Special Specification 6122
Bridge Electrical System Replacement

1. DESCRIPTION

1.1. Remove existing electrical system components and replace with new components for the electrical systems. The bridge electrical systems are for the permanent operation of the movable bridge and auxiliaries as indicated on the plans, and as required for complete functioning systems and furnishing, installing, and placing in satisfactory operating condition.

The major pieces of equipment or systems covered include, but are not limited to, the span drive motors and brakes, limit switches, programmable logic Controller (PLC), power distribution and motor control equipment, service lights, navigation lights, vector motor drives, complete raceway and conductor systems, aerial cables and aerial cable terminal cabinets, CCTV and monitoring equipment. In addition to furnishing and installing the new bridge electrical systems, the work also includes demolition of the existing electrical systems.

1.2. **Conformance.** Electrical equipment and its installation will conform to the requirements of the latest revision of the American Association of State Highway Transportation Officials (AASHTO), except as may be otherwise provided herein. In addition, it will conform to the requirements of the current National Electrical Code (NEC), National Electrical Manufacturer's Association (NEMA), Underwriters Laboratory (UL), Institute of Electrical and Electronics Engineers (IEEE) and to any applicable local rules and ordinances. Obtain any required permits and approvals of all departments or agencies having jurisdiction.

2. MATERIALS

2.1. **Working Drawings and Samples.** Provide shop drawings and operation and maintenance manuals as specified on the plans.

2.1.1. Prepare and submit for review working drawings in accordance with the approved project schedule. Provide the following working drawings in accordance with the provisions of the contract.

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

2.1.1.2. 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.

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

2.1.1.4. 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.

2.1.1.5. Complete interconnection diagrams for all electrical apparatus and equipment used in the operation of the span and its auxiliaries. The diagrams will be of the point-to-point type and will show the external connections of all devices and equipment. The control system vendors shop drawings will include complete drawings of terminal block layouts to allow the Contractor to properly develop interconnect drawings. Computer-generated interconnection lists will not be acceptable in lieu of a true interconnection diagram.

2.1.1.6. 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 percentage of wire fill. As built the final installed length.

2.1.1.7. 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.

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

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

2.1.1.10. A complete list of all spare parts furnished as part of the Contract.

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

2.1.1.12. 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.

2.1.1.13. Aerial Cable specification and details.

2.1.1.14. Detail drawings showing the construction of cabinets, brackets, and special supports required for the installation of the aerial cables between the east and west machinery platforms.

2.1.1.15. Material listing and complete schematic for the CCTV system.

2.1.1.16. 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 document, 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 Square D, Allen-Bradley, Cutler-Hammer, or General Electric 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 do not meet the requirements of the contract documents. Any rejected equipment or device will be replaced with engineer approved equipment or device at no additional cost to the department or impact with 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 provide one set of reproducible Mylar drawings. In addition, submit in computerized file form in Adobe Acrobat (pdf) Format all electrical schematics, ladder diagrams, internal ladder logic diagrams, systems documentation, dimension drawings of equipment, and devices submitted by the electrical systems vendor.

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.

2.2. **Instruction Books and Drawings Books.**

2.2.1. Furnish to the engineer seven (7) bound copies and a CD, 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:

- Detailed, technical operating instructions, which cover span operation, manual operation, span operation with PLC disabled, etc.
- Detailed description of all control equipment including instructions to achieve optimum settings of all limit switches, detectors, etc.
- Description of control, which will describe 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 control house and the machinery platforms. Cross-reference all descriptions with reference drawings.

2.2.2. Furnish to the engineer seven (7) bound copies and a CD, 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:

- Maintenance instructions for the electrical equipment, including warnings and precautions to be observed during maintenance actions. All preventive maintenance procedures are to be outlined and a chart listing all maintenance procedures in chronological order will be provided.
- Set of descriptive leaflets, bulletins, maintenance instructions, and drawings covering all approved items of equipment furnished and installed under the item "Bridge Electrical Work."
- A troubleshooting flow chart for troubleshooting the bridge electrical system will be provided to facilitate the diagnosing and correcting of malfunctions.
- Instructions for diagnosing malfunctions of the programmable control system and for detecting failures in the external controls connected thereto.
- Reduced size prints of working drawings, including all schematic wiring diagrams, control console and control panel layouts and connection diagrams.
- PLC schematic wiring, relay logic, PLC input/output hardwire diagram, PLC logic and PLC ladder diagrams.
- Control console and control panel layouts and wiring diagrams.
- Composite schedule of electrical apparatus.
- Complete spare parts list.
- Test data, equipment, criteria, and performance curves for all span drive motors.
- Conduit layout and installation drawings.
- Matrix of parts and equipment installed, manufacturers name and contact information, dates of installation and expiration of warranties.

2.2.2.1. **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 in. by 12 in. with 3 in. "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 department, the location, yr. 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 hereinafter specified 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 lb., 3 hole pre-punched loose leaf paper and reinforced with plastic or cloth tape.

2.3. **Equipment and Material Provisions.** Provide all new equipment and materials. Provide equipment, materials, and workmanship that is first-class in every particular and that is manufactured and erected to the satisfaction of the engineer. Provide a warrantee for the in-service working of the electrical installations for one (1) yr. following project acceptance. If the Contractor has any objection to any feature of the electrical equipment as designed and laid out, he must state his objection at once in writing to the engineer, otherwise his objection will be ignored if offered as an excuse for malfunctioning of the equipment or for defective or broken apparatus.

Provide 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. Provide structural steel incidental to the electrical work conforming to the requirements given under Structural Steel – General Requirements.

Provide vibration proof mounting hardware, wire and cable terminals.

Submit for approval, as soon as possible, details of any departures from the plans or the specifications that are deemed necessary and reasons therefore on. No such departures will be made nor work started without approval of the engineer.

2.4. **Bridge Control System Vendor.** Use a single, qualified control system vendor for the manufacture 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 Underwriters Laboratory approved Facility in accordance with UL 508.

The control system vendor 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 AC vector motor drives, DC drives and programmable controllers. Identify a minimum of five vertical lift movable bridges for which the system vendor has provided complete systems, including solid-state drive motor control and programmable controller logic featuring dynamic skew correction within the past 10 yr.

2.4.1. The following applies to the control system vendor:

- Assume complete system responsibility for the integrated functioning of all components to provide a satisfactory assembled system operating in accordance with specified requirements.
- 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.
- Assume responsibility for developing the program for the Programmable Logic Controller (PLC) based on the performance specification for operation of the bridge.
- Assume responsibility for developing and integrating PanelView operator display and diagnostic screens.

- Provide supervisory assistance in the installation of equipment to ensure maximum reliability and ease of maintenance.
- 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 department.
- 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 bridge, provide on-call warranty service, including parts and trouble-shooting, for a period of 1 yr. Field staff will be capable of responding to an emergency within 24 hr.

Provide written certification of compliance with specified requirements for the control system vendor. Include this certification in the bid documents. The certification will be subject to approval by the engineer.

2.5. **Factory Inspection and Testing.** The control cabinets and other apparatus fabricated or assembled by the control system vendor will be 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. Limit switches will be simulated with temporary switches, and reduced horsepower motors will be connected 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.

Special testing will include complete verification, adjustment, and testing of the regulator circuits and equipment using regulator simulators as necessary. 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. Provide 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.

2.6. **Span Drive Motors.** The drive motors will be vector duty motors. They will be built in strict accordance with NEMA publication MG-1 and designed for use with an Insulated Gate Bipolar Transistor AC closed loop vector control. They will be 3 phase 60 Hz, with moisture resistance insulation, 50°C temperature rise, and capable of reversing. Motor frame will be constructed of cast iron.

The span drive motors will be 25 hp, 900 rpm, 480 VAC, 60 Hz, with a full load amp rating of 35 amperes with a 364T frame.

The motors will be totally enclosed non-ventilated construction, with re-greaseable ball bearings, moisture resistant insulation and internal space heater sized by manufacturer. The motors will have special extended shafts to complement the new motor brakes and new motor grid coupling components as indicated on the plans and in the special provisions. The motor shafts will be cadmium plated. A drain hole will be provided at the bottom of the motor.

All windings will be copper. The motor will be capable of having a minimum break-down torque of 300%. Motor must have a speed range of 1000:1 and be capable of having full torque at zero speed. Motor design will be low inertia and slip design. An N/O temperature sensor will be installed in the windings.

The conduit boxes will be liberally sized and located to avoid interference with the machinery. The conduit boxes will be sized in accordance with the requirements of the NEMA MG 1-1987 PART 11. The conduit boxes will be provided with suitable terminal blocks for the motor power connections.

Provide motors with a heavy mill duty modular magnetic encoder. They will be of stainless steel and designed for washdown and marine duty. They will be provided with magnetic sensors that are fully potted, to withstand dirt and liquids, with no moving or wearing parts. They will 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. They will operate at 5 - 24 VDC, 100 mA no load. The output format will be A Quad B with Marker (A, A–, B, B–, Z, Z–). It will provide a maximum instantaneous current output of 3000 mA. Provide 1024 PPR output or as recommended by the drive manufacturer. The electronics will be fully encapsulated and rated IP67. They will operate at a temperature range of -40°F to 200°F (300°F rotor). They will be provided with a polyurethane enamel paint to protect against salt spray, mild acids, and bases.

Provide motors designed and manufactured in the United States of America. All motors must be manufactured to the following standards:

- IEEE Marine Standards No. 45;
- American Bureau of Shipping (A.B.S.); and
- U.S. Coast Guard Inspection Service.

Modifications needed to meet the requirements of these specifications include:

- Cadmium plate shaft and hardware (FED-QQ-P-416).
- Double Sealed ball bearings.
- Seal all joints and eye bolt holes.
- Sealed leads in terminal box
- Shaft seals
- Removable drain plugs
- Final coat of epoxy paint
- Corrosion resistant coating - rotor and stator laminations.
- Stainless steel and/or Mylar nameplate.
- Super 'H' insulation. Includes protection against fungus growth per MIL-V173B.

The motor frames will be finished with a corrosion-resistant paint or coating. Exposed unpainted metal surfaces will be of a corrosion-resistant material.

Motors must be designed to operate at carrier frequencies up to 20 kHz.

All motors must be dynamically balanced.

Subject each motor to a complete test consisting of a full-load heat run and the determination of efficiency and power factor at 50%, 75%, 100%, and 150% of full load. In addition to the complete testing, test the motor to determine the power input in kilowatt versus the output torque in foot-pounds for intervals from no-load to full-load torque (0%, 25%, 50%, 75%, and 100%).

Prepare a complete set of speed-torque-current curves for the motors and submit to the engineer for approval. Provide curves corresponding to full speed and low speed. The curves will cover the interval from 150% braking torque to breakdown driving torque, referred to full-load motor torque.

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 National Electrical Manufacturers Association. Have all test reports and curve sheets certified by the manufacturer, and submit seven copies of each. Do not ship motors from the plant of the manufacturer until the test reports have been approved by the engineer.

