MICHIGAN

DEPARTMENT OF TRANSPORTATION

SPECIAL PROVISION

FOR

**BRIDGE ELECTRICAL WORK**

BRG:JST 1 of 102 APPR:SCK:SW:11-02-23

**a. Description.** This special provision covers the fabrication and installation of the bridge power, control, and electrical equipment for the Lafayette bridge. The work will consist of furnishing, installing, and placing in satisfactory operating condition the complete electrical control and power distribution system for the permanent operation of the movable span and its auxiliaries, in accordance with the plans, and specifications, or as directed by the Engineer. Where not specifically covered in the contract, install all equipment in accordance with the manufacturer’s published recommendations.

Included in this work is the furnishing and installing of power distribution equipment, automatic transfer switch, span position instrumentation, programming logic, programmable logic controllers, control console, main motor drives, motors, motor control centers, motor controls, auxiliary control system, tail locks, submarine cables, navigation lights, traffic gates, heating, lighting, receptacles, conduit, conductors and all other materials necessary for controlling the movable bridge span and it auxiliary systems. Ensure all apparatus for controlling and supporting the operation of the bridge signals and gates is furnished and installed under this item.

Ensure any incidental apparatus, appliance, material, or labor not herein specifically mentioned or included that may be found necessary to comply with the requirements of the related documents and referenced standards or codes or to provide a complete and functioning system is furnished as if specifically mentioned in the contract and without extra cost to the contract.

Also included in this work are the removal, storage, and/or disposal of all existing material that is to be demolished. If, at the discretion of the Department, existing components are to be salvaged, the Contractor will coordinate delivery to an agreed upon location.

Motors, traffic gates, gongs, navigation lights, brackets, and foundations are included under this pay item. All conduits, boxes, wiring, cables, and other equipment required to extend the necessary circuits from the control house to the bridge signals, traffic gates, gongs, navigation lights, etc. are included under this pay item.

Ensure the alignment and fastening of electrical equipment to be incorporated into the bridge machinery, such as motors, brakes, rotary limit switches, position encoders, tail lock limit switches, and fully seated limit switches are done under the appropriate machinery item.

It is the intent and purpose of this special provision to cover and include all apparatus and appliances to properly install, wire, connect, equip, test, adjust, and put into approved working order the respective portions of the electrical work specified herein. Furnish any incidental apparatus, appliance, material, or labor not herein specifically mentioned or included, but that the Engineer deems necessary to comply with the requirements of the related documents and referenced standards or codes, just as if specifically mentioned in this special provision and without extra cost to the contract.

Obtain any required permits and approvals of all Departments or Agencies having jurisdiction.

Ensure all work performed and all materials furnished are in accordance with the lines, grades, cross sections, and dimensions and materials requirements, including tolerances, shown in the contract.

Plan dimensions and contract specification values are to be considered as the target value to be strived for and complied with as the design value from which any deviations are allowed. It is the intent of the special provision that the materials and work quality are uniform in character and in accordance with the prescribed target value or to the middle portion of the tolerance range.

If the Engineer finds the materials or the finished product are not in accordance with the contract, but that reasonably acceptable work has been produced, they will then decide if the work will be accepted and remains in place.

1. References. Utilize the most recent version of the following references in the performance of this work.

A. *National Fire Protection Association (NFPA) 70 – National Electric Code (NEC)*

B. *American Association of State Highway and Transportation Officials (AASHTO) LRFD Movable Highway Bridge Design Specifications*

C. *InterNational Electrical Testing Association (NETA) Acceptance Testing Specifications*

D. *American Society for Testing and Materials (ASTM)*

E. *American National Standards Institute (ANSI)*

F. *American Institute of Steel Construction (AISC)*

G. *Electrical Apparatus Service Association (EASA)*

H. *National Electrical Manufacturers Association (NEMA)*

I. *Underwriter Laboratories (UL)*

J. *Institute of Electrical and Electronics Engineers (IEEE)*

2. Codes. Comply with all local codes, all laws applying to electrical installations in effect and with the regulations of the *NEC*, where such regulations do not conflict with the laws in effect and with the requirements of the utility company.

3. Field Measurements and Verification. Before commencing any work, ordering any materials, or fabricating any items, verify all relevant dimensions at the job site and ensure their accuracy.

Verify field point-to-point wiring for connections of new installation, modifications, and replacement. Verify all field measurements that are critical to the fabrication of new items, and clearly indicate to differentiate from other dimensions on working drawings that are submitted for review and approval.

The Department and the Engineer will not, as a part of shop drawings review, bear responsibility for verification of any field measurements made by the Contractor. Review of shop drawings by the Department and the Engineer does not in any way relieve the Contractor from responsibility for the accuracy of field measurements. The Contractor bears full responsibility for any errors that may result from inaccuracy of field measurements.

4. Working Drawings and Samples. Furnish shop drawings, operation, and maintenance manuals as specified herein. Prepare and submit for review working drawings in accordance with the approved project schedule. Furnish the following working drawings in accordance with the provisions of the contract:

A. Certified dimension prints of all motors, span brakes, brake wheels, limit switches, and other electrical apparatus external to the control panels.

B. Complete schematic wiring diagrams, including all power, control, and lighting connections. Identify electrical devices and each wire between devices by an individual designation of letters, numbers, or a combination of both; and use such designations wherever the devices or wires appear on other drawings. Include a complete set of catalog cuts for materials furnished for review at time of schematic submittal.

C. Layout drawings and internal connection diagrams of the control panels.

D. A schedule of electrical apparatus which lists each electrical device by its designation as shown on the schematic wiring diagram and states for each device its rating, number of poles or contacts, function, catalog number, and location.

E. Complete interconnection diagrams for all electrical apparatus and equipment used in the operation of the spans and their auxiliaries. Ensure the diagrams are of the point-to-point type and show the external connections of all devices and equipment. The control system vendors shop drawings must include complete drawings of terminal block layouts to allow the Contractor to properly develop interconnect drawings.

F. A complete schematic conduit and cable diagram or diagrams showing the interconnection of all devices and equipment, including ducts and junction boxes, and showing all multi conductor cables. Show the size of each conduit, and the wire number of each conductor in multi conductor cables on the diagrams. Suitably number or letter each conduit and multi conductor cable and show percent wire fill. As built the final installed length.

G. A complete set of layout and installation drawings for the electrical work showing the location and installation, including support and mounting details, of all electrical apparatus and equipment. Make these drawings to scale and show the exact location of all conduits, cables, wiring ducts, boxes, motors, brakes, limit switches, disconnect switches, and other electrical equipment and the method of supporting them on the structure.

H. Outline drawings and mounting details of all navigation lights and air horns.

I. Detail drawings showing the construction and mounting details of all submarine cables and submarine cable terminal cabinets.

J. Detail drawings showing the construction and mounting details of all wiring troughs and raceways.

K. A complete list of all spare parts furnished as part of the contract.

L. Material listing and specifications for programmable controller, including input/output units, programming terminal, and equipment for interfacing.

M. The programmable controller program listings in ladder-rung formats. Describe circuit functions; identify all contacts and outputs by word description and by number designation. Number ladder rungs sequentially for reference. Fully document and comment the ladder diagram and identify and list internal ladder logic relay contacts usage in other rungs. Reference inputs and outputs to locations of signals on interconnection diagram. Include a full cross-reference report.

N. Detail drawings showing the construction of cabinets, brackets, and special supports required for the installation of the movable span flexible cable between the fixed span terminal cabinets and the movable span terminal cabinets.

Any other drawings, which may, in the opinion of the Engineer, be necessary to show the electrical work. Where specific manufacturers catalog numbers and/or class/type/form are noted on the contract, these items need not be submitted for review, so long as these exact devices are utilized. For contactors, starters, pilot devices, circuit breakers, disconnect switches and control relays, any *NEMA* rated device that meets the required ratings from Schneider Electric, Allen-Bradley, or Eaton, may be utilized without submitting for review, save that the Engineer reserves the right to reject as unsuitable, during the shop inspection or in the field, devices, or equipment that in his sole opinion does not meet the requirements of the contract. Ensure any rejected equipment or device is replaced with Engineer approved equipment or device at no additional cost to the contract or impact to the construction schedule. In addition, using the pre-approved equipment and material does not relieve the Contractor of the requirements to properly integrate this equipment into a complete, fully operational system.

On certified dimension prints of the apparatus, state in the certification the name of the job, the application of the apparatus, device designation, number required, right-hand or left-hand assembly, electrical rating, number of poles or contacts, material, finish, and any other pertinent data to show that the apparatus meets the specified requirements.

Upon completion of the work, correct all electrical shop or working drawings to show the work as constructed and submit all electrical schematics, ladder diagrams, internal ladder logic diagrams, systems documentation, dimension drawings of equipment, and devices submitted by the electrical systems vendor in PDF format.

Submit for inspection and test, if directed by the Engineer, samples of any apparatus or device, which is proposed for use as a part of the electrical installation.

5. Instruction Books and Drawing Books.

A. Furnish to the Engineer for the bridge one bound copy and six Universal Serial Bus (USB) flash drives, one of which remains with the Design Consultant Engineer, of an instruction manual with the title Operation and Maintenance Manual, Volume 1, Operation of Electrical Equipment, containing the following:

(1) Table of Contents.

(2) Detailed, technical operating instructions, which cover span operation, manual operation, span operation with Programmable Logic Controller (PLC) disabled, etc.

(3) Detailed description of all control equipment including instructions to achieve optimum settings of all limit switches, detectors, etc.

(4) Description of control, which describes in full the functions of all protective devices, limit switches, contactors, relays, PLC and associated equipment and all other electrical equipment used, both in the power service and in the control system, in connection with each step in the operating sequence. Use wire and apparatus numbers appearing on the wiring diagrams in this description for identifying the various devices and circuits.

To augment the description of control and operations, include reference drawings showing locations of equipment. Include a layout of control apparatus in the machinery rooms. Cross-reference all descriptions with reference drawings.

B. Furnish to the Engineer for the bridge one bound copy and six USB flash drives, one of which remains with the Design Consulting Engineer, of a book with the title Operation and Maintenance Manual, Volume 2, Maintenance of Electrical Equipment, containing the following:

(1) Table of Contents.

(2) Maintenance instructions for the electrical equipment, including warnings and precautions to be observed during maintenance actions. Outline all preventive maintenance procedures and furnish a chart listing all maintenance procedures in chronological order.

(3) Set of descriptive leaflets, bulletins, maintenance instructions, and drawings covering all approved items of equipment furnished and installed under the item Bridge Elec Work.

(4) Furnish a troubleshooting flow chart for troubleshooting the bridge electrical system to facilitate the diagnosing and correcting of malfunctions.

(5) Instructions for diagnosing malfunctions of the programmable control system and for detecting failures in the external controls connected thereto.

(6) Reduced size prints of working drawings, including all schematic wiring diagrams, control console and control panel layouts and connection diagrams.

(7) PLC schematic wiring, relay logic, PLC input/output hardwire diagram, PLC logic and PLC ladder diagrams.

(8) Control console and control panel layouts and wiring diagrams.

(9) Composite schedule of electrical apparatus.

(10) Complete parts list, indicating furnished spares.

(11) Test data, equipment, criteria, and performance curves for all span drive motors.

(12) Conduit layout and installation drawings.

(13) Names, addresses and telephone numbers of vendors and suppliers.

(14) PLC Software Program. Assemble the material for the operation and maintenance manuals to form a booklet for each volume with heavy plastic covers. Assemble each booklet in a three-ring binder, approximately 9 inch by 12 inch with 3 inch D rings, with a vinyl cover to allow insertable Title Sheets. Neatly entitle each booklet with a descriptive title, the name of the bridge, the Owner, the location, year of installation, Contractor, and Designer. Include easily legible copies of drawings in black on a white background. Submit the arrangements of the booklets, the method of binding, material to be included, and the text to the Engineer for approval. Complete the final bound volumes of the instruction books and make them available at the bridge site for use during the field-testing period specified herein for the electrical work.

Number and list by section in the Table of Contents all literature and descriptive materials included in any manual.

Separate each section/subsection with tabbed divider sheets. Suitably title each tab. Use 20 pound, 3-hole pre-punched loose-leaf paper and reinforced with plastic or cloth tape.

6. Execution. Employ electricians and helpers who are trained and experienced in the installation and maintenance of industrial electrical power and control systems to perform electrical work, and specialty technicians, mechanical and structural workers who are trained and experienced in the type of work they are performing. Ensure all electrical work is supervised by supervisory personnel.

Complete all work in accordance with *National Electrical Contractors Association* *(NECA) 1-2015*. Verify all relevant dimensions prior to performing any work and ensure compliance with *NEC* required clearances (i.e., Working Space, Dedicated Equipment Space, etc.). Immediately inform the Engineer of any conflict between equipment locations shown on the plans and *NEC* required clearances. Ensure in the case of any such conflict, the equipment in question is relocated or similar remedial action taken, as directed by the Engineer at no additional cost to the contract.

Physically install all products in a secure manner as indicated and as required to provide a reliable installation. Inspect and test all installed products for correct installation, performance, and workmanship. Torque all terminals and other current carrying connections per the manufacturer's recommendations using calibrated tools. Furnish nameplates and necessary warning labels for all equipment, cabinets, and boxes.

7. Bridge Control System Vendor. The electrical contractor will be responsible for hiring a single, qualified control system vendor for the manufacturing and/or furnishing and assembly of all apparatus and equipment comprising the bridge control systems, including, but not limited to, drives, motors, brakes, limit switches, motor controls, control cabinets, special control panels, programmable controllers, interfacing equipment, laptop hardware for local troubleshooting, and other apparatus required to provide a complete functioning system. The vendor will assemble the control panels and console at an *UL* approved facility in accordance with *UL 508*.

The control system vendor (CSV) is required to have experience in providing electrical control systems for movable bridges of various types, including bascule, vertical-lift, swing bridges, and control systems, including alternating current (AC) vector motor drives and programmable controllers. Identify a minimum of five movable bridges for which the system vendor has provided complete systems, including solid-state drive motor control and programmable controller logic within the past 5 years.

The following applies to the control system vendor:

A. Assume complete system responsibility for the integrated functioning of all components to furnish a satisfactory assembled system operating in accordance with specified requirements.

B. Assume responsibility for the detailed schematics and fabrication of the total control systems to ensure compatibility of equipment and suitability for the intended system functioning.

C. Assume responsibility for developing the program for the PLC based on the performance specification for operation of the bridges.

D. Assume responsibility for developing and integrating Human Machine Interface (HMI) operator display and diagnostic screens.

E. Furnish supervisory assistance in the installation of equipment to ensure maximum reliability and ease of maintenance.

F. During testing of the electrical systems, it may be found that deviations from the performance specifications are required for optimum bridge operation. Include all hardware and software required for these modifications in the control system vendor scope of work at no additional cost to the contract.

G. Provide a field service staff having the capability of providing services for field coordination of construction and final adjustments to the drive system. Upon final acceptance of the bridges, furnish on-call warranty service for a period of 1 year.

Vendors known to meet the requirements are:

● Panatrol Corporation, Burr Ridge, IL

● Faith Technologies, Appleton, WI

● Dmytryka Jacobs Engineering, Toldeo, OH

Alternate vendors must submit certification of compliance with the requirements for control systems vendor to the Engineer for approval.

8. Factory Inspection and Testing. The control cabinets and other apparatus fabricated or assembled by the control system vendor are subjected to shop inspection to demonstrate compliance with all specified requirements. The inspection is intended as a means of facilitating the work and avoiding errors, and it is expressly understood that it will not relieve the Contractor of responsibility for imperfect material or workmanship.

Assemble and temporarily interconnect for operational testing, at the plant of the control system vendor, the power and control cabinets and drives with programmable controllers with all required interfacing equipment. Simulate limit switches with temporary switches and connect reduced horsepower motors to the drives. The testing is intended to demonstrate proper programmed operation of all bridge drives and auxiliary equipment in accordance with specified requirements for system functioning, including the programmable controllers, vector drives, and all control relays and motor starters.

Ensure span motors and drives are separately dynamometer tested.

Perform all tests required herein in the presence of the Engineer or his authorized representative. Do not ship any equipment from the factory until it has been released for shipment by the Engineer. Furnish notification sufficiently in advance of the date of the tests so that arrangements can be made for the Engineer to be present at the tests.

During the witnessed inspection, the Engineer will check nameplate legends, conductor identifications, instrument scales, escutcheon plate engraving, and all other details of construction for conformity with specified requirements.

9. Warranty. Store all product warranty certificates, and similar warranty information, at a single location on the project site and turn over to the Department prior to final acceptance.

Register warranties to the Department where registration is necessary as a condition of warranty coverage.

Upon final acceptance of the completed work by the Department, warrant the satisfactory in-service operation of the completed bridge electrical installation, materials, products, and related components. This warranty must extend for a minimum period of 1 year following the date of final acceptance.

When requested by the Department, within 1 year of the date of final acceptance, the CSV must provide a minimum of two project-site visits to adjust and calibrate components, make programming adjustments and revisions, and assist the Department personnel in making program changes and in adjusting equipment and controls. Provide up to 40 hours of services, exclusive of travel time, for these purposes.

10. Related Sections. Conform to applicable requirements from the following construction special provisions:

A. Special Provision for Electric Service Feed.

B. Special Provision for Bridge Machinery – General.

C. Special Provision for Operating Machinery.

D. Special Provision for Tail Lock Machinery.

**b. Materials.** Material requirements for specific apparatus, equipment, and materials are found in this section of this special provision and the following subsections of the Standard Specifications for Construction:

Conduit 918.01.A

Equipment Grounding Conductor 918.05

1. Equipment and Material Provisions. Furnish each piece of electrical equipment and apparatus with a corrosion-resisting metal nameplate on which is stamped the name of the manufacturer and the rating or capacity of the equipment or apparatus.

Use corrosion-resisting material, such as aluminum, bronze, or stainless steel, for all metal parts of the installation, except parts that are specified to be structural steel. Use cast-iron, malleable iron, or steel with a hot-dip galvanized finish where specified herein. For structural steel conform to the requirements given in the Special Provision for Bascule Span Structural Steel.

Furnish vibration proof mounting hardware, wire, and cable terminals.

Submit for approval, as soon as possible, details of any departures from the contract that are deemed necessary, and reasons for the departures. No such departures can be made, nor work started, without approval of the Engineer.

Materials are subject to inspection at any time during the contract. Failure of the Engineer to note faulty material or faulty installation during construction does not relieve the Contractor of responsibility for removing or replacing such materials or redoing work which may fail to pass any of the Engineer’s inspections of this work at no additional cost to the contract.

2. Demolition. The removal work at the bridge under this subsection will be done in conformance with all requirements from the standard specifications.

3. Provision for Salvaging Existing Equipment.  Prior to removal of previously listed items, confer with the Engineer, MDOT Maintenance Department and MDOT Project Manager as to which items are to be retained. Remove these items, properly store in a protected area, and deliver to a location specified by the Engineer and MDOT.

Salvage the following equipment from the demolition and deliver to MDOT:

A. Warning gate arms and housings and other related accessories.

B. Main Motor Drives.

C. Spare PLC Parts and Relays.

D. Bridge traffic signal standards and gongs.

E. Navigation signals and pier light fixtures.

F. CCTV monitors.

G. Any other miscellaneous equipment, if selected and required by MDOT.

4. Electric Service. Electric power for operation of the bridge and its auxiliaries is to be supplied by the local utility. All equipment, materials, and work in connection with the electric service is to be in strict accordance with the Utility’s current regulations and construction standards and will meet with their approval and the requirements of the local Electrical Code.

Conform to applicable requirements from the following construction special provision:

A. Special Provision for Electric Service Feed.

5. Automatic Transfer Switch. Furnish auto transfer switch (ATS) meeting the following minimum requirements:

A. The ATS is 600 Ampere (A), 480 VAC rated, Type 0.

B. The ATS is electrically operated and mechanically held. The electrical operator is a momentarily energized, single-solenoid mechanism. Main operators utilizing overcurrent disconnect devices, or linear motors are not acceptable. Make the switch mechanically interlocked to ensure only two possible positions, normal or emergency.

C. The switch is positively locked and unaffected by momentary outages, so that contact pressure is maintained at a constant value and contact temperature rise is minimized for maximum reliability and operating life.

D. Main contacts with silver composition.

E. Ensure inspection of all contacts is possible from the front of the switch without disassembly of operating linkages and without disconnection of power conductors. Ensure all stationary and moveable contacts are replaceable without removing power conductors and/or bus bars.

F. Furnish a neutral conductor plate with fully rated aluminum-copper (AL-CU) pressure connectors for solidly connected neutral conductors.

G. An ATS controller with sensing and logic provided in a single built-in microprocessor for maximum reliability, minimum maintenance, and the ability to communicate serially through an optional serial communication module or Ethernet connectivity module.

H. A single controller that provides 12 selectable nominal voltages for maximum application flexibility and minimal spare part requirements. Voltage sensing is to be true rms type and is to be accurate to ±1 percent of nominal voltage. Frequency sensing is to be accurate to ±0.2 percent. The control panel is to be capable of operating over a temperature range of -20 °C to +60 °C and storage from -55 °C to +85 °C.

I. Connect the controller to the transfer switch by an interconnecting wiring harness. The harness is to include a keyed disconnect plug to enable the controller to be disconnected from the transfer switch for routine maintenance. Sensing and control logic is provided on multi-layer printed circuit boards. Interfacing relays are to be industrial grade plug-in type with dust covers. Enclose the control panel with a protective cover and mount separately from the transfer switch unit for safety and ease of maintenance. Ensure the protective cover includes a built-in pocket for storage of the operator’s manuals.

J. A four-line, 20 character LCD display and keypad that is integral to the controller that allows for viewing of all available data and setting desired operational parameters. Furnish operational parameters for viewing and limited control through the communications interface port. The ATS will only allow the following parameters to be adjusted via dual in-line package (DIP) switches on the controller:

(1) Nominal line voltage and frequency.

(2) Single or three phase sensing.

(3) Operating parameter protection.

(4) Transfer operating mode configuration.

K. Make voltage and frequency settings to be field adjustable in 1 percent increments either locally with the display and keypad or remotely via the communications interface port.

L. Ensure controller is provided with a minimum of one programmable digital input that is configured to inhibit re-transferring of sources during a span operation. A fully seated indication is to be provided to allow for retransferring.

M. Ensure the controller is capable (when activated by the keypad or the communications interface port) of sensing the phase rotation of both the normal and emergency sources. The source will be considered unacceptable if the phase rotation is not the preferred rotation selected (ABC or CBA).

N. Furnish source status screens for both normal and emergency with a digital readout of voltage on all 3 phases, frequency, and phase rotation.

O. Furnish an adjustable time delay of 0 to 6 seconds to override momentary normal source outages and delay all transfer and engine starting signals.

P. Furnish a time delay on transfer to emergency, adjustable from 0 to 60 minutes, for controlled timing of transfer of loads to emergency.

Q. Furnish two-time delay modes (which are independently adjustable) on re-transfer to normal. One time delay for actual normal power failures and the other for the test mode function. The time delays are to be adjustable from 0 to 60 minutes. Ensure the time delay is automatically bypassed if the emergency source fails and the normal source is acceptable.

R. Furnish a time delay on shut down of engine generator for cool down, adjustable from 0 to 60 minutes.

S. Furnish a time delay activated output signal to drive an external relay(s) for selective load disconnect control. The controller is to have the ability to activate an adjustable 0 to 5 minute time delay in any of the following modes:

(1) Prior to transfer only.

(2) Prior to and after transfer.

(3) Normal to emergency only.

(4) Emergency to normal only.

(5) Normal to emergency and emergency to normal.

(6) All transfer conditions or only when both sources are available.

T. All time delays will be adjustable in 1 second increments.

U. All time delays will be adjustable by using the LCD display and keypad or with a remote device connected to the communications interface port.

V. Furnish a single pole double throw (SPDT) contact, rated 5 A at 30 VDC, for a low-voltage engine start signal. The start signal is to prevent dry cranking of the engine by requiring the generator set to reach proper output and run for the duration of the cool down setting, regardless of whether the normal source restores before the load is transferred.

W. Furnish auxiliary contacts, rated 10 A, 250 VAC consisting of two contacts, closed when the ATS is connected to the normal source and two contacts closed, when the ATS is connected to the emergency source.

X. Furnish LED indicating lights; one to indicate when the ATS is connected to the normal source (green) and one to indicate when the ATS is connected to the emergency source (red).

Y. Furnish LED indicating lights energized by controller outputs. Ensure the lights provide true source availability of the normal and emergency sources, as determined by the voltage sensing trip and reset settings for each source.

Z. Provide the ability to select commit/no commit to transfer to determine whether the load should be transferred to the emergency generator if the normal source restores before the generator is ready to accept the load.

AA. Ensure the controller is capable of accepting a normally open (N.O.) contact that allows the transfer switch to function in a non-automatic mode when a non-automatic version of the user interface membrane is furnished.

BB. Ensure the controller provides an internal engine exerciser. The engine exerciser allows the user to program up to seven different exercise routines. For each routine, the user will be able to:

(1) Enable or disable the routine.

(2) Enable or disable transfer of the load during routine.

(3) Set the start time, time of day, day of week, week of month (1st, 2nd, 3rd, 4th, alternate or every).

(4) Set the duration of the run.

At the end of the specified duration the switch must transfer the load back to normal and run the generator for the specified cool down period. A 10-year life battery that supplies power to the real time clock in the event of a power loss must maintain all time and date information.

CC. Ensure automatic transfer switches are ASCO 4000 Series or approved equals by Eaton or Siemens.

6. Standby Generator. Furnish a standby, natural gas-fueled, open engine generating set in a sound attenuated enclosure with radiator mounted load bank as shown on the plans.

Ensure the generator is the latest commercial type and design rated for standby service at a minimum of 400 KW, at 0.8 PF, 60 hertz (Hz), 480 V, 3 phase, and 4 wire. The total allowable instantaneous voltage dip will be a maximum of 25 percent. The maximum instantaneous frequency dip will be 15 percent.

Ensure the standby natural gas-fueled engine generator package of new equipment consists of:

A. A natural gas-fueled, engine-driven electric generating set in a sound attenuated enclosure, complete with starting battery pack, and charger. Sound attenuating enclosure will attenuate the sound from the generator at 7 meters to a maximum of 88dBA.

B. An engine start-stop control system set.

C. Mounted accessories as specified.

D. A load bank complete with controls integral to the set, sized as per manufacturer recommendations.

E. Automatic load step controller will be provided to maintain load of the generator at minimum 50 percent of rating.

Mount the generator on a new concrete slab as shown on the plans. Use Grade 3500 concrete in accordance with section 1004, steel reinforcement in accordance with section 905, and adhesive anchoring in accordance with subsection 712.03.J of the standard specifications for construction. The concrete slab, reinforcement, conduit sleeves, and anchors will be included in the overall generator price. Ensure conduit sleeves are provided in concrete slab.

7. Feeder Fusible Disconnect Switches. Ensure individual feeder disconnect switches are quick-make, quick-break gang-operated type utilizing Class R fuse clips if required by the manufacturer. Ensure disconnect switches are *NEMA 12* and sized as shown on plans.

Ensure during normal operation of the switch, that operation of the contacts will not be capable of being restrained by the operating handle after the closing or opening action of the contacts has started. Ensure that the disconnect switch operating handle is an integral part of the box, not the cover. Ensure the disconnect switch has provisions for padlocking the switch in the OFF position with at least three padlocks provided. Ensure the handle position travels at least 90 degrees between OFF and ON positions to clearly distinguish and indicate handle position.

Ensure that the disconnects are supplied with auxiliary contacts that open when the disconnect switch is in the open position.

