

SECTION 26 05 11  
REQUIREMENTS FOR ELECTRICAL INSTALLATIONS

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section applies to all sections of Division 26.
- B. Furnish and install electrical wiring, systems, equipment and accessories in accordance with the specifications and drawings. Capacities and ratings of motors, transformers, cable, switchboards, switchgear, panelboards, motor control centers, and other items and arrangements for the specified items are shown on drawings.
- C. Electrical service entrance equipment (arrangements for temporary and permanent connections to the utility's system) shall conform to the utility's requirements. Coordinate fuses, circuit breakers and relays with the utility's system, and obtain utility approval for sizes and settings of these devices.
- D. Wiring ampacities specified or shown on the drawings are based on copper conductors, with the conduit and raceways accordingly sized. Aluminum conductors are permissible per Duct Alternate as specified in Section 26 05 21.

1.2 MINIMUM REQUIREMENTS

- A. References to the International Building Code (IBC), National Electrical Code (NEC), Underwriters Laboratories, Inc. (UL) and National Fire Protection Association (NFPA) are minimum installation requirement standards.
- B. Drawings and other specification sections shall govern in those instances where requirements are greater than those specified in the above standards.

1.3 TEST STANDARDS

- A. All materials and equipment shall be listed, labeled or certified by a nationally recognized testing laboratory to meet Underwriters Laboratories, Inc., standards where test standards have been established. Equipment and materials which are not covered by UL Standards will be accepted provided equipment and material is listed, labeled, certified or otherwise determined to meet safety requirements of a nationally recognized testing laboratory. Equipment of a class which no nationally recognized testing laboratory accepts, certifies, lists, labels, or determines to be safe, will be considered if inspected or tested in accordance with national industrial standards, such as NEMA, or ANSI. Evidence of compliance shall include certified test reports and definitive shop drawings.

**B. Definitions:**

1. Listed; Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production or listed equipment or materials or periodic evaluation of services, and whose listing states that the equipment, material, or services either meets appropriate designated standards or has been tested and found suitable for a specified purpose.
2. Labeled; Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.
3. Certified; equipment or product which:
  - a. Has been tested and found by a nationally recognized testing laboratory to meet nationally recognized standards or to be safe for use in a specified manner.
  - b. Production of equipment or product is periodically inspected by a nationally recognized testing laboratory.
  - c. Bears a label, tag, or other record of certification.
4. Nationally recognized testing laboratory; laboratory which is approved, in accordance with OSHA regulations, by the Secretary of Labor.

**1.4 QUALIFICATIONS (PRODUCTS AND SERVICES)**

- A. Manufacturers Qualifications: The manufacturer shall regularly and presently produce, as one of the manufacturer's principal products, the equipment and material specified for this project, and shall have manufactured the item for at least three years.
- B. Product Qualification:
- C. Manufacturer's product shall have been in satisfactory operation, on three installations of similar size and type as this project, for approximately three years.
- D. The Government reserves the right to require the Contractor to submit a list of installations where the products have been in operation before approval.
- E. Service Qualifications: There shall be a permanent service organization maintained or trained by the manufacturer which will render satisfactory service to this installation within four hours of receipt of notification that service is needed. Submit name and address of service organizations.

**1.5 APPLICABLE PUBLICATIONS**

- A. Applicable publications listed in all Sections of Division are the latest issue, unless otherwise noted.

**1.6 MANUFACTURED PRODUCTS**

- A. Materials and equipment furnished shall be of current production by manufacturers regularly engaged in the manufacture of such items, for which replacement parts shall be available.

- B. When more than one unit of the same class or type of equipment is required, such units shall be the product of a single manufacturer.
- C. Equipment Assemblies and Components:
- D. Components of an assembled unit need not be products of the same manufacturer.
- E. Manufacturers of equipment assemblies, which include components made by others, shall assume complete responsibility for the final assembled unit.
- F. Components shall be compatible with each other and with the total assembly for the intended service.
- G. Constituent parts which are similar shall be the product of a single manufacturer.
- H. Factory wiring shall be identified on the equipment being furnished and on all wiring diagrams.
- I. When Factory Testing Is Specified:
  - 1. The Government shall have the option of witnessing factory tests. The contractor shall notify the VA through the Resident Engineer a minimum of 15 working days prior to the manufacturers making the factory tests.
  - 2. Four copies of certified test reports containing all test data shall be furnished to the Resident Engineer prior to final inspection and not more than 90 days after completion of the tests.
  - 3. When equipment fails to meet factory test and re-inspection is required, the contractor shall be liable for all additional expenses, including expenses of the Government.

#### 1.7 EQUIPMENT REQUIREMENTS

- A. Where variations from the contract requirements are requested in accordance with the GENERAL CONDITIONS and Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES, the connecting work and related components shall include, but not be limited to additions or changes to branch circuits, circuit protective devices, conduits, wire, feeders, controls, panels and installation methods.

#### 1.8 EQUIPMENT PROTECTION

- A. Equipment and materials shall be protected during shipment and storage against physical damage, vermin, dirt, corrosive substances, fumes, moisture, cold and rain.
- B. Store equipment indoors in clean dry space with uniform temperature to prevent condensation. Equipment shall include but not be limited to switchgear, generators, switchboards, panelboards, transformers, motor control centers, motor controllers, uninterruptible power systems, enclosures, controllers, circuit protective devices, cables, wire, light fixtures, electronic equipment, and accessories.
- C. During installation, equipment shall be protected against entry of foreign matter; and be vacuum-cleaned both inside and outside before testing and operating. Compressed air shall not be used to clean equipment. Remove loose packing and flammable materials from inside equipment.

- D. Damaged equipment shall be, as determined by the Resident Engineer, placed in first class operating condition or be returned to the source of supply for repair or replacement.
- E. Painted surfaces shall be protected with factory installed removable heavy kraft paper, sheet vinyl or equal.
- F. Damaged paint on equipment and materials shall be refinished with the same quality of paint and workmanship as used by the manufacturer so repaired areas are not obvious.

#### 1.9 WORK PERFORMANCE

- A. All electrical work must comply with the requirements of NFPA 70 (NEC), NFPA 70B, NFPA 70E, OSHA Part 1910 subpart J, OSHA Part 1910 subpart S and OSHA Part 1910 subpart K in addition to other references required by contract.
- B. Job site safety and worker safety is the responsibility of the contractor.
- C. Electrical work shall be accomplished with all affected circuits or equipment de-energized. When an electrical outage cannot be accomplished in this manner for the required work, the following requirements are mandatory:
- D. Electricians must use full protective equipment (i.e., certified and tested insulating material to cover exposed energized electrical components, certified and tested insulated tools, etc.) while working on energized systems in accordance with NFPA 70E.
- E. Electricians must wear personal protective equipment while working on energized systems in accordance with NFPA 70E.
- F. Before initiating any work, a job specific work plan must be developed by the contractor with a peer review conducted and documented by the Resident Engineer and Medical Center staff. The work plan must include procedures to be used on and near the live electrical equipment, barriers to be installed, safety equipment to be used and exit pathways.
- G. Work on energized circuits or equipment cannot begin until prior written approval is obtained from the Resident Engineer.
- H. For work on existing stations, arrange, phase and perform work to assure electrical service for other buildings at all times. Refer to Article OPERATIONS AND STORAGE AREAS under Section 01 00 00, GENERAL REQUIREMENTS.
- I. New work shall be installed and connected to existing work neatly, safely and professionally. Disturbed or damaged work shall be replaced or repaired to its prior conditions, as required by Section 01 00 00, GENERAL REQUIREMENTS.
- J. Coordinate location of equipment and conduit with other trades to minimize interferences.

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1.10 EQUIPMENT INSTALLATION AND REQUIREMENTS

- A. Equipment location shall be as close as practical to locations shown on the drawings.
- B. Working spaces shall not be less than specified in the NEC for all voltages specified.
- C. Inaccessible Equipment:
  - 1. Where the Government determines that the Contractor has installed equipment not conveniently accessible for operation and maintenance, the equipment shall be removed and reinstalled as directed at no additional cost to the Government.
  - 2. "Conveniently accessible" is defined as being capable of being reached quickly for operation, maintenance, or inspections without the use of ladders, or without climbing or crawling under or over obstacles such as, but not limited to, motors, pumps, belt guards, transformers, piping, ductwork, conduit and raceways.

## 1.11 EQUIPMENT IDENTIFICATION

- A. In addition to the requirements of the NEC, install an identification sign which clearly indicates information required for use and maintenance of items such as panelboards, cabinets, motor controllers (starters), safety switches, separately enclosed circuit breakers, individual breakers and controllers in switchboards, switchgear and motor control assemblies, control devices and other significant equipment.
- B. Nameplates for Normal Power System equipment shall be laminated black phenolic resin with a white core with engraved lettering. Nameplates for Essential Electrical System (EES) equipment, as defined in the NEC, shall be laminated red phenolic resin with a white core with engraved lettering. Lettering shall be a minimum of 1/2 inch [12mm] high. Nameplates shall indicate equipment designation, rated bus amperage, voltage, number of phases, number of wires, and type of EES power branch as applicable. Secure nameplates with screws.
- C. Nameplates for all equipment, panels, disconnect switches shall also indicate where equipment is "served from".
- D. Provide Arc Flash warnings and categories on all distribution equipment, panels, etc.
- E. Refer to nameplate details on drawings.

## 1.12 SUBMITTALS

- A. Submit in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES.
- B. The Government's approval shall be obtained for all equipment and material before delivery to the job site. Delivery, storage or installation of equipment or material which has not had prior approval will not be permitted at the job site.
- C. All submittals shall include adequate descriptive literature, catalog cuts, shop drawings and other data necessary for the Government to ascertain that the proposed equipment and materials comply with specification requirements. Catalog cuts submitted for approval shall be legible and clearly identify equipment being submitted.

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- D. Submittals for individual systems and equipment assemblies which consist of more than one item or component shall be made for the system or assembly as a whole. Partial submittals will not be considered for approval.
1. Mark the submittals, "SUBMITTED UNDER SECTION\_\_\_\_\_".
  2. Submittals shall be marked to show specification reference including the section and paragraph numbers.
- E. Submit each section separately.
- F. The submittals shall include the following:
1. Information that confirms compliance with contract requirements. Include the manufacturer's name, model or catalog numbers, catalog information, technical data sheets, shop drawings, pictures, nameplate data and test reports as required.
- G. Elementary and interconnection wiring diagrams for communication and signal systems, control systems and equipment assemblies. All terminal points and wiring shall be identified on wiring diagrams.
- H. Parts list which shall include those replacement parts recommended by the equipment manufacturer.
- I. Manuals: Submit in accordance with Section 01 00 00, GENERAL REQUIREMENTS.
- J. Maintenance and Operation Manuals: Submit as required for systems and equipment specified in the technical sections. Furnish four copies, bound in hardback binders, (manufacturer's standard binders) or an approved equivalent. Furnish one complete manual as specified in the technical section but in no case later than prior to performance of systems or equipment test, and furnish the remaining manuals prior to contract completion.
- K. Inscribe the following identification on the cover: the words "MAINTENANCE AND OPERATION MANUAL," the name and location of the system, equipment, building, name of Contractor, and contract number. Include in the manual the names, addresses, and telephone numbers of each subcontractor installing the system or equipment and the local representatives for the system or equipment.
- L. Provide a "Table of Contents" and assemble the manual to conform to the table of contents, with tab sheets placed before instructions covering the subject. The instructions shall be legible and easily read, with large sheets of drawings folded in.
- M. The manuals shall include:
1. Internal and interconnecting wiring and control diagrams with data to explain detailed operation and control of the equipment.
  2. A control sequence describing start-up, operation, and shutdown.
  3. Description of the function of each principal item of equipment.
  4. Installation instructions.
  5. Safety precautions for operation and maintenance.
  6. Diagrams and illustrations.
  7. Periodic maintenance and testing procedures and frequencies, including replacement parts numbers and replacement frequencies.
  8. Performance data.

- 9. Pictorial "exploded" parts list with part numbers. Emphasis shall be placed on the use of special tools and instruments. The list shall indicate sources of supply, recommended spare parts, and name of servicing organization.
  - 10. List of factory approved or qualified permanent servicing organizations for equipment repair and periodic testing and maintenance, including addresses and factory certification qualifications.
- N. Approvals will be based on complete submission of manuals together with shop drawings.
- O. After approval and prior to installation, furnish the Resident Engineer with one sample of each of the following:
- P. A 300 mm (12 inch) length of each type and size of wire and cable along with the tag from the coils of reels from which the samples were taken.
- Q. Each type of conduit coupling, bushing and termination fitting.
- R. Conduit hangers, clamps and supports.
- S. Duct sealing compound.
- T. Each type of receptacle, toggle switch, occupancy sensor, outlet box, manual motor starter, device wall plate, engraved nameplate, wire and cable splicing and terminating material, and branch circuit single pole molded case circuit breaker.

#### 1.13 SINGULAR NUMBER

- A. Where any device or part of equipment is referred to in these specifications in the singular number (e.g., "the switch"), this reference shall be deemed to apply to as many such devices as are required to complete the installation as shown on the drawings.

#### 1.14 ACCEPTANCE CHECKS AND TESTS

- A. The Contractor shall furnish the instruments, materials and labor for field tests.

#### 1.15 TRAINING

- A. Training shall be provided in accordance with Article 1.25, INSTRUCTIONS, of Section 01 00 00, GENERAL REQUIREMENTS.
- B. Training shall be provided for the particular equipment or system as required in each associated specification.
- C. A training schedule shall be developed and submitted by the contractor and approved by the Resident Engineer at least 30 days prior to the planned training.

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SECTION 26 05 11.10  
3D BUILDING INFORMATION MODELING

1.1 RELATED DOCUMENTS

- A. Drawings and general provisions of the Contract, including Common Work Results for HVAC and Steam Generation, Section 23 05 11, Division 25 and other Division 1 Specification Sections, apply to this Section.
- B. LEED™ REQUIREMENTS, Refer to Section 018113 – SUSTAINABLE DESIGN REQUIREMENTS

1.2 OVERVIEW

- A. Building Information Modeling (BIM) is the development and use of a 3-dimensional computer model to represent a virtual model of the facility and the process for constructing the facility. Once the model is developed, it can be used to simulate the construction process and to manage the operations of the facility. The Building Information Model can be created by combining many different 3D models from the designers and contractors into a composite model. From this composite model, views and data appropriate to various users' needs can be extracted and analyzed to generate information, to make decisions and to improve the process of delivering the building.

1.3 OUTCOME

- A. The purpose of BIM is to create a model that may be used for coordination of all trades throughout the construction process, with the final product being an as-built model of the Project which contains all of the major elements of construction that could be used by the Owner for future operation and maintenance of the building.

1.4 REQUIRED DISCLAIMER

- A. All users shall be required to sign a disclaimer as follows:

*TERMS OF USE OF 3D COMPUTER MODEL FOR THE SLVHCS REPLACEMENT MEDICAL CENTER PROJECT ("Project")*

*This 3D Computer Model for the Project is provided by NBBJ (Architect) to user (individually, a "User", or collectively, "Users") at the User's request subject to the terms and conditions stated below (the "Terms of Use"):*

*The 3D Model is made available to User solely for his convenience and for informational purposes only. The User is not to rely upon the 3D Computer Model and the data and/or information contained therein in preparing any of the coordination documents for the Project. The User acknowledges that the 3D Computer Model is not a part of the Construction or Contract Documents for the Project and that the Architect makes no representations or warranties, express or implied, regarding the 3D Computer Model's, accuracy or completeness or the data and/or information contained therein.*



*By opening the files provided, the User agrees that these terms apply to the 3D Model in its entirety, together with all of its component parts and data. The User acknowledges that the requirements of these Terms of Use apply to all of User's principals, employees and agents.*

*The User agrees that the use of the 3D Computer Model is solely at the User's risk and that the User assumes full responsibility and liability in connection with the User's use of the 3D Computer Model and the information and/or data contained therein. The User agrees that the Architect has no responsibility for any deficiencies, inaccuracies, errors and/or omissions contained in the 3D Computer Model or the data and/or information contained therein. The Architect has no responsibility for any deficiencies or defects in the User's documents, work and/or services resulting from the User's use of the 3D Computer Model in lieu of the Construction and/or Contract Documents for the Project.*

*The User acknowledges and agrees a) that the use of the 3D Computer Model is not a substitute for professional judgment; b) that the use of the 3D Computer Model does not relieve the User from applying the appropriate standard of care and skill relevant to the use of the 3D Computer Model and its contents; c) that the 3D Computer Model is only to be used as a tool to assist the User in connection with the Project; d) that the User is solely responsible for verifying the accuracy of all results created with the use of the 3D Computer Model; and (e) the Architect is not responsible or liable for the means and methods of construction and the User's use of the 3D Computer Model shall in no way give rise to such responsible or liable by the Architect or its consultants.*

*THE ARCHITECT AND ITS CONSULTANTS SPECIFICALLY DISCLAIM ALL WARRANTIES WHETHER EXPRESSED, IMPLIED OR STATUTORY, INCLUDING, WITHOUT LIMITATION, ALL WARRANTIES OF MERCHANTABILITY, TITLE, FITNESS FOR A PARTICULAR PURPOSE, CONSTRUCTABILITY, NON-INFRINGEMENT, COMPATIBILITY, SECURITY OR ACCURACY AND USERS' USE OF THE 3D COMPUTER MODEL IS AT ITS OWN RISK. USER ASSUMES FULL RESPONSIBILITY AND RISK OF LOSS RESULTING FROM USE OR INABILITY TO USE THE 3D COMPUTER MODEL OR ITS CONTENT.*

*The User further agrees that the 3D Computer Model contains information that is confidential and proprietary to the Architect, and that the Architect retains the copyright and all other reserved rights in the work product reflected in the 3D Computer Model that was prepared by the Architect or its consultants for the Project. The Architect grants the User a non-exclusive, non-transferable royalty-free license to use the 3D Computer Model for informational purposes only in connection with the Project in strict accordance with these Terms of Use. The User agrees that the 3D Computer Model will be used solely and exclusively for the Project and that it will not use the 3D Computer Model and the data and/or information contained therein, in whole or in part, for any purpose or project other than the Project. The User further agrees that the 3D Computer Model will continue to be kept confidential by the User, and that it shall not be disclosed in any manner, transferred or exchanged to any third parties by the User without the express written consent of the Architect.*

*Upon completion of the User's involvement with the Project or at any time upon written request of the Architect, the User shall promptly deliver to the Architect the 3D Computer Model and any other material containing or reflecting any information or data in the 3D Computer Model (whether prepared by the Architect, the User or otherwise) and will not retain copies, extracts or other reproductions, tangible or intangible, in whole or in part of the 3D Computer Model. The User's non-disclosure and non-use obligations set forth herein shall survive the return, destruction or deletion of the 3D Computer Model. If the User becomes legally compelled, by subpoena or court order, to disclose the 3D Model, or any information contained therein, the*

*User shall provide the Architect with prompt notice so that a protective order or other appropriate remedy may be sought by and at the expense of the Architect and/or compliance with the provisions of this Terms of Use may be waived.*

*User hereby agrees that the Architect shall be entitled to equitable relief, including injunction, in the event of any breach of the Terms of Use, including without limitation its obligations to maintain the confidentiality of the 3D Model, that the granting of such relief will not be opposed and that such relief shall not be the exclusive remedy for such breach. The Architect's failure to insist upon strict adherence to any term of these Terms of Use shall not be considered a waiver thereof or deprive the Architect of the right subsequently to insist upon strict adherence to that term or any other term of this Terms of Use.*

*The User hereby agrees, to the fullest extent permitted by law, that in no event shall the Architect be liable to User for any damages or losses of any kind including, but not limited to, damages for death or bodily injury to persons, injury to property, and direct, indirect, consequential, special, or incidental damages, resulting from any error, omission, inaccuracy, deficiency or defect in or problem with, the 3D Computer Model or the data and/or information contained therein. Without limiting the foregoing, the User acknowledges that the 3D Computer Model and the data and/or information contained therein may be inaccurate and/or incomplete and that the Architect will have no obligation to update or modify the 3D Computer Model or any of the data and/or information contained in it because the 3D Computer Model was prepared solely for informational purposes and is not part of the Construction or Contract Documents for the Project.*

*The User agrees that in the event the User, its officers, directors, shareholders, partners, agents, employees, consultants or independent contractors use the 3D Computer Model or the information and/or data contained therein, it shall, to the fullest extent permitted by law, defend, indemnify and hold the Architect and its officers, directors, shareholders, partners, principals, consultants, agents and employees harmless from and against any and all actions, damages, demands, claims, suits, losses, liability, judgments, recoveries, costs and expenses, including, but not limited to, reasonable attorney's fees which any of them may incur in connection with, arising from, resulting from or related to any use of the 3D Computer Model or the data and/or the information contained therein by the User or any third party who receives the 3D Computer Model from the User. Such claims include, without limitation, any claim which may arise due to deletions, omissions or variations of data due to mechanical or technical failure in connection with the transmission of the 3D Computer Model.*

*The User acknowledges and agrees that it is not in privity of contract with the Architect as of result of these Terms of Use with respect to any claims or causes of action related to or arising out of the Project. The User further agrees to obligate any contractor, consultant or other party who uses the 3D Computer Model to be bound by the terms and conditions contained herein. Any User's use of the 3D Computer Model and the information and/or data contained therein constitutes such User's acceptance of all the terms here specified.*

ACCEPTED & AGREED:

Name: \_\_\_\_\_

Title: \_\_\_\_\_

Date: \_\_\_\_\_

## 1.5 SCOPE OF WORK

### A. General Scope Requirements

1. In general, the BIM scope of work for the Project is to create a technically accurate and detailed 3D computer model of the architectural, structural, mechanical, plumbing and electrical systems.
2. The computer model (in plan view) shall extend to five feet beyond the exterior walls of the building. Vertically, the model shall extend from the lowest extent of the foundations up through and including the roof of the top-most floor. To the extent that the scope includes building systems, those systems will be included to the full horizontal and vertical extents of the model including underground utilities and roof mounted items.
3. The level of detail defined in the Specific Scope Requirements is the minimum level of detail required in the model. Greater detail than the minimum should be incorporated into the model where important details are necessary for communicating information about a system.
4. Each Trade Contractor shall provide shop drawings in both 2D and 3D model format.
5. The 3D model shall be located and oriented to the pre-determined world coordinates for the project to allow easy integration into the BIM for the project.
6. The 3D model shall include the project control grid. This grid should be visible when viewing the model in a true view along the X, Y or Z axis.
7. The 3D model shall be layered and constructed in a manner such that all elements of the model can be converted into a 2D dimensioned drawing for use in the field.
8. The 2d shop drawing scale should be 1'-0" = 3/8" unless specified otherwise or as required for full comprehensible and reviewable details.
9. Each drawing should include a key map referencing the location in the building.
10. In addition to the native file format, the Trade Contractor shall provide translation of the 3D model into a .DWG, CIS/2 or other agreed upon file format that can be viewed using NavisWorks Manager.
11. The following changes shall be promptly incorporated into the drawings and model, on a regular basis:
  - a. RFIs, Bulletins and Owner changes
  - b. Changes in the sequence of work
  - c. Field modifications
  - d. Shop drawing review comments
  - e. Changes requested by the Construction Manager
12. All revised 3d model or 2D drawing submittals shall have a written narrative to define changes from previous submittals. Typical drafting techniques such as 'clouds' or 'bubbles' are acceptable means of tracking changes on the 2D drawings. [Layer control shall be used to define changes in the 3D model. All revisions shall be shown in both 2D and 3D formats].
13. The working 3D model will be shared with the Trade Contractors and design team at least once every two weeks. This will be performed by posting the model to the project FTP site or PrologWeb. The Trade Contractor will post the native file format and an agreed upon file format as defined in Item 10 above.
14. Pre-detailing meeting:
  - a. Shall determine the lead trade.
  - b. The order that coordination work will be added to the model.

15. The 3D modeling and layering conventions will be established at a pre-detailing meeting to be attended by:
  - a. Concrete Contractor and detailer
  - b. Steel Fabricator and detailer
  - c. Mechanical Contractors and detailers
  - d. Electrical Contractors and detailers
  - e. Plumbing Contractors and detailers
  - f. Fire protection Contractors and detailers
  - g. Other trades.
16. Each Trade Contractor will submit its 3D modeling software and proposed file format(s) for approval prior to proceeding with detailing. The Trade Contractor will also provide a 3D mock-up of a specific portion of the project, to be agreed upon at a future time, in full detail in order to verify the compatibility of the file formats.
17. Each Trade Contractor shall provide viewer licenses only for its specific 3D software to the following:
  - a. Owner
  - b. Construction Manager
  - c. Architect
  - d. Engineer of Record
18. Each Trade Contractor and detailers shall have the capability to host and attend web meeting using Microsoft Live Meeting software.
19. Each Trade Contractor shall complete the drawings and model in a time frame capable of meeting the Project Schedule.
20. The Trade Contractors are advised that the model shall be shared among all trades and shall be the basis of coordination and fabrication. Costs incurred for post-coordination changes caused by unauthorized deviations from the model shall be borne by the Trade Contractor that initially deviated from the model. This determination is at the sole discretion of the Construction Manager.
21. The base architectural BIM will be created using AutoDesk's Revit Building.
22. The 3D modeling effort is intended to augment and assist in the MEP coordination process. Before first submission shop drawings, the elements shall be first pass coordinated in the 3D model. The model is intended to find conflicts before shop drawings are reviewed and approved.
23. In addition to the requirements set forth in the contract documents, final models shall be submitted reflecting true "as-built" conditions.

**B. Plumbing Technical Scope Requirements**

1. All plumbing piping will be modeled. All plumbing equipment will be modeled to its overall height, width and depth. Pipes will be modeled to the outside diameter of the pipe or the pipe insulation, whichever is greater. Pipe slope will be incorporated in the model.
2. Pipe fittings and connections will not be modeled. All valves, clean outs and accessories will be modeled.
3. Each Trade Contractor to provide a list of minimum typical clearances for all model components and coordinate necessary clearances within the model. The 3D model is to include clearances for equipment – included as a modeled volume such that clash detection and coordination can be accommodated relating to necessary clearances.
4. Each Trade Contractor shall be prepared to attend weekly coordination meetings to resolve conflicts within the model.

5. The 3D models submitted by the Trade Contractor for overall coordination are required to be checked and coordinated with the structure and the Trade Contractor's own work prior to submittal.
6. The 3D model is to include access areas for equipment – included as a modeled element such that clash detection and coordination can be accommodated relating to access.
7. Coordinated model data is to be distributed weekly and 1 day prior to coordination meetings.
8. Penetrations through building systems shall be identified in the 3D model by means of a modeled sleeve.
9. All items modeled shall have a level of intelligence associated with them, including, at a minimum, material type, size, insulation, etc.
10. All items located within mechanical rooms shall have a level of intelligence associated with them that includes, at a minimum, material type, size, insulation, manufacturer, product numbers, serial numbers, maintenance schedules, operation and maintenance data, etc.

C. Electrical Technical Scope Requirements

1. All electrical equipment including switchgear, transformers and panelboards will be modeled to its overall size. All necessary clearances for electrical equipment will be modeled as a separate volume. All conduit 1-1/2" and larger shall be modeled.
2. All light fixtures will be modeled as an overall volume require for that fixture.
3. Each Trade Contractor shall provide a list of minimum typical clearances for all model components and coordinate necessary clearances within the model. The 3D model is to include clearances for equipment – included as a modeled volume such that clash detection and coordination can be accommodated relating to necessary clearances.
4. Each Trade Contractor shall be prepared to attend weekly coordination meetings to resolve conflicts within the model.
5. The 3D models submitted by the Trade Contractor for overall coordination are required to be checked and coordinated with the structure and the Trade Contractor's own work prior to submittal.
6. The 3D model is to include access areas for equipment – included as a modeled element such that clash detection and coordination can be accommodated relating to access.
7. Coordinated model data is to be distributed weekly and 1 day prior to coordination meetings.
8. Penetrations through building systems shall be identified in the 3D model by means of a modeled sleeve.
9. All panelboards modeled shall have a level of intelligence associated with them that accurately identifies at a minimum the panel schedule.
10. All items located within electrical rooms and closets shall have a level of intelligence associated with them that includes, at a minimum, material type, size, manufacturer, product numbers, serial numbers, maintenance schedules, operation and maintenance data, etc.

D. Fire Protection Technical Scope Requirements

1. All fire protection equipment including pipe, valves, heads, risers and drains will be modeled.
2. Each Trade Contractor to provide a list of minimum typical clearances for all model components and coordinate necessary clearances within the model. The 3D model is to include clearances for equipment – included as a modeled volume such that clash detection and coordination can be accommodated relating to necessary clearances.
3. This Trade Contractor shall be prepared to attend weekly coordination meetings to resolve conflicts within the model.

4. The 3D models submitted by the Trade Contractor for overall coordination are required to be checked and coordinated with the structure and the Trade Contractor's own work prior to submittal.
5. Coordinated model data is to be distributed weekly and 1 day prior to coordination meetings.
6. Penetrations through building systems shall be identified in the 3D model by means of a modeled sleeve.
7. All items modeled shall have a level of intelligence associated with them that accurately identifies at a minimum the material type, rating, model number, etc.

E. Mechanical / Sheetmetal Technical Scope Requirements

1. All ducts and air handling equipment will be modeled. Ducts will be modeled to the outside face dimension. Equipment will be modeled to its overall height, width and depth. All piping associated with the mechanical system will be modeled. Pipes will be modeled to the outside diameter of the pipe or pipe insulation (whichever is greater).
2. Pipe hangers and hanger assemblies and dunnage will be modeled for clash detection and coordination. Fittings and connections will not be modeled. The intent of this model is to show the ductwork and piping, etc. in a true representation of the actual condition at construction completion.
3. Pipe fittings and connections will not be modeled. All valves, clean outs and accessories will be modeled.
4. Each Trade Contractor to provide a list of minimum typical clearances for all model components and coordinate necessary clearances within the model. The 3D model is to include clearances for equipment – included as a modeled volume such that clash detection and coordination can be accommodated relating to necessary clearances.
5. Each Trade Contractor shall be prepared to attend weekly coordination meetings to resolve conflicts within the model.
6. The 3D models submitted by the Trade Contractor for overall coordination are required to be checked and coordinated with the structure and the Trade Contractor's own work prior to submittal.
7. The 3D model is to include access areas for equipment – included as a modeled element such that clash detection and coordination can be accommodated relating to access.
8. Coordinated model data is to be distributed weekly and 1 day prior to coordination meetings.
9. Penetrations through building systems shall be identified in the 3D model by means of a modeled sleeve.
10. All items modeled shall have a level of intelligence associated with them including, at a minimum, the material type, size, insulation, etc.
11. Each Trade Contractor shall include in their base bid BIM/Coordination facilities on site. The Construction Manager shall provide a Coordination Trailer for the Construction Team's use throughout the duration of the project. The HVAC Trade Contractor must provide a CAD workstation capable of running the Trade Contractor's CAD software as well as the following BIM software:
  - a. NavisWorks Manager (current version)
  - b. AutoCAD Revit Architecture Suite (current version)
  - c. AutoCAD Revit MEP Suite (current version)
12. Each Trade Contractor shall turn over the above software complete with Licenses at Final Completion for the Owner's use.

--- END ---

SECTION 26 05 13  
MEDIUM-VOLTAGE CABLES

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies the furnishing, installation and connection of the high voltage cables.

1.2 RELATED WORK

- A. Bedding of conduits: Section 31 20 00, EARTH MOVING.
- B. General electrical requirement and items that are common to more than one section of Division 26: Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.
- C. Conduits for high voltage cables: Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS.
- D. Requirements for personnel safety and to provide a low impedance path for possible ground fault currents: Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS.
- E. Section 26 05 41, UNDERGROUND ELECTRICAL CONSTRUCTION

1.3 SUBMITTALS

- A. Submit in accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES and Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.
- B. Shop Drawings:
1. Sufficient information, clearly presented, shall be included to determine compliance with drawings and specifications.
  2. Include splice and termination kit information prior to purchase and installation.
  3. Provide cable minimum bend radius, and flammability data.
- C. Samples:
1. After approval and prior to installation, furnish the Resident Engineer with a 300 mm (12 inches) length of each type and size of wire and cable along with the tag from the coils or reels from which the samples were taken. The sample shall contain the manufacturers markings.
- D. Certifications:
1. Factory test reports: Prior to installation of the cables, deliver four copies of the manufacturers certified NEMA WC 71 or WC 74, standard factory test reports to the Resident Engineer. Certified copies of test data shall show conformance with the referenced standards and shall be approved prior to delivery of cable.

- 
2. Field Test Reports: Test Reports on the following shall be in accordance with the paragraph entitled "Field Tests for High Voltage Cables" and include the following tests:
    - a. High Potential Tests
    - b. Dielectric Absorption Tests
    - c. Radiographic Tests
    - d. After testing, submit four certified copies of each of the graphs specified under field testing, to the Resident Engineer. Adequate information shall be included identifying the cable locations, types, voltage rating and sizes.
  3. Splices and terminations, after having been installed and tested, deliver four copies of a certificate by the Contractor to the Resident Engineer which includes the following:
    - a. A statement that the materials, detail drawings and printed instructions used, are those contained in the kits approved for this contract.
    - b. A statement that each splice and each termination was completely installed without any overnight interruption.
    - c. A statement that field made splices and terminations conform to the following requirements:
      - 1) Pencil the cable insulation precisely.
      - 2) Connector installations:
        - a) Use tools that are designed for the connectors being installed.
        - b) Round and smooth the installed connectors to minimize localized voltage stressing of the insulating materials.
      - 3) Remove contaminants from all surfaces within the splices and terminations before installing the insulating materials.
      - 4) Solder block throughout stranded grounding wires that will penetrate the splicing and terminating materials.
      - 5) Use mirrors to observe the installation of materials on the backsides of the splices and terminations.
      - 6) Eliminate air voids throughout the splices and terminations.
      - 7) Stretch each layer of tape properly during installation.
    - d. List all of the materials purchased and installed for the splices and terminations for this contract including the material descriptions, manufacturer's names, catalog numbers and total quantities.
  - E. Power Company Approval: Prior to construction, obtain written approval from the power company that will supply electrical service for the following items:
    1. Service entrance cables. Obtain the power company's written approval on the submittal papers for the cables before submitting them for VA approval.
    2. Employees who will splice and terminate the service entrance cables.
  - F. Installer Approval:
    1. Employees who install the splices and terminations and test the cables shall have not less than five years of experience splicing and terminating cables which are equal to those being spliced and terminated, including experience with the materials in the kits.
    2. Furnish satisfactory proof of such experience for each employee who splices or terminates the cables.



## G. Cable Voltage Ratings

1. Medium voltage power cables shall include multiple and single-conductor cable rated as follows:
  - a. 5000 Volts shall be used on 4160 3-phase 60hz distribution systems.
  - b. 15000 volts shall be used on 12,470, 13,200 and 13,800V 3 phase 60hz distribution systems.

## H. Shipment:

1. Cable shall be shipped on reels such that cable will be protected from mechanical injury. Each end of each length of cable shall be hermetically sealed and securely attached to the reel.

## 1.4 APPLICABLE PUBLICATIONS

- A. Publications listed below (including amendments, addenda, revisions, supplements and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by the designation only:

1. American Society for Testing and Materials (ASTM):  
B3-2001 ..... Standard Specification for Soft or Annealed Copper Wire

- B. Institute of Electrical and Electronics Engineers, Inc. (IEEE):  
386-95 (R2001) ..... Separable Insulated Connector Systems for Power Distribution Systems above 600 V  
400.2-2005 ..... Guide for Field Testing of Shielded Power Cable Systems  
404-2000 ..... Extruded and Laminated Dielectric Shielded Cable Joints Rated 2500-500,000 Volts

- C. National Electrical Manufacturers Association (NEMA):  
WC 71-1999 ..... Standard for Non-Shielded Cables Rated 2001-5000 Volts for Use in the Distribution of Electrical Energy (ICEA S-96-659)  
WC 74-2000 ..... 5-46 KV Shielded Power Cable for Use in the Transmission and Distribution of Electrical Energy (ICEA S-93-969)

- D. National Fire Protection Association (NFPA):  
70-2005 ..... National Electrical Code (NEC)

- E. Underwriters Laboratories (UL):  
1072-2006 ..... Medium-Voltage Power Cables

## PART 2- PRODUCTS

## 2.1 MATERIAL HIGH VOLTAGE CABLE

- A. High voltage cable shall be in accordance with the NEC and NEMA WC71, WC74 and UL 1072.
- B. Shall be single conductor stranded copper conforming to ASTM B3.

- C. Insulation:
  - 1. Insulation level shall be 133 percent.
  - 2. Types of insulation:
    - a. Cable type abbreviation, EPR: Ethylene propylene rubber insulation shall be thermosetting, light and heat stabilized.
- D. Conductors and insulation shall be wrapped separately with semiconducting tape.
- E. Insulation shall be wrapped with non-magnetic, metallic shielding except for cables for series type lighting systems.
- F. Heavy duty, overall protective jackets of chlorosulphonated polyethylene, neoprene or polyvinyl chloride shall enclose every cable.
- G. Cable temperature ratings for continuous operation, emergency overload operation and short circuit operation shall be not less than the NEC, NEMA WC71 or NEMA WC74 Standard for the respective cable.
- H. Manufacturer's name and other pertinent information shall be marked or molded clearly on the overall outside surface of the jackets, or incorporated on marker tapes within the cables at reasonable intervals.

## 2.2 MATERIAL, SPLICES AND TERMINATIONS

- A. The materials shall be compatible with the conductors, insulations and protective jackets on the cables and wires.
- B. The splices shall insulate and protect the conductors not less than the insulation and protective jackets on the cables and wires that protect the conductors. In locations where moisture might be present, the splices shall be watertight. In manholes and handholes the splices shall be submersible.
- C. Splicing and Terminating Fittings: Shall be in accordance with IEEE 386, 404.
  - 1. Shall be heavy duty, pressure type fittings, which will assure satisfactory performance of the connections under conditions of temperature cycling and magnetic forces from available short circuit currents.
  - 2. The fittings shall be suitably designed and the proper size for the cables and wires being spliced and terminated. Terminations to bus shall be with two hole lugs.
  - 3. Where the Government determines that unsatisfactory fittings have been installed, contractor shall replace the unsatisfactory installations with approved fittings at no additional cost to the Government.
- D. Splicing and Terminating Kits:
  - 1. General:
    - a. Shall be assembled by the manufacturer or supplier of the materials and shall be packaged for individual splices and terminations or for groups of splices and terminations.
    - b. Shall consist of materials designed for the cables being spliced and terminated and shall be suitable for the prevailing environmental conditions.

