelines and manuals, and for non-standard designs, the TxDOT Highway Illumination Manual.

1.1.6 The Designer shall coordinate with the Corridor sections/segments adjacent to the design they are responsible for. When the design of multiple roadway sections are apportioned to different design firms, all electrical work specified herein shall be coordinated with the work of the other Section Engineer's working on the Project and completed so that all installations shall operate as a single unified system design. The designer shall also consider all plans for future expansion.

1.1.7 All work shall be designed and installed in accordance with the latest versions of the National Electrical Code and the National Electrical Safety Code.
1.2 Inter-Local Agreement (ILA) Coordination with Design

1.2.1 An ILA is a binding legal document with the NTTA and assigns full responsibility for operations and maintenance costs associated with all elements of the design and any preferences for equipment selection or placement in regard to aesthetics, maintenance, third party agreements with utilities, etc.

1.2.2 Prior to preliminary or detailed design, the designer shall review and subsequently discuss with the NTTA the ILA's between all municipalities involved. This discussion should establish:

1.2.2.a The municipality's consent to assume the operational and maintenance costs for power and lighting systems and other assets through a documented and signed ILA between the NTTA and the municipality.

1.2.2.b That the design should not begin without the municipality's consent to maintain and operate the power and lighting systems for the non-NTTA facilities.

1.2.2.c That the ILA should make specific reference to the NTTA's responsibilities associated with the maintenance and repair of all power and illumination systems for all mainlanes, ramps, frontage roads, crossroad intersections and high mast lighting structures.

1.2.2.d Any local municipality's preferences for equipment selection or placement, thus allowing the designer to accommodate the municipality's need with regard to aesthetics, third party maintenance agreements with utilities, etc.

1.3 Responsibilities

1.3.1 The NTTA shall provide the roadway schematic plans based on the Final Environmental Impact Statement (FEIS) for the design of an Electrical, Illumination and ITS Master Plan. The Master Plans shall be coordinated with the local electrical service provider and the NTTA at the Plans, Specifications and Estimate (PS&E) level to identify all preliminary proposed electrical service center locations. Special requirements shall be identified.

1.3.2 The NTTA Project Delivery, Maintenance and IT Departments shall review the Master Plans prior to the PS&E process.

1.4 PS&E Plan Standards

1.4.1 A maximum plan scale of 1”=100’ shall be used to provide adequate detail for electrical, illumination and ITS layouts. This scale will allow all electrical and site work for the section to be shown with sufficient detail to enable the contractor to efficiently bid and install the system.
1.4.2 All line work and graphics within the PS&E plans shall be drafted to true scale. Where drawing scale does allow for legible plan graphics, symbols and line work should be exaggerated only as necessary to communicate the design intent. All station and offset callouts shall be to the actual position of the design elements. If the maximum plan scale does not allow for adequate detail in congested areas, additional blow-up details shall be provided to communicate the desired layout.

1.4.3 The NTTA has developed standard symbols in the NTTA CADD standards to aid in plan preparation and the numbering of illumination structures, circuits, ground boxes, communication systems and ESC’s.

1.4.4 Tables shall be used to summarize design requirements and will include the following: a legend explaining the symbols used; an ESC data table which identifies the various types of ESC’s used and their service locations, a table of roadway illumination assemblies, ITS pole types and locations; a sheet summary table; conduit and conductor run table; and a table of ground box types and locations. All NTTA pay item quantities shall be summarized in the plans and be included in the estimate and quantity sheet.

1.4.5 The Electrical/Power (PWR), Illumination (ILL) and Intelligent Transportation System (ITS) plans and details shall provide the information necessary for a contractor to bid and construct the complete electrical and communication systems. As a minimum, the following plan sheets should be provided:

1.4.5.a Roadway Electrical/PWR Plans – these sheets should show overall layout and provide the locations of proposed and existing features such as: edges of pavement, shoulders and curbs; existing/proposed utility company service points and meter locations; S/E and ESC locations with a detailed section cut, gantry power and interconnection along with conduit, conductors, with associated MPE’s, landscape controller locations and ground boxes.

1.4.5.b Roadway Illumination (ILL) Plans – these sheets should show overall layout and provide the locations of proposed and existing features such as: edges of pavement, shoulders and curbs; existing/proposed luminaire supports and spacing; illumination structure numbering, required lighting for any infrastructure elements.

1.4.5.c Roadway Intelligent Transportation System (ITS) Plans – these sheets should show overall layout and provide the locations of proposed and existing features such as: edges of pavement, shoulders and curbs; existing/proposed IT Equipment and ITS elements.

1.4.5.d Tables for ESC Installations, Luminaire Structures, Luminaires, Conduit & Conductor and Ground Boxes - the information on these sheets may be presented on the PWR/ILL/ITS plans or on separate sheets at the end of
the plan layout sequence. The tables shall specify the details associated with each asset. All assets shall be provided an identification number and located by station and lateral offset, (indicate what control line is used to measure from); and location by Northing and Easting coordinates. Include S/E and ESC foundation and luminaire structure elevation; and foundation type. Pole information will depict the material type and the type of mounting base used on the structure. Information shall also include the type and number of arms and the rise and length of the arms. Luminaire information will include luminaire model, IES distribution type, lamp size, voltage and mounting height. Conduit and conductor runs will show the size of the conduit and the size and quantity of the conductors to be installed. Ground box details will include the ground box type, location, (i.e. in-ground, rail, bridge, etc.) and the size if not a TxDOT standard.

1.4.5.e Wiring Details - these sheets shall provide details for circuit wiring, transformer base wiring, photocell and contactor wiring and One-Line diagrams for power distribution from an ESC to its associated gantries, illumination and ITS utilization equipment. The One-Line diagrams shall follow the ITS plans and the panel board schedules shall follow the One-Line diagrams.

1.4.5.f Illumination Structure Foundation Details - these sheets shall provide special installation details for cut or fill locations and dimensional requirements of foundation and conduit placements.

1.4.5.g Illumination Structure Details - these sheets shall provide for the NTTA's model and other identification numbers, general configuration details and other information deemed necessary by the NTTA.

1.4.5.h Miscellaneous Details - If required, these sheets shall provide information showing the limits of clearing and grubbing of existing trees in the path of the proposed lighting and in the vicinity of the luminaires, ITS components, and ground boxes.

1.5 Submittal Requirements

1.5.1 Upon review and completion of the Master Plans, the next submittal for roadway illumination and ITS will be at the 60% PS&E level. The design engineer shall inform the project team of problem areas for the roadway which will require inter-disciplines coordination.

1.6 Preliminary Electrical Report

1.6.1 A Preliminary Electrical report shall be submitted initially for NTTA review at the 30% design level. A final Electrical report shall be presented at the 100% design plans level. Prior to submitting the preliminary Electrical report, the designer shall establish the electrical design layout criteria based on the
specifications given in the NTTA Standard Guidelines, NTTA Standards, the NTTA Roadway Electrical Systems Manual, and any local requirements. The purpose of this step is to establish and agree upon the power requirements (design criteria) as design work begins for the 60% level plans.

1.6.2 The designer shall prepare the Preliminary Electrical report based on the Illumination and ITS Master Plan, and establish the basic components of the electrical system. The report shall identify all components in sufficient detail so that the electrical system can be laid out and completed during the design phase. This report shall include all POC (Point Of Connection) supply points, the location of all ESC's TY S/E, TY S and TY MLG, including the names of the ESC's as approved by a qualified member of the Electrical Maintenance staff who serves as the electrical plan reviewer within the Operations sub-division of the NTTA Maintenance Department.

1.6.3 The report will document and provide a means for reviewing the basis for the design, and insure that the design is consistent with the guidance provided herein as it progresses from inception to final design.

1.7 Final Electrical Report

1.7.1 The Final Electrical report shall build upon and resolve the comments made regarding the preliminary electrical report and any resolution from the 60% PS&E comment reviews. Design tasks performed leading up to and reflected in the final electrical report shall include: energy consumption and cost calculations, voltage drop calculations performed to determine conductor (wire) size, and other determinations necessary to finalize the plans.

1.8 Preliminary Lighting Report

1.8.1 A preliminary lighting report (photometrics) shall be submitted initially for NTTA review at the 30% design level. Prior to submitting the preliminary lighting report, the designer shall establish the lighting criteria based on the specifications given in the NTTA Standard Guidelines, NTTA Standards, the NTTA Roadway Electrical Systems Manual, and any local requirements. The purpose of this step is to establish and agree upon the lighting levels (design criteria) as design work begins for the 60% level plans.

1.8.2 The designer shall prepare the Preliminary Lighting report based on the Illumination and ITS Master Plan, and establish the basic components of the lighting system. The report shall identify all components in sufficient detail so that the lighting system can be laid out and completed during the design phase. The designer shall include the following information within the preliminary report: light source type, light source size and mounting height, luminaire type and location, luminaire spacing and arrangement, power supply point(s), hardware, and calculations (manual or computer printouts) which verify the lighting design criteria.
1.9 Final Lighting Report

1.9.1 A final lighting report shall be presented at the 100% design plans level. The Final Lighting report shall build upon and resolve the comments made regarding the preliminary lighting report and any resolution from the 60% PS&E comment reviews. Design tasks performed leading up to and reflected in the final design lighting report shall include: energy consumption and cost calculations, voltage drop calculations performed to determine conductor (wire) size, and other determinations necessary to finalize the plans.

1.10 Use and Disposition of Electrical and Lighting Reports

1.10.1 Once the Electrical and Lighting reports are approved, the engineer shall have the design plans complete with only minor coordination needed to finalize the drawings.

1.10.2 With the completion of each type and level of report, the Section Engineer shall submit 4 copies distributed to the Project Delivery Department and two to the Maintenance Department. This will allow for the NTTA's Project Manager to further coordinate with any municipality involvement and the local utility company. Continued coordination with these agencies should prevent issues associated with electric service connection, assumption of maintenance responsibility, or other issues which may be difficult to resolve late in project development or construction. A written reply from these agencies may be useful to document their concurrence with the design. It is important that the municipalities are satisfied in all aspects of the design for which they will become responsible for servicing and maintaining. All correspondence with the utility and municipality shall be copied to the project file.
1.11 Reference Standards (Industry)

AASHTO  American Association of State Highway and Transportation Officials

AEIC     Association of Edison Illuminating Companies

ANSI     American National Standards Institute, Inc.

ASME     American Society of Mechanical Engineers

ASTM     American Society for Testing and Materials

IEEE     Institute of Electrical and Electronic Engineers

IESNA    Illuminating Engineering Society of North America

IPCEA    Insulated Power Cable Engineers Association

JIC      Joint Industrial Conference

NEC      National Electrical Code

NEMA     National Electrical Manufacturer Association

NESC     National Electrical Safety Code

NFPA     National Fire Protection Association

OSHA     Occupations Safety and Health Act

TxDOT    Texas Department of Transportation

UL       Underwriters Laboratories

1.12 Reference Standards (NTTA)

AVI      Automatic Vehicle Identification

CCTV     Closed Circuit Television

DMS      Dynamic Message Sign

DG       NTTA Design Guidelines
ELMS  Electrical and Lighting Management System
ESC  Electrical Service Center
ESP  Electrical Service Provider
ETC  Electronic Toll Collection
GEC  General Engineering Consultant
ILA  Inter-Local Agreement
ILL  Illumination
IT  Information Technology
ITS  Intelligent Transportation System
MDP  Main Distribution Panel
MLG  Mainlane Gantry
MMC  Maintenance Management Consultant
MPE  Mini-Power Enclosure
NTTA  North Texas Tollway Authority
POD  Point of Delivery
PMC  Program Management Consultant
PWR  Power
RESM  Roadway Electrical Systems Manual
RG  Ramp Gantry
RWIS  Roadway Weather Information System
RWL  Roadway Lighting
TTS  Travel Time Sensor
<table>
<thead>
<tr>
<th>S/E</th>
<th>Service Entrance</th>
</tr>
</thead>
<tbody>
<tr>
<td>TY</td>
<td>Type</td>
</tr>
<tr>
<td>VTC</td>
<td>Video Tolling Camera</td>
</tr>
</tbody>
</table>
Chapter 2 – Guide to Electrical Service Centers

2.1 Introduction

2.1.1 This chapter explains the various ESC Enclosures in the NTTA Standard Drawings and how each relates to another.

2.2 ESC Type S/E (Service Entrance)

2.2.1 The ESC TY S/E enclosures’ function is to receive the incoming electrical conductors from the utility company, meter the supply and pass it along to its associated ESC. It contains the Code required disconnecting means for the ESC and serves as the isolation switch for allowing NTTA Maintenance to service the ESC TY S and ESC TY MLG equipment safely.

2.2.2 The Standard NTTA electrical power supply is a 277Y/480V, 3 phase, 4W service. “Y” signifies “Wye” which means the utility transformer is center-tapped to ground and the voltage available on each phase is equal. The “4W” indicates there are four (4) service entrance conductors brought from the utility transformer. These four conductors consist of the three (hot) phase conductors and a grounded service (or neutral) conductor. In addition to the conductors referenced above, the complete installation will include an equipment grounding conductor.

Figure 1: ESC TY S/E
2.2.3 It is against Electrical Utility company policy to allow a customer to place a
meter inside an enclosure even if the meter can be read externally. Therefore,
the ESC TY S/E is designed and sized to allow for the metering device to be
mounted outside the enclosure and to supply the service conductors through
the wall of the S/E enclosure to the service disconnect switch inside.

2.2.4 Inside each ESC TY S/E is a 277/480V, 3 phase, fused disconnect containing a
solid neutral assembly. There are four (4) conductors being supplied from the
utility company to the S/E, either as an aerial drop or as an underground supply
(service lateral). The utility company supplies three (3) phase conductors and a
neutral. Each phase conductor connects to a dedicated single fuse inside the
disconnect switch, and the neutral is terminated to a lug which is mounted to
the bolted neutral buss assembly.

2.3 ESC TY S/E (Locations)

2.3.1 ESC TY S/E enclosures are placed either remote or local to an ESC TY S or
ESC TY MLG.

2.3.2 The remote ESC TY S/E is utilized when the utility company expresses a
concern over their employees being placed in harm's way while performing
any required services, (i.e. meter reading, service work, etc.) and so the meter
can be read from a non-tolled location.