Ensure all heavy duty disconnect switches have a dual cover interlock mechanism to prevent unintentional opening of the switch cover when the switch is ON and prevent turning the switch ON when the cover is open. Ensure the cover interlock mechanism has an externally operated override but the override does not permanently disable the interlock mechanism. Ensure the tool used to override the cover interlock mechanism is required to enter the enclosure in order to override the interlock.

Ensure the fused switch is rated a minimum 42 kAIC at rated voltage.

Ensure generator is by Kohler, Caterpillar, Generac or approved equals.

8. Disconnect Switches. Ensure disconnect switches are rated as shown on plans, but in no instances can they be rated for less than 30 A. Ensure disconnect switches in the machinery rooms, pier areas, rack level, and any equipment outside of the control house are of the heavy-duty type *NEMA 4X Type 316* Stainless steel enclosures. Ensure all others in conditioned spaces are *NEMA 12*. Ensure disconnect switches are *UL* listed and in accordance with *NEMA KS 1* and *UL 98*.

Supply the disconnects with auxiliary contacts that open when the disconnect switch is in the open position. Ensure the auxiliary contacts feed the heater circuit for the motors, and PLC inputs. Ensure the contacts are rated at a minimum of 10 A.

Ensure the operating mechanism for heavy duty disconnect switches is a quick make, quick break such that, during normal operation of the switch, the operation of the contacts won’t be capable of being restrained by the operating handle after the closing or opening action of the contacts has started. Ensure the disconnect switch operating handle is an integral part of the box, not the cover. Ensure the disconnect switch has provisions for padlocking the switch in the OFF position with at least three padlocks being provided. The handle position will travel at least 90 degrees between OFF and ON positions to clearly distinguish and indicate handle position.

Ensure all heavy duty disconnect switches have a dual cover interlock mechanism to prevent unintentional opening of the switch cover when the switch is ON and prevent turning the switch ON when the cover is open. Ensure the cover interlock mechanism has an externally operated override, but the override must not permanently disable the interlock mechanism. Ensure the tool used to override the cover interlock mechanism is not required to enter the enclosure in order to override the interlock.

Ensure disconnects are by Schneider Electric or approved equals by Eaton or Siemens.

9. Span Drive Main Motors. Ensure the drive motors are vector duty motors. Build them in accordance with *NEMA publication MG-1* and ensure they are designed for use with an Insulated Gate Bipolar Transistor AC closed loop vector control. Ensure they are 3 phase 60 Hz base speed, with moisture resistance insulation, 50 °C temperature rise, and capable of reversing. Construct the motor frame of cast iron.

Ensure the span drive motors are *NEMA B*, 40 horsepower (HP), 900 revolutions per minute (RPM), 480 VAC, 60 Hz, with a full load amperage rating of 52 A with a frame as shown on the plans.

Ensure the motors are totally enclosed non-ventilated construction, with re-greaseable ball bearings, moisture resistant insulation, rated on a basis of 60 minutes for use in 40 °C ambient temperature. Use insulation Class H or better, with special treatment to retard a decrease in insulation resistance due to excessive moisture.

Furnish an in-sight disconnect switch within view of each motor as specified elsewhere.

Furnish the vector duty span motor with a heater. Ensure the heater is a single-phase, 120 V unit suitable for continuous operation under the conditions of installation. Wire the heater in each motor frame to the N.O. auxiliary contact in the corresponding motor disconnect switch.

Furnish a plugged drain hole at the bottom of the motor.

Ensure all windings are copper. Ensure the motor is capable of having a minimum breakdown torque of 250 percent. Motor must have a speed range of 1000:1 and be capable of having full torque at zero speed. Ensure motor design is low inertia and slip design. Install normally closed (N.C.) temperature sensors in the windings.

Ensure the conduit boxes are liberally sized and located to avoid interference with the machinery. Size the conduit boxes in accordance with the requirements of the *NEMA MG 1-2014*. Furnish the conduit boxes with suitable terminal blocks for the motor power, heater, and thermostat connections.

Ensure each motor is provided by the manufacturer with a heavy mill duty modular magnetic encoder. Ensure they are of stainless steel and designed for washdown and marine duty. Ensure they are provided with magnetic sensors that are fully potted, to withstand dirt and liquids, with no moving or wearing parts. They must have built in diagnostics, with a green light to confirm proper operation and adjustment, and in the event of failure the light changes to red and a remote alarm contact activates. Ensure they will operate at 5 – 24 VDC, 100 milliamperes (mA) no load. Ensure the output format is A Quad B with Marker (A,A–, B,B–, Z,Z–). Ensure it provides a maximum instantaneous current output of 3000 mA. Ensure they provide 1024 pulses per revolution (PPR) output or as recommended by the drive manufacturer. Ensure the electronics is fully encapsulated and rated Ingress Protection 67. Ensure they operate at a temperature range of -40 °C to 100 °C (150 °C rotor). Ensure they are provided with a polyurethane enamel paint to protect against salt spray, mild acids, and bases.

Ensure the motors are designed and manufactured in the United States of America. Ensure all steel for motors is locally sourced and certified in accordance with all Buy America requirements. Manufacture all motors to the following standards:

A. *IEEE Marine Standards 45*.

B. *American Bureau of Shipping (A.B.S.).*

C. *U.S. Coast Guard Inspection Service*.

Modifications needed to meet the requirements of these specifications are as follows:

D. Double sealed ball bearings.

E. Seal all joints and eye bolt holes.

F. Sealed leads in terminal box.

G. Shaft seals.

H. Removable drain plugs.

I. Final coat of epoxy paint.

J. Corrosion resistant coating - rotor and stator laminations.

K. Stainless steel and/or mylar nameplate.

L. Class H insulation. Includes protection against fungus growth per Military Standard (*MIL)-V­173B*.

Finish the motor frames with a corrosion-resistant paint or coating. Ensure exposed unpainted metal surfaces are of a corrosion-resistant material.

Design motors to operate at carrier frequencies up to 20 kilohertz (kHz).

Ensure all motors are dynamically balanced.

Perform *NEMA MG-1* full commercial test on each motor. Dynamometer test all motors to verify and document speed/torque and current characteristics. Submit to the Engineer for approval.

Subject all motors to an insulation resistance test per *NEMA standard MG-1, Section Nos. 12.02* and *12.03* or *IEEE 4*. Include insulation resistance values and test voltage on the test reports.

Report tests on the standard forms for induction motors from the *NEMA*. Have all test reports and curve sheets certified by the manufacturer and submit one digital copy of each. Do not ship motors from the plant of the manufacturer until the test reports have been approved by the Engineer.

Test each drive motor with one of the span drives. Conduct the tests using a four-quadrant dynamometer that will provide 200 percent overhauling load to 200 percent motoring load at 5 percent, 25 percent, 50 percent and 100 percent full load speed. Ensure 150 percent and 200 percent overhauling loads and motoring loads are only performed for 60 second and 10 second intervals, respectively.

Submit the facility performing the testing for approval of the Engineer along with a written test procedure. Ensure the tests are witnessed by the Engineer and 3 weeks’ notice is furnished prior to the testing.

After entire motor, brake, and control system installation, the Contractor will perform a speed/current/power test to demonstrate that the motor functions properly and provides the specified operating characteristics as called out in the testing section of this special provision. Ensure the data is recorded on a personal computer based data acquisition streamed to disk at a rate not less than 10 Hz and includes acceleration, deceleration, full speed, reduced speed, and creep speed.

Ensure the motors are manufactured by Marathon, Reuland, Baldor, or a manufacturer approved by the Engineer.

10. Vector Motor Drives. Size the drives based on the full load torque rating of the motors and ensure they allow for 150 percent overload for 60 seconds, and 200 percent for 10 seconds. The catalog numbers and ratings of the drives listed on the drawings is approximate and must be confirmed with the drive motor approved shop drawings. Furnish the correctly sized drive, meeting all the requirements, at no additional cost to the project.

Ensure vector drives are four quadrant drives and are capable to run in speed and torque mode with adjustable torque limits in all four quadrants.

To minimize electrical and acoustical noise, and to eliminate low speed cogging, ensure a minimum switching frequency of 15 kHz is used. The drive must not cog at any frequency with a 1000:1 speed regulation. Ensure there is no sudden frequency shifts and associated acoustical noise shifts as the output frequency is varied between 0 and 60 Hz.

The drive’s input displacement power factor will be 0.98 or better over the entire operating frequency and load range. Ensure efficiency is at 96 percent minimum at rated load. Furnish manufacturer’s typical test results or calculations with submittal to verify efficiency and power factor.

Furnish the drives with input (line) reactors as specified by the drive manufacturer.

The vector drive must have capability to maintain full performance without de-rating for up to 500 feet long motor feeders. Include line or load reactors (if required due to actual motor feeder length) as a standard equipment to minimize interference on the power bus.

Select *IEEE 519* compliant vector drives to limit harmonic distortion at the power distribution point of service, including line notching and transients. Take the necessary steps to limit Total Harmonic Distortion (THD) to reduce such harmonics to the allowable limits in excess of the prescribed limits of the utility company. Ensure THD measured at the power input terminals of variable-frequency drive (VFD) must not exceed 20 percent at 50 percent or higher load. Submit with VFD system voltage and current THD calculations at the point of service for the particular drive system for approval.

Supply output reactors as required per drive and motor manufacturer recommendations.

A. Ensure the vector drives have, but not be limited to, the following features:

(1) Manufacturer provided Ethernet communications module to allow transfer of all commands and operational data/faults to the PLC network.

(2) Digital Input/Output (I/O) Modules.

(3) High speed analog inputs.

(4) Allow for smooth and instantaneous connection into rotating loads, regardless of commanded direction, without the need for any speed feedback.

(5) Inertia Ride-Through to allow for trip-less operation during a prolonged power outage by using the rotating energy stored in high inertia, low-friction loads.

(6) Furnish a torque proving circuit to ensure proper control of the load when transferring control between the drive and a mechanical brake.

(7) Slip compensation to provide a minimum 0.5 percent speed regulation without feedback hardware.

(8) Encoder feedback to provide ±2 percent regulation and the ability to hold full load at zero speed.

(9) Furnish solid state output ground fault protection.

(10) Furnish adaptive electronic motor overload protection which will protect both the motor and the drives at all frequencies. Ensure this overload protection is *UL* approved. Electronic thermal overload circuits which only protect the motor at full speed will not be acceptable. The drive will sense the load and speed and will recalibrate the thermal trip curve to insure low speed motor protection. The initial trip point will be adjustable from at least 40 percent of the drive continuous rating to account for motor magnetizing current.

(11) Configure the drives for minimum 6-pulse operation to effectively reduce harmonic distortion content by using front end filtering.

(12) Input surge protection.

(13) Input and output (I/O) phase loss detection.

(14) Output short circuit protection.

(15) Programmable current limit.

(16) Remote drive reset contact.

(17) Minimum of 1,000:1 controllable constant torque speed range when in closed loop mode. Speed regulation will be 0.01 percent or better over the entire speed range.

(18) Minimum of 2 second power loss ride-through capability. In the event of a loss of three-phase power lasting 2 seconds or less, the drive must maintain operation and prevent nuisance trips upon return of power.

B. The ‘Drive Trouble’ fault condition will cause the drives to shut off and will be annunciated to the PLC control system through the Ethernet connection. All faults will be transmitted to the PLC. The following conditions at minimum will cause a drive shutdown fault:

(1) Blown fuse.

(2) Instantaneous overcurrent trip.

(3) Direct current (DC) bus overvoltage.

(4) DC bus undervoltage.

(5) Excessive ambient drive heat sink over temperature.

(6) External fault input.

(7) Internally diagnosed, control failure.

(8) Motor thermal overload.

(9) Drive thermal overload.

The drives will employ modular printed circuit board design for ease of troubleshooting. Ensure all connectors are polarized type and clearly marked on both the connector and printed circuit board to ensure proper connection.

C. Each drive will be provided with a door-mounted LCD Human Interface module station with the following minimum features:

(1) Remote versions for panel mount application.

(2) Large and easy to read 7-line by 21-character backlit display.

(3) Alternate function keys for shortcuts to common tasks.

(4) Calculator-like number pad for fast and easy data entry.

(5) Control keys for local start, stop, speed, and direction.

All drive functions will be programmable from the door-mounted keypad. Ensure the keypad is equipped with EEPROM and is removable so that the parameters can be downloaded into another drive.

Ensure the vector motor drives are manufactured by Allen Bradly, Siemens, Nidec or as approved by the Engineer.

11. Braking Resistors. Furnish drives with heavy duty dynamic braking modules and resistors capable of providing 100 percent braking on a continuous basis and 150 percent dynamic braking for 60 seconds.

Furnish braking modules as required. Design the braking modules for use with the drive, including all inputs and outputs required for proper interfacing with the drive. Converter protective features must include module overload.

Ensure braking resistors are edge-wound stainless steel, mounted in ventilated enclosures. Ensure openings are screened or otherwise protected to prevent entry of small rodents. Use stainless steel or similarly corrosion resistant hardware. Wire braking resistors to terminal blocks with high temperature silicone or Teflon wire rated for 150 °C or higher. Interconnect braking module fault contact and resistor built-in over-temperature sensor to the VFD to initiate an alarm and drive stop in the event of a resistor over-temperature condition. Where shown on the plans, braking resistors are permitted to be installed in outdoor locations. For resistors installed in outdoor locations, furnish enclosures suitably rated for outdoor locations (*NEMA 3R*), constructed from stainless steel, with rain hoods.

Locate the dynamic braking modules with the flux vector drive and mount the power dissipating resistors at locations shown on the plans.

12. Auxiliary Motors. Ensure the auxiliary drive motors are an AC induction type, squirrel cage type, motor. Ensure the motor is built in strict accordance with *NEMA publication MG 1*. Ensure it is a 3 phase 60 Hertz, with moisture resistance insulation, 120 °F temperature rise, and capable of instant reversing.

Ensure the auxiliary motors are *NEMA D*, 10 horsepower (HP), 900 revolutions per minute (RPM), 480 VAC, 60 Hz, with a frame as shown on plans.

Ensure the motors are totally enclosed non-ventilated construction, with re-greaseable ball bearings, moisture resistant insulation, rated on a basis of 60 minutes for use in 40 °C ambient temperature. Use insulation Class H or better, with special treatment to retard a decrease in insulation resistance due to excessive moisture.

Furnish an in-sight disconnect switch within view of each motor as specified elsewhere.

Furnish the motors with a heater. Ensure the heater is a single-phase, 120 V unit suitable for continuous operation under the conditions of installation. Wire the heater in each motor frame to the N.O. auxiliary contact in the corresponding motor disconnect switch.

Ensure each motor is provided by the manufacturer with a heavy mill duty modular magnetic encoder. Ensure they are of stainless steel and designed for washdown and marine duty. Ensure they are provided with magnetic sensors that are fully potted, to withstand dirt and liquids, with no moving or wearing parts. They must have built in diagnostics, with a green light to confirm proper operation and adjustment, and in the event of failure the light changes to red and a remote alarm contact activates. Ensure they will operate at 5 – 24 VDC, 100 milliamperes (mA) no load. Ensure the output format is A Quad B with Marker (A,A–, B,B–, Z,Z–). Ensure it provides a maximum instantaneous current output of 3000 mA. Ensure they provide 1024 pulses per revolution (PPR) output or as recommended by the drive manufacturer. Ensure the electronics is fully encapsulated and rated Ingress Protection 67. Ensure they operate at a temperature range of -40 °C to 100 °C (150 °C rotor). Ensure they are provided with a polyurethane enamel paint to protect against salt spray, mild acids, and bases.

Ensure the motors are designed and manufactured in the United States of America.  All motors steel will be locally sourced and certified in accordance with all Buy America requirements. Ensure all motors are manufactured to the following standards:

A. IEEE Marine Standards No. 45.

B. American Bureau of Shipping (A.B.S.).

C. U.S. Coast Guard Inspection Service.

Modifications needed to meet the requirements of these specifications are as follows:

A. Double sealed ball bearings.

B. Seal all joints and eye bolt holes.

C. Sealed leads in terminal box.

D. Shaft seals.

E. Removable drain plugs.

F. Final coat of epoxy paint.

G. Corrosion resistant coating - rotor and stator laminations.

H. Stainless steel and/or mylar nameplate.

I. Class H insulation. Includes protection against fungus growth per MIL-V­173B.

Ensure the motor frames are finished with a corrosion-resistant paint or coating. Ensure exposed unpainted metal surfaces are of a corrosion-resistant material.

Ensure all motors are dynamically balanced.

Perform *NEMA MG-1* full commercial test on each motor. Dynamometer test all motors to verify and document speed/torque and current characteristics. Submit to the Engineer for approval.

Subject all motors to an insulation resistance test per *NEMA standard MG-1, Section Nos. 12.02 and 12.03* or *IEEE 4*. Include insulation resistance values and test voltage on the test reports.

Report tests on the standard forms for induction motors of the *NEMA*. Have all test reports and curve sheets certified by the manufacturer and submit one digital copy of each. Do not ship motors from the plant of the manufacturer until the test reports have been approved by the Engineer.

Ensure the motors are manufactured by Marathon, Reuland, Baldor, or as approved by the Engineer.

13. Auxiliary Motor Clutch. Furnish an auxiliary electric clutch as shown on the plans. Mount the clutch on the output of the auxiliary motor gear reducer with a solid shaft. Furnish AC-DC rectifier controls to engage clutch. Ensure the rectifier is rated to operate at 115 VAC, and have an adjustable DC voltage output of 15-100 VDC. Clutches are to be by Stearns, Warner Electric, or Engineer approved equal.

14. Tail Lock Gearmotors. Ensure the tail lock gearmotors are an AC induction type, squirrel cage type, motor with mechanical reduction as shown on the plans. Build the motor in strict accordance with *NEMA publication MG 1*. Ensure it is a 3 phase 60 Hertz, with moisture resistance insulation, 120 °F temperature rise, and capable of instant reversing. Ensure the tail lock motors are 3 HP, 1200 RPM, 480 VAC, 60 Hz, *NEMA D*, with a full load amperage rating of 4.8 A, C face motor with a frame as shown on plans.

Ensure the motors are totally enclosed non-ventilated construction, with re-greaseable ball bearings, moisture resistant insulation, rated on a basis of 60 minutes for use in 40 °C ambient temperature. Use insulation Class H or better, with special treatment to retard a decrease in insulation resistance due to excessive moisture.

Furnish an in-sight disconnect switch within view of each motor as specified elsewhere.

Furnish the motors with a heater. Ensure the heater is a single-phase, 120 V unit suitable for continuous operation under the conditions of installation. Wire the heater in each motor frame to the N.O. auxiliary contact in the corresponding motor disconnect switch.

Ensure the motors are designed and manufactured in the United States of America. All motors steel will be locally sourced and certified in accordance with all Buy America requirements. Ensure all motors are manufactured to the following standards:

A. IEEE Marine Standards No. 45.

B. American Bureau of Shipping (A.B.S.).

C. U.S. Coast Guard Inspection Service.

Modifications needed to meet the requirements of these specifications are as follows:

A. Double Sealed ball bearings.

B. Seal all joints and eye bolt holes.

C. Sealed leads in terminal box.

D. Shaft seals.

E. Removable drain plugs.

F. Final coat of epoxy paint.

G. Corrosion resistant coating - rotor and stator laminations.

H. Stainless steel and/or mylar nameplate.

I. Class H insulation. Includes protection against fungus growth per MIL-V­173B.

Ensure the motor frames are finished with a corrosion-resistant paint or coating. Ensure exposed unpainted metal surfaces are of a corrosion-resistant material.

Ensure all motors are dynamically balanced.

Subject all motors to an insulation resistance test per *NEMA standard MG-1, Section Nos. 12.02 and 12.03* or *IEEE 4*. Include insulation resistance values and test voltage on the test reports.

Report tests on the standard forms for induction motors of the *NEMA*. Have all test reports and curve sheets certified by the manufacturer and submit one digital copy of each. Do not ship motors from the plant of the manufacturer until the test reports have been approved by the Engineer.

Ensure the motors are manufactured by Marathon, Reuland, Baldor, or as approved by the Engineer.

15. Span Brakes. Furnish four electrohydraulic thrustor type machinery brakes and four electrohydraulic thrustor type motor brakes as shown on the plans. The brakes act upon brake wheels press fit onto shafts as called out on the mechanical drawings. See the machinery specifications for details.

Provide spring-set, thrustor-released, shoe-type, open brakes with corrosion-resisting fittings. Brake will have the drum size and torque requirements as listed on the plans, with permanent torque setting limited as required.

Furnish all brake wheels with the brakes by the brake manufacturer. Leave the bores undersize and ship the wheels to the machinery manufacturer who will finish-bore and press the wheels onto the gearbox input shaft.

Equip each brake with a hand release, which will not change the torque setting or require removable levers or wrenches. Locate the hand release mechanism on the side of the brake away from the main reducer. (Right hand and left hand units are required.) Furnish each hand release with a lever type limit switch for interlocking purposes as described under Interlocking. Ensure it is not possible to set the hand release of the brakes without tripping these switches. Ensure switches are Cutler-Hammer Series E50, *NEMA 6P+* with epoxy potted cord sets or approved equal.

In addition to the hand release limit switch, mount two lever type limit switches on each brake. Ensure one indicates that the brake is fully set, the other that the brake is fully released. Assure that the brake released limit switch (which will have two N.O. contacts) trips when the brake is electrically released or hand released. Ensure the brake set limit switch has one N.O.

and one N.C. contact and is tripped when the brake is fully set. Ensure switches are Eaton Series E50, *NEMA 6P+* with epoxy potted cord sets or approved equal.

Ensure each thrustor actuator is provided with a time delay valve adjustable between 0 and 5 seconds for setting the brake. Only an internal time delay valve constructed of stainless steel is acceptable. Ensure the adjustment is infinitely adjustable between the minimum and maximum settings. Ensure these adjustments are allowable with the brake in full service. Set the down-stroke time delays of the thrustors in such a manner that the brakes are not applied simultaneously should electric power fail while the span is in motion. Adjust the intervals between the setting of the brakes to obtain smooth stopping of the span in the shortest possible time.

Furnish the oil used in the thrustor operating chambers of the brakes to be of a grade as recommended by the manufacturer and approved by the Engineer. It will have a free operating temperature range between -40 °C and 66 °C.

Furnish 480 V, 3-phase, 60 Hz, totally enclosed, squirrel cage motors controlled by magnetic contactors with manual-reset thermal overload relays to actuate the thrustors. Ensure the rated stalled thrust of each thrustor is not less than 135 percent of the thrust actually required to release the brake with the torque adjusted to the continuous rated value.

Equip each brake with a *NEMA 3R* enclosure, which encloses the entire brake assembly, including the brake thrustor unit, and the brake wheel, and should not prevent brake hand release operation.

Ensure each brake is provided with automatic wear compensators.

Ensure all brakes steel is locally sourced and certified in accordance with all Buy America requirements.

Ensure the brakes are Mondel Engineering type MBT/E, Ametek, or as approved by the Engineer.

16. Programmable Logic Controller (PLC) System. Ensure bridge main controls and monitoring functions are performed by a PLC system, which provides diagnostics of the bridge and its auxiliaries in accordance with the system functioning specified herein and the control logic shown on the plans.

A. Use an industrial quality, field expandable PLC system comprised of the PLC processor module, local and distributed input and output (I/O) modules, communication modules, interface components, digital and analog I/O modules, power supply, and/or special function modules installed together in multi-module blocks on Deutsches Institut für Normung (DIN) rail or panel, and all other hardware necessary for a complete working system. Use only PLC system components manufactured for use with each other in such a system, by one manufacturer to the extent practicable. Prior to purchase or installation, coordinate with the PLC system components manufacturers to ensure that all components are fully compatible with one another, suitable for the intended purpose, meet all applicable ratings and requirements, and are installed in accordance with manufacturer recommendations. Furnish the system complete with all components and accessories required for proper operation in accordance with the requirements and intents of the contract.

B. Provide a processor with an advanced instruction set including: file handling, sequencing, diagnostics, shift register(s), immediate I/O, program control instructions, timing, counters, and mathematical functions, to be programmable in ladder-logic, function block diagram, sequential function charts, and structured text programming formats. Use processor memory of 2 Megabyte (MB) or larger, with 2 gigabyte (GB) memory card for nonvolatile memory, capable of 32 tasks, 100 programs/task and event tasks: all event triggers. Include a secure digital card for program backup. Furnish PLC to communicate via Ethernet/Internet Protocol (IP) networking with optional DeviceNet communication, include at least 2 built-in Ethernet ports plus any additional communication capabilities necessary for proper system operation.

C. Furnish PLC system programming in ladder-logic format. Furnish all program development, programming, and debugging necessary to provide a complete program to perform the control functions indicated.

Submit the intended program (in ladder logic format) and installation wiring diagrams to the Engineer for review at least 30 days prior to the shop test.

D. Furnish PLC modules for the PLC system as required for proper system operation and installation. Determine and coordinate which modules are to be utilized to satisfy the installation and operation requirements of the plans and this document. Provide I/O modules with no less than 16 spare discrete inputs and 16 spare discrete outputs.

Furnish digital input modules with input filtering and LED indicating lights to indicate the status of each input, optical isolation shielding, operating voltage from 79 to 132 VAC at 47 to 63 Hz. Furnish AC digital output modules of the relay contact type, with built-in surge suppressors and LED indicating lights to indicate the status of each output, optical isolation, operating voltage from 5 to 265 VAC. Furnish fuses with a fuse blown LED indicator for all outputs. Use analog I/O modules with 16-bit or better analog-to-digital (A/D) and digital-to-analog (D/A) conversion and include selectable input filtering capability. Use analog modules with on-board diagnostics, including over/under range and signal lost detection, auto-calibration, on-line configuration, and scaling to engineering units. In the case of a module fault, furnish modules with the ability to react with a predetermined response to minimize the potential of dangerous system operation.

Provide power supplies for the PLC system with surge protection and isolation to serve all required modules, plus at least 20 percent spare capacity.

E. Surge Protection. Furnish surge protection via modular surge protection modules consisting of protective plug and base element with integrated status indicator for conductors and cables connected to the PLC system, including the following wiring:

(1) Conductors for the power supply to the bridge control system, connected directly to the respective branch circuit conductors on the load side of the branch circuit breaker, either at the panelboard or in the PLC cabinet ahead of the power conditioner. Furnish surge suppression device(s) with a nominal voltage rating of 120 VAC, capable of handling an 8/20 microsecond surge current pulse of 5,000 amperes normal or common, with a response time of 25 nanoseconds or less for a normal surge, and 100 nanoseconds or less for a common surge. Surge protection modules consisting of protective plug and base element with integrated status indicator.

(2) Conductors for digital and analog signals leaving the control console, or PLC cabinets for field wiring of limit switches, contacts, proximity switches, control switches, sensors, and other devices subjected to induce voltage transient. Furnish nominal voltage and current ratings as recommended by the module manufacturer. Furnish surge protection modules with protective plug and base element with integrated status indicator.

(3) Conductors from output modules to control relays, motor starters, solenoids, indicators, and other devices subject to induce voltage transient. Furnish nominal voltage and current ratings as recommended by the module manufacturer. Furnish surge protection modules with protective plug and base element with integrated status indicator.

(4) Network and Communications wiring of the PLC system, including Ethernet cables. Furnish nominal voltage and current ratings as recommended by the module manufacturer.

Use the required surge protection modules, as described above, generally as the terminal blocks for interconnection of shop and field wiring.

Furnish common, uninsulated ground bars in the PLC cabinet and control console for the interconnection of all equipment grounding conductors. Furnish NRTL listed ground bars fabricated from copper. Use screw type terminals for size 6 AWG to 14 AWG copper conductors, number of terminals as required, plus at least 2 spares.