Test each pair of drive motors with two of the span drives. The tests will be conducted using two four quadrant dynamometers that will provide 150% overhauling load to 150% motoring load at 5%, 25%, 50% and 100% full load speed. In addition, the tests will demonstrate the skew control algorithms by having the dynamometers applying differing loads to the motors and having the motors remain in skew. This will require using the span control PLC processor with power supply and Ethernet card at the testing facility, with high speed counter modules to verify the position matching. The control system vendor will develop a procedure to tests the skew control system and submit to the Engineer for approval. The use of one motor/drive combination turning another motor/ drive combination will not be acceptable in lieu of a true dynamometer test with calibrated load cells. The facility performing the testing will be submitted for approval of the engineer along with a written test procedure. These tests will be witnessed by the engineer and three weeks' notice will be provided prior to the testing.

After entire motor, brake and control system installation, perform speed/current/power vs position tests to demonstrate that the motors functions properly and provides the specified operating characteristics as called out in the testing section of this specification. The data will be recorded on a PC based data acquisition system, streamed to disk at a rate not less than 10 Hz and will include acceleration, deceleration, full speed, reduced speed and creep speed.

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

2.7. **Barrier Gate Motors.** Provide 2 hp, 3 phase, 60 Hz, 900 RPM, crane and hoist duty NEMA design D motors, built in strict accordance with NEMA publication MG-1 and designed for service code H.

The motors will be totally enclosed non-ventilated cast iron construction, with regreaseable ball bearings, moisture resistant insulation and internal space heater sized by manufacturer. The motor will have a special double extended shaft as required to accommodate the motor coupling on one end and the hand drive square shaft extension on the other. The hand drive extension will be provided with a cover that will activate a limit switch for a manual operation interlock. The motor shafts will be cadmium plated. A drain hole with removable plug will be provided at the bottom of the motor.

All winding will be copper. The motor will be capable of having a minimum locked rotor torque of 260%.

The conduit boxes will be liberally sized and located to avoid interference with the machinery. The conduit boxes will be sized in accordance with the requirements of the NEMA MG 1-1987 PART 11. The box will be provided with a suitably sized terminal block for the motor power and space heater connections.

Provide barrier gate motors designed and manufactured in the United States of America. The barrier gate motor must be manufactured to IEEE Marine Standards No. 45.

Modifications needed to meet the requirements of these specifications include:

- Cadmium plate shaft and hardware (FED-QQ-P-416).
- Double Sealed ball bearings.
- Seal all joints and eye bolt holes.
- Sealed leads in terminal box
- Shaft seals
- Removable drain plugs
- Final coat of epoxy paint
- Corrosion resistant coating - rotor and stator laminations.
- Stainless steel and/or Mylar nameplate.
- Super 'H' insulation. Includes protection against fungus growth per MIL-V173B.

The motor frame will be finished with a corrosion-resistant paint or coating. Exposed unpainted metal surfaces will be of a corrosion-resistant material.

The motors will be furnished with rear (opposite drive end) mounted brakes. The brake will be of the disc type, Reuland Electric series C or approved equal. They will be energized by 460/3/60 input power. Brakes will be sized by the manufacturer according to the rated output torque of the motor

The motors will be subjected to a full load heat run test in accordance with the current requirements of the NEMA MG 1-1987 PART 12, and IEEE STD 112-1984. The data, including speed/torque/power curves, will be certified and submitted to the engineer on the IEEE forms. The engineer will be notified of the time and place of the testing at least three weeks in advance of the testing.

Provide barrier gate motors manufactured by Reuland, Marathon, Baldor or as approved by the engineer.

2.8. **Span Lock Motor.** Provide 3 hp, 3 phase, 60 Hz, 900 RPM, crane and hoist duty NEMA design D motors, built in strict accordance with NEMA publication MG-1 and designed for service code H.

The motors will be totally enclosed non-ventilated cast iron construction, with regreaseable ball bearings, moisture resistant insulation and internal space heater sized by manufacturer. The motor will have a special double extended shaft as required to accommodate the motor coupling on one end and the hand drive square shaft extension on the other. The hand drive extension will be provided with a cover that will activate a limit switch for a manual operation interlock. The motor shafts will be cadmium plated. A drain hole with removable plug will be provided at the bottom of the motor.

All winding will be copper. The motor will be capable of having a minimum locked rotor torque of 260%.

The conduit boxes will be liberally sized and located to avoid interference with the machinery. The conduit boxes will be sized in accordance with the requirements of the NEMA MG 1-1987 PART 11. The box will be provided with a suitably sized terminal block for the motor power and space heater connections.

Provide span lock motors designed and manufactured in the United States of America. The span lock motors must be manufactured to IEEE Marine Standards No. 45.

Modifications needed to meet the requirements of these specifications include:

- Cadmium plate shaft and hardware (FED-QQ-P-416).
- Double Sealed ball bearings.
- Seal all joints and eye bolt holes.
- Sealed leads in terminal box.
- Shaft seals.
- Removable drain plugs.
- Final coat of epoxy paint.
- Corrosion resistant coating - rotor and stator laminations.
- Stainless steel and/or Mylar nameplate.
- Super 'H' insulation. Includes protection against fungus growth per MIL-V173B.

The motor frames will be finished with a corrosion-resistant paint or coating. Exposed unpainted metal surfaces will be of a corrosion-resistant material.

The motors will be furnished with rear (opposite drive end) mounted brake. The brake will be of the disc type, Reuland Electric series C or approved equal. They will be energized by 460/3/60 input power. Brakes will be sized by the manufacturer according to the rated output torque of the motor

The motors will be subjected to a full load heat run test in accordance with the current requirements of the NEMA MG 1-1987 PART 12, and IEEE STD 112-1984. The data, including speed/torque/power curves, will be certified and submitted to the engineer on the IEEE forms. The engineer will be notified of the time and place of the testing at least three weeks in advance of the testing.

Provide span lock motors manufactured by Reuland or as approved by the Engineer.

2.9. **Vector Motor Drives.** The drives will allow operation in a Master/Master mode whereby the drives will be controlled by the span PLC system via Ethernet connection.

Vector drives must be four quadrant drives and will be 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, a minimum switching frequency of 15 kHz will be used. The drive will not "cog" at any frequencies with a 1,000:1 speed regulation. There will be 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. Efficiency will be measured 96% minimum at rated load. Provide manufacturers typical test results or calculations with submittal to verify efficiency and power factor.

Input and output reactors will be supplied as required per drive and motor manufacturer recommendations.

The vector drives will have, but not be limited to the following features:

- Manufacturer provided ethernet communications module to allow transfer of all commands and operational data/faults to the PLC network.
- High speed analog inputs.
- Allow for smooth and instantaneous connection into rotating loads, regardless of commanded direction, without the need for any speed feedback.
- Inertia Ride-Through to allow for tripless operation during a prolonged power outage by using the rotating energy stored in high inertia, low-friction loads.
- Provide a torque proving circuit to ensure proper control of the load when transferring control between the drive and a mechanical brake.
- Slip Compensation to provide a minimum 0.5% speed regulation without feedback hardware.
- Encoder Feedback to provide ±2% regulation and the ability to hold full load at zero speed.
- Solid state output ground fault protection will be provided.
- Adaptive electronic motor overload protection will be provided, which will protect both the motor and the drives at all frequencies. This overload must be 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% of the drive continuous rating to account for motor magnetizing current.
- Input surge protection.
- Input and output phase loss detection.
- Output short circuit protection.
- Programmable current limit.
- Remote drive reset contact.
- Minimum of 1,000:1 controllable constant torque speed range when in closed loop mode. Speed regulation will be 0.01% or better over the entire speed range.

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.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 conditions that will cause a drive shutdown fault are as follows:

- blown fuse;
- instantaneous overcurrent trip;
- DC bus overvoltage;
- DC bus undervoltage;
- excessive ambient drive heat sink over temperature;
- external fault input;

- internally diagnosed, control failure;
- motor thermal overload; and
- drive thermal overload.

The drives will employ modular PC board design for ease of troubleshooting. All connectors must be polarized type and clearly marked on both the connector and PC board to ensure proper connection.

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

- Remote versions for panel mount application.
- Large and easy to read 7 line x 21 character backlit display.
- Alternate function keys for shortcuts to common tasks.
- “Calculator-like” number pad for fast and easy data entry.
- Keyed control switches for local start, stop, speed, and direction.

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

Two drives, and east drive and a west drive, will be mounted in one NEMA 12 enclosure, with the redundant pair in another cabinet, for a total of four drives The enclosures will be equipped with ‘through-the-door’ disconnect switch to de-energize the drives incoming services. Fluorescent enclosure lights will come on when the enclosure door is opened. A fused duplex 120 VAC GFCI receptacle will be mounted in the enclosure for any operator auxiliary equipment, powered from an internal control transformer. External reactors, filters or other components will not be accepted. Only the dynamic braking resistors will be located outside of the enclosure.

The drives will be provided with heavy duty dynamic braking resistors capable of providing 100% braking on a continuous basis and 150% dynamic braking for 60 seconds. The resistors will be provided with NEMA 3R enclosures. Conductors between the resistors and the drives will be high temperature rated.

The drives will be Allen Bradley Powerflex 700 series or equivalent by ABB or Magenatek.

2.10. **Span Brakes.** Furnish and install four (4) 8 in. electrohydraulic thrustor type motor brakes and four (4) 19 in. electrohydraulic thrustor type machinery brakes as shown on the plans. The new motor and machinery brakes will act upon new brake wheels press fit onto the shafts of the new motors and existing secondary gearboxes, respectively as called out on the drawings. Furnish all brake wheels and brakes by a single brake manufacturer. Install and align the new brakes and new brake wheels is accordance with Bridge Machinery Work.

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. Provide type MBT/E brakes by Mondel Engineering, Mississauga, Ontario, Canada, or engineer approved equal.

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.) Provide each hand release with a lever type limit switch for interlocking purposes as described under "Interlocking." It will not be possible to set the hand release of the brakes without tripping these switches. Switches will be 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. One will indicate 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 normally open contacts) trips when the brake is electrically released or hand released. The brake set limit switch will have one normally open and one normally closed contact and will trip

when the brake is fully set. Switches will be Cutler-Hammer Series E50, NEMA 6P+ with epoxy potted cord sets or approved equal.

Each thrustor actuator will be 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. Adjustment must be infinitely adjustable between the minimum and maximum settings. These adjustments must be allowable with the brake in full service. Set the down-stroke time delays of the thrustors in such a manner that the brakes will not be 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.

Provide 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°F and 150°F.

Provide 480V, 3-phase, 60 Hz, totally enclosed, squirrel cage motors controlled by magnetic contactors with manual-reset thermal overload relays to actuate the thrustors. The rated stalled thrust of each thrustor will be not less than 135% of the thrust actually required to release the brake with the torque adjusted to the continuous rated value. Each brake thrustor will be provided with a 120 VAC single phase anti-condensation space heater.

All exposed ferrous material will be treated with a nitro-carburizing process. This process will improve wear resistance, lower the coefficient of friction and greatly reduce the tendency to weld or seize with a metallic counterpart. It will also vastly improve corrosion resistance properties. The nitriting process will produce a thick E-Nitrite layer of at least 12μm. Painting and other finishes are not an acceptable replacement for Nitriting.

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.