2.3.2.a Remote ESC TY S/E enclosures can be placed anywhere required by the
utility company. Typical locations are on the right-of-way (ROW) and
accessible by utility company employees being able to pull off the roadway
to stop and perform their work, or out of the ROW across a service road
which allows the utility personnel to pull into a parking lot and perform their
tasks at a safe location. Any remote location is acceptable as long as the
ESC TY S/E enclosure is heavily protected from physical damage occurring from a traffic incident or a large vehicle turning a corner, jumping
a curb and running over the S/E. (ESC TY S/E remote placement and
connection can be found in the NTTA Standard drawings.)

2.3.2.b As used in the paragraph above, in allowing any acceptable location, the
designer shall make every effort to minimize the distance between the ESC
TY S/E and the ESC TY S or MLG. The designer must consider all costs
associated with the distance the ESC TY S/E remote enclosure will be
placed, in relation to its associated ESC. The greater the distance, the
more expense there is to the NTTA in relation to materials and labor; not
just at the time of construction, but in the event any future damage caused
to non-located conductors being cut, or in the possibility of a fault in the
conductors, requiring a high price to replace the conductors and conduit.

2.3.2.c In any scenario where a remote S/E is requested by a utility or required by
design, a cost comparison must be completed by the designer to insure the
most economic installation for the NTTA. The comparison must be calculated between the cost of having the utility company build infrastructure (pole and conductors) to come to where the NTTA has an economical advantage to the installation and alternatively, the costs associated with extending the NTTA owned supply conductors to the location required at the utility companies’ Point-Of-Delivery (POD). This is of paramount importance when the Authority is constructing roadway in rural areas or where municipality infrastructure has not yet grown to its incorporated limit.

2.3.3 Local ESC TY S/E enclosures are positioned adjacent to the ESC they support. They are identical to the remote S/E but utilize the same foundation pad as the associated ESC for mounting. (ESC TY S/E local placement and connection can be found in the NTTA Standard drawings.)

2.3.4 All coordination with utility providers including meter locations, meter addresses and load form applications shall be the responsibility of the design engineer and/or the construction manager.

2.3.5 ESC TY S/E equipment must be protected at any location chosen; either remote or local. Other than the actual POD which is maintained by the electrical utility provider, the ESC TY S/E is the primary source for all electrical energy serving the tolling infrastructure owned by the NTTA. The ESC TY S/E can only be turned off by the electric utility provider. Requesting this action is extremely time consuming in waiting for the utility provider to arrive and disconnect the primary power to the S/E. This delay becomes an even more critical factor if an incident occurs to the S/E and the utility fuses do not operate (open) properly, thus causing an immediate and severe electrical hazard due to any damaged or exposed conductors and the possibility of any equipment being energized.

2.4 ESC TY S (Ramp and Roadway Service)

2.4.1 The ESC TY S receives power from the ESC TY S/E. The ESC TY S serves as the distribution point for the various NTTA electrical systems along the roadway. The primary function of the TY S enclosure is to provide power to ETC ramp gantries, communications huts, ITS elements and roadway illumination.

2.4.2 No more than 4 ramp gantries shall be supplied from an ESC TY S. (See Appendixes)
2.5 ESC TY MLG (Mainlane Gantry)

2.5.1 The ESC TY MLG receives power from the ESC TY S/E. The ESC TY MLG serves as the distribution point for the various NTTA electrical systems. While the primary function of the TY MLG enclosure is to provide power to the two required mainlane gantry structures and their associated tolling components, the ESC TY MLG secondary function is to supply power to within the project limits of the MLG, or one thousand feet (1,000’) in both directions from the centerline of the two mainlane gantries. This area includes any ITS devices, roadway lighting structures, or irrigation controllers.
2.6 ESC TY MPE (Mini-Power Enclosure)

2.6.1 The ESC TY MPE is used to supply local power to any ITS element or landscaping controllers located along the roadway.

2.6.2 The ESC TY MPE receives power from a feeder circuit originating from panel ITS located inside either ESC TY S or ESC TY MLG.
2.7 ESC Enclosures (General)

2.7.1 The designer shall reference the NTTA ESC standards for enclosure and equipment details. Each enclosure shall be Type 316 stainless steel, and NEMA 3R rated with gasketed lockable door(s). Enclosures inside of the NEMA 3R enclosure shall be NEMA 1. The enclosure shall have two screened vents; one on the side wall near the bottom and the other on the opposite side near the top of the enclosure. Both vents will utilize insect resistant screening.

2.7.2 The enclosure shall be secured to a concrete foundation stabilized per geotechnical design based on the surrounding soil conditions to insure the foundation does not crack, sink, heave or shift. Any foundation found not in compliance with these conditions shall be replaced at the Contractor's expense. Foundation shall be constructed from the Standard drawing which will not permit standing water.

2.7.3 The enclosures are required to have in 4” letters “DANGER High Voltage” mounted on the front door. In addition, the following labels shall be provided and mounted on the front door of the enclosure on engraved, phenolic tags with black lettering on a yellow background in the following sizes:

- 2"- ESC Name*
- 2"- Street Address
- 1"- ESI Number
- 1"- GPS Location
- 1"- Arc Flash Warning/Information

2.7.4 *All ESC names shall consist of two letters which reference the nearest cross street and must be approved by a qualified member of the Electrical Maintenance staff who serves as the electrical plan reviewer within the Operations sub-division of the Maintenance Department prior to the Preliminary Electrical report.

2.7.5 All labels will be adhesive backed and permanently held in place by self-tapping stainless steel screws. Mounting holes in the label will be countersunk and appropriate screws used to achieve a flush finish.

2.8 ESC Information to be Provided

2.8.1 The following information about Electrical Service Centers and their associated service entrance metering and disconnect switch, (ESC TY S/E), shall be supplied to the project manager and Maintenance Department’s Infrastructure Engineer;

- Street address
- ESI Number
- GPS Location/Station & Offset
- Side of road with travel direction
- Access by service road or main lane
Chapter 3 – Placement of ESC Enclosures

3.1 Introduction

3.1.1 To reduce the number of electrical services on NTTA roadways, the Authority expects a minimum of one electrical service for any 5,280 foot segment of roadway. This chapter explains the priority placement of ESC electrical services.

3.2 Locations of Electrical Services

3.2.1 All S/E’s and ESC’s shall be placed so as to avoid damage from errant traffic on a maximum 4:1 slope. Where this cannot be achieved by location alone, rigid or flexible barrier shall be placed to protect the ESC. The preferred location for electrical service centers are at ramp and mainlane gantries. The placement shall be made on NTTA-owned property with enough space to accommodate a minimum of two service vehicles. The minimum width of the parking spaces shall be ten feet. A protected service pad shall be provided for emergency generator placement at all TY S locations.

3.3 Placement of Electrical Services

3.3.1 The NTTA prefers to limit the number of electrical services installed along the roadways. This is achieved by placing an ESC TY S enclosure for every 5,280 feet of roadway. The 5,280 foot limit means that in choosing locations for electrical services along the roadway, a typical distance of approximately one mile is required between any two electrical services.

3.3.2 Sizing the AIC Ratings for circuit breakers shall be the responsibility of the design engineer based on his fault current calculations for each project. Series ratings of circuit breakers are not acceptable.

3.3.3 The conductor sizes for circuit runs shown in the standards and in this manual shall be adjusted to comply with the voltage drop of the National Electrical Code of 5%. The section engineer shall not design a single circuit exceeding 2,640 feet in overall length\(^1\).

3.4 Prioritized Locations of Electrical Services (In order of Priority)

3.4.1 Ramp Gantry

3.4.1.a Ramp gantries are supplied by an ESC TY S. Up to four ramp gantries may be served from a single 200 amp ESC if they are within the 5,280 foot segment of roadway served by the ESC. If supplying four ramp gantries, a communications hut shall not be served. If three or less ramp gantries are served, a communications hut may be served from an ESC.
3.4.1.b In locating the placement of an ESC TY S enclosure which will provide power to four gantries, it is desirable to place the enclosure at the gantry closest to an available electric utility supply. Alternatively, if the Point of Delivery is an issue, location of the ESC TY S enclosure at a midpoint between the gantry locations is acceptable with NTTA permission.

![Image of Ramp Gantry Layout w/ ESC Ty S](image1)

Figure 5: Ramp Gantry Layout w/ ESC Ty S

3.4.2 Mainlane Gantries

3.4.2.a A mainlane gantry is always provided with one (1) dedicated ESC TY MLG. This single ESC TY MLG supplies power to each of the individual mainlane gantries tolling both directions of traffic. This ESC shall not supply power to any ramp gantries. It is permissible to utilize this service for powering roadway lighting, ITS elements and irrigation controllers within the project limits of the MLG, or one thousand feet (1,000') in both directions from the centerline of the two mainlane gantries.

![Image of Mainlane Gantry Layout w/ ESC Ty MLG](image2)

Figure 6: Mainlane Gantry Layout w/ ESC Ty MLG

3.4.3 Communications Hut

3.4.3.a An ESC TY S shall supply a communications hut and the surrounding illumination and ITS elements at any location required. A communications hut is generally located either at major interchanges spaced approximately ten miles apart, or at the beginning and/or ending of a proposed roadway phase or addition.
3.4.4 Continuous Roadway

3.4.4.a This Manual is intended to provide NTTA preferred electrical design criteria and offers guidance to designers in the development of electrical plans. The NTTA realizes there are project specific cases where the one mile rule will not work and will assist the Section Engineer with design options.

3.4.4.b An example would be if any entrance and/or exit ramps are co-located within an area served by an ESC TY MLG. The ESC TY MLG is required to supply power to the mainlane gantry because the MLG is backed up by a permanently installed generator. Therefore a separate ESC TY S is required to supply power to the ramps.

3.4.4.c The designer shall strive not to place two services in close proximity to one another and deviate from the one mile rule. The issue is resolved by understanding the TY MLG is dedicated to the mainlane gantry and must be installed, then adding two TY S services on either side of the TY MLG. These services would be spaced one half mile from the approach and departure sides of the mainlane gantry limits.

3.4.4.d Electrical power supplies required for illumination or ITS elements which cannot be served from one of the locations above shall use a 200 amp ESC TY S centered or positioned so the resulting placement will best provide for immediate and future service requirements.

3.4.4.e The designer shall use this option only in a design case where none of the above locations are available within the 5,280 foot limit.

3.4.4.f The NTTA standard drawing ESC TY R SHALL NOT be used without written consent and permissions from the NTTA. (Small TxDOT style services may be more readily available and offer the same flexibility at a lower cost.)

¹ Road lighting circuit lengths of 2,640 feet are based on the NTTA Standard #4 AWG copper XHHW-2 conductor. The design engineer shall verify this size of conductor for voltage drop unique to the project in design. It is permissible to extend a few limited circuits when doing so will effectively reduce the cost of having to add an additional ESC.

Circuits may be extended if the conductor size is increased and the conductor count and size will fit within a 2" conduit per NEC requirements. Voltage drop calculations must accompany any variation from the size of the Standard NTTA conductor.

If the circuit breaker is increased from the Standard, the section engineer must ensure the lug on the CB will accept the larger conductor, or take other measures to make the installation NEC compliant.
Chapter 4 – Electric Service Design

4.1 Introduction

4.1.1 This chapter explains typical electrical service layouts and associated design considerations using the various types of ESC enclosures listed in Chapter 2.

4.2 System Voltage and Amperage (Preferred)

4.2.1 All NTTA roadway electrical systems receive power from the utility provider as a 277Y/480V, 3 phase, 4 wire system. This voltage is distributed to gantries, ITS equipment, roadway illumination and irrigation equipment at 480 volts in both three phase and single phase from an ESC TY S or TY MLG. The maximum allowable design load for any ESC is 200 amps. Any design above 200 amps shall be brought before NTTA for their approval/disapproval.

4.3 System Voltage and Amperage (Alternative)

4.3.1 As stated above the preferred system voltage is a 277Y/480V, 3 phase, 4 wire system. There may be some projects constructed in areas where this voltage is not available. In those situations it may be necessary to design a single phase system. If this occurs then the alternative voltage shall be a 240/480V, single phase, 3 wire system. Just as the 3 phase system above, the single phase electrical service shall be capable of supplying 350 amps. For this case, the design engineer must coordinate the electrical design in conjunction with the NTTA and provide all standards and details required to accommodate the alternative design.

4.3.2 A single phase service capable of supplying 350 amps will require special design, waivers and/or agreements with the Electrical utility provider because the typical TxDOT roadway lighting electrical distribution system does not exceed 200 amps. An electrical system installed by TxDOT usually only provides power for illuminating one or two ramps, or a few high mast structures per location. The NTTA however designs its roadway electrical systems to supply a one mile section of roadway containing any gantries, ITS equipment, roadway illumination and irrigation equipment in that section of roadway. Each piece of electrical equipment must be connected to an NTTA Standard ESC.

4.3.3 The maximum available current which can be supplied to all roadway electrical systems from any single ESC is 200 amps. The service entrance conduit for the ESC shall be built with a single 3" conduit. When the ESC’s load exceeds 200 amps per the unique design of a unique project with the permission of NTTA then the maximum size of conduit shall be 3”. Multiple sets may be installed to accommodate the added load and voltage drop.
4.3.4 Only where a 277Y/480V, 3 phase, 4 wire system is not available is it permissible to use a 240/480V, single phase, 3 wire system.

4.4 System Layout (Point of Delivery)

4.4.1 Electrical utility providers establish a Point of Delivery (POD). The POD is negotiable and should be evaluated by the designer prior to acceptance of the utilities proposition.

4.4.2 Among the items to be considered is a costs comparison between the location offered by the electrical utility and the preferred POD acceptable to the NTTA.

4.4.3 Every POD supplies an NTTA owned ESC TY S/E. The costs to be considered are the length of a run of conduit between the POD and the ESC TY S/E in relation to costs associated with the electric utility provider extending their physical plant to reduce the costs of the NTTA owned service lateral. The service lateral is the underground supply to the ESC TY S/E.

4.4.4 The costs comparison does not end in supplying the ESC TY S/E from the POD, and the complete comparison must include the same conduit length considerations in locating the ESC TY S/E in relation to either an ESC TY S or an ESC TY MLG. Only then can the total costs be weighed one against the other; that is the Utility plant cost versus NTTA ESC TY S/E and associated TY S or TY MLG placement.

4.4.5 The NTTA owns the service lateral and the underground supply between the TY S/E and ESC enclosures. Shortening the overall distance of these service conductors belonging to the NTTA reduces long term Maintenance costs if by chance the conductors in these runs are damaged and require replacement at NTTA cost.