- c. Shall include detail drawings and printed instructions for each type of splice and termination being installed, as prepared by the manufacturers of the materials in the kits.
  - d. Detail drawings, and printed instructions shall indicate the cable type, voltage rating, manufacturer's name and catalog numbers for the materials indicated.
  - e. Voltage ratings for the splices and terminations shall be not less than the voltage ratings for the cables on which they are being installed.
  - f. Shall include shielding and stress cone materials.
2. Taped splices and terminations with insulating and semi-conducting rubber tapes shall withstand 200 percent elongation without cracking, rupturing or reducing their electric and self-bonding characteristics by more than 5 percent.
  3. Epoxy resin kits shall be as follows:
    - a. Compatible with the cable insulations and jackets and make the splices watertight and submersible.
    - b. Thermosetting and generate its own heat so that external fire or heat will not be required.
    - c. Set solid and cure in approximately 60 minutes in 21 degree C (70 degree F) ambient temperature.
    - d. Not deteriorate when subjected to oil, water, gases, salt water, sewage and fungus.
    - e. Furnished in pre-measured quantities, sized for each splice and each termination, with two resin components in an easy mixing plastic bag which will permit mixing the resin without entrapping air or contaminants. Other methods of packaging and mixing the epoxy resin components will be considered for approval, provided they include adequate safeguards to assure precise proportioning of the resin components and to prevent entrapping air and contaminants.
    - f. Use snap-together, longitudinally-split, interlocking seam, transplant mold bodies or taped frameworks, injection fittings and injection gun or pouring equipment. Completely fill voids within the splices and terminations.

E. Pre-molded Separable Connectors:

1. Furnish and install modular non-load break separable connectors for splicing in manholes where indicated on plan.
2. Separable connectors shall be designed and constructed in accordance with IEEE 386. Suitable for submersible applications.
3. The connector shall be manufactured of high quality peroxide cured electrical grade EPDM rubber, to provide excellent electrical, thermal and mechanical reliability.
4. All components and accessories shall be rated 600A. 15kV class.
5. Separable connector ratings:
 

Operating Voltage:	15kV, max line to ground 8.3 kV
BIL:	95kV
Withstand Voltage:	
AC-1 min	35kV
DC 15 min	53kV
Corona Extinction	11kV
Continuous Current:	600A
Symmetrical Momentary Current:	25kA, 10 cycle
6. Provide with all the necessary fittings and caps for a complete, fully-insulated submersible design. All splice units shall be properly supported on cable racks and cables shall be pre-trained to avoid any mechanical stress on splice fittings.
7. Splices and terminations shall be in accordance with IEEE 386, and 404.

8. Pre-molded rubber devices shall have a minimum of 3 mm (0.125 inch) semi-conductive shield material covering the entire housing. Test each rubber part prior to shipment from the factory.
9. Grounding of metallic shields shall be accomplished by a solderless connector enclosed in a watertight rubber housing covering the entire assembly. The grounding device and splice or terminator shall be of same manufacturer to insure electrical integrity of the shielded parts.
10. The pre-molded parts shall be suitable for indoor, outdoor or submersible applications.

### 2.3 MATERIAL, FIREPROOFING TAPE

- A. The tape shall consist of a flexible, conformable fabric of organic composition coated one side with flame-retardant elastomer.
- B. The tape shall be self-extinguishing and shall not support combustion. It shall be arc proof and fireproof.
- C. The tape shall not deteriorate when subjected to water, gases, salt water, sewage, or fungus. It shall be resistant to sunlight and ultraviolet light.
- D. The finished application shall withstand a 200 ampere arc for not less than 30 seconds.
- E. Securing tape: Shall be glass cloth electrical tape not less than 0.18 mm (7 mils) thick, and 19 mm (3/4 inch) wide.

### 2.4 MATERIAL, WARNING TAPE

- A. The tape shall be standard, 76 mm (3 inch) wide, 4-Mil polyethylene detectable type with aluminum backing.
- B. The tape shall be red with black letters indicating "CAUTION BURIED ELECTRIC LINE BELOW".

## PART 3 - EXECUTION

### 3.1 INSTALLATION, HIGH VOLTAGE CABLE

- A. Installation shall be in accordance with the NEC, and as shown on the drawings.
- B. Contractor shall ensure that radii of bends fittings, cable risers, and other conditions are suitable for the cable and conform with the recommendations of the cable manufacturer.
- C. Cable shall be installed in underground duct banks, in conduit above and below grade; inside buildings, on insulator hooks; on racks in wall and ceiling mounted cable trays in utility tunnels and manholes; and by direct burial.
- D. Cables shall be secured with heavy duty cable ties in existing or new trays mounted horizontally, where cable rests on tray bottom.
- E. Cables shall be secured with PVC coated metallic non-metallic cable clamps, straps, hangers, or other approved supporting devices to tunnel walls, ceilings, and in new or existing cable trays mounted vertically, where tray bottom is in a vertical plane.

- F. Contractor shall ensure that all cable tray is properly secured and supported prior to installing new armored cable. Contractor shall add new permanent and/or temporary tray support devices as required to preclude cable tray failure during cable pulling or after cable is installed.
- G. Cable or conductors of a primary distribution system shall be rejected when installed openly in cable trays or openly racked along interior walls; in the same raceway or conduit with AC/DC control circuits or ac power circuits operating at less than 600 volts; or in a manner allowing cable to support its own weight.
- H. Use suitable lubricating compounds on the cables and wires to prevent damage to them during pulling-in. Provide compounds that are not injurious to the cable and wire jackets and do not harden or become adhesive.
- I. Splice the cables and wires only in manholes and accessible junction boxes. Ground shields in accordance with Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS.
- J. In manholes, trenches and vaults install the cables on suitable porcelain insulators with steel cables racks. Ground cable racks in accordance with Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS.
- K. In manholes, underground raceways and other outdoors locations:
  - 1. Seal the cable ends prior to pulling them in to prevent the entry of moisture.
  - 2. For ethylene propylene rubber and polyethylene insulated cables, use bags of epoxy resin that are not less than 6 mm (1/4 inch) larger in diameter than the overall diameter of the cable. Clean each end of each cable before installing the epoxy resin over it.

### 3.2 PROTECTION DURING SPLICING OPERATIONS

- A. Blowers shall be provided to force fresh air into manholes or confined areas where free movement or circulation of air is obstructed. Waterproof protective coverings shall be available on the work site to provide protection against moisture while a splice is being made. Pumps shall be used to keep manholes dry during splicing operations. Under no conditions shall a splice or termination be made with the interior of a cable exposed to moisture. Conductor insulation paper shall be moisture-tested before the splice is made. A manhole ring at least 150 mm (6 inches) above ground shall be used around the manhole entrance to keep surface water from entering the manhole. Unused ducts shall be plugged and water seepage through ducts in use shall be stopped before the splice is started.

### 3.3 PULLING CABLES IN DUCTS, MANHOLES AND UTILITY TUNNELS

- A. Medium-voltage cables shall be pulled into ducts and utility tunnels with equipment designed for this purpose, including power-driven winch, cable-feeding flexible tube guide, cable grips, and lubricants. A sufficient number of trained personnel and equipment shall be employed to ensure the careful and proper installation of the cable.
- B. Cable reel shall be set up at the side of the manhole or tunnel hatch opening and above the duct or hatch level, allowing the cable to enter through the opening without reverse bending. Flexible tube guide shall be installed through the opening in a manner that will prevent the cable from rubbing on the edges of any structural member.

- C. Pulling force for a cable grip on lead-sheathed cable shall not exceed manufacturer's recommendation. A dynamometer shall be used in the pulling line to ensure that the pulling force is not exceeded. Pulling force for a nonmetallic-sheathed cable shall not exceed the smaller of 4400 Newton (1,000 pounds) or a value computed from the following equation:  
$$TM = 0.008 \times N \times CM$$
  
Where: TM = maximum allowable pulling tension in Newton pounds  
N = number of conductors in the cable  
CM = cross-sectional area of each conductor in square millimeter circular mils.
- D. Cable shall be unreeled from the top of the reel. Payout shall be carefully controlled. Cable to be pulled shall be attached through a swivel to the main pulling wire by means of a //pulling eye// suitable cable grip permitted only on cables less than 60 mm (200-feet) long and less than 50 mm (2 inches) in diameter//.
- E. Woven-wire cable grips shall be used to grip the cable end when pulling small cables and short straight lengths of heavier cables.
- F. Pulling eyes shall be attached to the cable conductors to prevent damage to the cable structure.
- G. Pulling eyes and cable grips shall be used together for nonmetallic sheathed cables to prevent damage to the cable structure.
- H. Cables shall be liberally coated with a suitable cable-pulling lubricant as it enters the tube guide or duct. Grease and oil lubricants shall be used only on lead-sheathed cables. Nonmetallic sheathed cables shall be covered with wire-pulling compounds when required which have no deleterious effects on the cable. Rollers, sheaves, or tube guides around which the cable is pulled shall conform to the minimum bending radius of the cable.
- I. Cables shall be pulled into ducts at a reasonable speed not in excess of maximum permissible pulling tension specified by the cable manufacturer. Cable pulling using a vehicle shall not be permitted. Pulling operations shall be stopped immediately with any indication of binding or obstruction and shall not be resumed until such difficulty is corrected. Sufficient slack shall be provided for free movement of cable due to expansion or contraction.
- J. Cable splices made up in manholes or utility tunnels shall be firmly supported on cable racks as indicated. No cable splices shall be pulled in ducts. Cable ends shall overlap at the ends of a section to provide sufficient undamaged cable for splicing. Cables to be spliced in manholes or utility tunnels shall overlap the centerline of the proposed joint by not less than 600 mm (2 feet).
- K. Cables cut in the field shall have the cut ends immediately sealed to prevent entrance of moisture. Nonlead cables shall be sealed with rubber tape wrapped down to 75 mm (3 inches) from the cable end. Rubber tape shall be cover-wrapped with polyvinylchloride tape. Lead-Covered cables shall be sealed with wiping metal making a firm bond with the end of the sheath or with a disk of lead fitted over the end and wiped to the sheath.

### 3.4 INSTALLATION, SPLICES AND TERMINATIONS

- A. Install the materials as recommended by their manufacturer including special precautions pertaining to air temperature during installation.

- 
- B. Cross-Linked Polyethylene (XLPE), Ethylene Propylene Rubber and Polyethylene Insulated Cables:
1. Cables rated 5000 volts or less: Install epoxy resin splices and terminations, or pre-molded rubber splices and terminations.
  2. Cables rated more than 5000 volts: Install taped splices and terminations, or pre-molded rubber splices and terminations.
- C. Installation shall be accomplished by qualified personnel trained to accomplish high voltage equipment installations. All instructions of the manufacturer shall be followed in detail.
- D. Splices shall be made in manholes or tunnels except where cable terminations are specifically indicated. Splicing and terminating of cables shall be expedited to minimize exposure and cable deterioration.
- E. Cables shall be terminated in potheads. Dry terminations with medium voltage pennants, preformed, and hand wrapped stress cones may be used for terminating cables. Potheads shall be provided with adequate means for making external connections to the cable conductors of single or multiple conductor cables; protecting the cable insulation against moisture, oil, or other contaminant; physically protecting and supporting cables, and maintaining the insulation level of the cable.
- F. Pothead terminations shall be field fabricated from termination kits supplied by and in accordance with the pothead manufacturer's recommendations for the type, size, and electrical characteristics of the cable.
- G. Installation shall include built-up or prefabricated heat or cold shrink stress-relief cones at the terminals of all shielded cables and at the terminals of single-conductor lead-covered cables rated 15 kV and above, ungrounded.
- H. Cable splices shall be field fabricated from splicing kits supplied by and in accordance with cable manufacturer's recommendations for the type, size, and electrical characteristics of the cable specified. Cable splices in manholes shall be located midway between cable racks on walls of manholes and supported with cable arms at approximately the same elevation as the enclosing duct.
- I. Cable splices in the tunnel that are not installed in cable trays shall be installed on cable racks or by other approved methods that will minimize physical stress on the splice connections. Splices shall be supported at approximately the same elevation as the installed cable except where space limitations or existing cable length limitations make this method impractical or impossible.
- J. Universal demountable splices shall be supported in such manner so as to minimize physical stress on the splice connections. Each cable end termination shall be supported using a pair of saddle type supports under the cable end termination and/or cable with a minimum 300 mm (12 inches) and a maximum 750 mm (30 inches) separation between the supports. Cable end termination and cable shall be secured to the supports in such a manner as to prevent movement of termination or cable at the support. Saddle type supports shall be installed on galvanized steel framing channel anchored to the wall or securely fastened to the cable tray or installed by other approved methods.

### 3.5 SINGLE-CONDUCTOR POTHEADS

- A. Single-conductor potheads shall be the hermetically sealed cap-nut type and shall be suitable for the type, size, and electrical characteristics of the cable specified. Potheads shall consist of cast bodies, bushings, cable connectors, lugs, and entrance fittings.
- B. Pothead bodies shall be metal castings with mounting brackets, when required, pipe plugs for filling and vent holes, and machined flanged surface for cable-entrance fitting. Bodies shall be cast iron for cables up to 130 mm<sup>2</sup> (250 kc mils) 250 amperes, and cast aluminum bronze nonmagnetic metal casting for cable of larger size and higher current ratings.
- C. Bushings shall be glazed wet-process electrical porcelain insulators, factory assembled and hermetically sealed to the pothead body.
- D. Cable connectors shall be high-conductivity copper accurately machined and threaded for internal and external electrical connections. Cross-sectional and contact areas shall be adequate to carry the full-load current rating of the conductors. Cable connectors shall be solder type with gasket seal between the connector and bushing.
- E. Potheads shall be completely filled, leaving no gaps or voids, with an insulating compound suitable for the type of cable, insulation, voltage rating, and ambient operating temperatures in accordance with the pothead manufacturer's recommendations. Pothead parts that do not carry current shall be grounded.

### 3.6 INSTALLATION, FIREPROOFING

- A. Cover all power cables located in manholes, handholes and junction boxes with arc proof and fireproof tape.
- B. Apply the tape in a single layer, one-half lapped or as recommended by the manufacturer. Install the tape with the coated side towards the cable and extend it not less than 25 mm (one inch) into each duct.
- C. Secure the tape in place by a random wrap of glass cloth tape.

### 3.7 FEEDER IDENTIFICATION

- A. In each manhole and pullbox install permanent tags on each circuit's cables and wires to clearly designate their circuit identification and voltage. In manholes the tags shall be the embossed brass type and shall also show the cable type and voltage rating. Position the tags so they will be easy to read after the fireproofing is installed.

### 3.8 FIELD TESTS FOR HIGH VOLTAGE CABLE

- A. New Cable:
  - 1. Acceptance tests shall be performed on new and service aged PE XLPE, PVC and paper cables in accordance with IEEE 400.2 and as specified herein.
  - 2. Test new cable after installation, splices, and terminations have been made, but before connection to equipment and existing cable.



3. Test equipment, labor and technical personnel shall be provided as necessary to perform the electrical acceptance tests. Arranges shall be made to have tests witnessed by the Resident Engineer.
- B. Service Age Cable:
1. Maintenance tests shall be performed on service-aged cable interconnected to new cable. See test voltages below.
  2. After new cable test and connection to an existing cable, test the interconnected cable. Disconnect cable from all equipment that might be damaged by the test voltages.
- C. Dielectric Absorption Test: Both new and service aged power cable shall be completely isolated from extraneous electrical connections at cable terminations and joints. Safety precautions shall be observed. Each cable shall be given a full dielectric – absorption test with a 5000v insulation resistance test set. Test shall be applied for a long enough time to charge the cable. Readings shall be recorded every 15 seconds during the first 3 minutes of test and at 1 minute intervals thereafter. Test shall continue until three equal readings 1 minute apart are obtained. Minimum readings shall be 200 megohms at an ambient temperature 20 degrees C (68 degrees F). Readings taken at other temperatures shall be corrected accordingly.
- D. High Potential Test: High potential test shall not be applied to the XLPE new or service aged cables. All other cables shall be subjected to the test but only upon successful dielectric absorption test.
1. Leakage current test shall be by high potential dc step voltage method.
  2. High potential test shall measure the leakage current from each conductor to the insulation shield. Use corona shields, guard rings, taping, mason jars, or plastic bags to prevent corona current from influencing the readings. Unprepared cable shield ends shall be trimmed back 25 mm (1 inch) or more for each 10 kV of test voltage. Upon the successful completion of the high potential test on new and service aged PE CCLP, PC PVC cables a second dielectric test will be run on the HV cable system to ensure the cables have not been damaged by the hi-pot test
- E. Safety Precautions:
1. Exercise suitable and adequate safety measures prior to, during, and after the high potential tests, including placing warning signs and preventing people and equipment from being exposed to the test voltages.
- F. Test Voltages:
1. New shielded EPR and CCLP cable dc test voltages shall be as follows:

Rated Circuit Voltage Phase-to-Phase Volt	Wire Size AWG or MCM	Test Voltage KV
2001-5000	8-1000	25
5001-8000	6-1000	35
8001-15000	2-1000	65
15001-25001	1-1000	100
25001-28000	1-1000	-
28001-35000	1/0-1000	-

2. Existing cable of all types interconnected to a new cable shall be tested at 1.7 times the existing cable rated voltage (maintenance test).

## G. High Potential Test Method:

1. Apply voltage in approximately 8 to 10 equal steps.
2. Raise the voltage slowly between steps.
3. At the end of each step, allow the charging currents to decay, and time the interval of decay.
4. Read the leakage current and plot a curve of leakage currents versus test voltage on graph paper as the test progresses. Read the leakage current at the same time interval for each voltage step.
5. Stop the test if leakage currents increase excessively or a "knee" appears in the curve before maximum test voltage is reached.
  - a. For new cable, repair or replace the cable and repeat the test.
  - b. For existing cable interconnected to new cable, notify the Resident Engineer for further instructions.
6. Upon reaching maximum test voltage, hold the voltage for five minutes. Read the leakage current at 30 second intervals and plot a curve of leakage current versus time on the same graph paper as the step voltage curve. Stop the test if leakage current starts to rise, or decreases and again starts to rise. Leakage current should decrease and stabilize for good cable.
7. Terminate test and allow sufficient discharge time before testing the next conductor.

## H. Test Data: Test data shall be recorded and shall include identification of cable and location, megohm readings versus time, leakage current readings versus time, and cable temperature versus time.

## I. Final Acceptance: Final acceptance shall depend upon the satisfactory performance of the cable under test. No cable shall be energized until recorded test data have been approved by the Resident Engineer. Final test reports shall be provided to the Resident Engineer. Reports shall have a cover letter/sheet clearly marked with the System name, Date, and the words "Final Test Report" Forward to the Resident Engineer for inclusion in the Maintenance Database.

## J. Radiographic Tests: Radiographic tests shall be performed on all potheads at the discretion of the Resident Engineer to determine if voids exist in the pothead. Unacceptable terminations shall be reworked at no additional expense to the Government.

## K. Series Outdoor Lighting Cables: Test the series outdoor lighting system cables by standard megger methods in lieu of testing by high potential methods.

## L. The Contractor shall furnish the instruments, materials and labor for these tests.

--- END ---

## SECTION 26 05 21

## LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES (600 VOLTS AND BELOW)

## PART 1 - GENERAL

## 1.1 DESCRIPTION

- A. This section specifies the furnishing, installation, and connection of the low voltage power and lighting wiring.

## 1.2 RELATED WORK

- A. Excavation and backfill for cables that are installed in conduit: Section 31 20 00, EARTH MOVING.
- B. Sealing around penetrations to maintain the integrity of time rated construction: Section 07 84 00, FIRESTOPPING.
- C. General electrical requirements that are common to more than one section in Division 26: Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.
- D. Conduits for cables and wiring: Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS.
- E. Requirements for personnel safety and to provide a low impedance path for possible ground fault currents: Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS.

## 1.3 SUBMITTALS

- A. In accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES, furnish the following:
  - 1. Manufacturer's Literature and Data: Showing each cable type and rating.
  - 2. Certificates: Two weeks prior to final inspection, deliver to the / Resident Engineer COTR four copies of the certification that the material is in accordance with the drawings and specifications and has been properly installed.

## 1.4 APPLICABLE PUBLICATIONS

- A. Publications listed below (including amendments, addenda, revisions, supplements and errata) form a part of this specification to the extent referenced. Publications are reference in the text by the basic designation only.
- B. American Society of Testing Material (ASTM):
  - D2301-04 ..... Standard Specification for Vinyl Chloride Plastic Pressure
  - ..... Sensitive Electrical Insulating Tape

- C. Federal Specifications (Fed. Spec.):  
A-A-59544-00 ..... Cable and Wire, Electrical (Power, Fixed Installation)
- D. National Fire Protection Association (NFPA):  
70-05..... National Electrical Code (NEC)
- E. Underwriters Laboratories, Inc. (UL):
- 44-02..... Thermoset-Insulated Wires and Cables  
83-03..... Thermoplastic-Insulated Wires and Cables  
467-01 ..... Electrical Grounding and Bonding Equipment  
486A-01 ..... Wire Connectors and Soldering Lugs for Use with Copper Conductors  
486C-02..... Splicing Wire Connectors  
486D-02.. Insulated Wire Connector Systems for Underground Use or in Damp or Wet Locations  
486E-00 ..... Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors  
493-001 ..... Thermoplastic-Insulated Underground Feeder and Branch Circuit Cable  
514B-02 ..... Fittings for Cable and Conduit  
1479-03 ..... Fire Tests of Through-Penetration Fire Stops

## PART 2 - PRODUCTS

RFI:08680 - MI Cable Support Spacing shall be per the manufacturers requirements.

## 2.1 CABLE AND WIRE (POWER AND LIGHTING)

- A. Cable and Wire shall be in accordance with Fed. Spec. A-A-59544, except as hereinafter specified.
- B. Single Conductor:
1. Shall be annealed copper.
  2. Shall be stranded for sizes No. 8 AWG and larger, solid for sizes No. 10 AWG and smaller.
  3. Shall be minimum size No. 12 AWG, except where smaller sizes are allowed herein.
  4. Unless indicated otherwise on the drawings, minimum size conductors for 20 ampere branch circuits shall be as follows:

Minimum Conductor Size	Distance to First Device			
	120 Volt	208 Volt	277 Volt	480 Volt
#12 AWG	<70'	<125'	<170'	<280'
#10 AWG	70' – 120'	125' – 200'	170' – 260'	280' – 450'
#8 AWG	>120'	>200'	>260'	>450'

NOTE:

For branch circuits utilizing #8 or larger, the branch circuit conductors from panel shall terminate to a network junction box in area where circuit(s) serve, and branch off conductors to device shall be #10 AWG for termination.

- C. Insulation:
1. THW, XHHW, or dual rated THHN-THWN shall be in accordance with UL 44, and 83.
  2. Direct burial: UF or USE shall be in accordance with UL 493.
  3. Isolated power system wiring: Type XHHW with a dielectric constant of 3.5 or less.

## D. Insulation

- Insulation types for all conductors shall be as follows:

Description	Location		
	Dry	Damp	Wet
Branch circuits #6 AWG and smaller	THHW	THWN	THWN
Feeder and branch circuits larger than #6 AWG	XHHW	XHHW	XHHW-2
Exterior feeder and branch circuit wiring	XHHW-2	XHHW-2	XHHW-2
Feeders connected to 100% rated circuit breakers *	XHHW-2	XHHW-2	XHHW-2

\* Draw-out Power Switchgear

## E. Color Code:

- Secondary service, feeder and branch circuit conductors shall be color coded as follows:

208/120 volt	Phase	480/277 volt
Black	A	Brown
Red	B	Orange
Blue	C	Yellow
White	Neutral	Gray *
* or white with colored (other than green) tracer.		

- The lighting circuit "switch legs" and 3-way switch "traveling wires" shall have color coding unique and distinct (i.e. pink and purple) from the color coding indicated above. The unique color codes shall be solid and in accordance with the NEC. Field coordinate for a final color coding with the Resident Engineer.
- Use solid color compound or solid color coating for No. 12 AWG and No. 10 AWG branch circuit conductors and neutral sizes.
  - Phase conductors No. 8 AWG and larger shall be color-coded using one of the following methods:
    - Solid color compound or solid color coating.
    - Stripes, bands, or hash marks of color specified above.
    - Color as specified using 19 mm (3/4 inch) wide tape. Apply tape in half overlapping turns for a minimum of 75 mm (three inches) for terminal points, and in junction boxes, pull boxes, troughs, manholes, and handholes. Apply the last two laps of tape with no tension to prevent possible unwinding. Where cable markings are covered by tape, apply tags to cable stating size and insulation type.
  - For modifications and additions to existing wiring systems, color coding shall conform to the existing wiring system.
  - Color code for isolated power system wiring shall be in accordance with the NEC.
  - All lighting and Power Branch circuits shall be run with separate dedicated neutrals. No shared neutrals.
  - All wiring shall be run in conduit as indicated in Section.

2.2 BRANCH CIRCUIT CABLE TYPE MC DEDUCT ALTERNATE (NORMAL POWER ONLY)

## A. General

1. Furnish and install multi-conductor branch circuit cable (Type MC) assemblies as specified herein, including all necessary fittings, hangers, accessories, etc. Multi-conductor cable assemblies shall be prefabricated at the factory and shipped to the site on cable reels.

B. MC Branch Circuit Cable Hospital Grade MC Cable Is Not Required (RFI 06298)

## 1. Uses Permitted

- a. MC cable may be utilized in lieu of conduit and cable in dry, hollow partitions and ceiling cavities for general purpose, 20 ampere, single phase, 120 or 277 volt, branch circuits for receptacles and lighting fixtures only. (Normal Power Only)
- b. Branch circuit homeruns to panels shall be run in conduit. AC branch circuit cable shall terminate in a network junction box above the accessible ceiling cavities of room/area served by branch circuits. AC branch circuit cable run in ceiling shall be limited to 25' when routed from network junction box to wall cavity.
- c. Branch circuit cable may be used for fixture whips limited to 6'0". Branch circuits shall be run with individual neutrals for each circuit. Shared neutrals not allowed.

2. Uses Not Permitted

- a. MC cable shall not be utilized in places of assembly.
- b. MC cable shall not be allowed in electric rooms or closets.
- c. MC cable shall not be used in mechanical or plumbing rooms, closets or shafts, including mechanical penthouse.
- d. MC cable shall not be used for life safety (emergency or equipment) circuits.

## 3. Reference Standards

- a. MC cable shall be in compliance with the latest applicable edition of the following industry standards:
  - 1) National Electrical Code (NEC)
    - a) NEC 517-13
    - b) NEC 517-30
  - 2) Federal Specification J-C-30B
  - 3) Underwriters laboratory (UL)
  - 4) UL 4
  - 5) UL 1479

## 4. Construction

## a. Conductors

- 1) Conductors shall be minimum #12 AWG, soft drawn 98% conductive copper with 90°C, THHN, 600 volt rated insulation.
- 2) Included with each length of MC cable shall be the required number of phase conductors, one neutral conductor per phase conductor, insulated, full size, green grounding conductor.

- 3) Each conductor, including ground conductor, shall be wrapped with nylon covering.
- 4) Color Coding
  - a) Color coding of conductors shall match the VA color coding standard. If no standard color coding system exists, use the following:

208/120 Volts			480/277 Volts		
A Phase	-	Black	A Phase	-	Brown
B Phase	-	Red	B Phase	-	Orange
C Phase	-	Blue	C Phase	-	Yellow
Neutral	-	White	Neutral	-	Grey
Ground	-	Green	Ground	-	Green with Yellow Stripe

- b) Color coding shall be continuous on insulation for all conductors.
  - c) Electrical Subcontractor shall provide additional identification to identify each neutral conductor with its associated phase conductor.
- b. Exterior armor
  - 1) The exterior sheath shall be manufactured of galvanized steel or aluminum armor and shall be wrapped around the conductors at the factory.
5. Manufacturer
  - a. MC cable shall be as manufactured by AFC or equivalent product as manufactured by Allflex or Alliance.
6. Fittings
  - a. Fittings for MC cable shall be suitable for use with the appropriate cable assembly.
  - b. Include manufacturers literature with shop drawings stating application compatibility with each cable type.

### 2.3 SPLICES AND JOINTS

- A. In accordance with UL 486A, C, D, E and NEC.
- B. Branch circuits (No. 10 AWG and smaller):
  1. Connectors: Solderless, screw-on, reusable pressure cable type, 600 volt, 105 degree C with integral insulation, approved for copper and aluminum conductors.
  2. The integral insulator shall have a skirt to completely cover the stripped wires.
  3. The number, size, and combination of conductors, as listed on the manufacturers packaging shall be strictly complied with.
- C. Feeder Circuits:
  1. Connectors shall be indent, hex screw, or bolt clamp-type of high conductivity and corrosion-resistant material.
  2. Field installed compression connectors for cable sizes 250 kcmil and larger shall have not less than two clamping elements or compression indents per wire.

3. Insulate splices and joints with materials approved for the particular use, location, voltage, and temperature. Insulate with not less than that of the conductor level that is being joined.
4. Plastic electrical insulating tape: ASTM D2304 shall apply, flame retardant, cold and weather resistant.

## 2.4 CONTROL WIRING

- A. Unless otherwise specified in other sections of these specifications, control wiring shall be as specified for power and lighting wiring, except the minimum size shall be not less than No. 14 AWG.
- B. Control wiring shall be large enough so that the voltage drop under inrush conditions does not adversely affect operation of the controls.

## 2.5 WIRE LUBRICATING COMPOUND

- A. Suitable for the wire insulation and conduit it is used with, and shall not harden or become adhesive.
- B. Shall not be used on wire for isolated type electrical power systems.

## 2.6 FIREPROOFING TAPE

- A. The tape shall consist of a flexible, conformable fabric of organic composition coated one side with flame-retardant elastomer.
- B. The tape shall be self-extinguishing and shall not support combustion. It shall be arc-proof and fireproof.
- C. The tape shall not deteriorate when subjected to water, gases, salt water, sewage, or fungus and be resistant to sunlight and ultraviolet light.
- D. The finished application shall withstand a 200-ampere arc for not less than 30 seconds.
- E. Securing tape: Glass cloth electrical tape not less than 0.18 mm (7 mils) thick, and 19 mm (3/4 inch) wide.

## 2.7 WARNING TAPE

- A. The tape shall be standard, 76 mm (3 inch) wide, 4-Mil polyethylene detectable type.
- B. The tape shall be red with black letters indicating "CAUTION BURIED ELECTRIC LINE BELOW".



## 2.8 2 HR FIRE RATED CABLE SYSTEM

## A. General

1. This section includes 2 hour fire rated type RHW and RHW-2 conductors with a UL Listed 2 hour fire rating.
2. RHW / RWH-2 wiring shall be manufactured of copper, rated at 600 volts, single conductor. Conductors shall be stranded.
3. Wire and cable operating between 50 and 600 volts shall be soft drawn, 98% conductive copper with 600 volt rated insulation.
4. All wiring shall be installed in EMT, no other raceway material allowed.

## B. Manufacturers

1. Pyrotenax
2. RSCC - Vitalink
3. Raychem

## C. References

1. All wiring shall conform to the National Electrical Code for construction and use.

## D. Conductor type RHW / RHW-2 shall meet or exceed the following:

1. ASTM B-8 and ASTM B-170
2. UL Standard 44
3. UL listed as type RHH/RWH-2
4. UL Listed as "FT4" (Vertical Flame Test) per UL 2556
5. UL Listed as "ST1" (Limited Smoke) per UL 2556
6. UL Listed as part of an Electrical Circuit Protective System per UL 2196. The system shall include the following:
  - a. Tested with pulling lubricants
  - b. Tested with ground wires
  - c. Tested in both vertical and horizontal orientations
  - d. Tested with 2-hour fire-rated splice
7. Conductor shall be engineered to minimize embrittlement due to fire exposure per ASTM B-170

## E. Insulation types for 2 hour fire rated conductors shall be as follows:

Description	Location		
	Dry	Damp	Wet
Interior feeders	RHW	RHW	RHW-2
Feeders connected to 100% rated circuit breakers	RHW-2	RHW-2	RHW-2

## F. Color Coding

1. Color coding of conductors shall match the Owners color coding standard. If no standard color coding system exists, use the following:

208/120 Volts			480/277 Volts		
A Phase	-	Black	A Phase	-	Brown
B Phase	-	Red	B Phase	-	Orange
C Phase	-	Blue	C Phase	-	Yellow
Neutral	-	White	Neutral	-	Grey
Ground	-	Green	Ground	-	Green with Yellow Stripe
Isolated Ground	-	Green with Orange Stripe			

2. Color coding shall be continuous on insulation for all conductors. For conductors larger than #6 where continuous color coding is not available, each conductor shall be marked with color tape at all connections and in all pull, junction and outlet boxes.

## 2.9 ALUMINUM CONDUCTORS (DEDUCT ALTERNATE)

## A. General

1. As Deduct Alternate, the Contractor shall provide proposed cost savings to the Resident Engineer for utilizing aluminum for selected feeders as shown on Riser Diagrams.
2. Base Bid conductors shall be copper. Aluminum conductors for 200A and larger may be substituted for copper and used for transformer conductors, switchboard feeders, and panelboard feeders.
3. Aluminum conductors shall not be used for emergency feeders, serving individual motors, chillers, VFD's and motor controllers.

## B. Conductors

1. Aluminum alloy conductors shall be compact stranded conductors of a recognized Aluminum Association 8000 Series aluminum alloy conductor material (AA-8000 series alloy).
2. It is the responsibility of the contractor to increase the size of the conduit, wire gutter, or enclosure, if necessary, to accommodate the aluminum conductors and meet allowable code requirements.
3. It is the responsibility of the contractor to increase the size of the aluminum conductor to match the ampacity of the copper conductor circuit shown on the Drawings.
4. The Contractor shall submit a feeder schedule to the Engineer for all conductor substitutions indicating the aluminum conductor wire size and the conduit size. The Contractor shall not begin the installation until written approval is granted by the Engineer.
5. All aluminum conductors shall terminate utilizing compression-type connector. Connector shall be dual rated (AL7CU or AL9CU) and Listed by UL for use with aluminum and copper conductors, and sized to accept aluminum conductors of the required ampacity. When using compression-type connectors, the lugs shall be marked with wire size, die index, number and location of crimps and shall be suitably color-coded. Using a suitable stripping tool, remove insulation from the required length of the conductor. Wire brush the conductor and apply a listed joint compound. Tighten or crimp the connection per the connector manufacturer's recommendation. Wipe off any excess joint compound.

6. When terminating aluminum conductors to copper bus, utilize compression-type connection. Bolts shall be plated or galvanized medium carbon steel; heat treated, quenched and tempered equal to current ASTM standard or SAE grade 5. Nuts shall conform to current ANSI standards. Washers shall be steel, Type A plain, standard wide series conforming to current ANSI standards. Belleville conical spring washers shall be of hardened steel, cadmium plated or silicone bronze. Lubricate and tighten the hardware per manufacturer's recommendations.
7. The contractor shall perform an infrared survey of all aluminum conductor connections after the installation is complete and in normal service. Infrared surveys shall be performed during periods of maximum possible loading with at least 30% of rated load of the equipment being inspected. All connections with elevated temperatures shall be corrected by the contractor. The infrared survey results shall be provided in report form, in the completed O&M manuals.
8. No copper-to-aluminum transitions permitted when splicing onto existing copper feeders.

### PART 3 - EXECUTION

#### 3.1 INSTALLATION, GENERAL

- A. Install in accordance with the NEC, and as specified.
- B. Install all wiring in raceway systems, except where direct burial or HCF Type AC cables are used.
- C. Splice cables and wires only in outlet boxes, junction boxes, pull boxes, manholes, or handholes.
- D. Wires of different systems (i.e. 120V, 277V) shall not be installed in the same conduit or junction box system.
- E. Install cable supports for all vertical feeders in accordance with the NEC. Provide split wedge type which firmly clamps each individual cable and tightens due to cable weight.
- F. For panelboards, cabinets, wireways, switches, and equipment assemblies, neatly form, train, and tie the cables in individual circuits.
- G. Seal cable and wire entering a building from underground, between the wire and conduit where the cable exits the conduit, with a non-hardening approved compound.
- H. Wire Pulling:
  1. Provide installation equipment that will prevent the cutting or abrasion of insulation during pulling of cables.
  2. Use ropes made of nonmetallic material for pulling feeders.
  3. Attach pulling lines for feeders by means of either woven basket grips or pulling eyes attached directly to the conductors, as approved by the Resident Engineer.
  4. Pull in multiple cables together in a single conduit.
- I. No more than (3) single-phase branch circuits shall be installed in any one conduit. Separate neutrals for each Branch Circuit, no shared neutrals.
- J. The wires shall be derated in accordance with NEC Article 310. Neutral wires, under conditions defined by the NEC, shall be considered current-carrying conductors.

### 3.2 INSTALLATION IN MANHOLES

- A. Install and support cables in manholes on the cable racks as specified in Section 26 05 41. Train the cables around the manhole walls, but do not bend to a radius less than six times the overall cable diameter.
- B. Fireproofing:
  - 1. Install fireproofing where low voltage cables are installed in the same manholes with high voltage cables; also cover the low voltage cables with arc proof and fireproof tape.
  - 2. Use tape of the same type as used for the high voltage cables, and apply the tape in a single layer, one-half lapped or as recommended by the manufacturer. Install the tape with the coated side towards the cable and extend it not less than 25 mm (one inch) into each duct.
  - 3. Secure the tape in place by a random wrap of glass cloth tape. //

### 3.3 SPLICE INSTALLATION

- A. Splices and terminations shall be mechanically and electrically secure.
- B. Where the Government determines that unsatisfactory splices or terminations have been installed, remove the devices and install approved devices at no additional cost to the Government.