2.11. **Programmable Logic Controller System (PLC).**

2.11.1. **General.** Bridge control logic functions will be performed by a Programmable Automation Controller system, which will provide for operation of the bridge and its auxiliaries in accordance with the system functioning specified herein and the control logic shown on the Plans. It will be programmed to provide for dynamic span drive motor drive skew correction, keeping the span skew within less than 6 in.

The Programmable Automation Controller will be an Allen Bradley (AB) ControlLogix brand PLC with components, hardware and remote input/output drops, or engineer approved equal by Siemens or Schneider. The PLC will be of modular construction, provide high-speed peer-to-peer networking, and be programmable with ladder logic.

The PLC system will consist of redundant 1756-L55M23 or equivalent CPU's. Only one CPU will be in use at a time, and the other CPU will be offline and de-energized. A selector switch mounted on the control console will select the CPU in use.

Modules are defined herein as devices that plug into a chassis and are keyed to allow installation in only one direction. The design must prohibit upside down insertion of the modules as well as safeguard against the insertion of a module into the wrong slot or chassis via an electronic method for identifying a module. Electronic keying performs an electronic check to insure that the physical module is consistent with what was configured. The Programmable Automation Controller will have downward compatibility whereby all new module designs can be interchanged with all similar modules in an effort to reduce obsolescence. The Programmable Automation Controller will have the ability to be updated electronically to interface with new modules.

All hardware of the Programmable Automation Controller will operate at an ambient temperature of 32°F to 140°F, with an ambient temperature rating for storage of - 40°F to 185°F. The Programmable Automation

Controller hardware will function continuously in the relative humidity range of 5% to 95% with no condensation. The Programmable Automation Controller system will be described and tested to operate in a high electrical noise environment.

The Programmable Automation Controller will have the capability of addressing over 100,000 discrete points or 4000 analog points. It will also have the ability to communicate with up to 500 connections that contain I/O. Each input and output module will be self-contained and housed within a chassis. These chassis, with their respective modules, will contain up to 512 (16 modules x 32 pts/module, using a 17 slot chassis) unique points. The Programmable Automation Controller will include as an optional feature the capability of addressing remote input and output modules on ControlNet, DeviceNet, EtherNet/IP, "RIO," HART and Foundation Field Bus.

The Programmable Automation Controller will use multiple independent, asynchronous scans. These concurrent scans will be designated for processing of input and output information, program logic, and background processing of other Controller functions. Input and output devices located in the same backplane (local I/O) as the CPU will produce at the rate of the configured RPI (Requested Packet Interval), and for discrete input modules enabled for Change of State (COS), at the time any point changes state.

The Programmable Automation Controller will have the ability to communicate with multiple remote I/O racks or devices configured with multiple I/O modules. Networks that allow remote I/O include "Remote I/O," ControlNet, EtherNet/IP, DeviceNet, HART, and Foundation Field Bus. It will be possible to communicate with remote I/O racks or other PACs via fiber optic cable by inserting fiber optic converters into the links. The fiber link must support distances up to 82,000 cable feet. Redundant fiber optic cabling will be an option.

The Programmable Automation Controller will have the ability to support multiple data communications networks in the same chassis by using DH+, DH-485, HART, ControlNet, DeviceNet, Ethernet/IP, Programmable Multi-Vendor Interface (RS232) modules, as well as other commonly used networks.

The Programmable Automation Controller will have one dedicated 9-Pin D-shell serial port, which supports RS-232-C signals at baud rates from 110bps to 38.4Kbps or a Universal Serial Bus Type B port (USB 2.0) communicating at 12mb/sec The 9-Pin serial port will be accessible in control logic and provide support for DF1 Master, DF1 Point to point, DF1 Slave, DF1 Radio Modem, Modbus Master/Slave, DH-485 (messaging only) and ASCII Read/Write communication protocols. The USB port is a device only programming port. Both RS-232 and USB ports must be usable for programming and data monitoring purposes.

2.11.2. **Controller Hardware.** The CPU will be a self-contained unit, and will provide control program execution and support remote or local programming. This device will also supply I/O scanning and inter-Controller and peripheral communication functions. The operating system firmware will be contained in non-volatile memory. An option will be possible to store both the user program and system firmware in a removable non-volatile memory for backup/restore purposes. The operating system firmware can be updated via a separate software update tool to allow for easy field updates. The Controllers will allow the operating system to be updated using a suitably configured removable non-volatile memory card. The Controller will contain a minimum of 4 Mbytes of user memory.

In a single chassis system all system and signal power to the Controller and support modules will be distributed on a single backplane. No interconnecting wiring between these modules via plug-terminated jumpers will be acceptable.

The CPU within the system will perform internal diagnostic checking and give visual indication to the user by illuminating a "green" (OK) indicator when no fault is detected and a "red" (OK) indicator (Blinking or Solid) when a fault is detected or by way of a display screen scrolling an error code and message. The front panel on the Controller will include color LED indicators or 4-digit display showing the following status information:

- Program or Run mode of the Controller;
- The fault status of the Controller;
- I/O status;
- RS-232 or Secure Digital (SD) activity;

- Battery or Energy storage module (ESM) status; and
- Force LED.

The front panel of the Controller will include a mounted keyswitch. The key will select the following Controller modes: RUN – No control logic edits possible, program always executing; PROGRAM – Programming allowed, program execution disabled; and REMOTE – Programming terminal can make edits and change Controller mode, including test mode, whereby the logic executes and inputs are monitored, but edits are not permanently active unless assembled. The front panel of the Controller will include a holder and a connector for a lithium battery or an energy storage module to provide power backup for user programs and data when the main power supply is not available. The front panel of the Controller will include a 9-pin D-shell serial RS232 port or USB port, to support upload and download, online edits, firmware upgrades, and bridging to other modules in the same chassis.

All system modules, local and remote chassis will be designed to provide for free airflow convection cooling. No internal fans or other means of cooling, except heat sinks, will be permitted. All system modules including the Controller may be removed from the chassis or inserted in to the chassis while power is being supplied to the chassis without faulting the Controller or damaging the modules. This is known as Removal and Insertion Under Power (RIUP). Alternately a software configurable option will exist to fault the Controller if required.

2.11.3. **Power Supplies.** The Programmable Automation Controller will operate in compliance with an electrical service of 85 to 265 VAC (120 to 220 VAC nominal), single phase, in the frequency range from 47 to 63 Hz, or 18-32 VDC (24 VDC nominal).

A single main power supply will have the capability of supplying power to the CPU and local input/output modules. Other power supplies will provide power to remotely located racks. The power supply will automatically shut down the Programmable Automation Controller system whenever its output power is detected as exceeding 125% of its rated power. The power supply will monitor the incoming line voltage for proper levels. When the power supply is wired to utilize AC input, the system will function properly within the range of 85 to 265 VAC. When the power supply is wired to utilize DC input, the system will function properly within the range of 18 to 32 VDC. The power supply will provide surge protection, isolation, and outage carry-over of up to 6 cycles of the AC line (120-240 VAC, 50/60 Hz) or 40 ms @ 24 VDC. Design features of the Programmable Automation Controller power supply will include a diagnostic indicator mounted in a position to be easily viewed by the user. This indicator will provide the operator with the status of the DC power applied to the backplane. In addition, a means of disabling power to the CPU will be possible from a power disconnect switch mounted in a position easily accessible by the operator. At the time of power-up, the power supply will inhibit operation of the Controller and I/O modules until the DC voltages of the backplane are within specifications. In addition to the electronic protection described above the power supply will offer a failsafe fuse that is not accessible by the user.

2.11.4. **Program Creation and Storage.** Memory state will be selectable to allow for the most economical match to the intended application. It will be possible to upgrade to a Controller with a larger memory size simply by saving the program, upgrading the Controller and downloading the program to the new system without having to make any program changes. Memory will be backed up by either battery or energy storage module and are capable of retaining all stored program data through a power cycle. A low battery condition must be detectable in ladder logic, but will not automatically generate a major fault. A low energy condition will generate a minor fault and will be detectable in ladder logic.

The Controller will write all variable data to internal nonvolatile memory storage (Flash) during the power down cycle. The Controller will provide the capability to use commercially available, removable nonvolatile memory storage. The card will be available from the supplier as an industrial rated device suitable for use in the same environment as the Controller.

The Controller will have the ability to store the user program, Controller firmware and firmware for all other modules residing in the same chassis to the removable nonvolatile memory card. Additionally when memory is restored a user selectable option to be restored in Run mode or Program mode will be provided. The Controller will have the capability to insure, that if required modules in the chassis are flashed using the firmware files stored on the removable nonvolatile memory card, to the correct revision level for the project.

The removable nonvolatile memory card will support a Windows file system allowing multiple files to be stored on the card. The user can manually trigger the Controller to save or load from the card and also configure the Controller to load from the card on power up. The operator should be able to backup volatile memory, including data and program logic onto a personal computer storage device.

All user memory in the Controller not used for program storage will be allocable from main memory for the purpose of data storage. The Programmable Automation Controller system will be capable of storing 4 data types:

- Predefined;
- User-defined;
- Module-defined;
- Add-on defined.

Pre-defined data types include the following: alarm, axis, bool, cam, cam-profile, control, coordinate system, counter, etc. User-defined data is limited to structures. Each structure contains one or more data definitions called members. Object includes a structure for each I/O module and system or module specific information (hidden from user). Add-on defined data type includes the Local and Parameter tags of the add-on instruction. It does not include the logic. Any data can be displayed in ASCII, Binary, Octal, Hexadecimal, or Decimal radices. Function-specific data types such as PID, Axis, Axis Group or Message will have dedicated displays available annotating the meaning of specific control bits and words within them and allowing for selective control where appropriate.

If instructions or entire rungs are intentionally deleted from an existing logic program, the remaining program will be automatically repositioned to fill this void. Whenever contacts or entire rungs are intentionally inserted into an existing program, the original program will automatically be repositioned to accommodate the enlarged program. All rung comments will maintain their original links.

The number of times a normally open (N.O.) and/or normally closed (N.C.) contact of an internal output can be programmed will be limited only by the memory state to store these instructions. The number of times a timer or counter can be programmed will be limited only by the memory state to store these instructions. Controller programs will have immediate access to the sub elements of control structures by address and sub element mnemonic, such as timer accumulator value, timer done bit, or PID Process Variable value.

2.11.5. **Interfacing and Peripherals.** The programming software will be on a Windows based workstation. The workstation will have the capability to be remotely located a maximum of 10,000 cable feet from the Controller over DH+ at 57.6 K-Baud or a maximum of 3280 cable feet from the Controller over ControlNet. The workstation will also be able to connect via Ethernet or RS232 for remote access.

The Programmable Controller system will be able to interface with a data terminal, which is RS-232-C compatible (up to 38400 baud) or via USB 2.0 @ 12 mb/s to generate hard copy messages. The system will have the capability to interface to a floppy disk, CD-ROM, DVD and/or a hard disk for loading a user program into, or recording the contents of, the Controller's memory. It will be possible to load or record the entire contents of memory.