4.5 System Layout (Conduits)

4.5.1 From the utility POD to the NTTA owned ESC TY S/E, per the Standard sheets, there is one 3” PVC schedule 40 conduit.

4.5.2 The Standard sheets show a single 3” PVC schedule 40 conduit from the ESC TY S/E to the ESC TY S.

4.5.3 In the case of a service utilizing an ESC TY MLG, per the Standard sheets, two (2) parallel 3” PVC schedule 40 conduits shall run from the ESC TY MLG to the required back-up generator’s automatic transfer switch (ATS) and one 3” PVC schedule 40 conduit from the ATS to the backup generator. See MLG One-Line Diagram in Appendix.

4.5.4 The ESC TY MLG installation must include four (4) 1” PVC schedule 40 conduits. Three conduits must be placed between the ESC TY MLG and the
generator. Two of the conduits will each contain a single 120V circuit; one circuit for the generator block heater and one circuit for the battery charger. The third conduit is a spare. One conduit shall be placed between the ATS and the generator for future remote monitoring of the generator.

4.6 System Layout (Conductors and Over Current Protection)

4.6.1 As discussed above, one 3" conduit is required from the POD through the ESC TY S/E and continuing to termination in the ESC TY S or TY MLG enclosure.

4.6.2 Both the ESC TY S/E fused disconnect, and the main circuit breaker supplying panel MDP located within either the ESC TY S or TY MLG enclosures, are rated at 200 amps.

4.6.3 Both the ESC TY S and the ESC TY MLG contain a Main Distribution Panel (MDP) supplied by a 200 amp main circuit breaker. The circuit conductors supplying the ESC are protected by the fuses inside the ESC TY S/E fused disconnect, and the sub-panels supplied by panel MDP and their associated wiring are protected by circuit breakers supplied from panel MDP.

4.6.4 Each ESC TY MLG installation shall utilize an emergency generator and ATS for utility power back-up. This generator shall be a 3 phase, 480/277V system rated at 60 KW. Output from the ATS is supplied to the 100 amp ITS Panel Board. This arrangement is specifically configured to keep tolling equipment in operation. Any other loads in the ESC TY MLG are considered secondary and their operation is not required. Load to the generator is regulated by a 90 amp circuit breaker at the generator output.

4.6.5 Each ESC TY S can be connected to a temporary portable generator utilizing “Cam-Lok® Connectors rated at 300 amps (Series 1016, for system interoperability) and connected to a 3 phase, 100 amp circuit breaker installed in panel MDP utilizing a mechanical lock-out device (Kirk Key system), or approved equal lock-out system. The Kirk Key system prevents the possibility of both the generator and utility power supplies from energizing the panel MDP bus bars simultaneously. The interlocking key system is a required safety device for this installation.

4.7 Generators

4.7.1 Permanently mounted generators are only installed where ESC TY MLG enclosures are located. The generator is located at the MLG to ensure the NTTA has continuous power to the tolling equipment in the event a utility power outage occurs.

4.7.2 ESC TY S enclosures are used to supply power to ramp gantry tolling systems. In costs comparisons, the Authority decided that the price of purchasing, installing and maintaining generators at ramp gantries is more
costly than any loss of revenue that would be expected in the event of a utility power outage. Therefore ESC TY S enclosures are not supported by permanently placed generators, but are alternatively supported by temporary generators. ESC TY S enclosures provide “Cam-Lok”® receptacles rated at 300 amps and attached through the outside wall of the ESC for connection of a portable generator.

4.7.3 The standard fuel supply for NTTA generators is diesel.

4.7.4 Any generator installed for a mainlane gantry TY MLG enclosure shall be a 3 phase, 277Y/480V, 75 kVA / 60 kW rated unit and include an auto leveling, resistive, factory installed “load bank”.

4.8 NTTA versus ILA Electrical Service Installations

4.8.1 In some cases there may be Inter-Local Agreements that require the NTTA to design and install an electrical service different from the NTTA standard ESC. These locations may require separate TxDOT standard services or municipality designed power supplies. This is most likely to occur where a service is required at an intersection requiring traffic signalization, and/or illumination for service roads or cross streets not normally a part of the NTTA roadway system. This service will revert to municipal ownership and maintenance after construction is complete.

4.8.2 The designer shall verify ILA requirements on each project. For these locations, the designer shall use the Municipality’s standards or the TxDOT standards.
4.8.3 The engineer shall submit to the NTTA a list of ALL project electrical service locations for approval prior to the Preliminary Electrical report submittal. Naming conventions will be supplied or approved by a qualified member of the Electrical Maintenance staff who serves as the electrical plan reviewer within the Operations sub-division of the NTTA Maintenance Department.
Chapter 5 – Electronic Toll Collection Electrical System Design

5.1 Introduction

5.1.1 This chapter explains the distribution of power from an ESC to a gantry structure for the operation of toll collection equipment.

5.2 Electrical - Mainlane Gantry

5.2.1 Mainlane gantries utilize two IT buildings supplied from an ESC TY MLG. The designer will coordinate with the NTTA mainlane gantry standard drawings for the exact location of the ESC TY MLG.

5.2.2 The combined electrical loads at each pair of mainlane gantries will include: electronic toll collection equipment, network equipment, ITS equipment and general electrical loads. Each mainlane gantry IT building will be supplied by an 35 amp, 3 pole circuit breaker located in panel ITS housed inside the ESC TY MLG enclosure.

5.2.3 Each ITS Panel Board located inside an ESC TY MLG enclosure will be connected through a 277Y/480V, 100 amp, 480 volt, 3-phase, 3-wire, 3-pole, NEMA-1 rated automatic transfer switch to a 277Y/480V, 3 phase, 75 kVA generator set. The generator will be placed in proximity to the ESC TY MLG enclosure. The automatic transfer switch (ATS) shall have provisions for a solid neutral connection.

5.2.4 Each of the two IT buildings located at a mainlane gantry structure will have a three phase, 120/208V, 100 amp service supplied from a 277Y/480V, three phase, NEMA 3R rated, 25 kVA transformer located adjacent to each building.

5.2.5 A three phase, 3 wire, NEMA 3R rated, 60 amp heavy duty non-fused disconnect switch will supply the transformer. The line side conductors

Figure 8: IT Building
serving this disconnect are supplied by the 35 amp, 3 pole circuit breaker located in Panel Board “ITS” located in the ESC TY MLG enclosure.

5.3 Electrical - Ramp Gantries

5.3.1 The combined electrical loads at a ramp gantry will include: electronic toll collection equipment, network equipment, ITS equipment and general electrical loads. Ramp gantries are supplied from an ESC TY S. Each ramp gantry IT screen wall will be supplied by an 25 amp, 3 pole circuit breaker located in panel MDP housed inside the ESC TY S enclosure.

5.3.2 Each IT Screen Wall located at a ramp gantry shall have a three phase, 120/208V, 40 amp service supplied from a 277Y/480V, 3 phase, NEMA 3R rated, 15 kVA transformer located adjacent to each wall.

5.3.3 A three phase, 3 wire, NEMA 3R rated, 30 amp heavy duty non-fused disconnect switch will supply the transformer. The line side conductors serving this disconnect are supplied by the 25 amp, 3 pole circuit breaker located in ESC TY S, panel MDP.

5.3.4 The total connected load at a ramp gantry is approximately 12.3 kVA.

![Figure 9: IT Screen Wall](image)

5.4 Electrical - Communications Hut

5.4.1 The combined electrical loads at a communications hut will include: ITS and network equipment, and general electrical loads. A communications hut is supplied from an ESC TY S. Each communications hut will be supplied by an 25 amp, 3 pole circuit breaker located in panel MDP housed inside the ESC TY S enclosure.

5.4.2 Each communications hut will have a 3 phase, 120/208V, panel board with a 40 amp main circuit breaker supplied from a 277Y/480V, 3 phase, NEMA 3R rated, 15 kVA transformer located outside each building.
5.4.3 A 3 phase, 3 wire, NEMA 3R rated, 30 amp heavy duty non-fused disconnect switch will supply the transformer. The line side conductors serving this disconnect are supplied by the 25 amp, 3 pole circuit breaker located in panel MDP housed inside the ESC TY S enclosure.

Figure 10: Communications Hut
Chapter 6 – Intelligent Transportation Systems Electrical System Design

Introduction

6.1 ITS Circuitry

6.1.1 The ESCs shall distribute power to all ITS elements with a 480V, single phase branch circuit. Each ITS element location shall utilize a local transformer to obtain the required 120/240V power supply. This transformer is shown in the Standards as an ESC TY MPE.

6.1.2 All ITS element locations (DMS, CCTV, and AVI TTS) served shall be supplied with a 480V, single branch circuit. This feeder will be derived from within the ESC and originate from panel “ITS” which is specifically designated for ITS power supplies.

6.1.3 Each ITS element or DMS location is served from an ESC TY MPE which transforms the 480V single phase supply voltage to the required 120/240V utilization voltage.

6.1.4 The 120/240V power shall be provided by a 10 kVA mini power enclosure.

6.1.5 A single DMS sign requires a 10 kVA mini power enclosure. At present, a typical DMS requires one (1) 40A, 2 pole, 240V circuit. See the NTTA ESC TY MPE standards for more details.

Figure 11: DMS

6.1.6 A typical ITS element is the combination of a DMS, a CCTV, and an AVI TTS.
6.1.7 A CCTV location typically consists of 4 fixed cameras and one pan-tilt-zoom (PTZ) camera. See Figure 12.

![CCTV Array](image.png)

Figure 12: CCTV Array

Other loads per section of roadway may include the following items:

<table>
<thead>
<tr>
<th><em>LOAD TYPE</em></th>
<th><strong>AMPS</strong></th>
<th><strong>VOLTS</strong></th>
<th><strong>Mini Power Enclosure (MPE) Size</strong></th>
<th><strong># POLES</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>DMS</td>
<td>$\varnothing A = 23A$</td>
<td>480V 1Ø-120/240V</td>
<td>10 kVA</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>$\varnothing B = 20.8A$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Verify current loading requirements with the NTTA IT Department. See single line and panel schedules for load breakdown.*
6.2  Device Locations

6.2.1  The contractor shall be directed to provide as a part of the “Project Record Documents”, the final location of any and all ETC gantries, communications huts, ITS elements, ESC (including ESC TY S/E meter address), and all fixture locations, both by station/offset and GPS coordinates.

6.3  ITS Conduit and Conductor Considerations

6.3.1  Feeder conduit size shall be 2” diameter with a minimum of 12” spacing (outside wall to outside wall) between other conduits occupying the same trench.

6.3.2  Each MPE location derives its’ power supply from the ITS Panel Board inside the ESC TY S Enclosure.

Figure 13: MPE Cabinet Layout
Chapter 7 – Roadway Lighting System Design

7.1 Introduction

7.1.1 This chapter covers the design of lighting circuits and design criteria associated with illuminating NTTA roadways including illumination coverage, illumination levels, and special concerns involving light trespass, curfews and “dark sky” requirements.

7.1.2 The illumination design shall be in accordance with the IES/ANSI RP-8, the American National Standard Practice for Roadway Lighting and the TxDOT Highway Illumination Manual. The illumination design shall use, in order of importance, any Inter-Local Agreement, the NTTA RESM and standards, NTTA special provisions, NTTA general notes, NTTA special specifications, and the TxDOT standard specifications.

7.2 Lighting Usage Definitions

7.2.1 Continuous Lighting – A continuous lighting system provides relatively uniform lighting on all mainlanes, direct connectors and complete interchange lighting at all interchanges. Frontage roads may be included if so directed by NTTA.

7.2.2 Safety Lighting – Safety lighting may be installed at any interchange, highway intersection, or other decision making point or points of night time hazard. Safety lighting may be used to provide for an increase in safety and the orderly movement of traffic. There are three kinds of safety lighting: partial interchange/intersection, complete interchange/intersection and spot.

7.2.2.a Partial interchange/intersection lighting covers acceleration and deceleration lanes up to and away from the mainlanes, ramps, intersections at frontage roads, ramp entrances from service roads and other areas as required.

7.2.2.b Complete interchange lighting covers the limits of the interchange including mainlanes, direct connectors, ramps, frontage roads and crossroad intersections.

7.2.2.c Spot lighting consists of luminaires intended to illuminate sections with complex geometry.

7.2.3 Bridge Lighting

7.2.3.a Underpass lighting is defined as the light fixtures which attach to the bottom of a cross street bridge which crosses over an NTTA roadway.
7.2.3.b Underbridge lighting is defined as the light fixtures which attach to the 
bottom of an NTTA bridge to illuminate the cross street over which it 
passes.

7.2.3.c Overpass lighting is considered as any illumination structure attached to 
the rail, barrier or bridge deck so as to illuminate the roadway surface as it 
passes over a cross street or obstacle.

7.3 Temporary Lighting

7.3.1 Temporary lighting may sometimes be required as part of a new project, or 
where the new project joins with an existing project.

7.3.2 Any temporary lighting must be protected from crash potential or installed on 
breakaway bases.

7.3.3 Existing locations containing roadway lighting which will remain after the 
project, or be replaced during the project, must be kept lighted throughout the 
project. Only after the new lighting system is installed and fully tested, 
witnessed as fully operable and accepted by the Authority, shall the older 
system be disconnected and removed.

7.3.4 In locations where it is necessary to disconnect existing lighting to perform 
construction activities, the roadway lighting circuitry shall be replaced and 
energized as soon as possible. If the disconnection of a roadway lighting 
circuit is necessary for the length of the project, then temporary wiring will be 
installed to resupply the circuit still existing outside of the construction area.

7.3.5 In all cases where existing roadway lighting is to be disconnected temporarily 
or permanently, the NTTA Maintenance department shall be contacted at 
(214) 224-2080 a minimum of 72 hours prior to the disruption in service.

7.4 Glare

7.4.1 Improperly placed and positioned roadway lighting fixtures can cause glare. 
correct placement of roadway lighting fixtures can reduce headlight glare.

7.4.2 Placement of all fixtures will take into consideration the issue of glare as 
perceived to anyone driving within NTTA right-of-ways.

7.4.3 Placement of all fixtures will take into consideration the issue of glare as 
perceived to anyone outside the area of NTTA right-of-ways.

7.4.4 Best design practice is to place illumination fixtures in locations which limit the 
line of sight to anyone not on NTTA right-of-way. This means a person off the 
NTTA right-of-way should not be able to view the light source contained within 
and emitted from the fixture.
7.4.5 It is expected the engineer designing the lighting system will be knowledgeable in the placement of roadway lighting fixtures to both reduce glare from roadway fixtures while using the positive aspects of roadway lighting fixture placement to reduce headlight glare. The engineer will design the project based on the latest and most innovative technologies available. All technologies must be approved by the NTTA prior to plan reviews.