### 3.4 CONTROL AND SIGNAL WIRING INSTALLATION

- A. Unless otherwise specified in other sections, install wiring and connect to equipment/devices to perform the required functions as shown and specified.
- B. Except where otherwise required, install a separate power supply circuit for each system so that malfunctions in any system will not affect other systems.
- C. Where separate power supply circuits are not shown, connect the systems to the nearest panelboards of suitable voltages, which are intended to supply such systems and have suitable spare circuit breakers or space for installation.
- D. Install a red warning indicator on the handle of the branch circuit breaker for the power supply circuit for each system to prevent accidental de-energizing of the systems.
- E. System voltages shall be 120 volts or lower where shown on the drawings or as required by the NEC.

### 3.5 CONTROL AND SIGNAL SYSTEM IDENTIFICATION

- A. Install a permanent wire marker on each wire at each termination.
- B. Identifying numbers and letters on the wire markers shall correspond to those on the wiring diagrams used for installing the systems.
- C. Wire markers shall retain their markings after cleaning.

- D. In each manhole and handhole, install embossed brass tags to identify the system served and function.

### 3.6 FEEDER IDENTIFICATION

- A. In each interior pulbox and junction box, install metal tags on each circuit cables and wires to clearly designate their circuit identification and voltage.
- B. In each manhole and handhole, provide tags of the embossed brass type, showing the cable type and voltage rating. Attach the tags to the cables with slip-free plastic cable lacing units.

### 3.7 FIELD TESTING

- A. Feeders and branch circuits shall have their insulation tested after installation and before connection to utilization devices such as fixtures, motors, or appliances.
- B. Tests shall be performed by megger and conductors shall test free from short-circuits and grounds.
- C. Test conductor phase-to-phase and phase-to-ground.
- D. The Contractor shall furnish the instruments, materials, and labor for these tests.

--- END ---

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SECTION 26 05 26  
GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies general grounding and bonding requirements of electrical equipment operations and to provide a low impedance path for possible ground fault currents.
- B. "Grounding electrode system" refers to all electrodes required by NEC, as well as including made, supplementary, lightning protection system grounding electrodes.
- C. The terms "connect" and "bond" are used interchangeably in this specification and have the same meaning.
- D. Due to the local soil conditions, all earthing terminal and ground rod installation shall include a "grounding enhancement material" (GEM).

1.2 RELATED WORK

- A. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS: General electrical requirements and items that are common to more than one section of Division 26.
- B. Section 26 05 21, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES (600 VOLTS AND BELOW): Low Voltage power and lighting wiring.
- C. Section 26 41 00, FACILITY LIGHTNING PROTECTION: Requirements for a lightning protection system.

1.3 SUBMITTALS

- A. Submit in accordance with Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.
- B. Shop Drawings:
  - 1. Sufficient information, clearly presented, shall be included to determine compliance with drawings and specifications.
  - 2. Include the location of system grounding electrode connections and the routing of aboveground and underground grounding electrode conductors.
- C. Test Reports: Provide certified test reports of ground resistance.

- D. Certifications: Two weeks prior to final inspection, submit four copies of the following to the Resident Engineer:
1. Certification that the materials and installation is in accordance with the drawings and specifications.
  2. Certification, by the Contractor, that the complete installation has been properly installed and tested.

#### 1.4 APPLICABLE PUBLICATIONS

- A. Publications listed below (including amendments, addenda, revisions, supplements, and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by the basic designation only.
- B. American Society for Testing and Materials (ASTM):
- |         |       |  |
|---------|-------|--|
| B1-2001 | ..... | Standard Specification for Hard-Drawn Copper Wire  |
| B8-2004 | ..... | Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft |
- C. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
- |         |       |   |
|---------|-------|---|
| 81-1983 | ..... | IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System |
|---------|-------|---|
- D. National Fire Protection Association (NFPA):
- |         |       |                                |
|---------|-------|--------------------------------|
| 70-2005 | ..... | National Electrical Code (NEC) |
| 99-2005 | ..... | Health Care Facilities         |
- E. Underwriters Laboratories, Inc. (UL):
- |                |       |  |
|----------------|-------|--|
| 44-2005        | ..... | Thermoset-Insulated Wires and Cables     |
| 83-2003        | ..... | Thermoplastic-Insulated Wires and Cables |
| 467-2004       | ..... | Grounding and Bonding Equipment          |
| 486A-486B-2003 | ..... | Wire Connectors                          |

### PART 2 - PRODUCTS

#### 2.1 GROUNDING AND BONDING CONDUCTORS

- A. Equipment grounding conductors shall be UL 83 insulated stranded copper, except that sizes 6 mm<sup>2</sup> (10 AWG) and smaller shall be solid copper. Insulation color shall be continuous green for all equipment grounding conductors, except that wire sizes 25 mm<sup>2</sup> (4 AWG) and larger shall be permitted to be identified per NEC.
- B. Bonding conductors shall be ASTM B8 bare stranded copper, except that sizes 6 mm<sup>2</sup> (10 AWG) and smaller shall be ASTM B1 solid bare copper wire.
- C. Isolated Power System: Type XHHW-2 insulation with a dielectric constant of 3.5 or less.
- D. Electrical System Grounding: Conductor sizes shall not be less than what is shown on the drawings and not less than required by the NEC, whichever is greater.

- E. 15kV feeder conduits terminating to pull boxes, switchgear, cabinets, shall utilize conduit grounding bushings.
- F. All 277/480V feeders terminating to switchgear, pull boxes, panels, cabinets, etc. shall utilize conduit grounding bushings.

## 2.2 GROUND RODS

- A. Ground rods for lightning protection system shall be 3/4" dia x 10' long copper bonded steel rods mounted vertically. Quantity of rods shall be as required to obtain the specified ground resistance and as detailed on drawings.
- B. Due to the high resistivity soil, all ground rod locations, "GEM" "grounding enhancement material" conductive concrete mixture shall be used, such as "PowerFil", "GEM", or Ultra Fill.
- C. Refer to details on Drawing OES502 and OES512.
- D. Grounding electrodes for service entrance grounding shall be Chem-Rod, grounding electrodes as detailed on Drawing OES502. Rods shall be 10' L x 2-5/8" Dia. Rods shall be filled with minerals. The rods shall be provided with factory-installed #4/0 copper pigtail. The Chem-Rod shall be installed using an auger, back fill shall be "GEM" highly conductive ground enhancement material.
- E. The grounding electrode system for the service entrance, as indicated on plan, shall be provided with flush-mounted access well and cover per detail on Drawing OES502.

## 2.3 SPLICES AND TERMINATION COMPONENTS

- A. Components shall meet or exceed UL 467 and be clearly marked with the manufacturer, catalog number, and permitted conductor size(s).

## 2.4 GROUND CONNECTIONS

- A. Below Grade: Exothermic-welded type connectors.
- B. Above Grade:
  - 1. Bonding Jumpers: compression type connectors, using zinc-plated fasteners and external tooth lockwashers.
  - 2. Ground Busbars: Two-hole compression type lugs using tin-plated copper or copper alloy bolts and nuts.
  - 3. Rack and Cabinet Ground Bars: one-hole compression-type lugs using zinc-plated or copper alloy fasteners.

## 2.5 EQUIPMENT RACK AND CABINET GROUND BARS

- A. Provide solid copper ground bars designed for mounting on the framework of open or cabinet-enclosed equipment racks with minimum dimensions of 4 mm thick by 19 mm wide (3/8 inch x 3/4 inch).



## 2.6 GROUND TERMINAL BLOCKS

- A. At any equipment mounting location (e.g. backboards and hinged cover enclosures) where rack-type ground bars cannot be mounted, provide screw lug-type terminal blocks.

## 2.7 SPLICE CASE GROUND ACCESSORIES

- A. Splice case grounding and bonding accessories shall be supplied by the splice case manufacturer when available. Otherwise, use 16 mm<sup>2</sup> (6 AWG) insulated ground wire with shield bonding connectors.

# PART 3 - EXECUTION

## 3.1 GENERAL

- A. Ground in accordance with the NEC, as shown on drawings, and as hereinafter specified.
- B. System Grounding:
  - 1. Secondary service neutrals: Ground at the supply side of the secondary disconnecting means and at the related transformers.
  - 2. Separately derived systems (transformers downstream from the service entrance): Ground the secondary neutral.
  - 3. Isolation transformers and isolated power systems shall not be system grounded.
- C. Equipment Grounding: Metallic structures (including ductwork and building steel), enclosures, raceways, junction boxes, outlet boxes, cabinets, machine frames, and other conductive items in close proximity with electrical circuits shall be bonded and grounded.
- D. Special Grounding: For patient care area electrical power system grounding, conform to NFPA 99, and NEC.

## 3.2 INACCESSIBLE GROUNDING CONNECTIONS

- A. Make grounding connections, which are buried or otherwise normally inaccessible (except connections for which periodic testing access is required) by exothermic weld.

## 3.3 MEDIUM-VOLTAGE EQUIPMENT AND CIRCUITS

- A. Switchgear: Provide a bare grounding electrode conductor from the switchgear ground bus to the grounding electrode system.

- B. Duct Banks and Manholes: Provide an insulated equipment grounding conductor in each duct containing medium or high voltage conductors, sized as shown on drawings. Bond the equipment grounding conductors to the switchgear ground bus, to all manhole hardware and ground rods, to the cable shielding grounding provisions of medium or high voltage cable splices and terminations, and equipment enclosures.
- C. Pad Mounted Transformers:
  - 1. Provide a driven ground rod and bond with a grounding electrode conductor to the transformer grounding pad metal steel.
  - 2. Ground the secondary neutral.
- D. Lightning Arresters: Connect lightning arresters to the equipment ground bus or ground rods as applicable.
- E. Outdoor Metallic Fences Around Electrical Equipment: Fences shall be grounded with a ground rod at each fixed gate post and at each corner post. Drive ground rods until the top is 300 mm (12 inches) below grade. Attach a 25 mm<sup>2</sup> (4 AWG) copper conductor, by exothermic weld to the ground rods and extend underground to the immediate vicinity of fence post. Lace the conductor vertically into 300 mm (12 inches) of fence mesh and fasten by two approved bronze compression fittings, one to bond wire to post and the other to bond wire to fence. Each gate section shall be bonded to its gatepost by a 3 by 25 mm (1/8 by one inch) flexible braided copper strap and ground post clamps. Clamps shall be of the anti-electrolysis type.
- F. Metallic Conduit: Metallic conduits which terminate without mechanical connection to an electrical equipment housing by means of locknut and bushings or adapters, shall be provided with grounding bushings. Connect bushings with a bare grounding conductor to the equipment ground bus.

### 3.4 SECONDARY EQUIPMENT AND CIRCUITS

- A. Main Bonding Jumper: Bond the secondary service neutral to the ground bus in the service equipment.
- B. Metallic Piping, Building Steel, and Supplemental Electrode(s):
  - 1. Provide a grounding electrode conductor sized per NEC between the service equipment ground bus and all metallic water and gas pipe systems, building steel, and supplemental or made electrodes. Jumper insulating joints in the metallic piping. All connections to electrodes shall be made with fittings that conform to UL 467.
  - 2. Provide a supplemental ground electrode and bond to the grounding electrode system.
- C. Service Disconnect (Separate Individual Enclosure): Provide a ground bar bolted to the enclosure with lugs for connecting the various grounding conductors.
- D. Switchgear, Switchboards, Unit Substations, and Motor Control Centers:
  - 1. Connect the various feeder equipment grounding conductors to the ground bus in the enclosure with suitable pressure connectors.
  - 2. For service entrance equipment, connect the grounding electrode conductor to the ground bus.
  - 3. Connect metallic conduits, which terminate without mechanical connection to the housing, by grounding bushings and grounding conductor to the equipment ground bus.

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E. Transformers:

1. Exterior: Exterior transformers supplying interior service equipment shall have the neutral grounded at the transformer secondary. Provide a grounding electrode at the transformer.
2. Separately derived systems (transformers downstream from service equipment): Ground the secondary neutral at the transformer. Provide a grounding electrode conductor from the transformer to the nearest ground bus in the Electric Room.

F. Conduit Systems:

1. Ground all metallic conduit systems. All metallic conduit systems shall contain an equipment grounding conductor.
2. Non-metallic conduit systems shall contain an equipment grounding conductor, except that non-metallic feeder conduits which carry a grounded conductor from exterior transformers to interior or building-mounted service entrance equipment need not contain an equipment grounding conductor.
3. Conduit containing only a grounding conductor, and which is provided for mechanical protection of the conductor, shall be bonded to that conductor at the entrance and exit from the conduit.

G. Feeders and Branch Circuits: Install equipment grounding conductors with all feeders and power and lighting branch circuits.

H. Boxes, Cabinets, Enclosures, and Panelboards:

1. Bond the equipment grounding conductor to each pullbox, junction box, outlet box, device box, cabinets, and other enclosures through which the conductor passes (except for special grounding systems for intensive care units and other critical units shown).
2. Provide lugs in each box and enclosure for equipment grounding conductor termination.
3. Provide ground bars in panelboards, bolted to the housing, with sufficient lugs to terminate the equipment grounding conductors.

I. Motors and Starters: Provide lugs in motor terminal box and starter housing or motor control center compartment to terminate equipment grounding conductors.

J. Receptacles shall not be grounded through their mounting screws. Ground with a jumper from the receptacle green ground terminal to the device box ground screw and the branch circuit equipment grounding conductor.

K. Ground lighting fixtures to the equipment grounding conductor of the wiring system when the green ground is provided; otherwise, ground the fixtures through the conduit systems. Fixtures connected with flexible conduit shall have a green ground wire included with the power wires from the fixture through the flexible conduit to the first outlet box.

L. Fixed electrical appliances and equipment shall be provided with a ground lug for termination of the equipment grounding conductor.

M. Raised Floors: Provide bonding of all raised floor components. //See details on the drawings. //

N. Panelboard Bonding: The equipment grounding terminal buses of the normal and essential branch circuit panelboards serving the same individual patient vicinity shall be bonded together with an insulated continuous copper conductor not less than 16 mm<sup>2</sup> (10 AWG). These conductors shall be installed in rigid metal conduit.

### 3.5 CORROSION INHIBITORS

- A. When making ground and ground bonding connections, apply a corrosion inhibitor to all contact surfaces. Use corrosion inhibitor appropriate for protecting a connection between the metals used.

### 3.6 CONDUCTIVE PIPING

- A. Bond all conductive piping systems, interior and exterior, to the building to the grounding electrode system. Bonding connections shall be made as close as practical to the equipment ground bus.
- B. In operating rooms and at intensive care and coronary care type beds, bond the gases and suction piping, at the outlets, directly to the room or patient ground bus.

### 3.7 LIGHTNING PROTECTION SYSTEM

- A. Bond the lightning protection system to the electrical grounding electrode system.

### 3.8 ELECTRICAL ROOM GROUNDING

- A. Building Earth Ground Busbars: Provide ground busbar hardware at each electrical room and connect to pigtail extensions of the building grounding ring.

### 3.9 WIREWAY GROUNDING

- A. Ground and Bond Metallic Wireway Systems as follows:
  - 1. Bond the metallic structures of wireway to provide 100 percent electrical continuity throughout the wireway system by connecting a 16 mm<sup>2</sup> (6 AWG) bonding jumper at all intermediate metallic enclosures and across all section junctions.
  - 2. Install insulated 16 mm<sup>2</sup> (6 AWG) bonding jumpers between the wireway system bonded as required in paragraph 1 above, and the closest building ground at each end and approximately every 16 meters (50 feet).
  - 3. Use insulated 16 mm<sup>2</sup> (6 AWG) bonding jumpers to ground or bond metallic wireway at each end at all intermediate metallic enclosures and cross all section junctions.
  - 4. Use insulated 16 mm<sup>2</sup> (6 AWG) bonding jumpers to ground cable tray to column-mounted building ground plates (pads) at each end and approximately every 15 meters.

### 3.10 GROUND RESISTANCE

- A. Grounding system resistance to ground shall not exceed 5 ohms. Make necessary modifications or additions to the grounding electrode system for compliance without additional cost to the Government. Final tests shall assure that this requirement is met.

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- B. Resistance of the grounding electrode system shall be measured using a four-terminal fall-of-potential method as defined in IEEE 81. Ground resistance measurements shall be made before the electrical distribution system is energized and shall be made in normally dry conditions not less than 48 hours after the last rainfall. Resistance measurements of separate grounding electrode systems shall be made before the systems are bonded together below grade. The combined resistance of separate systems may be used to meet the required resistance, but the specified number of electrodes must still be provided.
  - C. Services at power company interface points shall comply with the power company ground resistance requirements.
  - D. Below-grade connections shall be visually inspected by the Resident Engineer prior to backfilling. The Contractor shall notify the Resident Engineer 24 hours before the connections are ready for inspection.

### 3.11 GROUND ROD INSTALLATION

- A. Drive each rod vertically in the earth, not less than 3000 mm (10 feet) in depth.
- B. Where permanently concealed ground connections are required, make the connections by the exothermic process to form solid metal joints. Make accessible ground connections with mechanical pressure type ground connectors.
- C. Where rock prevents the driving of vertical ground rods, install angled ground rods or grounding electrodes in horizontal trenches to achieve the specified resistance.

### 3.12 METAL CURTAIN WALL GROUNDING

- A. In accordance with IBC 1404.5, exterior walls of steel construction need to be effectively grounded.
- B. The exterior sheathing curtain walls shall be grounded every 100 feet to building structural steel or connected to down conductor as part of the lightning protection system, with a #6 AWG Bare copper conductor, run concealed.
- C. 3rd Party Quality & Certification Testing & Cx Witnessing Coordinate with the Commissioning Authority for scheduling and witnessing of 3rd party quality and certification testing. All 3rd party quality and certification testing reports are to be provided to the Commissioning Authority. Refer to Section 019113, Commissioning.

--- END ---

SECTION 26 05 33  
RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS

## PART 1 - GENERAL

## 1.1 DESCRIPTION

- A. This section specifies the furnishing, installation, and connection of conduit, fittings, and boxes to form complete, coordinated, grounded raceway systems. Raceways are required for all wiring unless shown or specified otherwise.
- B. Definitions: The term conduit, as used in this specification, shall mean any or all of the raceway types specified.

## 1.2 RELATED WORK

- A. Bedding of conduits: Section 31 20 00, EARTH MOVING.
- B. Mounting board for telephone closets: Section 06 10 00, ROUGH CARPENTRY.
- C. Sealing around penetrations to maintain the integrity of fire rated construction: Section 07 84 00, FIRESTOPPING.
- D. Fabrications for the deflection of water away from the building envelope at penetrations: Section 07 60 00, FLASHING AND SHEET METAL.
- E. Sealing around conduit penetrations through the building envelope to prevent moisture migration into the building: Section 07 92 00, JOINT SEALANTS.
- F. Identification and painting of conduit and other devices: Section 09 91 00, PAINTING.
- G. General electrical requirements and items that is common to more than one section of Division 26: Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.
- H. Requirements for personnel safety and to provide a low impedance path for possible ground fault currents: Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS.

## 1.3 SUBMITTALS

- A. In accordance with Section 01 33 23, SHOP DRAWINGS, PRODUCT DATA, AND SAMPLES, furnish the following:
- B. Shop Drawings:
  - 1. Size and location of main feeders;
  - 2. Size and location of panels and pull boxes
  - 3. Layout of required conduit penetrations through structural elements.
  - 4. The specific item proposed and its area of application shall be identified on the catalog cuts.

- C. Certification: Prior to final inspection, deliver to the // Resident Engineer // COTR // four copies of the certification that the material is in accordance with the drawings and specifications and has been properly installed.

#### 1.4 APPLICABLE PUBLICATIONS

- A. Publications listed below (including amendments, addenda, revisions, supplements and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by the basic designation only.
- B. National Fire Protection Association (NFPA):  
70-05..... National Electrical Code (NEC)
- C. Underwriters Laboratories, Inc. (UL):  
1-03..... Flexible Metal Conduit  
5-01..... Surface Metal Raceway and Fittings  
6-03..... Rigid Metal Conduit  
50-03..... Enclosures for Electrical Equipment  
360-03 ..... Liquid-Tight Flexible Steel Conduit  
467-01 ..... Grounding and Bonding Equipment  
514A-01 ..... Metallic Outlet Boxes  
514B-02 ..... Fittings for Cable and Conduit  
514C-05..... Nonmetallic Outlet Boxes, Flush-Device Boxes and Covers  
651-02 ..... Schedule 40 and 80 Rigid PVC Conduit  
651A-03..... Type EB and A Rigid PVC Conduit and HDPE Conduit  
797-03 ..... Electrical Metallic Tubing  
1242-00 ..... Intermediate Metal Conduit
- D. National Electrical Manufacturers Association (NEMA):  
TC-3-04 ..... PVC Fittings for Use with Rigid PVC Conduit and Tubing  
FB1-03..... Fittings, Cast Metal Boxes and Conduit Bodies for Conduit, Electrical Metallic Tubing and Cable

## PART 2 - PRODUCTS

### 2.1 MATERIAL

- A. Conduit Size: In accordance with the NEC, but not less than 19 mm (3/4 inch) unless otherwise shown. Where permitted by the NEC, 19 mm (3/4 inch) flexible conduit may be used for tap connections to recessed lighting fixtures.
- B. Conduit:
1. Rigid galvanized steel: Shall Conform to UL 6, ANSI C80.1.
  2. Rigid aluminum: Shall Conform to UL 6A, ANSI C80.5.
  3. Rigid intermediate steel conduit (IMC): Shall Conform to UL 1242, ANSI C80.6.
  4. Electrical metallic tubing (EMT): Shall Conform to UL 797, ANSI C80.3. Maximum size not to exceed 105 mm (4 inch) and shall be permitted only with cable rated 600 volts or less.
  5. Flexible galvanized steel conduit: Shall Conform to UL 1.
  6. Liquid-tight flexible metal conduit: Shall Conform to UL 360.

7. Direct burial plastic conduit: Shall conform to UL 651 and UL 651A, heavy wall PVC or high density polyethylene (PE).
8. Surface metal raceway: Shall Conform to UL 5.

C. Conduit Fittings:

1. Rigid steel and IMC conduit fittings:
  - a. Fittings shall meet the requirements of UL 514B and ANSI/ NEMA FB1.
  - b. Standard threaded couplings, locknuts, bushings, and elbows: Only steel or malleable iron materials are acceptable. Integral retractable type IMC couplings are also acceptable.
  - c. Locknuts: Bonding type with sharp edges for digging into the metal wall of an enclosure.
  - d. Bushings: Metallic insulating type, consisting of an insulating insert molded or locked into the metallic body of the fitting. Bushings made entirely of metal or nonmetallic material are not permitted.
  - e. Erickson (union-type) and set screw type couplings: Approved for use in concrete are permitted for use to complete a conduit run where conduit is installed in concrete. Use set screws of case hardened steel with hex head and cup point to firmly seat in conduit wall for positive ground. Tightening of set screws with pliers is prohibited.
  - f. Sealing fittings: Threaded cast iron type. Use continuous drain type sealing fittings to prevent passage of water vapor. In concealed work, install fittings in flush steel boxes with blank cover plates having the same finishes as that of other electrical plates in the room.
  - g. Direct buried rigid galvanized steel shall be PVC coated.
2. Rigid aluminum conduit fittings:
  - a. Standard threaded couplings, locknuts, bushings, and elbows: Malleable iron, steel or aluminum alloy materials; Zinc or cadmium plate iron or steel fittings. Aluminum fittings containing more than 0.4 percent copper are prohibited.
  - b. Locknuts and bushings: As specified for rigid steel and IMC conduit.
  - c. Set screw fittings: Not permitted for use with aluminum conduit.
3. Electrical metallic tubing fittings:
  - a. Fittings shall meet the requirements of UL 514B and ANSI/ NEMA FB1.
  - b. Only steel or malleable iron materials are acceptable.
  - c. Couplings and connectors: Concrete tight and rain tight, with connectors having insulated throats. Use gland and ring compression type couplings and connectors for conduit sizes 50 mm (2 inches) and smaller. Use set screw type couplings with four set screws each for conduit sizes over 50 mm (2 inches). Use set screws of case-hardened steel with hex head and cup point to firmly seat in wall of conduit for positive grounding.
  - d. Indent type connectors or couplings are prohibited.
  - e. Die-cast or pressure-cast zinc-alloy fittings or fittings made of "pot metal" are prohibited.
4. Flexible steel conduit fittings:
  - a. Conform to UL 514B. Only steel or malleable iron materials are acceptable.
  - b. Clamp type, with insulated throat.



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5. Liquid-tight flexible metal conduit fittings:
    - a. Fittings shall meet the requirements of UL 514B and ANSI/ NEMA FB1.
    - b. Only steel or malleable iron materials are acceptable.
    - c. Fittings must incorporate a threaded grounding cone, a steel or plastic compression ring, and a gland for tightening. Connectors shall have insulated throats.
  6. Direct burial plastic conduit fittings:
    - a. Fittings shall meet the requirements of UL 514C and NEMA TC3.
    - b. As recommended by the conduit manufacturer.
  7. Surface metal raceway fittings: As recommended by the raceway manufacturer.
  8. Expansion and deflection couplings:
    - a. Conform to UL 467 and UL 514B.
    - b. Accommodate, 19 mm (0.75 inch) deflection, expansion, or contraction in any direction, and allow 30 degree angular deflections.
    - c. Include internal flexible metal braid sized to guarantee conduit ground continuity and fault currents in accordance with UL 467, and the NEC code tables for ground conductors.
    - d. Jacket: Flexible, corrosion-resistant, watertight, moisture and heat resistant molded rubber material with stainless steel jacket clamps.
- D. Conduit Supports:
1. Parts and hardware: Zinc-coat or provide equivalent corrosion protection.
  2. Individual Conduit Hangers: Designed for the purpose, having a pre-assembled closure bolt and nut, and provisions for receiving a hanger rod.
  3. Multiple conduit (trapeze) hangers: Not less than 38 mm by 38 mm (1-1/2 by 1-1/2 inch), 12 gage steel, cold formed, lipped channels; with not less than 9 mm (3/8 inch) diameter steel hanger rods.
  4. Solid Masonry and Concrete Anchors: Self-drilling expansion shields, or machine bolt expansion.
- E. Outlet, Junction, and Pull Boxes:
1. UL-50 and UL-514A.
  2. Cast metal where required by the NEC or shown, and equipped with rustproof boxes.
  3. Sheet metal boxes: Galvanized steel, except where otherwise shown.
  4. Flush mounted wall or ceiling boxes shall be installed with raised covers so that front face of raised cover is flush with the wall. Surface mounted wall or ceiling boxes shall be installed with surface style flat or raised covers.
- F. Wireways: Equip with hinged covers, except where removable covers are shown.
- G. Warning Tape: Standard, 4-Mil polyethylene 76 mm (3 inch) wide tape detectable type, red with black letters, and imprinted with "CAUTION BURIED ELECTRIC LINE BELOW".

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PART 3 - EXECUTION

## 3.1 PENETRATIONS

## A. Cutting or Holes:

1. Locate holes in advance where they are proposed in the structural sections such as ribs or beams. Obtain the approval of the Resident Engineer prior to drilling through structural sections.
2. Cut holes through concrete and masonry in new and existing structures with a diamond core drill or concrete saw. Pneumatic hammer, impact electric, hand or manual hammer type drills are not allowed, except where permitted by the Resident Engineer as required by limited working space.

## B. Fire Stop: Where conduits, wireways, and other electrical raceways pass through fire partitions, fire walls, smoke partitions, or floors, install a fire stop that provides an effective barrier against the spread of fire, smoke and gases as specified in Section 07 84 00, FIRESTOPPING, with rock wool fiber or silicone foam sealant only. Completely fill and seal clearances between raceways and openings with the fire stop material.

## C. Waterproofing: At floor, exterior wall, and roof conduit penetrations, completely seal clearances around the conduit and make watertight as specified in Section 07 92 00, JOINT SEALANTS.

## 3.2 INSTALLATION, GENERAL

## A. In accordance with UL, NEC, as shown, and as hereinafter specified.

## B. Essential (Emergency) raceway systems shall be entirely independent of other raceway systems, except where specifically "accepted" by NEC Article 517.

## C. Install conduit as follows:

1. In complete runs before pulling in cables or wires.
2. Flattened, dented, or deformed conduit is not permitted. Remove and replace the damaged conduits with new undamaged material.
3. Assure conduit installation does not encroach into the ceiling height head room, walkways, or doorways.
4. Cut square with a hacksaw, ream, remove burrs, and draw up tight.
5. Mechanically and electrically continuous.
6. Independently support conduit at 8'0" on center. Do not use other supports i.e., (suspended ceilings, suspended ceiling supporting members, lighting fixtures, conduits, mechanical piping, or mechanical ducts).
7. Support within 300 mm (1 foot) of changes of direction, and within 300 mm (1 foot) of each enclosure to which connected.
8. Close ends of empty conduit with plugs or caps at the rough-in stage to prevent entry of debris, until wires are pulled in.
9. Conduit installations under fume and vent hoods are prohibited.
10. Secure conduits to cabinets, junction boxes, pull boxes and outlet boxes with bonding type locknuts. For rigid and IMC conduit installations, provide a locknut on the inside of the enclosure, made up wrench tight. Do not make conduit connections to junction box covers.
11. Flashing of penetrations of the roof membrane is specified in Section 07 60 00, FLASHING AND SHEET METAL.

12. Do not use aluminum conduits in wet locations.
13. Unless otherwise indicated on the drawings or specified herein, all conduits shall be installed concealed within finished walls, floors and ceilings.

D. Conduit Bends:

1. Make bends with standard conduit bending machines.
2. Conduit hickey may be used for slight offsets, and for straightening stubbed out conduits.
3. Bending of conduits with a pipe tee or vise is prohibited.

E. Layout and Homeruns:

1. Install conduit with wiring, including homeruns, as shown.
2. Deviations: Make only where necessary to avoid interferences and only after drawings showing the proposed deviations have been submitted approved by the Resident Engineer.

### 3.3 CONCEALED WORK INSTALLATION

A. In Concrete: **RFI 5916.1 INSTALLATION TEMPORARY CONDUIT/CABLE IS NOT PERMITTED IN CONCRETE SLABS**

1. Conduit: Rigid steel, IMC or EMT. Do not install EMT in concrete slabs that are in contact with soil, gravel or vapor barriers.
2. Align and run conduit in direct lines.
3. Install conduit through concrete beams only when the following occurs:
  - a. Where shown on the structural drawings.
  - b. As approved by the Resident Engineer prior to construction, and after submittal of drawing showing location, size, and position of each penetration.
4. Installation of conduit in concrete that is less than 75 mm (3 inches) thick is prohibited.
  - a. Conduit outside diameter larger than 1/3 of the slab thickness is prohibited.
  - b. Space between conduits in slabs: Approximately six conduit diameters apart, except one conduit diameter at conduit crossings.
  - c. Install conduits approximately in the center of the slab so that there will be a minimum of 19 mm (3/4 inch) of concrete around the conduits.
5. Make couplings and connections watertight. Use thread compounds that are UL approved conductive type to insure low resistance ground continuity through the conduits. Tightening set screws with pliers is prohibited.

B. Furred or Suspended Ceilings and in Walls:

1. Conduit for conductors above 600 volts:
  - a. Rigid steel or rigid aluminum.
  - b. Aluminum conduit mixed indiscriminately with other types in the same system is prohibited.

2. Conduit for conductors 600 volts and below:
  - a. Rigid steel, IMC, rigid aluminum, or EMT. Different type conduits mixed indiscriminately in the same system is prohibited.
3. Align and run conduit parallel or perpendicular to the building lines.
4. Connect recessed lighting fixtures to conduit runs with maximum 1800 mm (six feet) of flexible metal conduit extending from a junction box to the fixture.
5. Tightening set screws with pliers is prohibited.

### 3.4 EXPOSED WORK INSTALLATION

- A. Unless otherwise indicated on the drawings, exposed conduit is only permitted in mechanical and electrical rooms.
- B. Conduit for conductors above 600 volts:
  1. Rigid steel or rigid aluminum.
  2. Aluminum conduit mixed indiscriminately with other types in the same system is prohibited.
- C. Conduit for Conductors 600 volts and below:
  1. Rigid steel, IMC, rigid aluminum, or EMT. Different type of conduits mixed indiscriminately in the system is prohibited.
- D. Align and run conduit parallel or perpendicular to the building lines.
- E. Install horizontal runs close to the ceiling or beams and secure with conduit straps.
- F. Support horizontal or vertical runs at not over 2400 mm (eight foot) intervals.
- G. Surface metal raceways: Use only where shown.
- H. Painting:
  1. Paint exposed conduit as specified in Section 09 91 00, PAINTING.
  2. Paint all conduits containing cables rated over 600 volts safety orange. Refer to Section 09 91 00, PAINTING for preparation, paint type, and exact color. In addition, paint legends, using 50 mm (two inch) high black numerals and letters, showing the cable voltage rating. Provide legends where conduits pass through walls and floors and at maximum 6000 mm (20 foot) intervals in between.

### 3.5 DIRECT BURIAL INSTALLATION

- A. Exterior routing of Lighting Systems and Other Branch circuits (600 Volt and Less, and 1500 mm (5 feet) from the buildings):
  1. Conduit: Thick wall PVC or high density PE, unless otherwise shown.
  2. Mark conduit at uniform intervals to show the kind of material, direct burial type, and the UL approval label.
  3. Install conduit fittings and terminations as recommended by the conduit manufacturer.

4. Tops of conduits shall be as follows unless otherwise shown:
    - a. Not less than 600 mm (24 inches) below finished grade.
    - b. Not less than 750 mm (30 inches) below road and other paved surfaces.
    - c. Installation under railroad tracks is prohibited.//
  5. Work with extreme care near existing ducts, conduits, cables, and other utilities to avoid damaging them.
  6. Excavation for conduit bedding and back-filling of trenches is specified in Section 31 20 00, EARTH MOVING.
    - a. Cut the trenches neatly and uniformly.
    - b. Do not kink the conduits.
  7. Seal conduits, including spare conduits, at building entrances and at outdoor terminations for equipment with a suitable compound that prevents the entrance of moisture and gases.
  8. Where metal conduit is shown, install threaded heavy wall rigid steel galvanized conduit or type A20 rigid steel galvanized conduit coated with .5 mm (20 mil) bonded PVC, or rigid steel or IMC, PVC coated or standard coated with bituminous asphaltic compound.
  9. Warning tape shall be continuously placed 300 mm (12 inches) above conduits or electric lines.
- B. Exterior routing of lighting systems and other branch circuits (600 volts and less-under buildings slab on grade to 1500 mm (5 feet) from the building):
1. PVC pre-coated rigid galvanized steel conduit in accordance with the requirements of Section 26 05 41, UNDERGROUND ELECTRICAL CONSTRUCTION.

### 3.6 HAZARDOUS LOCATIONS

- A. Use rigid steel conduit only, notwithstanding requirements otherwise specified in this or other sections of these specifications.
- B. Install UL approved sealing fittings, that prevent passage of explosive vapors, in hazardous areas equipped with explosive proof lighting fixtures, switches, and receptacles, as required by the NEC.

### 3.7 WET OR DAMP LOCATIONS

- A. Unless otherwise shown, use conduits of rigid steel or IMC.
- B. Provide sealing fittings, to prevent passage of water vapor, where conduits pass from warm to cold locations, i.e., (refrigerated spaces, constant temperature rooms, air conditioned spaces building exterior walls, roofs) or similar spaces.
- C. Unless otherwise shown, use rigid steel or IMC conduit within 1500 mm (5 feet) of the exterior and below concrete building slabs in contact with soil, gravel, or vapor barriers. Conduit shall include an outer factory coating of .5 mm (20 mil) bonded PVC or field coat with asphaltum before installation. After installation, completely coat damaged areas of coating.

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3.8 MOTORS AND VIBRATING EQUIPMENT

- A. Use liquid-tight flexible metal conduit for connections to motors and other electrical equipment subject to movement, vibration, misalignment, cramped quarters, or noise transmission.
- B. Provide liquid-tight flexible metal conduit for installation in exterior locations, moisture or humidity laden atmosphere, corrosive atmosphere, water or spray wash-down operations, inside (air stream) of HVAC units, and locations subject to seepage or dripping of oil, grease or water. Provide a green ground wire with flexible metal conduit.
- C. Maximum length 36".

## 3.9 EXPANSION JOINTS

- A. Conduits 75 mm (3 inches) and larger, that are secured to the building structure on opposite sides of a building expansion joint, require expansion and deflection couplings. Install the couplings in accordance with the manufacturer's recommendations.
- B. Provide conduits smaller than 75 mm (3 inches) with junction boxes on both sides of the expansion joint. Connect conduits to junction boxes with sufficient slack of flexible conduit to produce 125 mm (5 inch) vertical drop midway between the ends. Flexible conduit shall have a copper green ground bonding jumper installed. In lieu of this flexible conduit, expansion and deflection couplings as specified above for 375 mm (15 inches) and larger conduits are acceptable.
- C. Install expansion and deflection couplings as required to suite construction and at all building expansion joints.

## 3.10 CONDUIT SUPPORTS, INSTALLATION

- A. Safe working load shall not exceed 1/4 of proof test load of fastening devices.
- B. Use pipe straps or individual conduit hangers for supporting individual conduits. Maximum distance between supports is 2.5 m (8 foot) on center.
- C. Support multiple conduit runs with trapeze hangers. Use trapeze hangers that are designed to support a load equal to or greater than the sum of the weights of the conduits, wires, hanger itself, and 90 kg (200 pounds). Attach each conduit with U-bolts or other approved fasteners.
- D. Support conduit independently of junction boxes, pull boxes, fixtures, suspended ceiling T-bars, angle supports, and similar items.
- E. Fasteners and Supports in Solid Masonry and Concrete:
  - 1. New Construction: Use steel or malleable iron concrete inserts set in place prior to placing the concrete.
  - 2. Existing Construction:
    - a. Steel expansion anchors not less than 6 mm (1/4 inch) bolt size and not less than 28 mm (1-1/8 inch) embedment.
    - b. Power set fasteners not less than 6 mm (1/4 inch) diameter with depth of penetration not less than 75 mm (3 inches).