Furnish shielding and filtering where required to ensure compatibility and trouble-free operation in the intended installation environment, as may be recommended by the manufacturers of the various components. Furnish equipment that does not exhibit any malfunction, degradation of performance, or deviation from specified requirements when subjected to radiated electromagnetic fields of the intensities usually generated by typical two-way radios, marine radar, cellular phones, or other such equipment.

Coordinate with the PLC components manufacturers with respect to grounding requirements for the system, shielding of conductors, and any other necessary shielding or isolation of or from other equipment or conductors. Develop instructions for use by the Contractor to accomplish any special grounding, shielding, or isolation required, and submit these instructions to the Engineer for approval prior to installation of any affected equipment.

F. PLC Programming. Furnish a sufficiently descriptive and fully documented bridge PLC program with tag names given to every item and with extensive rung comments. Use descriptive tag names for all I/O, contacts, coils, functions, etc. in programming the bridge PLC, such that the program reader can logically ascertain by looking at just the tag name. Match tag names exactly to the device description shown on the I/O drawings and working drawings. Use comment to output coil or function of each rung as shown on contract drawings. Where analog values, or math functions are used, clearly specify numeric values or functions. Reference data registers for numeric values by their memory locations. Group all ladder logic rungs for each equipment under a same title or comment for the equipment.

G. Ensure the PLCs are manufactured by Allen Bradly, Siemens, Schneider or as approved by the Engineer.

17. Human Machine Interface (HMI). Furnish a UL listed HMI panel with at least 1 GHz processor to interface with the PLC control system to display control status, lift span position with graphic and digital displays, alarms and fault conditions, and other parameters as directed by the Engineer.

Furnish and install HMIs on the control console and each control cabinets as shown on the plans.

A battery-less design is preferred. In the event an internal battery is needed, ensure it is rated for a minimum of 10 years no-maintenance.

Ensure the screen is touch sensitive with a minimum 12.1-inch screen with backlit color thin-film transistor (TFT) LCD. The visualization display must have an 800 by 600 pixel viewing resolution and ensure it is properly visualized in a 55 degree viewing angle in any direction. The back light of the HMI will automatically switch off after a pre-adjustable time period. Other minimum requirements are specified as follows:

A. The HMI must have the following integrated communication ports and other connections at minimum:

(1) Ethernet registered jack (RJ)-45, interface: *IEEE 802.3.*

(2) Ethernet RJ-45, interface: 10BASE-T/100BASE-TX.

(3) Universal Serial Bus (USB) 2.0 port mini–B USB.

(4) USB 2.0 port USB type A.

Ensure the HMI is *UL* marked and complies with *UL508, Industrial Control Equipment*.

B. Ensure the HMI software has the following requirements at minimum:

(1) Display of animated synoptic screens with different types of animation (e.g., pressing touch-sensitive zone, changing of color, filling, movement, rotation, size, visibility, and value display).

(2) Possibility of control and modification of numeric and alphanumeric variables.

(3) Display of date and time.

(4) Real-time and trending curves with log.

(5) Multi-window with emerging menus management.

(6) Pages can be called up by the user.

(7) Application and log support in CompactFlash (CF), Secure Digital (SD) format external application memory card or USB.

(8) Management of sound messages and integration with images.

(9) Availability of screens design and configuration software in a Windows environment.

(10) Extension capabilities and migration utilities between terminals improvements.

(11) Built-in applications for alarms, event, and messages management with dynamic capabilities and with no limitation in the number of alarms.

(12) Built-in applications for login and control access.

(13) Resource files concept and facilities for Multilanguage migrations.

(14) Capability to customize the built-in applications in aspect and functionality.

(15) Dynamic screen capabilities: dynamic texts, graphs etc.

(16) HMI variables accessible to/from the display and to/from the HMI controller.

(17) Remote monitoring and control using Webgate.

(18) Program uploading and downloading using USB.

(19) All included, no extra cost for each function above.

C. Ensure the HMI alarms are capable of the following:

(1) Display alarms in Alarm Summaries or Alarm Banners.

(2) Display both diagnostic and variable alarms.

(3) Monitor bit and word addresses.

(4) Group alarms in Alarm Categories.

(5) Trigger alarms by Limit, Deviation by Percent, or Deviation by Fixed.

(6) View three types of Alarm Summary displays: Active, History, and Log.

(7) Acknowledge individually or as a group.

(8) Runtime language swapping for alarm messages.

(9) Print and save alarm logs.

D. Ensure the HMI data logging is capable of the following:

(1) Analyze, audit, and track performance.

(2) Display logged data in a trend graph.

(a) Historical trend graph.

(b) Real-time trend graph.

(c) Plot trend graph.

(d) Toolchest trend graph item.

(3) Collect data at regular intervals or when a trigger is activated.

(4) Store data in dynamic random-access memory, static random-access memory, USB storage, CompactFlash (CF) card, or network storage.

(5) Convert data logging files into .CSV files.

(6) Display logged data from multiple terminals.

E. Ensure the HMI is capable of the following communication requirements:

(1) Connect to Modbus Protocol.

(2) Can communicate with major industrial networking protocols.

(3) Use multiple protocols at once.

(4) Connect a wide range of peripherals including, printers, web cameras, barcode readers, USB keyboard and mouse, and external storage devices.

F. Ensure the HMI is capable of the following networking requirements:

(1) Use Dynamic Host Configuration Protocol (DHCP) for easy plug-in network configuration or configure IP settings manually.

(2) Use the terminal as a communication bridge between networks.

(3) Open hyperlinks to web sites embedded in local documents using Domain Name System (DNS).

G. Ensure the HMI is capable of the following remote monitoring requirements:

(1) Monitor a terminal remotely using Web Gate.

(2) Share data across a network between a terminal and a remote personal computer.

Ensure HMIs are manufactured by Allen Bradley, RedLion, Phoenix Contact, or approved equal.

18. Uninterruptible Power Supply (UPS). Furnish and install UPS units in each control cabinet, and control console as shown on the plans. Ensure each UPS is rated for 1.5 kilovolt-ampere (kVA) (minimum). Ensure the UPS is capable of providing power for 10 minutes at half load and 5 minutes at full load.

Ensure the UPS is rated for 120 VAC input and 24 VDC output.

Furnish a UPS by Phoenix Contact, Siemens or approved equal.

19. Laptop Computer. Furnish and install a semi-rugged, outdoor, environmentally protected laptop computer with specified software, suitable for programming the PLC, HMI, and flux vector drive systems. Ensure the computer is the latest commercially available unit Panasonic ToughBook, Dell Latitude or approved equal.

Ensure the minimum random-access memory (RAM) memory is 16 gigabyte (GB) Synchronous dynamic random-access memory (SDRAM) (DDR3L-1600 megahertz (MHz)) and equipped with a shock-mounted flex-connect hard drive with quick-release, 500 GB minimum. Ensure the unit is Wireless Fidelity (Wi-Fi) and Bluetooth enabled. Equip the unit with all ports and connectors required for the PLC software and the drive software to utilize the programming software and connect to the equipment. Ensure the unit is an intelligent terminal, functioning both as a PLC/vector drive programming and data monitoring terminal. It must permit PLC programming, including loading, editing, and monitoring ladder diagram programs in memory by entering through the keyboard and monitoring on the display. Ensure the PLC program instructions are in ladder logic.

Load the following software applications onto the computer and ensure they are fully operational:

A. Windows Operating System. Verify all software can operate properly on the operating system and coordinate with the software vendors and the operating platform requirements to select the proper software version.

B. HMI programming software.

C. PLC processor and network communication software.

D. Vector drive monitoring software.

Demonstrate operation and use of the software as part of the personnel training as specified in section Operation & Maintenance Manuals, Training and As-Built Documentation.

Include all electronic documentation, manuals, and other materials. Furnish all licenses and original executable installation software copies with the computer for all software installed upon final acceptance of the control system.

20. Rotary Limit Switches. Ensure the limit switch is a rotary, cam-operated limit switch in a *NEMA 4X*, stainless steel, enclosure and is driven by gearing furnished with the operating machinery, which will rotate the input shaft. The span limit switches must have 12 circuits individually micro-adjustable and provisions for internal vernier adjustments. The limit switch will allow for a ±1/4-degree contact operation repeatability. Ensure each contact of the limit switch is double pole double throw (DPDT) precision-type, snap-action switch. The switch contacts must have a minimum AC inductive continuous current carrying rating of 10 A and a minimum DC resistive continuous current carrying rating of 10 A. Ensure each limit switch is Ametek Series 1980R, Kamco K80, or an approved equal and is driven by gearing furnished with the operating machinery with direct drive coupling supplied with the switch as an option. Furnish the span rotary cam with a gear reducer at the input shaft as shown on plans. Furnish the span rotary cam limit switches with a resolver.

The rotary cam must house both the cam-operated limit switches and resolver. Ensure resolvers are heavy duty *NEMA 4X* rated. Ensure the resolver is capable of outputting an analog 4-20 mA signal to the span position indication meters or the PLCs as required. Ensure the resolver is rated for 24 VDC input voltage. Mount the resolver in the internal housing. Verify before ordering the equipment the rotation of the rotary cam limit switch so that the output increases with the appropriate shaft rotation. Verify the number of turns required to display full scale and choose the appropriate resolver. Ensure the connection between the resolver and the wiring is through a side mounted military standard (MS) connector. Ensure the wiring for the resolver is 2 twisted shielded pairs (TSP) #16 AWG (for a total of 4 conductors). Ensure the resolver is an AMETEK, Advanced Micro Controls, Inc (AMCI) series, Turck or approved equal.

21. Lever-less Limit Switches. Furnish and install lever-less mechanical limit switches for fully seated and tail lock indication and interlocking. Ensure they are enclosed in a stainless-steel housing rated *NEMA 4X*. Ensure they are furnished with DPDT contacts rated for 10 A. Ensure the contacts are silver cadmium oxide, gold flashed, and have a temperature rating of -40 °F to 221 °F. They must have a repeatability of 0.002 inches, and a response time of 8 milliseconds (ms). Ensure they are furnished with six-foot epoxy potted cord sets. They must have a nominal sensing distance of 1/4 inch and be provided with a magnetic sensor that provides for a 3/4 inch sensing distance. Ensure each lever-less proximity switch is provided with a junction box in the immediate facility and a *NEMA 6* rated cable gland fitting to transition the integral switch cord set to field installed wiring. Ensure the lever-less limit switches are Model 81 GO switch with model AMF6 TopWorx magnetic target as manufactured by Emerson or Engineer approved equal.

22. Deceleration Check Speed Switches. Furnish and install speed relays and encoder splitter interface modules in each drive cabinet and for each auxiliary motor control center (MCC) cubicle. Connect the encoder splitter interface modules to the span and auxiliary motor encoders.

Connect the incoming encoder conductors routed into the drive cabinets and MCCs to the splitter and routed to both the drive, motor controls and the new speed switch relay. The relay must accept the encoder signal and be programmed with the specified speed shown on the plans.

The speed switch relay must send an alarm contact to the PLC as specified herein to provide a failsafe under/over speed alarm contact to be used to monitor the deceleration speed at each drive when in operation. For the auxiliary motors, the speed switch must cut out motor operation.

The speed switch relay will be DIN rail mounted in the drive cabinets and MCCs. Ensure it is capable of over-speed and under speed detection. The relay must feature alarm override and reset functions and have LED status indication on the face of the relay. Each unit will operate at 120 VAC and rated for 1,000,000 cycles minimum.

Ensure the encoder splitter interface is a DIN railed mountable unit and capable of accepting the drive manufacturers specified encoder signals. Ensure the splitter provides two sets of optically isolated outputs.

23. Control Apparatus and Miscellaneous Equipment. Ensure the control apparatus is in accordance with the applicable requirements of *NEMA Publication ICS*, rated as shown on the plans or as required and to the following:

A. Multi-Functional Power Monitor. Furnish and install a multi-function 3-phase solid-state power monitor with the ability to connect to either 3-phase, 4-wire wye or 3-phase, 3-wire circuits. Power meter must include two 10-character, alphanumeric passwords, which will protect the unit from unauthorized tampering. Ensure voltage and current inputs to the meter are in accordance with the following at a minimum:

(1) Accept 4 independent voltage inputs and 4 independent current inputs of the stated capacity.

(2) Ensure voltage input is 120 VAC with available option for direct connection to voltage circuits of up to 600 VAC without the use of potential transformers.

(3) Ensure voltage input is optically isolated to 2500 VDC. It must meet or exceed *ANSI C37.90.1*.

(4) Ensure current input is rated for 5 A with inputs 2x continuous programmable to any current transformer range.

(5) Ensure current inputs are solid U-Bolt stud inputs with a 10 second over-current rating of 100 A and a 1-second over-current rating of 300 A.

B. Power meter will measure and report the following quantities at a minimum:

(1) Voltage, both phase to neutral and phase to phase, for all three phases; auxiliary voltage; phase angles for each voltage relative to each other. Ensure one cycle, 50 ms and one-second reading are available simultaneously.

(2) Current, phase A, B, C, N-measured, and N-calculated; phase angles for each current relative to voltages. Ensure one cycle, 50 ms and one second readings are available simultaneously.

(3) Watts (total and per phase), Volt-Amperes Reactives (total and per phase), Volt Ampere (VA) (total and per phase), power factor (total and per phase), and frequency. Fifty ms and 1 second readings are available simultaneously.

(4) Power meter must time-stamp maximum and minimum readings for every measured parameter.

The units must have an auto-calibration circuit designed to calibrate the readings using an internal reference. Power meter must provide the following accuracies:

|  |  |  |
| --- | --- | --- |
| Parameter | Reading 1 | Reading 2 |
| Voltage | <0.05% @ 1-second | <0.05% @ 50-millisecond |
| Current | <0.05% @ 1-second | <0.05% @ 50-millisecond |
| Power | <0.1% at 1.00 PF | <0.1% at 0.50 PF |

The power meter must provide sequence of events capture and recording. The meter must have at least 8 high-speed status inputs for capturing external events. Ensure all high-speed status inputs are monitored at a user set rate from 1 to 8 samples per ms. Ensure all changes in status are time stamped to the nearest ms and placed in an event log with time and event label information. The event log must enable users to recreate sequence of events involving external status points. Equip the power meter with non-volatile RAM for recording logs and programming information. The power meter must provide historical data logging for trending of measured values. Ensure transient detection is provided.

Power meter must provide an external display to accommodate access to readings locally and/or remotely. Ensure the display is a three line, LED, or LCD format touch screen display, capable of supporting multiple displays. Ensure the display is powered directly from the power meter. Ensure the display is surface mounted.

The power monitor must have manufacturer provided Ethernet communications to allow transfer of all data/faults to the PLC network.

Ensure the power monitor is an Allen Bradley PowerMonitor 500 with local display module or approved equal by Siemens, or Phoenix Contact.

C. Circuit Breakers. Ensure all branch circuits from the power buses are protected by molded-case circuit breakers mounted on the control panels. All breakers must have quick-make and quick-break contacts, and ensure the mechanism is trip-free and trip indicating. Furnish all circuit breakers and motor circuit protectors with at least two form C auxiliary contacts for PLC input and status indication. Ensure frame sizes are not less than 100 A. Equip the breakers with thermal-magnetic trips or adjustable, instantaneous, magnetic trip units, with trip rating as shown on the plans or as required. Molded-case circuit breakers must meet the requirements of the *NEMA Publication AB1*. Ensure the service entrance circuit breakers are rated 600 V, with frame size as shown on the plans and furnished with electronic trip unit with independently adjustable short time pick-up and time delay, set to trip as per the plans. Ensure interrupting capacity is no less than 65,000 Ampere Interrupting Capacity (AIC).

D. Motor Starters and Magnetic Contactors. Ensure the continuous current rating of contactors and starters are adequate for the connected loads, and no starters are smaller than *NEMA Size 0* unless otherwise noted. Ensure all starters are full voltage types, 600 VAC, 60 Hz, rated with 120 VAC operating coils. Ensure all contact poles are furnished with arc chutes, and contactors rated 150 A and equipped with magnetic blowouts. Ensure three-element manual reset overload relays are furnished to protect gate and lock motors and wiring against overheating due to excessive current. Select heater elements based on motor full-load running current. Ensure each overload relay is furnished with a set of auxiliary form C contacts for PLC interfacing and indication. Ensure reversing contactors are electrically and mechanically interlocked.

E. Overload Relays. Select heater elements based on motor full load running current. Ensure each overload relay is furnished with two N.O./N.C. auxiliary contacts. Ensure instantaneous-trip overcurrent relays are of the magnetic type with automatic reset. Ensure they are furnished with an adjustable range from 100 percent to 230 percent of motor full-load current. Initially set the relays to trip at 150 percent motor full-load current.

F. Control Transformers. Ensure control transformers are high voltage regulation type, low temperature rise, rated 480/120 VAC. Ensure control power transformers are furnished and installed as required and shown on the plans. Ensure each control power transformer is single-phase, 500 VA minimum or as the application requires, 480 V primary, 120 V secondary, epoxy resin encapsulated, non-ventilated transformer. Ensure control transformers are approved equal to the Type MTK Industrial Control Transformers as manufactured by Eaton.

G. Control Relays. Ensure auxiliary control relays are multi contact magnetic relays with contacts rated at 10 A, 600 V, on a continuous basis. Relays known to meet the specified requirements are the Schneider Electric class 8501 type X or approved equal.

H. Phase Failure and Reversal Relay. This relay must prevent energizing operating the span in the event of reversed phase sequence, loss of one phase, or low voltage. Ensure the phase failure and reversal relay is the Schneider Electric Class 8430 Type MPD or approved equal.

I. Selector Switches and Pushbuttons. Ensure pushbuttons and control switches are heavy-duty, oil-tight, contact blocks operated by glove handle selector knobs, key switches and push-button operators as shown on the plans. Ensure contacts are fine silver, capable of interrupting 6 A at 120 VAC, and of continuously carrying 10 A. Ensure switches and pushbuttons are Schneider Electric class 9001, type K, *NEMA 4* or approved equal.

J. Indicating Lights. Ensure indicating lights are heavy-duty, oil-tight pilot lights with one or two fields as required as per the plans. Ensure they are provided with LED lamps the color of the lamp lens and rated at 120 VAC. Where group testing cannot be accomplished through the PLC ensure the lights are provided with a push to test feature. Ensure all lenses are polycarbonate, with color and marking as shown on the plans.

K. Bypass Switches. Ensure these switches are held in their open position by hinged plates at least 51mm long, which have to be unlocked and turned over backwards in order to release the switch handles for bypassing. Paint the underside of these plates bright red. Make provision so that each bypass switch can be locked in the Off position by means of a lockable brass cover plate.

L. Terminal Blocks. Terminal blocks for conductors of size #8 AWG and smaller will be fed through terminal blocks with stud and nut type connection DIN rail mounted modular terminal blocks. Ensure barriers are not less than 13mm high and 3mm thick and spaced 16mm center-to-center. Ensure straps, studs, and nuts are of a material for use in highly corrosive atmospheres and are rated for 57 A for a terminated conductor. The blocks must provide a withstand voltage rating of 800 V per *IEEE* switchgear standards. The terminal blocks must furnish studs and nuts suitable for use with flanged fork wire connectors. Furnish corrosion resistant marking strips for conductor identification. Furnish at least 10 percent spare terminals. Ensure terminal blocks are Phoenix Contact type RBO 5, Marathon or approved equal.

M. Terminal Connectors. Ensure terminal connectors are seamless, heavy duty compression locking fork terminals manufactured from pure electrolytic copper tubing. Ensure terminals are tin plated and furnished with a double-thick tongue and insulation grip. Ensure terminals and compression tools are approved by the Engineer.

N. Wire Ferrules Connectors. For conductors not suitable for locking fork terminals, furnish seamless, heavy-duty insulated wire ferrules terminal lugs. Install terminal lugs per lug manufacturer recommendations using the proper tools approved by the manufacturer.

O. Power Distribution Blocks. Use power distribution blocks for conductors’ sizes #8 and larger and that are *UL* listed. Ensure terminal blocks are suitable for use with copper wire and provide a withstand voltage rating of 750 V per *IEEE* switchgear standards. Furnish corrosion resistant marking strips for conductor identification. Furnish at least 10 percent spare terminals. Ensure terminal blocks are Gould Shawmut Power Distribution Blocks –Series FSPDB, Marathon or approved equal.

P. Wire Number Identification. Use permanent wire markers for wire marking at all splices, terminals and lugs in all cabinets, wire ways and junction boxes. Ensure both ends of every single length of conductor are permanently and clearly tagged in accordance with the same numbers or designations appearing on the approved wiring diagrams. Ensure wire tags for marking the conductors are heavy duty, heat shrink, waterproof, permanently marked, and resistant to UV light deterioration. Ensure numbers and letters are black or blue on a white background. Other wire marker types meeting the general specifications above, applied by professional marking equipment may be considered by the Engineer, when submitted. Use clear vinyl to protect the legend in all cases. Embossing or painting wire insulation for wire identification is prohibited. The Engineer reserves the right to deny the use of any type of wire marker he deems to be inferior to the type specified for use.

Attach wire numbers permanently to the wire within 1.0 inches of termination. All wiring connections at any terminal strips or lugs must have the numbers facing out for easy troubleshooting.

Q. Nameplates. Furnish nameplates for all aforementioned devices made of laminated phenolic plastic with white front and back and black core and not less than 2.3 mm (0.09 in) thick. Etch the lettering through the front layer to show black engraved letters on a white background. Ensure lettering is not less than 6mm high, unless otherwise shown on the plans. Securely fasten nameplates to the equipment with stainless steel screws.

R. Transient Voltage Surge Suppression. Ensure the transient voltage surge suppression module is an active tracking network (ATN) *UL 1283* listed as an electromagnetic interference (EMI)/radio frequency interference (RFI) filter. Ensure it is rated for 300 kA and for a nominal 480 VAC delta electrical system. Encapsulate all components to provide a high dielectric and protection from adverse environmental conditions. Furnish large diameter Metal Oxide Varistors (MOVs) to protect against high stress transient environments. Ensure they are furnished with comprehensive monitoring of critical system functions, with real-time audible and visual reporting of unit status, phase loss/protection loss and transient events (alarm with reset and mute). Furnish them with a dual function surge counter providing non-volatile event history recording. Furnish them with dry form C contacts for remote status monitoring, an integral disconnect switch, and LED monitoring on each phase. Furnish a *NEMA Type 4 (Ingress Protection 66)* stainless steel enclosure. Ensure it is listed *UL 1449 2nd Edition* for surge suppression devices, and *UL 1283 complementary*.

Furnish an Eaton PVL TVSS or approved equal by Schneider Electric or Siemens.

24. Bridge Street Lights. Furnish materials in accordance with the following section and subsection of the Standard Specifications for Construction:

Electrical and Lighting 819

Traffic Signal 820.02

Ensure the bridge signals and foundations are in accordance with MDOT standard drawings:

A. SIG-030-B - Traffic Signal Mast Arm Pole and Mast Arm Details - Category I

B. SIG-040-A - Traffic Signal Mast Arm Standard Foundations

25. Bridge Signals. Furnish materials in accordance with the following subsections of the Standard Specifications for Construction:

Permanent Traffic Signs and Supports 810.02

Traffic Signal 820.02

Ensure the bridge signals and foundations are in accordance with MDOT standard drawings:

A. SIG-030-B - Traffic Signal Mast Arm Pole and Mast Arm Details - Category I

B. SIG-040-A - Traffic Signal Mast Arm Standard Foundations

The cost of the bridge signals includes the entire assembly including, luminaire, luminaire bracket, mast arm, traffic signals, pole, foundation, steel reinforcement, and any other accessories.

26. Traffic Gates. Furnish gates that are explicitly designed for traffic control on movable bridges as described in *AASHTO’s Standard Specifications for Movable Highway Bridges*, High-Occupancy Vehicle (HOV) and reversible lanes and similar applications. Ensure they are provided with both roadway arms.

Ensure the operating mechanism and main control components are contained in a weatherproof housing. Ensure the housing is constructed of 0.188 inch (4.8mm) carbon steel, hot dip galvanized after fabrication. Paint exterior surfaces aluminum. All fasteners are to be corrosion resistant. Arm shaft openings are to incorporate O-ring seals.

Ensure front and rear access doors are mounted on full cross bronze straps. Ensure hinges are of the slip-off type and have stainless steel pins. Ensure door latches, two per door, use a vise action to compress a neoprene bulb-type gasket to seal the door openings.

Ensure the gate are be fixed to the foundation using four 3/4 inch (20mm) diameter minimum anchor bolts. Ensure the gate housing base provide four 1.00 inch (25mm) holes on a 20¼ inch (514mm) square pattern.

Ensure the traffic gate arm is 4 inch (102mm) square, 6005-T5 aluminum extruded tubing. Furnish stainless steel truss cables and a damping type bumper rod with longer arms at the discretion of the manufacturer. Ensure front and rear arm surfaces are covered with alternating red and white high intensity reflective sheeting. Stripes are to be 6 inches (152mm) wide, and vertical in accordance with the MMUTCD. Ensure remaining exposed surfaces are painted white.

Ensure the gate is provided with a sidewalk arm. Ensure the arms are of fiberglass, sized by the manufacturer. Ensure front and rear arm surfaces are covered with alternating red and white high intensity reflective sheeting. Ensure stripes are 6 inches (152mm) wide, and vertical in accordance with the MMUTCD. Ensure remaining exposed surfaces are painted white.

Ensure the warning lights are used as a traffic signaling light to mark and draw attention to the traffic gate. Ensure the housing is high impact plastic. Ensure assembly are double- faced. Ensure light assembly is mounted to warning gate arm using an aluminum adapter plate. Lenses will be red fresnel plastic, approximately 4 inches in diameter. Lamp will be 12 V 100,000-hour LED lamp.

Ensure the flasher is moisture and corrosion resistant and is capable of dissipating heat sufficient for continuous duty. The flasher must have two alternately flashing circuits, and one steady burn circuit. Each flashing circuit must flash 0.50 seconds on and 0.50 seconds off. Ensure the input voltage is 120 VAC. Ensure a 120 V/12 V transformer provides 12 V for the flasher and the arm lights. The flasher must operate properly for input voltages within 10 percent of nominal. Ensure the output circuits are rated at 10 A at 12 VAC each (10 A total load). A voltage drop of up to 0.5 V to the output terminals is acceptable. It must have a built-in, internal overload protection with auto-reset. Ensure terminals are clearly labeled and are compression type screw terminals.

Design the arm base with a shear pin mechanism to minimize damage to the gate and vehicle in the event of a collision. In the event of an impact, the shear pin must break, allowing the arm to swing approximately 75 to 80 degrees. At the full open position, a spring-loaded latch must engage, preventing the arm from swinging back into traffic. Ensure the arm is easily reset by manually releasing the latch, rotating the arm back into position and replacing the shear pin.

Affix a pair of carbon steel channels, hot dip galvanized, painted aluminum, to the ends of the main arm shaft. The channels and a steel crossmember must provide a sturdy mount for the arm, arm base assembly and counterweights. Shorten the channels as required so that they do not extend past the curb line.

At the rear end of the side arm channels, mount hot dip galvanized counterweights to balance the arm. Ensure the counterweights are sectional and permit at least 10 percent adjustment.

Ensure the main arm shaft is of 2 inch (51mm) diameter *AISI 4150* with a minimum tensile strength of 140,000 psi. Mount the shaft in heavy duty relubricable ball bearings.

The warning arm must pivot in the vertical plane via a mechanical 4-bar linkage. The linkage must utilize cranks keyed to the main arm shaft and transmission shaft and an adjustable connecting rod between a pair of self-aligning spherical rod ends. Ensure the connecting rod is of 1 inch (25mm) diameter *AISI 4150*. Ensure the linkage is driven by a fully enclosed, double reduction, worm gear speed reducer. Gear ratio used must produce an operation time of 11 seconds. The velocity of the arm will follow a sinusoidal pattern to provide smooth operation. The arm must begin and end its full motion path with zero velocity and accelerate smoothly to maximum velocity at mid-travel.