7.5 Light Trespass

7.5.1 Lighting systems shall be designed to minimize light trespass outside of the roadway area.

7.5.2 Light trespass levels shall be less than 1% of the average illumination level at the edge of the right-of-way line. Special consideration shall be given to residential areas.

7.5.3 It is expected the engineer designing the lighting system will be knowledgeable in light trespass issues and will design the project based on the latest and most innovative technologies available. All technologies must be approved by the NTTA prior to plan reviews.

7.6 Sky Glow

7.6.1 All fixtures shall be full cut off type.

7.6.2 It is expected that the engineer designing the lighting system will be knowledgeable in sky glow issues and will design the project based on the latest and most innovative technologies available. All technologies must be approved by the NTTA prior to plan reviews.

7.7 ELMS Control/Lighting Curfews

7.7.1 At this time NTTA does not utilize an Electrical and Lighting Management System (ELMS) to control lighting, but this may be directed as part of a future project.

7.7.2 Curfews for lighting involve the use of controls to turn off or dim selected parts of the lighting systems as permitted by reduced traffic flow, favorable weather conditions and other local conditions.

7.8 Illumination Levels

7.8.1 Lighting Illumination levels vary depending on the type of roadway surface being illuminated. In determining the correct illumination levels required on NTTA projects for the various road surface classifications, all calculations shall be made utilizing the illuminance method and comply with the standards as

7.8.2 The Small Target Visibility (STV) method of design shall not be used for calculating illumination levels for any NTTA project.

7.8.3 The minimum acceptable NTTA standard of illumination, whether continuous or safety lighting, shall be 0.6 to 0.9 foot candles depending on the roadway surface while maintaining an approximate uniformity ratio of 3:1.

7.9 Design Logic; The “H” Pattern

7.9.1 The “H” pattern conductor layout design was originally based on the use of continuous lighting for NTTA roadways, however the basic design philosophy remains the same for either continuous or safety lighting.

7.9.2 The term “H” pattern was chosen because of the resemblance of the roadway lighting circuits in relation to their power supply.

7.9.3 All roadway lighting circuits are distributed from any ESC TY S or ESC TY MLG electrical service along the roadway.

7.9.4 In relation to the “H” pattern, each ESC TY S or ESC TY MLG enclosure is centered at the junction between the horizontal bar of the “H” and either center point of the vertical portion of the “H”.

7.9.5 Each ESC TY S or ESC TY MLG enclosure shall have a minimum of four (4) 2” conduits exiting the enclosure. Two (2) of the 2” conduits will separate and run in opposite directions to one another and parallel to the roadway.

7.9.6 Conversely, the remaining two (2) 2” conduits shall traverse the roadway along the horizontal portion of the “H” design. These two (2) conduits will then separate and run in opposite directions from one another and parallel to the roadway. These runs represent the vertical leg opposite the ESC location on the far side of the roadway.

7.9.7 As the individual circuits proceed in their respective directions, they supply power to the illumination structures located in their path.

7.9.8 As underpass and underbridge conditions are encountered, one of the circuits on one side of the “H” pattern will be tapped and supply power to one half of the lights under the bridge. The circuit diagonally opposite to this circuit will also be tapped and supply the remaining one half of the lights under the bridge. This dual circuiting of the underpass and underbridge lighting allows a safety advantage in the event one of the parallel circuits fail.
7.10  Power Supply

7.10.1  All ESC enclosures, TY S and TY MLG contain a dedicated Roadway Lighting (RWL) panel. This panel is switched by a 100A lighting contactor.

7.10.2  In an ESC TY MLG and ESC TY S enclosure, the contactor controlling panel RWL, is a 3 pole unit, rated at 600V, 100A, and electrically held. The contactor is operated by a 277V control coil. Each contactor shall have a HAND-OFF-AUTO (HOA) switch to override the photocell.

7.10.3  The 100A contactor is supplied by a 480V, 100A, 3 phase circuit breaker supplied from panel MDP.

7.10.4  In the above scenario, the 277 volt lighting contactor coil is operated by a photocell inserted into a factory photocell receptacle atop the ESC TY S or TY MLG enclosure. If the enclosure is located under a bridge (or other situation that would keep the photocell from operating correctly) the remote locate the photocell as required for proper operation.

7.10.5  The 277 volt photocell control circuit is obtained from a single phase 277 volt, 1 pole circuit breaker located in panel MDP. In the control schematic.

7.11  Roadway Illumination Circuitry

7.11.1  Although current NTTA policy is not to use continuous lighting along NTTA roadways, the electrical service should account for future continuous lighting. It is estimated continuous illumination of a 5280 foot section of roadway will require 25 kVA without high mast structures. In areas where high mast structures are utilized, the structures shall be circuited independently from other types of roadway lighting.

7.11.2  Roadway and Underpass/Underbridge Luminaires: All roadway and underpass/underbridge luminaires served on any particular branch of the “H” pattern design and within the service area covered by an ESC TY S shall be supplied with a 480V, single phase circuit. This circuit will be derived from within the ESC and originate from panel RWL. All circuit breakers within panel RWL are sized to accommodate the maximum number of roadway luminaires along any one leg of the “H” pattern. Therefore each leg of the “H” pattern is supplied by #4 AWG copper conductor and one (1) 40 amp, 2 pole circuit breaker. There shall be a minimum of one (1) dedicated circuit breaker for each leg of the “H” pattern layout.

The preceding item describes the standard conductor sizing for an installation that does not exceed the 2,640 foot circuit length as recognized in this Manual. Any additional lengths or loads will require additional voltage drop calculations and possible circuit breaker and conductor size changes.
7.11.3 High Mast Lighting: HM lighting shall be supplied by an ESC TY S enclosure and supplied with a 480V, single phase circuit. This circuit will be derived from within the ESC and originate from panel RWL. All circuit breakers within panel RWL are sized to accommodate two high mast structures, (24 – 400 watt fixtures total) per dedicated circuit. Therefore each pair of HM lighting structures is supplied by #4 AWG copper conductor and (1) 40 amp, 2 pole circuit breaker.

The preceding item describes the standard conductor sizing for an installation that does not exceed the 2,640 foot circuit length as recognized in this Manual. Any additional lengths or loads will require additional voltage drop calculations and possible circuit breaker and conductor size changes.

7.11.4 Illumination circuit breakers and conductors in this Manual have been sized for voltage drop, insulation deterioration and fault currents over a 2,640 foot circuit run. The 2,640 foot run will not be linear. Portions of roadway requiring transitions from various grades or adjacent runs will reduce the conductor length. Actual field routing and placement of conduit will be less than the linear design distance of 2,640 foot from the centerline of an ESC in each direction. This Manual is a design guide only and actual project conditions and calculations will vary depending on various design criteria. However, failure to follow these guidelines will result in an increase to the number of ESC’s required within a one mile increment. The section engineer shall not design a single circuit exceeding 2,640 feet in overall length¹.

7.11.5 There may be instances where the number of high mast structures at an interchange requires the use of one or more strategically placed ESC TY S distribution centers to supply the load required. An ESC TY S can be modified to accommodate a larger number of roadway lighting loads (HM structures) by adding an additional 100 amp lighting contactor and a second panel “RWL” and removing the “ITS” panel. The mini power enclosure, (MPE) shall remain for low voltage loads.

7.12 Conduit and Conductor Considerations

7.12.1 The minimum size conduit size used for routing roadway illumination conductors shall be 2” diameter unless supplying an illumination structure from a rail or wall mounted junction box where a 1” galvanized rigid steel conduit routing from the junction box to inside the pole shaft is permissible.

7.12.2 The maximum conductor size brought to and exiting or passing through any illumination structure shall be #2 AWG. The minimum size conductor shall be #10 AWG and only used to supply the luminaire attached to the illumination structure.

7.12.3 In some rare occasions it may be necessary to increase the size of a conductor to match a larger than anticipated load not anticipated in this RESM.
In those circumstances where the additional load and resulting voltage drop calculations produce a conductor size that cannot be accommodated in a 2” conduit, it will be necessary to install a conduit larger than the minimum acceptable 2”.

7.12.4 When installing a larger conduit and conductor, it is of paramount importance that the larger combination does not enter any electrical equipment or illumination structures. This requirement can be satisfied by terminating all conduit runs in a junction box in close proximity to the equipment or structure, and using the actual required conductor size, (installed in a 2” conduit) to supply the load. This assumes the circuit breaker serving the load, is sized to accommodate the smallest acceptable (per NEC) conductor utilized in the branch circuit/feeder for the load or combined loads.

7.13 **Illumination Structure and Luminaire Identification**

7.13.1 Each illumination structure and each underpass and/or underbridge light shall be specifically identified by circuit number, ESC location and linear sequence in the circuit from the ESC. Each ESC shall be abbreviated with two letters based on the nearest cross street to the service center. An example of an illumination structure and/or fixture number is: 1ER5 where “1” signifies circuit 1, “ER” represents the ESC is located at or near Example Road and “5” identifies this as the fifth illumination structure and/or fixture counted linearly from the ESC. Illumination structure and/or fixture numbering will always begin from the ESC for each circuit. Due to space limitations on the structures, preceding zeros shall not be used; i.e. “1” shall be used in lieu of “01”.

7.13.2 Asset data collection and management require; station and offset identification, GPS coordinates, type of light, mounting height, shaft length, base type, base diameter, structure material, etc. All information shall be recorded by the Contractor/Construction Manager and included as part of the record drawings. The data shall be recorded in both hard copy and electronic formats and submitted to the Project Delivery Department and the Maintenance Department’s Infrastructure Engineer.

¹ Circuit lengths are based on the NTTA standard #4 AWG copper XHHW-2 conductor. It is permissible to extend a few limited circuits when doing so will effectively reduce the cost of having to add an additional ESC.
Circuits may be extended if the conductor size is increased to accommodate the additional distance and load required, and the conductor count and size will fit within a 2” conduit per NEC requirements. Additional voltage drop calculations must accompany any variation from the conductor size referenced as the standard NTTA conductor above.

If the circuit breaker is increased from the Standard, the section engineer must ensure the lugs on the CB will accept the larger conductors, or take other measures to make the installation NEC compliant.
Chapter 8 – Bridge Electrical System Design

8.1 Introduction

8.1.1 The purpose of this chapter is to specify and detail exact electrical system design for bridges over 500 feet in length.

8.1.2 This chapter covers the types of luminaires used for the illumination of elevated structures and their associated appurtenances (rails, barriers and the various types of retaining walls).

8.1.3 The illumination design shall be in accordance with the American National Standards Institute/Illuminating Engineering Society of North America, (ANSI/IESNA RP-8-00; Roadway Lighting), and the TxDOT Highway Illumination Manual. The illumination design shall use, in order of importance, any Inter-Local Agreement, NTTA standards, NTTA special provisions, NTTA general notes, NTTA special specifications, and TxDOT standard specifications.

8.2 Placement of Illumination Structures

8.2.1 If it is necessary for the bridge to be illuminated from both sides of the roadway, layout of the roadway illumination structures shall be staggered and spaced equally between both sides of the bridge.

8.3 Illumination Circuits

8.3.1 All lighting structures along one side of a bridge shall be supplied by two circuits. If more than one side of the bridge is required to be illuminated due to required illumination levels, two more circuits will be supplied to the opposite side of the bridge. In both cases the reason for the two circuits is to supply power to alternate light structures in an A/B/A/B pattern.

8.3.2 Each circuit supplying power to bridge illumination structures shall be installed in a separate conduit inside the rail. Therefore the alternating structures on one side of the bridge shall be supplied by two separate conduits alternatively supplying every other illumination structure and each carrying a single circuit. If illumination is required on the opposite side of the bridge, the same installation of two conduits with individual circuits shall be required.

8.4 Illumination Structures attached to Bridge Rails

8.4.1 Provide 2” diameter galvanized rigid steel conduit, and malleable iron junction boxes in the bridge single slope rails or single slope median barrier. The conduit will terminate in TxDOT Type D ground boxes with aprons outside of the bridge limits.
8.4.2 Provide 2" diameter galvanized rigid steel conduit and malleable iron junction boxes in the single slope rails on retaining walls. The conduit will terminate in TxDOT Type D ground boxes with aprons at the beginning and end of the retaining wall.
Chapter 9 – Tunnel Electrical System Design

9.1 Introduction

9.1.1 This chapter is for the overall electrical design of tunnel sections as defined by NFPA.

9.2 Design

9.2.1 At the time of design, the latest edition of NFPA 502 “Standard for Road Tunnels, Bridges, and other Limited Access Highways” shall dictate all electrical system requirements including any primary fire protection and life safety requirements provided by electrical systems.

9.3 Illumination

9.3.1 The illumination design shall be in accordance with the American National Standards Institute/Illuminating Engineering Society of North America, (ANSI/IESNA RP-22-05; Tunnel Lighting), and the TxDOT Highway Illumination Manual.

9.3.2 The illumination design shall use, in order of importance, requirements by the American National Standards Institute/Illuminating Engineering Society of North America, (ANSI/IESNA RP-22-05; Tunnel Lighting), any Inter-Local Agreement, NTTA standards, NTTA special provisions, NTTA general notes, NTTA special specifications, and TxDOT standard specifications.

9.3.3 The “luminance” method is preferred for tunnel lighting. Tunnel lighting should be designed for asymmetric or pro-beam lighting systems only, except that tunnel transition zones may be counter-beam. Tunnel lighting should be designed in accordance with the above referenced AASHTO design guide or may be designed in accordance with the more comprehensive guidelines of CIE or IESNA.
Chapter 10 – Sand Stockpile Electrical System Design

10.1 Introduction

10.1.1 This chapter covers the power supply to a NTTA sand stockpile location when derived from an ESC TY S or TY MLG. It continues to describe the distribution of the power and lighting circuits in relation to their specific functions. See NTTA RESM Appendixes.

10.2 ESC Source

10.2.1 Per the NTTA Standards there is a spare ground box in close proximity to the ESC. The ground box contains a 2" conduit containing a flat, woven polyester 1,800 lb. tensile strength pull tape from the ESC. It is intended that the designer incorporate this spare ground box assembly in their design.

10.2.2 The designer shall instruct the contractor to enter the bottom of the ground box with a 2" conduit and continue the run to the sand stockpile location. The conduit run shall terminate at either an electrical equipment service support or a sand stockpile wall.