- c. Use vibration and shock resistant anchors and fasteners for attaching to concrete ceilings.
- F. Hollow Masonry: Toggle bolts are permitted.
- G. Bolts supported only by plaster or gypsum wallboard are not acceptable.
- H. Metal Structures: Use machine screw fasteners or other devices specifically designed and approved for the application.
- I. Attachment by wood plugs, rawl plug, plastic, lead or soft metal anchors, or wood blocking and bolts supported only by plaster is prohibited.
- J. Chain, wire, or perforated strap shall not be used to support or fasten conduit.
- K. Spring steel type supports or fasteners are prohibited for all uses except: Horizontal and vertical supports/fasteners within walls.
- L. Vertical Supports: Vertical conduit runs shall have riser clamps and supports in accordance with the NEC and as shown. Provide supports for cable and wire with fittings that include internal wedges and retaining collars.

### 3.11 BOX INSTALLATION

- A. Boxes for Concealed Conduits:
  - 1. Flush mounted.
  - 2. Provide raised covers for boxes to suit the wall or ceiling, construction and finish.
- B. In addition to boxes shown, install additional boxes where needed to prevent damage to cables and wires during pulling in operations.
- C. Remove only knockouts as required and plug unused openings. Use threaded plugs for cast metal boxes and snap-in metal covers for sheet metal boxes.
- D. Outlet boxes in the same wall mounted back-to-back are prohibited. A minimum 600 mm (24 inch), center-to-center lateral spacing shall be maintained between boxes.)  

RFI 7880 : It is acceptable to install putty pads on the boxes that are back to back
- E. Minimum size of outlet boxes for ground fault interrupter (GFI) receptacles is 100 mm (4 inches) square by 55 mm (2-1/8 inches) deep, with device covers for the wall material and thickness involved.
- F. Stencil or install phenolic nameplates on covers of the boxes identified on riser diagrams; for example "SIG-FA JB No. 1".
- G. On all Branch Circuit junction box covers, identify the circuits with black marker.

--- END ---

SECTION 26 05 37  
CABLE TRAYS

PART 1- GENERAL

1.1 SUMMARY

- A. The work covered under this section consists of the furnishing of all necessary labor, supervision, materials, equipment, tests and services to install complete cable tray systems as shown on the drawings.
- B. Cable tray systems are defined to include, but are not limited to straight sections of single rail cable trays, fittings, drop-outs, supports and accessories.

1.2 RELATED WORK

- A. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS: General electrical requirements that are common to more than one section of Division 26.
- B. Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS: Conduits, fittings, and boxes for raceway systems.
- C. Section 26 05 21, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES (600 VOLTS AND BELOW): Cables and conductors.
- D. Section 26 05 26, GROUNDING
- E. Section 27 15 00, COMMUNICATIONS HORIZONTAL CABLING

1.3 REFERENCES

- A. ASTM International:
  - 1. ASTM A653/A653M - Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process.
- B. National Electrical Manufacturers Association:
  - 1. NEMA VE 1-1998 - Metal Cable Tray Systems.
  - 2. NEMA VE 2-2000 - Cable Tray Installation Guidelines.
- C. ANSI/NFPA 70 – National Electrical Code

1.4 DRAWINGS

- A. The drawings, which constitute a part of these specifications, indicate the general route of the cable runway systems. Data presented on these drawings is as accurate as preliminary surveys and planning can determine until final equipment selection is made. Accuracy is not guaranteed and field verification of all dimensions, routing, etc., is required.



- B. Specifications and drawings are for assistance and guidance, but exact routing, locations, distances and levels will be governed by actual field conditions. Contractor is directed to make field surveys as part of his work prior to submitting system layout drawings.

## 1.5 QUALITY ASSURANCE

- A. Manufacturers: Firms regularly engaged in manufacture of cable trays and fittings of types and capacities required, whose products have been in satisfactory use in similar service for not less than 5 years.
- B. NEMA Compliance: Comply with NEMA Standards Publication Number VE1, "Cable Tray Systems".
- C. NEC Compliance: Comply with NEC, as applicable to construction and installation of cable tray and cable channel systems (Article 318, NEC).
- D. UL Compliance: Provide products that are UL-classified and labeled.
- E. NFPA Compliance: Comply with NFPA 70B, "Recommended Practice for Electrical Equipment Maintenance" pertaining to installation of cable tray systems.

## 1.6 SUBMITTALS

- A. Submit in accordance with Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.
- B. Shop Drawings:
  - 1. Sufficient information, clearly presented, shall be included to determine compliance with the drawings and specifications.
  - 2. Show size and location of raceway components, main feeders panels and pullboxes, ductwork and equipment provided by other trades, and radiology equipment items. Carefully coordinate with manufacturer's shop drawings. Shop drawing approval is required by the radiology equipment manufacturer's technical representative prior to fabrication and installation of the raceway and conductor system.
- C. Certifications: Two weeks prior to final inspection, submit four copies of the following to the Resident Engineer:
  - 1. Certification that the materials are in accordance with the drawings and specifications.
  - 2. Certification, by the Contractor, that the complete installation has been properly installed.

## PART 2 - PRODUCTS

### 2.1 CABLE TRAY REQUIREMENTS

- A. Available Support Spans: 8, 12, 16, and 20 feet.
- B. Working Load Designation:
  - 1. A - 50 pounds per foot (74.4 kg/m).
  - 2. B - 75 pounds per foot (111.6 kg/m).

3. C - 100 pounds per foot (148.8 kg/m).

C. Cable tray systems shall be designed for 75 lbs. per foot.

## 2.2 CABLE TRAY SECTIONS AND COMPONENTS

A. General: Except as otherwise indicated, provide aluminum cable trays, of types, classes, and sizes indicated; with splice plates, bolts, nuts and washers for connecting units. Construct units with rounded edges and smooth surfaces; in compliance with applicable standards; and with the following additional construction features. Cable tray shall be installed according to the latest revision of NEMA VE-2.

B. Material and Finish: Straight section, fitting side rails, rungs and splice plates shall be extruded from Aluminum Association Alloy 6063. All fabricated parts shall be made from Aluminum Association Alloy 5052.

## 2.3 TYPE OF TRAY SYSTEM

A. Ladder Cable Trays shall consist of two longitudinal members (side rails) with transverse members (rungs) mechanically fastened to the side rails. Rungs shall be spaced 9 inches on center. Rung spacing in radiused fittings shall be industry standard 9" and measured at the center of the tray's width. Each rung must be capable of supporting a 200 lb. concentrated load at the center of a 24" wide cable tray with a safety factor of 1.5. Rungs shall be capable of easy removal, reinstallation, or replacement if necessary.

B. Cable tray loading depth shall be 4 and 6 inches per NEMA VE-1 as indicated on Drawings.

C. Straight sections shall be supplied in standard 10 foot lengths.

D. Cable tray widths shall be as shown on drawings.

E. Splice plates shall have 4 nuts and bolts per plate. The resistance of fixed splice connections between adjacent sections of tray shall not exceed 0.00033 ohms. Splice plates shall be furnished with straight sections and fittings.

F. All fittings must have a minimum radius of 24.

## 2.4 LOADING CAPACITIES

A. Cable tray shall be capable of carrying a uniformly distributed load of 75 lbs./ft on an 8 foot support span with a safety factor of 1.5 when supported as a simple span and tested per NEMA VE 1 Section 5.2.

**PART 3 – EXECUTION****3.1 INSTALLATION**

- A. Install cable trays as indicated: Installation shall be in accordance with equipment manufacturer's instructions, and with recognized industry practices to ensure that cable tray equipment comply with requirements of NEC and applicable portions of NFPA 70B. Reference NEMA-VE2 for general cable tray installation guidelines.
- B. Coordinate cable tray with other electrical work as necessary to properly integrate installation of cable tray work with other work.
- C. Provide sufficient space encompassing cable trays to permit access for installing and maintaining cables.
- D. Cable tray fitting supports shall be located such that they meet the strength requirements of straight sections. Install fitting supports per NEMA VE-2 guidelines, or in accordance with manufacturer's instructions.

**--- E N D ---**

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SECTION 26 05 41  
UNDERGROUND ELECTRICAL CONSTRUCTION

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies the furnishing, installation and connection of precast manholes, handholes and ducts to form a complete underground raceway system.
- B. "Duct" and "conduit", and "rigid metal conduit" and "rigid steel conduit" are used interchangeably in this specification and have the same meaning.

1.2 RELATED WORK

- A. Section 31 20 00, EARTH MOVING: Trenching, backfill and compaction.
- B. Section 05 50 00, METAL FABRICATIONS: Ladders.
- C. Section 07 92 00, JOINT SEALANTS: Sealing of conduit penetrations.
- D. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS: General electrical requirements and items that are common to more than one section of Division 26.
- E. Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS: Conduits, fittings and boxes for raceway systems.
- F. Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS: Requirements for personnel safety and to provide a low impedance path for possible ground fault currents.
- G. Section 26 05 13, MEDIUM VOLTAGE CABLES.

1.3 SUBMITTALS

- A. Submit in accordance with Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.
- B. Shop Drawings:
  - 1. Sufficient information, clearly presented, shall be included to determine compliance with drawings and specifications.
  - 2. Include manholes, handholes, duct materials, and hardware. Proposed deviations from details on the drawings shall be clearly marked on the submittals.
  - 3. If necessary to locate manholes or handholes at locations other than shown on the drawings, show the proposed locations accurately on scaled site drawings, and submit four copies to the Resident Engineer for approval prior to construction.
  - 4. Reinforcement shop drawings for precast manholes prepared in accordance with ACI-SP-66.

5. Precast manholes and handholes: Submit plans on elevation showing openings, pulling irons cable supports, sump and other details. Also, submit detail drawings and design calculations for approval prior to installation. Submittal shall bear the seal of a registered structural engineer.
- C. Certifications: Two weeks prior to final inspection, submit four copies of the following to the Resident Engineer:
  1. Certification that the materials are in accordance with the drawings and specifications.
  2. Certification, by the Contractor, that the complete installation has been properly installed and tested.

#### 1.4 APPLICABLE PUBLICATIONS

- A. Publications listed below (including amendments, addenda, revisions, supplements, and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by the basic designation only.
- B. American Concrete Institute (ACI):  
Building Code Requirements for Structural Concrete
   
318/318M-2005 .....Building Code Requirements for Structural Concrete & Commentary
   
SP-66-04 .....ACI Detailing Manual
- C. American Society for Testing and Materials (ASTM):
   
C478/C478M 2006(b) .....Standard Specification for Precast Reinforced Concrete Manhole Sections
   
C990 REV A 2003 .....Standard Specification for joints concrete pipe, Manholes and Precast Box using performed flexible Joint sealants.
- D. Institute of Electrical and Electronic Engineers (IEEE):
   
C2-2002 .....National Electrical Safety Code
- E. National Electrical Manufacturers Association (NEMA):
   
RNI 2005 .....Polyvinyl Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit
   
TC 2 2003.....Electrical Polyvinyl Chloride (PVC) Tubing And Conduit
   
TC 3-2004.....PVC Fittings for Use With Rigid PVC Conduit And Tubing
   
TC 6 & 8 2003 .....PVC Plastic Utilities Duct For Underground Installations
   
TC 9-2004.....Fittings For PVC Plastic Utilities Duct For Underground Installation
- F. National Fire Protection Association (NFPA):
   
70 2005.....National Electrical Code (NEC)

- G. Underwriters Laboratories, Inc. (UL):
- 6-2004 ..... Electrical Rigid Metal Conduit-Steel
  - 467-2004 ..... Standard for Grounding and Bonding Equipment
  - 651-2005 ..... Standard for Schedule 40 and 80 Rigid PVC Conduit and Fittings
  - 651A-2003 ..... Type EB and A Rigid PVC Conduit and HDPE Conduit, (RTRC)
  - 651B-2002 ..... Continuous Length HDPE Conduit
- H. U.S. General Services Administration (GSA):
- A-A-60005-1998 ..... Frames, Covers, Gratings, Steps, Sump and Catch Basin,  
Manhole
  - SS-S-210A-1981 ..... Sealing Compound, Preformed Plastic for Expansion joints And  
Pipe Joints

## PART 2 - PRODUCTS

### 2.1 CONCRETE MANHOLES AND HARDWARE

- A. Reinforced Concrete: ACI 318, 20MPA (4000 psi) minimum 28-day compressive strength. Manholes shall be precast construction, minimum dimensions as detailed on plan.
- B. Reinforcing Steel: Number 4 minimum.
- C. Manhole Hardware:
1. Frames and covers (traffic type):
    - a. GSA A-A-60005 Type III.
    - b. Frames: Style A, size 30A.
    - c. Covers, Type D, size 30A, marked as noted in these Specifications.
    - d. Refer to details on plans
    - e. All manhole covers shall be watertight and gasketed.
    - f. Provide with inner security cover.
  2. Sump frames and gratings:
    - a. GSA A-A-60005.
    - b. Frames, Type VII.
    - c. Gratings, Type I.
    - d. Refer to details on plans.
  3. Pulling Irons: 22 mm (1") diameter hot-dipped galvanized steel bar with exposed triangular shaped opening on all sides.
  4. Cable supports:
    - a. Cable rack stanchions shall be non-metallic, 50% glass reinforced Nylon or a non-metallic material.
    - b. Cable arms shall be 20" long, mounted on stanchion. The racks shall be adjustable with a lock in place on stanchions. The stanchion shall be secured to manhole wall with stainless steel hardware.
    - c. Spares: Equip each cable stanchion with two spare cable arms for future use.
    - d. Miscellaneous hardware, stainless steel.

## D. Manhole Hardware:

1. Frames and covers configuration as shown on the drawings. Cast the words "Electric" "Emergency Electric" and "Telephone" in the top face of the power and telephone manhole covers respectively. Frame and covers shall be heavy duty type with self sealing gaskets to prevent surface water inflow. Manhole openings below main manhole cover shall be provided with a security cover requiring special access tooling.
2. Pulling irons, 1" diameter galvanized steel bar with exposed triangular shaped opening on all sides.

## E. Ground Rod Sleeve: Provide a 75 mm (3 inches) PVC sleeve in manhole floors so that a driven ground rod may be installed. The openings shall be sealed with hydraulic cement.

## F. Site preparation shall be as follows:

1. Size: Plan area and clear height shall be not less than that shown on the drawings for poured-in-place type.
2. Accessories, hardware, and facilities shall be the same as required for poured-in-place type.
3. Assume ground water level 900 mm (3 feet) below ground surface unless a higher water table is shown in the boring logs and adjust design accordingly.
4. Construction:
  - a. Units, precast monolithically or of assembled sections. Base and first riser shall be monolithic.
  - b. Provide tongue-and-groove joints to firmly interlock adjoining components. Seal joints watertight using preformed plastic or rubber materials conforming to ASTM C990 or GSA SS-S-210A. Install sealing material in strict accordance with the sealant manufacturers' printed instructions.
  - c. Provide lifting devices cast into units.
  - d. Identify all structures with manufacturer's name embedded in, or otherwise permanently attached to an interior wall face.

## 2.2 HANDHOLES

- A. Shall be matched die molded of pre-cast polymer concrete with approximate dimensions as shown on plan. When buried, the unit shall be capable of supporting an ultimate downward load of 2955 kg (6500 pounds) distributed over a 150 by 150 mm (6 by 6 inch) area imposed anywhere on the cover surface. Unit shall have precut 150 by 150 mm (6 by 6 inches) cable entrance at the center bottom of each side. A gasketed weatherproof cover with nonskid surface shall be provided for each handhole. Covers shall be capable of being locked into position.

## 2.3 DUCTS

- A. Number and sizes shall be as shown on drawings.
- B. Ducts (concrete encased):

1. Plastic Duct:
  - a. NEMA TC6 & 8 and TC9 plastic utilities duct UL 651 and 651A Schedule 40 PVC.
  - b. Duct shall be suitable for use with 90 degree C rated conductors.

2. Conduit Spacers: Prefabricated plastic.

C. Ducts (direct burial):

1. Plastic duct:
  - a. NEMA TC2 and TC3
  - b. UL 651, 651A and 651B, Schedule 40 PVC.
  - c. Duct shall be suitable for use with 75 degree C rated conductors.
2. Rigid metal conduit, PVC-coated: UL6 and NEMA RN1 galvanized rigid steel, threaded type, coated with PVC sheath bonded to the galvanized exterior surface, nominal 1 mm (0.040 inch) thick.

## 2.4 GROUNDING

- A. Rods: Per Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS and UL 467
- B. Ground Wire: Stranded bare copper 16 mm<sup>2</sup> (6 AWG) minimum.

## 2.5 WARNING TAPE

- A. Standard 4-mil polyethylene 76 mm (3 inch) wide tape, detectable type, red with black letters, imprinted with "CAUTION BURIED ELECTRIC CABLE BELOW".

## 2.6 PULL ROPE

- A. Plastic with 890N (200 pound) minimum tensile strength.

## PART 3 - EXECUTION

### 3.1 MANHOLE AND HANDHOLE CONSTRUCTION AND INSTALLATION

- A. General Requirements:
  1. Construct pre-cast manholes of reinforced concrete.
  2. Locate manholes and handholes at the approximate locations shown on the drawings with due consideration given to the location of other utilities, grades, and paving. Exact locations shall be determined from the site civil drawings.
  3. Duct terminations: Provide windows at duct bank terminations and fill with concrete after duct placement. Terminations shall be sealed watertight.
  4. Pulling irons:
    - a. Provide pulling irons opposite each duct entrance.
    - b. Cast pulling irons in the walls opposite duct windows approximately 152mm (6 inches) above the top of the window.



**B. Manhole Access:**

1. Manhole chimney shall consist of a sufficient number of pre-cast collars between top of manhole and manhole frame to reach the required level. Grout the manhole frame to the chimney and make water tight.
2. The top of frames and covers shall be flush type, with the finish flush with finished grade in paved and unpaved areas.
3. Frames and covers shall be traffic type.

**C. Access for Handholes: Make the top of frames and covers flush with finished grade.****D. Manhole Cable Racks:**

1. Provide heavy duty non metallic cable racks constructed of UL listed glass reinforced polmar in each manhole to support all cables and termination devices. The cable racks consist of a stanchion that shall be attached to the manhole wall in accordance with the manufacturer's recommendations and adjustable arms that lock into the stanchion.
2. Cable support intervals shall not exceed 900mm (36 inches).
3. Install racks at the above spacing on all walls for not less than one cable, whether or not the racks will be used for cables. Install additional racks as required for the cables.
4. Each rack shall include cable support insulators.

**E. Ground Rods and Grounding in Manholes:**

1. Ground rods:
  - a. Rods shall protrude approximately 100 mm (4 inches) above the manhole floor.
  - b. Poured-in-place manholes: Drive a ground rod into the earth, before the floor is placed, at a convenient point close to the manhole wall.
  - c. Precast manholes: Drive a ground rod into the earth, through the floor sleeve, after the manhole is set in place. Fill the sleeve with a sealant to make a watertight seal.
2. Grounding Conductors:
  - a. Install a 95 mm<sup>2</sup> (3/0 AWG) bare copper ring grounding conductor around the inside perimeter of the manhole and anchor to the walls with metallic cable clips.
  - b. Connect the ring grounding conductor to the ground rod by an exothermic welding process.
  - c. Bond the ring grounding conductor to the duct bank equipment grounding conductors, the exposed non-current carrying metal parts of racks, sump covers, and like items in the manholes with a minimum 16 mm<sup>2</sup> (6 AWG) bare copper jumper.

**F. Precast Units:**

1. Precast units shall have the same accessories and facilities as specified above.
2. Assembly and installation of precast components shall follow the printed instructions and recommendations of the manufacturer of the units.
3. Units shall be installed on a 300 mm (12 inch) level bed of 90% compacted granular fill, well-graded from the 25 mm (1 inch) sieve to the No. 4 sieve. Granular fill shall be compacted with a minimum of four passes with a plate compactor.
4. Seal duct terminations watertight.
5. Provide waterproof coating on all sides of manholes

### 3.2 TRENCHING

- A. Refer to Section 31 20 00, EARTH MOVING for trenching back-filling, and compaction.
- B. Work with extreme care near existing ducts, conduits, cables, and other utilities to avoid damaging them.
- C. Cut the trenches neatly and uniformly.
- D. For Concrete Encased Ducts:
  - 1. After excavation of the trench, stakes shall be driven in the bottom of the trench at 1200 mm (4 foot) intervals to establish the grade and route of the duct bank.
  - 2. Pitch the trenches uniformly towards manholes or both ways from high points between manholes for the required duct line drainage. Avoid pitching the ducts towards buildings wherever possible.
  - 3. The walls of the trench may be used to form the side walls of the duct bank provided that the soil is self-supporting and that concrete envelope can be poured without soil inclusions. Forms are required where the soil is not self-supporting.
  - 4. After the concrete encased duct has sufficiently cured, the trench shall be backfilled to grade with earth, with appropriate warning tape attached.
- E. Conduits to be installed under existing paved areas, roads, and railroad tracks that are not to be disturbed shall be jacked into place. Conduits shall be PVC-coated rigid metal.

### 3.3 DUCT INSTALLATION

- A. General Requirements:
  - 1. Ducts shall be in accordance with the NEC and IEEE C2, as shown on the drawings, and as specified.
  - 2. Slope ducts to drain towards manholes and handholes, and away from building and equipment entrances. Pitch not less than 100 mm (4 inches) in 30 M (100 feet).
  - 3. Underground conduit stub-ups and sweeps to equipment inside of buildings shall be PVC-coated galvanized rigid steel, and shall extend a minimum of 1500 mm (5 feet) outside of building foundation.
  - 4. Stub-ups, sweeps, and risers to equipment mounted on outdoor concrete slabs shall be PVC-coated galvanized rigid steel, and shall extend a minimum of 1500 mm (5 feet) away from edge of slab.
  - 5. Install insulated grounding bushings on the terminations.
  - 6. PVC-coated rigid steel conduits shall be coupled to the ducts with suitable adapters, and the whole encased with 75 mm (3 inches) of concrete.
  - 7. PVC coated rigid steel conduit turns of direction for all duct lines shall have minimum 1200 mm (4 feet) radius in the horizontal and vertical directions. PVC conduit sweeps for all duct lines shall have a minimum 12000 mm (40 feet) radius in the horizontal and 1200 mm (4 feet) in the vertical directions. Where a 12000 mm (40 feet) radius is not possible, horizontal turns of direction shall be rigid steel.
  - 8. All multiple conduit runs shall have conduit spacers. Spacers shall securely support and maintain uniform spacing of the duct assembly a minimum of 75 mm (3 inches) above bottom of trench during the concrete pour. Spacer spacing shall not exceed 1500 mm (5 feet).
  - 9. Duct lines shall be installed no less than 300 mm (12 inches) from other utility systems, such as water, sewer, and chilled water.

10. Clearances between individual ducts:
  - a. For like services, not less than 75 mm (3 inches).
  - b. For power and signal services, not less than 150 mm (6 inches).
  - c. Provide plastic spacers to maintain clearances.
  - d. Provide nonferrous tie wires to prevent displacement of the ducts during pouring of concrete. Tie wires shall not act as substitute for spacers.
11. Duct lines shall terminate at window openings in manhole walls as shown on the drawings. All ducts shall be fitted with end bells.
12. Couple the ducts with proper couplings. Stagger couplings in rows and layers to insure maximum strength and rigidity of the duct bank.
13. Keep ducts clean of earth, sand, or gravel during construction, and seal with tapered plugs upon completion of each portion of the work.

B. Concrete Encased Ducts and Conduits:

1. Install concrete encased ducts for medium and high voltage systems, low voltage systems, and signal systems unless otherwise shown on the drawings.
2. Duct lines shall consist of single or multiple duct assemblies encased in concrete. Ducts shall be uniform in size and material throughout the installation.
3. Tops of concrete-encased ducts shall be:
  - a. Not less than 600 mm (24 inches) and not less than shown on the drawings, below finished grade.
  - b. Not less than 750 mm (30 inches) and not less than shown on the drawings, below roads and other paved surfaces.
  - c. Conduits crossing under grade slab construction joints shall be installed a minimum of 1200 mm (4 feet) below slab.
4. Extend the concrete envelope encasing the ducts not less than 75 mm (3 inches) beyond the outside walls of the outer ducts and conduits.
5. Within 3000 mm (10 feet) of building, manhole and handhole wall penetrations, install reinforcing steel bars at the top and bottom of each concrete envelope to provide protection against vertical shearing.
6. Install reinforcing steel bars at the top and bottom of each concrete envelope of all ducts underneath roadways and parking areas.
7. Where new ducts, conduits, and concrete envelopes are to be joined to existing manholes, handholes, ducts, conduits, and concrete envelopes, make the joints with the proper fittings and fabricate the concrete envelopes to insure smooth durable transitions.
8. Conduit joints in concrete may be placed side by side horizontally but shall be staggered at least 150 mm (6 inches) vertically.
9. For medium voltage duct bank installations, a grounding conductor shall be extend along all electrical duct banks including stubs through each electrical distribution system manhole and to each transformer and switching-station installation.
10. Duct Bank Markers:
  - a. Duct bank markers, where required, shall be located at the ends of duct banks except at manholes or handholes at approximately every 60 meter (200 feet) along the duct run and at each change in direction of the duct run. Markers shall be placed 600 mm (2 feet) to the right of the duct bank, facing the longitudinal axis of the run in the direction of the electrical load.

- b. The letter "D" with two arrows shall be impressed or cast on top of the marker. One arrow shall be located below the letter and shall point toward the ducts. Second arrow shall be located adjacent to the letter and shall point in a direction parallel to the ducts. The letter and arrow adjacent to it shall each be approximately 75 mm (2-inches) long. The letter and arrows shall be V-shaped, and shall have a width of stroke at least 6 mm ( $\frac{1}{4}$  inch) at the top and a depth of 6 mm ( $\frac{1}{4}$  inch).
  - c. In paved areas, the top of the duct markers shall be flush with the finished surface of the paving.
  - d. Where the duct bank changes direction, the arrow located adjacent to the letter shall be cast or impressed with an angle in the arrow the same as the angular change of the duct bank.
- C. Direct Burial Duct and Conduits:
  - 1. Install direct burial ducts and conduits only where shown on the drawings. Provide direct burial ducts only for low voltage systems.
  - 2. Join and terminate ducts and conduits with fittings recommended by conduit manufacturer.
  - 3. Direct burial ducts and conduits are prohibited under railroad tracks.
  - 4. Tops of ducts and conduits shall be:
    - a. Not less than 600 mm (24 inches) and not less than shown on the drawings, below finished grade.
    - b. Not less than 750 mm (30 inches) and not less than shown on the drawings, below roads and other paved surfaces.
  - 5. Do not kink the ducts or conduits.
- D. Concrete-Encased and Direct Burial Duct and Conduit Identification: Place continuous strip of warning tape approximately 300 mm (12 inches) above ducts or conduits before backfilling trenches. Warning tape shall be preprinted with proper identification.
- E. Spare Ducts and Conduits: Where spare ducts are shown, they shall have a nylon pull rope installed. They shall be capped at each end and labeled as to location of the other end.
- F. Duct and Conduit Cleaning:
  - 1. Upon completion of the duct bank installation or installation of direct buried ducts, a standard flexible mandrel shall be pulled through each duct to loosen particles of earth, sand, or foreign material left in the line. The mandrel shall be not less than 3600 mm (12 inches) long, and shall have a diameter not less than 13 mm ( $\frac{1}{2}$  inch) less than the inside diameter of the duct. A brush with stiff bristles shall then be pulled through each duct to remove the loosened particles. The diameter of the brush shall be the same as, or slightly larger than the diameter of the duct.
  - 2. Mandrel pulls shall be witnessed by the Resident Engineer.
- G. Duct and Conduit Sealing: Seal the ducts and conduits at building entrances, and at outdoor terminations for equipment, with a suitable non-hardening compound to prevent the entrance of moisture and gases.
- H. Connections to Manholes: Duct bank envelopes connecting to underground structures shall be flared to have enlarged cross-section at the manhole entrance to provide additional shear strength. Dimensions of the flared cross-section shall be larger than the corresponding manhole opening dimensions by no less than 300 mm (12 inches) in each direction.

Perimeter of the duct bank opening in the underground structure shall be flared toward the inside or keyed to provide a positive interlock between the duct bank and the wall of the structure. Use vibrators when this portion of the encasement is poured to assure a seal between the envelope and the wall of the structure.

- I. Connections to Existing Manholes: For duct bank connections to existing structures, break the structure wall out to the dimensions required and preserve steel in the structure wall. Cut steel and extend into the duct bank envelope. Chip the perimeter surface of the duct bank opening to form a key or flared surface, providing a positive connection with the duct bank envelope.
- J. Connections to Existing Ducts: Where connections to existing duct banks are indicated, excavate around the duct banks as necessary. Cut off the duct banks and remove loose concrete from the conduits before installing new concrete-encased ducts. Provide a reinforced concrete collar, poured monolithically with the new duct bank, to take the shear at the joint of the duct banks.
- K. Partially Completed Duct Banks: During construction wherever a construction joint is necessary in a duct bank, prevent debris such as mud and dirt from entering ducts by providing suitable conduit plugs. Fit concrete envelope of a partially completed duct bank with reinforcing steel extending a minimum of 600 mm (2 feet) back into the envelope and a minimum of 600 mm (2 feet) beyond the end of the envelope. Provide one No. 4 bar in each corner, 75 mm (3 inches) from the edge of the envelope. Secure corner bars with two No. 3 ties, spaced approximately 300 mm (1 foot) apart. Restrain reinforcing assembly from moving during pouring of concrete.

--- END ---

SECTION 26 05 71  
ELECTRICAL SYSTEM PROTECTIVE DEVICE STUDY

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies the requirements of the Electrical System Protective Device Study.
- B. The following Electrical Engineering Studies shall be performed by the distribution equipment manufacturer or a firm engaged by the distribution equipment manufacturer:
  - 1. Short Circuit Studies
  - 2. Protective Device Evaluation Studies
  - 3. Protective Device Coordination Studies
  - 4. Arc Flash Protection Studies
- C. A short circuit and coordination study shall be prepared for the electrical over current devices to be installed under this project to assure proper equipment and personnel protection.
  - 1. The short circuit study shall include, but not be limited to, the following:
    - a. Utility Co. short circuit contribution from main service.
    - b. Substation line up, primary and secondary.
    - c. Low voltage switchboards.
    - d. Motor controllers and motor control systems.
    - e. Distribution panels.
    - f. Lighting and receptacle branch circuit panels.
    - g. All equipment panels.
    - h. Lighting control relay panels.
    - i. Emergency generator modeled through automatic transfer switches.
    - j. Automatic transfer switches.
    - k. VFD's and equipment disconnect devices.
    - l. Generator and utility contribution during momentary closed transition.
  - 2. The power system studies are required to confirm the adequacy of the ratings of all electrical system components and proper coordination settings of all circuit breakers to the satisfaction of the resident Engineer. These studies shall not be used as a basis to compromise the electrical system and do not imply that short circuit ratings of distribution equipment and devices may be lower than those indicated on the drawings or specified herein.
- D. The study shall present an organized time-current analysis of each protective device in series from the main incoming 13.2kv service including individual device and back to the utility and the on-site generator sources. The study shall reflect the operation of each device during normal and abnormal current conditions.

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1.2 RELATED WORK

- A. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS: General electrical requirements that are common to more than one section of Division 26.
- B. Section 26 24 16, PANELBOARDS: Low voltage panelboards.
- C. Section 26 13 00, MEDIUM-VOLTAGE SWITCHGEAR: Primary distribution switchgear.
- D. Section 26 18 41, MEDIUM-VOLTAGE SWITCHES: Primary switches.
- E. Section 26 24 11, DISTRIBUTION SWITCHBOARDS: Low voltage distribution switchboards.
- F. Section 26 23 00, LOW-VOLTAGE SWITCHGEAR: Low voltage switchgear.

## 1.3 SUBMITTALS

- A. In accordance with Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS , submit the following:
- B. Complete short circuit and coordination study as described herein.
- C. Protective equipment shop drawings shall be submitted simultaneously with or after the protective device study. Protective equipment shop drawings will not be accepted prior to protective device study.
- D. Certification: Two weeks prior to final inspection, submit four copies of the following to the Resident Engineer:
  - 1. Certification by the Contractor that the protective devices have been adjusted and set in accordance with the approved protective device study.

## 1.4 QUALIFICATIONS

- A. The protective device study shall be prepared by qualified engineers of the high voltage switchgear manufacturer or an approved consultant. The Contractor is responsible for providing all pertinent information required by the preparers to complete the study.

## 1.5 REQUIREMENTS

- A. The complete study shall include a system one line diagram, short circuit and ground fault analysis, and protective coordination plots.
- B. One Line Diagram:
  - 1. Show, on the one line diagram, all electrical equipment and wiring to be protected by the overcurrent devices installed under this project. Clearly show, on the one line, the schematic wiring of the electrical distribution system.

- 
2. Also show on the one line diagram the following specific information:
    - a. Calculated fault impedance, X/R ratios, and short circuit values at each bus.
    - b. Breaker and fuse ratings.
    - c. Generator kW and Transformer kVA and voltage ratings, percent impedance, X/R ratios, and wiring connections.
    - d. Voltage at each bus.
    - e. Identification of each bus.
    - f. Conduit material, feeder sizes, length, and X/R ratios.
- C. Short Circuit Study:
1. Systematically calculate the fault impedance to determine the available short circuit and ground fault currents at each bus. Incorporate the motor contribution in determining the momentary and interrupting ratings of the protective devices.
  2. The study shall be calculated by means of a computer program. Pertinent data and the rationale employed in developing the calculations shall be incorporated in the introductory remarks of the study.
  3. Present the data determined by the short circuit study in a table format. Include the following:
    - a. Device identification.
    - b. Operating voltage.
    - c. Protective device.
    - d. Device rating.
    - e. Calculated short circuit current.
- D. Protective Device Evaluation and Coordination Study
1. Prepare the coordination curves to determine the required settings of protective devices to assure selective coordination. Graphically illustrate on log-log paper that adequate time separation exists between series devices, including the utility company upstream device. Plot the specific time-current characteristics of each protective device in such a manner that all upstream devices will be clearly depicted on one sheet.
  2. The following specific information shall also be shown on the coordination curves:
    - a. Device identification.
    - b. Voltage and current ratio for curves.
    - c. 3-phase and 1-phase ANSI damage points for each transformer.
    - d. No-damage, melting, and clearing curves for fuses.
    - e. Cable damage curves.
    - f. Transformer inrush points.
    - g. Maximum short circuit cutoff point.
  3. Develop a table to summarize the settings selected for the protective devices. Include the following in the table:
    - a. Device identification.
    - b. Relay CT ratios, tap, time dial, and instantaneous pickup.
    - c. Circuit breaker sensor rating, long-time, short-time, and instantaneous settings, and time bands.
    - d. Fuse rating and type.
    - e. Ground fault pickup and time delay.



4. Include all adjustable settings for ground fault protective devices. Include manufacturing tolerance and damage bands in plotted fuse characteristics. Show transformer full load and 150, 400, or 600 percent currents, transformer magnetizing inrush, ANSI transformer withstand parameters, and significant symmetrical and asymmetrical fault currents. Terminate device characteristic curves at a point reflecting the maximum symmetrical or asymmetrical fault current to which the device is exposed.
5. Provide settings for the chiller motor starters or obtain from the Mechanical Subcontractor, include in the study package, and comment.
6. Select each primary protective device required for a delta-wye connected transformer so that its characteristic or operating band is within the transformer characteristics, including a point equal to 58 percent of the ANSI withstand point to provide secondary line-to-ground fault protection. Where the primary device characteristic is not within the transformer characteristics, show a transformer damage curve. Separate transformer primary protective device characteristic curves from associated secondary device characteristics by a 16 percent current margin to provide proper coordination and protection in the event of secondary line-to-line faults. Separate medium-voltage relay characteristic curves from curves for other devices by at least a 0.4-second time margin.
7. Include phase and ground coordination of the generator protective devices. Show the generator decrement curve and damage curve along with the operating characteristic of the protective devices. Obtain the information from the generator manufacturer and include the generator actual impedance value, time constants and current boost data in the study. Do not use typical values for the generator.
8. Evaluate proper operation of the ground relays in 4-wire distributions with more than one main service circuit breaker, or when generators are provided, and discuss the neutral grounds and ground fault current flows during a neutral to ground fault.
9. For motor control circuits, show the MCC full-load current plus symmetrical and asymmetrical of the largest motor starting current and time to ensure protective devices will not trip during major or group start operation.
10. For distribution transformer primary protection, the system study engineer shall use 12.0 times the transformer full load amps to determine transformer in-rush. If a miscoordination occurs between the calculated in-rush and the primary circuit breaker, prior to issuance of the study, the system study engineer shall contact the manufacturer and obtain the actual in-rush for the transformer(s) in question and/or change the circuit breaker to a type that will coordinate the transformer in-rush with the circuit breaker trip curve. If, after determination of actual in-rush and proper selection of primary circuit breaker, a miscoordination still exists, it shall be reported in the submitted study.

#### E. Selective Coordination

1. Overcurrent protection devices associated with the normal power distribution system shall be selectively coordinated from 0.10 seconds and longer with all upstream overcurrent protection devices based on the available short circuit current at the overcurrent protection device terminals. If a miscoordination occurs between upstream and downstream overcurrent protection devices, the system study Engineer shall contact the successful switchgear manufacturer to obtain results of factory laboratory testing for the selected overcurrent protection devices. If a miscoordination still exists, the system study Engineer shall advise the manufacturer. The manufacturer shall be responsible to select proper frame sizes/types to assure each upstream overcurrent protection device will selectively coordinate with all breakers downstream and include the generator actual impedance value, time constants and current boost data in the study. Do not use typical values for the generator.

2. All overcurrent protection device(s) associated with the Elevator distribution system shall be selectively coordinated with all upstream overcurrent protection devices based on the available short circuit current at the overcurrent protection device terminals to meet the requirements of the National Electrical Code Article 620.62. If a miscoordination occurs between upstream and downstream overcurrent protection devices, the system study Engineer shall contact the successful switchgear manufacturer to obtain results of factory laboratory testing for the selected overcurrent protection devices. If a miscoordination still exists, the system study Engineer shall advise the manufacturer. The manufacturer shall be responsible to select proper frame sizes/types to assure each upstream overcurrent protection device will selectively coordinate with all breakers downstream.
3. All overcurrent protection device(s) associated with the Emergency, Life Safety, Critical , Equipment and Legally Required Branches of the emergency distribution system shall be selectively coordinated from .01 sec with all upstream overcurrent protection devices based on the available short circuit current at the overcurrent protection device terminals to meet the requirements of the National Electrical Code Articles 700.27 and 701.18. If a miscoordination occurs between upstream and downstream overcurrent protection devices, the system study Engineer shall contact the successful switchgear manufacturer to obtain results of factory laboratory testing for the selected overcurrent protection devices. If a miscoordination still exists, the system study Engineer shall advise the Resident Engineer.