2.11.6. **Communication Interfaces.** The Programmable Automation Controller will have communication interface modules for Ethernet/IP, ControlNet, DeviceNet, DH+, DH-485, Remote I/O (RIO), and RS232, HART and foundation field bus.

The Ethernet/IP interface will support the following:

- Standard TCP/IP communications;
- Standard Ethernet media (10base2, 10base5, 10baseT, 100baseT, fiber);
- CSMA/CD access method;
- Subnet masking;
- Standard repeaters, bridges, routers, host computers, peer PLCs;
- RJ-45;

- Bootp client;
- Manual configuration using RSLogix5000, RSLinx, or BootP/DHCP Servers;
- Programmable Controller messaging to peer Controllers and workstations;
- I/O Control;
- Device Level Ring (DLR); and
- CIP Motion (Motion over Ethernet/ IP).

The Ethernet/IP interface will support bridging between Ethernet/IP links within a ControlLogix chassis. The Ethernet/IP interface will support bridging to ControlNet, DH+, DH-485, DeviceNet, and other Controllers. Bridging allows for configuration (program up/download) and data collection.

The DH/RIO interface will support the following:

- Two channels of communications;
- Each channel independently configurable for DH+ or RIO;
- DH+ baud rate will be 57.6, 115, 230 Kbaud;
- DH+ will support routing tables;
- RIO baud rates will be 57.6, 115.2, 230.4 KBaud;
- Message error checking;
- Retries of unacknowledged messages; and
- Diagnostic checks on other stations.

The DH+ interface will support bridging to/from ControlNet, EtherNet and DeviceNet.

2.11.7. **Programming.** The programming format will be IEC 1131-3 compliant Ladder Diagram (LD), Function Block Diagram (FBD), Sequential Function Chart (SFC), and Structured Text (ST) languages. The Controller will organize user applications as Tasks, which can be specified as continuous, periodic, or event based.

Periodic tasks will run via an interrupt at a user-defined interval in one microsecond increments from 1 millisecond to 2000 seconds. The interrupt mechanism of periodic and event tasks will adhere to the IEC 1131-3 definition of pre-emptive multitasking. The Controller will be able to accommodate a maximum of 32 individual tasks of which one can be continuous. The periodic and event tasks will have an associated, user assignable priority from one to fifteen (one being the highest priority), which specifies that task's relative execution priority in the multitasking hierarchy. The event task can be triggered by hardware events (an input point) or software events (event instruction). Each task will have a user settable watchdog timeout which is unique to that task. Each task can include a maximum of 100 programs, which can be prioritized for execution within the task. Each program can include routines programmed in LD, FBD, SFC, or ST languages. One of the routines can be specified as the main routine and one can be specified as an optional fault routine. All routines will be capable of being edited when on-line. The number of routines which can be contained in a program is limited only by memory.

Variables within the Controller will be referenced as unique, default or user defined tags. Tag naming convention will adhere to specifications in IEC 1131-2. Tags may be created off-line, on-line and at the same time the routine logic is entered. The system will have the capability to store user tags names in the Controller. Tags will be available to all tasks in the Controller (Controller Scoped) or limited in scope to the routines within a single program (Program Scoped) as defined by the user. Any tag will have the ability to be aliased by another tag, which is defined and has meaning to the user. The ability to program control logic via tags of the Programmable Automation Controller will exist.

It will be possible to program ladder diagram rungs with the following restrictions:

- Series instruction count limited only by user memory;
- Branch extensions limited only by user memory; and
- Branch nesting to six levels.

The capability will exist to interleave input and output instruction types on the same contiguous rung in the ladder diagram rungs. The capability will exist to change a contact from normally open to normally closed, add instructions, change referenced tags, etc. It will not be necessary to delete and reprogram the entire ladder diagram rung. It will be possible to insert ladder diagram rungs anywhere in the program, even between existing rungs, insofar as there is sufficient memory to accommodate these additions. A single program command or instruction will suffice to delete an individual ladder diagram rung from memory. It will not be necessary to delete the rung contact by contact. A clock/calendar feature will be included within the CPU. Access to the time and date will be from the programming terminal or user program.

Latch functions will be internal and programmable. The system will have the capability to address software timers and software counters in any combination and quantity up to the limit of available memory. All management of these instructions into memory will be handled by the CPU. Instructions will permit programming timers in the "ON" or "OFF" delay modes. Timer programming will also include the capability to interrupt timing without resetting the timers. Counters will be programmable using up-increment and down-increment. Timer instructions will have a time base of 1.0 ms. The timing range of each timer will be from 0 to 2,147,483,648 increments. It will be possible to program and display separately the timer's preset and accumulated values.

The Programmable Automation Controller will use a signed double integer format ranging from -2,147,483,648 to +2,147,483,648 for data storage of the counter preset and accumulated values.

The Programmable Automation Controller will store data in the following formats:

- Boolean values (0 or 1).
- Short Integer Numbers ranging from -128 to +127.
- Integer Numbers ranging from -32,768 to +32,767.
- Double Integer Numbers ranging from –2,147,483,648 to +2,147,483,647.
- Floating Point Numbers consisting of eight significant digits. For numbers larger than eight digits, the CPU will convert the number into exponential form with a range of plus/minus 1.1754944 E -38 to plus/minus 3.402823 E +38.
- Long Integer Numbers consisting of 64 bits.

The capability will exist to organize data in the form of User Defined Data Structures. All aforementioned data types, as well as others, can be used in such structures along with embedded arrays and other User Defined Structures.

The Programmable Automation Controller will have support for integer and floating point signed math functions consisting of addition, subtraction, multiplication, division, square root, negation, modulus, and absolute value. Trigonometric instructions supported must include Sine, Cosine, Tangent, Inverse Sine, Inverse Cosine, and Inverse Tangent. These instructions must fully support floating-point math. Additional floating point instructions supported must include Log 10, Natural Log, and Exponential. It will be possible to complete complex, combined calculations in a single instruction, such as flow totalizing or equations of the format ((A+((B-C)*D))/E).

File function instructions supported will also include Sort, Average and Standard Deviation. Value arrays will be limited in size only by the amount of available memory. Arrays will be configurable with one, two or three dimensions. The CPU will support indexed addressing of array elements. Array element manipulation instructions such "array copy" (COP), “array copy with data integrity” (CSP) and "array fill" (FLL), "array to array" (MOV), "element to array" (FAL), "array to element" (FAL), and "first in-first out" (FIFO) will be supported by the system. The four function and math instructions and instructions for performing "logical OR," "logical AND," "exclusive OR," and comparison instructions such as "less than," "greater than," and "equal to" will be included within the system. All instructions will execute on either single words or array elements.

For any module specifically associated with the Programmable Automation Controller, it will be possible to configure operation and query the current status of all channels through Controller scoped tags without any programming.

The system will contain instructions, which will construct word shift registers (SQI, SQO, and SQL). Additional instructions will be provided to construct synchronous bit shift registers (BSR and BSL).

The Programmable Automation Controller will have a jump instruction which will allow the programmer to jump over portions of the user program to a portion marked by a matching label instruction.

The Programmable Automation Controller will have an embedded motion planner capable of doing coarse motion planning for up to 100 axes. This planner must be the highest priority task of the Controller.

The Programmable Automation Controller will have a ladder diagram instruction interface to the motion planner which allows the user to request that the motion planner create and execute a specific motion profile. The profile can be changed dynamically through the ladder diagram program.

The Programmable Automation Controller will have the ability to provide a master system clock and the 1588 PTP v2 CIP Sync object to allow time synchronization and transport and routing of a system clock to the control system and motion axes in a local chassis or on an Ethernet/IP network.

It will be a function of the CPU to automatically manage all data types. For example, if a word stored in an Integer tag is transferred into a Floating Point tag, the CPU will convert the integer value into floating point prior to executing the transfer.

In applications requiring repeatable logic it will be possible to place such logic in a subroutine section. Instructions which call the subroutine and return to the main program will be included within the system. It will be possible to program several subroutines and define each subroutine by a unique program file designator. The Controller will support nesting of subroutines up to available stack at the moment of the call. It will be possible to pass selected values (parameters) to a subroutine before its execution. The number of these parameters is limited only by available memory. This allows the subroutine to perform mathematical or logical operations on the data and return the results to the main program upon completion. These subroutines will be accessed by jump-to-subroutine instructions.

The system will have the capability to enter rung comments above ladder diagram rungs. These comments may be entered at the same time the ladder logic is entered. The program will be fully commented.

The capability will exist for adding, removing, or modifying logic during program execution in routines of LD, FBD, SFC, and ST languages. When changes to logic are made or new logic is added it will be possible to test the edits of such logic before removal of the prior logic occurs. It will be possible to manually set (force) either on or off all hardwired discrete input or output points from the programming panel. It will also be possible to manually set (force) an analog input or output to a user specified value. Removal of these forced I/O points will be achieved either individually or totally through selected keystrokes. The programming terminal will be able to display forced I/O points.

A means to program a fault recovery routine will exist. When a major system fault (Controller Fault) occurs in the system, the Controller fault recovery routine will be executed and then the system will determine if the fault has been eliminated. If the fault is eliminated, program execution resumes. If the fault still exists, the system will shut down. The capability will exist for each program to have its own fault routine for program fault recovery. Each having the same features as the Controller based fault routine. An instruction will be available to give the control program diagnostic information, state control, and sequencing of a process simultaneously, while allowing the capability of user-friendly state programming techniques.

An instruction will be supported to incorporate closed loop control systems. The "proportional," "integral," and "derivative" elements will be accessible to the user in order to tune a closed loop system. This instruction must fully support floating-point math.

The system will support both bit and word level diagnostic instructions.

To facilitate conditional event detection programming, output instructions will include "one shot" instructions, which may be triggered on either low-to-high (rising) or high-to-low (falling) rung conditions. To facilitate debugging, an "always false" instruction will exist which may be utilized to temporarily inhibit the execution of control logic.

The Controller will support Master Control Reset (Relay) type functionality to selectively disable sections of logic.

The Controller will include direct support of FOR-NEXT loop constructions.

Controller files will have the ability to be exported and edited in L5k, (text) format or XML format.

UPS: Furnish and install a UPS unit. The UPS will be rated for 1 KVA (minimum). The UPS will be rated to provide power for 20 minutes at half load and 10 minutes at full load. Provide UPS sizing calculations for engineer approval. The UPS will be rated for 120 VAC input and 120 VAC output. The UPS output will be a sine wave with less than 3% distortion. The UPS unit will provide automatic bypass and an audible alarm upon UPS failure. The UPS will have provisions for hardwired connections.

2.12. **Noise Filter.** Furnish and install one active tracking noise filter on the input of each PLC rack. The noise filter will be a series connected high frequency noise filter with transient protection. It will offer hard wired connection to all critical loads and rated for an industrial environment and equipment. It will reduce mode transient to +/- 2 V, have a surge capacity of 45,000 amps, provide transient protection in all modes (line to neutral, line to ground, and neutral to ground), have an LED power indication, and be UL approved. The 120 VAC MCOV will be rated 150 VRMS. The line frequency response time will be less than 0.5 nano-seconds. The operating temperature will be –40°F to 115°F at full load. The unit will be capable of protecting against a peak surge current of 15,000 amps in all modes.