Ensure the motor is per manufactures recommendations, 480 VAC, three phase, 60 Hz. Ensure the motor is a C-face design and is mounted directly to the transmission. Ensure the motor is instantly reversing, and overload protected.

Equip the motor with a solenoid-release, automatic brake. The brake must have a manual release lever to permit manual operation of the gate during emergencies or setup.

Furnish a handcrank with each gate to facilitate manual operation of the gate.

Ensure the gate limit switch assembly is a self-contained unit. The assembly must provide 8 independent SPDT control switches. Ensure switches are rated for 15 A at 480 VAC. Ensure switches are controlled by individually adjustable cams. The limit switch assembly design must permit adjustment of all cams with the gate in any position. The limit switch assembly must have a removable cover to help prevent accidental contact with switch terminals. Ensure shaft, cams, bushings, and housing pieces are of non-ferrous corrosion resistant materials.

Furnish a manual disconnect switch, pre-wired at the factory to break the main motor leads, to protect personnel during service. Furnish a handcrank safety switch to prevent powered actuation of the gate during manual operation. Install door safety switches and set at the factory to break the control circuit when either access door is opened. Door safety switches must have a pull-to-override feature for test operation and will automatically reset when doors are closed. Mount control components and terminal blocks inside an electrical enclosure mounted facing the rear side access opening. Ensure pressure-type, modular terminal blocks are fully labeled and clearly coded to the control system vendor wiring diagrams. Ensure all control wiring is clearly coded to wiring diagrams and terminates at the terminal block. Connections to screw-type terminals must have lugs. Ensure conductors are type XHHW #14 AWG stranded, minimum.

Ensure traffic gate foundations are as shown on the plans. Payment for foundations is included under this item.

The traffic gates will be Model VW-4, as manufactured by B&B Roadway, or approved equal by Bridge Roadway Products, and FedTransit Safety Systems.

27. Warning Gongs. Furnish a warning gong attached to each of the on-coming traffic gate housings.

Ensure the housings are of heavy duty, cast aluminum construction. Ensure gong assembly is equipped with an aluminum mounting adapter for mounting to the top of warning gate housing. Ensure mounting is designed to enclose all wiring. A hinged and gasketed rear door is to be furnished for service access. Furnish a cast aluminum guard above the shell to provide weather protection. Ensure gong produces a sound level of 90db at 10 feet. Ensure gong operates on 120 V power at a current draw of 0.45 Full-Load amperes. The gong shell is to be spun silicon bronze.

Ensure the warning gong is a B&B Roadway G12 or approve equal by Bridge Roadway Products, and FedTransit Safety Systems.

28. Bridge Control Console. Ensure the sheet-steel portions of the console and all reinforcing metal is painted inside with two coats and outside with three coats of paint, consisting of one coat of primer followed by two coats of enamel on the outside surfaces and one coat of rust inhibiting white enamel inside. Ensure the two outside finish coats are of *ANSI #61* gray enamel. Furnish color samples to the Engineer for approval. Do not paint the stainless-steel console top. Furnish spare terminals totaling at least 10 percent of those actually used.

Ensure the console is of neat, substantial construction. Ensure the console is fabricated from #10 gauge sheet-steel, properly formed, and suitably reinforced to provide adequate strength. Fabricate the console tops of #10 gauge, Type 302, stainless steel sheet with a non-glare, satin finish. Furnish removable doors in the front and side panels of the console, pivoted on 90-degree hinges, and secured with flush type, three-point latches. Furnish a 3/4 inch return lip for all openings on the top and front of the console. Ensure the console is fitted up with close joints, and all rough edges or corners ground off smoothly, and all projecting edges rounded off. Furnish metal hardware of substantial construction and with a satin-chrome plate finish. Furnish stainless steel equipment mounting screws and bolts.

29. Digital displays. Furnish digital display units as standalone devices for span position and auxiliary motor speed during relay mode operation. Ensure the display units can power their associated cable-extension transducer and receiving the 4-20 mA feedback signal. Ensure the displays contain four form C relays that must energize at specified setpoints. Ensure the displays are model PAX by Red Lion, PD6000 by ProVU, or approved equal.

30. Bridge Control Cabinets. Furnish and install control panels enclosed in a freestanding cabinets as shown on the plans. Mount all circuit breakers, Vector Drives, UPS, PLC racks, switches, contactors, relays, regulating equipment, and other apparatus for control of the span and its auxiliaries on these enclosed panels. Ensure the arrangement and line-up of the individual control cabinets are as shown on the plans.

Mount all equipment in each control cabinet on sheet-steel bases and ensure each device is front-connected, front-wired, and removable from the front. Arrange the equipment in all cabinets for ease of access and for safety and convenience of operation. Take care to obtain a systematic and neat arrangement of the equipment. Ensure each device is suitably named and plainly marked by a laminated nameplate mounted near the device on the panel. Each nameplate must show an approved descriptive title for the apparatus, together with the device designation appearing on the schematic wiring diagrams.

Ensure the indoor control cabinet is a *NEMA Type 12* enclosure constructed of #12 gauge sheet-steel and reinforced with steel angles or channels to provide a rigid, freestanding structure. Ensure the exterior walk-in cabinet is *NEMA 4X 316* stainless steel. Furnish the control cabinets with hinged doors on the front of each panel section. Ensure door panels are gasketed and provided with three-point, vault-type latches. Furnish drive and control panels with fan and filter ventilation. Furnish corrosion resistant hardware. Furnish thermostatically controlled strip heaters in each cabinet to prevent build-up of excess moisture. Furnish each panel with suitable interior light fixtures and a duplex receptacle.

Ensure each control cabinet enclosure is as shown on the plans. If the final cabinet dimensions, as established by the manufacturer, should necessitate rearrangement or modification of the equipment in order to fit in the available space, ensure such rearrangement or modifications are made at no extra cost to the contract. The final arrangement of all equipment in the operator house is subject to the approval of the Engineer.

Ensure the indoor control cabinet enclosures and all metal reinforcing is painted inside with two coats and outside with three coats, consisting of one coat of primer followed by one coat of gray enamel on the inside surfaces and two coats of gray enamel outside. Ensure the finish coat is *ANSI #61* light gray enamel.

Ensure all contactors, relays, and other devices are of required current carrying and interrupting capacity. Ensure all apparatus are of substantial construction and conform to the requirements of *NEMA Standards Publications ICS 1 and 2, 2000*, for industrial control devices.

Ensure all wire is flame-retardant, ethylene-propylene insulated, switchboard wire, Type SIS. Ensure conductors are stranded copper not smaller than #14 AWG.

Furnish one local HMI on each control panel (North and South) as specified herein.

31. Motor Control Center (MCC). The MCCs must include, but not be limited to, all parts, materials and associated appurtenances described below, such as MCC enclosures, covers, wireways, mounting hardware, motor control and protection devices.

Construct the MCCs to meet or exceed the requirements within *NEMA ICS-2* and *UL845* for motor control centers. The MCCs will be designed, manufactured, and tested in facilities registered to *ISO 9001* quality standards. The MCC enclosures will be *NEMA/EEMAC* *Type 12* rated.

The MMCs will be 600 V class suitable for operation on a three-phase, 60 Hz system. Ensure the system operating voltage and number of wires are as shown on the plans.

Each MCC must consist of one or more vertical sections of heavy gauge steel bolted together to form a rigid, free-standing assembly, and mounted on top of a 2 inch concrete sill or pad, as shown on the plans. Ensure the entire assembly is constructed and packaged to withstand all stresses included in transit and during installation. Ensure the MCC is delivered in individually wrapped factory fabricated fiberboard type containers, with lifting angles mounted on each supporting structure. Handle the MCC with care to prevent internal component damage, and denting or scoring of enclosure finish. Do not install damaged MCCs.

Ensure structures are totally enclosed dead-front, free-standing assemblies. Ensure they are no more than 90 inches high and 20 inches deep. Structures must contain a horizontal wireway at the top, isolated from the horizontal bus and be readily accessible through a hinged cover. Ensure adequate space for conduit and wiring to enter the top or bottom is provided without structural interference.

Ensure structures are capable of being bolted together to form a single assembly. The total width of one section must be 20 inches. Widths of 25 inches, 30 inches, and 35 inches can be used for larger devices.

Each section must have all the necessary hardware and bussing for modular plug-in units to be added and moved around. Ensure all unused space is covered by hinged blank doors and equipped to accept future units. Cover vertical bus openings by manual bus shutters.

Ensure a vertical wireway with minimum of 35 square inches of cross-sectional area is adjacent to each vertical unit and is covered by a hinged door. Wireways must contain steel rod cable supports.

Ensure all full voltage starter units are of the drawout type. Drawout provisions must include a positive guide rail system and stab shrouds to absolutely ensure alignment of stabs with the vertical bus. Drawout units must have a tin-plated stab assembly for connection to the vertical bus. No wiring to these stabs can extend into the bus compartment. Paint interior of all units white for increased visibility. Equip units with side-mounted, positive latch pull-apart type control terminal blocks rated 600 V. Furnish knockouts for the addition of future terminal blocks. All control wire is to be #14 AWG SIS type.

Ensure all drawout units are secured by a fastening device located at the front of the unit. Furnish each unit compartment with an individual front door.

Mount an operating mechanism on the primary disconnect of each starter unit. Ensure it is mechanically interlocked with the unit door to prevent access unless the disconnect is in the OFF position. Furnish a defeater to bypass this interlock. With the door open, ensure an interlock is provided to prevent inadvertent closing of the disconnect. Ensure a second interlock is provided to prevent removal or reinsertion of the unit while in the ON position. Ensure padlocking facilities are provided to positively lock the disconnect in the OFF position with from one to three padlocks with the door open or closed. In addition, ensure means are provided to padlock the unit in a partially withdrawn position with the stabs free of the vertical bus.

Each structure must contain a main horizontal copper tin-plated bus, with minimum ampacity of 600 A as shown on the drawings. Ensure the horizontal bus is rated at 150 °F temperature rise over a 104 °F ambient in compliance with *UL* standards. Ensure vertical bus feeding unit compartments are copper and securely bolted to the horizontal main bus. Ensure all joints are front-accessible for ease of maintenance. Ensure the vertical bus section containing the Main Breaker (CB-MCC) is fully rated 600 A. Other bus vertical sections will be rated 300 A.

Ensure the vertical bus is completely isolated and insulated. It must effectively isolate the vertical buses to prevent any fault-generated gases to pass from one phase to another. The vertical bus must include a shutter mechanism to provide complete isolation of the vertical bus when a unit is removed.

Brace buses for minimum 42,000 A rms symmetrical.

Furnish a copper ground bus to be firmly secured to each vertical section structure and extending the entire length of the MCC.

Each structure must contain tin plated vertical ground bus rated 300 A. Connect the vertical ground bus directly to the horizontal ground bus via a tin-plated copper connector. Units must connect to the vertical bus via a tin-plated copper stab.

All combination starters must utilize a unit disconnect. Equip magnetic starters with double-break silver alloy contacts. Each starter must have minimum one N.O. auxiliary contact or as shown on the plans. All coils to be color-coded through size 5 and permanently marked with voltage, frequency and part number.

Furnish all starters with overload relays. Ensure overload relays are an ambient compensated bimetallic-type with interchangeable heaters, calibrated for 1.0 and 1.15 service factor motors. Ensure electrically isolated N.O. and N.C. contacts are furnished on the relay. Ensure visual trip indication is standard. Furnish a test trip feature for ease of troubleshooting and must be conveniently operable without removing components or the motor starter. Overload must have ±24 percent adjustability, single-phase sensitivity, and isolated alarm contact. Overload relays must have manual or automatic reset. The west side auxiliary motor and tail lock overloads must have remote reset capabilities.

When provided, control circuit transformers must include primary protection and one secondary fuse in the non-ground secondary conductor. Ensure the transformer rating is fully visible from the front when the unit door is opened.

When a unit control circuit transformer is not provided, the disconnect must include an electrical interlock for disconnection of externally powered control circuits.

Furnish auxiliary control circuit interlocks where indicated. Ensure auxiliary interlocks are field convertible to N.O. or N.C. operation.

Ensure minimum starter and contactor size is *NEMA Size 0*.

Desing motor starters and contactors to accommodate two auxiliary contact blocks, each capable of a combination of up to four N.C. or four N.O. auxiliary contacts. Contacts to be color-coded; black designating N.C. and silver designating N.O. Ensure contacts are rated 10 amp continuous, 7200 VA make, 720 VA break for 120 through 600 VAC, and 69 VA make and break for 125 through 300 VDC. Provide a minimum of one spare N.O. contact and one spare N.C. contact in addition to any auxiliary contacts required.

Furnish a mechanical interlock on reversing or multispeed contactors of the lever-type mechanism (with electrical contacts included) to prevent closing of one contactor when the other is closed.

Each unit door will have an engraved acrylic nameplate, white with black lettering. Ensure a master nameplate is provided on each MCC lineup.

Furnish wiring diagrams at a centralized location in the MCC. Each modular unit must also be supplied with wiring diagrams and product data. The diagram must show the exact devices inside the unit and must not be a generic diagram.

The entire MCC must go through a quality inspection before shipment. This inspection will include:

A. Physical Inspection of: structure, electrical conductors, including bussing, general wiring, and units.

B. General electrical tests including power circuit phasing, control circuit wiring, instrument transformers, ground fault system, device electrical operation.

C. AC dielectric tests of power circuits and control circuits.

D. Markings/Labels verification, including instructional type, UL, and inspector's stamps.

The manufacturer must use integral quality control checks throughout the manufacturing process to ensure that the MCC meets operating specifications.

MCC will be Eaton Freedom series, Schneider Electric Model 6 series, Allen-Bradley or Engineer approved equal.

32. Wiring Trough. Ensure indoor wiring trough is *NEMA 12*, constructed of #12 gauge sheet steel, suitably reinforced with structural steel angles, and welded continuously at all seams and joints. It must have a removable cover on the front side to provide access to the interior. Ensure covers are secured by stainless steel screw clamps spaced no more than 8 inches apart.

Ensure outdoor wiring trough is *NEMA 4X*, constructed of #12 gauge type 316 stainless steel, suitably reinforced with stainless steel angles, and welded continuously at all seams and joints. It must have a removable, gasketed (oil-resistant) cover on the front side to provide access to the interior. Ensure covers are secured by stainless steel screw clamps spaced no more than 8 inches apart.

Furnish intermediate diaphragms of molded phenolic compound, not less than1/2 inch thick, in the trough. Space diaphragms no less than 36 inches apart throughout the trough. Bolt the diaphragms to interior, structural steel mounting angles. Ensure the wiring trough is painted inside and out with one coat of primer followed by one coat of gray enamel on the inside surfaces and two coats of gray enamel on the outside. Ensure the finish coat is *ANSI #61* light gray enamel.

33. Raceways. Except for multi-conductor, jacketed cables, ensure all wiring is installed in conduit or steel wireway as shown on the plans.

Ensure all other conduits installed in indoor locations are standard weight, threaded, rigid steel conduit conforming to the requirements of *ANSI Standard C80.1*. Hot-dip galvanize all conduits inside and out, to meet the requirements of the above standard for protective coating. Make conduit couplings and fittings of malleable iron or steel, hot-dip galvanized.

Ensure all conduits to be installed in outdoor locations are plastic coated as hereinafter specified. Conduit fittings, including couplings, unions, elbows, expansion and deflection fittings, and other items, must also be plastic coated. Ensure conduits and fittings, which are to be plastic coated, are provided with a factory-applied PVC coating in the following manner. Coat the exterior of the galvanized rigid steel conduit or fitting with an epoxy acrylic, heat-polymerizing adhesive not to exceed 0.1mm (4 mils). Bond a PVC plastic coating, 0.8mm to 1mm (31 to 39 mils) thick to the outside metal surface the full length of the pipe, except for the threads. The plastic coating must have an 85+Shore A Durometer rating and conform to *NEMA RNI-1998 (Type A)*, *ASTM D746*, and *Federal Specifications LP406b, Method 2051, Amendment 1*. Apply a two-part red urethane, chemically cured coat to the interior of all conduit and fittings. Ensure this internal coating is at the nominal 2 mil (0.05 mm) thickness and sufficiently flexible to permit field bending without cracking or flaking. Ensure the Plasti-bond, PVC coated, hot-dip galvanized steel conduit is *UL* labeled and listed.

Coat all hollow conduit and fittings, which serve as part of the raceway, with the same exterior PVC coating and red interior urethane coating. Install PVC coated conduit in accordance with the manufacturer's installation manual.

Ensure unions to connect sections of conduit that cannot be joined to each other or to boxes in the regular manner are of malleable iron or steel, hot-dip galvanized, PVC coated.

Conduits must not be less than 3/4 inch in diameter. The interior surfaces must have a smooth finish and be free of burrs or projections, which might cause injury to the cables. Ensure all conduits are free from blisters, cracks, or injurious defects and reamed at each end after being threaded. Connect sections to each other with screw couplings made up so that the ends of both conduits will butt squarely against each other inside of the coupling. Install conduits to be continuous and watertight between boxes and equipment. Ensure conduits are protected at all times from the entrance of water or other foreign matter by being well-plugged overnight or when the work is temporarily suspended.

Make conduit bends and offsets by cold bending using approved methods and equipment. The use of a pipe tee or vise for bending conduit is prohibited. Ensure conduit, which has been crushed or in any way deformed, is discarded. Ensure all bends are long sweeps, free from kinks, and of such easy curvatures as to permit the drawing of conductors without injury. Make conduit runs with as few couplings as standard lengths permit, and the total angle of all bends between any two boxes or cabinets must not exceed 90 degrees, unless otherwise approved by the Engineer. Ensure the radius of curvature of pipe bends is not less than eight times the inside diameter of said conduit. Long running threads is prohibited. Use pull boxes whenever necessary to facilitate the installation of the wire.

Except for installation indoors or where specifically permitted by the Engineer, ensure condulets or conduit bodies are not used for pulling conductors or for making turns in conduit runs or for branching conductors. Condulets or conduit bodies, where permitted, must consist of malleable iron castings with gasketed covers of the same material and fastened with brass cover screws. Ensure the bodies are hot-dip galvanized, and PVC coated when used with PVC coated conduit.

Where conduits pass through the floors or walls of the houses, ensure they are provided with PVC pipe sleeves for free passage of the conduits. After the conduits are installed, ensure the openings are caulked with an elastic compound and escutcheon plates provided on the interior walls, ceilings, and floors.

Ensure conduits and wireways are securely clamped and supported at intervals not exceeding five feet in length.

Ensure conduit and wireway runs exposed on the steel structure are securely clamped to the steelwork. The conduit clamps, in general, must consist of U-bolts attached to structural steel supports bolted to the members. The wireway clamps, in general, must consist of manufacturer recommended stainless steel bracket hangers attached to structural steel supports bolted to the members. Ensure the wireway cover is on the top or on the side of the wireway and clear of opening obstructions. Ensure the minimum thickness of the structural supports is 3/8 inch. Arrange supports so that conduits and wireways rest on top of the support and conduit U-bolts rest on top of the conduits. The use of J-bolts to fasten structural supports or to clamp conduits is prohibited.

Ensure all U-bolts and bracket hangers are provided with medium-series lock washers and hexagonal nuts. Ensure the bolts, nuts, and washers are of stainless-steel in accordance with the requirements of *ASTM A276/A276M, Type 316*.

Ensure where conduits and wireways are mounted exposed on non-steel surfaces, they are securely clamped to the surface using bent plate pipe supports with back spacers held by not less than two bolts. The stock size for the bent steel plate supports will be 1/4 inch thick by 2 inches wide. Furnish back plates that are 3/8 inch thick steel. Hot-dip galvanize supports and spacers. Ensure bolts are not less than 1/2 inch in diameter and of stainless-steel conforming to the requirements specified for U-bolts.

At any point where a conduit crosses an expansion joint longitudinally or where movement between adjacent sections of conduit can be expected, ensure conduit expansion fittings are installed. Ensure the fittings are bronze expansion fittings and provided with flexible bonding jumpers to maintain the electrical continuity across the joints. The fittings must permit a total conduit movement of 8 inches and be an Engineer approved equal to the O.Z./Gedney Type EX, Spring City Type EF, or the Crouse-Hinds Type XJ.

At any point where a conduit crosses a joint laterally or where an offsetting type movement between adjacent sections of conduit can be expected, ensure expansion and deflection fittings are installed. The fittings must permit a movement of 3/4 inch from the normal in any direction. Furnish fittings from O.Z./Gedney Type DX, Spring City Type EDF, Adalet Type STX, or Engineer approved equal.

Make flexible conduits for the connections between the rigid conduit system, all motors, and limit switches with sections of PVC coated, flexible, metallic, liquid tight conduit. Each section must not exceed 18 inches without prior approval of the Engineer.

Ensure all conduit embedded in concrete, insofar as possible, is completely encased by concrete of not less than 3 inches, measured in any direction, and securely held in place during pouring and construction operations. Ensure a group of conduits terminating together is held in place by a template.

Examine all conduit, wireway, and fittings carefully before being installed, and all pieces having defects set aside and removed from the site. Make all conduit bends with standard size conduit elbows. Assemble conduit hand tight and then using strap wrenches tightened two more turns. Touch up wrench marks or chuck marks with the appropriate touch-up compound. Perform all cuttings and threading as recommended by the conduit manufacturer. Ensure all conduit, enclosures, and fittings are mechanically joined together to form a continuous electrical conductor to provide effective electrical continuity.

Cap ends of abandoned conduits, spare conduits/wireway, and empty conduits/wireway and stubs during and after construction, and care taken to ensure that no moisture or other matter is in or enters the conduits.

Ensure all conduits are pitched not less than 1 inch in 10 feet (except by special permission). Where conduits cannot be drained to pull boxes, ensure a drain T with drain fitting is installed at the low point and drained to a dry well of broken stone. Ensure drain fittings are of stainless steel and capable of passing 1 ounce of water per minute.

Furnish the ends of all conduits projecting into boxes and equipment enclosures with bronze insulated grounding bushings. Ensure the insulated portion is of molded phenolic compound, and each fitting has a screw type combination lug for bonding. Furnish insulated bushings from O.Z./Gedney Type RBLG, Spring City Type GB, or Engineer approved equal manufactured by Appleton. Bond all bushings in any box or enclosure together with #8 AWG bare copper wire. Where conduit hubs are provided use locking nuts with grounding terminals.

Clean all conduits and wireways both before and after installation. Upon completion of the conduit and box installation, clear each conduit by snaking with a steel band, fitted with an approved tube cleaner equipped with a mandrel of a diameter not less than 85 percent of the nominal inside diameter of the conduit, and with a wire brush of the same diameter as the conduit and then draw in the cables.

Furnish both ends of each conduit or wireway run with a brass tag having the same number stamped thereon in accordance with the conduit diagrams. Securely fastened the tag to the conduit ends with #20 AWG brass wire.

Furnish and install separate conduits or wireways to carry the circuit wiring to all span driving motors.

Ensure all wireways are 16-gauge 304 stainless steel bodies with covers and oil-resistant gasket and adhesive. Ensure the flanges are 10-gauge stainless steel. Ensure wireway fittings, nipples, and elbows are 304 stainless-steel. Position a solid oil-resistant gasket between flanges when sections and fittings are bolted together.

Wireways must not be less than 6 inch by 6 inch. Ensure the seams are continuously welded and ground smooth. Ensure there are no holes or knockouts. Ensure the edges on all sections and fittings are smooth and rounded to prevent damage to cable and conductor insulation.

The wireway covers must have heavy butt hinges and external screw clamps to assure complete seal between covers, gaskets, and bodies.

When a wireway enters an enclosure, use a box connector on the inside of the enclosure to ensure a tight and stable seal. Closure plates must seal the end of wireway sections or runs.

At any point where a wireway crosses a joint, where an offsetting type movement between adjacent sections of conduit can be expected, or where movement between adjacent sections of conduit can be expected, install flexible wireway fittings. Ensure the fittings are the wireway manufacturer’s recommended fitting.

Furnish all conduits projecting into boxes and equipment enclosures with watertight, weatherproof, insulated throat conduit hubs. Ensure the conduit hubs are Meyers Watertight Rigid Conduit Hubs with ground lugs except for PVC coated conduit which is provided with PVC hubs of the same manufacture as the conduits or approved equal.

34. Boxes. Ensure all surface mounted pull, junction, and terminal boxes are of type 316 stainless steel, and provided with full length hinged gasketed, covers held with stainless steel fast operating clamps to provide *NEMA 4X* watertight construction. Furnish Hoffman bulletin A4S or Engineer approved equivalent by Weiggman or Hammond.

Furnish interior and exterior boxes with external mounting lugs and fastened in position with stainless steel through bolts. Ensure conduit entries are by means of galvanized malleable iron hubs. Use PVC coated hubs with PVC coated conduit. Ensure no box is drilled for more conduits or cables than actually enter it. Furnish exterior boxes with drain fittings of the same type as specified for conduit drains.

Size all boxes in accordance with the requirements of the *NEC* and the dimensions shown on the plans.

Furnish terminal boxes of sufficient size to provide ample room for the terminal blocks and interior wiring and for the installation of conduit terminations and multi conductor cable fittings. Furnish interior mounting back panels with tapped holes for mounting the terminal blocks.

Ensure junction and pull boxes to be cast into sidewalks are extra heavy-duty galvanized cast iron boxes designed for heavy duty pedestrian traffic. Ensure they have minimum interior dimensions of 12 inches by 24 inches by 12 inches deep. Ensure they are listed by *UL* as Type 4. Ensure they are suitable for use outdoors where they would be subjected to rain or dripping or splashing of water. Design them especially for flush mounting in floors and supplied with steel checkered plate covers suitable for foot traffic. Construct the box of cast iron with 3/8 inch walls with checkered cover, hot dip galvanized finish, neoprene gasket and stainless-steel cover screws. Ensure they meet *UL Standard: 514A, 50* and *NEMA 250-1997 Type 4*. Furnish OZ Gedney type YR or Engineer approved equal by Appleton or Hope.

35. Hardware and Supports. Ensure supports for conduits, wireways, cables, boxes, cabinets, disconnect switches, small limit switches, and other separately mounted items of electrical equipment are fabricated from structural steel not less than 3/8 inches thick. Clip angles and other supporting members, which are fabricated from structural steel plates and shapes and bolted to the structural members, are included with the structural steel. All other supporting members are included under the electrical work.

Ensure structural steel brackets, boxes, and other equipment mounted on concrete surfaces are provided with a full neoprene gasket not less than 1/8 inch thick between the equipment and the surface of the concrete.

Ensure expansion anchors for fastening equipment or brackets to concrete surfaces are wedge type anchor bolts, which lock in place by an expansion wedge as the nut is tightened. Ensure all parts of the expansion anchors are of Type 303 stainless steel. Drill holes for the anchors to the size and depth recommended by the manufacturer using carbide tipped masonry drills.

Ensure mounting bolts, nuts, washers, and other detail parts used for fastening boxes, disconnect switches, small limit switches, conduit clamps, cable supports, brackets, and other electrical equipment are of stainless-steel in accordance with the requirements of *ASTM A276/A276M, Type 316*. Ensure bolt heads and nuts are hexagonal and furnished with medium-series lock washers. Do not use bolts smaller than 3/8 inch in diameter, except as may be necessary to fit the mounting holes in small limit switches, boxes, and similar standard devices.

Usage of beam clamps for supporting conduits, boxes, or other equipment are prohibited, except where specifically approved by the Engineer.

Preformed metal framing channels, such as Kindorf, Unistrut, Superstrut, etc., are prohibited for mounting or supporting electrical equipment, conduits, or boxes except where specifically approved by the Engineer.