10.2.3.a The electrical equipment service support referenced above may currently be found on the TxDOT ED (6)-03 sheet and referenced as “Service Support Type SF (U)”. It is of paramount importance the designer of the electrical system for the sand stockpile understand the example referenced is for construction of the structure/support only, and not the associated equipment as shown on the TxDOT drawings. The structure consisting of the foundations, the galvanized base plates, uprights and channel strut are described in Note 1 of the TxDOT sheet ED (6)-03.

10.3 Sand Stockpile Electrical Service

10.3.1 At the location of the planned sand stockpile electrical service, the designer shall terminate the 2" conduit from the ground box next to the ESC to a 277Y/480V, three phase, NEMA 3R rated panelboard. The panelboard shall be labeled “Panel HV” and contain a three phase main circuit breaker (MCB) rated at 70 amps. The panelboard buss will be rated at 125 amps. There should be a minimum of 18 single pole spaces available in the panelboard.

10.3.2 In addition to the 70 amp MCB, Panel HV shall contain a second 3 pole, 70 amp, 277/480V circuit breaker to serve as the primary supply for a 45 kVA 3 phase, 277Y/480V - 120/208V NEMA 3R transformer.

10.3.3 The secondary side of the 45 kVA transformer shall supply a 120/208V, 3 phase, NEMA 3R rated panelboard. The panelboard shall be labeled “Panel LV”. The conductors from the transformer shall terminate on a 100 amp main
lug only (MLO) buss. There shall be a minimum of 18 single pole spaces available in the panelboard.

10.4 Distribution of 480 Volt Circuitry from Panel HV

10.4.1 As described above; a 3 pole, 70 amp circuit breaker will serve the 45 kVA transformer.

10.4.2 Originating from Panel HV are a number of 2 pole, 480 volt circuits for the supply of all specified sand stockpile lighting fixtures with the exception of the photocell controlled fixture specified for security purposes. It is important to note that underbridge lighting is not the same as sand stockpile lighting.

10.4.2.a Underbridge lighting is installed as part of the roadway illumination plan and is used in locations such as U-turns to illuminate the roadway under a bridge.

10.4.2.b Sand stockpile lighting is derived solely from the sand stockpile electrical service. These circuits are used exclusively for lighting the sand stockpile material bins during a snow and ice event and/or for supplying “night” lighting in areas where a lighted area or path is desired at times other than during a snow and ice event.

10.4.3 Circuits supplying power to lighting fixtures for the illumination of the sand stockpile bins are controlled by a 2 pole, 30 amp, 600 volt NEMA 3R heavy duty disconnect switch. Each circuit used for sand stockpile lighting shall be controlled by a separate disconnect switch. These switches may be mounted in a cluster at the first column supporting a bent cap where illumination fixtures are located. All illumination circuit disconnect switches shall be pad-lockable and mounted 5’ (five feet) above finished grade (AFG) to the top of the switch, and protected from physical damage by bollards or other means. These disconnect switches are supplied by circuits originating in Panel HV and are only operated during a snow and ice event.

In some sand stockpile locations there may be a need to provide night lighting for security or access to the sand stockpile location. Circuits supplying night lighting are operated by an enclosed NEMA 3R lighting contactor controlled by a photocell. The photocell shall be of the “twist lock” type and used in a twist lock style receptacle expressly for use with the photocell. All wiring for the photo controls and contactor shall be enclosed in conduit.

10.4.4.a Photocells may be installed in close proximity to the lighting contactor mounted at the service location unless there is an unacceptable level of ambient light in this location. If operation of the photocell is unavoidable due to ambient light at the contactor location, the photocell shall be remotely mounted in a location where ambient light is not an issue. Under no circumstances shall a time clock be used to control the lighting.
10.5 Distribution of 120/208 Volt Circuitry from Panel LV

10.5.1 Panelboard LV is supplied by the secondary side of the 45 kVA transformer. The conductors from the transformer shall terminate on MLO.

10.5.2 This panelboard contains two (2) 60 amp 3 pole circuit breakers specifically for supplying power to two (2) “out buildings” located within the sand stockpile area. These buildings are a restroom and a storage room.

10.5.3 Each of the buildings shall be served by a 120/208V, three phase, NEMA 3R rated panelboard. The conductors from Panelboard LV shall terminate on a 60 amp MCB connected to the 100 amp buss. There shall be a minimum of 18 single pole spaces available in the panelboard.

10.5.4 The panelboards shall be labeled “Panel RR LV” or “Panel SR LV”, depending on which building they are attached to. Both panels shall be mounted externally on the wall of the building.

10.5.4.a For designer calculations, typical Panel RR LV loading includes a 208 volt instant water heater which must operate at 16 amps or less, a 208 volt ceiling mounted space heater rated at 1,875 watts, two (2) 120 volt 4 foot fluorescent fixtures (one mounted in the restroom and one mounted in the restroom storage area), a general purpose 15 amp 120 volt GFCI receptacle located inside the restroom, and a general purpose 15 amp 120 volt receptacle located inside the storage room. All light fixtures shall utilize cold start ballasts.

10.5.4.b The restroom equipment room shall also include a plywood backboard for the mounting of security and camera control equipment. This backboard shall have one (1) 20 amp, 120 volt dedicated circuit supplied for the permanent connection of the equipment.

10.5.4.c For designer calculations, typical Panel SR LV loading includes a 208 volt ceiling mounted space heater rated at 1,875 watts, one (1) 120 volt 4 foot fluorescent fixture, and two (2) general purpose 15 amp 120 volt receptacles mounted opposite one another on the interior of the storage room. All light fixtures shall utilize cold start ballasts.
10.6 Conduit

10.6.1 All underground conduits installed on NTTA sand stockpile projects shall follow NTTA Standards for typical applications in specifying the use of Schedule 40 PVC, GRS and PVC coated GRS.

10.6.2 Typically, all underground conduit runs shall be two inch (2”). Where the underground run transitions from the two inch (2”) PVC coated GRS 90° fitting; the “stub-up” to four inches (4”) above grade shall utilize a section of straight two inch (2”) PVC coated GRS. GRS conduit should be connected to the PVC coated GRS at the four inch (4”) point above grade.

10.6.3 From the four inch (4”) point AFG and continuing up to a junction box, disconnect switch, and/or between light fixtures, one inch (1”) GRS may be used if the calculated fill volume does not exceed the NEC fill maximum requirement.

10.6.4 Transition from the 2” underground conduit run to the 1” conduit run is achieved by the use of a 2” to 1” reducing bushing.

10.7 Ground Boxes

10.7.1 The use of ground boxes is left to the discretion of the designer.
10.7.2 One recommended location for utilizing a ground box is near the sand stockpile electrical service support structure. This is located where the two inch (2") conduit which will supply the required sand stockpile lighting and the conduit from the lighting contactor which may be installed to provide power for any night time or other 480 volt pc-controlled security lighting intersecting at the base of the electrical service support structure.

10.7.3 Another recommended location for a ground box is at column structures where a conduit run loops from column to column and it is not practical to attach the conduit to overhead structural beams. The use of ground boxes allows tapping an individual run instead of transitioning up to a column mounted junction box at each location.

10.7.4 Maximum distance between ground boxes is 460 feet.

10.8 Optional Electrically Driven Vehicular Entry/Exit Gates

10.8.1 Some NTTA sand stockpile areas are designed with powered entry gates. If specified, it is recommended the additional required circuits be supplied from Panelboard HV for both better operating efficiency of the higher voltage and the ability of the 277/480V system to provide power over a greater distance before becoming overly concerned with voltage drop. This branch circuit still needs to be calculated for voltage drop to insure NEC compliance at 3%.
Chapter 11 – Equipment and Materials

11.1 Introduction

11.1.1 This chapter covers the equipment that should be selected during design so as to match current NTTA inventory. Matching the equipment is important not only to expedite needed repairs but for overall consistency of appearance. The designer shall refer to the NTTA RID standards for further details.

11.2 Luminaires – Mainlane

11.2.1 Luminaires for mainlane illumination shall be KIM luminaires, 400W High Pressure Sodium (HPS); 480V with IESNA Type AR3 distribution mounted a nominal 40 feet above finished paving grade. The luminaire shall have a Platinum Silver finish and include a terminal board for luminaire connection and a 2" horizontal slip fitter for luminaire attachment to an illumination structure. NTTA approved equals must mount exactly the same as the KIM fixtures. Unless there is no other way to light the center of a particular roadway, center or median mounted fixtures shall not be used. Illumination structures shall be located off the shoulder of the roadway, and the designer should make every attempt to position the associated luminaire over, and centered on, the shoulder. The luminaire shall be mounted with a 2" diameter mast arm. See NTTA standards.

11.2.2 Mount the photo electric control atop the ESC TY MLG Enclosure. If this location prohibits the proper function of the photo electric control then locate as required to function properly even if it is remote from the ESC TY MLG Enclosure.

11.3 Luminaires – Ramps

11.3.1 Luminaires for ramps shall be identical to those specified for the mainlanes except that ramp luminaires shall be 250W HPS with IESNA Type AR2 distribution mounted a nominal 40 feet above finished paving grade.

11.3.2 The photo electric control shall be located at the lighting contactor enclosure for the ramp lighting unless the ramp lighting control is provided for by the photo electric control at the ESC.

11.4 Luminaires – Underbridge

11.4.1 Luminaires for underbridge illumination shall be GE luminaires, Model# MDCL15S5M12FMC22F. This is a 150W High Pressure Sodium (HPS); 480V fixture with an IES distribution Type 2. Fixtures shall be bent or beam mounted per NTTA RID drawings. The luminaire shall have a gray paint finish and include a terminal board for luminaire connection to the branch circuit. Fixture will utilize a 2" horizontal slip fitter for luminaire attachment to the support
bracket. The luminaire shall be mounted with a 2” diameter mast arm typically 2’ in length. NTTA approved equals must mount exactly the same as the GE fixtures. See NTTA Standards.

**11.5 Luminaires – Communications Hut Security Lighting**

11.5.1 Luminaires for communications hut security lighting shall be Kim Archetype model SAR luminaires, Model# 1SA-SAR2-150HPS208-PS-A31-VSF-1SA. This is a 150W High Pressure Sodium (HPS); 208V fixture with an IES distribution Type 2. Fixtures shall be pole mounted. The luminaire shall have a platinum silver finish and include a terminal board for luminaire connection to the branch circuit. Fixture will utilize a 2” horizontal slip fitter for luminaire attachment to the support bracket. The luminaire shall be mounted with a 2” diameter mast arm. NTTA approved equals must mount exactly the same as the GE fixtures. See NTTA Standards.

**11.6 Luminaires – Sand Storage Areas**

11.6.1 Luminaires for sand storage area illumination shall be GE luminaires, Model# MDCL25P5A12FMC32FNU. This is a 250W Pulse Start Metal Halide; 480V fixture with an IES distribution Type 3. Fixtures shall be bent or beam mounted per NTTA RID drawings. The luminaire shall have a gray paint finish and include a terminal board for luminaire connection to the branch circuit. Fixture will utilize a 2” horizontal slip fitter for luminaire attachment to the support bracket. The luminaire shall be mounted with a 2” diameter mast arm typically 2’ in length. NTTA approved equals must mount exactly the same as the GE fixtures. See NTTA Standards.

**11.7 Luminaires – High Mast**

11.7.1 If selected and approved by the NTTA corridor manager, the design for the high mast lighting shall be calculated for 100 MPH wind loads and in accordance with the TxDOT Illumination Manual, the TxDOT HMID, HMIP and HMIF standard drawings, TxDOT standard specifications and NTTA General Notes. Luminaires shall be per TxDOT standards. High Mast lighting requires a 480V, single phase dedicated circuit. These fixtures should only be used at major interchanges with no residential housing in close proximity which allows for an individual to establish a line of site directly with the light source. These illumination structures will require City approval prior to starting the design even if NTTA project managers have previously approved their use. All municipalities adjoining the Tollway will have some degree of light trespass concerns and limitations within their geographic boundaries.

**11.8 Illumination Structures**

11.8.1 New structure mounted illumination structures shall be steel. New transformer base mounted illumination structures (breakaway) shall be aluminum.
11.8.2 All new project illumination structures shall maintain their luminaire(s) at an approximate 40’ mounting height (MH) above the lighted roadway.

11.8.3 Illumination structure shafts shall be manufactured in even 5 foot increments using a common base plate and anchor bolt dimensions as shown in the NTTA Standards. The shaft diameter at the bottom of the structure may change to accommodate the common base plate dimensions; the diameter at the top of the shaft shall remain constant to ensure proper fitting with the davit arm.

11.8.4 All illumination structure davit arms shall have a rise of 6’-6”. The davit arms shall have a 4’-0” radius and only incorporate an 8’ or 12’ arm length. It is preferred to keep the fixture head as close as possible to the center of the shoulder to permit maintenance without closing a lane and interrupting traffic. This may require the use of a different IESNA type distribution pattern other than those specified above. If other than the directed patterns are used, insure photometrics are still within guidelines.

11.8.5 Breakaway transformer bases shall be used on illumination structures where required.

11.8.6 The longitudinal spacing between illumination structures will be established during the design procedure and based on the uniformity ratio. Appurtenances along the roadway and the roadway geometry influence the final luminaire support location. The designer shall use the following recommendations:

11.8.6.a To avoid being struck by vehicular traffic, illumination and ITS structures in the area between mainlanes and exit ramps should not be located within 50 ft. of the physical gore.

11.8.6.b Illumination structures should be located no closer than 30 feet to non-lighted sign structures or DMS installations and coordinated with CCTV locations.

11.9 Shoulder vs. Median mounting

11.9.1 Shoulder mounting refers to the placement of luminaries between the back side of the curb and the right-of-way line along the roadway shoulder or behind a concrete traffic rail. Some design cases may require the use of rail or barrier mounted illumination structures along the shoulder.

11.9.2 Median mounting refers to placement of illumination structures in open medians or on concrete traffic barrier. The NTTA is reducing the drive times for customers by requiring maintenance be performed on illumination structures without lane closures. Median mounting of illumination structures is not an acceptable option and will be rejected unless a written explanation is received prior to the plan reviews detailing why there is no other suitable
means to illuminate any particular portion of the roadway. Once the explanation is received, the NTTA will either approve or disapprove the request.

11.10 Two types of Illumination Structures

11.10.1 There are two types of poles used for conventional lighting: Non-breakaway and Breakaway. Non-breakaway poles are rigidly mounted, usually remaining upright when hit by a vehicle. Breakaway poles are designed so the base will easily shear on impact.