2.13. **Laptop Computer.** A laptop computer will be provided to allow the PLC and vector drive programs to be modified as required in the future. The laptop computer will be a Panasonic Touchbook with touchscreen or engineer approved equal. It will have the following features at a minimum:

- 3rd gen Intel® Core™ i7-3520M Processor (2.9 GHz, 4M cache, Upgradable to Intel® vPro™ technology)
- Windows 7 Professional, No Media, 64-bit, English
- 14.0 in. HD (1366x768) Anti Glare LED-backlit
- 4 GB2 DDR3 SDRAM at 1600 MHz
- 500 GB 7200 RPM Hard Drive
- 8X DVD
- Express Card
- 1 Yr. Basic Hardware Service with 1 Yr. NBD Limited Onsite Service After Remote Diagnosis Nylon Carrying Case
- 1 Yr. Ltd Hardware Warranty
- The unit will be an intelligent terminal, functioning both as a programming and a data terminal. It will permit PLC programming, including loading, editing, and monitoring ladder diagram programs in memory by entering through the keyboard and monitoring on the display. Program instructions will be in the form of standard symbols similar to those used for electromagnetic control equipment.
- The laptop will have the latest editions of Microsoft Word and Excel preinstalled, along with software packages required for programming, viewing, and interfacing and any other software tools required for the PLC and vector drives. Include all CD-ROM’s, manuals and other materials. Provide all licenses and original CD-ROM or Disk copies with the computer for all software installed.

2.14. **Ethernet Absolute Position Encoders.** The absolute position encoders will provide absolute feedback for position control and high resolution incremental feedback for speed control. They will be dual port Ethernet encoders including an embedded Ethernet/IP switch to connect additional E/IP capable product in series and/or support a Device Level Ring (DLR) for Ethernet media redundancy. They will be designed for high performance and reliability in harsh industrial environments providing high resolution absolute positioning. They will be provided with multi-turn 30 bit resolution.

They will feature:

- EtherNet/IP Interface;
- Embedded switch;
- Hardware/software IP address setting;
- Resolution up to 30 bits;
- Protection class up to IP67;
- Device Level Ring (DLR);
- Revolution divisor;
- Solid shaft as per the mechanical drawings;
- M12 Connectors;
- Status indication LEDs; and
- RSLogix 5000 Add-On-Profile.

The following parameters will be Configurable:

- Counting direction;
- Counts per revolution;
- Preset value;
- Velocity unit;
- IP address; and
- Counts of revolution.

The encoders will be Allen Bradley model 842E, Sick model AFM60 or Engineer approved equal.

2.15. **Limit Switches.**

2.15.1. **Rotary Type Limit Switches.** Furnish and install six (6) rotary cam limit switches for span position, barrier gate position and span lock position on the machinery platforms where indicated on the Plans. Each limit switch will be a rotary, cam-operated limit switch in a NEMA 4X enclosure and will be coupled to the operating machinery as shown on the drawings, which will rotate the input shaft.

The switch contacts will have a minimum AC inductive continuous current carrying rating of 15 A and a minimum DC resistive continuous current carrying rating of 15 A. They will be UL and CSA listed.

The limit switches will have circuits individually micro-adjustable and provisions for internal vernier adjustments. The number of contacts will be as shown on the plans. The limit switch will allow for a + or - 1/4 degree contact operation repeatability. Each contact of the limit switch will be SPDT precision-type, snap-action switches.

Provide Gemco 1980 series with contacts as shown on the plans, adjustable input couplings, 3:1 straight gearboxes for span position and span lock limit switches and NEMA 4X stainless steel enclosure or approved equal, and they will be driven as shown on the plans furnished with the operating machinery.

2.15.2. **Motor Brake and Machinery Brake Lever Type Limit Switches.** Each limit switch will be a heavy-duty, lever-operated, submersible, two-circuit, snap-action limit switch in a watertight, NEMA 6P, epoxy-sealed enclosure with epoxy sealed SOOW cord set. The switches will be Cutler-Hammer E-50 6P+ or approved equal.

Span Seated and Span Lock Interlocking Proximity Type Limit Switches. Lever-less mechanical limit switches (12) will be provided for span seated and span lock indication and interlocking. They will be enclosed in a stainless steel housing rated NEMA 4X and 6P. They will be provided with single pole, double throw contacts end sensing contacts rated for 10 amperes. The contacts will be silver cadmium oxide, gold flashed, and will have a temperature rating of -40°F to 221°F. They will have a repeatability of 0.002 in., and a response time of 8ms. They will be provided with 6 ft. epoxy potted cordsets. They will have a nominal sensing distance of 1/4 in., and will be provided with a magnetic sensor that will provide for a 3/4 in. sensing distance. The lever-less limit switches will be Model 81 GO switch with model AMP3 magnetic target as manufactured by Topworx or engineer approved equal.

2.16. **Encoder Buffers.** The encoder buffer will accept 4-26 VDC signals and provide two independent and completely isolated line driver outputs of 5-26 VDC based on user defined voltage levels. It will be provided with optically isolated inputs that accept quadrature or single channel inputs, with or without their complements, from differential line drivers, open collector, or from proximity probes. The encoder buffer will also have the ability to repeat and amplify signals. Each output of the encoder buffer will be user definable from 5 to 26 VDC. In addition to having short circuit protection, outputs will be ESD protected according to MIL-STD-883. Each connector of the encoder buffer will be equipped with two positions for +VCC and common, as well as two extra field accessible tie points. The encoder buffer will be capable of driving the output signal up to 26 VDC, and will function with either output disconnected.

2.16.1. Provide model RIM SS2 encoder buffers as manufactured by Dynapar or engineer approved equal with the following standard operating characteristics:

- Input Signal: 2 or 3 channel quadrature signal, sine or square wave, open collector, differential, or single ended line driver.
- Input Signal Current: 2.2 mA minimum, 3.5 mA typical.
- Input Impedance: Optically isolated, 1 kOhm at 4 V, 6.8 kOhms at 24 V typical. Current limited.
- Frequency Range: 0 - 120 kHz.
- Output Signal: Two independent, isolated line driver output sets (A/A, B/B).
- Supply Voltage: 5 - 26 VDC.
- Output Current: 150 mA (maximum per channel).
- Wire Gauge Accepted: 26 -16 AWG.
- Environmental range: 32°F to 122°F at 98% RH non-condensing.

2.17. **Deceleration Check Speed Switches.** The electronic speed switches will be rotation monitoring systems with two adjustable set points designed to detect unwanted over speed, under speed or stoppage in motors. In the event of rotational failure, the relays can be used for equipment shutdown and to provide an alarm. The sensor receives a pulse output from a motor encoder buffer and measures this frequency signal to determine shaft speed, and compares this to the pre-adjusted set point. The relay output can then be used for equipment shutdown or to provide an alarm, assuring machine protection and process integrity. The sensor will be fail-safe; any malfunction during operation will de-energize the control circuit.

Provide a model LRB 2000 sensor specifically ordered with no start delay loss of feedback as manufactured by Electro-Sensors or engineer approved equal with the following characteristics:

- Housing and Cover NEMA1, Approved to UL 508 and CSAC 22.2 #14-95 Standards;
- Stand-Alone Mounting;
- Input Power 115 VAC, 60 Hz;
- Sensor Input Signal Type NPN Open Collector, Amplitude 5 VDC, Pull-Up 4.7 KOhms, max Frequency Range 0-666.67 Hz;
- Under or Over Speed Set Point Relays Two form C, SPDT isolated 5 A 115 V AC resistive; and
- Set Point Adjustment Rotary Switches: (1) tens and (1) ones digit.

2.18. **Motor Control Center.** The Motor Control Center (MCC) will 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.

The MCC will be constructed to meet or exceed the requirements within NEMA ICS-2 and UL845 for motor control centers. The MCC 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 Motor Control Center will be 600 V class suitable for operation on a three-phase, 60 Hz system. The system operating voltage and number of wires will be as indicated on the Plans.

The MCC will consist of one or more vertical sections of heavy gauge steel bolted together to form a rigid, free-standing assembly, as shown on the Plans. The entire assembly will be constructed and packaged to withstand all stresses included in transit and during installation. MCC will be delivered in individually wrapped factory fabricated fiberboard type containers, with lifting angles mounted on each supporting structure. MCC will be handled with care to prevent internal component damage, and denting or scoring of enclosure finish. The Contractor will not install damaged MCC.

Structures will be totally enclosed dead-front, free-standing assemblies. They will be no more than 90 in. high and 20 in. deep. Structures will contain a horizontal wireway at the top, isolated from the horizontal bus and will be readily accessible through a hinged cover. Adequate space for conduit and wiring to enter the top or bottom will be provided without structural interference.

Structures will be capable of being bolted together to form a single assembly. The total width of one section will be 20 in.. Widths of 25 in., 30 in., and 35 in. can be used for larger devices.

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

A vertical wireway with minimum of 35 in. square of cross-sectional area will be adjacent to each vertical unit and will be covered by a hinged door. Wireways will contain steel rod cable supports.

All full voltage starter units will be of the drawout type. Drawout provisions will include a positive guide rail system and stab shrouds to absolutely ensure alignment of stabs with the vertical bus. Drawout units will have a tin-plated stab assembly for connection to the vertical bus. No wiring to these stabs will extend into the bus compartment. Interior of all units will be painted white for increased visibility. Units will be equipped with side-mounted, positive latch pull-apart type control terminal blocks rated 600 V. Knockouts will be provided for the addition of future terminal blocks. All control wire to be 14 AWG SIS type.

All drawout units will be secured by a fastening device located at the front of the unit. Each unit compartment will be provided with an individual front door.

An operating mechanism will be mounted on the primary disconnect of each starter unit. It will be mechanically interlocked with the unit door to prevent access unless the disconnect is in the OFF position. A defeater will be provided to bypass this interlock. With the door open, an interlock will be provided to prevent inadvertent closing of the disconnect. A second interlock will be provided to prevent removal or reinsertion of the unit while in the ON position. Padlocking facilities will be provided to positively lock the disconnect in the OFF position with from one (1) to three (3) padlocks with the door open or closed. In addition, means will be provided to padlock the unit in a partially withdrawn position with the stabs free of the vertical bus.

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

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

Buses will be braced for minimum 42,000 amperes rms symmetrical.

A copper ground bus will be furnished firmly secured to each vertical section structure and will extend the entire length of the MCC.

Each structure will contain tin plated vertical ground bus rated 300 amperes. The vertical ground bus will be directly connected to the horizontal ground bus via a tin-plated copper connector. Units will connect to the vertical bus via a tin-plated copper stab.

All combination starters will utilize a unit disconnect. Magnetic starters will be equipped with double-break silver alloy contacts. Each starter will have minimum one (1) NO auxiliary contact or as indicated on the plans. All coils to be color-coded through size 5 and permanently marked with voltage, frequency and part number.

All starters will be provided with overload relays. Overload relays will be an ambient compensated bimetallic-type with interchangeable heaters, calibrated for 1.0 and 1.15 service factor motors. Electrically isolated NO and NC contacts will be provided on the relay. Visual trip indication will be standard. A test trip feature will be provided for ease of troubleshooting and will be conveniently operable without removing components or the motor starter. Overload to have (+/-) 24% adjustability, single-phase sensitivity, and isolated alarm contact. Overload relays will have manual reset.