#### F. Flash Protection Boundaries

1. Calculation of flash protection boundaries shall be performed on all parts of the electrical system, for the Owner's documentation and implementation of details of limits of approach boundaries as required by NFPA 70E Standard for Electrical Safety Requirements for Employee Workplaces.
2. Flash protection boundaries shall be calculated for equipment required to be worked on while energized electrical conductors or circuit parts are exposed. Calculations shall be provided for the following equipment including but not limited to:
  - a. Substation and switchboard assemblies
  - b. Dimming and relay panels
  - c. Panelboards
  - d. Disconnect switches
  - e. Controller equipment such as variable frequency/adjustable speed drives
  - f. Fuses and circuit breakers
  - g. Rotating equipment
  - h. Batteries
  - i. Generators
  - j. Automatic transfer switches
  - k. Premises wiring
3. Flash protection boundaries for circuits rated 600V and less shall be calculated utilizing one of the following formulae:
 
$$D_c = [ 2.65 \times MVA_{bf} \times f ]^{1/2}$$
 or,
 
$$D_c = [ 53 \times MVA \times f ]^{1/2}$$
 where:
 

$D_c$  = distance of person from an arc source for a just curable burn in feet  
 $MVA_{bf}$  = bolted fault MVA at point involved  
 $MVA$  = MVA rating of transformer. For transformers with MVA ratings below 0.75 MVA, multiply the transformer MVA rating by 1.25  
 $t$  = time of arc exposure in seconds

4. All electrical distribution equipment shall be identified and labeled with Arch Flash Boundaries.

G. Incident Energy Exposures

1. Calculation of incident energy exposures shall be performed on all parts of the electrical system, for the Owner's determination and implementation of details of personal protective equipment as required by NFPA 70E Standard for Electrical Safety Requirements for Employee Workplaces.
2. Incident energy exposures shall be calculated for equipment required to be worked on while energized electrical conductors or circuit parts are exposed. Incident energy exposures for circuits rated 600V and less and emanating from any of the equipment listed in Paragraph titled Flash Protection Boundaries shall be calculated utilizing the 'Arc in a Cubic Box' formula listed as follows with results expressed in calories/square centimeter (cal/cm<sup>2</sup>):

$$E_{MB} = 1038.7 \times D_B^{-1.4738 \times t_A} \times [(0.0093 \times F^2) - (0.3453 \times F) + 5.9675]$$

where:

$E_{MB}$  = maximum 20 in. cubic box incident energy, cal/cm<sup>2</sup>

$D_B$  = distance from arc electrodes, inches (for distances 18 in. and greater)<sup>Note 1</sup>

$t_A$  = arc duration, seconds

$F$  = bolted fault short circuit current, kA (for the range of 16 to 50 kA)

Note 1: Incident energy exposure level shall be based on the working distance of the employee's face and chest areas from a prospective arc source for the specific task to be performed. Utilize 18 inches for all calculations.

3. Incident energy exposure calculations for lower level (downstream) components shall be considered the same as for higher level (upstream) components of the same feeder or branch circuit where the same overcurrent protective device serves both higher and lower components and where the available short circuit current is not depreciably reduced due to increased system impedances such as would be introduced with long conductor lengths.

## 1.6 ANALYSIS

- A. Analyze the short circuit calculations, and highlight any equipment that is determined to be underrated as specified. Propose approaches to effectively protect the underrated equipment. Provide minor modifications to conform with the study (Examples of minor modifications are trip sizes within the same frame, the time curve characteristics of induction relays, C.T. ranges, etc.).
- B. After developing the coordination curves, highlight areas lacking coordination. Present a technical evaluation with a discussion of the logical compromises for best coordination.

## 1.7 STUDY REPORT

- A. The results of the study shall be summarized in a final report. Six (6) bound copies of the final report shall be submitted to the Resident Engineer.

B. The report shall include the following sections:

1. Descriptions, purpose, basis and scope of the study.
2. Tabulations of circuit breaker, fuse and other protective device ratings versus calculated short circuit duties, and commentary regarding same.
3. Protective device time versus current coordination curves, tabulations of relay and circuit breaker trip settings, fuse selection, and commentary regarding same.
4. Fault current calculations including a definition of terms and guide for interpretation of computer printout.
5. Flash protection boundaries indicated on a table of listing all equipment.
6. Flash protection incident energy exposures including a definition of terms and guide for interpretation of calculations.

1.8 ADJUSTMENTS, SETTINGS AND MODIFICATIONS

- A. Necessary final field adjustments, settings and minor modifications shall be made to conform with the protective device study without additional cost to the Government.
- B. All final circuit breaker and relay settings and fuse sizes shall be made in accordance with the recommendations of the protective device study.
- C. Electrical boundaries shall be painted in yellow around switchgear access.

--- END ---

SECTION 26 05 80  
ELECTRICAL ACCEPTANCE TESTS

## PART 1 - GENERAL

## 1.1 DESCRIPTION OF WORK

- A. The Contractor shall engage the services of a recognized independent NETA testing firm for the purpose of performing inspections and tests as herein specified.
- B. The testing firm shall provide all material, equipment, labor, and technical supervision to perform such tests and inspections. It is the purpose of these specifications to assure that all tested electrical equipment, both Contractor and Owner supplied, is operational and within industry and manufacturer's tolerances and is installed in accordance with design specifications.
- C. The tests and inspections shall determine suitability for energization.
- D. An itemized description of equipment to be inspected and tested follows:
  - 1. Substation:
    - a. 15 kV load interrupter switch and fuses.
    - b. Surge arresters.
    - c. Substation transformer.
    - d. Low voltage switchboard including:
      - 1) Main, tie and feeder drawout power circuit breakers.
      - 2) Metering, instrumentation and relays.
      - 3) Instrument transformers.
      - 4) Bussing.
  - 2. Grounding system.
  - 3. Ground fault protection systems.
  - 4. Conductors
    - a. Medium voltage conductors.
    - b. 600 volt conductors. (60 amperes and larger)
  - 5. Low voltage distribution equipment
    - a. Metering.
    - b. Motor control centers.
    - c. Panelboards.
    - d. Switchboards.
    - e. Enclosed circuit breakers.
  - 6. Motors.
  - 7. Emergency system equipment
    - a. Automatic transfer switches.
  - 8. Surge arresters.

## 1.2 RELATED WORK

- A. For work to be included as part of this Section, to be furnished and installed by the Contractor, refer to the following:
1. Section 26 05 13 – Medium Voltage Cable
  2. Section 26 05 21 – Low Voltage Electrical Power Conductors and Cables (60 Volts and Below)
  3. Section 26 05 26 – Grounding and Bonding for Electrical Systems
  4. Section 26 05 71 – Electrical System Protective Device Study
  5. Section 26 11 16 – Secondary Unit Substations
  6. Section 26 22 00 – Low Voltage Switchgear
  7. Section 26 23 00 – Low Voltage Switchgear
  8. Section 26 24 11 – Distribution Switchboards
  9. Section 26 24 16 – Panelboards
  10. Section 26 29 11 – Low Voltage Motor Starters
  11. Section 26 29 21 – Disconnect Switches
  12. Section 26 36 23 – Automatic Transfer Switches
  13. Section 26 43 13 – Transient Voltage Surge Suppression
- B. Carefully examine all of the Contract Documents, criteria sheets and all other Sections of the specifications for requirements which affect work under this Section, whether or not such work is specifically mentioned in this Section.

## 1.3 REFERENCES

- A. All inspections and field tests shall be in accordance with the latest adopted edition of the following codes, standards, and specifications except as provided otherwise herein.
1. American National Standards Institute - ANSI
  2. Institute of Electrical and Electronic Engineers - IEEE
    - a. ANSI/IEEE C2, National Electrical Safety Code
    - b. ANSI/IEEE C37, Guides and Standards for Circuit Breakers, Switchgear, Relays, Substations, and Fuses.
    - c. ANSI/IEEE C57, Distribution, Power, and Regulating Transformers.
    - d. ANSI/IEEE C62, Surge Protection.
    - e. ANSI/IEEE Std. 43 (R1992). IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machinery.
    - f. ANSI/IEEE Std. 81. IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System.
    - g. ANSI/IEEE Std. 142. IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems (IEEE Green Book.).
    - h. ANSI/IEEE Std. 241. IEEE Recommended Practice for Electric Power Systems in Commercial Buildings (Gray Book).
    - i. ANSI/IEEE Std. 242. IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems (Buff Book).
    - j. ANSI/IEEE Std. 399. IEEE Recommended Practice for Power Systems Analysis (Brown Book).
    - k. ANSI/IEEE Std. 446. IEEE Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications (Orange Book).
    - l. ANSI/IEEE Std. 493. IEEE Recommended Practice for the Design of Reliable Industrial and Commercial Power Systems (Gold Book).

- m. ANSI/IEEE Std. 602. IEEE Recommended Practice for Electric Systems in Health Care Facilities (White Book).
  - n. ANSI/IEEE Std 1100. IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment (Emerald Book).
  - o. ANSI/IEEE Std. 48. IEEE Standard Test Procedures and Requirements for High-Voltage AC Cable Terminations.
  - p. ANSI/IEEE Std. 400. IEEE Guide for Making High-Direct-Voltage Tests on Power Cable Systems in the Field.
  - q. ANSI/IEEE Std. 450. IEEE Recommended Practice for Maintenance, Testing, and Replacement of Large Lead Storage Batteries for Generating Stations and Substations.
  - r. ANSI/IEEE Std. 1106. IEEE Recommended Practice for Maintenance, Testing, and Replacement of Nickel-Cadmium Storage Batteries for Generating Stations and Substations.
- 3. Insulated Cable Engineers Association - ICEA
  - 4. InterNational Electrical Testing Association - NETA
    - a. NETA Maintenance Testing Specifications for Electrical Power Distribution Equipment and Systems.
  - 5. National Electrical Manufacturer's Association - NEMA
    - a. NEMA Standard for Publication No. AB4: Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications.
    - b. NEMA Publication MG1: Motors and Generators
  - 6. National Fire Protection Association - NFPA
    - a. ANSI/NFPA 70: National Electrical Code.
    - b. ANSI/NFPA 70B: Recommended Practice for Electric Equipment Maintenance.
    - c. ANSI/NFPA 70E: Electrical Safety Requirements for Employee Workplaces.
    - d. ANSI/NFPA 99: Standard for Healthcare Facilities.
    - e. ANSI/NFPA 101: Life Safety Code.
    - f. ANSI/NFPA 110: Emergency and Standby Power Systems.
    - g. ANSI/NFPA 780: Lightning Protection Code.
  - 7. Occupational Safety and Health Administration - OSHA
  - 8. State and local codes and ordinances
  - 9. Underwriters Laboratory - UL

#### 1.4 QUALIFICATIONS OF THE TESTING FIRM

- A. The testing firm shall be an independent testing organization which can function as an unbiased testing authority, professionally independent of the manufacturers, suppliers, and installers of equipment or systems evaluated by the testing firm.
- B. The testing firm shall be regularly engaged in the testing of electrical equipment devices, installations, and systems.
- C. The testing firm shall meet the criteria for Full Membership or be a Full Member company of the InterNational Electrical Testing Association.

- D. The lead, on site, technical person shall be currently certified by the InterNational Electrical Testing Association (NETA) or the National Institute for Certification in Engineering Technologies (NICET) in electrical power distribution system testing.
- E. The testing firm shall utilize technicians who are regularly employed by the firm for testing services.
- F. The testing firm shall submit proof of the above qualifications with bid documents when requested.

#### 1.5 DIVISION OF RESPONSIBILITY

- A. The Contractor shall perform routine insulation-resistance, continuity, and rotation tests for all distribution and utilization equipment prior to, and in addition to, tests performed by the testing firm specified herein.
- B. The Contractor shall supply a suitable and stable source of electrical power to each test site. The testing firm shall specify the specific power requirements.
- C. The Contractor shall notify the testing firm when equipment becomes available for acceptance tests. Work shall be coordinated to expedite project scheduling.
- D. The Contractor shall supply a short-circuit analysis and coordination study, a protective device setting sheet, a complete set of electrical plans, specifications, and any pertinent change orders to the testing firm prior to commencement of testing.
- E. The Architect shall be notified prior to commencement of any testing.
- F. Any system, material, or workmanship which is found defective on the basis of acceptance tests shall be reported.
- G. The testing firm shall maintain a written record of all tests and shall assemble and certify a final test report.
- H. Safety and Precautions
  - 1. Safety practices should include, but are not limited to, the following requirements:
    - a. Occupational Safety and Health Act.
    - b. Accident Prevention Manual for Industrial Operations, National Safety Council.
    - c. Applicable state and local safety operating procedures.
    - d. Owner's safety practices.
    - e. ANSI/NFPA 70E, Electrical Safety Requirements for Employee Workplaces.
    - f. American National Standards for Personnel Protection: Lockout/Tagout.
  - 2. All tests shall be performed with apparatus de-energized except where otherwise specifically required.
  - 3. The testing organization shall have a designated safety representative on the project to supervise operations with respect to safety.



## 1.6 SUITABILITY OF TEST EQUIPMENT

- A. All test equipment shall be in good mechanical and electrical condition.
- B. Split-core current transformers and clamp-on or tong-type ammeters require careful consideration of the following in regard to accuracy:
  - 1. Position of the conductor within the core.
  - 2. Clean, tight fit of the core pole faces.
  - 3. Presence of external fields.
  - 4. Accuracy of the current transformer ratio in addition to the accuracy of the secondary meter.
- C. Selection of metering equipment should be based on a knowledge of the waveform of the variable being measured. Digital multimeters may be average or RMS sensing and may include or exclude the dc component. When the variable contains harmonics or dc offset and, in general, any deviation from a pure sine wave, average sensing, RMS scaled meters may be misleading.
- D. Field test metering used to check power system meter calibration must have an accuracy higher than that of the instrument being checked.
- E. Accuracy of metering in test equipment shall be appropriate for the test being performed but not in excess of two percent of the scale used.
- F. Waveshape and frequency of test equipment output waveforms shall be appropriate for the test and tested equipment.

## 1.7 TEST INSTRUMENT CALIBRATION

- A. The testing firm shall have a calibration program which assures that all applicable test instruments are maintained within rated accuracy.
- B. The accuracy shall be directly traceable to the National Institute of Standards and Technology. (NIST).
- C. Instruments shall be calibrated in accordance with the following frequency schedule:
  - 1. Field instruments: Analog, 6 months maximum; Digital, 12 months maximum
  - 2. Laboratory instruments: 12 months
  - 3. Leased specialty equipment: 12 months where accuracy is guaranteed by lessor.
- D. Dated calibration labels shall be visible on all test equipment.
- E. Records, which show date and results of instruments calibrated or tested, must be kept up-to-date.
- F. Up-to-date instrument calibration instructions and procedures shall be maintained for each test instrument.
- G. Calibrating standard shall be of higher accuracy than that of the instrument tested.

## 1.8 TEST REPORT

- A. The test report shall include the following:
1. Summary of project.
  2. Description of equipment tested.
  3. Description of test.
  4. Test results.
  5. Analysis and recommendations.
- B. Furnish a copy or copies of the complete report to the Owner as required in the acceptance Contract.

## PART 2 – PRODUCTS NOT USED

## PART 3 - EXECUTION

### 3.1 SWITCHGEAR AND SWITCHBOARD ASSEMBLIES

- A. Visual and Mechanical Inspection
1. Compare equipment nameplate data with drawings and specifications.
  2. Inspect physical, electrical, and mechanical condition.
  3. Confirm correct application of manufacturer's recommended lubricants.
  4. Verify appropriate anchorage, required area clearances, physical damage, and correct alignment.
  5. Inspect all doors, panels, and sections for paint, dents, scratches, fit, and missing hardware.
  6. Verify that fuse and/or circuit breaker sizes and types correspond to drawings and coordination study as well as to the circuit breaker's address for microprocessor-communication packages.
  7. Verify that current and potential transformer ratios correspond to drawings.
  8. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
  9. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
    - a. Attempt closure on locked-open devices. Attempt to open locked-closed devices.
    - b. Make key exchange with devices operated in off-normal positions.
  10. Inspect insulators for evidence of physical damage or contaminated surfaces.
  11. Verify correct barrier and shutter installation and operation.
  12. Exercise all active components.
  13. Inspect all mechanical indicating devices for correct operation.
  14. Verify that filters are in place and/or vents are clear.
  15. Test operation, alignment, and penetration of instrument transformer withdrawal disconnects, current-carrying and grounding, as indicated elsewhere in these specifications.

16. Inspect control power transformers.
  - a. Inspect physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.
  - b. Verify that primary and secondary fuse ratings or circuit breakers match drawings.
  - c. Verify correct functioning of drawout disconnecting and grounding contacts and interlocks.

B. Electrical Tests

1. Perform tests on all instrument transformers as indicated elsewhere in these specifications.
2. Perform ground resistance tests as indicated elsewhere in these specifications.
3. Perform resistance tests through all bus joints with a low-resistance ohmmeter. Any joints that cannot be directly measured due to permanently installed insulation wrap shall be indirectly measured from closest accessible connection.
4. Perform insulation-resistance tests on each bus section, phase-to-phase and phase-to-ground.
5. After insulation resistance test levels are above minimum published values, perform an overpotential test on each bus section, each phase to ground with phases not under test grounded, in accordance with manufacturer's published data. The test voltage shall be applied for one minute.
6. Perform insulation-resistance tests at 1000 volts dc on all control wiring. Do not perform this test on wiring connected to solid-state components.
7. Perform control wiring performance test in accordance with System Function Tests indicated elsewhere in these specifications.
8. Perform current injection tests on the entire current circuit in each section of switchgear.
  - a. Perform current tests by primary injection, where possible, with magnitudes such that a minimum of 1.0 ampere flows in the secondary circuit.
  - b. Where primary injection is impractical, utilize secondary injection with a minimum current of 1.0 ampere.
  - c. Test current at each device.
9. Determine accuracy of all meters and calibrate watt-hour meters in accordance with the metering section of these specifications. Verify multipliers.
10. Perform phasing check on double-ended switchgear to insure correct bus phasing from each source.
11. Perform the following tests on control power transformers.
  - a. Perform insulation-resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with manufacturers published data.
  - b. Perform secondary wiring integrity test. Disconnect transformer at secondary terminals and connect secondary wiring to correct secondary voltage. Confirm potential at all devices.
  - c. Verify correct secondary voltage by energizing primary winding with system voltage. Measure secondary voltage with the secondary wiring disconnected.
  - d. Verify correct function of control transfer relays located in switchgear with multiple power sources in following energized source for control power transformers.

## 12. Potential Transformer Circuits

- a. Perform secondary wiring integrity test. Disconnect transformer at secondary terminals and connect secondary wiring to correct secondary voltage. Confirm correct potential at all devices.
- b. Verify secondary voltage by energizing primary winding with system voltage. Measure secondary voltage with the secondary wiring disconnected.

## 13. Verify operation of switchgear/switchboard heaters.

## C. Test Values

1. Bolt-torque levels shall be in accordance with manufacturers published data.
2. Compare bus connection resistances to values of similar connections.
3. Insulation-resistance values for bus, control wiring, and control power transformers shall be in accordance with manufacturer's published data. Values of insulation resistance less than manufacturer's minimum should be investigated. Overpotential tests should not proceed until insulation-resistance levels are raised above minimum values.
4. Apply overpotential test voltages in accordance with manufacturer's recommendations.
5. The insulation shall withstand the overpotential test voltage applied.

## 3.2 DRY TYPE TRANSFORMERS

## A. Air-Cooled, 600 Volt and Below - Small (167 kVA Single-Phase, 500 KVA Three-Phase, and Smaller)

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Verify that resilient mounts are free and that any shipping brackets have been removed.
4. Perform insulation-resistance test. Calculate polarization index. Measurements shall be made from winding-to-winding and each winding-to-ground. Test voltages and minimum resistance shall be in accordance with manufacturers published data. Results shall be temperature corrected as applicable.
5. Verify that as-left tap connections are as specified.

## B. Air-Cooled, All Above 600 Volt and 600 Volt and Below - Large (Greater than 167 Single-Phase and 500 kVA Three-Phase)

## 1. Visual and Mechanical Inspection

- a. Compare equipment nameplate data with drawings and specifications.
- b. Inspect physical and mechanical condition.
- c. Verify that control and alarm settings on temperature indicators are as specified.
- d. Verify that cooling fans operate correctly and that fan motors have correct overcurrent protection.
- e. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
- f. Perform specific inspections and mechanical tests as recommended by manufacturer.
- g. Make a close examination for shipping brackets or fixtures that may not have been removed during installation. Insure that resilient mounts are free.
- h. Verify that winding core, frame, and enclosure grounding are correct.
- i. Verify that as-left tap connections are as specified.

## 2. Electrical Tests

- a. Perform insulation-resistance tests winding-to-winding and each winding-to-ground, with test voltage in accordance with manufacturers published data. Calculate polarization index.
- b. Perform power-factor or dissipation-factor tests in accordance with the test equipment manufacturer's instructions.
- c. Perform a turns-ratio test on all tap connections. Verify that winding polarities are in accordance with nameplate.
- d. Verify that core is solidly grounded. If core is insulated and a removable core ground strap is available, perform core insulation-resistance test at 500 volts dc.
- e. Verify correct secondary voltage phase-to-phase and phase-to-neutral after energization and prior to loading.

### C. Test Values

1. Bolt-torque levels shall be in accordance with manufacturers published data.
2. Insulation-resistance test values at one minute should not be less than values recommended by the manufacturer. Results shall be temperature corrected as applicable.
3. The polarization index should be compared to manufacturer's factory test results. If manufacturer's data is not available, acceptance test results will serve as baseline data.
4. Turns-ratio test results should not deviate more than one-half percent from either the adjacent coils or the calculated ratio.
5.  $C_H$  and  $C_L$  dissipation-factor/power-factor values will vary due to support insulators and bus work utilized on dry transformers. The following should be expected on  $C_{HL}$  power factors:
  - a. Power Transformers: two percent or less
  - b. Distribution Transformers: five percent or less
6. Consult transformer manufacturer's or test equipment manufacturer's data for additional information.
7. If winding-resistance test results vary more than one percent from adjacent windings, consult manufacturer.
8. Typical excitation current test data pattern for three-legged core transformer is two similar current readings and one lower current reading.
9. If core insulation resistance is less than one megohm at 500 volts dc, consult manufacturer.
10. AC overpotential test shall not exceed 75 percent of factory test voltage for one minute duration. DC overpotential test shall not exceed 100 percent of the factory RMS test voltage for one minute duration. The insulation shall withstand the overpotential test voltage applied.

### 3.3 CABLES - 600 VOLT, 60 AMPERES AND ABOVE

#### A. Visual and Mechanical Inspection

1. Compare cable data with drawings and specifications.
2. Inspect exposed sections of cables for physical damage and correct connection in accordance with single-line diagram.
3. Verify tightness of accessible bolted connections by calibrated torque wrench in accordance with manufacturer's published data.
4. Inspect compression-applied connectors for correct cable match and indentation.

5. Verify cable color coding with applicable engineer's specifications and National Electrical Code standards.

B. Electrical Tests

1. Perform insulation-resistance test on each conductor with respect to ground and adjacent conductors. Applied potential to be 1000 volts dc for one minute.
2. Perform continuity test to insure correct cable connection.

C. Test Values

1. Bolt-torque levels shall be in accordance with manufacturers published data.
2. Minimum insulation-resistance values shall be not less than 50 megohms.
3. Investigate deviations between adjacent phases.

### 3.4 CABLES - MEDIUM VOLTAGE

A. Visual and Mechanical Inspection

1. Compare cable data with drawings and specifications.
2. Inspect exposed sections of cables for physical damage.
3. Verify tightness of accessible bolted connections by calibrated torque wrench in accordance with manufacturer's published data.
4. Inspect compression-applied connectors for correct cable match and indentation.
5. Inspect for shield grounding, cable support, and termination.
6. Verify that visible cable bends meet or exceed ICEA and/or manufacturer's minimum allowable bending radius.
7. Inspect for adequate fireproofing in common cable areas, if specified.
8. If cables are terminated through window-type current transformers, make an inspection to verify that neutral and ground conductors are correctly placed and that shields are correctly terminated for operation of protective devices.
9. Visually inspect jacket and insulation condition.
10. Inspect for correct identification and arrangements.

B. Electrical Tests

1. Perform a shield-continuity test on each power cable by ohmmeter method.
2. Perform an insulation-resistance test utilizing a megohmmeter with a voltage output of at least 2,500 volts. Individually test each conductor with all other conductors and shields grounded. Test duration shall be one minute.
3. Perform a dc high-potential test on all cables. Adhere to all precautions and limits as specified in the applicable NEMA/ICEA Standard for the specific cable. Perform tests in accordance with ANSI/IEEE Standard 400. Test procedure shall be as follows, and the results for each cable test shall be recorded as specified herein. Test voltages shall not exceed 80 percent of cable manufacturer's factory test value.
  - a. Insure that the input voltage to the test set is regulated.
  - b. Current-sensing circuits in test equipment shall measure only the leakage current associated with the cable under test and shall not include internal leakage of the test equipment.
  - c. Record wet and dry bulb temperatures or relative humidity and temperature.
  - d. Test each section of cable individually.
  - e. Individually test each conductor with all other conductors grounded. Ground all shields.

- f. Terminations shall be adequately corona-suppressed by guard ring, field reduction sphere, or other suitable methods as necessary.
- g. Insure that the maximum test voltage does not exceed the limits for terminators specified in IEEE Standard 48 or manufacturer's specifications.
- h. Apply a dc high-potential test in at least five equal increments until maximum test voltage is reached. No increment shall exceed the voltage rating of the cable. Record dc leakage current at each step after a constant stabilization time consistent with system charging current.
- i. Raise the conductor to the specified maximum test voltage and hold for 15 minutes on shielded cable and five minutes on nonshielded cable. Record readings of leakage current at 30 seconds and one minute and at one minute intervals thereafter.
- j. Reduce the conductor test potential to zero and measure residual voltage at discrete intervals.
- k. Apply grounds for a time period adequate to drain all insulation stored charge.
- l. When new cables are spliced into existing cables, the dc high-potential test shall be performed on the new cable prior to splicing in accordance with this Section. After test results are approved for new cable and the splice is completed, an insulation-resistance test and a shield-continuity test shall be performed on the length of new and existing cable including the splice. After a satisfactory insulation-resistance test, a dc high-potential test shall be performed on the cable utilizing a test voltage acceptable to Owner and not exceeding 60 percent of factory test value.

#### C. Test Values

- 1. Shielding must exhibit continuity. Investigate resistance values in excess of ten ohms per 1,000 feet of cable.
- 2. Graphic plots may be made of leakage current versus step voltage at each increment and leakage current versus time at final test voltages.
  - a. The step voltage slope should be reasonably linear.
  - b. Capacitive and absorption current should decrease continually until steady state leakage is approached.

### 3.5 MEDIUM-VOLTAGE, METAL-ENCLOSED AIR SWITCHES

#### A. Visual and Mechanical Inspection

- 1. Compare equipment nameplate data with drawings and specifications.
- 2. Inspect physical and mechanical condition.
- 3. Confirm correct application of manufacturer's recommended lubricants.
- 4. Verify appropriate anchorage and required area clearances.
- 5. Verify appropriate equipment grounding.
- 6. Verify correct blade alignment, blade penetration, travel stops, and mechanical operation.
- 7. Verify that fuse sizes and types are in accordance with drawings and short-circuit and coordination studies.
- 8. Verify that expulsion-limiting devices are in place on all holders having expulsion-type elements.
- 9. Verify that each fuse holder has adequate mechanical support.
- 10. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
- 11. Test all interlocking systems for correct operation and sequencing.
- 12. Verify correct phase-barrier materials and installation.
- 13. Compare switchblade clearances with industry standards.

14. Inspect all indicating and control devices for correct operation.

B. Electrical Tests

1. Perform insulation-resistance tests on each pole, phase-to-phase and phase-to-ground with switch closed and across each open pole for one minute. Test voltage shall be in accordance with manufacturer's published data.
2. Perform an overpotential test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with manufacturer's published data.
3. Measure contact resistance across each switchblade and fuse holder.
4. Measure fuse resistance.
5. Verify heater operation.

C. Test Values

1. Bolt-torque levels shall be in accordance with manufacturers published data.
2. The insulation shall withstand the overpotential test voltage applied.
3. Minimum insulation resistance shall be in accordance with manufacturer's published data.
4. Investigate any contact resistance values which deviate from adjacent poles or similar switches by more than 25 percent.
5. Investigate fuse resistance values that deviate from each other by more than 15 percent.

3.6 INSULATED CASE/MOLDED CASE CIRCUIT BREAKERS (400 AMPERES AND ABOVE)

A. Visual and Mechanical Inspection

1. Compare nameplate data with drawings and specifications.
2. Inspect circuit breaker for correct mounting.
3. Operate circuit breaker to insure smooth operation.
4. Inspect case for cracks or other defects.
5. Verify tightness of accessible bolted connections and/or cable connections by calibrated torque-wrench method in accordance with manufacturer's published data.
6. Inspect mechanism contacts and arc chutes in unsealed units.

B. Electrical Tests

1. Perform a contact-resistance test.
2. Perform an insulation-resistance test at 1000 volts dc from pole-to-pole and from each pole-to-ground with breaker closed and across open contacts of each phase.
3. Perform adjustments for final settings in accordance with coordination study supplied by Contractor.
4. Perform long-time delay time-current characteristic tests by passing 300 percent rated current through each pole separately unless series testing is required to defeat ground fault functions.
5. Determine short-time pickup and delay by primary current injection.
6. Determine ground-fault pickup and time delay by primary current injection.
7. Determine instantaneous pickup current by primary injection using run-up or pulse method.
8. Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, and anti-pump function.



## C. Test Values

1. Bolt-torque levels shall be in accordance with manufacturers published data.
2. Compare microhm or millivolt drop values to adjacent poles and similar breakers. Investigate deviations of more than 25 percent. Investigate any value exceeding manufacturer's recommendations.
3. Insulation resistance shall not be less than 100 megohms.
4. Trip characteristic of breakers shall fall within manufacturer's published time-current characteristic tolerance band, including adjustment factors.
5. For molded-case circuit breakers all trip times shall fall within times indicated in Table 5-3 of NEMA Standard AB4-1991. Circuit breakers exceeding specified trip time at 300 percent of pickup shall be tagged defective.
6. For molded-case circuit breakers instantaneous pickup values shall be within values shown on Table 5-4 of NEMA Standard AB4-latest adopted edition.

## 3.7 POWER CIRCUIT BREAKERS

## A. Visual and Mechanical Inspection

1. Compare nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Confirm correct application of manufacturer's recommended lubricants.
4. Inspect anchorage, alignment, and grounding. Inspect arc chutes. Inspect moving and stationary contacts for condition, wear, and alignment.
5. Verify that all maintenance devices are available for servicing and operating the breaker.
6. Verify that primary and secondary contact wipe and other dimensions vital to satisfactory operation of the breaker are correct.
7. Perform all mechanical operator and contact alignment tests on both the breaker and its operating mechanism.
8. Verify tightness of accessible bolted bus connections by calibrated torque-wrench method. Refer to manufacturer's instructions for correct torque levels.
9. Check cell fit and element alignment.
10. Check racking mechanism.

## B. Electrical Tests

1. Perform a contact-resistance test.
2. Perform an insulation-resistance test at 1000 volts dc from pole-to-pole and from each pole-to-ground with breaker closed and across open contacts of each phase.
3. Make adjustments for the final settings in accordance with the coordination study supplied by the Contractor.
4. Determine minimum pickup current by primary current injection.
5. Determine long-time delay by primary current injection.
6. Determine short-time pickup and delay by primary current injection.
7. Determine ground-fault pickup and delay by primary current injection.
8. Determine instantaneous pickup value by primary current injection.
9. Activate auxiliary protective devices, such as ground-fault or undervoltage relays, to insure operation of shunt trip devices. Check the operation of electrically-operated breakers in their cubicles.
10. Verify correct operation of any auxiliary features such as trip and pickup indicators, zone interlocking, electrical close and trip operation, trip-free, and anti-pump function.
11. Check charging mechanism.

## C. Test Values

1. Bolt-torque levels shall be in accordance with manufacturers published data.
2. Compare microhm or millivolt drop values to adjacent poles and similar breakers. Investigate deviations of more than 25 percent.
3. Insulation resistance shall not be less than 100 megohms. Investigate values less than 100 megohms.
4. Trip characteristics of breakers shall fall within manufacturer's published time-current tolerance bands.

## 3.8 MEDIUM VOLTAGE VACUUM CIRCUIT BREAKERS

## A. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Confirm correct application of manufacturer's recommended lubricants.
4. Inspect anchorage, alignment, and grounding.
5. Perform all mechanical operational tests on both the circuit breaker and its operating mechanism.
6. Measure critical distances such as contact gap as recommended by manufacturer.
7. Verify tightness of accessible bolted connections by calibrated torque-wrench method in accordance with manufacturer's published data.
8. Record as-found and as-left operation counter readings.

## B. Electrical Tests

1. Perform a contact-resistance test.
2. Perform minimum pickup voltage tests on trip and close coils.
3. Verify trip, close, trip-free, and anti-pump function.
4. Trip circuit breaker by operation of each protective device.
5. Perform insulation-resistance tests pole-to-pole, pole-to-ground, and across open poles at 2,500 volts minimum.
6. Perform vacuum bottle integrity (overpotential) test across each vacuum bottle with the breaker in the open position in strict accordance with manufacturer's instructions. **Do not exceed maximum voltage stipulated for this test.** Provide adequate barriers and protection against x-radiation during this test. Do not perform this test unless the contact displacement of each interrupter is within manufacturer's tolerance. (Be aware that some dc high-potential test sets are half-wave rectified and may produce peak voltages in excess of the breaker manufacturer's recommended maximum.)

## C. Test Values

1. Bolt-torque levels shall be in accordance with manufacturers published data.
2. Compare contact resistance to adjacent poles and similar breakers. Investigate deviations of more than 25 percent. Investigate any value exceeding manufacturer's tolerance.
3. Contact displacement shall be in accordance with factory recorded data marked on the nameplate of each vacuum breaker or bottle.
4. The interrupter shall withstand the overpotential voltage applied.
5. Compare circuit breaker travel and velocity values to manufacturer's acceptable limits.
6. Control wiring insulation resistance shall comply with manufacturer's published data. Values of insulation resistance less than manufacturer's minimum should be investigated.

7. Dissipation-factor/power-factor test results shall be compared to manufacturer's published data. In the absence of manufacturer's published data the comparison shall be made to similar breakers.
8. Dissipation-factor/power-factor and capacitance test results shall be within ten percent of nameplate rating for bushings.
9. The insulation shall withstand the overpotential test voltage applied.

### 3.9 PROTECTIVE RELAYS

#### A. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect relays and cases for physical damage. Remove shipping restraint material.
3. Tighten case connections. Inspect cover for correct gasket seal. Clean cover glass. Inspect shorting hardware, connection paddles, and/or knife switches. Remove any foreign material from the case. Verify target reset.
4. Inspect relay for foreign material, particularly in disc slots of the damping and electromagnets. Verify disk clearance. Verify contact clearance and spring bias. Inspect spiral spring convolutions. Inspect disk and contacts for freedom of movement and correct travel. Verify tightness of mounting hardware and connections. Burnish contacts. Inspect bearings and/or pivots.
5. Set relays in accordance with coordination study supplied by owner.

#### B. Electrical Tests

1. Perform insulation-resistance test on each circuit-to-frame. Determine from the manufacturer's instructions the allowable procedures for this test for solid-state and microprocessor-based relays.
2. Inspect targets and indicators.
  - a. Determine pickup and dropout of electromechanical targets.
  - b. Verify operation of all light-emitting diode indicators.
  - c. Set contrast for liquid-crystal display readouts.

#### C. Functional Operation

1. 2/62 Timing Relay
  - a. Determine time delay.
  - b. Determine instantaneous contacts.
2. 21 Distance Relay
  - a. Determine maximum reach.
  - b. Determine maximum torque angle.
  - c. Determine offset.
  - d. **[Plot impedance circle.]**
3. 24 Volts/Hertz Relay
  - a. Determine pickup frequency at rated voltage.
  - b. Determine pickup frequency at a second voltage level.
  - c. Determine time delay.

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4. 25 Sync Check Relay
    - a. Determine closing zone at rated voltage.
    - b. Determine maximum voltage differential that permits closing at zero degrees.
    - c. Determine live line, live bus, dead line, and dead bus set points.
    - d. Determine time delay.
    - e. Verify dead bus/live line, dead line/live bus and dead bus/dead line control functions.
  5. 27 Undervoltage Relay
    - a. Determine dropout voltage.
    - b. Determine time delay.
    - c. Determine the time delay at a second point on the timing curve for inverse time relays.
  6. 32 Directional Power Relay
    - a. Determine minimum pickup at maximum torque angle.
    - b. Determine closing zone.
    - c. Determine maximum torque angle.
    - d. Determine time delay.
    - e. Verify the time delay at a second point on the timing curve for inverse time relays.
    - f. **[Plot the operating characteristic.]**
  7. 40 Loss of Field (Impedance) Relay
    - a. Determine maximum reach.
    - b. Determine maximum torque angle.
    - c. Determine offset.
    - d. **[Plot impedance circle.]**
  8. 46 Current Balance Relay
    - a. Determine pickup of each unit.
    - b. Determine percent slope.
    - c. Determine time delay.
  9. 46N Negative Sequence Current Relay
    - a. Determine negative sequence alarm level and trip.
    - b. Determine negative sequence minimum trip level.
    - c. Determine maximum time delay.
    - d. Verify two points on the  $(I_2)^2t$  curve.
  10. 47 Phase Sequence or Phase Balance Voltage Relay
    - a. Determine positive sequence voltage to close the normally open contact.
    - b. Determine positive sequence voltage to open the normally closed contact (undervoltage trip).
    - c. Verify negative sequence trip.
    - d. Determine time delay to close the normally open contact with sudden application of 120 percent of pickup.
    - e. Determine time delay to close the normally closed contact upon removal of voltage when previously set to rated system voltage.