11.11 Breakaway Structures

11.11.1 Breakaway illumination structures shall be used in areas where it is necessary to place a luminaire near a roadway and the surrounding area does not permit protection of the illumination structure by distance or barrier.

11.11.2 Breakaway illumination structures are not normally used if substantial pedestrian traffic is a consideration in the area, and a falling structure could be more hazardous to the pedestrians than to the passengers involved in an automobile striking a rigid structure. Non-breakaway illumination structures should also be used if overhead electric lines are too close or within the impact arc of a falling illumination structure.

11.11.3 It is desirable to have the side slope 6:1 or flatter prior to the breakaway base. This is to ensure the vehicle will impact the base at an acceptable height which will allow the base to fail in shear (as intended) versus in bending. In addition, the height above ground for any portion of the anchor bolts or foundation should not exceed 4 inches. This is to prevent the bottom of a vehicle from snagging the foundation or base.

11.12 Non-Breakaway Illumination Structures

11.12.1 Generally, non-breakaway roadway illumination structures may be used on the shoulder side of roadways when placed outside of the clear zone or inside the clear zone when protected from impact.

11.12.2 Wherever possible, non-breakaway illumination structures should be placed among other non-yielding structures to minimize the potential for a fall hazard.

11.12.3 Non-breakaway illumination structures should be used if mounted atop a concrete traffic barrier, rail, retaining wall or coping.

11.12.4 Non-breakaway illumination structures may be used if mounted behind a metal beam guard fence.
11.13 Aluminum Illumination Structures

11.13.1 Aluminum illumination structures shall be used for replacement of an existing lighting pole or the existing structure cannot support a steel replacement structure.

11.13.2 Aluminum poles are preferred on breakaway, transformer base, mountings to facilitate ease of cleanup when a lighting assembly is damaged.

11.14 Electrical Conduit

11.14.1 All conduits shall be UL listed and comply with the NEC.

11.14.2 All exposed conduits shall be GRS.

11.14.3 All conduits encased in concrete shall be GRS except encased conduits for lightning protection shall be PVC.

11.14.4 All underground conduits not bored shall be Schedule 40 PVC and any bends shall be PVC coated GRS.

11.14.5 Stub-up’s shall be PVC coated GRS and extend a minimum of 2” above finished surface (AFS).

11.14.6 Boring will be permitted and shall be made utilizing HDPE conduit. Fittings shall be installed by heat fusion joint methods.

11.14.7 A non-metallic, 5/8-inch, 1800 lb. tensile rated pull cord shall be installed in each empty conduit run.

11.14.8 Duct cable shall not be used.

11.15 Galvanized Rigid Steel Conduit

11.15.1 Galvanized rigid steel (GRS) conduit shall be used for all above grade, surface mounted conduit runs. The conduit shall be galvanized on both the inside and outside surfaces.

11.15.2 Galvanized rigid steel conduit ends shall be cut square, threaded and reamed to remove burrs and sharp edges. Field threads shall be of the same type and have the same effective length as factory cut threads.

11.15.3 Galvanized rigid steel conduit shall be bent using only approved factory methods. Hickey benders shall only be used to straighten conduits penetrating slabs. All other bends shall be factory made or mechanically bent in the field. Rigid foot benders may be used on rigid conduit sizes 1” or less.
11.16 PVC Coated Galvanized Rigid Steel Conduit

11.16.1 PVC coated GRS shall be used for all underground conduit bends and stub-ups. The conduit shall be zinc coated rigid steel utilizing a 40 mil PVC coating externally and a 2 mil urethane coating internally, and restricted for use with threaded fittings only. The exterior and interior coatings shall be installed as an integral part of the conduit manufacturing process. No substitutions will be allowed. All PVC-GRS conduit shall be restricted for use with threaded fittings only. All field-cut threaded sections shall be cleaned and coated with clear urethane coatings in accordance with the manufacturer’s recommendations.

11.16.2 PVC coated galvanized rigid steel conduit ends shall be cut square, threaded and reamed to remove burrs and sharp edges. Field threads shall be of the same type and have the same effective length as factory cut threads.

11.16.3 It is recommended that all PVC coated GRS bends required in the field be purchased from the manufacturer of the conduit system. This alleviates the need for using a specialized set of conduit bending shoes which are required for forming PVC coated GRS bends without damaging coatings.

11.17 Rigid Non-metallic Conduit (PVC)

11.17.1 Rigid non-metallic conduit shall be used for all underground conduit runs. The conduit shall be rigid polyvinyl chloride, Schedule 40, of the size indicated on the Plans and shall conform to NEMA standards. Conduit, fittings, cement, and cleaner/ primer shall be produced by the same manufacturer. Rigid non-metallic conduit shall not be used for runs above ground. PVC coated GRS shall be used for all conduit bends and stub-ups.

11.18 HDPE Conduit

11.18.1 Any required conduits installed under existing pavement shall be HDPE and bored by horizontal directional drilling. All boring shall be of the dry type only. Minimum depth of bore shall be 72” below grade to the top of the conduit.

11.18.2 Conduits and conduit sleeves installed under new pavement or bored under existing pavement shall be extended to a point three feet beyond the shoulder edge, or back of the curb, turned up into an accessible ground box and capped. The location of each conduit crossing shall be marked at the edge of the pavement by a surveyor’s pin and noted on the project record drawings. Conduit sleeves will be located by GPS coordinates and noted by station and offset.

11.18.3 HDPE conduit shall only be used in a boring situation where trenching is not feasible or cost effective. Fittings shall be installed by submitted and approved heat fusion joint methods or conduit adhesive. Both installations must be per
the manufacturer’s instructions. Conduit adhesive shall be of the type specified currently as BonDuit™ or approved equal.

11.18.4 PVC schedule 40 (2") is the typical conduit size used for powering the individual toll gantries, roadway lighting and ITS electrical circuits. If HDPE conduit is not used as a sleeve to house the 2” PVC, and instead utilized as a portion of the conduit system, the Standard Dimension Ratio (SDR) of the HDPE conduit should be a minimum of 13.5 to closely match the interior dimension of 2” schedule 40 PVC conduit.

11.19 Liquid-Tight Flexible Metal Conduit

11.19.1 Liquid tight flexible metal conduits (LTFMC) shall be used for all final connections and miscellaneous locations where required, such as a conduit run from a bridge deck to bridge bent.

11.19.2 Liquid-tight flexible metal conduit shall be constructed of a flexible galvanized continuous steel core covered with an extruded PVC jacket and limited to 6’ in length.

11.20 Conduit Placement

11.20.1 Conduit shall be installed so as to be continuous and watertight between boxes or components. During installation, conduits shall be protected at all times from the entrance of water and other foreign matter by being capped or plugged overnight and at other times when work may be temporarily suspended.

11.20.2 All conduits vertically stubbed at grade and at walls and/or rails where supplying illumination structures shall have a 2” projection to prevent water flowing into the conduit.

11.20.3 All conduits shall be installed so they will drain properly and drainage tees shall be provided at low points, where required.

11.20.4 Conduit runs shall be made with as few couplings as standard lengths will permit, and the total angle of all bends between any two pull points shall not exceed 360 degrees. The minimum radius of pipe bends shall not be less than those shown in the NEC.

11.20.5 Pull boxes shall be used wherever necessary to facilitate the installation of the conductors. Bushings shall be used on all conduits per NEC.

11.20.6 Exposed conduit runs shall be straight and parallel or at right angles to any general structure lines.
11.20.7 Conduits attached to concrete shall be held in place with malleable iron clamps and malleable iron clampbacks utilizing galvanized bolts for attachment.

11.20.8 Underground conduits shall maintain a minimum 12" horizontal and vertical spacing. Measurement between conduits is made from outside edge to outside edge.

11.20.9 Conduits for poles located in the median and mounted to precast concrete barrier, either CTB or SSCB, shall be PVC Schedule 40 and buried 24" below grade terminating 2" above the poured pole foundation section. All bends and stub ups shall be PVC coated galvanized rigid steel conduit.

11.20.10 Conduits for poles located in the median and mounted to slipped-in place concrete barrier, either CTB or SSCB, shall be galvanized rigid steel and located within 8" of the barrier base. These installations may terminate at a malleable iron junction box located within the barrier, or directly inside the pole, depending on the number of conduits. (No more than two (2) 2" conduits are acceptable at each pole foundation.) If the barrier placed junction box method is chosen, a 1" GRS conduit shall be installed between the barrier junction box and the pole base, terminating 2" above the poured pole foundation section. All bends and stub ups encased in concrete shall be galvanized rigid steel conduit.

Figure 16: Conduit Placement in Traffic Barrier

11.21 Ground, Junction and Pull Boxes

11.21.1 Ground box construction and installation: All electrical ground boxes shall be TxDOT Type D w/apron, installed per TxDOT ED standard. The conduit shall enter from the bottom of the box. This box shall not be subjected to traffic loading. Ground boxes shall be located every 460 feet of continuous conduit run. The tables shall specify the details associated with the ground box such as: how the cover should be labeled, the ground box number; location by station; lateral offset of ground box (indicate what control line is used to
measure from); final location by Northing and Easting coordinates; and ground
box type.

11.21.2 Ground boxes shall be labeled and their covers embossed with a minimum of
1” inch lettering. Following are the required embossed cover imprint
descriptions as determined by the use of the box:

- Service conductors between ESC and SE
  “NTTA POWER” and “HIGH VOLTAGE”

- Feeder for toll gantries
  “NTTA ETC” and “HIGH VOLTAGE”

- Feeder for MPE
  - Branch circuits for DMS, CCTV and AVI
    “NTTA ITS” and “HIGH VOLTAGE”
  - Branch circuits for roadway lighting
    "NTTA ILLUMINATION” and "HIGH VOLTAGE”

- Grounding Electrode Conductor installed in test well
  "NTTA GROUNDING”

- Loop detectors at gantries
- Loop detectors at any location other than a gantry.
  “NTTA LOOPS”

- Feeder for communication hut
  “NTTA COMM” and "HIGH VOLTAGE”

- Communication cabling for fiber optic and data
  ”NTTA COMMUNICATIONS”

- Branch circuit for irrigation
- Control wiring for irrigation
  "NTTA IRRIGATION”

- Branch circuits for traffic signals
- Branch circuits for roadway illumination fixtures on traffic signals
  "TRAFFIC” and "HIGH VOLTAGE”

- Communication cabling for traffic signals
  "TRAFFIC”
11.21.3 Rail or Barrier Junction Boxes: All junction boxes mounted in the rail or CTB shall be cast iron and recessed 1/2”. All boxes shall be straight and level and their opening plumbed to be parallel with the face of the structure they are mounted in.

11.22 Conductors within Buildings

11.22.1 Conductors installed above grade and considered part of an interior building system shall be copper and insulated with THWN or THHN insulation.

11.22.2 Conductors #12 AWG and larger shall be stranded copper. Conductors #14 AWG and smaller shall be solid copper.

11.22.3 Conductors installed on devices shall be attached by an approved method. The use of Sta-Kon® brand extra long nylon insulated crimp-on forked terminals is preferred.

11.22.4 Conductors installed in any Type ESC for any purpose shall be stranded copper conductors with XHHW-2 insulation.

11.22.5 Conductors installed in any type of barrier, wall, rail or bridge for any purpose shall be stranded copper conductors with XHHW-2 insulation.

11.23 Conductors outside of Buildings

11.23.1 Conductors #12 AWG and larger shall be stranded copper. Conductors #14 AWG and smaller shall be solid copper.

11.23.2 Conductors installed on devices shall be attached by an approved method. The use of Sta-Kon® brand extra long nylon insulated crimp-on forked terminals is preferred.

11.23.3 Any conductors contained in underground conduit systems shall be stranded copper conductors with XHHW-2 insulation.

11.23.4 Conductors installed in any Type ESC for any purpose shall be stranded copper conductors with XHHW-2 insulation.

11.23.5 Conductors installed in any type of Barrier, Wall, Rail or Bridge for any purpose shall be stranded copper conductors with XHHW-2 insulation.

11.24 Irrigation Controllers

11.24.1 The locations of landscape controllers and weather stations are typically adjacent to an ITS site where power and communications are readily available. If there are no ITS sites available, the second preferred location for landscape controllers is adjacent to mainlane or ramp gantry ESC’s. The landscape architect shall be responsible to ensure this coordination between
controller and power supply. A 120V circuit for irrigation controllers is available at all mini power enclosure transformer locations. The ESC has a mini power enclosure and therefore a circuit for the landscape controller is available.
Chapter 12 - Calculating Voltage Drop

12.1 Introduction

12.1.1 This chapter explains voltage drop and how to calculate losses for roadway illumination branch circuits. Voltage drop can be calculated manually, using the methods described in this section or automatically using spreadsheets or using a calculator specifically designed for voltage drops.

12.2 Maximum Allowable Voltage Drop

12.2.1 Typical service line voltage for illumination is 480V AC. However, since copper conductors have some amount of resistance, a voltage drop (or loss) will occur in the conductor. This energy is lost in the form of heat.

12.2.2 Magnetic regulator ballasts for HPS of the type specified for roadway illumination (and shown on Roadway Illumination Details) will operate satisfactorily at 10 percent under rated line voltage. (This is not true for all electrical equipment. For equipment other than roadway illumination that uses the regulator ballast, see the equipment manufacturer’s documentation.) Good design practice allows the utility company 2 percent variation from rated line voltage, leaving 8 percent available for voltage drop in branch circuits. Therefore, the maximum allowable voltage drop for a 480 volt circuit would be 38.4 volts, derived as follows:

\[ 480V \times 0.08 = 38.4V \]

Equation 1: Maximum Allowable RWL Voltage Drop

12.2.3 This results in a minimum acceptable line voltage to each illumination fixture in any given circuit being 441.6 volts.

12.2.4 ITS circuits require a tighter range of voltage drop regulation. As stated above in 10.2.2, good design practice allows the utility company 2 percent variation from rated line voltage, leaving 8 percent available for voltage drop in ITS feeder circuits. However, due to the voltage sensitivity of some ITS equipment, it is required that a maximum of 3 percent voltage drop be maintained between the distribution transformer ESC TY MPE and the ITS operating equipment. Therefore, the maximum allowable voltage drop for a 120 volt circuit supplied from the transformer would be 3.6 volts, derived as follows:

\[ 120V \times 0.03 = 3.6V \]

Equation 2: Maximum Allowable ITS Voltage Drop

12.2.5 This results in a minimum acceptable line voltage to the ITS equipment of 116.4 volts.
12.2.6 The ESC TY MPE shall have adjustable taps ranging from 2 – 5% FCBN (Full Capacity Below Normal) of the supply voltage.