36. Wiring and Cables. Ensure except where otherwise noted, wiring in conduits are single-conductor.

Ensure all wires and their insulation and covering are from a nationally recognized brand, acceptable to the Engineer, and have marks always used on the particular brand for identifying it.

All wiring and cables must conform to the requirements of *NEMA Publication WC70*. Before wire and cable orders are placed with any manufacturer, submit for approval typical published test data for the type of insulation proposed, showing that it meets the requirements of *NEMA Publication WC70*. Ensure all materials used to fabricate insulated wiring and cables are certified to be from stock not more than 1 year old.

Ensure all other conductors are of stranded copper large enough to safely carry the maximum currents required without injurious heating or serious voltage drop. Ensure conductors are not smaller than #12 AWG, except as approved for control panel and console wiring or for lighting fixtures. Ensure all conductors are soft-annealed copper wire in accordance with the requirements of *NEMA Publication WC70*. All conductors must have Class B concentric stranding, except for conductors in flexible cables.

Ensure the insulation is a chemically cross-linked, polyethylene compound in accordance with the requirements of *NEMA Publication WC70, Part 3.7*. Ensure the thickness of insulation is that required for 600 V rated circuit voltage listed under *Column A of Table 3-1* of the *NEMA WC70*. Ensure insulation type is Type XHHW-2.

Ensure equipment ground conductors are bare, stranded, coated copper in accordance with the requirements of *NEMA Publication WC70, Part 2*.

Test single conductor wiring, including the insulating material, to demonstrate that it meets specified requirements. Do the testing as stipulated in *NEMA Publication WC70, Part 6*. Do not ship wiring and cables from the plant of the manufacturer until certified test reports on the cable properties have been approved by the Engineer.

The conductor sizes and number of wires shown on the plans are approximate and based on the design drawings. Furnish wiring and cables of sufficient size and number as may be required for the installation in accordance with the wiring diagrams on the approved working drawings. In each conduit and multi conductor cable furnish at least one spare wire for every 10 conductors actually used.

Do not install wiring in any conduit before all joints are made up tightly and the conduits rigidly secured in place. Draw cables into conduits without injury to the wires or their insulation or covering. Do not use lubricant of any kind for the pulling of wires, unless specifically authorized by the Engineer. Leave sufficient slack in all cables to permit proper connections in boxes, cabinets, and enclosures.

Ensure both ends of every single length of conductor are permanently and clearly tagged in accordance with the same numbers or designations appearing on the approved wiring diagrams. Ensure wire tags for marking the conductors are heavy duty, heat shrink, waterproof, permanently marked, and resistant to UV light deterioration. Ensure numbers and letters are black or blue on a white background. Submit the proposed wire marking system and a sample of the wire markers to be installed to the Engineer for approval. Ensure each conductor, except for control and instrument conductors, are color coded with colored insulation. Ensure color coding for 120/208 V conductors are black for phase A or 1, red for phase B or 2, blue for phase C or 3, white for neutral, and green for equipment ground. Ensure color coding for three-phase 480 V conductors are brown for phase A or 1, purple for phase B or 2, yellow for phase C or 3, gray for neutral, and green for equipment ground. Ensure each conductor is marked at panelboard gutters, pull boxes, outlet and junction boxes and each load connection, and must include each branch circuit or feeder and control wire.

Ensure conductors inside terminal boxes, the control console, and control panels are neatly formed into cables and laced with approved cable ties, with the individual conductors leaving the cable at their respective terminal points. Loop these conductors to allow not less than three inches of free conductor when disconnected. Ensure the formed cables are held securely away from the terminals and from contact with the enclosure by means of approved insulating supports.

Ensure all outgoing wires, #8 AWG or smaller, in the control console and control panels and in terminal boxes are connected to stud and nut style terminal blocks of molded phenolic compound. Ensure terminals are suitable for use with solderless, locking fork, wire connectors. Ensure connectors which extend beyond the ends of terminal block barriers, are furnished with an insulating sleeve covering the metal part of the connector. Taping of extended terminals is prohibited.

Ensure each terminal of all terminal blocks are permanently marked to show the same number or designation as appears on the wire connected thereto.

Splicing of wires is prohibited, except for wiring to service lighting fixtures and receptacles. Wherever it becomes necessary to joint or branch conductors, use terminal blocks, and clearly tag wires.

Secure multi-conductor cables supported on the steelwork by bent plate cable clamps spaced not more than 3 foot on centers. Fabricate the cable clamps from stainless steel plates bent to suit the outside diameters of the cables. In general, fasten the clamps to structural brackets bolted to the steelwork.

Where multi-conductor cables enter the control console or any cabinets or boxes, ensure they are furnished with watertight cable terminators. Each cable terminator must provide a watertight seal by compressing a tapered neoprene-sealing ring around the outer jacket of the cable. Make cable terminator parts of bronze and use the Series SF-327OB Watertight Cable Entrance Seals as made by O.Z./Gedney or approved equal.

Take insulation resistance readings on all circuits installed, with electronic equipment disconnected, and furnish to the Engineer a complete record of the results obtained. These circuits must include connected motors when tested. Ensure conductors rated 600 V, or more, are one megohm, or more. Replace defective circuits at the Contractor’s expense.

37. Ethernet Cables. Ensure all Ethernet cabling is by means of industrial grade category (CAT) 6A cables. They must consist of #24 AWG stranded copper conductors, with a HDPE insulation. The twisted pair copper conductors are to be wrapped with a foam polypropylene core. All pairs are to be surrounded by an overall braided shield and metallic foil and covered with a thermoplastic elastomer (TPE) jacket that is industrial grade sunlight and oil resistant and has sequential footage marking every two feet.

Ensure installation temperature range is -20 °C to +80°C, operating temperature range is -40 °C to +80°C, and the *UL* temperature rating is 80 °C. Use Belden IEA005, Panduit ISFCH6X04ATL-UG, TPC Wire & Cable EN650H-024-4UTP-SFB or approved equal.

Use 8-conductor, highly flexible Ethernet cable with thermoplastic elastomer jacket and RJ-45 crimp connectors with boot for installation in locations other than rigid conduit to allow movement of device.

38. Fiber Optic Cables. Ensure new fiber optic cables are 48 strand outdoor heavy duty rated jacket, multi-mode 62.5 microns core size, 125-micron cladding, less than 3.4 decibels per kilometer (dB/km) at 850 nanometer (nm) and less than 1.0 dB/km at 1300 mm attenuation, greater than 200 megahertz over one kilometer (MHz/km) at 850 nm and greater than 500 MHz/km at 1300 nm bandwidth.

Furnish the fiber optic cables with an interlocking armor for mechanical protection.

Ensure the fiber optic cables are acceptable for indoor/outdoor applications and be tray-rated industrial cables and flame-retardant.

Utilize a fiber optic repeater if necessary to achieve the attenuation values specified herein.

39. Droop Cables. Furnish droop cable components as shown on the plans and as specified herein. Ensure all equipment and materials furnished under the items specified herein are brand-new.

The work must meet the requirements of all other codes and standards as specified elsewhere in this special provision. Where codes and standards are mentioned for any pay item, it is intended to call particular attention to them, it is not intended that any other codes and standards are assumed to be omitted if not mentioned.

A. Design and manufacture all cables in accordance with:

(1) *ICEA S-73-532, NEMA WC-57* (#22 - #16 AWG).

(2) *ICEA S-95-658, NEMA WC-70* (#14 AWG and larger).

General configuration consists of multiple conductor extra flexible copper conductors, ethylene propylene rubber (EPR) insulation, cabled with fillers as necessary, binder tape, and jacketed with a weather resistant arctic neoprene jacket which is reinforced with aramid fiber reinforcement.

Ensure conductors are annealed copper in accordance with *ASTM B174* for #10 AWG and smaller, and *ASTM B172* for #9 AWG and larger. Ensure conductors are stranded in accordance with *ASTM B174* or *ASTM B172*, *class K stranding*, and *Section 2* of *ICEA S-95-658*, *NEMA WC-70*, as applicable.

B. Ensure conductor insulation is an EPR compound meeting the requirements for EPR – Type II insulation, in accordance with:

(1) *ICEA S-73-532*, *NEMA WC-57, Table 3-2* (#22 - #16 AWG), 600 V.

(2) *ICEA S-95-658*, *NEMA WC-70, Table 3-1* (#14 AWG and larger), 600 V to 2000 V.

C. The EPR insulation must meet the following physical and thermal aging requirements:

(1) Unaged.

(a) Tensile Strength – 1200 psi, minimum.

(b) Elongation – 150 percent, minimum.

(c) Tensile Stress at 100 percent elongation 500 psi, minimum.

(2) Aged.

(a) After air oven 168 hours at 121 °C

(b) Tensile Strength and Elongation requirements:

(i) At rupture - 75 percent of unaged, minimum.

(c) Hot Creep at 150 °C requirements:

(i) Hot Creep elongation, 50 percent, maximum .

D. The EPR insulation must meet the following accelerated water absorption requirements when tested in accordance with *ICEA T-27-581*, *NEMA WC-53*, *Electrical Method EM-60*:

(1) Dielectric Constant after 1 day, 6.0 maximum.

(2) Increase in Capacitance - percent, maximum:

(a) 1 to 6 days 5.0

(b) 7 to 14 days 3.0

(3) Stability Factor after 14 days, 1.0 maximum.

E. The insulation thickness must comply with, as applicable:

(1) *ICEA S-73-532*, *NEMA WC57, paragraph 3.2* and *Table 3-1* for cables as follows:

(2) *ICEA S-95-658*, *NEMA WC70, paragraph 3.3* and *Table 3-4* for cables as follows:

|  |  |  |
| --- | --- | --- |
| Conductor Size AWG or KCMIL | 600 Volts Insulation  Average Thickness - mils | 2,000 Volts Insulation  Average Thickness - mils |
| 22 - 16 | 30 | --- |
| 14 - 9 | 45 | 60 |
| 8 - 2 | 55 | 60 |
| 1 - 4/0 | 65 | 80 |
| 225 - 500 | 80 | 95 |
| 525 - 1000 | 95 | 110 |

Ensure the insulation is readily removable from the conductor. To enhance stripability, ensure a separator is employed between the conductor and the insulation. Color the separator so as to be distinguishable from the conductor once the insulation is removed.

Ensure color coding of the insulated conductors is accomplished by surface printed legends consisting of numbers and words (1-One, 2-Two, 3-Three…19-Nineteen… 37-Thirty-Seven, etc.).

Ensure color coding sequence is in accordance with *ICEA S-73-532*, *NEMA WC-57, Appendix E, Method No.4*.

Sequence must begin from the inner conductor layer and progress to the outer conductor layer. Employ contrasting color print and ensure it is legible after normal handling during installation.

Ensure the cable components are cabled into a tight concentric configuration. Reverse the direction of lay for adjacent layers of cable conductors. Ensure the maximum lay length is 12 times the outside diameter of the cabled layer.

Employ fillers as necessary within the cable core to produce a substantially circular cross section. Ensure fillers are non-hygroscopic.

Cover the cabled conductors with a rubber/fabric binder tape. Apply the tape helically with a minimum overlap of 25 percent.

F. Ensure the cable core is covered with two layers of a black arctic heavy-duty Neoprene® (Polychloroprene) jacket in accordance with *ICEA S-95-658*, and *NEMA WC-70, paragraph 4.1.3*. Ensure the jacket is sunlight (UV) and weather resistant.

The Neoprene® jacket must meet the following physical and thermal aging requirements:

(1) Unaged.

(a) Tensile Strength – 1800 psi, minimum.

(b) Elongation – 300 percent, minimum.

(c) Tensile Stress at 200 percent elongation, 500 psi, minimum.

(d) Set – 30 percent, maximum.

(2) Aged.

(a) After air oven 168 hours at 100 °C

(b) Tensile Strength/Elongation at rupture - 85/65 percent of unaged, minimum.

(c) After oil immersion 18 hours at 121 °C

(d) Tensile Strength and Elongation at rupture - 60 percent of unaged, minimum.

Ensure the two-layer cable jacket thickness is as follows (similar to heavy duty Type W jacket thickness):

Calculated Diameter of Jacket Average.

Cable Under Jacket – inches Thickness – mils

0.325 and less 60

0.326 0.326 - 0.430 80

0.327 0.431 - 0.540 95

0.328 0.541 - 0.640 110

0.329 0.641 - 0.740 125

0.330 0.741 - 0.850 140

0.331 0.851 - 1.000 155

0.332 1.001 - 1.320 170

0.333 1.321 - 1.550 190

0.334 1.551 - 1.820 205

0.335 1.821 - 2.050 220

0.336 2.051 - 2.300 235

0.337 2.301 - 2.550 250

0.338 2.551 - 2.800 265

0.339 2.801 - 3.100 280

0.340 3.101 - 3.500 295

0.341 3.501 - 3.950 310

0.342 3.951 - 4.450 330

0.343 4.451 - 5.000 345

Employ a flexible preformed stainless steel 302 or 304 aircraft cable as the strength member (if recommended by cable manufacturer). Cover the strength member with a tape, extruded rubber, or other material prior to assembling of cable core. This covering must serve as a cushion for subsequent components that are cabled over the strength member. Select the size of the strength member and its breaking strength based on the weight of the cable, the length of the suspension, and the construction of the cable. Ensure it is positioned in the center of the cable construction.

Pack the finished cable on reels capable of supporting the weight during transportation and normal handling. Seal cable ends to prevent moisture from entering the conductor core area during shipping.

40. Droop Cable Termination Cabinets. Furnish and install four droop cable termination cabinets, one in each machinery room and corresponding ones at each bascule pier as shown on the plans, to provide termination for the new droop cables. Ensure each cabinet is of adequate size to mount all terminal blocks, and to provide ample space between blocks for routing of the wires. Ensure cabinets are no smaller than 24 inches tall, 24 inches wide, and 8 inches deep.

Ensure each droop cable terminal cabinet enclosure is a single door wall mountable 316L SS *NEMA 4X* type enclosure, fabricated from #14 gauge sheet steel. Ensure the doors are constructed of #14 gauge sheet steel, suitably reinforced, and furnished with lockable hasp. Droop cable cabinets must have a continuous piano hinge. Furnish the doors with a seamless foam in place rubber gasket.

Furnish each terminal cabinet with a stainless steel *NEMA 4X* breather fitting to minimize condensation. Furnish an Eaton type DPE3030S3 breather fitting or approved equal.

Furnish terminal blocks and power distribution blocks in each terminal cabinet for the connection of all conductors in the droop cables. Furnish sufficient terminals for termination of all spare conductors and other conductors to be terminated inside the cabinet. Ensure terminal blocks/power distribution blocks are one-piece blocks suitable for use in highly corrosive atmospheres and in accordance with to the requirements specified herein.

Ensure the ends of all conduits projecting into terminal cabinets and junction boxes are furnished with bronze insulated grounding bushings. Ensure the insulated portion is of molded phenolic compound, and each fitting must have a screw type combination lug for bonding. Furnish insulated bushings from OZ-Gedney (Emerson) Type RBLG or approved equal. Ensure all bushings in any box or enclosure are bonded together with #8 AWG bare copper wire.

Secure all exposed droop cables entering the droop cable termination cabinets with an OZ-Gedney (Emerson) Type GPE or approved equal support and sealing bushing. Seal droop cables with manufacture recommended sealing compound. Supply Type GPE bushings with Lay-In-Lug grounding lug. Secure all droop cables within conduit entering the droop cable termination cabinets with an OZ-Gedney (Emerson) Type GRK, or approved equal, sealing bushing. Seal droop cables with manufacture recommended sealing compound. Supply Type GRK bushings with Lay-In-Lug grounding lug. All fittings must utilize corrosion resistant materials.

41. Cable Supports. Droop cables in conjunction to the OZ-Gedney (Emerson) type GPE cabinet fittings (where exposed droop cables enter cabinets), on either fixed end of the traveling section of all droop cables, ensure cables are supported with heavy duty, double eye, split mesh, stainless steel cable grips or approved equal. Ensure the support grips maximum breaking strength is a minimum of 10 times the actual load to be exerted on the support grip. Ensure each cable is supported by two mesh grips, one attached to existing support structure on the fixed tower, and one attached to the support structure on the movable span as shown on the plans.

Ensure all horizontal and vertical installations of droop cable not in conduit are attached to new support plates by type 316 Stainless steel U-bolts and double nuts. Fabricate the U-bolts with stainless steel large bearing surface ‘saddles’ and sized to match droop cable diameter. Ensure droop cables are U-bolted to new support plates which will bolt to the structural supports as shown on the plans.

42. Submarine Cables. Should submarine cables be utilized, the following requirements must be met.

The submarine cable will be obtained from a manufacturer that is experienced in producing submarine cable of similar types to those described below.

Materials and construction must conform to the requirements of the *NEC* and to any applicable local rules and ordinances.

Furnish new submarine cables under the navigation channel. Ensure the cables, cable supports, armor clamps, bell ends, cable terminators, brackets, and hardware are provided as needed for installation.

Before cable orders are placed with any manufacturer, determine the true length of each cable between the submarine cable terminal cabinets. Splicing or joining of conductors between these points is prohibited. In addition, verify the conductor count of each cable with the vendor of the bridge control system to ensure the specified number of spare conductors are provided.

The Contractor is responsible for ascertaining and ordering the correct conductor counts based on his approved working drawings supplied by the control system vendor. In no case, will the conductor counts be less than those hereinbefore specified.

The Contractor is responsible for ascertaining and ordering the correct continuous length of submarine cables, including sufficient excess length to accommodate pulling eyes, adequate slack for submarine cable settling, cable clamping, connections, and for samples.

Materials and construction of the submarine cables must conform to referenced requirements of *NEMA Publication No. WC70*. Ensure all conductors are soft annealed copper wire in accordance with the requirements of *NEMA Pub. No. WC70*. All conductors will have Class B concentric stranding. Ensure the insulation of each conductor is a moisture-resisting, cross-linked, polyethylene compound in accordance with the requirements of *NEMA WC7, Part 3.7*. Ensure the thickness of insulation is as given under *Column A of Table 3-1* for 2,000 V rated circuit age. The insulation must incorporate mineral fillers (not carbon) to inhibit treeing. The fiber optic cable must meet all requirements as specified herein.

In each cable, ensure the insulated conductors are cabled to a full circular section using non-hygroscopic fillers, where necessary, to fill out the section. Ensure each layer of the conductors are covered with a single serving of binder tape. Ensure conductors in each layer are identified by coloring or marking the outer surface of the insulation. Over the cabled conductors, ensure there is applied one layer of binder tape followed by a homogeneous synthetic sheath in accordance with the requirements of *NEMA WC7, Part 4.4.2*, Polyethylene, Black. Ensure the thickness of the sheath is in accordance with the requirements of *Table 4-7*. Over the sheath, ensure there is applied cable armor consisting of a single layer of galvanized plow steel wire, each wire covered with a layer of polyethylene. Ensure a high-density polyethylene jacket is placed over the armor. The polyethylene jacket, jacket thickness, and armor jacket must be in accordance with *NEMA WC7, Parts 4.4.2, 4.4.3*, and *4.5.8* and be sunlight and weather resistant. Ensure any variations in cable construction or materials are submitted to the Engineer for review and approval.

Ensure approved moisture-resistant filler material suitable for submarine cable application is used in the interstices between and over the insulated conductors to give the complete cable a circular cross-section. Ensure binder tape of approved, suitable, flame-resistant, and moisture-resistant fabric material with a thickness not less than 10 mils is applied over the multi conductor/filler assembly and overlapped not less than 10 percent of its width between turns.

Typical published test data showing physical and electrical characteristics of the proposed cable insulating compound.

Manufacturer's construction drawings of all submarine cables showing the sizes of conductors, thickness of insulation, makeup of the cable layers, type and size of jackets, armor, jute serving and other components, and the outer diameters of the finished cables.

Ensure all cable at the factory is tested in accordance with the latest test methods of *ICEA/NEMA Standards* for the types of cable and insulating materials specified and will meet or exceed the minimum requirements and criteria for acceptance as set forth therein.

Prior to assembly and fabrication of the submarine cables, ensure the individual insulated conductors to be incorporated in the cables are tested to demonstrate the quality of the production run. The conductors and insulating compounds must meet the minimum physical and electrical requirements set forth in *NEMA Publication No. WC-7*. Submit the test reports for approval prior to shipping any cable.

After each multi conductor cable is completely assembled and armored, ensure it is subjected to tests for insulation resistance and high voltage. Ensure high-voltage tests are made at the same voltage used on the individual wires, and the insulation resistance must not be less than 80 percent of the original values for the individual wires.

Test the fiber optic cable as per the requirements specified herein.

Submit to the Engineer one electronic certified copy of all the factory test data for approval before accepting shipment of cable from the manufacturer. The test data must include, in tabulated form, a description of the material undergoing test, a description of each test performed, the measured or observed results, and the value and limits required by the *ICEA/NEMA Standard* for acceptance.

In addition, submit to the Engineer one electronic certified copy of a statement certifying that the cable delivered for use under this contract has passed the required factory inspections and tests and complies with all the requirements, including materials and construction, of the contract.

Ensure the following inspections, measurements, and tests are performed, and the results recorded by the testing laboratory, on the section of cable sample taken from each reel, in accordance with test methods described in the applicable *ICEA/NEMA Standards*, for compliance with the contract.

A. Inspection of markings on cable for proper size, grade, type, and voltage rating.

B. Inspection of cable for physical condition of all materials with respect to defects and damage.

C. Quantity and measured size of each conductor, including quantity and size of its conductor strands, and the associated color code.

D. DC resistance and material of each conductor.

E. Measured wall thickness of insulation for each conductor, including minimum and average wall thickness per *ICEA Standards*.

F. Measured wall thickness of overall non-metallic jacket.

G. Visual inspection of condition of filler materials and identification of type of materials used.

H. Measured thickness of tapes and binders and types of materials used.

I. Measured diameter and quantity of individual wires used in wire armor and type and condition of protective finish.

J. Measured and observed test results and computations for accelerated water absorption test on insulation.

K. Measured and observed original and aged properties of insulation.

L. Insulation resistance.

The laboratory must submit one electronic copy of certified test data results on the cable samples to the Engineer for approval. The Contractor must pay the cost for testing the cable samples, including the costs of cable material, transportation of materials to the laboratory, and the submission of certified test data to the Engineer.

If, as a result of the laboratory tests, it is found that the cable does not comply with the approved certified factory test results or with the applicable *ICEA/NEMA Standard*, the Contractor will be ordered to remove all cable that came from the reel containing the defective cable sample and to remove the reel of defective cable from the work site, and will replace the defective cable with new cable, all without additional cost to the contract. The Contractor is responsible for any delays in the execution of the work caused by the defective cable.

After the submarine cables have been installed in the trench, clamped, secured, and terminal connectors attached, but prior to final connections, all conductors must then be tested for insulation resistance by the Contractor in the presence of the Engineer and the test results recorded and submitted for approval.

Ensure that the Engineer receives at least 72 hours written notice in advance when field tests are to be made.

Submit the results of the test to the Engineer for approval before proceeding further with the work.

After approval of the insulation resistance test of the installed but unconnected submarine cables, connect the submarine cables and test the energized installation as directed by the Engineer.

If a fault or defect is found to exist or a cable does not otherwise pass the tests, the Contractor must identify and tag the faulty cable or conductor in question.

If a fault or defect is located in a cable, remove all cable and furnish and install new cable, subject to all the aforementioned tests and acceptance requirements, all without additional cost to the contract.

If it is definitely established that the fault or defect is due to a termination of the cable, the decision to correct or repair the cable or replace that section of cable rests with the Engineer.

43. Terminal Cabinets and Hardware. Furnish and install terminal cabinets as shown on the plans, to provide termination for the submarine direction drilled duct cabling or submarine cables.

The terminal cabinets will be *NEMA 4X*, fabricated from No. 10 gauge Type 316 stainless steel reinforced by steel angles. Install in the front cover a framed door on continuous stainless steel piano hinge and which provides access to the equipment inside. Ensure the door is constructed of No. 10 gauge sheet Type 316 stainless steel, suitably reinforced, and provided with a three point, vault latch and padlock. Furnish the door with a rubber gasket, which will prevent water from entering the cabinet. Weld reinforcing plates to the walls where conduits and cables enter the cabinets.

Ensure terminal blocks, terminations, drain fittings, concrete pads, hardware and supports, and space heaters are as specified herein.

Should submarine cable be installed, ensure clamp fittings for supporting each submarine cable at the top end of its conduit run are a threaded cable support clamp screwed onto the end of the threaded conduit. Fabricate the clamp assembly of hot dipped galvanized steel and made specifically for this use. Ensure all hardware is stainless steel in accordance with the requirements of *ASTM A276/A276M, Type 316*. Ensure bolt heads and nuts are hexagonal and furnished with medium series lock washers.

Each termination cabinet must have a *NEMA 4X* rated 48 Port fiber optic patch panel mounted inside the cabinet. Ensure the fiber optic patch panel is an environmental distribution center which can hold up to 12 closet connector housing (CCH) connector panels. Ensure CCH panels are ST type and compatible with 62.5 µm multi modal fiber optic cable.

44. Ethernet to Fiber Converters. Ensure the Ethernet to Fiber convertor is powered by 120 VAC and is furnished with an integrated power supply, and able to operate between 32 °F and 122 °F.

Ensure the Fiber media convertor is a 10/100Base-T to 100Base-X Fiber. Ensure the media convertor can convert from fiber back to ethernet and have a power injector to provide power over ethernet (ethernet to fiber and fiber to ethernet may be different model numbers if required).

The fiber to ethernet media converter can power up to 15.4 W.

Ensure Media convertors are IEEE 802.3 compliant.

Ensure Media convertor can transmit data a minimum distance of 5 KM.

Ensure Media converters are DIN rail mounted.

45. Air Horn. For giving the necessary boat signals, furnish and install one compressed air horn with mounting brackets on the operator house, pointing parallel to the navigable channel.

Ensure the horn is a diaphragm type, 4 inch vibratory horn having a frequency of about 300 cycles per second. Ensure the horn is of weatherproof construction with a projector bell of bronze. Furnish the horn with a stainless-steel bracket for mounting on the machinery house as shown on the plans.

Ensure the compressed air horn is actuated by a rotary air compressor driven by an integral 1-horsepower electric motor. Ensure the motor is a 120 V, single-phase, 60-cycle unit. Mount the compressor unit in the operator house and extend a brass pipe through the house wall to the horn.

The air horn must produce a minimum 120 decibels and capable of being tuned in the field to produce a tone acceptable to the Engineer.

The dual projector unit will be a B&B Roadway Manufacturing Model AHR-2, Clark Cooper Model EP-2, or Engineer approved equal.

46. Pier Protection and Mid Span Navigation Lights. Furnish navigation lights in accordance with the rules and regulations of the United States Coast Guard (USCG) as shown on the plans.

Ensure for all navigation lights, the doors and lenses are gasketed, and each entire unit is completely weatherproof and vandal resistant. Ensure fittings are non-corroding, and the sockets are of porcelain mounted on shock absorbers. Ensure the housings for all units are cast-bronze, and an LED 120-V lamp with brass base is installed in each socket.

Ensure the movable span lights are controlled by the fully open limit switches so that the green lights show when the span is fully raised, and the red lights show at all other times.

Equip all navigation lights with bronze junction boxes.

Ensure the housing is of cast bronze and suitable for a marine environment. Ensure construction is rain-tight and fully gasketed. Design the light assembly for heavy-duty, long-life service. Design must provide ready access for lamp service.

Ensure the lens is heat-resistant fresnel glass. Ensure lens sections are 180 degrees red over 360 degrees green. Inside lens diameter must measure approximately 7 inches. Outside lens diameter must measure approximately 8 inches.

Suspend lamp fixture head from the swivel on a stainless steel 2-inch schedule 40 pipe, 2.375 inch outer diameter.