The disconnect will include an electrical interlock for disconnection of externally powered control circuits.

Auxiliary control circuit interlocks will be provided where indicated. Auxiliary interlocks will be field convertible to normally open or normally closed operation.

Minimum starter and contactor size will be NEMA Size 1, except for brakes which will be NEMA size 00.

Motor starters and contactors will be Cutler-Hammer Freedom Series, Square D type S series, or Engineer approved equal.

Motor starters and contactors will be designed to accommodate two (2) auxiliary contact blocks, each capable of a combination of up to four (4) normally closed or four (4) normally open auxiliary contacts. Contacts to be color-coded; black designating NC and silver designating NO. Contacts to be rated ten (10) amperes continuous, 7200 VA make, 720 VA break for 120 through 600V AC, and 69 VA make and break for 125 through 300V DC. Provide a minimum of one (1) spare NO contact and one (1) spare NC contact in addition to any auxiliary contacts required.

Provide 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.

Control transformers where used will be high voltage regulation type, low temperature rise, rated 480/120VAC. Each transformer will have a cover to prevent accidental contact with the energized components. The transformer will be de-energized when the unit operator handle is in the off position.

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

Motor starter cubicles for gates, locks and brakes will be provided with keyed selector switches for PLC/Local operation and keyed spring return switches for local operation. Warning placards will be provided indicating that local control bypasses all control system interlocks and door switch/MOI safety interlocks.

The MCC will contain the lighting transformer and lighting panel as specified elsewhere.

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

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

- Physical Inspection of: structure, electrical conductors, including bussing, general wiring, and units.
- General electrical tests including power circuit phasing, control circuit wiring, instrument transformers, ground fault system, device electrical operation.
- AC dielectric tests of power circuits and control circuits.
- Markings/Labels verification, including instructional type, Underwriters Laboratory (UL), and inspector's stamps.
- The manufacturer will use integral quality control checks throughout the manufacturing process to ensure that the MCC meets operating specifications.
- MCC will be Cutler-Hammer Freedom & Advantage series, Square D Model 6 series, Allen-Bradley or Engineer approved equal.

2.19. **Control Apparatus and Miscellaneous Equipment**

2.19.1. **General.** Control apparatus will conform to the applicable requirements of NEMA Publication No. ICS, latest revision, Industrial Control and Systems, rated as shown on the Plans or as required herein.

2.19.2. **Circuit Breakers.** All branch circuits from the power buses will be protected by molded-case circuit breakers mounted on the control panels. All breakers will have quick-make and quick-break contacts, and the mechanism will be trip-free and trip indicating. All circuit breakers and motor circuit protectors will be provided with at least two form C auxiliary contacts for PLC input and status indication. Frame sizes will not be less than 100 amperes. The breakers will be equipped 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 will meet the requirements of the latest revision of NEMA Publication No. AB1. The service entrance circuit breakers are to be 600 V rated, frame size as indicated on the plans and will be provided with electronic trip unit with independently adjustable short time pick-up and time delay, set to trip as per the plans. Interrupting capacity will be no less than 100,000 AIC. Circuit breakers will be Westinghouse Series C, Type LD with LS trip unit, Type TA or engineer approved equal manufactured by General Electric or Square D Company.

2.19.3. **Motor Starters and Magnetic Contactors.** The continuous current rating of contactors and starters will be adequate for the connected loads, and no starters will be smaller than NEMA Size 0 unless otherwise noted. All starters will be full voltage types, 600 VAC, 60 Hz, rated with 120 VAC operating coils. All contact poles will be provided with arc chutes, and contactors rated 150 amperes and above will be equipped with magnetic blowouts. Three-element manual reset overload relays will be provided to protect gate, lock and brake motors and wiring against overheating due to excessive current. Heater elements are to be selected based on motor full-load running current. Each overload relay will be provided with a set of auxiliary form C contacts for PLC interfacing and indication. Reversing contactors will be electrically and magnetically interlocked.

2.19.4. **Service Disconnect Switches.** Unfused safety switches, for use as disconnects, will be installed where shown on the plans. The switches will be nonfusible, heavy-duty, 600 VAC safety switches in watertight and dust-tight NEMA 4X, stainless-steel enclosures. Each disconnect will be furnished with two N.O. auxiliary contacts and phenolic name-plate to identify the switch. The rating will be as required and/or shown on the plans.

2.19.5. **Motor Disconnect Switches.** Unfused safety switches for use as disconnects, where required, will be installed within the range of view of its respective motor, brake, or span lock. The switches will be tag out lockable, non-fusible, heavy-duty, safety switches, rated as shown on the Plans, 30 ampere minimum, in waterproof, NEMA 4X, stainless steel enclosures. Each disconnect will be furnished with two N.O./N.C.

auxiliary contacts, one for the motor heater and one for PLC interlocking, and phenolic nameplate to identify corresponding motor.

2.19.6. **Control Relays.** Auxiliary control relays will be multi contact magnetic relays with contacts rated at 10 amperes, 600 V, on a continuous basis. Relays known to meet the specified requirements are the Square D class 8501 type X or approved equal.

2.19.7. **Phase Failure and Reversal Relay.** This relay will prevent energizing operating the span in the event of reversed phase sequence, loss of one phase, or low voltage. The phase failure and reversal relay will be the Square D Class 8430 Type MPD or approved equal.

2.19.8. **Selector Switches and Pushbuttons.** Pushbuttons and control switches will be heavy-duty, oil-tight, contact blocks operated by glove handle selector knobs, key switches and push-button operators as indicated on the Plans. Contacts will be fine silver, capable of interrupting 6 amperes at 120 V AC, and of continuously carrying 10 amperes. Switches and pushbuttons will be Square D class 9001, type K, NEMA 4 or approved equal.

2.19.9. **Indicating Lights.** Indicating will be heavy-duty, oil-tight pilot lights with one or two fields as required as per the plans. They will be provided with LED lamps the color of the lamp lens and will be rated at 120 VAC. Where group testing cannot be accomplished through the PLC the lights will be provided with a push to test feature. All lenses will be glass, with color and marking as shown on the Plans.

2.19.10. **Terminal Blocks.** Terminal blocks for conductors of Size No. 8 AWG and smaller will be stud and nut type one-piece blocks of phenolic or 257°F material recognized under the UL Component Recognition Program. Barriers will be not less than 1/2 in. high and 1/8 in. thick and will be spaced 5/8 in. center-to-center. Straps, studs and nuts will be of brass, nickel plated for use in highly corrosive atmospheres, and will be rated for 50 amperes for a terminated conductor. The blocks will provide a withstand voltage rating of 600 V per IEEE switchgear standards. The terminal blocks will provide studs and nuts suitable for use with flanged fork wire connectors. Corrosion resistant marking strips will be provided for conductor identification. At least 10% spare terminals will be provided. Terminal blocks will be Buchanan Type 2B112, General Electric Series CR 151B or Marathon 1500 Series or engineer approved equal.

2.19.11. **Terminal Connectors.** Terminal connectors will be seamless, heavy duty compression locking fork terminals manufactured from pure electrolytic copper tubing. Terminals will be tin plated and provided with a double-thick tongue and insulation grip. Terminals and compression tools must be approved by the engineer.

2.19.12. **Power Distribution Blocks.** Power distribution blocks for all conductors larger than No. 8 AWG, will be finger-safe, fabricated from copper and approved equal to Ferraz Shawmut FSPDB series, sized as required. Finger-safe fully insulated block will ensure that no one can touch live parts. They will be provided with recessed termination screws and wire openings providing IP20 grade protection and qualify as "finger-safe" per IEC 529, integral DIN rail adaptors allowing for quick and easy installations on 35mm DIN rail, and captive termination screws. Provide end anchors for rigid end stops.

2.19.13. **Nameplates.** Nameplates will be provided for all aforementioned devices and will be made of laminated phenolic plastic with white front and back and black core and will be not less than 0.09 in. thick. The lettering will be etched through the front layer to show black engraved letters on a white background. Lettering will be not less than 0.24 in. high, unless otherwise detailed on the Plans. Nameplates will be securely fastened to the equipment with stainless steel screws.

2.20. **Step Down Transformer.** Provide open dry type transformers for lighting circuits designed according to the latest revision of NEMA ST-20 within the MCC. Ratings for the transformers will be as shown on the plans. Provide transformers designed for continuous operation at rated KVA, 24 hr. a day, 365 days a yr. Required performance must be obtained without exceeding 150°C average temperature rise by resistance or 180°C hot spot temperature rise in a 40°C maximum ambient and 30°C average ambient. Maximum coil hot spot temperature will not exceed 220°C. Transformers will be equipped with solid copper cores.

2.21. **Bridge Control Cabinets.** Control panels enclosed in freestanding cabinets will be furnished and installed in the operator house and machinery spaces where shown on the Plans. All circuit breakers, UPS, PLC racks, switches, contactors, relays, regulating equipment, and other apparatus for control of the span and its auxiliaries will be mounted on these enclosed panels. The arrangement and line-up of the individual control cabinets will be as shown on the Plans.

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

Each indoor control cabinet will be a NEMA Type 12 enclosure constructed of No. 12 gauge sheet-steel and will be reinforced with steel angles or channels to provide a rigid, freestanding structure. Exterior control cabinets will be NEMA 4X or NEMA 12 stainless steel. The control cabinets will be provided with hinged doors on the front of each panel section. Door panels will be gasketed and will be provided with three-point, vault-type latches. Drive and control panels will be provided with fan and filter ventilation. All hardware will be corrosion resistant. Thermostatically controlled strip heaters will be provided in each cabinet to prevent build-up of excess moisture. Each panel will be provided with suitable interior light fixtures and a duplex receptacle.

Each control panel enclosure will be 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, such rearrangement or modifications will be made and at no extra cost. The final arrangement of all equipment in the operator house will be subject to the approval of the engineer.

The indoor control panel enclosures and all metal reinforcing will be 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. The finish coat will be ANSI 61 light gray enamel.

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

All wire will be flame-retardant, ethylene-propylene insulated, switchboard wire, Type SIS. Conductors will be stranded copper not smaller than No. 14 American Wire Gauge.

For each assembled control panel, all outgoing wire, No. 8 AWG or smaller, will be connected to terminal blocks installed at the sides of the cabinet. The control panels will 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. Spare terminals totaling at least 10% of those actually used will be provided. Each terminal will be identified per wire number shown on the Contractor's schematic wiring diagrams.

All panel wiring will be arranged systematically so that circuits can be readily traced. The wiring will be installed in a network of troughs consisting of horizontal and vertical sections securely bolted to the panels. The troughs will be fabricated from heavy duty Noryl plastic shaped into a channel cross-section. After installation of the wiring, an insulated, flanged cover will be snapped over the open side of each trough section.

2.22. **Raceways**. Except for multi conductor, jacketed cables, all wiring will be installed in conduit or stainless steel wireway as shown in the Plans.