11. 49R Thermal Replica Relay
  - a. Determine time delay at 300 percent of setting.
  - b. Determine a second point on the operating curve.
12. 49T Temperature (RTD) Relay
  - a. Determine trip resistance.
  - b. Determine reset resistance.
13. 50 Instantaneous Overcurrent Relay
  - a. Determine pickup.
  - b. Determine dropout.
14. 51 Time Overcurrent
  - a. Determine minimum pickup.
  - b. Determine time delays at two points on the time current curve.
15. 55 Power Factor Relay
  - a. Determine tripping angle.
  - b. Determine time delay.
16. 59 Overvoltage Relay
  - a. Determine overvoltage pickup.
  - b. Determine time delay to close the contact with sudden application of 120 percent of pickup.
17. 60 Voltage Balance Relay
  - a. Determine voltage difference to close the contacts with one source at rated voltage.
18. 63 Transformer Sudden Pressure Relay
  - a. Determine rate-of-rise or the pickup level of suddenly applied pressure in accordance with manufacturer's specifications.
  - b. Verify operation of the 63 FPX seal-in circuit.
  - c. Verify trip circuit to remote breaker.
19. 64 Ground Detector Relay
  - a. Determine maximum impedance to ground causing relay pickup.
20. 67 Directional Overcurrent Relay
  - a. Determine directional unit minimum pickup at maximum torque angle.
  - b. Determine closing zone.
  - c. Determine overcurrent unit pickup.
  - d. Determine overcurrent unit time delay at two points on the time current curve.

## 21. 79 Reclosing Relay

- a. Determine time delay for each programmed reclosing interval.
- b. Verify lockout for unsuccessful reclosing.
- c. Determine reset time.
- d. **[Determine close pulse duration.]**
- e. Verify instantaneous overcurrent lockout.

## 22. 81 Frequency Relay

- a. Verify frequency set points.
- b. Determine time delay.
- c. Determine undervoltage cutoff.

## 23. 85 Pilot Wire Monitor

- a. Determine overcurrent pickup.
- b. Determine undercurrent pickup.
- c. Determine pilot wire ground pickup level.

## 24. 87 Differential

- a. Determine operating unit pickup.
- b. Determine the operation of each restraint unit.
- c. Determine slope.
- d. Determine harmonic restraint.
- e. Determine instantaneous pickup.

## D. Control Verification

1. Verify that each of the relay contacts performs its intended function in the control scheme including breaker trip tests, close inhibit tests, 86 lockout tests, and alarm functions.

## E. System Tests

1. After the equipment is initially energized, measure magnitude and phase angle of all inputs and compare to expected values.

## F. Test Values

1. When not otherwise specified, use manufacturer's recommended tolerances.
2. When critical test points are specified, the relay should be calibrated to those points even though other test points may be out of tolerance.

## 3.10 INSTRUMENT TRANSFORMERS

## A. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Verify correct connection of transformers with system requirements.
4. Verify that adequate clearances exist between primary and secondary circuit wiring.
5. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.

6. Verify that all required grounding and shorting connections provide contact.
7. Verify correct operation of transformer withdrawal mechanism and grounding operation.
8. Verify correct primary and secondary fuse sizes for potential transformers.

B. Electrical Tests - Current Transformers

1. Perform insulation-resistance test of the current transformer and wiring-to-ground at 1000 volts dc. Do not perform this test on solid-state devices.
2. Perform a polarity test of each current transformer.
3. Perform a ratio-verification test using the voltage or current method in accordance with ANSI C57.13.1 (IEEE Guide for Field Testing of Relaying Current Transformers).
4. Perform an excitation test on transformers used for relaying applications in accordance with ANSI C57.13.1. (IEEE Guide for Field Testing of Relaying Current Transformers).
5. Measure current circuit burdens at transformer terminals and determine the total burden.
6. When applicable, perform insulation-resistance and dielectric withstand tests on the primary winding with secondary grounded. Test voltages shall be in accordance with NETA standards and ANSI C57.13-1993 respectively.

C. Electrical Tests - Voltage Transformers

1. Perform insulation-resistance tests winding-to-winding and each winding-to-ground. Test voltages shall be applied for one minute in accordance with NETA standards. Do not perform this test with solid-state devices connected.
2. Perform a polarity test on each transformer to verify the polarity marks or H1-X1 relationship as applicable.
3. Perform a turns ratio test on all tap positions, if applicable.
4. Measure potential circuit burdens at transformer terminals and determine the total burden.

D. Test Values

1. Insulation-resistance measurement on any instrument transformer shall be not less than NETA standards.
2. Polarity results shall agree with system drawings.
3. Compare measured burdens to calculated burdens supplied by owner.
4. Ratio accuracy shall be within 0.5 percent of nameplate or manufacturer's published data.
5. The insulation shall withstand the overpotential test voltage applied.

### 3.11 METERING

A. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Verify tightness of electrical connections.
4. Inspect cover gasket, cover glass, condition of spiral spring, disc clearance, contacts, and case-shorting contacts, as applicable.
5. Verify mechanically for freedom of movement, correct travel and alignment, and tightness of mounting hardware.

B. Electrical Tests

1. Check calibration of meters at all cardinal points.

2. Calibrate watt-hour meters according to manufacturer's published data.
  3. Verify all instrument multipliers.
- C. Electrically confirm that current transformer and voltage transformer secondary circuits are intact.

### 3.12 GROUNDING SYSTEMS

A. Visual and Mechanical Inspection

1. Verify ground system is in compliance with drawings and specifications.

B. Electrical Tests

1. Perform fall-of-potential test or alternative in accordance with IEEE Standard 81-1991 on the main grounding electrode or system.
2. Perform point-to-point tests to determine the resistance between the main grounding system and all major electrical equipment frames, system neutral, and/or derived neutral points.

C. Test Values

1. The resistance between the main grounding electrode and ground should be no greater than five ohms for commercial or industrial systems and one ohm or less for generating or transmission station grounds unless otherwise specified by the owner. (Reference: IEEE Standard 142.)
2. Investigate point-to-point resistance values which exceed 0.5 ohm.

### 3.13 GROUND-FAULT PROTECTION SYSTEMS

A. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Visually inspect the components for damage and errors in polarity or conductor routing.
  - a. Verify that ground connection is made ahead of neutral disconnect link and on the line side of any ground fault sensor.
  - b. Verify that neutral sensors are connected with correct polarity on both primary and secondary.
  - c. Verify that all phase conductors and the neutral pass through the sensor in the same direction for zero sequence systems.
  - d. Verify that grounding conductors do not pass through zero sequence sensors.
  - e. Verify that the grounded conductor is solidly grounded.
3. Verify tightness of all electrical connections including control circuits.
4. Verify correct operation of all functions of the self-test panel.
5. Verify that the control power transformer has adequate capacity for the system.
6. Set pickup and time-delay settings in accordance with the settings provided in the Owner's specifications. Record appropriate operation and test sequences as required by NEC Article 230-95.



**B. Electrical Tests**

1. Measure the system neutral-to-ground insulation resistance with the neutral disconnect link temporarily removed. Replace neutral disconnect link after testing.
2. Perform the following pickup tests using primary injection:
  - a. Verify that the relay does not operate at 90 percent of the pickup setting.
  - b. Verify pickup is less than 125 percent of setting or 1,200 amperes, whichever is smaller.
3. For summation type systems utilizing phase and neutral current transformers, verify correct polarities by applying current to each phase-neutral current transformer pair. This test also applies to molded-case breakers utilizing an external neutral current transformer.
  - a. Relay should operate when current direction is the same relative to polarity marks in the two current transformers.
  - b. Relay should not operate when current direction is opposite relative to polarity marks in the two current transformers.
4. Measure time delay of the relay at 150 percent or greater of pickup.
5. Verify reduced control voltage tripping capability: 55 percent for ac systems and 80 percent for dc systems.
6. Verify blocking capability of zone interlock systems.

**C. Test Values**

1. System neutral-to-ground insulation shall be a minimum of one megohm.
2. Insulation resistance values shall be in accordance with NETA standards.
3. Relay timing shall be in accordance with manufacturer's specifications but must be no longer than one second at 3,000 amperes.

**3.14 INDUCTION MOTORS****A. Visual and Mechanical Inspection**

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect for correct anchorage, mounting, grounding, connection, and lubrication.
4. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
5. When applicable, perform special tests such as air gap spacing and pedestal alignment.
6. Verify the absence of unusual mechanical or electrical noise or signs of overheating during initial test run.

**B. Electrical Tests**

1. Perform insulation-resistance tests in accordance with ANSI/IEEE Standard 43.
  - a. For motors larger than 200 horsepower, Test duration shall be for ten minutes. Calculate polarization index.
  - b. For motors 200 horsepower and less, Test duration shall be for one minute. Calculate the dielectric-absorption ratio.

2. Perform dc overpotential tests on motors rated at 1,000 horsepower and greater and at 4,000 volts and greater in accordance with ANSI/IEEE Standard 95.
3. Perform insulation-resistance test on pedestal in accordance with manufacturer's published data.
4. Test surge protection devices as indicated elsewhere in these specifications.
5. Test motor starter as indicated elsewhere in these specifications.
6. Verify that resistance temperature detector (RTD) circuits conform to drawings. Verify that metering or relaying devices using the RTD's have the correct rating.
7. Verify that the motor space heater is functional.
8. Perform a rotation test to insure correct shaft direction.
9. Measure running current and evaluate relative to load conditions and nameplate full-load amperes.

C. Test Values

1. Bolt-torque levels shall be in accordance with manufacturers published data.
2. Insulation-resistance test results should comply with values listed NETA standards. Investigate dielectric absorption ratios less than 1.4 and polarization index ratios less than 2.0 for Class B and Class F insulation.

**NOTE:** Overpotential, high-potential, and surge comparison tests shall not be made on motors having values lower than those indicated above.

3. Stator winding dc overpotential test voltage shall be in accordance with NEMA publication MG 1, paragraph 3.01. Test results are dependent on ambient conditions, and evaluation is on a withstand basis. If phase windings can be separately tested, values of leakage current may be compared for similar windings.
4. Vibration amplitudes shall not exceed values shown in MG 1-1987.
5. Salient pole voltage drop should be equal for each pole. Investigate values that differ by more than ten percent.
6. The measured resistance values of motor-field winding, exciter-stator winding, exciter-rotor windings, and field-discharge resistors shall be compared to manufacturer's recommended values.

### 3.15 LOW-VOLTAGE SURGE PROTECTION DEVICES

A. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect for correct mounting and adequate clearances.
4. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
5. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.

B. Electrical Tests

1. Perform insulation-resistance tests. Use manufacturer's recommended values.

C. Test Values

1. Bolt-torque levels shall be in accordance with manufacturers published data.
2. Insulation-resistance values shall be in accordance with NETA standards.

### 3.16 MEDIUM AND HIGH VOLTAGE SURGE PROTECTION DEVICES

#### A. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect for correct mounting and adequate clearances.
4. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
5. Verify that the ground lead on each device is individually attached to a ground bus or ground electrode.
6. Verify that stroke counter, if present, is correctly mounted and electrically connected.

#### B. Electrical Tests

1. Test grounding connection as indicated elsewhere in these specifications.
2. Perform an insulation-resistance test at voltage levels indicated in NETA standards.

#### C. Test Values

1. Bolt-torque levels shall be in accordance with manufacturers published data.
2. Resistance between the arrestor ground terminal and the ground system shall be less than 0.5 ohms.
3. Compare watts loss to similar units.
4. Insulation-resistance values should be in accordance with NETA standards.

### 3.17 CAPACITORS

#### A. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Inspect capacitors for correct mounting and required clearances.
4. Verify that capacitors are electrically connected in their specified configuration.
5. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.

#### B. Electrical Tests

1. Perform insulation-resistance tests from terminal(s) to case for one minute on capacitors with more than one bushing. Test voltage and minimum resistance shall be in accordance with manufacturer's instructions.
2. Measure the capacitance of all terminal combinations.
3. Measure resistance of internal discharge resistors.

#### C. Test Values

1. Bolt-torque levels shall be in accordance with manufacturers published data.
2. Insulation-resistance values less than NETA standards shall be investigated.
3. Investigate capacitance values differing from manufacturer's published data.

4. Investigate discharge resistor values differing from manufacturer's published data. In accordance with NEC Article 460, residual voltage of a capacitor shall be reduced to 50 volts in the following time intervals after being disconnected from the source of supply:

Rated Voltage	Discharge Time
< 600V	1 minute
> 600V	5 minutes

### 3.18 AUTOMATIC TRANSFER SWITCHES

#### A. Visual and Mechanical Inspection

1. Compare equipment nameplate data with drawings and specifications.
2. Inspect physical and mechanical condition.
3. Confirm correct application of manufacturer's recommended lubricants.
4. Verify that manual transfer warnings are attached and visible.
5. Verify tightness of all control connections.
6. Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with manufacturer's published data.
7. Perform manual transfer operation.
8. Verify positive mechanical interlocking between normal and alternate sources.

#### B. Electrical Tests

1. Measure contact-resistance.
2. Perform insulation-resistance tests, phase-to-phase and phase-to-ground, with switch in both source positions.
3. Verify settings and operation of control devices.
4. Calibrate and set all relays and timers as indicated elsewhere in these specifications.
5. Perform automatic transfer tests:
  - a. Simulate loss of normal power.
  - b. Return to normal power.
  - c. Simulate loss of emergency power.
  - d. Simulate all forms of single-phase conditions.
6. Verify correct operation and timing of the following functions:
  - a. Normal source voltage-sensing relays.
  - b. Engine start sequence.
  - c. Time delay upon transfer.
  - d. Alternate source voltage-sensing relays.
  - e. Automatic transfer operation.
  - f. Interlocks and limit switch function.
  - g. Time delay and retransfer upon normal power restoration.
  - h. Engine cooldown and shutdown feature.

#### C. Test Values

1. Bolt-torque levels shall be in accordance with manufacturers published data.
2. Insulation-resistance test voltages and minimum values shall be in accordance with NETA standards.
3. Compare microhm values to adjacent poles and similar switches. Investigate deviations of more than 25 percent.

**3.19 SYSTEM FUNCTION TESTS**

- A. Perform system function tests upon completion of equipment tests. It is the purpose of system function tests to prove the correct interaction of all sensing, processing, and action devices.
- B. Implementation
  - 1. Develop test parameters for the purpose of evaluating performance of all integral components and their functioning as a complete unit within design requirements. Perform these tests.
  - 2. Verify the correct operation of all interlock safety devices for fail-safe functions in addition to design function.
  - 3. Verify the correct operation of all sensing devices, alarms, and indicating devices.

**3.20 FUNCTIONAL PERFORMANCE & INTEGRATED SYSTEMS TESTING**

- A. Functional Performance & Integrated Systems Testing is part of the Commissioning Process. Functional Performance & Integrated Systems Testing shall be performed by the contractor and witnessed and documented by the Commissioning Authority. Refer to Section 019113, Commissioning, for functional performance and integrated systems testing and commissioning requirements.
- B. 3rd Party Quality & Certification Testing & Cx Witnessing Coordinate with the Commissioning Authority for scheduling and witnessing of 3rd party quality and certification testing. All 3rd party quality and certification testing reports are to be provided to the Commissioning Authority. Refer to Section 019113, Commissioning.

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SECTION 26 09 23  
LOW VOLTAGE LIGHTING CONTROL

PART 1 - GENERAL

1.1 DESCRIPTION

- A. This section specifies the furnishing, installation and connection of the low voltage lighting controls
- B. Furnish and install a complete lighting control system. System shall include lighting control relays, microprocessor based programmable lighting controllers, low voltage switches, occupancy sensors, daylight photosensors, power packs, stand-alone room control systems, and other control devices as required including, but not limited to, wire, conduit and other materials required for the installation. Exact quantities and equipment configurations shall be determined by the equipment manufacturer based on plans, specifications, details, and control schedules. The system shall be provided with interface protocols to allow integration with BMS, via BACnet MS/TP based network communications.
- C. In general, all open public corridor and circulation spaces as well as concourse and exterior lighting will be controlled by time of day scheduling via timeclock and Building Automation System (BAS).
- D. Individual suites, office areas, private offices, and other infrequently or intermittently used non-patient care areas will be controlled via occupancy sensor and low voltage switch operating in vacancy mode.
- E. Critical areas such as those involved with patient care or areas critical to the control or function of patient care shall be controlled by conventional line voltage toggle switches.
- F. Where applicable, larger utility spaces will utilize digital timer switches to safely allow automatic shut-off, after pre-determined time.
- G. The system shall also include photocell daylight sensors as indicated on plans to allow programmed lighting curtailment in natural daylight spaces, controlled in an area by area basis.
- H. Lighting control systems shall be installed for selected interior spaces and exterior lighting controls as indicated on plans.
- I. Short circuit ratings shall be appropriate with fault current available at each panel.
- J. Provide arc flash identification labeling on panels.
- K. Dimming systems shall work with selected ballast, based on lighting fixture schedule, to provide dimming in specified fixtures at required control locations.
- L. All control systems including power packs, digital room control systems, and microprocessor based relay systems shall be equipped with distributed intelligence such that the loss of one device or the loss of network connectivity does not affect the function of other devices in the building.

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- M. Provide hot, neutral, and associated switch leg conductors to each line voltage switch device. Secure and cap any unused neutral conductors for future use.
- N. Provide auxiliary dry contacts for all occupancy sensors or all zones controlled by occupancy sensor for integration with HVAC system.
- O. Alternative or comparable technologies other than those described in this specification will be considered where both cost effective and appropriate in meeting the described control intent on either a single component/space or a system-wide basis.
- P. Any emergency lighting circuits controlled shall be provided with a UL924 bypass relay that will bypass any switch/relay control when normal power fails.
- Q. As an add alternate, interconnect stand alone digital room controller and relay control panel system to provide a fully networked lighting control system on a floor by floor basis for each building. System would include but not be limited to stand alone, addressable low voltage control devices with distributed intelligence-capable of network connectivity for additional remote or time-based operation than provided in base design. Such systems would include the following features:
1. Multiple control devices can be combined into a single enclosure to limit overall project device count.
  2. Addressable devices can be interconnected via RJ45 connectors or low voltage cabling and do not require any specific order or hierarchy to function limiting quantity of required low voltage interconnections and installation labor.
  3. Relays for switched zones can be remote mounted without the use of centralized relay panels thereby limiting required line voltage cable and installation labor.
  4. Control operations and settings for relay zones are distributed throughout system increasing system robustness over centralized relay system.
  5. Additional zones not currently scheduled or controlled on a time of day basis or integrated with building automation system can be connected to lighting control system network without additional cost for the purposes of remote monitoring and adjustment of control settings.
  6. Occupancy integration with HVAC system can occur once per floor as opposed to once per room.
  7. The Vivarium Animal Holding Rooms shall be provided with a separation lighting control system as manufactured by Edstrom Industries or Rese Scientific.

## 1.2 RELATED WORK

- A. Section 26 05 11, BASIC METHODS AND REQUIREMENTS (ELECTRICAL): General requirements that are common to more than one section of Division 26.
- B. Section 26 05 21, CABLES, LOW VOLTAGE (600 VOLTS AND BELOW): Cables and wiring.
- C. Section 26 27 26, WIRING DEVICES: Wiring devices used as part of the lighting systems.
- D. Section 26 05 26, GROUNDING: Requirements for personnel safety and to provide a low impedance path to ground for possible ground fault currents.
- E. Section 26 51 00, INTERIOR LIGHTING FIXTURES.

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### 1.3 QUALITY ASSURANCE

- A. Refer to Paragraph, QUALIFICATIONS, in Section 26 05 11, BASIC METHODS AND REQUIREMENTS (ELECTRICAL).
- B. Commissioning of a system or systems specified in this section is part of the construction process. Documentation and testing of these systems, as well as training of the VAMC operation and maintenance personnel, is required in cooperation with the VA Resident Engineer and the Commissioning Authority. Project Closeout is dependent on successful completion of all commissioning procedures, documentation, and issue closure. Refer to Section 019113, Commissioning, for detailed commissioning requirements.

### 1.4 SUBMITTALS

- A. In accordance with Section 26 05 11, BASIC METHODS AND REQUIREMENTS (ELECTRICAL) and Division 01, Section 01 78 23, O&M submit the following:
- B. Shop Drawings:
  - 1. Sufficient information, clearly presented, shall be included to determine compliance with drawings and specifications.
  - 2. Include electrical ratings, dimensions, mounting details, materials, required clearances, terminations, wiring and connection diagrams.
  - 3. Submit panel relay schedules and circuit designations.
  - 4. Complete wiring diagrams of all relay panel systems.
  - 5. Digital control wiring diagrams and wiring layouts including all line and low voltage devices.
  - 6. Programming requirements.
- C. Manuals:
  - 1. Submit, simultaneously with the shop drawings companion copies of complete maintenance and operating manuals including technical data sheets, and information for ordering replacement parts.
  - 2. Two weeks prior to the final inspection, submit four copies of the final updated maintenance and operating manuals, including any changes, to the Resident Engineer.
- D. Certifications:
  - 1. Two weeks prior to final inspection, submit four copies of the following certifications to the Resident Engineer:
    - a. Certification by the Contractor that the equipment has been properly installed, adjusted, and tested.
    - b. Include with shop drawings, certification from the manufacturers that all electronic high-frequency ballasts meet the transient protection required by IEEE C62.41, Cat. A. Include with initial shop drawing submittal.



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1.5 APPLICABLE PUBLICATIONS

- A. Publications listed below (including amendments, addenda, revisions, supplements, and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by designation only.
- B. UL & ULc Approvals: The control panels shall be tested and listed under the UL 9316 Energy Management Equipment standard and CSA C22.1 #205 by a nationally recognized testing laboratory.
- C. NEC Compliance: The control system shall comply with all applicable National Electrical Codes regarding electrical wiring standards.
- D. NEMA Compliance: The control system shall comply with all applicable portions of the NEMA standards regarding the types of electrical equipment enclosures.

## PART 2 - PRODUCTS

## 2.1 LOW VOLTAGE RELAY CONTROL PANELS

## A. General

- 1. Complete lighting control panel system shall be furnished and installed in electric rooms adjacent to lighting panelboards by electrical contractor.
- 2. Lighting control panel system shall control lighting in public corridors, lobbies, waiting areas, concourse, and exterior to the buildings per contract documents.
- 3. All timeclock and scheduling shall be performed by the Building Automation System.
- 4. Upon satisfactorily installing, testing, and grouping all relay circuits into channels per contract documents, electrical contractor shall complete manufacturer's scheduling and points list documentation and present to BAS controls contractor for programming.

## B. Description

- 1. Modular Relay Panels shall be UL listed and consist of the following:
  - a. Tub: NEMA 1 enclosure that can accept an interior sized to accept up to 8, 16, 24, or 48 mechanically latching relays. Refer to drawings for relay count in each panel.
  - b. Power Supply: Transformer assembly with two 40VA transformers with separate secondaries. Transformers include internal overcurrent protection with automatic reset and metal oxide varistor protection against power line spikes. 120 or 277 VAC as required, 60 Hz +/- 10%.
  - c. Cover: Surface with captive screws in a hinged, lockable configuration.
  - d. Interior: Bracket and intelligence board backplane with pre-mounted relays. Interiors shall be provided with installed and tested relays.
  - e. Eight channels for grouping relays shall be provided in each interior regardless of size, each with an associated pushbutton to toggle the channel ON/OFF, and a terminal block for a separate dry contact input. Any number of relays in the panel can be assigned to each channel, with overlapping allowed. Channels shall be set up via digital addressable, i.e. no hand held programmer or keypad is required. Systems that require programmers or keypads, or that change relay states during set up, are not acceptable.

- f. Each channel pushbutton shall provide LED status indication: RED shall indicate that all relays within the channel group are ON; NO LED shall indicate that all relays within the group are OFF, and GREEN shall indicate the channel's relays are in a MIXED state (some OFF, some ON).
- g. Each panel shall be provided with terminals to receive momentary switch inputs. Switch input contacts shall be capable of overriding individual relays or channels.

## 2. Features

- a. Relays shall be momentary-pulsed mechanically latching contactors with plug in connector. Relays shall have mechanically latching contacts with single moving part design for improved reliability. Relays will have the following characteristics:
  - 1) Coil
    - a) Magnetically held, momentary coil activation (50 milliseconds).
    - b) 2.2 VA max per relay to allow up to 20 relays to be controlled in parallel using class 2 wiring.
    - c) Split coil – ½ for ON, ½ for OFF.
  - 2) Power Contacts
    - a) 20 amp tungsten and NEMA electronic ballast rated.
    - b) Rated for 50,000 ON/OFF cycles at full load.
    - c) Support #10 - #14 AWG solid or stranded wire.
    - d) 120, 277 and 347 volt rated.
    - e) Standard 1 year warranty.
  - 3) 30 VAC Isolated contacts for status feedback and pilot light indication.
  - 4) FCC approved for commercial and residential use.
- b. Next to each relay shall be an individual override button and a bi-color LED to indicate status.
- c. Panels shall support the "blink warning" function, with LED indication for each relay.
- d. Captive screw terminations will be provided for all wiring connections.
- e. Each channel button's dry control contact input terminal shall accept either 2 or 3-wire, maintained or momentary inputs. They shall also accept a 2-wire toggling input.
- f. Each channel shall also have an associated 1 amp, 30 VDC isolated contact which may be used for status feedback or pilot light control.
- g. Each panel shall include simple dials for setting a 2-digit panel address.
- h. The Relay Panel shall use an EEPROM to record the channel's smartwiring assignments and the current status of all relays, thus insuring a 20-year backup of information in the event of a power failure. Systems that require a chargeable battery with less than 10 year's life shall not be allowed.
- i. The unit shall provide LED status indication of the power supply status. Access to 24VAC and 24V rectified power for accessory devices shall be provided within the panel.

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C. Interior photometric Sensors for Use with lighting Control Panel

1. Provide where required an interior photometric sensor capable of sensing from 1-60,000 lux. The sensor shall be connected to the lighting control system via photocell interface module.
2. One interior sensor shall be capable of controlling one, some or all relays in the entire lighting control network and shall permit different relays to switch at different light levels.

D. Photocell Control Modules

1. Accessory for lighting control system to allow use of interior photocells as override device for lighting zones adjacent to facades over normally schedule-based programming.
2. Features
  - a. Device shall be mounted either in lighting control panel or in an accessory enclosure adjacent to lighting control. panel.
  - b. Module shall interface with lighting control panel via manufacturer's proprietary low voltage cable, CAT 5, or as momentary contact input.
  - c. Capable of controlling multiple relays as indicated on drawings.
  - d. Photocell switching threshold, and time delay of 3 seconds to 5 minutes shall be adjustable from control module.

E. Building Automation System Interface

1. Each lighting control panel shall be capable of interfacing with the building automation system via BACnet MS/TP either natively or by means of an interface module. All lighting control functions and parameters will be adjustable via the BAS.
2. At minimum, Relay Panel shall provide the following commands and signals to the BAS via BACnet MS/TP interface:
  - a. Relay Status (on, off, override, blink)
  - b. Relay on/off command
  - c. Channel Relay Assignment
  - d. Channel Status (all on, all off, override, blink, mixed)
  - e. Channel Blink time status
  - f. Channel Blink time set
  - g. Channel Override time status
  - h. Channel Override time set
  - i. Photocell light level
  - j. Photocell switching status (on, off, delay)
  - k. Photocell time delay status
  - l. Photocell time delay set
  - m. Photocell light level status
  - n. Photocell light level set
3. Relays shall default to the "on" position in the event of network trouble or connection loss to the BAS.

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F. Low Voltage Momentary Switches

1. General:
  - a. Class 2 (low voltage) switch with momentary contact to turn lights on or off in vacancy mode or bypass lighting control panel relay or channel state.
2. Features:
  - a. Wall stations can be replaced without reprogramming.
  - b. Color:
    - 1) Match NEMA WD1, Section 2 White.
    - 2) Color variation in same product family
    - 3) Visible parts: Exhibit ultraviolet color stability when tested with multiple actinic light sources as defined in ASTM D4674. Provide proof of testing upon request.
3. Wall Stations shall be designed in (1)(2)(4)(6) or (8) button configurations as indicated on plans.

2.2 STAND ALONE DIGITAL ROOM CONTROLLER SYSTEM

A. General

1. Individual suites, office areas, private offices, and other infrequently or intermittently used non-patient care areas shall be controlled via digital room control system.
2. Room controller system to include all relays, enclosures, power supplies, low voltage switches, occupancy sensors, and control wiring for fully functional vacancy mode system.
3. Provide appropriate quantity of controllers based on required source circuits. Under no circumstances shall different source branches be wired in the same enclosure.
4. Provide appropriate quantity of relays and outgoing control ways based on required switching zones and components.
5. Separate packs and/or relays shall be used for emergency circuits when switching of emergency lighting is shown.

B. Room Controller Module

1. General
  - a. Self contained relay and power pack system for all devices on stand alone room controller system network
  - b. Class 2 (low voltage).
2. Features
  - a. All devices shall be plug and play, interconnect via RJ45 connections
  - b. Devices shall be equipped with distributed intelligence and capable of operating without networking or connection to central system

- 
- c. Power failure memory:
    - 1) Controls incorporate non-volatile memory. Should power be interrupted and subsequently restored, settings and learned parameters saved in protected memory shall not be lost.
  - C. Low Voltage Wall Stations for Use with Room Controller System
    - 1. General:
      - a. Class 2 (low voltage).
    - 2. Features
      - a. Device shall be plug and play with room controller system, interconnected via RJ45 connection
      - b. Wall stations can be replaced without reprogramming.
      - c. Color:
        - 1) Match NEMA WD1, Section 2 White.
        - 2) Color variation in same product family
        - 3) Visible parts: Exhibit ultraviolet color stability when tested with multiple actinic light sources as defined in ASTM D4674. Provide proof of testing upon request.
      - d. All wiring shall run in conduit per VA Standards.
  - D. Occupancy Sensors for Use with Room Control System
    - 1. General
      - a. Ceiling and wall mounted occupancy/vacancy sensors for use with room controller system.
      - b. Class 2 (low voltage).
      - c. Controller shall be capable of operation in vacancy mode manual "on".
    - 2. Features
      - a. Connect directly to room controller module without the need of a power pack or other interface
      - b. Sensing mechanism:
        - 1) Passive infrared: Utilize multiple segmented lens, with internal grooves to eliminate dust and residue build-up.
        - 2) When installed in spaces with offices or obstructions between work spaces and sensors, provide dual technology sensors to ensure continued occupancy detection.
          - a) Passive infrared: utilize multiple segmented lens, with internal grooves to eliminate dust and residue build-up.
          - b) Ultrasonic: utilize an operating frequency of 32kHz or 40kHz that shall be crystal controlled to operate within plus or minus 0.005 percent tolerance.

- c. Sensors shall turn off or reduce lighting automatically after adjustable 30 second to 30 minute time delay when a room or area is vacated by the last person to occupy the space
- d. Sensor shall accommodate all conditions of space utilization and all irregular work hours and habits.
- e. Sensors shall be UL listed
- f. Sensors shall be fully adaptive and adjust their sensitivity and timing to ensure optimal lighting control for any use of the space
- g. Sensors shall have field adjustable controls for time delay and sensitivity to override any adaptive features.
- h. Power failure memory:
  - 1) Controls incorporate non-volatile memory. Should power be interrupted and subsequently restored, settings and learned parameters saved in protected memory shall not be lost.
- i. Provide all necessary mounting hardware and instructions.
- j. Sensors shall be Class 2 devices.
- k. Indicate viewing directions on mounting bracket for all Ceiling mount sensors.
- l. Provide customizable mask to block off unwanted viewing areas for all ceiling mounted sensors using infrared technology.
- m. Provide swivel mount base for all wall mount sensors.
- n. All wiring shall run in conduit per VA Standards.

E. Isolated Contact Interface

1. General

- a. Single pole isolated relay contact for use with digital room controller and integration with HVAC system.
- b. Class 2 (low voltage device)

2. Features

- a. Device shall be plug and play with room controller system, interconnection via RJ45 connection.
- b. Activates based on signal from occupancy sensor on digital room controller network.
- c. All wiring shall run in conduit per VA Standards.

2.3 POWERPACKS, SENSORS AND SWITCHES FOR MISCELLANEOUS SPACES

A. General

- 1. Provide equipment as shown on plans and details for stairwells, exterior building mounted lighting, and miscellaneous storage spaces.
- 2. All low voltage cable shall be run in conduit per VA standards.

B. Power Packs

1. Description

- a. Self contained power supply relay system

- b. Capable of manual on (vacancy) mode through the use of momentary low voltage switch by either integral or field selectable setting.
- c. Provide 24V power to occupancy sensors
- d. Accept low voltage momentary contact signal from digital switch to operate fixtures in vacancy mode.

## 2. Features

- a. For ease of mounting, installation and future service, power pack(s) shall be able to mount through a 1/2" knock-out in a standard electrical enclosure and be an integrated, self-contained unit consisting internally of an isolated load switching control relay and a transformer to provide low-voltage power. Transformer shall provide power to a minimum of three (3) sensors.
- b. Power pack shall be plenum rated.
- c. Control wiring between sensors and power pack shall be Class 2, 18-24 AWG, stranded U.L. Classified, PVC insulated or TEFLON jacketed cable suitable for use in plenums, where applicable.
- d. All wiring shall run in conduit per VA Standards.

## C. Occupancy Sensors

### 1. General

- a. Ceiling and wall mounted occupancy/vacancy sensors for use with single zone power packs and integration with HVAC system.
- b. Class 2 (low voltage).

### 2. Features

- a. Sensing mechanism:
  - 1) Passive infrared: Utilize multiple segmented lens, with internal grooves to eliminate dust and residue build-up.
  - 2) When installed in spaces with offices or obstructions between work spaces and sensors, provide dual technology sensors to ensure continued occupancy detection
    - a) Passive infrared: utilize multiple segmented lens, with internal grooves to eliminate dust and residue build-up.
    - b) Ultrasonic: utilize an operating frequency of 32kHz or 40kHz that shall be crystal controlled to operate within plus or minus 0.005 percent tolerance.
- b. Sensors shall be capable of operating in manual (on/off) vacancy mode.
- c. Sensors shall turn off or reduce lighting automatically after adjustable 30 second to 30 minute time delay when a room or area is vacated by the last person to occupy the space
- d. Sensor shall accommodate all conditions of space utilization and all irregular work hours and habits.
- e. Sensors shall be UL listed
- f. Sensors shall be fully adaptive and adjust their sensitivity and timing to ensure optimal lighting control for any use of the space
- g. Sensors shall have field adjustable controls for time delay and sensitivity to override any adaptive features.

- h. Power failure memory:
  - 1) Controls incorporate non-volatile memory. Should power be interrupted and subsequently restored, settings and learned parameters saved in protected memory shall not be lost.
- i. Provide all necessary mounting hardware and instructions.
- j. Indicate viewing directions on mounting bracket for all Ceiling mount sensors.
- k. Provide customizable mask to block off unwanted viewing areas for all ceiling mounted sensors using passive infrared technology.
- l. Provide swivel mount base for all wall mount sensors.
- m. Provide with integral auxiliary contact for integration with HVAC system.
- n. All wiring shall run in conduit per VA Standards.

D. Wall Stations with Integral Occupancy Sensor

1. Description

- a. Self contained power supply relay system with integral occupancy sensor and switches
- b. Provide with one or two relays and switches depending on switching requirements of specified space.
- c. Capable of operating in manual on (vacancy) mode by either integral or field selectable setting.
- d. Capable of integration with HVAC system.

2. Features

- a. Sensing mechanism:
  - 1) Infrared: Utilize multiple segmented lens, with internal grooves to eliminate dust and residue build-up.
- b. Sensors shall turn off or reduce lighting automatically after adjustable 30 second to 30 minute time delay when a room or area is vacated by the last person to occupy the space
- c. Sensor shall accommodate all conditions of space utilization and all irregular work hours and habits.
- d. Sensors shall be UL listed
- e. Sensors shall be fully adaptive and adjust their sensitivity and timing to ensure optimal lighting control for any use of the space
- f. Sensors shall have field adjustable controls for time delay and sensitivity to override any adaptive features.
- g. Power failure memory:
  - 1) Controls incorporate non-volatile memory. Should power be interrupted and subsequently restored, settings and learned parameters saved in protected memory shall not be lost.
- h. Provide all necessary mounting hardware and instructions.
- i. Indicate viewing directions on mounting bracket for all Ceiling mount sensors.
- j. Provide customizable mask to block off unwanted viewing areas.



## k. Color:

- 1) Match NEMA WD1, Section 2 White.
- 2) Color variation in same product family: Maximum  $\Delta E=1$ , CIE  $L^*a^*b$  color units.
- 3) Visible parts: Exhibit ultraviolet color stability when tested with multiple actinic light sources as defined in ASTM D4674. Provide proof of testing upon request.

l. Provide with integral auxiliary contact for integration with HVAC system.

m. All wiring shall run in conduit per VA Standards.

## E. Photosensor

## 1. General

- a. Class 2 (low voltage device)
- b. Provide weatherproof enclosure as required.
- c. Sensor shall be 24V and capable of switching lighting via powerpack relay.

## 2. Features

- a. The photosensor shall have an adjustable time delay range of 3 seconds to 5 minutes.
- b. Sensor shall be adjustable to prevent lighting from cycling due to minor changes in cloud cover.
- c. All wiring shall run in conduit per VA Standards.

## 2.4 ACCESSORIES

## A. Emergency Bypass Relay:

1. UL 924 device
2. Monitors unswitched normal circuit to turn emergency life safety lighting on regardless of switch or relay position.
3. Provide with secondary relay to monitor switched normal circuit to switch emergency lighting with other branch in non-emergency condition where required.

## 2.5 SOURCE QUALITY CONTROL

- A. Perform full-function testing on all completed assemblies at end of line. Statistical sampling is not acceptable.