Equip each span navigation light with a swivel. The swivel design must provide for all wiring to be completely contained inside the light assembly. Use gaskets and O-rings to provide a weather tight assembly. Ensure swivel, fixture head and base are stainless steel.

Light assembly must mount via four 1/2 inch diameter bolts through the base, provided by installer to suit installation. Furnish a junction box with gasketed access cover at the base of the unit. Ensure junction box is of the same material as the fixture assembly and matches the navigation light base footprint. Ensure orientation of junction box is capable of rotation in 90-degree increments.

Furnish the pier protection lights that are model PL as manufactured by B&B Roadway, Type 1 Pier Light by Bridge Roadway Products, or FedTransit Safety Systems. Furnish the movable span lights that are model BS as manufactured by B&B Roadway.

Ensure the navigation light system is controlled by photoelectric control device. Ensure the photoelectric control unit is a completely self-contained, weatherproof device rated 1,800 VA at 120 V and provided with a time-delay feature and a deluxe, encapsulated lightning arrestor for protection against surges and lightning. The unit must provide turn-on of the pier navigation lighting system at 10.74-lux nominal. Ensure the unit is suitable for operation within a temperature range of -50 °Celsius to 70 °Celsius and has a fail-safe feature so that the lighting load remains energized in the event of component failure. Ensure the unit is suitable for installation in a twist lock receptacle with adapter for mounting on PVC-coated rigid metal conduit. Locate the photoelectric controller on the machinery house, as approved by the Engineer.

Furnish a three-position selector switch on the control console for operating the pier navigation lights. When in the Auto position, the lights are controlled by the photoelectric control device. The On position will override the photocell and turn the lights on. The lights can be turned to the off position for safety during maintenance.

47. Closed-Circuit Television (CCTV) System. Ensure the CCTV system is provided by a single approved vendor. Ensure the CCTV system consists of strategically located cameras installed as shown on the plans.

Mount the CCTV cameras as shown and configured as described on the plans.

Ensure Dome type Pan/Tilt/Zoom IP network, power over ethernet CCTV cameras, with ingress protection-66-class protection enclosures and are suitable for low temperature operation (-40 °C).

The CCTV camera protective dome is to be constructed of optically clear polycarbonate and be vandal-resistant with built-in heater, fan, and dehumidifier.

Ensure each camera is furnished with an automatically removable infrared cut filter, which enables adjustment of the color video in high and low light conditions as well as infrared sensitive black/white video at night.

Furnish standard 100/1000 network switches with two multimode fiber small form-factor pluggable (SFP) ports to satisfy the CCTV system configuration as shown on the plans.

Furnish the CCTV system switch media converters to enable Ethernet to be converted to optical fiber. Ensure media converters are as specified within.

Ensure the converter is fully compatible with the specified CCTV system and support 100/1000 Mbps and be furnished with two SFP slots and two RJ-45 ports.

Ensure the network digital video recorder (NDVR) is capable of connecting directly to a Transmission Control Protocol/IP network and remotely access digital video and system administration tools, using a standard web browser.

Ensure the NDVR accommodates up to eight cameras with Pan/Tilt/Zoom and is provided complete with built-in web server and self-maintained.

Ensure the NDVR provides event trigger, response, and notification. Ensure the NDVR has remote access/monitoring capability. Furnish a minimum of 2 software licenses to the bridge. Furnish a hard drive with the NDVR and sized to provide minimum of 30 days continuous recording for 6 cameras in their full resolution.

Furnish a wireless keyboard and mouse with the CCTV. The wireless keyboard is to be full sized with smart backlighting and customable keys. The mouse is to be a speed-adaptive scroll wheel mouse with Darkfield laser sensor which tracks anywhere including on glass.

The keys of the keyboard provided are to be large concave, laser etched keys and auto-adjusting backlighting.

The wireless keyboard and mouse provided are to be complete with rechargeable batteries that hold their charge during operation for up to 10 days and provided complete with charging cable.

Ensure the CCTV system is provided with a CCTV video management software. The software will manage video for live monitoring and recording. Ensure the management software provides the following functionality:

A. Simultaneous viewing and recording of live video from multiple cameras.

B. Video motion detection and alarm.

C. Alarm management functions.

D. Frame rate control.

E. Camera management and access control.

Furnish the system with two system monitors. One to be a 22 inch free standing monitor and the second to be a 32 inch monitor and mounted above the operator’s control console provided complete with mounting hardware for mounting from the ceiling.

Ensure monitors are LED-backlit intrusion prevention system type with minimum resolution of full high definition 1920X1080 with1170 degree view angle and 6.7 million color capacity.

Ensure the CCTV system is provided with a complete CCTV worktable adequately sized for the NDVR and local monitor.

Submit outline-dimensioned drawings of proposed CCTV system, mounting details, block, schematic and wiring diagrams of the CCTV system, monitor and personal computer interface and specification in the form of catalog cuts and data sheets of proposed system to the Engineer for approval prior to procurement.

Ensure all necessary /mounting brackets, supports, and means of cabling termination are furnished. Furnish power over ethernet injector power supplies standard with each camera.

Ensure the cameras are manufactured by ACTI, model I98 P/T/Z or approved equal by Bosch or Pelco.

Ensure the DVR is manufactured by ACTI, model ENR-020P or approved equal by Bosch or Pelco.

48. Power Distribution Transformer. Furnish *UL* listed, dry-type, three-phase, lighting transformers with kilo-volt-amps (kVA) and voltage ratings as shown on plans. Ensure they have 98 percent efficiency, ventilated in *NEMA* 2 enclosure painted with weather-resistant enamel coating. Insulate with 200 °C with 115 °C rise, flame-retardant insulation system. Provide the enclosure with lifting provisions.

Construct with high-grade, non-aging, silicon steel with high magnetic permeability, and low hysteresis and eddy current losses, tightly clamped and compressed core laminations, copper coils with continuous wound construction. Impregnate the core and coil assembly with non-hydroscopic, thermosetting varnish and cure to reduce hot spots and seal out moisture. Ground the core to the enclosure with a flexible copper strap.

49. Panelboard. Furnish panelboard meeting the following minimum requirements:

A. *UL* listed and in accordance with the requirements of *NEMA PB 1*, and fully rated to withstand short circuit currents of 22,000 A at 240 VAC. Do not use series ratings. Use ratings as indicated and as required by the circuits served.

B. Completely factory assembled and designed such that switching and protective devices may be replaced without disturbing adjacent devices and without removing the main bus connections.

C. Furnish copper tin-plated busses, sized in accordance with *UL* and *NEMA* standards. Use full-size (100 percent rated), insulated, copper neutral bus, furnished with suitable lugs to provide a connection for each branch circuit requiring a neutral. Use un-insulated, copper ground bus. Arrange switching and protective device taps to the main bus for the distributed phase or ABC phase sequencing such that adjacent poles are not connected to the same phase.

D. Enclosed in a *NEMA* *12* enclosure, constructed from steel, minimum 14 gauge, in accordance with *UL 50*, with rust-inhibiting primer and finish, and sized in accordance with *UL*, *NEMA*, and *NEC* requirements. Use corrosion-resistant hardware. Construct the front panel flush and removable to permit access to the panelboard interior, with a hinged and lockable door to cover all switching and protective device handles. Fabricate the front panel with at least 12 gage steel, and the door to have a flush, stainless steel, cylinder tumbler-type lock with a catch and spring-loaded door pull, flush with the front panel.

E. Opening the door must permit access to all device handles but must not uncover any energized parts. Furnish the enclosure with an engraved nameplate with the manufacturer's name, model number, serial number, system electrical data, bus ampacity, and bus short circuit rating.

F. Include main and branch circuit molded-case circuit breakers having both inverse-time and instantaneous tripping characteristics, and ratings as indicated.

G. Use *UL* listed, thermal-magnetic molded-case circuit breakers of the same manufacturer as of the panelboard, with tripping characteristic in accordance with *UL 489*/*NEMA AB 1*. Use bolt-on type breakers with a permanent trip unit containing individual thermal and magnetic trip elements in each pole, calibrated for operation in an ambient temperature of 40 °C.

H. Furnish spaces for 42 circuits as indicated, with blank covers for all unused spaces, and a typewritten circuit directory placed in a clear plastic cover inside the panelboard door.

50. Heating. Furnish heating equipment in bridge areas as shown on plans. Under this item, furnish and install all conduits, wiring, boxes, in-sight disconnects, maintenance receptacles, and other equipment required to extend power to the electrical equipment and connect thereto. Also under this item, furnish and install the unit heater and all associated manufacturer recommended mounting hardware. Unit heaters must meet the following minimum specifications:

A. Stainless steel tubular elements.

B. Individually adjustable louvers.

C. Outlet mesh screen.

D. Automatic reset thermal cutout.

E. Wall or ceiling mounting bracket.

F. Built-in manual reset thermal cutout.

G. Built-in disconnect switch.

H. Built-in or remote room thermostat.

I. Built-in Heater On Pilot light.

Ensure heaters are by Chromalox, Dayton, Qmark, or Engineer approved equal.

51. Service Receptacles and Lighting. Receptacles are to be 20 A, 125 V, three-wire, ground-fault-indicating type, polarized, duplex, convenience outlets. Ensure each receptacle has a heat-resistant melamine body, is flush or surface mounted in an outlet box, and is provided with a waterproof cover plate. Receptacles are to be manufactured by Hubbell, Arrow Hart or Leviton.

All lights are to be controlled from tumbler switches as shown on the plans. Ensure all tumbler switches are specification grade, 20 A, 125 V switches. Mount switches in waterproof, cast-brass, surface mounted boxes. Mount switches 4 feet above the adjacent floor or platform. Switches are to be manufactured by Hubbell, Arrow Hart, Leviton or approved equal.

Ensure service lighting on the piers, track, rack levels and machinery rooms is as shown on the plans. The fixtures are to be located to illuminate all, walkways, and work areas, to the satisfaction of the Engineer. Use junction box type for wall mounting.

Ensure all mounting hardware is stainless steel. Ensure housing and optical unit is sealed with extruded silicone gasket; supply conductors with molded ethylene propylene diene terpolymer bushing. Locate the fixtures to illuminate all stairwells, walkways, and work areas, to the satisfaction of the Engineer. Fixture must have a two-stage surge protection feature and rated for universal voltage of 120-277 VAC. Furnish fixtures with either 28 or 48 LEDs as needed by the location and as shown on plans. Ensure fixtures are LSI Industries Greenbriar Wall Sconce (XGBWM3), Cooper Lighting WKP, Lithonia Lighting CSXW, or Engineer approved equal.

Supplemental service lighting in miscellaneous access areas will be LED vaporproof type with all die-cast aluminum construction. Furnish service light with high temperature silicone gasket. Ensure vapor proof luminaire is selected with the wall mounting option. Ensure LED lights are rated for a 100,000 hour lifespan. Ensure lights are furnished with globe and guards and are capable of operating in a -40 °C to 40 °C environment. Ensure driver is rated for universal voltage 100 V-277 V, with a minimum power factor of 97.9 percent. Ensure lights are rated for 27 W maximum. Locate the fixtures on the service platform and access walkways, to the satisfaction of the Engineer. Ensure fixtures are RAB VXBRLED26DG, or approved equal from Cooper Lighting, and Lithonia Lighting.

52. Heat Trace. Ensure heat tracing for the water service and sewer piping is 277V self-regulating rapid trace type SLR-C rated for 3 watts per foot as manufactured by Chromalox Industrial Heating Products, Trasor or Tyco. The system must consist of all the equipment detailed on the plans.

53. Sump Pump. Furnish and install a new sump pump in each pier pit. Ensure the pump system consists of but not be limited to; two submersible pump/motor assemblies, automatic liquid level control, a steel basin cover containing a pump access plate and a 3 inch compression discharge flange, an inspection opening, a level control switch plate and a 3 inch vent flange are to be installed onto the basin with gastight gasketing and all other necessary appurtenances required for a properly operating pumping system.

Ensure sump pump motor horsepower and gallons per minute (GPM), are rated as shown on plans. Ensure sump pump is manually operated from a local motor starter *NEMA 4X*, stainless steel enclosure with a START/STOP control mounted on the front cover. Each enclosure must contain one main disconnect switch with through the-door handle, one motor circuit protector, one magnetic starter with overload protection, two auxiliary contacts and low voltage release, one red pump running light, one electric alternator alarm horn with silence switch, and auxiliary switches and a numbered and wired terminal strip. Sump pump and control panel are to be by Dayton, Goulds Pump Company, Weil Pump Company or Engineer approved equal.

Size pump to fit in 24 inch diameter by 24 inch deep sumps. Make electrical connections using Leviton BX230-V INL&RCPT Back Box, Leviton 420R9W 3 pole, 4 wire, 20 A, 3 phase, 25 V receptacle and a 420P9W Leviton 3 phase, 4 wire, 20 A, 3 phase, 250 V plug, or equivalent items from Emerson, and Mennekes. Route discharge piping to the stormwater pipe on rear pier wall.

Furnish liquid level *NEMA 6P* float switches designed for controlling the pumping system and a tether design consisting of a single pole non-mercury float switches, each sealed in a corrosion resistant polypropylene float, corrosion resistant switch brackets for attaching switches to suspension rod, galvanized steel suspension rods, and a well mounted suspension plate. Ensure each switch is provided with a 30-foot long power cable. Systems utilizing a free handing float suspended from the float power cords by pipe clamps will not be acceptable. Ensure a switch is provided to enable the pumps. A second switch must indicate high water level, in the event the pump is to fail. The pump manufacturer is to furnish the entire unit switch mounting assembly. Float switches are to be Goulds Pump Company Pump Master Plus model A2E23 or approved equal by Dayton, Weil Pump Company.

Ensure discharge pipe is schedule 80 PVC pipe. Ensure the discharge pipe is a minimum size of 3 inches in diameter schedule 80 PVC pipe. Furnish flange type fittings. Furnish DI pipes and fittings at the sump pump. Furnish flange type fittings. Polyethylene tubing is to conform to the requirements of *AWWA C901* and *ASTM D2239*. The tubing is to be rated for 200 psi. Ensure sump discharge line is field routed to discharge to the storm water connection on the rear of the bascule piers. All piping is to be paid under this item.

54. Grounding. Ensure equipment ground conductors are seven-strand, soft-drawn, bare, tinned copper wire in accordance with *ASTM B33* and not smaller than #8 AWG.

Use exothermic welds to connect ground conductors to ground rods and ground bus bars. Ensure the resistance to ground is 5 ohms or less. Ensure exothermic welds are molded fusion, type as required, as manufactured by Cadweld, Thermoweld, Metalweld, or approved equal.

The utility service neutral conductor, the bridge grounding conductor and grounding electrode conductors must all be #4/0 AWG and exothermically welded together. Ensure the utility service neutral conductor is grounded in accordance with the utility company’s standard requirements.

Ensure grounding system terminals are solderless lugs and secured by means of hexagonal-head, copper plated, steel machine bolts with lock washers or lock nuts. Ensure ground system conductors are continuous unspliced connections between terminal lugs.

Ensure ground rods are made of copper or copper-clad steel and not be less than 1 inch in diameter and10-feet in length unless otherwise specified. A permanent, exothermic weld connection to the permanent steel sheet piling at the bridge piers is an acceptable grounding means at the indicated locations. If the steel sheet piling is not accessible, ensure ground rods are used as grounding electrodes. Use insulated green ground conductor when exposed to wet environment.

55. Voltage and Arc Flash Warning Labels. Furnish warning labels to identify the equipment or panel operating voltage and arc flash warnings. Furnish the arc flash warning in accordance with *NEC 110.16*, *National Fire Protection Association (NFPA) 70E* and the *Institute for Electrical and Electronic Engineers (IEEE) 1584*. Print the approved labels on weather resistant vinyl labels and installed on the equipment.

56. Selective Coordination Study. Submit to the Engineer for review and approval the completed Selective Coordination Study based on actual field components, meeting the requirements found in this special provision, in addition the Contractor must submit:

A. Product data on the software program to be used for the study. Ensure software is in mainstream use in the industry, provides device settings and ratings, and shows selective coordination by time-current drawings.

After approval of the selective coordination settings and study, certification of setting all overcurrent protective devices to the required values.

57. Spare Parts. Supply spare parts in accordance with *AASHTO* requirements and the contract plans. The spare parts supplied for each bridge must include, but not be limited to, the following:

A. Six fuses of each kind and size installed.

B. Two switches of each type provided, and six contact blocks for each type of switch.

C. Four limit switch or proximity switch of each type specified. In addition, a full set of contacts and contacts fingers for each type of limit switch.

D. A set of contacts and contact fingers for each unit or fractional unit of five or less of each kind or size installed, including contactors and starters. For units that do not incorporate replaceable contacts, furnish a complete unit with coil.

E. One coil for every five or less of each size relay, contactor, and motor starter installed.

F. One complete relay timer, time delay relay, contactor, and starter for each unit or fractional unit of five or less of each kind and size installed.

G. Two heaters for overload relays of each size installed.

H. For the machinery brakes:

(1) One spare thrustor complete with heater and motor.

(2) One limit switch for hand-release mechanism.

(3) One limit switch - brake released.

(4) One limit switch - brake set.

I. For tail locks:

(1) One spare motor.

(2) Two limit switches.

J. For the navigation lights:

(1) One each color and type lens.

(2) Two each color and type LED lamp.

(3) Six lens gaskets.

K. For the PLC system:

(1) One each of every type PLC input card and PLC output card.

(2) In addition, a quantity of 4 discrete input cards and 4 relay contact output cards.

(3) One PLC chassis power supply module.

L. One spare drive with all appurtenances.

M. One traffic gate motor, complete with motor pinion.

N. One traffic gate rotary cam limit switch with operating mechanism.

O. Two access door limit switch.

P. Six arm light fixtures complete with lamps.

Q. Six lamps for arm lights.

R. One traffic gate arm.

S. One flasher unit.

T. One digital display.

U. One HMI.

Arrange the spare parts in uniform size cartons of substantial construction, with typed and clearly varnished labels to indicate their contents and store them in a location as directed by the Engineer. Furnish large spare parts with moisture-proof wrapping. Furnish a directory of permanent type, describing the parts. In the directory state the name of each part, the manufacturer's number thereof, and the rating of the device for which the part is a spare. Mark the spare parts to correspond with their respective item numbers as shown on the elementary wiring diagram.

**c. C****onstruction.**

1. General. Document all as found conditions prior to installation of any wiring and or equipment shown and described in the contract. If the as found conditions conflict with the contract notify the Engineer for review and approval. Submit the conflict in writing describing the conflict and including any backup drawings or sketches to explain the conflict.

Ensure the control system and its installation are in accordance with regulations of the *NEC*, all applicable local codes, and in accordance with *AASHTO LRFD Movable Highway Bridge Design Specifications, 2nd Edition*, except as otherwise provided herein.

Ensure all construction and installation is done by workmen skilled in this type of work and under the supervision of an experienced and qualified electrical supervisor. In addition, the approved control system vendor must provide supervisory assistance to the electrical contractor as specified herein. Ensure all work is executed in a neat and workman-like manner and presents a neat mechanical appearance when completed. Upon completion of the contract, the Contractor must deliver to the Engineer a corrected plan showing in detail all changes on construction from the original plans, especially locations and sizes of conduits, complete schematic circuit diagrams and the like.

Furnish written certification of compliance with specified requirements for his control system vendor. Include this certification with the bid documents and it is subject to approval by the Department.

Retain the services of a qualified control system vendor who will have complete system responsibility for the detailed integration of all system components, in order to ensure a complete operating system is furnished and installed in accordance with specified requirements of this project. The control system vendor is responsible for ensuring total compatibility of all equipment and devices furnished and installed and must provide supervisory assistance in the selection, installation, and integration of all bridge associated control equipment. Components associated with bridge span drive operations include but will not be limited to span drive control, limit switches, motor controls, control console, control cabinets and associated devices. The control system vendor must comply with all items listed herein.

The Contractor is responsible for coordinating all aspects of equipment installation including matters of construction staging and methods of bringing equipment into the spaces where it is to be installed.

Each piece of electrical equipment and apparatus must have a permanent type of corrosion-resisting metal nameplate on which is stamped the name of the manufacturer, the catalog or model number, and the rating or capacity of the equipment or apparatus.

Ensure all electrical devices, printed circuit boards, including their components, and any other electrical or electronic parts, are identified in such a way as to be easily procured from a supplier of that device. All prints and drawings of it must show complete circuitry and identify all components as to their specific use and function in the circuit.

Ensure all ferrous metal work is hot-dip galvanized in accordance with *ASTM A123/A123M* or *ASTM A153/A153M*, whichever is applicable. If any galvanizing is damaged, ensure the metal work is refinished by cleaning and painting, with two coats of approved galvanizing repair paint, or approved zinc spelter paint.

Furnish lock washers on all mechanical fastenings. In order to prevent deterioration due to corrosion, ensure all bolts, nuts, studs, washers, pins, terminals, springs, hangers, cap screws, set screws, tap bolts, brackets, and other hardware fastenings and fittings are of an approved corrosion-resisting material such as silicon bronze, or stainless steel. Hot-dip galvanizing, per *ASTM A153/A153M*, is considered approved treatment for all non-moving ferrous hardware.

Reference to a particular product by manufacturer, trade name, or catalog number establishes the quality standards of material and equipment required for this installation and is not intended to exclude products equal in quality and similar in design.

Ensure equipment for which an acceptable manufacturer is not specifically named, or named equipment for which substitution is proposed, is manufactured by a company which has had a minimum of 10 years of experience in the manufacture of similar equipment and which, in the Department's opinion, has demonstrated its proficiency in the manufacture of such equipment. All equipment is subject to the Department's approval.

2. Bridge Electric Service. Contractor is responsible for coordinating with the utility for the provision and installation of service entrance and metering equipment, and all associated service applications, permitting, and fees. Utility service grounding is to be as per the recommendations of the utility.

3. Bridge Power System Distribution. Ensure the feeders from the utility power source are connected to a power distribution bus in the MCC through surge suppressors, main circuit breakers and an automatic transfer switch.

In the event of failure of the utility source, the automatic transfer switch will operate automatically to connect the generator to the power distribution bus.

The main 480 V subfeed circuit breakers will distribute power from the MCC to all motors and controls for operation of the bridge, auxiliaries, climate control systems, and lighting systems. The bridge power selector switch position on the control desk determines the actual source for the automatic transfer switch.

The Contractor must arrange for and provide all the necessary field tests prescribed by the manufacturer, as directed by the Engineer, to demonstrate that the entire engine-generator installation is in proper working order and in accordance with the plans and special provisions.

During the testing period, the Contractor must arrange to have at the site a representative of the manufacturer of the engine-generator. Ensure this representative is a service engineer experienced in the installation of generator sets, and is capable of making adjustments to the equipment; of locating faults or defects and correcting them, if possible; and of obtaining from the manufacturer, without delay, new parts or replacements for apparatus which does not perform satisfactorily.

Field-testing will also include complete operating tests to show that the engine-generator, automatic transfer switch and all components operate satisfactorily to sustain the loads imposed during operation of the span and its auxiliaries. Ensure all alarms and safety shutdown devices are tested for proper operation and annunciation.

Perform at least three complete bridge opening/closing sequences with the generator supplying electric power to the span drives and motors, and auxiliary equipment.

Automatic start-up by means of simulated power outage to test remote-automatic starting, transfer of the load, and automatic shutdown must also be performed. Prior to this test, ensure all transfer switch timers are adjusted for proper system coordination. Ensure engine coolant temperature, oil pressure, and battery charge level along with generator voltage, amperes, and frequency are monitored throughout the test. Perform the tests with both the external load bank and the bridge load for a minimum of three additional openings.

Should the tests show that the engine-generator or any component piece of equipment or apparatus, in the judgment of the Engineer, is defective or functions improperly, ensure such adjustments and/or replacements are made by the Contractor as to make the installation satisfactory to the Engineer and at no additional cost.

4. Span Drive Motors. Ensure the motor and brake frame and strip heaters are fed from a branch circuit on a lighting panelboard. Furnish all conduit, boxes, conductors, and other equipment necessary to extend power to the heaters.

Ensure each motor is connected to the turning machinery by a flexible coupling furnished with the turning machinery. Ensure the motor half of each coupling is pressed on the motor keyed shaft at the plant of the manufacturer of the motors.

Install each span motor with approved sizes and types of wire terminals and splice fittings for the connection of the motors to the circuit wiring. Furnish each motor with conduit boxes. Ensure connections between the rigid conduit system and the motors are made with the flexible conduit sections not exceeding six feet in length.

5. Brakes. Equip each brake with a hand release, which must not change the torque setting or require removable levers or wrenches. Locate the hand release mechanism on the side of the brake away from the main reducer (right hand and left-hand units are required). Furnish each hand release with a lever type limit switch for interlocking purposes. Ensure it is not possible to set the hand release of the brakes without tripping these switches.

In addition to the hand release limit switch, ensure two lever type limit switches, are mounted on each brake. One must indicate that the brake is fully set, the other that the brake is fully released. The brake released limit switch (which must have two N.O. contacts) must trip when the brake is electrically released, or hand released. The brake set limit switch must have one N.O. and one N.C. contact and must trip when the brake is fully set.

Set the down-stroke time delays of the thrustors in such a manner that the brakes cannot be applied simultaneously should electric power fail while the span is in motion. Adjust the intervals between the brakes setting to obtain smooth stopping of the span in the shortest possible time.

6. Control System.

A. The control system vendor is responsible to generate a complete relay-logic operating system and develop the PLC program and alarm messages using:

(1) The Software Programming, Sequence of Operation, other PLC Functions, and Alarm sections provided in this section.

(2) All logic and wiring shown on the plans.

(3) Testing requirements.

The control system vendor must furnish a laptop computer, interconnection cables, power supplies, software, HMI programming, and PLC programming to accomplish the specified monitoring of the bridge and its auxiliaries. Ensure software for the PLC, HMI, drives, and laptop computer are loaded and coordinated by the Contractor to achieve the correct operation of all software.

B. The control system vendor is responsible for developing the PLC, and HMI software to accomplish the specified monitoring of the bridge and its associated equipment. The Contractor must assume software debugging must occur in the shop as well as in the field during start-up and subsequent testing. No additional payment will be made for software debugging due to logic changes made in the field.

Ensure the PLC program is in accordance with the following items:

(1) Ensure the ladder logic is easy to understand and troubleshoot.

(2) Ensure the ladder logic is fully documented, including rung comments and address comments, for each rung in the ladder logic.

C. Ensure the ladder logic is written with regards to the operational sequence of the bridge, containing separate sections for each of the major equipment areas such as gates, center locks, etc. with interlocks.

The ladder logic must not utilize or contain the following flaws:

(1) Latched coils. Ensure PLC logic is based upon real world conditions and reset when required. When the PLC loses power, and then power is returned, the PLC must determine the position of the leaves and other electrical equipment, but not expect the bridge to be in the exact same position. If any equipment was operated manually, the PLC program will determine the new position of the equipment and operate normally including encoder/resolver positioning system.

(2) Unnecessary internal coils. Ensure PLC logic is as simplified as possible and not use multiple relays for a single function. The intent of this is to make the program easy to troubleshoot and understand.

(3) Improper bypass logic. When bypass switches are utilized, the bypass must bypass only the required interlocks. The intent of this item is to provide programming that will utilize the bypasses and only bypasses the correct interlock but does not remain active in the logic or bypass other interlocks in the program.

(4) Problems transferring between automatic and manual modes of operation. PLC logic must allow simple transfer from automatic and manual modes without generating unnecessary alarms for causing failures in the program. The intent of this item is to provide programming that transfers between manual and automatic mode without problems or inaccurate alarms.

Document all timer settings in the program. Adjust to match the selected equipment and adjusted during shop and field testing for proper operation.

Add alarm messages and associated alarm ladder logic as required.