Within the electrical rooms the Contractor will have the option of using cable trays and tray cable. This installation will be detailed by the Contractor and submitted for review by the Engineer.

All conduits will be standard weight, threaded, rigid steel conduit conforming to the requirements of ANSI Standard C80.1. All conduits will be hot-dip galvanized, inside and out, to meet the requirements of the above standard for protective coating. Conduit couplings and fittings will be made of malleable iron or steel, hot-dip galvanized. Electro-Metallic Tubing (EMT) may be used in the control house where approved by the Engineer.

All conduits to be installed in outdoor locations will be plastic coated as hereinafter specified. Conduit fittings, including couplings, unions, elbows, expansion and deflection fittings, and other items, will also be plastic coated. Conduits and fittings, which are to be plastic coated, will be provided with a factory-applied polyvinyl chloride (PVC) coating in the following manner. The exterior of the galvanized rigid steel conduit or fitting will be coated with an epoxy acrylic, heat-polymerizing adhesive not to exceed 0.004 in. A 40 mil PVC plastic coating thick will be bonded to the outside metal surface the full length of the pipe, except for the threads. The plastic coating will 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 or 25 September, 1952. A two-part red urethane, chemically cured coat will be applied to the interior of all conduit and fittings. This internal coating will be at the nominal 2-mil thickness and will be sufficiently flexible to permit field bending without cracking or flaking. The Plasti-bond, PVC coated, hot-dip galvanized steel conduit will be UL labeled and listed.

All hollow conduit and fittings, which serve as part of the raceway, will be coated with the same exterior PVC coating and red interior urethane coating. The plastic exterior coating and the red interior urethane coating will be factory applied by the same manufacturer who produces the PVC coated hot-dip galvanized conduit. PVC coated conduit will be installed in accordance with the manufacturer's installation manual.

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

Conduits will not be less than 3/4 in. in diameter. The interior surfaces will have a smooth finish and be free of burrs or projections, which might cause injury to the cables. All conduits will be free from blisters, cracks, or injurious defects and will be reamed at each end after being threaded. Sections will be connected 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. Conduits will be installed to be continuous and watertight between boxes and equipment. Conduits will be 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.

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

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

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

Conduits and wireway will be securely clamped and supported at intervals not exceeding five feet in length.

Conduit and wireway runs exposed on the steel structure will be securely clamped to the steelwork. The conduit clamps, in general, will consist of U-bolts attached to structural steel supports bolted to the members. The wireway clamps, in general, will consist of manufacturer recommended stainless steel bracket hangers attached to structural steel supports bolted to the members. The wireway cover will be on the top or on the side of the wireway and be clear of opening obstructions. The minimum thickness of the structural supports will be 3/8 in. Supports will be arranged so that conduits and wireway 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 will not be permitted.

All U-bolts and bracket hangers will be provided with medium-series lock washers and hexagonal nuts. The bolts, nuts, and washers will be of stainless steel conforming to the requirements of the Standard Specification for Stainless and Heat-Resisting Steel Bars and Shapes, ASTM Designation A276, Type 316.

Where conduits and wireways are to be mounted exposed on non-steel surfaces, they will be 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 in. thick by 2 in. wide. Back plates will be of 3/8 in. thick steel. Supports and spacers will be hot-dip galvanized. Bolts will be not less than 1/2 in. diameter and will be of stainless steel conforming to the requirements specified for U-bolts.

At any point where a conduit crosses an expansion joint longitudinally or where move-ment between adjacent sections of conduit can be expected, conduit expansion fittings will be installed. The fittings will be bronze expansion fittings and will be provided with flexible bonding jumpers to maintain the electrical continuity across the joints. The fittings will permit a total conduit movement of 8 in. and will be 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 move-ment between adjacent sections of conduit can be expected, expansion and deflection fittings will be installed. The fittings will permit a movement of 3/4 in. from the normal in any direction. The fittings will be the O.Z./Gedney Type DX, Spring City Type EDF, Adalet Type STX, or engineer approved equal.

Flexible conduits for the connections between the rigid conduit system, all motors, and limit switches will be made with sections of PVC coated, flexible, metallic, liquid tight conduit. Each section will not exceed 18 in. without prior approval of the engineer.

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

All conduit, wireway, and fittings will be carefully examined before being installed, and all pieces having defects will be set aside and removed from the site. All conduit bends will be made with standard size conduit elbows. Conduit will be assembled hand tight and then using strap wrenches tightened two more turns. Wrench marks or chuck marks will be touched up with the appropriate touch-up compound. All cuttings and threading will be performed as recommended by the conduit manufacturer. All conduit, enclosures, and fittings will be mechanically joined together to form a continuous electrical conductor to provide effective electrical continuity.

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

All conduits will be pitched not less than 1 in. in 10 ft. (except by special permission). Where conduits cannot be drained to pull boxes, a drain "T" with drain fitting will be installed at the low point and drained to a dry well of broken stone. Drain fittings will be of stainless steel and will be capable of passing 1oz of water per minute.

The ends of all conduits projecting into boxes and equipment enclosures will be provided with bronze insulated grounding bushings. The insulated portion will be of molded phenolic compound, and each fitting

will have a screw type combination lug for bonding. Insulated bushings will be the O.Z./Gedney Type RBLG, Spring City Type GB, or engineer approved equal manufactured by Appleton. All bushings in any box or enclosure will be bonded together with No. 8 AWG bare copper wire. Where conduit hubs are provided use locking nuts with grounding terminals.

All conduits and wireway will be carefully cleaned both before and after installation. Upon completion of the conduit and box installation, clear each conduit by snaking with a steel band, to which will be attached an approved tube cleaner equipped with a mandrel of a diameter not less than 85% of the nominal inside diameter of the conduit and with a wire brush of the same diameter as the conduit, and will then draw in the cables.

Both ends of each conduit or wireway run will be provided with a brass tag having the same number stamped thereon in accordance with the conduit diagrams, and these tags will be securely fastened to the conduit ends with No. 20 AWG brass wire.

Separate conduits or wireways will be furnished and installed to carry the circuit wiring to all span driving motors.

All wireways will be 16 gauge 316 stainless steel bodies with covers and oil-resistant gasket and adhesive. The flanges will be 10-gauge stainless steel. Wireway fittings, nipples, and elbows will be 316 stainless steel. A solid oil-resistant gasket will be positioned between flanges when sections and fittings are bolted together.

Wireways will not be less than 6 in. x 6 in. The seams will be continuously welded and ground smooth. There will be no holes or knockouts. The edges on all sections and fittings will be smooth and rounded to prevent damage to cable and conductor insulation.

The wire way covers will have heavy butt hinges and external screw clamps to assure complete seal between covers, gaskets, and bodies.

When wireway enters an enclosure, a box connector will be used on the inside of the enclosure to ensure a tight and stable seal. Closure plates will 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 flexible wireway fittings will be installed. The fittings will be the wireway manufacturer’s recommended fitting.

All conduits projecting into boxes and equipment enclosures will be provided with water tight, weather proof, insulated throat conduit hubs. The conduit hubs will be approved equal to Meyers Watertight Rigid Conduit Hubs except for PVC coated conduit which will be provided with PVC hubs of the same manufacture as the conduits.

2.23. **Boxes.** All surface mounted pull, junction, and terminal boxes will be of type 316 stainless steel, and will be provided with full length hinged gasketed, covers held with stainless steel fast operating clamps to provide NEMA 4X watertight construction. They will be engineer approved equal to the Hoffman bulletin A4S or equivalent by Weiggman or Hammond.

Interior and exterior boxes will be provided with external mounting lugs and will be fastened in position with stainless steel through bolts. Conduit entries will be means of galvanized malleable iron hubs. PVC coated conduit will use PVC coated hubs. No box will be drilled for more conduits or cables than actually enter it. Exterior boxes will be provided with drain fittings of the same type as specified for conduit drains.

All boxes will be sized in accordance with the requirements of the National Electrical Code and the dimensions as shown on the Plans.

Terminal boxes will be 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. Interior mounting backpanels with tapped holes will be provided for mounting the terminal blocks.

2.24. **Hardware and Supports.** Supports for conduits, wireways, cables, boxes, cabinets, disconnect switches, small limit switches, and other separately mounted items of electrical equipment will be fabricated from stainless steel not less than 1/4 in. thick. All supporting members will be included under the electrical work.

Structural steel brackets, boxes, and other equipment mounted on concrete surfaces will be provided with a full neoprene gasket not less than 1/8 in. thick between the equipment and the surface of the concrete.

Expansion anchors for fastening equipment or brackets to concrete surfaces will be wedge type anchor bolts, which will be locked in place by an expansion wedge as the nut is tightened. All parts of the expansion anchors will be of Type 316 stainless steel. Holes for the anchors will be drilled to the size and depth recommended by the manufacturer using carbide tipped masonry drills.

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 will be of stainless steel conforming to the requirements of ASTM Designation A276, Type 316. Bolt heads and nuts will be hexagonal and will be provided with medium-series lock washers. Bolts smaller than 1/2 in. in diameter will not be used, 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 will not be acceptable without prior approval of the engineer.

Preformed metal framing channels, such as Kindorf, Unistrut, Superstrut, etc., will not be acceptable for mounting or supporting electrical equipment, conduits, or boxes except where specifically approved by the engineer.

2.25. **Wiring and Cables**

2.25.1. **General.** Except where otherwise noted, wiring in conduits will be single-conductor.

All wires and their insulation and covering will be of a nationally recognized brand, acceptable to the engineer, and will have marks always used on the particular brand for identifying it. All wiring will be purchased from a TXDOT appoved supplier as referenced under the State Standard Specifications for Roadway Illumination and Electrical Supplies.

All wiring and cables will conform to the requirements of NEMA Publication No. WC70-2000. 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 No. WC7. All materials used to fabricate insulated wiring and cables will be certified to be from stock not more than 1 yr. old.

All conductors will be of stranded copper large enough to carry safely the maximum currents required without injurious heating or serious voltage drop. Conductors will not be smaller than No. 12 AWG, except as approved for control panel and console wiring or for lighting fixtures. All conductors will be soft-annealed copper wire conforming to the requirements of NEMA Publication No. WC70. All conductors will have Class B concentric stranding, except for conductors in flexible cables.

The insulation will be a chemically cross-linked, polyethylene compound conforming to the requirements of Part 3.7 of NEMA Publication No. WC70. The thickness of insulation will be that required for 600 V rated circuit voltage listed under Column A of Table 3-1. Insulation type will be Type XHHW-2.

Equipment ground conductors will be bare, stranded, coated copper conforming to the requirements of NEMA Publication No. WC70, Part 2.

Single conductor wiring, including the insulating material, will be tested to demonstrate that it meets specified requirements. The testing will be done as stipulated in NEMA Publication No. WC70, Part 6. Wiring and cables will not be shipped 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 the minimum permissible. The Contractor will provide wiring and cables of sufficient size and number as may be required for the installation in accordance with the wiring diagrams on his approved working drawings. In each conduit and multi conductor cable containing ten or more conductors, at least one spare wire will be provided for every ten conductors actually used.