12.2.7 This means on a standard single phase transformer with a 4:1 turns ratio, the voltage supplied to the MPE should be limited to a minimum of 3 percent to yield a secondary output of 116.4 volts for the ITS equipment.

12.2.8 The above statement does not include the use of the required transformer taps supplied with the ESC TY MPE, but will provide a voltage acceptable for regulation by the ESC TY MPE to insure the required voltage is available to the ITS equipment.

12.3 Formula

12.3.1 Voltage \((V)\) is equal to current \((I)\) times resistance \((R)\), expressed as:

Equation 3: Ohm’s Law

\[ V = I \times R \]

Therefore, voltage drop \((V_d)\) in any given run may be calculated as;

Equation 4: Voltage Drop Formula

\[ V_d = \text{Current in the run} \times \text{Conductor resistance} \times \text{Length of the run} \]

Discussions of each of the factors in this formula follow.

12.4 Current in the Run

When calculating voltage drop manually, the designer must determine the current in each run (that is, from the last illumination structure to the next-to-last, etc., all the way back to the ESC). The current depends on the number and type of fixtures. The following table shows the current required for the various types of fixtures.

Table 2: Design Amperes for Various Luminaires

<table>
<thead>
<tr>
<th>Lamp Wattage and Type*</th>
<th>- Line Voltage -</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>120 V</td>
</tr>
<tr>
<td>150 W HPS</td>
<td>1.6 A</td>
</tr>
<tr>
<td>250 W HPS</td>
<td>2.6 A</td>
</tr>
<tr>
<td>400 W HPS</td>
<td>3.9 A</td>
</tr>
</tbody>
</table>

*HPS= High Pressure Sodium
Note: The amperage shown for HPS fixtures is for magnetic regulator type ballasts only. If other types of ballasts are used, refer to the manufacturer's specifications.

12.5 Conductor Resistance

12.5.1 To calculate voltage drop, you need to know the resistance of the conductor used in the branch circuit. Resistance is a function of conductor size and length. Resistance for both conductors going to the luminaire must be considered.

12.5.2 The following table shows conductor resistance for various American Wire Gauge’s (AWG). Since both conductors are the same size in typical circuits, the table shows “loop resistance”; thus the designer need only calculate the distance between luminaire poles.

Table 3: Wire Resistance by Gauge

<table>
<thead>
<tr>
<th>Resistance</th>
<th>Conductor Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wire Size</td>
<td># of Conductors</td>
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<tr>
<td>Ohms/ft</td>
<td>2</td>
</tr>
<tr>
<td>14</td>
<td>0.003190</td>
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<tr>
<td>12</td>
<td>0.002010</td>
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<td>10</td>
<td>0.001260</td>
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<tr>
<td>8</td>
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<td>6</td>
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<td>3/0</td>
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<td>400</td>
<td>0.000033</td>
</tr>
<tr>
<td>500</td>
<td>0.000026</td>
</tr>
</tbody>
</table>

12.5.3 Larger conductor sizes have lower resistances. Using larger conductors is one way to reduce the voltage drop in the circuit. If conductors larger than #4 AWG are required, the designer shall tap the conductor in a TxDOT Type D ground box to a smaller size conductor to supply the load. The conductor shall not be smaller than the circuit breaker protecting it.
12.6 Length of Run

12.6.1 When using the preceding table to obtain conductor resistance per meter or foot, the “length of the run” used in the voltage drop formula will simply be the one-way distance between the illumination structures.

12.6.2 Because of the way luminaries are wired, the height of the illumination structure is of no consequence in voltage drop calculations. Only at the last structure would the height be a factor, and then only if the structure were very tall (high mast, for instance).

12.7 Calculation Example

12.7.1 On a 480V branch circuit, the run from the source to the last illumination structure is 200 feet. The twin-arm structure supports two 400 watt HPS fixtures. The conductor is #4 AWG.

12.7.2 Using data from the tables provided in this section, we obtain the following information:

- Current in the run = 2 x 1.2 amps or 2.4 amps
- Loop resistance of the conductor = 0.000642 Ω/ft. x 200 ft.

Using the formula for calculating voltage drop, we find

\[ V_d = 2.4 \text{ amps} \times 0.000642 \text{ Ω/ft.} \times 200 \text{ ft.} \]

Therefore;

\[ V_d = 0.308 \text{ volts.} \]

12.8 Total Voltage Drop

12.8.1 Each run of the branch circuit will have a voltage drop. Therefore, as you work toward the electrical service, the total voltage dropped in the conductor’s increases as the drop for each successive run is added. This total must not exceed 5 percent at the structure farthest from the electrical service. The 5 percent is based on a mag-reg ballast that operates at plus-or-minus 10 percent line voltage. The allowable voltage drop should be adjusted to accommodate the specific ballast used.
**PANELBOARD "MDP"**

**ESC TY S** (ELECTRICAL SERVICE CENTER "YPE "S")

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<tr>
<th>LOAD</th>
<th>DESCRIPTION</th>
<th>WIRE &amp; CONDUCT</th>
<th>VA(*)</th>
<th>CB</th>
<th>PHASE</th>
<th>CB</th>
<th>VA(*)</th>
<th>WIRE &amp; CONDUCT</th>
<th>DESCRIPTION</th>
<th>POLE</th>
<th>LOCATION</th>
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<td>GENERATOR POWER BREAKER CONNECTION</td>
<td>4/1 &amp; 6/0-RG IN 2°C</td>
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Notes:
1. DSE TO FILL IN THIS WIRE SIZE AND CONDUCT FROM THE ONE LINE DIAGRAM GENERATED AT THE END OF THE ITS PLANS. THIS NOTE IS NOT TO BE INCLUDED IN CONTRACT DOCUMENTS; VERIFY ALL OTHER CONDUCTOR SIZES.
2. DSE TO FILL IN MV ADDING CURRENT ABOVE; THIS NOTE IS NOT TO BE IN CONTRACT DOCUMENTS.

(*): LOADS VARY PER DESIGN; (**): WIRING AND CONDUCT VARY PER DESIGN; (**): SIZED ACCORDING TO NEC FOR PROJECT.

**PANEL LOAD SUMMARY TABLE**

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<tr>
<th>LOAD CLASS</th>
<th>CONNECTED</th>
<th>DEMAND</th>
<th>TOTAL CONNECTED LOAD</th>
<th>157.12 VA</th>
<th>169.3 A</th>
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</thead>
<tbody>
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<td>LIGHTING</td>
<td>68,270 VA</td>
<td>83,291 VA</td>
<td>TOTAL DEMAND LOAD</td>
<td>14,510 VA</td>
<td>159.4 A</td>
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<td>5,200 VA</td>
<td>PHASE A (CONNECTED)</td>
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<td>4,900 VA</td>
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<td>NON-CONTINUOUS</td>
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<td>PHASE C (CONNECTED)</td>
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**SUB-FEED (SF) LOAD INFORMATION TABLE**

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<th>MPE</th>
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<td>180</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>CONTINUOUS</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>NON-CONTINUOUS</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>EXISTING</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**SUB-FEED (SF) LOAD INFORMATION TABLE**

<table>
<thead>
<tr>
<th>LOAD CLASS</th>
<th>RD</th>
<th>RD</th>
<th>RD</th>
<th>RD</th>
<th>CH</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIGHTING</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>RECEPTEACLE</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>CONTINUOUS</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>MME LOAD</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>EXISTING</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**PANEL BOARD LOCATION**

1. PANEL BOARD LOCATED WITHIN ESC TY S ENCLOSURE.
2. THIS IS A MAXIMUM CONFIGURATION BASED ON THE ONE-LINE DIAGRAM FOR ESC TY S. REFER TO APPENDIX A.
3. CONFIGURE THIS PANEL BOARD TO REFLECT ACTUAL PROJECT DESIGN CONDITIONS.
4. REFER TO DOWNSTREAM PANELS FOR THE LOADING OF THIS PANEL BOARD.
### Panel Load Summary Table

<table>
<thead>
<tr>
<th>Load Class</th>
<th>Connected</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Connected Load</td>
<td>147,467 VA</td>
<td>177.5 A</td>
</tr>
<tr>
<td>Total Demand Load</td>
<td>168,680 VA</td>
<td>197.9 A</td>
</tr>
</tbody>
</table>

### Sub-Feed (SF) Load Information Table

<table>
<thead>
<tr>
<th>Phase</th>
<th>kVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase A</td>
<td>270.2</td>
</tr>
<tr>
<td>Phase B</td>
<td>225.0</td>
</tr>
<tr>
<td>Phase C</td>
<td>225.0</td>
</tr>
</tbody>
</table>

### Notes:
1. Panel boards located within ESC TY MLG enclosure.
2. This is a maximum configuration based on the one-line diagram for ESC TY MLG. Refer to Appendix B.
3. Configure this panel board to reflect actual project design conditions.
4. Refer to downstream panel boards for the loading of this panel board.
## Panel Load Summary Table

<table>
<thead>
<tr>
<th>Load Class</th>
<th>Connected</th>
<th>Demand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lighting</td>
<td>68,980 VA</td>
</tr>
<tr>
<td>2</td>
<td>Receptacle</td>
<td>200 VA</td>
</tr>
<tr>
<td>3</td>
<td>Continuous</td>
<td>0 VA</td>
</tr>
<tr>
<td>4</td>
<td>Non-Continuous</td>
<td>0 VA</td>
</tr>
<tr>
<td>5</td>
<td>Existing</td>
<td>0 VA</td>
</tr>
<tr>
<td>6</td>
<td>No Space</td>
<td>0 VA</td>
</tr>
</tbody>
</table>

**TOTAL CONNECTED LOAD:** 65,300 VA
**TOTAL DEMAND LOAD:** 100,700 VA

### Sub Feed (SF) Load Information Table

<table>
<thead>
<tr>
<th>Load Type</th>
<th>Phase A</th>
<th>Phase B</th>
<th>Phase C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lighting</td>
<td>2230 VA</td>
<td>2230 VA</td>
<td>2230 VA</td>
</tr>
<tr>
<td>Receptacle</td>
<td>2230 VA</td>
<td>2230 VA</td>
<td>2230 VA</td>
</tr>
<tr>
<td>Continuous</td>
<td>0 VA</td>
<td>0 VA</td>
<td>0 VA</td>
</tr>
<tr>
<td>MISC. LOAD</td>
<td>0 VA</td>
<td>0 VA</td>
<td>0 VA</td>
</tr>
<tr>
<td>Existing</td>
<td>0 VA</td>
<td>0 VA</td>
<td>0 VA</td>
</tr>
</tbody>
</table>

### General Notes
1. Panel Board located within ESC TY S or ESC TY MLG enclosure.
2. This is a manual configuration using four lighting circuits when normally four will be used and two high mast lighting circuits. Therefore a 100 AMP panelboard should be sufficient for any condition.
3. Consult this panel board to reflect actual project design conditions.
4. Conditions are the input watts per type of fixture on the symbol legend on the one-line diagrams ESC TY S or ESC TY MLG for calculating the load for circuits.

### Notes
1. Use a different size of wire above satisfies the voltage drop requirements. Change if required to comply with voltage drops.
   - This note is not to be in the contract documents.
2. Use a different size of current above. This note is not to be in the contract documents.
3. In the two circuits, the voltage drop between the source and the point of application shall be calculated.
### Panel Load Summary Table

<table>
<thead>
<tr>
<th>Load Class</th>
<th>Connected</th>
<th>Demand</th>
<th>Total Connected Load</th>
<th>Total Demand Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lighting</td>
<td>1,052 VA</td>
<td>1,315 VA</td>
<td>10,327 VA</td>
<td>96.9 A</td>
</tr>
<tr>
<td>2. Receptacle</td>
<td>2,756 VA</td>
<td>2,756 VA</td>
<td>2,756 VA</td>
<td>97.2 A</td>
</tr>
<tr>
<td>3. Continuous</td>
<td>180 VA</td>
<td>180 VA</td>
<td>180 VA</td>
<td>0 VA</td>
</tr>
<tr>
<td>4. Non-Continuous</td>
<td>78.75 VA</td>
<td>78.75 VA</td>
<td>78.75 VA</td>
<td>0 VA</td>
</tr>
<tr>
<td>5. Existing</td>
<td>0 VA</td>
<td>0 VA</td>
<td>0 VA</td>
<td>0 VA</td>
</tr>
<tr>
<td>6. SPARE</td>
<td>0 VA</td>
<td>0 VA</td>
<td>0 VA</td>
<td>0 VA</td>
</tr>
</tbody>
</table>

### Sub-Feed (SF) Load Information Table

<table>
<thead>
<tr>
<th>Load Class</th>
<th>NPE</th>
<th>MPE</th>
<th>NPE</th>
<th>MPE</th>
<th>EPE</th>
<th>MPE</th>
<th>ITB</th>
<th>ITB</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Lighting</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2. Receptacle</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3. Continuous</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4. Non-Continuous</td>
<td>78.75</td>
<td>78.75</td>
<td>78.75</td>
<td>78.75</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5. Existing</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>6. SPARE</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**General Notes:**

1. Panel board located within ESC TVW enclosure.
2. This is a maximum configuration based on the one-line diagram for ESC TVW. Refer to Appendix B.
3. Configure this panel board to reflect actual project design conditions.
### PANEL BOARD "RG"

#### RAMP GANTRY

**SERVICE:** 240Y/132V, 3PH, 480VGNH

**MIN. INTERRUPTING CURRENT:** 3,000A

**BREAKER MOUNTING:** BOLT ON

**ENCLOSURE:** NEBKJR

**MOUNTING:** SURFACE

**BRANCH:** NORMAL

---

### PANEL LOAD SUMMARY TABLE

<table>
<thead>
<tr>
<th>LOAD CLASS</th>
<th>CONNECTED</th>
<th>DEMAND</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 LIGHTING</td>
<td>203 VA</td>
<td>313 VA</td>
</tr>
<tr>
<td>2 RECEPTACLE</td>
<td>720 VA</td>
<td>720 VA</td>
</tr>
<tr>
<td>3 CONTINUOUS</td>
<td>9,26 VA</td>
<td>9,26 VA</td>
</tr>
<tr>
<td>4 NON-CONTINUOUS</td>
<td>2,025 VA</td>
<td>2,025 VA</td>
</tr>
<tr>
<td>5 EXISTING</td>
<td>2,085 VA</td>
<td>2,085 VA</td>
</tr>
</tbody>
</table>

**TOTAL CONNECTED LOAD:** 5,271 VA

**TOTAL DEMAND:** 5,334 VA

---

### GENERAL NOTES:

1. Panel board located on ramp gantry screen wall.
2. All loads shown on this panel board shall be used for electrical devices shown. Cut sheets can be provided upon request to verify loads.
3. This panel board layout reflects the loading layout of a ramp gantry.