Submit a documented and cross-referenced copy of the new PLC program for review and approval.

Ensure the HMI alarm panel is programmed to timestamp, print, and store each PLC alarm. Store the alarms in chronological order so the operator can scroll through the alarm screen to review alarms. Store the alarms in the Panel View and be identified by a numerical identifier. When the PLC processor transmits the alarm bit to the Panel View, the HMI must display the alarms, print the alarms, and store the alarms in an alarm history screen.

(5) PLC Installation. Mount magnetic components (contactors, relays, and other electro-mechanical components) near the top or bottom of the enclosure in an area segregated from the PLC components. Place barriers with at least 6-inch separation between the magnetic area and the PLC.

Use thermostatically controlled blowers for cooling the components inside any enclosure containing PLC equipment and placed in a location not close to the heat-generating device.

D. Ensure that that the programming provides for three modes of operation as follows:

(1) Automatic Mode. Under this mode the operator will operate the complete bridge and associated equipment from the control desk under complete PLC control.

(2) Manual Mode. Under this mode, the bridge is operated from the control desk located in the control room. This mode of operation has the following features:

(a) Operated by a competent person, trained in the operation of the bridge.

(b) Other competent and trained personnel (e.g. maintenance staff) may be required to assist the Operator with bridge operations.

(c) Each sequence of bridge operation is controlled by a separate push button laid out in a logical manner on the control desk simulating the correct order of operation.

(d) Protective interlocks are still active.

(e) Bypasses are allowed.

(3) Maintenance Mode. Under this mode, the bridge is operated from the control desk located in the control room. This mode of operation has the following features:

(a) Operated only by a competent person, trained in the operation of the bridge in manual/maintenance mode. Switching to this control requires additional authorizations.

(b) Other competent and trained personnel (e.g. maintenance staff) may be required to assist the Operator with bridge operations.

(c) Each sequence of bridge operation is controlled by a separate push button laid out in a logical manner on the control desk simulating the correct order of operation.

(d) Protective interlocks are not active and do not therefore enforce the correct sequence of operation.

7. Sequence of Operation. The following is a general sequence of operation based on the general requirements of *AASHTO*. During the shop drawing submittal process the operating sequence will be further refined with input from the Engineer and the Department.

A. Turn bridge control power on. PLC enables desk controls. Turn bridge signals from green, through yellow, to red. PLC energizes the traffic gate flashers and gongs.

B. Lower the oncoming followed by the off going traffic gates. Once the gates are fully lowered, the gongs will de-energize. If there is a circuit breaker fault, an overload, or a manual operation interlock fault, the operations will stop, and an alarm sent to the HMI. If a gate takes longer than 30 seconds to lower, the operation will stop, and an alarm will be sent to the HMI. If an oncoming traffic gate is lowered but the proper indications are not given, the traffic gate lowered bypass will allow the offgoing traffic gates to lower and alarm will be sent to the HMI. The traffic gate lowered bypass will permit the operation to continue. The operation of the bypass switch will cause an alarm to be sent to the HMI.

C. Confirm that all gates are lowered and pull the tail locks. If there is a circuit breaker fault, an overload, or a manual operation interlock fault, the operations will stop, and an alarm sent to the HMI. If a tail lock takes longer than 30 seconds to pull, the operation will stop, and an alarm will be sent to the HMI. The tail locks pulled bypass will permit the operation to continue. The operation of the bypass switch will cause an alarm to be sent to the HMI.

D. If there is a static drive fault, or a circuit breaker is not closed, the operation will stop, and an alarm will be sent to the HMI. If any brake is hand released, the operation will not continue, and an alarm will be sent to the HMI.

(1) Span Raising.

(a) Initiate span raise by momentarily turning the span control selector switch to raise. Normal operation requires that both main motors on each span are active and load sharing. The bridge heating loads will be disabled for a minimum of 10 seconds. Following the time delay, the drives will enable. The drives will smoothly ramp to 5 percent speed at 100 percent torque with the brakes still set. The system will verify that the motor shafts are not turning. If the motor shafts turn, the operation will stop, and an alarm will be sent to the HMI. If the shafts are not turning, the brakes will release, and the drives will ramp the motors to 100 percent speed. If after 3 seconds the brakes do not release, the operation will cease, and an alarm will be sent to the HMI. At any time, the operator can press the stop button to stop the span and the drives will ramp down and the brakes will be deenergized after 5 seconds.

(b) Once the span reaches the nearly open position (52.7 degrees) the drives will ramp down to and remain at 5 percent speed until the span reaches fully open (56 degrees). The drive output torque will be limited to 80 percent, the brakes will set and then the drives will shut down. An independent electronic speed switch and encoder combination will verify deceleration, and will emergency stop the span if deceleration does not occur at the nearly open position. Should deceleration failure occur, an alarm will be sent to the HMI. If the time to raise the span exceeds 90 seconds, to be field determined, the operation will stop, and an alarm will be sent to the HMI. If the overtravel proximity sensor (56.5 degrees) is triggered, the PLC will emergency stop the span. At any time, the operator can press the stop button to stop the span and the drives will ramp down and the brakes will be deenergized after 5 seconds.

(c) The span navigation lights will change from red to green based on the input from the fully open limit switch.

(d) Allow navigation traffic to clear.

(2) Span Lowering.

(a) Initiate span lower by momentarily turning the span control selector switch to lower. The span navigation lights will change from green to red based on the input from the fully open proximity sensor. The drives will smoothly ramp to 5 percent speed at 100 percent torque with the brakes still set. The system will verify that the motor shafts are not turning. If the motor shafts turn the operation will stop and an alarm will be sent to the HMI. If the shafts are not turning, the brakes will release, and the drives will ramp the motors to 100 percent speed. If after 3 seconds the brakes do not release, the operation will cease and an alarm will be sent to the HMI. At any time, the operator can press the stop button to stop the span and the drives will ramp down and the brakes will be deenergized after 5 seconds.

(b) To mate the span locks, the east leaf with the diaphragm will run slightly ahead of the west leaf, the jaw, by approximately 5 seconds (subject to change during testing) and decelerate normally to a stop at 1 degrees of opening. The east leaf running slightly behind will do the same but will reduce the torque at 12 degrees to 80 percent until contact is made. Contact will be confirmed by checking span positions and verifying that motion has stopped. Once it is confirmed by span positions that the span locks are engaged, the east leaf will be lowered at 10 percent speed while the west leaf follows with the torque limited to 80 percent. Torque on the east leaf will be monitored during the lowering sequence to make sure torque does not get too high. If high torque is sensed, then the torque setting on the west leaf can be reduced to provide less force pushing down on the diaphragm. When the fully seated limit switch is sensed, the bridge will decelerate to a stop. The drive setpoints on both leaves will be reduced to 80 percent torque and held while the brakes are set. The drives will shut down. An independent electronic speed switch and rotary cam check combination will verify deceleration, and will emergency stop the span if deceleration does not occur before or after mating. Should deceleration failure occur, an alarm will be sent to the HMI. If the time to close the span exceeds 90 seconds, to be field verified, the operation will stop and an alarm will be sent to the HMI. At any time, the operator can press the stop button to stop the span and the drives will ramp down and the brakes will be deenergized after 5 seconds.

(c) Drive the tail locks. If the span is fully closed but the limit switches fail to provide proper indication, the span fully closed bypass switch will be used to allow the tail locks to drive, and an alarm will be sent to the HMI. If there is a circuit breaker fault, an overload, or a manual operation interlock fault, the operations will stop, and an alarm sent to the HMI. If a tail lock takes longer than 30 seconds to drive, the operation will stop, and an alarm will be sent to the HMI. If the tail lock driven limit switches fail to register, the tail lock driven bypass switch will allow the operation to continue and an alarm will be sent to the HMI.

(d) PLC energizes the traffic gate gongs. Operator will choose between raising the gates manually (go to subsection c.7.D.(3).(a)) or raising them via the group raise (go to subsection c.7.D.(4).(a)).

(3) Manually raise traffic gates.

(a) Raise the offgoing and then oncoming traffic gates. If an offgoing gate traffic gates is raised but the proper indications are not given, the traffic gate raised bypass will allow the oncoming traffic gates to raise and alarm will be sent to the HMI. If there is a circuit breaker fault, an overload, or a manual operation interlock fault, the operations will stop, and an alarm sent to the HMI. If a gate takes longer than 30 seconds to raise the operation will stop and an alarm will be sent to the HMI. PLC de-energizes both the traffic gate flashers and gongs.

(4) Automatically raise traffic gates via group raise.

(a) Automatically raise the traffic gates by pressing the group raise button. Offgoing traffic gates will raise first, followed by oncoming traffic gates. If an offgoing traffic gates is raised but the proper indications are not given, the traffic gate raised bypass will allow the oncoming traffic gates to raise and alarm will be sent to the HMI. If there is a circuit breaker fault, an overload, or a manual operation interlock fault, the operations will stop, and an alarm sent to the HMI. If a gate takes longer than 30 seconds to raise the operation will stop and an alarm will be sent to the HMI. PLC de-energizes both the traffic gate flashers and gongs.

(5) Preparing the bridge for roadway traffic.

(a) Turn bridge signals to green. Turn bridge control power off. PLC disables desk controls.

(b) In general, any circuit breaker trip, any overload trip, any drive fault, any bypass, any overtime fault, or any manual operation interlock fault will send a fault to the HMI which will display a message unique to that fault. The vendor will submit a complete list of proposed fault messages for review and comment and additional messages will be added as required. These messages will be recorded in order with the time and date of the fault. Many operations can be bypassed; only one bypass can be enabled at any time, if more than one is enabled, the operation will stop.

8. HMI. General programing and operating requirements for each HMI touchscreen display screen is specified below. Each display screen must consist of multiple selectable screens which are also noted below that are activated via the touchscreen. The Contractor must adjust and add to the HMI screen program as directed by the Engineer and MDOT during HMI and network testing as specified herein. The following is a list of the minimum screens required:

A. Maintenance Operation Screen.

(1) Includes general layout of indicators to mimic the layout of the hardwired switches on the control desk unless otherwise specified.

(2) Each device on the bridge will have an individual button or switch represented pictorially which when selected will operate the device as specified.

(3) Time and date stamp.

(4) Angle of opening display.

(5) Active alarm message display.

(6) Selection tabs of alternate screens.

(7) Time of traffic stopped display.

B. Main Display Screen (Default Screen).

(1) Includes general image of the bridge including pictorial image of gates, locks, signals, brakes, etc. and their status (green for open to traffic, red for closed to traffic).

(2) Time and date stamp.

(3) Angle of opening display.

(4) Active alarm message display.

(5) Selection tabs of alternate screens.

(6) Time of traffic stopped display.

C. Traffic and Gates Screen.

(1) Includes general traffic gates and signals and their status (green for open to traffic, red for closed to traffic).

(2) Time and date stamp.

(3) Angle of opening display.

(4) Active alarm message display.

(5) Selection tabs of alternate screens.

(6) Time of traffic stopped display.

(7) Operational status of each gate when selected including limit switch contact set point and status (open or closed) and activate alarms.

D. Locks Screen.

(1) Includes general image tail locks and their status (green for open to traffic, red for closed to traffic).

(2) Time and date stamp.

(3) Angle of opening display.

(4) Active alarm message display.

(5) Selection tabs of alternate screens.

(6) Time of traffic stopped display.

(7) Operational status of each lock when selected including limit switch contact set point and status (open or closed) and activate alarms.

E. Span and Brakes Screen.

(1) Includes general image span operating machinery and their status (green for open to traffic, red for closed to traffic).

(2) Time and date stamp.

(3) Angle of opening display.

(4) Active alarm message display.

(5) Selection tabs of alternate screens.

(6) Time of traffic stopped display.

(7) Operational status of each set of span motors when selected including voltage, current, limit switch status (open or closed) and activate alarms.

(8) Operational status of each drive when selected including speed, command, voltage, current, limit switch status (open or closed), angle of opening, etc.

F. Alarm Screen.

(1) Active alarm page with last 12 alarms with date and time stamps and active or inactive status.

(2) Acknowledge alarm button,

(3) Silence alarm button.

(4) Alarm history pages with date and time stamps.

G. Power Screen.

(1) Includes status of incoming service, generator and ATS.

(2) Includes voltage and current values for each phase on the incoming service.

(3) Time and date stamp.

(4) Angle of opening display.

(5) Active alarm message display.

H. Maintenance Screen.

(1) Directions screen when selected.

(2) System network.

(3) Password protected bypass operation for manual operation and testing.

(4) Status screens of all PLC input and output devices with PLC address and device designation.

I. Alarms. The PLC program must generate alarms when they occur. Ensure the alarm is sent once to the HMI and not again until the next time the alarm condition occurs. The HMI must provide an audible tone with each alarm message until the HMI acknowledge button is pressed.

Ensure all the standard PLC processor and equipment fault conditions and alarms, furnished as part of the PLC equipment, generate an alarm.

Ensure all the standard communications equipment fault alarms and conditions, furnished as part of the communications equipment, will generate an alarm.

Be prepared to add an additional 250 alarms during the Factory Testing and another 250 during Start Up and Commissioning as directed by the Engineer.

The following is a list of the minimum alarms required. Some of the alarm descriptions are typical, provide a dedicated alarm for each piece of equipment.

(1) PLC communication fault to Remote I/O Rack in west control cabinet.

(2) PLC communication fault to Remote I/O Rack in east control cabinet.

(3) PLC processor fault.

(4) Rack fault in the Remote I/O Rack in west control cabinet.

(5) Rack fault in the Remote I/O Rack in east control cabinet.

(6) Power fault alarm.

(7) Any circuit breaker in MCC tripped.

(8) Any motor overload tripped.

(9) Check lost input control power for each circuit breaker for all PLC panels.

(10) Control power has been turned off.

(11) Emergency stop pushbutton was de-pressed.

(12) Any emergency stop control relay operated when the emergency stop pushbutton was not depressed.

(13) Any emergency stop control relay did not operate when the emergency stop pushbutton was depressed.

(14) Any warning gate did not lower after 30 seconds.

(15) Any tail lock did not withdraw after 30 seconds.

(16) Any warning gate did not raise after 30 seconds.

(17) Any warning gate door open or hand crank operation.

(18) Any tail lock did not drive after 30 seconds.

(19) Tail lock motor manual operation.

(20) Drive did not start running after 30 seconds.

(21) Any brake hand released.

(22) Any brake released improperly.

(23) Any brake set improperly.

(24) Auxiliary system operation.

(25) Drive has a trouble alarm.

(26) Drive is not ready.

(27) Drive or any motor is disconnected at the local motor disconnect switch.

(28) Position transmitter failure.

(29) Any brake failed to release while operating span.

(30) Position transmitter is not in synch with rotary limit switch.

(31) Span deceleration check during span operation failed.

(32) Any bypass was activated.

(33) PLC communication fault.

(34) Generator on.

(35) ATS not in auto.

(36) ATS failure.

(37) Generator failure/alarm.

(38) Generator low fuel.

(39) Generator low battery.

9. Limit Switches.

A. Span Position Rotary Cam Limit Switches. Furnish and install a total of two, 12-circuit rotary limit switches where shown on the plans.

B. Lever Type Limit Switches.

(1) Interlock Limit Switches. Furnish and install limit switches at each machinery brake and motor brake to provide the control system with sequence interlocking and indication as specified herein. Ensure the installation and adjustment of each switch circuit controller is done in accordance with the manufacturer’s service specifications. Determine the proper direction of rotation of each switch and advise the manufacturer accordingly.

C. Lever-less Limit Switches.

(1) Fully Closed Limit Switches. Furnish one lever-less type limit switch and installed at each corner of the spans where shown on the plans. Install targets at the east and west abutments, as shown on the plans.

10. Position Resolver. Mount two absolute position resolvers in the rotary cam limit switch housing. The resolvers must produce a signal transmitted via analog signals to the corresponding PLC equipment to indicate absolute movable span angular position and drive controls.

11. Transformers. Install transformers as indicated in accordance with:

A. Manufacturer's written instructions.

B. Applicable requirements of *NEC* standards.

C. *NECA 409-2015, (ANSI)*.

D. Recognized industry practices to ensure that products fulfill requirements.

Tighten connectors and terminals including screws and bolts, in accordance with equipment manufacturer's published torque tightening values for equipment connectors. Where manufacturer's tensioning requirements are not given, tighten connectors and terminals to comply with tightening torques specified in *UL Standard 486A*.

Fasten enclosure firmly to the floor and structural surfaces, ensuring that they are permanently and mechanically anchored.

Furnasih equipment grounding connections for the transformer as indicated in the contract.

12. Bridge Control Console. Furnish and install a bridge control console in the Control House. Mount on the console all devices for controlling operation of the movable span, and its auxiliaries.

Mount indicating lights on the control console to show that the various steps in the sequence of operation have taken place so that the operator may proceed to subsequent steps at the proper time. Ensure the functions to be indicated and the color of the lenses are as shown on the plans.

Take care throughout the construction to ensure that the stainless-steel console tops and the equipment mounted thereon are always protected from damage or defacement.

Both the inclined panel and the bridge main control console top are hinged where they meet, so they can be lifted (singly) for easy access to the components mounted through the console top and inclined panel. Furnish handles on the inclined panel and console top for ease in opening them. Hold the inclined panel door open with cable stops. Hold the console top open at approximately 60 degrees with leg braces on each side of the door.

Ensure the console interior is suitably lighted and controlled by a switch mounted near the front doors. Mount one duplex receptacle in the console's interior and two duplex receptacles on the console's exterior (one on each side).

Mount all contact blocks for control switches, pushbuttons, and other control devices within the body of the console. The operators for these devices must protrude through the console top. Mount the indicating lights for each operation adjacent to the control device governing that operation.

Ensure the wiring within the control console is insulated switchboard wire in accordance with the requirements herein specified for wiring on the control panels. Ensure the wiring is arranged systematically so that all circuits can be readily traced. Ensure all conductors are terminated on easily accessible terminal blocks mounted inside the console at the rear, with crimped fork connectors. Identify wiring at equipment terminals by marking the adjacent area with brightly painted numbers to correspond to conductor designations appearing on the wiring diagrams.

Ensure the bottom of the console is open type construction. Frame the opening with standard size struts arranged to facilitate the clamping of cables or conduits.

13. Bridge Control Cabinets. For each assembled control cabinet, ensure all outgoing wire, #8 AWG or smaller, is connected to terminal blocks installed at the sides of the cabinet with locking fork crimped connectors. For each assembled control cabinet, ensure all internal wire, #8 AWG or smaller, is terminated with fork crimped connectors. The control cabinets must also provide sufficient extra terminals to allow connection of all wires coming from limit switches and other devices that go on to the bridge control console and other locations as required, even though these wires do not connect to apparatus on the control panels. Ensure spare terminals totaling at least 10 percent of those actually used are provided. Ensure each terminal is identified per wire number shown on the schematic wiring diagrams.

Ensure all panel wiring is arranged systematically so that circuits can be readily traced. Install the wiring in a network of troughs consisting of horizontal and vertical sections securely bolted to the panels. After installation of the wiring, ensure an insulated, flanged cover is snapped over the open side of each trough section.

14. Wiring. Use insulated wires and cables with stranded copper conductors for the installation. Do not use solid and/or aluminum conductors. Use conductors with green colored insulation only for grounding conductors. The re-identification of conductors with green colored insulation, such as with colored tape, is prohibited. Unless otherwise indicated in the contract, use Type XHHW-2 conductors for general wiring. Use wires rated 90 °C as indicated.

Supply a dedicated neutral conductor for all branch and feeder circuits requiring a neutral. Ensure a dedicated neutral conductor is not shared by phase conductors of other circuits.

Furnish equipment grounding conductors in all conduit and cable runs. Size equipment grounding conductors equal to the largest circuit conductor in the conduit or cable. Coordinate all wire and cable requirements with manufacturers of the equipment served.

Handle and install wires and cables with care to avoid damage to conductors, insulation, jackets, armor, etc. Replace any wire or cable which is found to be damaged. All costs associated with this work will be borne by the Contractor.

Permanently label all conductors, cables, and terminal blocks at every terminal or connection, splice, and tap. Assign each conductor or cable with one identifying number (including spares) throughout the entire electrical or control system. Coordinate identification numbers for consistency and accuracy with conductor numbers on the Contractor's approved wiring diagrams and shop drawings, field wiring diagrams, and any other diagrams containing the same respective conductor or cable.

Label all conductors with machine printed sleeve-type labels. Use water and smudge resistant text. Coordinate label text with shop drawings and wiring diagrams. Handwritten labels are not acceptable.

15. Conduit and Cable. Unless specifically indicated otherwise, install connections of conduit and cable entrances only in the bottom of cabinets and enclosures which are located outdoors and in damp locations.

Maintain at least a 4-inch separation between power wiring and communication and/or instrumentation cables.

Furnish insulated throat bonding bushings or bonding nuts where conduits or metal armored cables enter metal boxes or enclosures. Properly bond/ground conduit to the bonding/grounding hub. Connect bonding bushings and bonding nuts to the equipment grounding conductor included in the conduit or cable.

Install metal conduit and tubing in accordance with the *Steel Tube Institute of North America's Guidelines* for Installing Steel Conduit/Tubing.

Make bends in rigid conduit with tools which are specifically designed for bending the type and size of conduit in question. When bending conduit maintain proper internal diameter and wall thickness.

Do not make more than three quarter bends, equivalent to 270 degrees, in one conduit run between pull points such as conduit bodies, junction/pull boxes, terminal cabinets, and enclosures.

Make field cuts square to conduit and ream conduit ends to remove burrs. Field cut threads must have same length, dimensions, and taper as factory-cut threads. Clean field cut threads with an appropriate degreasing solvent after cutting and coat with a touch-up compound as recommended by the conduit manufacturer and a urethane topcoat. Similarly treat any area on the interior of the conduit which has been disturbed by reaming.

Install PVC coated rigid metal conduit using tools and methods which will not cause damage to the PVC coating, and in accordance with installation instructions provided by the conduit manufacturer. Coat any area on the exterior of the conduit which has been damaged during installation with an exterior patching compound as recommended by the conduit manufacturer.

Remove and replace any metal conduit with damage to the coating that exposes the metal at no additional cost to the Department. Repair, by replacing the entire section of conduit, any defect (nick, scar, cut, tear, abrasion, etc.) to the PVC coating of PVC coated rigid metal conduit that is 3 inches or more in length. Repair any defect to the PVC coating which is less than 3 inches long with an appropriate repair compound as recommended by the conduit manufacturer and approved by the Engineer. However, the Engineer may, at his discretion, alternatively require that defects 3 inches long or less be repaired by replacing the entire section of conduit. Any costs associated with required replacement of conduits due to damaged coating, including if such replacement requires the removal and re-installation of conductors will be borne by the Contractor. Submit proposed conduit repair details for approval.

Use flexible conduits in accordance with the following conditions:

A. In lengths not to exceed 18 inches for final connection to motors and similar equipment subject to vibration.

B. Where flexibility is required, lengths must not exceed 18 inches, unless explicitly indicated otherwise or with the special permission of the Engineer. Do not use flexible conduit in lieu of bends in rigid conduit, except as may be allowed by the Engineer by special permission.

16. Wire and Cable Pulling. Thoroughly swab raceway system before installing conductors. Use pulling lubricant to facilitate installation of wire and/or cable in conduits. Ensure lubricant is NRTL listed, environmentally friendly, Teflon based lubricant which is safe for use with all cable types and does not harden in conduit.

Replace conductors and cables, which are damaged during shipping, handling, storage or during the installation, or due to high pulling tension during the installation as revealed during any inspection or tests, as required, or as directed by the Engineer to his satisfaction. Such replacement will not be considered cause for delay or additional payment.

17. Conduit and Cable Supports. Support rigid conduits near each elbow and within 18 inches of each box, enclosure, conduit body, or similar termination, and at regular intervals not to exceed 6 feet.

Support flexible conduits near each elbow and within 12 inches of each box, enclosure, conduit body, or similar termination, and at regular intervals not to exceed 3 feet, except where flexibility is required.

18. Conduit Penetrations. Perform conduit penetrations through walls, floors, and ceilings as necessary for the installation of conduits. Following the installation, restore floors, walls, and ceilings with materials equal to the original construction and finish to match surrounding surfaces. Materials used are subject to the approval of the Engineer for appropriateness. Repair conduit penetrations, for penetrations in concrete use non-shrink grout, and seal with silicone caulk as necessary. The Engineer will advise the Contractor regarding the method to be used at each penetration location.

19. Low Voltage Splices, Terminals, and Terminal Blocks. Splice and tap conductors only in equipment enclosures, cabinets, or junction boxes, and on terminal blocks or with insulated compression crimping-type connectors or as described herein. Do not terminate more than two conductors per terminal block. Make splices and taps at equipment or in locations which do not permit the use of terminal blocks with crimp or mechanical type connectors with the Engineer’s permission.

After the installation, insulate all splices made with a manufactured insulating cover specifically designed for use with the connector. The Engineer may require the use of special splices or splice kits to address specific application considerations.

For splices without integral insulating sleeves, tightly apply a minimum of one half-lapped layer of rubber tape, tacky side up, over entire splice and extending onto the conductor insulation at least one tape width on both sides of splice. Apply a minimum of two half-lapped layers of vinyl tape completely over rubber tape and extending onto conductor insulation past ends of rubber tape.

For splices which are provided with integral insulating sleeves, apply a minimum of two half-lapped layers of vinyl tape completely over splice and extending onto conductor insulation, past ends of splice.

Use 3M 33+, Super 88 vinyl electrical tape, Scotch electrical vinyl tape, or an approved equal. Ensure rubber insulating tape is 3M 130C linerless rubber splicing tape, or Scotch rubber linerless tape, or approved equal.

20. Grounding and Bonding. Perform grounding and bonding in compliance with the requirements of *NEC Article 250* for grounding and bonding.

Do not use raceways and metallic cable armor/sheaths as the sole grounding or bonding conductor for any circuit.

Size bonding jumpers equal to the equipment grounding conductors serving the equipment. Install the bonding jumper in accordance with the requirements for grounding electrode conductors given in the *NEC*. Use bare ground wire when installing a bonding wire in junction boxes, terminal cabinets, and enclosures.

Where bolted connections are used for connection of equipment grounding conductors to equipment, clean the area around the connection down to bear metal prior to making the connection. Touch-up the area with paint after the connection is made in accordance with section 715 of the Standard Specifications for Construction.

Ensure bridge steel work on each side of the navigation channels are solidly bonded and grounded to 1 inch copper plated steel ground rods installed using #2/0 AWG bare, stranded, tinned copper cable.

Ensure the resistance to ground is no higher than 25 ohms. Furnish exothermic welds, molded fusion, type as required, as manufactured by Cadweld, Thermoweld, Metalweld, or Engineer approved equal.

Bond together and solidly connect to a ground bus in the machinery and/or electrical rooms grounding conductors in submarine cable, navigation lighting units, all metal framing, cases, and enclosures of the electrical equipment, such as motors, control console, control cabinets, conduits, and all other metal parts in the proximity of current carrying conductors or equipment. Extend a #2/0 AWG bridge-grounding conductor connected to this ground bus to the service disconnect.

Ground new utility service neutral conductors in accordance with local utility grounding requirements.

Exothermically weld together the utility service neutral conductor, the bridge grounding conductor and two #2/0 AWG grounding electrode conductors.

Furnish grounding system terminals that are solderless lugs and that are secured by means of hexagonal-head, copper plated, steel machine bolts with lock washers or lock nuts. Ensure ground system conductors are continuous unspliced connections between terminal lugs. Remove paint, rust, and scale over the contact area. Make up all connections as tightly as possible, and spot paint any bare metal or paint undercoat remaining exposed to restore the surface with the same coating and number of coats as applied to the adjacent metal.