## 2.6 VIVARIUM LIGHTING CONTROL SYSTEM

## A. General

1. The Vivarium Lighting Control System shall be a computer-based data management, monitoring and control system specifically designed for laboratory animal facilities. The system provides secure, real-time, and permanent data collection along with centralized alarm notification and system configuration.

The modular system design allows for addition of devices and sensors to meet the changing needs of the facility. The system shall be based on Edstrom Industry Watchdog.

2. The lighting control system shall include the following:

RFI 6522: SUBMIT AN ALTERNATE PRODUCT IF WATCHDOG SYSTEM IS UNAVAILABLE

- a. Server, with UPS
- b. Lighting (photocell) sensor
- c. Advanced lighting control module (ALM) and lighting control relays
- d. Environmental 6 Sentry Panel (ESP)
- e. 24V Power Supply Units (PSU)
- f. "Tap" ALM switches assemblies
- g. Component mounting boxes
- h. Cabling, wiring and conduit

#### B. Operation

1. Watchdog is specifically designed to aid in the management and control of animal facilities and laboratories. Watchdog is unique in its ability to provide several facility management tools in one easy-to-use integrated system. Watchdog is flexible in design to meet the needs of your facility through two configuration options. These two options can be combined to meet the monitoring needs of any situation.
2. Room-Based Configuration – In room-based configuration, the sensors that detect the actual environmental parameters connect to local processors. The local processors, in turn, connect to a smart box, which is then connected to the Watchdog server. Room-based monitoring includes the ability to view current environmental conditions locally at the local processor, as well as the ability to control lights, watering, and access at the room level.
3. Point-Based Configuration – In a point based configuration, sensors connect to Environmental Sentry Panels or Automated Watering System Controllers. These panels are then connected to the Watchdog server. The point-based configuration adapts to any monitoring situation but is especially well suited to monitoring cubicle, refrigerators, freezers, or animal rooms where local display and control are not necessary.
4. Watchdog keeps accurate records of the many data parameters, including analog parameters. Data readings are taken at user-defined intervals and stored in a database. This data can be later used in reports for verification of environmental conditions. If a parameter is critical to a facility's operation, Watchdog can notify staff various ways via email or phone notification.

#### C. System Components

1. Watchdog Server
  - a. Intel Quad Core Xeon computer system with 2GB RAM and (2) integrated 100/1000 Gigabit Ethernet Adapters (NICS)
  - b. 5 - 250GB SATA hard drives using RAIS configuration with online spare
  - c. Microsoft Windows Server 2008 Standard Edition
  - d. Watchdog software package Version 5 current release custom configured for the application
  - e. Anti-virus software application
  - f. Modem to support remote access dial-in
  - g. DVD Data Back-up System with (3) DVD+RW disks
  - h. Redundant power supplies at 460 watts
  - i. Redundant fans
  - j. Convertible case for tower or rack configuration

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- k. Telephony card – analog used for voicemail and call-out notification
  - l. Peripherals
    - 1) 19 in (483 mm) LCD Monitor
    - 2) 104 Keyboard / PS/2 mouse
  - m. Uninterruptible Power Supply 1440VA (tower) or 1500VA (rack mount). Provides a minimum of 10 minutes of backup-up power. Provides a communication interface to obtain power line monitoring statistics.
  - n. One Color LED Printer (optional in rack configuration)
  - o. Multi-Port Serial device for connection to Smart Boxes, Watchdog ESP, Automated Watering System Controller panels, RO machines and bottle filling stations.
  - p. Physical Specification - Tower Option
    - 1) Server Dimensions 18.4 in. H x 8.58 in. W x 23.5 in. D (467.36 mm H x 217.93 mm W x 596.90 mm D)
    - 2) Server Weight 65 lbs (29 kg)
    - 3) UPS Dimensions 8.62 in. H x 6.73 in. W x 17.28 in. D (219 mm H x 171 mm W x 439 mm D)
    - 4) UPS Weight 53 lbs (24 kg)
  - q. Physical Specification - Rack Option
    - 1) Rack Server Dimensions 8.54 in. H x 17.5 in. W x 21.9 in. D (216.92 mm H x 444.50 mm W x 556.26 mm D) (5U height)
    - 2) Server Weight 65 lbs (29 kg)
    - 3) UPS Dimensions 3.50 in. H x 17 in. W x 19.29 in. D (89 mm H x 432 mm W x 490 mm D) (1U height)
    - 4) UPS Weight 55 lbs (2 kg)
  - r. Environmental Specification
    - 1) Relative Humidity 10 – 90%
    - 2) System Inlet Temperature 50 - 90°F (10 - 35°C)
    - 3) System performance may be reduced if running server with a fan fault at or above 86°F (30°C)
  - s. Power Requirements
    - 1) Line Voltage 100 – 240 VAC
    - 2) Input Current 7.1 Amps (120 VAC) to 3.5 Amps (240 VAC) per power supply
    - 3) Input Frequency 50 – 60 Hz
    - 4) Input Power 852 Watts
  - t. The customer is responsible for the placement of the Watchdog Server in a physically secure location. The server is meant for use on a private network with firewall protection. It is not designed or intended to operate on the public Internet.

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D. Power Supply Unit

1. Powers Watchdog Panels and Network Sensor Devices
2. Enclosure – Surface-mounted
  - a. NEMA 12 painted steel 8 in. W x 10 in. H x 6 in. D (203 mm W x 254 mm H x 152 mm D)
3. Power input and output
  - a. Input power: 120 VAC, 50/60Hz, 240 Watts Fused
  - b. Output power: 26 VAC, 2 outputs fused at 5 amps each
  - c. Plug in screw connectors requiring no tools for disassembly
4. Capacity
  - a. The number of Panels and Network Modules supported by a single Power Supply Station is a function of the type of Panels, the type of Modules, and the distance these loads are from the Power Supply Station.
  - b. For a typical installation that includes lighting, one Power Supply Station will support a single Panel and six rooms.

E. Power Supply Station

1. Powers Local Processors, Analog Summing Processors, and EWS Sequencers
2. Enclosure – surface mounted
  - a. NEMA 1 painted steel 10 in. W x 12 in. H x 6 in. D (254 mm W x 305 mm H x 152 mm D)
3. Power input and output
  - a. Input power: 120 VAC, 50/60 Hz 180 Watts
  - b. Output power: 8 VDC filtered and 24 VDC
  - c. Plug in screw connectors requiring no tools for disassembly
4. Capacity
  - a. Maximum of 4 processors or maximum of 4 door locks per Power Supply
5. Regulatory Compliance
  - a. ETL listed, conforms to UL508, certified to CAN/CSA Std C22.2 no. 14
6. Powers Smart Box
  - a. Enclosure – surface mounted
    - 1) NEMA 1 painted steel 10 in. W x 12 in. H x 6 in. D (254 mm W x 305 mm H x 152 mm D)

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- b. Power input and output
    - 1) Input power: 120 VAC, 50/60 Hz 120 Watts fused
    - 2) Output power: 24 VAC fused at 3 amps
    - 3) Screw terminal connectors
  - c. Capacity
    - 1) 1 Smart Box per power supply
  - d. Regulatory Compliance
    - 1) ETL listed, conforms to UL508, certified to CAN/CSA Std C22.2 no. 14
- F. Smart Box
- 1. Interface between the Watchdog Server and local processors. Collect and transmit local processor information to Watchdog Server. Receive and transmit Watchdog Server commands to local processor.
  - 2. Enclosure and Display
    - a. Recessed galvanized enclosure with stainless steel flush mount panel
    - b. Surface mounted low profile stainless steel enclosure and cover
    - c. 5 key keypad with poly dome switches
    - d. 16 x 2 liquid crystal display
  - 3. Processor and Communications
    - a. Nonvolatile memory
    - b. Communicate with Watchdog Server station via a RS422 serial protocol
    - c. Communicate with local processors with DTMF communications circuit on 2 separate busses each supporting up to 32 local processors
    - d. Poll local processors at least once per minute
    - e. Identical, interchangeable circuit board with individual software assignable address
  - 4. User Interface
    - a. Provide communication interface between Watchdog Server and local processors
    - b. Collect and transmit LP data to Watchdog Server at least once per minute
    - c. Receive and transmit Watchdog Server commands to local processor
    - d. Provide trouble-shooting capabilities with communication problems
- G. Local Processor (LP)
- 1. Interface between sensor and control components and smart box. Collect and transmit sensor data to smart box. Receive and transmit control commands to control components. Local user interface for data, display, input for lights, Automated Watering System, access control, and sensor calibration.
  - 2. Enclosure and Display
    - a. Recessed galvanized enclosure with stainless steel flush mount panel
    - b. Surface mounted low profile stainless steel enclosure and cover

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- c. 13 key keypad with poly dome switches
    - d. 16 x 2 liquid crystal display
  - 3. Processor and Communications
    - a. Non-volatile memory
    - b. 7 digital input channels - 2 assignable
    - c. 4 assignable analog 4-20 mA input channels
    - d. 2-way communications circuit with smart box
    - e. Identical, interchangeable circuit board with individual software assignable address
    - f. Store all parameter limits, set-up information and up to 750 PIN codes in non-volatile memory
    - g. Special diagnostic programs for field calibration of connected sensors
    - h. Perform all control and local display functions during communication loss with smart box
    - i. Transmit data to smart box at least once per minute
  - 4. Connections
    - a. Plug-in screw connectors requiring no tools for disassembly
  - 5. User Interface
    - a. Access current conditions, limits and alarm status of all connected sensors
    - b. Activate connected control and access features after entering valid PIN
    - c. Allow calibration of connected sensors after entering valid PIN
    - d. Display current time
    - e. Display data in non-coded, direct reading numeric and English messages
    - f. Activate clean mode after entering valid PIN to suppress alarm notification process during a user defined time interval
  - H. Environmental Sentry Panel (ESP)
    - 1. Collect and process all data from sensors, provide user interface to view status, troubleshoot, set-up and calibrate, provide data interface for light control and generate calibration report via local connection of printer.
    - 2. Enclosure and display
      - a. Surface mount stainless steel enclosure 14 in. W x 16 in. H x 6 in. D (356 mm W x 406 mm H x 152 mm D)
      - b. Recessed stainless steel back box and Flush Mount Panel 16 in. W x 20 in. H x 6 in. D (406 mm W x 508 mm H x 152 mm D)
      - c. 40x2 character liquid crystal display
      - d. 22 key keypad, all dome switches
      - e. Input power: 24vac, 1 amp fused input
    - 3. Communications
      - a. Non-volatile user program memory
      - b. (32) 4-20ma., 0-20ma., 0-5V thermistor analog or multifunctional digital inputs
      - c. 1 network input/output to monitor up to 62 network sensors and/or light modules
      - d. Auxiliary form C dry remote alarm contact to signal loss of communication with Watchdog Server
      - e. RS-485 communication port

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- f. Audible alarm
      - g. Alarm, service, power LED indicators
  - 4. User Interface
    - a. Provide status screens to display time, date and panel status
    - b. Provide calibrate screens to allow user to calibrate individual analog sensors and generate calibration reports.
    - c. Provide install screens to allow users to troubleshoot monitoring devices after entry of PIN
  - 5. Regulatory Compliance
    - a. CE
  - I. Advanced Alarm Relay (AAR)
    - 1. Watchdog Advanced Alarm Relay allows other systems the capability to link to Watchdog via dry contact relays. The AAR feature supports multiple dry contact relays. Each relay can be configured as normally open or normally closed. A relay can be configured to have as many parameters as it needs and the same parameter can be assigned to multiple relays. AAR can be used to integrate Watchdog with other systems that support Dry Contact relays.
    - 2. Advanced Alarm Relay
      - a. Each AAR provides 16 dry contact relays
      - b. Multiple AAR's can be connected to the Watchdog System to add additional relays
      - c. Each relay is configurable as normally open or normally closed
      - d. Each relay is configurable to your specifications, representing from one parameter to every parameter on your system
      - e. Dimensions: 10 in. W x 12 in H x 6 in D (254mm W x 305mm H x 125mm D)
      - f. Communication interface RS-422
      - g. Power Requirements: 12 to 16 VDC @ 835 mA
      - h. AC - DC Converter: 120 VAC @ 1Amp, 240 VAC @ 0.5Amp
      - i. Contact Rating: 8Amp @ 24 VAC/5 Amp @ 30 VDC
      - j. Regulatory Compliance
        - 1) CE
    - 3. Power supply
      - a. Enclosure - Surface Mounted
        - 1) NEMA 12 painted steel 10 in. W x 12 in. H x 6 in. D (254 mm W x 305 mm H x 152 mm D)
      - b. Power input and output
        - 1) Input power: 100-240 VAC, 50/60 Hz, 120 Watts
        - 2) Output power: 12 VDC, 100 Watts, Class 2 Energy limited
        - 3) Terminal block screw connectors

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c. Regulatory Compliance

- 1) ETL Listed, Conforms to UL 61010-1, FCC47 CFR PT 15-B, Certified to CAN/CSA STD C22.2 NO.61010-1, CE

J. System Communications and Cabling

1. Applicable cabling required for specified communications to interconnect components of modular design system.

K. Communication Types

1. Proprietary – local processor to smart box
2. RS-422 – Smartbox to Watchdog Server
3. Lon works – Watchdog panels to network devices
4. RS-485 – Watchdog panels to Watchdog Server
5. Ethernet – Watchdog Server to facility network and VLP panels. Watchdog server to ESP, AWSC, RO, and SmartBox via serial to Ethernet converters

L. Cabling

1. Refer to system layout drawings for types and routings
2. General Specifications
  - a. PVC jacketed standard (plenum rated optional)
  - b. Stranded copper conductors
  - c. Shielded (when applicable)
3. Cable types – conductor quantity and sizes (use as applicable)
  - a. Standard – 2 to 7 conductors, 22 to 18 gauge
  - b. Shielded – 2 conductor, 18 gauge
  - c. Twisted pair- 1 or 2 pair, Level IV 22 AWG
  - d. Ethernet Cat5e specification

M. Network Monitoring Devices

1. Network monitoring devices are used in conjunction with the Environmental Monitoring Panel. Network devices utilize a daisy chain wiring method with wiring going from monitoring device to monitoring device and then back to panel rather than using home run wiring for each device.

N. Sensor Module – Type 4 (SM4)

1. Temperature, humidity and light sensors in multiple combinations mounted on a single assembly
2. Temperature Sensor:
  - a. 100 Ohm platinum thin-film RTD
  - b. Calibrated accuracy ° F or ° C  $\pm 1^\circ$
  - c. Temperature range, 0 to 120°F (-18 to 49°C)



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3. Humidity Sensor:
    - a. Interchangeable capacitive element with filter
    - b. Field Calibrated Accuracy  $\pm 5\%$  RH, 20% to 85% RH
  4. Light Sensor:
    - a. Photo cell
  5. Housing and Connections
    - a. 316 polished stainless steel housing for wall surface mount or mounting on standard switch box
    - b. Watertight, with sensor elements exposed behind stainless steel guard
    - c. Screw on, watertight cable connection
  6. Regulatory Compliance
    - a. CE
  7. 4-20 mA Current Loop
  8. Temperature Sensor:
    - a. 100 Ohm platinum thin-film RTD
    - b. Calibrated accuracy  $^{\circ}\text{F}$  or  $^{\circ}\text{C} \pm 1$
    - c. 4-20 mA. Linear
  9. Housing and Connections
- O. Light Sensor
1. Monitors "off", "on" and "on high" light status through cable connection to light module
  2. Photo Cell with intensity threshold adjustability
  3. Mount in stainless steel wall plate and provide Scotchlok connectors for cable connection
- P. Advanced Light Module (ALM)
1. Works in conjunction with the ESP to control a maximum of 2 light levels and monitor the light "off", "on" and "on high" status within a room with the following additional functionality
  2. Advanced Functions
    - a. Detect and report of failed relays using feedback from pilots
    - b. Redundant relay configuration/control for continuous operation upon any relay failure
    - c. Explicit support for non-redundant paralleled relays
    - d. Explicit support for night lighting utilizing red or blue lights
    - e. Diagnostic features to aid in installation/wiring
    - f. Manual override capabilities
  3. Processor and Communications
    - a. 8 bit microprocessor
    - b. Nonvolatile program memory

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- c. Real time clock
    - d. 7 relay driver outputs protected to 1 amp nominal, 3.5 Amps short circuit (24 VDC)
    - e. Beeper
    - f. (OPTIONAL) Inputs
    - g. Light sensor (photo cell)
    - h. Manual tap switches (low and high)
  - 4. Enclosure and Display
    - a. Input power: Operating voltage- 24-29 VAC or 12-40 VDC
    - b. Mountable inside a GE style lighting control panel
      - 1) Up to 6 ALM's can be mounted inside a 24 relay panel
      - 2) Up to 12 ALM's can be mounted inside a 48 relay panel
    - c. Communication, service and power LED indicators
    - d. 8 character, alphanumeric display
    - e. Single button interface for diagnostics mode
  - 5. Regulatory Compliance
    - a. CE
  - Q. ALM Tap Switch
    - 1. Activate light on/off
    - 2. Momentarily contact push plate switch with Mylar label and aluminum push pad
      - a. Stainless steel plate assembly for wall surface or standard electrical switch box mounting
      - b. LED Indicator
  - R. User Interface
    - 1. Watchdog system incorporates standard user interface options available both at the Watchdog Server and remotely. User interface facilitates configuration of the system, daily interaction operations and reporting functions. These operations available to the user vary based on the interface selected and are summarized below:
    - 2. Unless specifically indicated to the contrary, all features are supported in web client and standard user interface.
    - 3. User access to control or configuration interfaces requires login with assigned user login name and password.
      - a. All user login attempts (valid or invalid) are logged as an activity by the system
      - b. All user logouts are logged by the system
      - c. All user timeouts are logged by the system
    - 4. Watchdog Server – Watchdog applications allow the user to interact with the Watchdog system using Microsoft Windows compatible applications.
      - a. Configuration and Control interface allows users to set up and configure system
      - b. Reporting tool allows user to generate reports from multiple data sources including archive data sets
      - c. Number of simultaneously logged users controlled by license

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- d. Default idle time out on the web is 10 minutes but is user adjustable
  - e. Book marking of pages to subvert login is not allowed
5. Web Client – allows user remote from the Watchdog Server to perform reporting, configuration and control operations using internet browser interfaces running over intranet backbone
- a. Does not require any Watchdog related software to be installed on the client machines
  - b. Client computer requirements
    - 1) Internet browser Microsoft Internet Explorer Version 6 (or higher)
    - 2) Internet browser JavaScript and cookie features must be enabled
    - 3) Report download to PDF (portable document format) requires Adobe Acrobat Reader V5.05 or greater
  - c. User can custom configure the following information on the home page.
    - 1) Company name
    - 2) Department
  - d. Warning message
- S. Integration to Building Automation Systems Via OPC
- 1. Watchdog OPC Client
    - a. Supports OPC XML-DA V1.0 standard
    - b. Supports reading Boolean, Integer and Floating Point values from a compatible system
    - c. External Points are mapped into the Watchdog system using Edstrom's OPC Client Configuration software program.
    - d. Integrated points are treated as Environmental Monitoring values and support Environmental Monitoring, Alarm Detection, Alarm Notification, and Configuration Management functions as defined herein
  - 2. Watchdog OPC Server
    - a. Supports OPC XML-DA V1.0 standard
    - b. Hosts all available readings as String, Integer, Boolean, and Floating Point as appropriate
    - c. Each point value also supports point quality attributes
    - d. OPTION: Advanced Alarm Relay (AAR) allows other systems to retrieve alarm information from the Watchdog system via “virtual” relays.
- T. Data Collection
- 1. Collect data from connected hardware including panels, processors and sensors at least once per minute
  - 2. Monitor communication between hardware and Watchdog Server as an alarm condition. Utilize user defined alarm notification method to control system response to communication losses
  - 3. Capture statistics on utilization of web user interface features

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**U. Light Control**

1. Allow user defined setting of all lighting control parameters on an individual room basis including
  - a. Light schedule
  - b. Low level light extend time ranging from 0 to 255 minutes
  - c. High level light extend time ranging from 0 to 255 minutes
  - d. Alarm delay ranging from 0 to 255 minutes
  - e. Alarm notification method
  - f. Alarm check list
  - g. (2) programmable light flash times ranging from 0 to 15 minutes
2. Control low level light in rooms using a user defined light schedule
3. Allow local override of current light state using user defined low level light extend time. Return lights to previous state after extend time expires
4. Allow local switch activation of high level lights for a user defined high level light extend time only when low-level lights are already on
5. Turn off high-level lights in conjunction with low-level lights
  - a. Provide high-level light override capability of low-level light during flash period
6. Allow override of current light control state via the Watchdog Server at any time
7. Begin alarm notification process when lights are in the incorrect state after user defined alarm delay period
  - a. Allow user to disable lighting alarming on an individual room basis
8. Notify users of pending light transition from on to off via light blink
  - a. Allow global operational preference for light blink on every on/off state transition or only override transitions
9. Log all light over-ride events

**V. Alarm Detection and Notification**

1. Handle all alarms generated by the system with a common alarm notification interface consisting of alarm notification methods and alarm checklists
2. Show current alarm conditions in centralized alarm folder from which user can acknowledge alarms and view current conditions
3. Allow system response to alarm conditions to be defined by alarm notification methods and user set-ups
  - a. Allow user defined label to identify alarm method throughout system
  - b. Allow force acknowledge, which when enabled, requires user acknowledgement of alarm prior to stopping alarm notification process
  - c. Allow user defined priority level ranging from 1 to 10 to distinguish alarms at the user interface
  - d. Provide e-mail notification
    - 1) Send alarm start messages to designated e-mail address via SMTP
    - 2) Send alarm clear messages to designated e-mail address via SMTP
    - 3) Send alarm acknowledge messages to designated e-mail address via SMTP

- 4) Construct list of users to notify via e-mail from system user list and/or by direct entry of e-mail addresses
- 5) Provide message format to include location date, time, alarm condition and current reading. Acknowledge message format to include name of user acknowledging alarm and appropriate notes. Clear message format to indicate duration of alarm
- 6) Notes can be captured with acknowledgement of alarms

e. Provide pager notification

- 1) Send alarm start message to user on alpha-numeric pager via SMTP
- 2) Repeat alarm messages at a user defined interval range from 15 minutes to 8 hours
- 3) Send alarm clear message to user on alpha-numeric pager via SMTP
- 4) Send alarm acknowledge message to user on alpha-numeric pager via SMTP
- 5) Construct list of users to notify via pager from system user list and/or by direct entry of pager identifications
- 6) Provide message format to include location, time, alarm condition and current reading

f. Voice Notification

W. Configuration Management

1. Allow customization of room status information in the room's folder by allowing user to create room groups.
2. Show current status and alarm conditions based on each room in a room's folder. In rooms folder provided color-coded display of current conditions where red indicates alarm condition, pink indicates acknowledged alarm condition and black indicates okay condition
3. Allow further customization of the room information through the use of user defined info fields. Allow unlimited number of info fields to be defined for the system
4. Allow creation of unlimited number of user defined schedules
  - a. Allow schedules to be used for configuration of light control, alarm notification paging, access control and waste flushing
  - b. Allow schedules to be assigned to multiple parameters
  - c. Provide permanent pre-defined schedules for Always On, Never On, and Lighting Standard
  - d. Allow schedule to consist of 4 "on times". Allow for variations based on day of week or holiday conditions
  - e. Allow creation of user defined "holidays"
  - f. Allow changes in the configuration of the schedule to automatically be propagated to all parameters utilizing the schedule with no requirement to re-apply the configuration
5. Allow creation of unlimited number of user defined templates for use with the environmental, access control or watering related parameters
  - a. Allow user defined label to identify the template
  - b. Allow user to define a collection of settings for monitoring analog, digital, light, watering and access parameters

- c. Allow changes in the configuration of the template to automatically be propagated to all parameters utilizing the template with no requirement to re-apply the configuration
- d. Use templates as the primary mechanism for configuring the system allowing the user to perform drag/drop operations on the room name to perform configuration
- e. Provide user with pre-defined AAALAC templates for the following species: rodent, rabbit, dog, guinea pig and non-human primate

#### X. User Accounts

1. Allow definition of user accounts to provide access to the system, where user account information must minimally contain a name, a PIN number and access level and may optionally contain
  - a. Room access list
  - b. Contact information including phone numbers, e-mail address, pager identification and schedules
  - c. User photo
2. Provide 4 levels of user access to limit feature capabilities including Administrator, Super User, User and Keypad only. Allow Administrator level to control feature accessibility for other account levels
3. Enforce unique PIN numbers among active system users
4. Require minimum of USER level access to be able to gain access to the system configuration features
5. Require user login name and password in order to login to system configuration and status interface
  - a. Passwords can be 5-15- characters and must contain both a letter and a number
6. Require unique login names
7. Allow configuration of user account expirations to automatically remove user accounts
8. Allow use of password expiration feature to force periodic change of account passwords
9. Record and store all attempts to login to Watchdog
10. Allow drag/drop to make user accounts active or deleted
11. Capture of daily user login statistics including login, logout and timeout operation (Viewable on Web Interface Only)

#### Y. Electronic Records/Electronic Signature Compliance (21 CFR Part 11)

1. Disallow modifications of logged records
2. Create complete audit trails including date and time stamp as well as user identification on additions/deletions/changes to alarm methods, schedules, templates, user accounts, checklists, watering system configuration parameters, info fields and general system configuration parameters
3. Disallow disabling or modification of audit trails
4. Include before and after values when performing audit logs
5. Show name of active user on screen of Watchdog Server user interface
6. Provide optional provisions to force users to change password at established intervals
7. Provide automatic user timeout if the Watchdog Server or Watchdog Web is left idle for 10 minutes
8. Provide optional mechanism to allow users to attach text notes when making changes/additions/deletions
9. Force notes to be captured on all changes

10. User can be locked out if user does not login correctly after a selectable number of attempts

Z. Reporting

1. System shall provide report data in interactive onscreen format
  - a. System shall allow attachment of notes provided data has not been archived
    - 1) Entered notes will be date/time stamped and attributed to user
    - 2) Note can be free entry text or selected from user defined pick list
      - a) Pick list notes supported in Web interface only
2. System shall provide reports in printed hard copy format (Report Writer Only)
3. System shall provide PDF formatted reports suitable for printing to hard copy printer (Web Only)
4. Provide standard reports including
  - a. Configuration Reports based on system data including alarm methods, Configuration History, Location, Template, and user configuration
  - b. Historical Reports including Daily Graph, combo, environmental, high/low/average, high/low/average graph, lighting, lighting graph, access, alarm notification, hardware, user activity, watering and equipment processing
  - c. Current status report
  - d. Hardware configuration and diagnostic reporting available through web client only
  - e. Report availability varies based on interface being used. Not all reports available on all platforms
5. Allow user to create macros that automate the report generation process to a daily, weekly or monthly event. (Report Writer Only)
  - a. Automatically generate required reports to hard copy format
  - b. Automatically generate required reports PDF format available from the web
6. Allow user-defined data location or location groups for applicable report
7. Allow user defined report starting and ending dates for applicable report
8. Allow export of data to comma separated value format (limited support on web client)
9. Allow user selected report inclusions of activities, alarms, individual points, state changes, attached notes, checklist replies, and separate pages
10. Allow access to archived data

### PART 3 - EXECUTION

#### 3.1 INSTALLATION

- A. Furnish all equipment, labor, system setup, and other services necessary for the proper installation of the devices as indicated on the drawings and specified herein. System setup shall include defining each switch zone, and setting the control functions.
- B. Provide a type-written directory of relays, which shall include circuit origination and destination.

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- C. Provide detailed point to point wiring diagrams for every device termination. Provide wire specifications and wire colors to simplify contactor termination requirements
  - D. Coordinate device locations with architectural plans.
  - E. Locate sensor devices so as to minimize false indications.
  - F. Install the work of this Section in accordance with manufacturer's printed instructions unless otherwise indicated.
  - G. All low voltage cables shall be tested prior to installation per manufacturer's instructions.
  - H. Calibrate all sensor time delays and sensitivity to guarantee proper detection of occupants and energy savings.
    - 1. Adjust time delay so that controlled area remains lighted for 5 minutes after occupant leaves area.
  - I. Provide written or computer-generated documentation on the commissioning of the system including room by room description including:
    - 1. Sensor parameters, time delays, sensitivities, and photosensor setpoints.
    - 2. Sequence of operation, (e.g. manual ON, Auto OFF. etc.)
    - 3. Load Parameters (e.g. blink warning, etc.)
  - J. Contractor Re-commissioning – After 30 days from occupancy re-calibrate all sensor time delays and sensitivities to meet the Owner's Project Requirements. Provide a detailed report to the Architect / Owner of re-commissioning activity.

### 3.2 FIELD SUPPORT

- A. Manufacturer shall be capable of providing on-site service support within 24 hours anywhere in the continental U.S.A., and within five business days anywhere in the world, except where special visas are required.

### 3.3 SYSTEM COMMISSIONING

- A. The system manufacturer shall provide on-site, factory technicians to thoroughly inspect the lighting control system installation and verify proper operation. The commissioning shall include three (3) separate visits to the project as defined below:
  - 1. First Visit: Pre-Wire Inspection
    - a. Review all low voltage wiring requirements
      - 1) Network wiring
      - 2) Maximum run lengths
      - 3) Control switching panel links
      - 4) Cable requirements
    - b. Review separation of power and low voltage/data wiring
    - c. Review wire labeling



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- d. Review information required on load schedules
  - e. Review lighting control panel locations and installation
  - f. Review control locations and addressing
  - g. Review analog phone lines requirements and computer jack locations
  - h. Review load circuit wiring
  - i. Review connections to "equipment by others"
  - j. Develop project schedule, including:
    - 1) Contractor completion dates
    - 2) Building opening dates
    - 3) End user training
    - 4) Contact names and numbers
2. Second Visit: Start-Up of System and Installation of System Software/data
- a. Verify proper connection of
    - 1) Power feeds
    - 2) Load circuits
  - b. Verify proper connection of all controls
  - c. Verify system operation control by control, circuit by circuit
  - d. Verify proper operation of interfacing equipment.
  - e. Program and provide fine-tune adjustments of the following for each individual area with the Owner, Architect and Lighting Consultant present.
    - 1) All switch zones and channel controls for each area.
    - 2) Photosensor controls for each area.
  - f. Obtain sign off on systems function
  - g. Provide completed relay schedules to Controls Contractor, including BACnet control points for all functions.
  - h. Support both Controls Contractor and Commissioning Agent in all programming and testing of system components to deliver fully functional system to Owner.
3. Third Visit: Operator/End-User Training
- a. Upgrade systems software to the latest revision level, if necessary
  - b. Train the end users on system operation and software (Set-Up and Operate programs)
    - 1) How to set switch and channel controls
    - 2) How to set photosensor controls
  - c. System maintenance and trouble shooting
    - 1) Job telephone numbers
    - 2) Who to call
    - 3) Diagnostics available
    - 4) Telephone support
    - 5) Service visit

d. Persons to be available for this visit should include:

- 1) Manufacturer's Service Engineer
- 2) Electrical maintenance staff
- 3) System operators

B. The manufacturer shall carry in his bids sufficient time to accomplish the above requirements to the satisfaction of the resident Engineer.

### 3.4 FUNCTIONAL PERFORMANCE & INTEGRATED SYSTEMS TESTING

A. Functional Performance & Integrated Systems Testing is part of the Commissioning Process. Functional Performance & Integrated Systems Testing shall be performed by the contractor and witnessed and documented by the Commissioning Authority. Refer to Section 019113, Commissioning, for functional performance and integrated systems testing and commissioning requirements. Training of the VAMC operation and maintenance personnel is required in cooperation with the VA Resident Engineer. Provide competent, factory authorized personnel to provide instruction to operation and maintenance personnel concerning the location, operation, and troubleshooting of the installed systems. The instruction shall be scheduled in coordination with the VA Resident Engineer after submission and approval of formal training plans. Refer to Section 017900, Demonstration and Training, and Section 019113, Commissioning, for Contractor training requirements.

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SECTION 26 11 16  
SECONDARY UNIT SUBSTATIONS

## PART 1 - GENERAL

## 1.1 DESCRIPTION

- A. This section specifies the furnishing, installation, and connection of the secondary unit substation, complete and ready for operation.
- B. The secondary substation shall consist of primary equipment, transformers and secondary distribution switchgear. The substation shall be of a single manufacturer from primary to secondary switchgear.
- C. This Specification is for Normal Power and Emergency Substations.
- D. Refer to the following table for substation equipment. Transformer size per Schedule on Drawings.

Secondary Substation Schedule				
<u>Substation</u>	<u>Configuration</u>	<u>Voltage</u>	<u>Transformer Type</u>	<u>Secondary Distribution</u>
USS08	Double-Ended	13.2kV – 277/480V	VPE	Section 26 33 00
EUSS08	Single-Ended	13.2kV – 277/480V	Cast Coil	Section 26 33 00

## 1.2 RELATED WORK

- A. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS: General electrical requirements and items that are common to more than one section of Division 26.
- B. Section 26 05 71, ELECTRICAL SYSTEM PROTECTIVE DEVICE STUDY: Electrical coordination study of overcurrent protection devices.
- C. Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS: Conduits and outlet boxes.
- D. Section 26 05 13, MEDIUM-VOLTAGE CABLES: High voltage cables.
- E. Section 26 05 21, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES (600 VOLTS AND BELOW: Cable and wiring.
- F. Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS: Requirements for personnel safety and to provide a low impedance path for possible ground fault currents.
- G. Section 26 23 00, LOW-VOLTAGE SWITCHGEAR: Secondary distribution switchgear.
- H. Section 26 10 10, ADVANCED UTILITY METERING SYSTEM
- I. Section 26 27 14, SCADA MONITORING AND CONTROL SYSTEM

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1.3 FACTORY TESTING

- A. Substations shall be thoroughly tested at the factory to assure that there are no electrical or mechanical defects. Tests shall be conducted as per UL and ANSI Standards. Factory tests shall be certified.

## 1.4 SUBMITTALS

- A. Submit in accordance with Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS.

B. Shop Drawings:

1. All shop drawings shall have clearly marked the appropriate specification number of drawing designation, for identification of the submittal.
2. Disposition of shop drawings shall not relieve the Contractor from the responsibility for deviations from drawing or specifications, unless he has submitted in writing a letter itemizing or calling attention to such deviations at time of submission and secured written approval from the Resident Engineer, nor shall such disposition of shop drawings relieve the Contractor from responsibility for errors in shop drawings or schedules.
3. Shop drawings shall include, but shall not be limited to, the following:
  - a. Primary equipment
  - b. Transformers
  - c. A  $\frac{1}{4}$ "=1'-0" scale floor plan of the main electric room housing the substation with dimensions, Code clearances, etc., shall be submitted with the equipment shop drawings. Acceptance of these shop drawings shall be obtained prior to installation of feeder conduits:
4. The switchgear manufacturer shall submit the following information with each submittal:
  - a. Master drawing index.
  - b. Front view elevation.
  - c. Floor plan.
  - d. Top view.
  - e. Single line.
  - f. Control schematics and wiring diagrams.
  - g. Nameplate schedule.
  - h. Component list/bill of material.
  - i. Conduit entry/exit locations.
  - j. Assembly ratings including:
    - 1) Short circuit rating.
    - 2) Voltage.
    - 3) Continuous current.
    - 4) Basic Impulse level (BIL).
    - 5) KVA.
  - k. Major component ratings including:
    - 1) Voltage.
    - 2) Continuous current.
    - 3) Interrupting ratings.
  - l. Cable terminal sizes.

- m. Connection details between close-coupled assemblies.
- n. Composite floor plan of close-coupled assemblies.
- o. Impedance for transformers.
- p. Manufacturer's catalog data sheets.
- q. Test reports.
  
- r. The following additional information shall be submitted to the Resident Engineer:
  - 1) Key interlock scheme drawing and sequence of operations.
  
- s. The following product information shall be submitted:
  - 1) Descriptive bulletins.
  - 2) Product sheets.
  - 3) Transformers.

C. Manuals:

- 1. Submit, simultaneously with the shop drawings, companion copies of complete maintenance and operating manuals including technical data sheets, wiring diagrams, and information for ordering replacement parts. It shall also include installation, operating instructions, maintenance, trouble shooting and repair procedures and technical literature pertaining to all components or instruments provided.
- 2. Two weeks prior to final inspection, submit four copies of the final up-dated maintenance and operating manuals to the Resident Engineer.
- 3. Submit in accordance with Division 01, Section 01 78 23, O&M.

D. Certificates:

- 1. Two weeks prior to final inspection, submit four copies of the following to the Resident Engineer:
  - a. Certification by the Contractor that the substations have been properly installed, adjusted, and tested, including final circuit breaker settings.
  - b. Certified copies of all of the factory design and production tests, field test data sheets and reports for the substations.
  - c. As-built information.

E. The manufacturer shall submit a computerized Electro Magnetic Transient Program (EMTP) study to determine the need for snubbers (RC suppressors) on the MV system due to vacuum breaker induced switching transients and the application of lightning arrestors.

- 1. The study shall take into account the following:
  - a. High frequency voltage amplification due to short cables.
  - b. Dry-type/cast coil technology.
  - c. Sustained impulses at the BIL Ratings of the Transformers.
  - d. Breaker opening transients.
  - e. Breaker closing transients.
  
- 2. The results of the study shall determine/prove the snubber component values that are required to protect the transformer from switching (chop current or pre-strike) transients and oscillatory ring wave phenomenon and to protect the vacuum breaker from re-ignition.