---

### SUB-FEED (SF) LOAD INFORMATION TABLE

<table>
<thead>
<tr>
<th>LOAD CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 LIGHTING</td>
</tr>
<tr>
<td>2 RECEPTACLE</td>
</tr>
<tr>
<td>3 CONTINUOUS</td>
</tr>
<tr>
<td>4 NON-CONTINUOUS</td>
</tr>
<tr>
<td>5 EXISTING</td>
</tr>
<tr>
<td>6 SPARE</td>
</tr>
</tbody>
</table>

- Phase A
- Phase B
- Phase C
### PANELBOARD "ITB"

**IT BUILDING**

<table>
<thead>
<tr>
<th>LOAD CLASS</th>
<th>POLE</th>
<th>LOAD DESCRIPTION</th>
<th>WIRE &amp; CONDUIT</th>
<th>VA</th>
<th>CB</th>
<th>PHASE</th>
<th>CB &amp; Act</th>
<th>DESCRIPTION</th>
<th>POLE</th>
<th>LOAD CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>RECI</td>
<td>191</td>
<td>201</td>
<td>A</td>
<td>201</td>
<td>180</td>
<td>REC-1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>SPARE</td>
<td>201</td>
<td>201</td>
<td>3,000</td>
<td>201</td>
<td>180</td>
<td>REC-2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>SPARE</td>
<td>201</td>
<td>201</td>
<td>180</td>
<td>SPARE</td>
<td>6</td>
<td>REC-3</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>LTI-IT COLUM</td>
<td>201</td>
<td>201</td>
<td>3,000</td>
<td>201</td>
<td>180</td>
<td>REC-4</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>LTI-IT COLUMN</td>
<td>201</td>
<td>201</td>
<td>180</td>
<td>LTI-IT SPARE</td>
<td>12</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>LTI-IT COLUMN</td>
<td>201</td>
<td>201</td>
<td>180</td>
<td>LTI-IT SPARE</td>
<td>14</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>LTI-IT COLUMN</td>
<td>201</td>
<td>201</td>
<td>180</td>
<td>LTI-IT SPARE</td>
<td>16</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>LTI-IT COLUMN</td>
<td>201</td>
<td>201</td>
<td>180</td>
<td>LTI-IT SPARE</td>
<td>18</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>LTI-IT COLUMN</td>
<td>201</td>
<td>201</td>
<td>180</td>
<td>LTI-IT SPARE</td>
<td>20</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**GENERAL NOTES:**

1. PANELBOARD LOCATED IN MLG IT BUILDING.
2. THE VA LOADS SHOWN ON THE PANEL BOARD SHALL BE USED FOR THE ELECTRICAL DEVICES SHOWN. CUT SHEETS CAN BE PROVIDED UPON REQUEST TO VERIFY LOADS.
3. THE PANEL BOARD LAYOUT REFLECTS THE LOADING LAYOUT OF MAINLANE GANTY IT BUILDING.

### PANEL LOAD SUMMARY TABLE

<table>
<thead>
<tr>
<th>LOAD CLASS</th>
<th>CONNECTED</th>
<th>DEMAND</th>
<th>TOTAL CONNECTED LOAD</th>
<th>20,900 VA</th>
<th>56.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 LIGHTING</td>
<td>989 VA</td>
<td>688 VA</td>
<td>20,900 VA</td>
<td>56.1</td>
<td></td>
</tr>
<tr>
<td>2 RECEPTACLE</td>
<td>989 VA</td>
<td>989 VA</td>
<td>1,000 VA</td>
<td>30.3</td>
<td></td>
</tr>
<tr>
<td>3 CONTINUOUS</td>
<td>13,700 VA</td>
<td>13,700 VA</td>
<td>1,000 VA</td>
<td>30.3</td>
<td></td>
</tr>
</tbody>
</table>

### SUB-FEED (SF) LOAD INFORMATION TABLE

<table>
<thead>
<tr>
<th>LOAD CLASS</th>
<th>PHASE A</th>
<th>PHASE B</th>
<th>PHASE C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 LIGHTING</td>
<td>989 VA</td>
<td>688 VA</td>
<td>20,900 VA</td>
</tr>
<tr>
<td>2 RECEPTACLE</td>
<td>989 VA</td>
<td>989 VA</td>
<td>1,000 VA</td>
</tr>
<tr>
<td>3 CONTINUOUS</td>
<td>13,700 VA</td>
<td>13,700 VA</td>
<td>1,000 VA</td>
</tr>
<tr>
<td>4 NON-CONTINUOUS</td>
<td>13,700 VA</td>
<td>13,700 VA</td>
<td>1,000 VA</td>
</tr>
<tr>
<td>5 EXISTING</td>
<td>989 VA</td>
<td>688 VA</td>
<td>20,900 VA</td>
</tr>
<tr>
<td>6 SPARE</td>
<td>989 VA</td>
<td>688 VA</td>
<td>20,900 VA</td>
</tr>
</tbody>
</table>
GENERAL NOTES:
1. MINI POWER ENCLOSURE LOCATED AS REQUIRED. SEE ITS PLANS FOR LOCATIONS.
2. THE VA LOADS SHOWN ON THIS PANEL BOARD SHALL BE USED FOR THE ELECTRICAL DEVICES SHOWN. CUT SHEETS CAN BE PROVIDED UPON REQUEST.
3. THE PANEL BOARD LAYOUT REFLECTS THE LOADING LAYOUT OF A MINI POWER ENCLOSURE.

APPENDIX I PANEL SCHEDULE MINI POWER ENCLOSURE EXAMPLE

PANELBOARD "MPE"
MINI POWER PANEL

<table>
<thead>
<tr>
<th>LOAD CLASS</th>
<th>CKT #</th>
<th>DESCRIPTION</th>
<th>WIRE &amp; CONDUIT</th>
<th>VA</th>
<th>CB</th>
<th>PHASE</th>
<th>CB</th>
<th>VA</th>
<th>WIRE &amp; CONDUIT</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>RECEPTACLE</td>
<td>2 #12 &amp; 2 #25 G N 3/4&quot;</td>
<td>100</td>
<td>251</td>
<td>A</td>
<td>402</td>
<td>5,000</td>
<td>2 #16 &amp; 4 M O IN 2&quot;</td>
<td>ORNL 4</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>FALCON 15KVA UPS</td>
<td>2 #12 &amp; 2 #25 G N 3/4&quot;</td>
<td>150</td>
<td>251</td>
<td>B</td>
<td>2,000</td>
<td>2,000</td>
<td>SPARE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>LOOP</td>
<td>2 #12 &amp; 2 #25 G N 1/2&quot;</td>
<td>75</td>
<td>251</td>
<td>A</td>
<td>202</td>
<td>200</td>
<td>SPARE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>AVI</td>
<td>2 #10 &amp; 2 #25 G N 1/2&quot;</td>
<td>25</td>
<td>251</td>
<td>B</td>
<td>251</td>
<td>250</td>
<td>SPARE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>SPARE</td>
<td>2 #10 &amp; 2 #25 G N 1/2&quot;</td>
<td>25</td>
<td>251</td>
<td>A</td>
<td>251</td>
<td>250</td>
<td>SPARE</td>
<td></td>
</tr>
</tbody>
</table>

NOTES:
1. EQUIVALENT TO SQUARE D 10 KVA MINI POWER/ZONE 400 Volts Primary (30A/GPC MCB); 120/240 Volts Secondary (60A/GP).
2. USE TO DETERMINE TOTAL WIRE SIZE REQUIRED TO SATISFY THE VOLTAGE DROP REQUIREMENTS. CHARGE IS REQUIRED TO COMPACT WITH VOLTAGE DROPS.
3. THIS NOTE IS NOT TO BE IN THE CONTRACT DOCUMENTS.
4. WHEN THIS "MPE" SCHEDULE IS USED FOR CASE #1 PER ESC-003 STANDARD (RADIAL READER), THE 4000 CIRCUIT BREAKER SHALL BE CHANGED TO TWO 2000 CIRCUIT BREAKERS. THE VA AND DESCRIPTION FOR CIRCUIT #2 SHALL BE 1920 AND RADIAL UPS. VA AND DESCRIPTION FOR CIRCUIT #2 SHALL BE 2320 AND FUTURE RADIAL UPS. CIRCUIT #2 SHALL BE CHANGED FROM A SPARE TO A VA OF 2320 AND A DESCRIPTION OF "RADIAL ENCLOSURE AC." WIRE SIZE FOR ALL THREE CIRCUITS SHALL BE 20/2 & 12/2 G N 3/4".

LOAD CLASS | CONNECTED | DEMAND |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LIGHTING</td>
<td>400 VA</td>
</tr>
<tr>
<td></td>
<td>3-125A</td>
<td>100 VA</td>
</tr>
<tr>
<td></td>
<td>CONTINUOUS</td>
<td>795 VA</td>
</tr>
<tr>
<td></td>
<td>3-125A</td>
<td>100 VA</td>
</tr>
<tr>
<td></td>
<td>SPARE 20%</td>
<td>1,011 VA</td>
</tr>
</tbody>
</table>

TOTAL CONNECTED LOAD: 1,060 VA
TOTAL DEMAND LOAD: 1,060 VA

PHASE-A (CONNECTED): 284 A @ 480 Volts
PHASE-B (CONNECTED): 284 A @ 480 Volts

NORTH TEXAS TOLLWAY AUTHORITY

CONSULTANT LOGO

APPENDIX I PANEL SCHEDULE MINI POWER ENCLOSURE EXAMPLE
## Panelboard "CH"
### Communications Hut

### Panel Schedule

<table>
<thead>
<tr>
<th>LOAD CLASS</th>
<th>POLE</th>
<th>LOAD DESCRIPTION</th>
<th>WIRE &amp; CONDUIT</th>
<th>VA</th>
<th>CB</th>
<th>PHASE</th>
<th>CB</th>
<th>VA</th>
<th>WIRE &amp; CONDUIT</th>
<th>DESCRIPTION</th>
<th>POLE</th>
<th>LINE CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>380/240 VAC 3PH</td>
<td>2R BX &amp; RIGID</td>
<td>200</td>
<td>300</td>
<td>300</td>
<td>60</td>
<td>200</td>
<td>2R BX &amp; RIGID</td>
<td></td>
<td>2</td>
<td></td>
</tr>
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### Panel Load Summary Table

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<td>2 Receptacle</td>
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<td>4 Non-Continuous</td>
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<td>5 Existing</td>
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<td>6 Spare</td>
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### Sub-Feed (SF) Load Information Table

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<tr>
<td>Phase C</td>
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### General Notes:
1. Panel board is located in the communications hut. See its plans for location.
2. The VA loads shown on this panel board shall be used for the electrical devices shown. Cut sheets can be provided upon request.
3. This panel board layout reflects the loading layout of a mini power enclosure.

### Power Enclosure:
This panel board layout reflects the loading layout of a mini power enclosure.
CIRCUIT LAYOUT / FIXTURE NUMBERING

NOTE: ALTERNATING POLE CIRCUITRY ON BRIDGES SPANNING OVER 500' REQUIRES THE ADDITION OF THE ALTERNATING CIRCUIT.

THE METHOD OF NUMBERING ALLOWS MAINTENANCE TO KNOW THE QUANTITY OF POLES ASSOCIATED WITH A PARTICULAR RAMP.

BRIDGE SAFETY LIGHTING
ALTERNATING CIRCUIT LAYOUT
(SPANS > 500 FT)
GENERAL NOTES:

1. THE LAYOUT SHOWN IS FOR DIAGRAMMATIC PURPOSES ONLY.

2. THE ENGINEER SHALL DESIGN THE LIGHTING LAYOUT TO SITE SPECIFIC CONDITIONS.

3. GROUND BOX ON BOTH SIDES OF ROADWAY

4. EACH ROADWAY CROSSING REQUIRES A GROUND BOX ON BOTH SIDES OF ROADWAY (UNDERGROUND OR STRUCTURE MOUNTED)

H-PATTERN LAYOUT

CIRCUIT 1

CIRCUIT 2

CIRCUIT 3

CIRCUIT 4

460' MAX GROUND BOX SPACING

2EX1

3EX1

1EX1

EX6

1EX2

2EX3

1EX3

1EX4

2EX5

3EX2

3EX3

2EX4

3EX1

4EX1

3EX4

H-PATTERN LAYOUT EXAMPLE
CIRCUITS 1-4
1 AB 1 1
2 BC 1 1
3 CA 1 1
4 AB 1 1
CIRCUITS 5 & 6
5 BC 1 1
6 CA 1 1
7 AB 1 1
8 BC 1 1
9 CA 1 1
10 AB 1 1
CIRCUITS 7-10
11 BC 1 1
12 CA 1 1
CIRCUITS 11 & 12
13 AB 1 1
14 BC 1 1
CIRCUITS 13 & 14
15 AB 1 1
16 BC 1 1
17 AB 1 1
CIRCUITS 7-12 ARE A REPEAT OF THE ABOVE SEQUENCING.
CIRCUITS 5 & 6 ARE USED FOR ADDITIONAL CIRCUITING SUCH AS ALTERNATING CIRCUITS ON BRIDGES WITH SPANS CLOSER THAN 500 FT IN LENGTH.
CIRCUITS 1, 2, 3, 4 REPRESENT THE 4 REQUIRED SEGMENTS OF THE "H" PATTERN.
CIRCUITS 13 & 14 ARE ADDITIONAL SPARES.

INSTALL SINGLE POLE BLANK
FOR 277V LOADS (PHASES A & C).

THIS TYPE OF PHASING BEST SIMPLIFIES WIRING AND LOAD BALANCING. THIS LAYOUT PROVIDES THE MOST EFFICIENT USE OF THE PANEL SPACES AND MAXIMIZES AVAILABLE SPACES TO BALANCE THE LOADS. 2 SPARES (BLANKS) MAY BE USED FOR 277V LOADS (PHASES A & C).