Furnish equipment ground conductors composed of seven-strand, soft-drawn, bare, tinned copper wire in accordance with *ASTM B33* and not smaller than #10 AWG.

21. Mounting Brackets. Fabricate mounting brackets as required by the contract, or for the specific equipment and devices, or as proposed by the Contractor to accommodate the specific mounting locations and equipment. Submit to the Engineer, for approval, shop drawings and details of mounting brackets proposed for installation with indicated dimensions, materials, type, and materials of anchorage.

Clean and paint the mounting surfaces of the structural members in accordance with section 715 of the Standard Specifications for Construction before installing mounting brackets and supports. Except for stainless steel brackets and supports, paint all mounting brackets and supports in accordance with section 716 of the Standard Specification for Construction.

22. Painting. The requirements for painting structural steel also apply to painting electrical equipment, unless otherwise specified.

A. Shop Painting. Electrical equipment such as conduits, boxes, supports, and other devices which have a galvanized finish and equipment such as motors, brakes, control console, and control panel frames and enclosures which normally are given a factory finish need not be shop painted. Give all other electrical equipment one shop coat.

B. Field Painting. Electrical equipment, which is normally given a factory painted finish suitable to the Engineer, need not be field painted if undamaged. Give all other unfinished electrical equipment, such as conduits, boxes, device enclosures, supporting clips and brackets, and other devices, paint as specified under the requirements for painting structural steel. Before applying field coats, thoroughly clean galvanized surfaces, removing any grease, oil, dirt, and foreign material. Etch the surface with a copper sulfate solution, and then apply the paint. In lieu of etching and paint, the Contractor may use galvanizing primer as a first coat for galvanized surfaces. Apply a final field coat on electrical equipment in the operator house the color and type of paint to match the house interior.

23. Submarine Cables. Submit proposed installation methods with installation procedures clearly described to the Engineer for approval before the installation.

Work to include excavation of a cable trench in the river bottom, removal of existing submarine cables, installing new submarine cables in the trench and backfilling the trench to restore the river bottom, as well as the on-site services of the cable manufacturer's representative and Inspection Diver.

Identify and mark all existing submarine cables in the channel before any new cable installation. Use divers and diving equipment, or other approved means to locate any existing cables, utility, and conduit in the channel which are to remain. Plan a route for the new submarine cable across the channel which will avoid interference and damage to such utilities and raceway. All cost associated with any damage to existing utilities resulted from the construction will be borne by the Contractor. The Contractor is cautioned of existing utilities in the vicinity of the existing submarine cables.

Ensure the Inspection Divers are provided for the necessary number of days to perform the specified inspections of the trench and placement of the cables therein. Ensure that the cost of supplying the Diver and necessary diving equipment is included in the unit prices bid for the submarine cables.

Notify and coordinate all work with all local, state and federal agencies, including but not limited to the USCG, having jurisdiction over the waterway and with any utilities using the waterway. Obtain any required permits and approvals of all Departments or Agencies having jurisdiction.

Confirm correct length of submarine cables prior to ordering the correct continuous length. Ensure lengths include sufficient excess length to accommodate pulling eyes, adequate slack for submarine cable settling, cable clamping, connections, and for samples.

Before the installation of the submarine cables, perform soundings to determine the elevations of the navigable channel bottom based on the International Great Lakes Datum (IGLD) 1985 datum. Employ professional divers to assist the Contractor in the submarine cable installation, and to survey the channel bottom for any existing underwater installation that may obstruct or interfere with the lay-down, or excavation, or other installation process of the submarine cables.

Remove existing submarine cables for the installation of the new submarine cables following the same routing as the existing cables.

Prior to commencing installation, submit a request to the Engineer to receive the new submarine cables delivered to the work site for the installation. Submit this request at least 2 weeks prior to the date scheduled by the Installer for the receipt of the submarine cables. Protect and properly store the submarine cables at the work site until installation.

When the ambient temperature of the submarine cable storage at the work site is below 30 °F, heat the submarine cables within an enclosure to an ambient temperature of at least 35 °F for 2 hours before reeling off the cables for installation. Test conductors for continuity, measure insulation resistance of conductors and verify test results that they are within acceptable test values from the manufacturer. Document all test results.

Excavate a trench in the bottom of the navigable channel to bury the submarine cables at a depth approved by the USCE. Excavate using a method that has been approved by the USCE. Construct the cable trench in such a way to avoid cave-ins during placement of the cables and backfill. Lay each cable side by side without any sharp bend, loop, or twist. Ensure when placing cables that they do not cross another cable. Reroute the cable path as necessary to avoid any unforeseen obstruction or remove the obstruction of any abandoned material which will interfere with the installation of the cables to the required depth.

Use clean washed septic/concrete grade sand for the back filling of the submarine cable trench.

Provide supports for each submarine cable riser.

Survey the location of each submarine cable as it is being installed. Identify the cable path with points at 10-foot maximum spacing and ±1 foot accuracy. Use professional divers and diving equipment to verify the burial depth of each cable. Survey, prepare the survey drawings indicating the path and burial depth of each cable and submit to the Engineer.

Cover the cables with bedding aggregate to a depth of at least 12 inches. Backfill the remainder of the trench with backfill aggregate to the elevation of the river bottom.

Upon completion of the installation, inspect the channel bottom again to ensure that all construction waste materials have been removed from the channel. During construction, notify the USCG immediately for any material, machinery, or equipment that is lost, dumped, sunk, or thrown overboard and may obstruct, or interfere with the navigation traffic, and remove such material immediately. Mark location of such material until the obstruction is removed.

Perform continuity test and insulation resistance measurement of conductors of the submarine cables after being installed in place and ready for connections to ensure that there is no damage to the conductors during installation. Ensure the measured or tested values are not less than 90 percent of the values documented before the installation.

Properly dispose of all unused excavated materials away from the construction site in accordance with the contract, requirements of the permit, all applicable federal, state, and local laws and regulations, and in accordance with section 205 of the Standard Specifications for Construction.

Ensure the as-built record drawings attest to the actual location and depth and elevation (referred to the NGVD 1929) to which the new submarine cables have been installed and ensure said drawings are certified by a Land Surveyor licensed in the State of Michigan. Ensure depths are at 10-foot intervals. Ensure the soundings are submitted to the U.S. Coast Guard/Corps of Engineers.

Warranty the in-service performance of the submarine cables for 1 year following final project acceptance.

24. Bedding and Backfill Material. Furnish fill material for submarine cable in accordance with section 902 and 916 and table 902-1 of the Standard Specifications for Construction and as directed herein.

A. Bedding Aggregate. Coarse Aggregate, Class 17 A.

B. Backfill Aggregate. Coarse Aggregate 3x1 that meets the requirements of subsection 916.01.B of the Standard Specifications for Construction.

25. Submarine Cable Terminal Cabinet. Furnish terminal cabinets with terminals blocks to terminate submarine cables. Construct cabinets from #12 gauge, type 316 stainless steel, to *NEMA* 4X rating. Use surface-mounted boxes and cabinets meeting the requirements of *NEMA* 250, *UL* 50, and *NEMA* 4X Type 316 stainless steel with stainless steel hinges and hardware.

Furnish terminal blocks and power distribution blocks to connect field wiring from one cabinet or location to another, including terminal blocks for all spares. Furnish heavy duty, NRTL listed terminal blocks and power distribution blocks, rated 600 V, suitable for use with copper conductors, *NEMA* style, barrier type, tin plated copper or aluminum, and Valox or phenolic insulated, with tubular set-screw type terminals. Mount terminal blocks with stainless steel bolts or machine screws. Furnish printed or engraved labels for all terminals.

Enclose patch panels for the termination of the optical fiber cables in *NEMA* 4X stainless steel box.

26. Manufacturer's Field Start-Up Service. Included with the furnishing of the major items of electrical equipment by the manufacturer is the furnishing of all necessary field supervisory start-up time by the manufacturer's service engineering department to facilitate proper adjustment of the drive equipment to achieve satisfactory functioning of the drives.

The manufacturer's field service engineering personnel are required to be experienced in the adjustment and functioning of the control equipment furnished by the manufacturer. The personnel are required to be capable of locating and correcting faults or defects and of obtaining from the manufacturer, without delay, new parts, or replacements for apparatus that, in the opinion of the Engineer, does not perform satisfactorily.

27. Bridge Electrical Testing.

A. Furnish all labor, materials, plant, and equipment and do all work necessary, such as adjustments or corrective measures, to properly test all systems included in the field testing and final acceptance testing.

All test results, parameters, data specified herein to be recorded must reference the appropriate paragraph number and will be presented in legible, tabular format, listing associated parameters and conditions. For example, motor current must reference speed in revolutions per minute (RPM), span height in feet and inches, raise or lower mode, normal or emergency drive control, drive control selector position number, etc.

Ensure the results of the normal systems tests are presented in a matrix form on an Inspection Report Data Sheet. Ensure the proposed format of these sheets are submitted to the Engineer for approval prior to the actual testing. Any parameter value, which falls beyond the recommended range, would require the readjustment or replacement of the defective device.

The table of the test results must have references to the specific sections of the testing procedure. The precision of the results depend on the accuracy of recording equipment, the observer and weather conditions. For each stage of testing of the bridge control equipment, record the name of the person who performs the test, the instruments used with calibration data if required, the exact date, time, and weather conditions.

Some devices such as the transfer switch, lamps, console indicator lights, brake function indicator lights, horn, can be easily tested without performing any bridge opening operation.

The bridge main parameters must also be observed and visually compared to the control desk indicating meters. Record any discrepancy between results. Resolve any discrepancy between critical measurements prior to continuing the tests.

The testing will be accomplished sequentially, following the bridge operation instructions for normal operation and emergency operation. Monitor the major bridge systems while the bridge operates. Keep all monitored parameters for future reference and ensure a printout copy is attached to the Operating and Maintenance (O & M) Manual for reference. Furnish a printout copy to the Engineer.

The testing of the bridge electrical equipment would necessitate the use of the following recording and testing devices:

(1) A computerized 16-bit, data acquisition system providing simultaneous sampling every 0.1 second of span position, motor input power, current, voltage, and motor RPM. Data must stream to disk at a rate of 10 Hz. Ensure the data is transferred to graphing software.

(2) Portable tachometer.

(3) Portable ohmmeter.

(4) Ampere-probe.

(5) Recording ammeter.

(6) Recording voltmeter.

(7) Infrared scanner.

(8) Measuring tape.

(9) Stopwatch (Timer).

(10) All other necessary instrumentation and tools to monitor, adjust and/or replace items during the bridge testing procedure.

Calibrate all meters per *NIST* guidelines within 6 months of the testing.

B. Arrange for and furnish all the necessary field tests and provide a testing procedure to submit for approval of the Engineer, to demonstrate that the entire electrical system is in proper working order and in accordance with the contract. The tests include, but not be limited to, operational testing of bridge signals, traffic gates, movable span, navigation lights and signals and manual transfer switch.

Should the tests show that any piece of equipment, cable or wiring connection, in the judgment of the Engineer, is defective or functions improperly, ensure such adjustments and/or replacements are made to make the installation satisfactory to the Engineer and at no extra cost to the contract.

During testing of the electrical systems, it may be found that minor deviations from the performance specification are required for optimum bridge operation. All hardware and software required for these modifications are included in the control system vendor scope of work at no additional cost to the contract.

The bridge field tests are intended to confirm each major sub-component acceptance factory tests, and that the subsystem is operational, as well as the complete system. Demonstrate the correct operation of sub-components through successful operation of the component. However, the Contractor is still responsible for the factory acceptance tests as required per contract specifications. Examples of subsystems are the span drive systems, control and power wiring, limit switches, starters, span lock system, etc.

This acceptance test is intended to show and/or demonstrate that the normal, emergency control and power systems are operational, trouble free, operating with all interlocks properly functioning, and in compliance with the requirements of the contract.

The bridge acceptance tests are not intended to substitute each sub-component acceptance factory and field tests. Correct operation of sub-components must be demonstrated through successful operation of the total control system. However, the Contractor is still responsible for the factory and field tests acceptance tests as required per the contract. For example, it is not the intent to manually operate and test each limit switch. This must have been accomplished prior to demonstration of the system under test. Prove that the results of the sub-component tests are in conformance with the contract. The recommended values of various device parameters can be found in the appropriate manufacturer's catalog cuts and instruction manuals. Correct operation of the sub-components, and control circuit wiring connections must be verified through the successful completion of the entire bridge control and power systems tests.

This testing procedure must evaluate performance and confirm correct and proper operation of all major subsystems and devices including the control desk meters and HMI, control switches and pushbuttons, bridge signals, traffic gates, tail locks, brakes, the span drives and motors, bypass switches, auto transfer switch, etc. Visual inspections and physical measurements of some equipment are required for the purpose of recording valid parameter values. Furnish bridge run printouts for each test and kept for the record together with all other recorded data.

Ensure the Department is in possession of the final, new O & M manuals at least 30 days before acceptance testing may begin. Start approval submissions of the O & M manuals as soon as possible, as several revisions may be required.

There must be 14 consecutive days of nominal bridge operation using the new permanent systems, with a minimum of five successful openings per day, before the final acceptance test will be scheduled.

During the field-testing period, arrange to have at the site representatives of the manufacturer of all major pieces of equipment or systems. Ensure the representatives can supervise all adjustments to the equipment; of locating faults or defects and correcting them if possible; and of obtaining from the manufacturers, without delay, new parts, or replacements for apparatus which, in the opinion of the Engineer, does not perform satisfactorily.

C. General. Ensure results and observations are carefully recorded throughout the various tests.

Ensure the bridge is balanced and strain gage conditions verified by the Contractor prior to any final acceptance testing of the span control system.

Prior to performance of these tests, ensure all temporary PLC forces, bypasses, jumpers, switches, etc., installed during any previous testing are removed. Ensure the control circuits are in the state presented in the originally As-Built control wiring diagrams (restored to normal).

D. Ensure all tests and verifications are for equipment at both the near and far sides. In addition to all devices listed below, all associated devices must also be tested.

E. Tests To Be Performed.

(1) PLC System. The bridge primary control system is provided by the PLC system, span drives and power distribution system. Prior to any other test, visually verify the wiring connection integrity of the major components including:

(a) All limit switches.

(b) Control cabinets contactors.

(c) Bridge signals, traffic gates, tail locks, interlocked heating and ventilating devices, etc.

(d) Control desk indicating lights.

(e) Control Desk HMI screens.

(2) Auxiliary System. The bridge auxiliary control system is provided by a relay based system, low speed motors and power distribution system. Prior to any other test, visually verify the wiring connection integrity of the major components including:

(a) All limit switches.

(b) Control cabinets contactors.

(c) Bridge signals, traffic gates, tail locks, interlocked heating and ventilating devices, etc.

(d) Control desk indicating lights.

(e) Auxiliary mode selector switch is ON.

(3) Control Desk. The control desk devices (HMI, switches, pilot lights,) must be used throughout the tests, and all irregularities observed noted during and after the tests from the notes and printouts. Special attention must be given to the desk meters accuracy verification.

(a) Provide one desk multifunctional power monitor verification as follows:

(b) File the manually recorded values. The results must be compared.

(4) Air Horns.

(a) Test that the air horn produces a tone acceptable to the Engineer. If necessary, the air horn sound tone must be re-tuned to an acceptable pitch and level.

(5) Bridge Signals Control.

(a) Test that the bridge signals change state upon activation of the desk selector switch. The duration time of the amber light must be of an acceptable time to the Engineer. If necessary, the TSR timing relay must be re-set to an acceptable time delay.

(6) Main Traffic Gate Control.

(a) Testing of the gates must demonstrate the balance condition of the gate arms such that a stationery arm remains in the same position when the brake is released.

(b) Proper manual operation and proper normal operation upon activation of the desk selector switches and MCC must be demonstrated.

(c) Lower individually, group raise commands, lower/raise sequencing checks.

(d) Follow the Sequence of Operation.

(e) Verify that the gates are lowered in the right sequence and the traffic bells de-activated at the appropriate time.

(f) Bypass checks.

(i) Verify that when the Interlock Bypass keyswitch is enabled in the main system, the interlocks listed below are overridden.

(g) Group/Individual Control Operation Interlocks.

(i) Verify that gate operation is prevented when any of the following occur:

1) Gate housing door opened;

2) Handcrank inserted;

3) Gate motor disconnect switch opened;

4) Gate motor overloaded;

(7) Auxiliary Traffic Gate Control:

(a) Testing of the gates must demonstrate the balance condition of the gate arms such that a stationery arm remains in the same position when the brake is released.

(b) Proper manual operation and proper normal operation upon activation of the desk selector switches and MCC must be demonstrated.

(c) Verify auxiliary mode switch is On.

(d) Lower individually, group raise commands, lower/raise sequencing checks.

(e) Follow the Sequence of Operation.

(f) Verify that the gates are lowered in the right sequence and the traffic bells de-activated at the appropriate time.

(g) Verify that gates are lowered in the right sequence and the traffic bells de-activated under auxiliary control at the appropriate time.

(8) Main Tail Locks Control:

(a) Drive/pull Main system commands:

(i) Follow the Sequence of Operation up to the span operation.

(ii) Pull locks using the control desk switches, and verify the locks are pulled.

(iii) Drive back the locks using the control desk switches, and verify the locks are driven.

(b) Interlock checks:

(i) Verify that the gates cannot be raised electrically unless the tail locks are driven.

(ii) Verify that the bridge signals cannot be turned to green when the gates are not raised and the tail locks not driven.

(iii) Verify that the span cannot be operated electrically unless the tail locks are pulled.

(c) Bypass checks:

(i) Verify that when the Tail locks pulled bypass and Tail locks driven bypass keyswitches are enabled in the main system, the interlocks listed below are overridden.

(d) Group/Individual Control Operation Interlocks:

(i) Verify that when the tail locks are operated by the group drive/pull control switch, any of the following conditions:

1) Manual handcrank inserted;

2) Lock motor disconnect switch opened;

3) Lock motor overloaded, on any of the tail locks, will disable the group drive/pull operation. Verify that any individual span lock operation is disabled by any of the above conditions on that span lock.

(9) Auxiliary Tail Locks Control:

(a) Drive/pull system commands:

(i) Verify Auxiliary Mode Switch is On.

(ii) Follow the relay logic up to the span operation.

(iii) Pull locks using the control desk switches, and verify the locks are pulled.

(iv) Drive back the locks using the control desk switches, and verify the locks are driven.

(b) Interlock checks:

(i) Verify that the gates cannot be raised electrically unless the tail locks are driven.

(ii) Verify that the bridge signals cannot be turned to green when the gates are not raised.

(iii) Verify that the span cannot be operated electrically unless the tail locks are pulled.

(10) Main Span Brakes Control:

(a) The normal automatic set and released operation of the brakes must be visually recorded during the span raise and lower operations.

(b) The brakes must be hand released, each brake one at a time, and the hand-released indication monitored through the control desk.

(c) With the span in non-permissive operation mode (tail locks driven, drives not energized), the brake set and release switches can be activated manually and their set/released indication monitored on to the control desk.

(11) Auxiliary Span Brakes Control:

(a) Verify auxiliary mode switch is ON.

(b) The normal automatic set and released operation of the brakes must be visually recorded during the span raise and lower operations.

(12) Span Normal Operation:

(a) Several bridge openings may be required to demonstrate that all the operational parameters are acceptable and interlock functions safe. Subsequent runs will be required to simulate failures, and to test interlocking and bypass functions. The normal sequence of operation as described in the Sequence of Operation section of the general specifications will be followed up to the indicated operational step of the equipment to be tested. All tests must be performed for both main span motors on each side.

(13) Normal Operation.

(a) Follow the full Sequence of Operation. During the span Raise and Lower operation, the following parameters must be monitored and recorded:

(i) Span position [degrees];

(ii) Motor power [kilowatt];

(iii) 3-phase current [amperes];

(iv) 3-phase voltage [V];

(v) Motor speed [RPM];

(vi) Manually record maximum angle during the Raise [degrees];

(vii) Manually record Raise time and Lower time;

(b) These parameters will also be manually recorded at the fully closed, nearly closed, nearly open and fully open position as indicated at the control desk by PLC HMI.

(c) Verify that the span operated normally within the permissible position limits.

(d) Verify that the recorded position, the control desk indicated position and the limit switches indicated position are equal or within the set design tolerances.

(e) Interlock Checks:

(i) Verify that the span cannot be operated electrically if more than one brake in each machinery room has been released by hand.

(ii) Verify that the traffic gates and bridge signals cannot be operated unless the span is seated and locked.

(iii) Verify that the tail locks cannot be operated unless the span is fully seated.

(f) Bypass Checks:

(i) Verify that when the Bypass Span Control Interlocks switch is enabled, the interlocks listed above are overridden.

(g) Emergency Span Stops:

(i) Under normal opening procedures, push the Emergency Stop red mushroom head button.

(ii) Verify that all motor and brake contactors drop out and the span brakes set immediately.

(14) Span Auxiliary Operation:

(a) Several bridge openings may be required to demonstrate that all the operational parameters are acceptable and interlock functions safe. Subsequent runs will be required to simulate failures, and to test interlocking and bypass functions. The auxiliary relay logic must be followed up to the indicated operational step of the equipment to be tested. All tests must be performed for auxiliary span motors on each side.

(15) Auxiliary Operation.

(a) Verify that auxiliary mode switch is ON. During the span Raise and Lower operation, the following parameters must be monitored and recorded:

(i) Span position [degrees];

(ii) Motor power [kilowatt];

(iii) 3-phase current [amperes];

(iv) 3-phase voltage [V];

(v) Motor speed [RPM];

(vi) Manually record maximum angle during the Raise [degrees];

(vii) Manually record Raise time and Lower time;

(b) These parameters must also be manually recorded at the fully closed, nearly closed, nearly open and fully open position.

(c) Verify that the span operated normally within the permissible position limits.

(d) Verify that the recorded position, the control desk indicated position and the limit switches indicated position are equal or within the set design tolerances.

(e) Interlock Checks:

(i) Verify that the span cannot be operated electrically if more than one brake in each machinery room has been released by hand.

(ii) Verify that the traffic gates and bridge signals cannot be operated unless the span is seated and locked.

(iii) Verify that the tail locks cannot be operated unless the span is fully seated.

(f) Emergency Span Stops:

(i) Under normal opening procedures, push the Emergency Stop red mushroom head button.

(ii) Verify that all motor and brake contactors drop out and the span brakes set immediately.

29. Warranty. Store all product warranty certificates, and similar warranty information, at a single location on the project site and turn over to the Department prior to final acceptance.

Register warranties to the Department where registration is necessary as a condition of warranty coverage.

Upon final acceptance of the completed work by the Department, warrant the satisfactory in-service operation of the completed bridge electrical installation, materials, products, and related components. This warranty must extend for a minimum period of 1 year following the date of final acceptance.

When requested by the Department, within 1 year of the date of final acceptance, the CSV must provide a minimum of two project-site visits to adjust and calibrate components, make programming adjustments and revisions, and assist the Department personnel in making program changes and in adjusting equipment and controls. Provide up to 40 hours of services, exclusive of travel time, for these purposes.

30. Training. Furnish people to supervise the operation of the bridges and to train personnel for a period of 30 consecutive working days after the construction of the permanent control system has been completed, fine-tuned, field tested, and utilized for span operations. Instructors include, but not be limited to, representatives from manufacturers of the major equipment and a Control Engineer.

Furnish operators who are skilled people competent to operate the bridge and who are completely familiar with the operating equipment of the bridge and its auxiliaries, such as bridge security, the communications system, and fire alarm system. The operators are required to be able to make any adjustments required to the electrical and mechanical equipment.

During the 30-day period specified above, the operator(s) is(are) required to be in attendance at the bridge for the normal working period of 8 hours per day.

Included in the 30-day training and instruction period, provide on-site training of electricians, maintenance workers, and other personnel as indicated by the Department on subjects such as troubleshooting, repair of electronic motor controls, drive circuit logic, maintenance and adjustment of all electrical equipment, software, PLC hardware, and other items required for full bridge operation and maintenance. Devote three 8-hour sessions to hardware and maintenance related topics. In addition, devote three 8-hour sessions to software requirements. Offer instruction pertaining to hardware and maintenance on two separate occasions to allow bridge personnel to coordinate the course with their normal activities. Devote one 8-hour session to training on the public address system, CCTV camera system, and remote-control equipment. Furnish all necessary instruction sheets, student training aids, books, paper, and booklets to supplement training. Submit to the Department, a minimum of 2 weeks prior to training session, an outline of topics to be covered and training material for review. Coordinate with the Department the location where training sessions will be held. Supplying of visual aid equipment and other miscellaneous items required for training is the responsibility of the Contractor.

Furnish the instruction booklet that was specified above, O & M manual, Volume 1, Operation of Electrical Equipment, available for use during the training period.

Training of the designated bridge operational personnel will commence 3 weeks prior to the official bridge opening date. This will allow training of personnel without interruption of normal traffic flow.

**d.** **Measurement and Payment.** The completed work, as described, will be measured as a lump sum and paid at the contract price using the following pay item:

**Pay Item Pay Unit**

Bridge Elec Work (Structure Identification) Lump Sum

**Bridge Elec Work (Structure Identification)** includes, but is not limited to, labor, materials, equipment, finishing, testing, spare parts listed and incidental expenses to complete all electrical work as described in this special provision and as shown on the plans.

The pay item will include the following:

1. Provision for salvaging existing equipment.

2. Automatic transfer switch.

3. Standby generator.

4. Disconnect switches.

5. Span drive main motors.

6. Vector motor drives.

7. Braking resistors.

8. Auxiliary motors.

9. Tail lock motor actuators.

10. Span brakes.

11. Main PLC control system.

12. HMIs.

13. Control system laptop.

14. Instrumentation (position encoders, speed switch, rotary cam, proximity, lever arm, and tail lock limit switches).

15. Control apparatus and miscellaneous equipment.

16. Bridge street lights.

17. Bridge signals.

18. Traffic gates.

19. Warning gongs.

20. Bridge control console, digital displays.

21. Bridge control cabinets.

22. Motor control center (MCC).

23. Raceways, wiring troughs, hardware and supports.

24. Wiring, cables, multi-conductor tray cables.

25. Instrumentation, Ethernet, and fiber optic cables.

26. Media converters.

27. Air horn.

28. Pier and mid span navigation lights.

29. Droop cables, cabinets, and supports.

30. Submarine cables, cabinets, and supports.

31. Panelboards.

32. CCTV system.

33. Heating.

34. Access lighting.

35. Heat trace.

36. Sump pump.

37. Grounding

38. Voltage and arc flash warning labels.

39. Selective coordination.

40. Spare parts.

41. Shop testing.

42. Field start-up.

43. Testing.

44. Training.

45. Operation & maintenance manuals.

The Contractor must submit a detailed breakdown of costs under this item within 30 days of award of the contract. This breakdown will be evaluated by the Department and be utilized as the basis of payments for work satisfactorily completed.

The Contractor agrees that the detailed breakdown does not become effective until it has been approved by the Department.

The progress payments for Item **Bridge Elec Work (Structure Identification)** will be made in accordance with MDOT standard specifications, Department standard payment practices and in the following manner:

46. Upon completion of shop fabrication, shop inspection, shop testing, delivery and storage of materials and acceptance of such by the Department, the Contractor will be paid 30 percent of the bid price for the item.

47. Upon completion of the Bridge Elec Work (Structure Identification) installation, termination, bolting, and protection of materials during construction and acceptance of such by the Department, the Contractor will be paid 20 percent of the bid price for the item.

48. Upon completion of the Bridge Elec Work (Structure Identification) and field testing at the end of construction and final acceptance of such by the Department, the Contractor will be paid 30 percent of the bid price for the item.

49. Upon completion of training and receipt and acceptance of approved Operating and Maintenance Manuals, the Contractor will be paid the remaining 20 percent of the bid price for the item.