3. Plots shall be provided showing the system response with and without application of the snubbers. The plots shall indicate the reduction in oscillatory frequency and DC offset values.
4. In addition, an insulation coordination plot of Voltage (KVcrest vs. Crest of system voltage on the surge arrester lead wire. Chopped wave withstand, BIL protection, Switching Surge Protection) shall be provided which identifies the minimum protective margin per ANSI C62.22, the protected equipment insulation level, the rating of the selected lightning class arrester and the voltage drop

#### 1.5 APPLICABLE PUBLICATIONS

- A. Publications listed below (including amendments, addenda, revisions, supplements, and errata), form a part of this specification to the extent referenced. Publications are referenced in the text by basic designation only.
- B. American Concrete Institute (ACI):  
  
ACI 318-02 ..... Building Code Requirements for Structural Concrete
- C. American Society for Testing and Materials (ASTM):  
  
D3487-00 ..... Standard Specification for Mineral Insulating Oil Used in Electrical Apparatus
- D. Institute of Electrical and Electronic Engineers (IEEE):  
  
C62.11-99 ..... Metal Oxide Surge Arresters for AC Power Circuits  
C62.41-95 ..... Surge Voltage in Low Voltage AC Power circuits
- E. National Fire Protection Association (NFPA):  
  
70 ..... National Electrical Code (NEC):

#### 1.6 DELIVERY, STORAGE AND HANDLING

- A. Manufacturer's directions shall be followed completely in the delivery, storage, protection and installation. Promptly notify the Resident Engineer in writing of any conflict between any requirements of the Contract Documents and the manufacturer's directions. Obtain the written instructions before proceeding with the work. Should Electrical Subcontractor perform any work that does not comply with the manufacturer's directions or written instructions from the Resident Engineer, he shall bear all costs arising in correcting any deficiencies that should arise.
- B. Equipment and materials shall be delivered to the site and stored in original sealed containers, suitably sheltered from the elements, but readily accessible for inspection by the Resident Engineer until installed. All items subject to moisture damage such as controls shall be stored in dry, heated spaces. Equipment such as switchgear with heater elements installed shall have the heater elements energized after the equipment is received by the Electrical Subcontractor.
- C. The Electrical Subcontractor shall be responsible to fully inspect all shipments for damage and report damage to the manufacturer and the Resident Engineer.

- D. Equipment shall be tightly covered and protected against dirt, water, and chemical or mechanical injury and theft. At the completion of the work, equipment and materials shall be cleaned and polished thoroughly and turned over to the Owner in a condition satisfactory to the Architect. Damage or defects that develop before acceptance of the work shall be made good at the Electrical Subcontractor's expense.
- E. The Electrical Subcontractor shall make necessary field measurements to ascertain space requirements, for equipment and connections to be provided under his respective Trade and shall furnish and install such sizes and shapes of equipment to allow for the final installation to conform to the drawings and specifications.
- F. The secondary unit substation shall be split into shipping groups for handling as directed by the Electrical Subcontractor or as the manufacturer's limitations dictate. Shipping groups shall be designed to be shipped by truck, rail or ship. Shipping groups shall be bolted to skids. Accessories shall be packaged and shipped separately. Each switchgear shipping group shall be equipped with lifting eyes for handling solely by crane.
- G. The secondary unit substation being stored prior to installation shall be stored so as to maintain the equipment in a clean and dry condition. If stored outdoors, indoor gear shall be covered and heated.
- H. Where substation transformers and switchgear are stored for long duration, the unit shall be shrink-wrapped to prevent dust and moisture build up.

#### 1.7 SELECTIVE COORDINATION

- A. The emergency distribution system, the elevator distribution system and the fire pump distribution system shall be selectively coordinated to meet the requirements of the National Electrical Code, Articles 517.26, 620.62, 700.27 and NFPA 20.
- B. For system reliability, the entire normal distribution system shall be coordinated down to 0.10 seconds to the extent practicable.
- C. The switchgear manufacturer shall be responsible to select appropriate overcurrent protective device, fuse and/or circuit breaker frame, sensor and trip sizes for all devices upstream of other devices for a completely coordinated system. Refer to specification 26 0571 for additional information.

#### 1.8 WITHSTAND AND INTERRUPTING RATINGS OF ELECTRICAL COMPONENTS

- A. Calculated available 3 phase and single phase to ground short circuit currents indicated on the drawings are provided for information only to assist in the selection of withstand and interrupting ratings and coordination of devices and equipment.
- B. Prior to submission of shop drawings, the manufacturer shall perform short circuit calculations in accordance with specification section 26 0571 to determine actual available 3 phase and single line to ground short circuit current at each component in the system based on actual equipment, feeder lengths, impedances, etc. of the equipment proposed for this project. Failure to perform the study prior to submission of shop drawings shall not relieve the manufacturer from providing devices that meet the requirements of the final study report.
- C. Each component shall be UL listed and labeled and shall be fully rated to withstand and interrupt calculated available 3 phase and single phase to ground short circuit current levels. Series ratings will not be acceptable.

## 1.9 COMMISSIONING

- A. Commissioning of a system or systems specified in this section is part of the construction process. Documentation and testing of these systems, as well as training of the VAMC operation and maintenance personnel, is required in cooperation with the VA Resident Engineer and the Commissioning Authority. Project Closeout is dependent on successful completion of all commissioning procedures, documentation, and issue closure. Refer to Section 019113, Commissioning, for detailed commissioning requirements.

## PART 2 - PRODUCTS

### 2.1 GENERAL REQUIREMENTS

- A. Unit substations shall be in accordance with ASTM, ANSI, IEEE, NEC, and as shown on the drawings.
- B. The substations shall be complete, grounded, continuous-duty, unitized integral assembly, metal clad, dead-front, dead-rear types, with Dry type Transformers.
- C. Provide substations that conform to the arrangements and details shown on the drawings and to the space designated for installation.
- D. Coordinate the components of the substations and their arrangements electrically and mechanically. Coordinate all circuit entrances into the substations, including methods of entrance and connections.
- E. The substation equipment shall have the capability to withstand and interrupt fault currents supplied by the system, as calculated in the short circuit and coordination study, as specified in Section 26 05 71.
- F. Incorporate interlocking as shown on the drawings and as required for the safe operation of the substations.
- G. The substation shall be assembled and prewired by the manufacturer at the factory.
- H. Substation shall be thoroughly cleaned, phosphate treated and painted at the factory with rust-inhibiting paint and baked enamel or lacquer (ANSI 61) finish.
- I. Coordinate the high and low voltage switchgear sections with their associated transformers. Sections shall be fabricated by a single manufacturer.
- J. Bolts, nuts and washers shall be rustproof metal, corrosion resistant (zinc chrome plated).
- K. Provide 120v thermostatically controlled space heaters in all switchgear and transformer sections. Heaters shall be connected to external power source.



## 2.2 HIGH VOLTAGE SECTION

## A. The 15 kV switchgear assembly ratings shall be as follows:

Maximum Design Voltage	15.0 kV
Basic Impulse Level	95 kV
Nominal System Voltage	13.2kV three-phase three wire
System Grounding	solid ground
Short-Time (2-Second) Current	25 kA Symmetrical RMS
Main Cross Bus Continuous Current Rating	600 Amperes

## B. The 15 kV Breaker/Switch ratings shall be as follows:

3-Phase MVA Class	650 MVA at 15 kV
Continuous Current Rating	1200 Amperes
Circuit Breaker Rated Short-Circuit Current at Rated Maximum kV	25 kA Symmetrical RMS
Voltage Range Factor K=	1
Short-Time (2-Second) Current	25 kA Sym RMS
Circuit Breaker Closing and Latching Capability (and assembly momentary)	40 kA Asym RMS/65 kA Peak
Switch continuous/load break	1200 Amperes
Switch Fault Close	40 kA Asymmetrical RMS/65 kA Peak

## C. Load Interrupter Switch Ratings

1. Load Interrupter Switch (Continuous and Load Break)	600 Amperes
2. Momentary withstand	40kA Asym RMS
3. Switch Fault close (3 times, minimum)	40kA Asymmetrical RMS
4. Switch 2-Second short circuit current	25kA Sym RMS

## D. Construction

1. The metal-enclosed switchgear assembly shall consist of deadfront, completely metal-enclosed vertical sections each containing a non-fused load interrupter switch in series with a vacuum circuit breaker configured as a primary selective operation (open transition) with Kirk-Key interlock system to prevent paralleling of incoming power sources. Where shown, furnish additional vertical sections containing load interrupter switches and fuses or miscellaneous auxiliary apparatus of the number, rating and type noted on the drawings or specified herein.
2. The following features shall be supplied on every vertical section containing a three-pole, two-position open-closed switch:
  - a. A minimum 8-inch x 16-inch high-impact viewing window that permits full view of the position of all three switch blades through the closed door. The window shall not be more than 58-inches above the switch pad level to allow ease of inspection
  - b. On vertical sections without a circuit breaker, the door shall be interlocked with the switch so that:
    - 1) The switch must be opened before the door can be opened.
    - 2) The door must be closed before the switch can be closed.
3. High voltage parts within circuit breaker compartments shall be isolated with grounded metal barriers.

4. A hinged grounded metal barrier bolted closed in front of every switch to prevent inadvertent contact with any live part, yet allow for a full-view inspection on the switch blade position
5. Provision for padlocking the switch in the open or closed position.
6. Green OPEN, Red CLOSED switch position indicators with the words Open and Closed in French, Spanish and English.
7. A hinged cover with rustproof quarter turn nylon latches over the switch operating mechanism to discourage casual tampering.
8. The primary switch shall be removable from the structure as a complete operational component.
9. Vertical section construction shall be of the universal frame type using die-formed and bolted parts. All enclosing covers and doors shall be fabricated from steel whose thickness shall be equal to or greater than those specified in ANSI/IEEE C37.20.3. No owner removable hardware for covers or doors shall be thread-forming type. To facilitate installation and maintenance of cables and bus in each vertical section, a split removable top cover and hinged, bolted rear door with padlock provisions shall be provided. A G90 grade galvanized base shall isolate equipment from contact with the concrete pad providing protection from rust. Heavy-duty hot dipped galvanized anchor clips shall be provided to anchor the switchgear to the concrete pad.
10. Each vertical section containing a switch shall have a single, full-length, flanged front door and shall be equipped with two (2) rotary latch-type padlockable handles. Provision shall be made for operating the switch and storing the removable handle without opening the full-length door.

#### E. Bus

1. All buses shall be silver-plated copper.
2. Ground bus shall be silver-plated copper and be directly fastened to a galvanized metal surface of each vertical section, and be of a size sufficient to carry the rated (2-second) current of the switchgear assembly.
3. A neutral bus shall be provided when indicated on the drawings. It shall be insulated for 1000 Vac to ground. The current rating of the neutral bus shall be 600 amperes.

#### F. Bus Supporting Systems

1. All bus shall be supported utilizing a high strength and high creep support providing 10.5-inch of creep between phases and ground. The molded fins shall be constructed of high track resistant material.
2. All standoff insulators on the primary switches and fuse mountings shall be cycloaliphatic epoxy.

#### G. Wiring/Terminations

1. One (1) terminal pad per phase shall be provided for attaching contractor supplied cable terminal lugs for a maximum of two (2) conductors per phase of the sizes indicated on the drawings. Sufficient space shall be allowed for Contractor supplied electrical stress relief termination devices.
2. Small wiring, fuse blocks and terminal blocks within the vertical section shall be furnished as indicated on the drawings. Each control wire shall be labeled with wire markers. Terminal blocks shall be provided for customer connections to other apparatus.

#### H. Vacuum Circuit Breaker

1. Each vacuum circuit breaker shall be operated by a motor-charged spring stored energy mechanism. The spring may be charged manually in an emergency or during maintenance procedures.

2. Each circuit breaker shall have three (3) vacuum interrupter assemblies. Each vacuum interrupter shall have a contact wear indicator which does not require any tools to indicate the contact wear. The current transfer from the vacuum interrupter moving stem to the breaker main conductor shall be a non-sliding design. The breaker front panel shall be removable when the compartment door is open for ease of inspection and maintenance of the mechanism.
3. The breakers shall be electrically operated by:
  - a. 120Vac close and AC capacitor trip.
4. Each breaker shall be complete with control switch and red and green indicating lights to indicate breaker contact position.
5. The control voltage shall be derived from a control power transformer mounted in the switchgear.

I. Protective Relays

1. The switchgear manufacturer shall furnish and install, in the metal-enclosed switchgear, the quantity, type and rating of protection relays as indicated on the drawings and described hereinafter in this specification.
2. Microprocessor Three-Phase Protective Relay.
3. The protective relay shall be a multi-function microprocessor based.
4. Provide communications capabilities and connect to switchgear network as specified as part of the secondary switchgear Section 26 23 00.
5. The device shall be solid state microprocessor based multi-function type with protective functions, ANSI 50/51 and 50/51G.
6. The relay shall be provided with a built-in alphanumeric display capable of displaying the following:
  - a. Individual phase current
  - b. Cause of trip
  - c. Magnitude of phase current cause trip
  - d. Peak current demand
  - e. Programmed set points

J. Accessories

1. Supply key interlocks as shown on the drawings
2. Furnish distribution class surge arresters with ratings in accordance with manufacture's recommendations.

K. Enclosures

1. Enclosures shall be constructed per IEEE/ANSI C37.20.3 indoor specifications. (Meets or exceeds NEMA 1.)
2. Each vertical section shall be ventilated at the top and bottom, both front and rear, to allow airflow to provide cooling and to help prevent buildup of moisture within the structure.
3. Each vertical section shall be provided with a. minimum of one (1) 250-watt, 120-volt space heater. Power for the space heater(s) shall be furnished as indicated on the drawings by a transformer mounted within the low voltage switchboard/switchgear.

L. Nameplates

1. A nameplate shall be mounted on the front door of each switch vertical section in accordance with the drawings.

## M. Finish

1. Prior to assembly, all enclosing steel shall be thoroughly cleaned and phosphatized. A powder coating shall be applied electrostatically, then fused on by baking in an oven. The coating is to have a thickness of not less than 1.5 mils. The finish shall have the following properties:

Impact resistance (ASTM D-2794)	60 direct/60 indirect
Pencil hardness (ASTM D-3363)	H
Flexibility (ASTM D-522)	Pass 1/8-inch mandrel
Salt spray (ASTM B117-85 [20])	600 hours
Color	ANSI 61 gray

## N. Miscellaneous Devices

1. Communication equipment where indicated on the drawings, shall have the following features:
  - a. The communication network system shall be within switchgear as specified in Section 26 23 00.
  - b. Each load interrupter switch position (open and closed) shall be communicated via an addressable relay. This relay shall communicate over a network. The relay shall monitor an auxiliary switch contact that monitors the primary switch position and shall be rated for the application. Each relay shall have a unique address so that it is possible to "call up" and "read" each load interrupter switch's position from a host computer
  - c. Each breaker position (open and closed), where shown, shall be communicated via an addressable relay. This relay shall communicate over a network. The relay shall monitor an auxiliary breaker contact that monitors the breaker position and shall be rated for the application. Each relay shall have a unique address so that it is possible to "call up" and "read" each breaker's position from a host computer
  - d. The manufacturer shall wire a network to all communication capable devices within the switchgear and wire the network to a set of easily accessible terminal blocks
  - e. Control power for the addressable relay shall be 120 volts, 60 Hz available from an external source as shown on the drawings.

## 2.3 DRY TRANSFORMER CAST COIL

## A. Ratings

1. The ratings of the transformer shall be as follows:
  - a. kVA Rating: As scheduled AA/FA
  - b. Impedance: 5.75 +/- 7 1/2%
  - c. HV: 13.2kV Delta
  - d. HV BIL: 60kV
  - e. HV Taps: +/-2 - 2 1/2% full capacity
  - f. LV: 277/480 Volts, 3 Phase, 4 Wire, Wye
  - g. LV BIL: 10kV

- B. Cast coil design shall be used for designated emergency power substations.

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C. Construction

1. Forced air (FA) units for 500kVA and above shall contain all necessary components and wiring, including fans, for automatically increasing the kVA rating by 33%. The (FA) package shall include an electronic temperature monitor and fan control unit with the following features:
  - a. Digital readout
  - b. Indicating Lights
    - 1) green - power on
    - 2) yellow - fan on
    - 3) red - high temperature
  - c. Audible high temperature alarm with alarm silence pushbutton
  - d. Max. temperature memory with read and reset switch
  - e. Auto/manual fan control switch
  - f. System test switch
  - g. Temperature sensing in all three low voltage coils.
  - h. Auxiliary alarm contact and means for remote control and temperature monitoring shall be provided.
  - i. RS-485 data link for communications to ModBus and integrated into switchgear network for remote starters via SCADA.
2. Control power shall be provided from a control power transformer in the secondary equipment
3. The electrical insulation system shall utilize Class F material in a fully rated 185 degree C system. Transformer design temperature rise shall be based on a 30 degrees C average ambient over a 24 hour period with a maximum of 40 degrees C. Solid insulation in the transformer shall consist of inorganic materials such as porcelain, glass fiber, silica, electrical grade epoxy and Nomex. All insulating materials must be rated for continuous 185 degree C duty.
4. For enhanced environmental protection and improved withstandability to thermal shock and short circuit stresses, the primary and secondary coil assemblies shall be of a solid cast coil design. Each cast coil shall be cast under vacuum to assure complete, void free epoxy resin impregnation throughout the entire insulation system.
5. The average temperature rise of the transformer windings shall not exceed 115 degrees C when the transformer is operated at full nameplate rating. The transformer(s) shall be capable of carrying 100% of nameplate kVA rating in a 40 degrees C max. 30 degrees C average ambient as defined by ANSI C57.12.00.
6. The transformer shall be supplied with a Category B enclosure per ANSI C57.12.55. The enclosure shall be a knockdown case design, for ease in fitting through limited openings, and shall be of heavy gauge sheet steel construction, equipped with removable panels for access to the core and coils. Front and rear panels shall incorporate ventilating grills.
7. The transformer shall be designed to meet the sound level standards for dry transformers as defined in NEMA TR1.
8. The transformer shall have aluminum coils.
9. Transformers shall include thermostatically controlled space heaters fed from an external source.
10. Transformers shall meet or exceed Class 1 efficiency levels per NEMA TP-1, DOE 2010 or the latest adopted edition.

## D. Terminal Connections

1. Connections between the primary device and transformer shall be copper cable, and between the transformer and secondary shall be flexible copper bus braid.

## E. Accessories

1. The secondary unit substation manufacturer shall furnish accessories for the cast coil transformer for test, inspection, maintenance and operation, including:
  - a. Diagram instruction plate.
  - b. Provisions for lifting and jacking.
  - c. Removable case panel for access to high voltage strap type connector taps for de-energized tap changing.
  - d. Two ground pads.

- F. During the interim service period where the Transformer Section will not be energized for a period of time, the Transformer and incoming primary switchgear shall be completely sealed, and shrink wrapped for extended storage.

## 2.4 DRY TYPE TRANSFORMER VPE TYPE

## A. Ratings

1. The ratings of the transformer shall be as follows:
  - a. kVA Rating: As scheduled AA/FA
  - b. Impedance: 5.75 +/- 7 1/2%
  - c. HV: 13.2kV Delta
  - d. HV BIL: 60kV
  - e. HV Taps: +/-2 - 2 1/2% full capacity
  - f. LV: 277/480 Volts, 3 Phase, 4 Wire, Wye
  - g. LV BIL: 10kV

- B. VPE transformer design is allowable to be used for normal power substation only.

## C. Construction

1. Forced air (FA) units for 500kVA and above shall contain all necessary components and wiring, including fans, for automatically increasing the kVA rating by 33%. The (FA) package shall include an electronic temperature monitor and fan control unit with the following features:
  - a. Digital readout
  - b. Indicating Lights
    - 1) green - power on
    - 2) yellow - fan on
    - 3) red - high temperature
  - c. Audible high temperature alarm with alarm silence pushbutton
  - d. Max. temperature memory with read and reset switch
  - e. Auto/manual fan control switch
  - f. System test switch
  - g. Temperature sensing in all three low voltage coils.
  - h. Auxiliary alarm contact and means for remote control and temperature monitoring shall be provided.
  - i. RS-485 data link for communications to ModBus and integrated into switchgear network for remote starters via SCADA.

2. Control power shall be provided from a control power transformer in the secondary equipment
3. The electrical insulation system shall utilize Nomex Class H, in a fully rated 220 degree C system. Transformer design temperature rise shall be based on a 30 degrees C average ambient over a 24 hour period with a maximum of 40 degrees C. Solid insulation in the transformer shall consist of inorganic materials such as porcelain, glass fiber, silica, electrical grade epoxy and Nomex. All insulating materials must be rated for continuous 185 degree C duty.
4. For enhanced environmental protection and improved withstandability to thermal shock and short circuit stresses, the primary and secondary coil assemblies shall be of a Vacuum Pressure Encapsulated (VPE) design. The VPE process is a Silicone resin encapsulating the core and coil assembly.
5. The average temperature rise of the transformer windings shall not exceed 150 degrees C when the transformer is operated at full nameplate rating. The transformer(s) shall be capable of carrying 100% of nameplate kVA rating in a 40 degrees C max. 30 degrees C average ambient as defined by ANSI C57.12.00.
6. The transformer shall be supplied with a Category B enclosure per ANSI C57.12.55. The enclosure shall be a knockdown case design, for ease in fitting through limited openings, and shall be of heavy gauge sheet steel construction, equipped with removable panels for access to the core and coils. Front and rear panels shall incorporate ventilating grills.
7. The transformer shall be designed to meet the sound level standards for dry transformers as defined in NEMA TR1.
8. The transformer shall have aluminum windings.
9. Transformers shall include thermostatically controlled space heaters fed from an external source.
10. Transformers shall meet or exceed Class 1 efficiency levels per NEMA TP-1, DOE 2010 or the latest adopted edition.

D. Terminal Connections

1. Connections between the primary device and transformer shall be copper cable, and between the transformer and secondary shall be flexible copper bus braid.

E. Accessories

1. The secondary unit substation manufacturer shall furnish accessories for the cast coil transformer for test, inspection, maintenance and operation, including:
  - a. Diagram instruction plate.
  - b. Provisions for lifting and jacking.
  - c. Removable case panel for access to high voltage strap type connector taps for de-energized tap changing.
  - d. Two ground pads.

- F. During the interim service period where the Transformer Section will not be energized for a period of time, the Transformer and incoming primary switchgear shall be completely sealed, and shrink wrapped for extended storage.

## 2.5 LOW VOLTAGE SECTION

- A. Refer to Section 26 23 00, LOW-VOLTAGE SWITCHGEAR.
- B. Refer to Section 26 24 11, DISTRIBUTION SWITCHBOARDS.

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2.6 AUXILIARIES

- A. Install additional components as shown on the drawings or otherwise required for the substations.

## PART 3 - EXECUTION

## 3.1 INSTALLATION

- A. Install the equipment in accordance with the NEC, as shown on the drawings and as recommended by the equipment manufacturer.
- B. Concrete Housekeeping Pads
  - 1. Concrete pads shall be installed for all freestanding substations.
  - 2. The Contractor shall provide the concrete work. Electrical contractor shall supervise and coordinate concrete work to ensure that proper grounding cable, rods, conduit, etc., are located as detailed and as required. The electrical contractor shall also ensure that the concrete is level to within manufacturers published tolerances.
  - 3. All concrete housekeeping pads shall extend a minimum of 6" on each side from the equipment mounted on it. Mounting height of each overcurrent/disconnect device in the above equipment shall not exceed 6'-6" above finished floor.
- C. Electrical Distribution Equipment
  - 1. The Electrical contractor shall install the secondary unit substation per the manufacturers recommendations and the Contract Drawings.
  - 2. The installation of all equipment, including working space requirements, shall conform to all NEC and local codes.
  - 3. All necessary hardware to secure the assembly in place shall be provided by the Electrical Subcontractor.
  - 4. The Electrical contractor shall ensure that no piping, ductwork or other equipment foreign to the electrical trade passes through the area extending from the floor to the structural ceiling with the width and depth equal to that of the electrical distribution equipment plus 6" on either side of panel.
  - 5. Floor mounted assemblies shall be installed on concrete housekeeping pads and shall be provided with adequate lifting means. Floor mounted assemblies shall be capable of being moved into installation position and bolted directly to floor. All electrical equipment shall be installed such that the handle of the highest circuit breaker does not exceed 6'-6" above finished floor.
  - 6. The location of all electrical distribution equipment installed in mechanical or plumbing equipment rooms shall be coordinated with the respective Subcontractor.
  - 7. Electrical distribution equipment that is part of the emergency distribution system shall be located in spaces fully protected by an approved automatic fire suppression system or in spaces with a one (1) hour fire resistance rating.
  - 8. The equipment shall be installed and checked in accordance with the manufacturer's recommendations prior to first energization. This shall include but not limited to:
    - a. Checking to ensure that the pad location is level to within .125 inches.
    - b. Checking to ensure that all bus bars are torqued to the manufacturer's recommendations.
    - c. Assemble all shipping sections, remove all shipping braces and connect all shipping split mechanical and electrical connections.
    - d. Secure assemblies to foundation or floor channels.



- e. Measure and record megger readings phase-to-phase, phase-to-ground, and neutral-to-ground (four-wire systems only).
  - f. Inspect and install all circuit breakers, components, etc. in their proper compartments.
9. Identification shall be provided for all electrical distribution equipment. The electrical system identification shall clearly describe the equipment connected. Method of identification shall be by laminated nameplate made of bakelite or similar material with engraved letters at least 1/4" high and securely attached to the equipment with galvanized screws. Adhesives or cements shall not be used. A list of nameplates shall be submitted to the Architect for approval prior to fabrication.
10. Control wiring shall be provided as required. Interface all local and remote control wiring and operational systems for each load.

D. Substations

1. The substation, including the transformer, shall be installed on vibration isolators for acoustical concerns.
- a. Select the areas and locations of pads such that the bearing pressure is within manufacturer's recommended range. Isolate hold-down bolts using elastomer bushings and washers, minimum 0.25 inches thick.
2. Above grade substations
- a. Install the transformer and entire substation on elastomer-in-shear mounts made of material suited for the service.
  - b. Mounts shall be selected for minimum deflections as follows:
    - 1) Transformer: 0.2 inch
    - 2) Substation Cabinet: 0.1 inch
  - c. Provide steel rails under the transformer to transfer the load to the isolator mounts and provide a stable installation.

3.2 FACTORY TESTING

- A. The following standard factory tests shall be performed on the primary equipment provided under this section. All tests shall be in accordance with the latest version of ANSI and NEMA standards.

1. Medium Voltage Primary Switchgear

- a. Standard factory tests shall be performed on the equipment under this section. All tests shall be in accordance with the latest version of ANSI and NEMA standards.

B. Transformers

1. The following factory tests shall be made on all transformers. All tests shall be in accordance with the latest revision of ANSI and NEMA standards:
- a. Resistance measurements of all windings on the rated voltage connection of each unit and at the tap extremes of one unit only of a given rating on this project.
  - b. Ratio tests on the rated voltage connection and on all tap connections.
  - c. Polarity and phase-relation tests on the rated voltage connections.

- d. No-load loss at rated voltage on the rated voltage connection.
  - e. Exciting current at rated voltage on the rated voltage connection.
  - f. Impedance and load loss at rated current on the rated voltage connection of each unit and on the tap extremes of one unit only of a given rating on this project.
  - g. Applied potential test.
  - h. Induced potential tests.
2. The following special factory tests shall be performed on the equipment provided under this section. All tests shall be in accordance with the latest revision of ANSI and NEMA standards.
- a. Temperature test(s) shall be made on one unit only of a project covering one or more units of a given kVA rating. Tests shall not be required when there is available a record of a temperature test on an essentially duplicate unit. When a transformer is supplied with auxiliary cooling equipment to provide more than one kVA rating, temperature tests as listed above shall be made on the lowest kVA OA or AA rating and the highest kVA FA rating.
  - b. Basic impulse test on all windings.
- C. Low Voltage Metal Enclosed Switchgear
- 1. The switchgear shall be completely assembled, wired, adjusted and tested at the factory. After assembly, the complete switchgear shall be tested to assure the accuracy of the wiring and the functioning of all equipment. The main bus system shall be given a dielectric test of 2200 volts for one minute between live parts and ground and between opposite polarities.
  - 2. The wiring and control circuits shall be given a dielectric test of 1500 volts for one minute or 1800 volts for one second between live parts and ground, in accordance with ANSI C37.20.1.
- D. Factory tests as outlined above shall be witnessed by the Resident Engineer.
- 1. The manufacturer shall notify the Owner two (2) weeks prior to the date the tests are to be performed.
  - 2. The manufacturer shall include the cost of transportation and lodging for up to three (3) Owner's representatives. The cost of meals and incidental expenses shall be the Owner's responsibility.
- E. The manufacturer shall provide three (3) certified copies of factory test reports.

### 3.3 FIELD SETTINGS

- A. The Electrical contractor shall perform field adjustments of the circuit breakers as required to place the equipment in final operating condition. The settings shall be in accordance with the approved protective device coordination study or as directed by the resident Engineer.
- B. For transformers, adjust taps to deliver appropriate voltage and measure primary and secondary voltage to confirm proper setting.

### 3.4 INSTRUCTIONS

- A. Furnish the services of a competent instructor for two, 4 hour periods for instructing personnel in the operation and maintenance of the substation, on the date requested by the Resident Engineer.

- B. The training session shall be conducted by a manufacturer's qualified representative. The training program shall consist of the instruction on the operation of the assembly, circuit breakers, and major components within the assembly.
- C. The training program shall include the following:
  - 1. Review of the project one-line drawings and schedules.
  - 2. Review of the factory record shop drawings.
  - 3. Review of all equipment in the electrical distribution system.
  - 4. Discuss the maintenance timetable and procedures to be followed in an ongoing maintenance program.
  - 5. Provide three ring binders to participants complete with copies of drawings and other course material covered.
- D. Training of the VAMC operation and maintenance personnel is required in cooperation with the VA Resident Engineer. Provide competent, factory authorized personnel to provide instruction to operation and maintenance personnel concerning the location, operation, and troubleshooting of the installed systems. The instruction shall be scheduled in coordination with the VA Resident Engineer after submission and approval of formal training plans. Refer to Section 017900, Demonstration and Training, and Section 019113, Commissioning, for contractor training requirements.

### 3.5 FUNCTIONAL PERFORMANCE AND INTEGRATED SYSTEMS TESTING

- A. Functional Performance & Integrated Systems Testing is part of the Commissioning Process. Functional Performance & Integrated Systems Testing shall be performed by the contractor and witnessed and documented by the Commissioning Authority. Refer to Section 019113, Commissioning, for functional performance and integrated systems testing and commissioning requirements.

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SECTION 26 22 00  
LOW-VOLTAGE TRANSFORMERS

PART 1 – GENERAL

1.1 DESCRIPTION

- A. This section specifies the furnishing, installation and connection of the dry type general-purpose transformers.

1.2 RELATED WORK

- A. Section 13 05 41, SEISMIC RESTRAINT REQUIREMENTS FOR NON-STRUCTURAL COMPONENTS: Requirements for seismic restraint of nonstructural components.
- B. Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS: General electrical requirements and items that are common to more than one section of Division 26.
- C. Section 26 05 33, RACEWAY AND BOXES FOR ELECTRICAL SYSTEMS: Conduits and outlet boxes.
- D. Section 26 05 21, LOW-VOLTAGE ELECTRICAL POWER CONDUCTORS AND CABLES (600 VOLTS AND BELOW): Cables and wiring.
- E. Section 26 05 26, GROUNDING AND BONDING FOR ELECTRICAL SYSTEMS: Requirements for personnel safety and to provide a low impedance path for possible ground fault currents.

1.3 SUBMITTALS

- A. In accordance with Section 26 05 11, REQUIREMENTS FOR ELECTRICAL INSTALLATIONS, submit the following:
- B. Shop Drawings:
  - 1. Sufficient information, clearly presented, shall be included to determine compliance with drawings and specifications.
  - 2. Include electrical ratings, impedance, dimensions, weight, mounting details, decibel rating, terminations, temperature rise, no load and full load losses, and connection diagrams.
  - 3. Complete nameplate data including manufacturer's name and catalog number.
- C. Manuals:
  - 1. Submit, simultaneously with the shop drawings, companion copies of complete maintenance and operating manuals including technical data sheets and wiring diagrams.
  - 2. If changes have been made to the originally submitted maintenance and operating manuals, then two weeks prior to final inspection submit four copies of updated maintenance and operating manuals to the Resident Engineer.
  - 3. Submit in accordance with Division 01, Section 01 78 23, O&M.

- D. Certifications: Two weeks prior to the final inspection, submit four copies of the following to the Resident Engineer:
1. Certification by the manufacturer that the transformers conform to the requirements of the drawings and specifications.
  2. Certification that the equipment has been properly installed and tested.

#### 1.4 APPLICABLE PUBLICATIONS

- A. Publications listed below (including amendments, addenda, revisions, supplements and errata) form a part of this specification to the extent referenced. Publications are referenced in the text by designation only.
- B. National Fire Protection Association (NFPA):
- 70-05..... National Electrical Code (NEC)
- C. National Electrical Manufacturers Association (NEMA):
- ST 20-97 ..... Dry-Type Transformers for General Applications
- D. National Electrical Manufacturers Association (NEMA):
- TPI..... Energy Efficiencies

### PART 2 - PRODUCTS

#### 2.1 GENERAL PURPOSE DRY TYPE TRANSFORMERS

- A. Unless otherwise specified, dry type transformers shall be in accordance with NEMA, NEC and as shown on the drawings. Transformers shall be UL listed or labeled.
- B. Dry type transformers shall have the following features:
1. Self-cooled by natural convection, isolating windings, indoor, dry type. Autotransformers will not be accepted.
  2. Rating and winding connections shall be as shown on the drawings.
  3. Transformers shall have copper windings.
  4. Ratings shown on the drawings are for continuous-duty without the use of cooling fans.
  5. Insulation systems:
    - a. Transformers 30 KVA and larger: UL rated 220 degrees C system having an average maximum rise by resistance of 150 degrees C in a maximum ambient of 40 degrees C.
    - b. Transformers below 30 KVA: Same as for 30 KVA and larger or UL rated 185 degrees C system having an average maximum rise by resistance of 115 degrees C in a maximum ambient of 40 degrees C.

6. Core and coil assemblies:
- Rigidly braced to withstand the stresses caused by short circuit currents and rough handling during shipment.
  - Cores shall be grain oriented, non-aging, and silicon steel.
  - Coils shall be continuous windings without splices except for taps.
  - Coil loss and core loss shall be minimum for efficient operation.
  - Primary and secondary tap connections shall be brazed or pressure type.
  - Coil windings shall have end fillers or tie downs for maximum strength.
7. Certified sound levels determined in accordance with NEMA, shall not exceed the following:

Transformer Rating	Sound Level Rating
0 - 9 KVA	40 dB
10 - 50 KVA	45 dB
51 - 150 KVA	50 dB
151 - 300 KVA	55 dB
301 - 500 KVA	60 dB

8. Nominal impedance shall be as shown on the drawings. If not shown on drawings, nominal impedance shall be as permitted by NEMA.
9. Single phase transformers rated 15 KVA through 25 KVA shall have two, 5 percent full capacity taps below normal rated primary voltage. All transformers rated 30 KVA and larger shall have two, 2-1/2 percent full capacity taps above, and four, 2-1/2 percent full capacity taps below normal rated primary voltage.
10. Core assemblies shall be grounded to their enclosures by adequate flexible ground straps.
11. Enclosures:
- Not less than code gage steel.
  - Outdoor enclosures shall be NEMA 3R.
  - Temperature rise at hottest spot shall conform to NEMA Standards, and shall not bake and peel off the enclosure paint after the transformer has been placed in service.
  - Ventilation openings shall prevent accidental access to live components.
  - Thoroughly clean and paint enclosure at the factory with manufacturer's prime coat and standard finish.
12. Standard NEMA features and accessories including ground pad, lifting provisions and nameplate with the wiring diagram and sound level indicated on it.
13. Dimensions and configurations shall conform to the spaces designated for their installations.
14. Transformers shall meet the minimum energy efficiency values per NEMA TP1 as listed below:

kVA Rating	Output efficiency (%)
15	97
30	97.5
45	97.7

kVA Rating	Output efficiency (%)
75	98
112.5	98.2
150	98.3
225	98.5
300	98.6
500	98.7
750	98.8

## 2.2 NONLINEAR TRANSFORMERS

- A. Transformers shall be designed to withstand the overheating effects caused by harmonics resulting from non-linear (non-sinusoidal) loads such as office equipment using solid-state switching power supplies (i.e. computers, laser printers and copiers).
- B. Copper coils' neutrals shall carry at least 200% of normal phase current.
- C. Minimum efficiency designed to supply circuits with a harmonic profile equal to or less than a K factor of 13 without exceeding specified temperature rise. Transformers with K factor of 13 shall be provided, if K factor is not shown on contract drawings. Table below applies to K-13 transformers only.

Harmonic	K-13 (%)
Fundamental	100
3 <sup>rd</sup>	70
5 <sup>th</sup>	42
7 <sup>th</sup>	5
9 <sup>th</sup>	3
11 <sup>th</sup>	3
13 <sup>th</sup>	1
15 <sup>th</sup>	0.7
17 <sup>th</sup>	0.6

## PART 3 - EXECUTION

### 3.1 INSTALLATION

- A. Installation of transformers shall be in accordance with the NEC, as recommended by the equipment manufacturer and as shown on the drawings.
- B. Install the transformers with adequate clearance at a minimum of 100 mm (4 inches) from wall and adjacent equipment for air circulation to remove the heat produced by transformers.
- C. Install transformers on vibration pads designed to suppress transformer noise and vibrations.
- D. Use flexible metal conduit to enclose the conductors from the transformer to the raceway systems.

### 3.2 SPARE PARTS

- A. Deliver the following spare parts for the project to the Resident Engineer two weeks prior to final inspection:
1. Six stand-off insulators.
  2. Six insulated protective caps.
  3. One spare set of high voltage fuses for each size fuse used in the project.

### 3.3 TRAINING

- A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain systems. Refer to Division 01, Section 01 79 00. Training of the VAMC operation and maintenance personnel is required in cooperation with the VA Resident Engineer. Provide competent, factory authorized personnel to provide instruction to operation and maintenance personnel concerning the location, operation, and troubleshooting of the installed systems. The instruction shall be scheduled in coordination with the VA Resident Engineer after submission and approval of formal training plans. Refer to Section 017900, Demonstration and Training, and Section 019113, Commissioning, for contractor training requirements.

### 3.4 FUNCTIONAL PERFORMANCE AND INTEGRATED SYSTEMS TESTING

- A. Functional Performance & Integrated Systems Testing is part of the Commissioning Process. Functional Performance & Integrated Systems Testing shall be performed by the contractor and witnessed and documented by the Commissioning Authority. Refer to Section 019113, Commissioning, for functional performance and integrated systems testing and commissioning requirements.

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