Wiring will not be installed in any conduit before all joints are made up tightly and the conduits rigidly secured in place. The drawing of cables into conduits will be done without injury to the wires or their insulation or covering. No lubricant of any kind will be used for the pulling of wires, unless specifically authorized by the engineer. Sufficient slack will be left in all cables to permit proper connections in boxes, cabinets, and enclosures.

Both ends of every single length of conductor will be permanently and clearly tagged in accordance with the same numbers or designations appearing on the approved wiring diagrams. Wire tags for marking the conductors will be heavy duty, heat shrink, water-proof, permanently marked, and resistant to ultraviolet light deterioration. Numbers and letters will be 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. Each conductor, except for control and instrument conductors, will be color coded with colored insulation. Color coding for 120/208 V conductors will be 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. Color coding for three phase 480 V conductors will be 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. Each conductor will be marked at panelboard gutters, pull boxes, outlet and junction boxes and each load connection and will include each branch circuit or feeder and control wire.

Conductors inside terminal boxes, the control console, and control panels will be neatly formed into cables and laced with approved cable ties, with the individual conductors leaving the cable at their respective terminal points. These conductors will be looped to allow not less than 3 in. of free conductor when disconnected. The formed cables will be held securely away from the terminals and from contact with the enclosure by means of approved insulating supports.

All outgoing wires, No. 8 AWG or smaller, in the control console and control panels and in terminal boxes will be connected to stud and nut style terminal blocks of molded phenolic compound. Terminals will be suitable for use with solderless, locking fork, wire connectors. Connectors which extend beyond the ends of terminal block barriers, will be furnished with an insulating sleeve covering the metal part of the connector. Taping of extended terminals will not be permitted.

Each terminal of all terminal blocks will be permanently marked to show the same number or designation as appears on the wire connected thereto.

Splicing of wires will not be permitted, except for wiring to service lighting fixtures and receptacles. Wherever it becomes necessary to joint or branch conductors, terminal blocks will be used, and wires will be clearly tagged.

Multi conductor cables supported on the steelwork will be secured thereto by bent plate cable clamps spaced not more than 3 ft on centers. The cable clamps will be fabricated from stainless steel plates bent to suit the cables' outside diameters. In general, the clamps will be fastened to structural brackets bolted to the steelwork.

Where multi conductor cables enter the control console or any cabinets or boxes, they will be provided with watertight cable terminators. Each cable terminator will provide a watertight seal by compressing a tapered neoprene-sealing ring around the outer jacket of the cable. Cable terminator parts will be made of bronze

and will be approved equal to the Series SF-327OB Watertight Cable Entrance Seals as made by O.Z./Gedney.

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 will include connected motors when tested. Conductors rated 600 V, or more, will be 1 Mohm, or more. Defective circuits will be replaced at the Contractor's expense.

Flexible cable for specified connections will be rubber-insulated, multiple-conductor portable cords conforming to the requirements of NEMA Pub. No. WC3, Part 7.7 or NEMA Pub. No. WC8, Part 7.4 for hard service. Each cable will be provided with a heavy-duty neoprene jacket conforming to the requirements NEMA Pub. No. WC3, Part 7.7.5.1 or NEMA Pub. No. WC8, Part 7.4.5.1. Flexible cables will conform to the National Electrical Code, Article 400 for hard service. Flexible cables will be provided with strain relief fittings and basket weave cable grips at each end. Strain relief fittings will be malleable iron, liquid tight strain relief fittings. The cable grips will be stainless steel, heavy long, closed wire mesh, single weave with a double eye support. All mounting hardware will be stainless steel.

2.25.1.1. **Ethernet Cable.**

Ethernet cables for PLC and encoder communications, as well as CCTV camera cabling will be four pair 24 AWG stranded copper PVC jacket Cat 5e shielded cable. Except as otherwise stated herein, the industrial Ethernet cables furnished in accordance with the specification will comply with the latest applicable codes and standards of the American National Standards Institute (ANSI), the Telecommunications Industry Association (TIA), the International Standardization Organization (ISO), the International Electro technical Commission (IEC), the Institute of Electrical and Electronic Engineers (IEEE), the National Electrical Manufacturers Association (NEMA), the American Society for Testing and Materials (ASTM), and Underwriters Laboratory (UL).

As a minimum, the latest edition of the following individual standards will apply:

- ANSI/TIA/EIA-568-B;
- ISO/IEC 11801;
- UL444, UL1666, UL1581;
- ASTM B-3, B-8, B-33, B-470;
- IEEE 802.3;
- NFPA 70 NEC; and
- CSA C22.1-06 CEC.

Submit manufacturer's product data for cables. Cable data will include both physical and electrical characteristics, as well as all applicable ratings.

The cables will be rated for use in outdoor communications circuits and riser applications in a 125 degree F rated ambient. The cables will pass a -40 degree Celsius cold bend test per UL 1581. The cables must be UL third party verified to ANSI/TIA/EIA-586-B.2 Category 5e Patch requirements. The cables will be RoHS and CE compliant.

The conductors will be stranded, tinned copper per ASTM B-33 and ASTM B470 Type III construction. The conductors will be #24 AWG (20 sq. mm) stranded (7x#32). The insulation will be polyolefin, free of defects and splices.

The cable will contain four pairs. The insulated conductors will be bonded together down the entire length of the pair. The pairs will be marked with a permanent, extruded stripe identification of tip and ring insulated conductors. Each pair will have a unique twist length to minimize pair to pair coupling. Shielding will be an aluminized foil with the foil facing inward, where required.

All cables will have a continuous jacket of Polyvinyl Chloride (PVC). Jacket thickness will be .030 in. (75 mm) nominal thickness. The jackets will be ultraviolet (UV) radiation and sunlight resistant per UL 1581. The jackets will be oil resistant per UL 1581 Class 43.

The cables will be permanently marked with the following information at 2 ft. (61 cm) intervals:

- Manufacturer's name and or trademark;
- The electrical performance rating (i.e. Cat 5e);
- The number of pairs and size (AWG);
- UL NEC and CEC listings;
- Sequential footage marking; and
- RoHS compliance.

Lot testing will be performed per UL 444 requirements for continuity, shorts and dielectric withstand. Lot testing will be performed in accordance with ANSI/TIA.EIA-568-B.2 for the following:

- Insertion Loss (Attenuation);
- Conductor Direct Current Resistance;
- Conductor Direct Current Resistance Unbalance;
- Capacitance Unbalance;
- Delay;
- Delay Skew;
- Near End Crosstalk (NEXT);
- Power Sum Near End Crosstalk (PSNEXT);
- Equal Level Far End Crosstalk (ELFEXT);
- Power Sum Equal Level Far End Crosstalk (PSELFEXT);
- Input Impedance; and
- Return Loss.

Lot test results will be recorded and archived for a period no less than one (1) yr.

2.25.1.2. **Motor Encoder Twisted Shielded Pair Cable.**

Motor encoder cables will be 600 V rated, instrumentation type, three pair, twisted shielded pair tray cables. They will have no. 16 AWG soft annealed tinned copper conductors with XLPE insulation, a nylon rip cord and a PVC outer jacket. These cables will be rated for wet or dry locations. The cable jackets will be resistant to sunlight, moisture and vapor penetration, suitable for use in raceways, outdoor applications and direct burial applications.

Each pair will be individually 100% shielded, and the overall assembly will also be 100% shielded. The cables will meet the following standards:

- UL Subject 1277 TC.
- UL 1685 (UL 1581) Vertical Tray Flame Test comparable to IEEE 383-1974 (70,000 BTU/hr.) Flame Test.
- NEC Type TC Listed, which is approved for cable tray use in Class 1, Division 2 areas, per NEC Articles 340, 318 and 501 and for Class 1 circuits as permitted in Article 725.
- IEEE 1202/IEEE 383-2003/FT4 (70,000 BTU) Flame Test.

2.25.1.3. **Fiber Optic Cable.**

The fiber optic cable will be an outside plant, loose tube, single mode, 12 fiber, fiber optic dry core cable with moisture blocking gel inside the thermoplastic buffer tube. Individually colored 250µm fibers will be surrounded by gel for moisture resistance. Each individual 6 or 12 fiber group will be protected with a colored pbt jacket and cabled around a rigid epoxy fiberglass central strength member to provide protection against thermal expansion and contraction over the operating temperature range of -40°F to +150°F. An overall water swellable tape will provide axial water penetration protection. The core will be helically wrapped with

Aramid yarn for tensile strength and protected with an overall water, fungus and uv resistant black medium density polyethylene jacket.

Mechanical & environmental characteristics:

- Crush resistance (eia- 455- 41) 2000 n/cm
- Impact resistance (eia- 455- 25) 2000 impacts w1.6 n-m
- Minimum bend radius long term, no load 15x cable diameter, minimum bend radius short term, loaded, 20x cable diameter
- Operating temp. -40°F to +160°F
- Installation temp. -20°F to +140°F
- Storage temp. -60°F to +175°F

The cable will be designed and manufactured for building interconnections and data trunk, long haul networking, ducts between buildings and aerial lashing applications requiring good ozone, moisture and weather resistance.

Fiber cabling will be terminated in patch panels using SC connectors.

Fiber cable strands will be tested and certified to 10 Gbps. All certification test results will be provided to the Engineer for verification.

All fiber patch cables will have an SC connection for the patch panel side to an LC connection on the switch. The patch panel port density will not limit the ability to connect or disconnect patch cables. All patch panel cable slack will be managed using a cable manager to neatly organize cable. All workmanship and fiber termination methods used must provide for a Db loss of no more than 0.3 per connection.

2.26. **Cable Reels.** Spring driven cable reels will be furnished and installed to power the barrier gate lights and the midspan navigation lights. The cable reel frames will be welded assemblies painted with a baked polyester finish. All components will be on the outboard of the frame to allow for component replacement without disassembly. The spring motor will be a power spring sealed in a disposable housing, eliminating the need to handle loose springs. The spring motor will be located outboard on the frame such that replacement does not require the reel to be removed from its frame. The motors will be readily re-tensioned. The spring motors will be equipped with an inspection hole to visually check the integrity of the spring while reel is in service. The spring motors will be protected from damage in the case of the cable being severed. Gears used for reeling longer lengths of cable will be protected from dust and moisture by a sealed housing. Provide external grease fitting for lubrication of gears during service without opening the enclosure. Provide a spool lock to facilitate cable changes, allowing cable change while the reel is under full tension. When released, reel will rewind entire length of new cable.

Cables will be no. 12 AWG type SOOW cables. The cables for the barrier gate lights will be four conductors and the cable for the lift span will be eight conductors. Provide a positive, watertight connector at the shaft where the cable enters the spool area. The cable will feed through the hollow shaft for termination within the slip ring enclosure. Connections are required at one point only. Provide removable slip ring enclosure with an “O” ring seal providing a watertight, dust-tight seal suitable for any type of atmosphere. The enclosure will be removable for inspection or service by means of the three toggle clamps. The slip ring assembly will be replaceable as a unit. The cable spools will allow for even winding with multiple layers. The edges of the steel flanges on cable spool will be die-formed to eliminate cable pileup in corners.

The cable reels will be the type S as manufactured by Gleason Reel or approved equal.

2.27. **Aerial Cables and Aerial Cable Cabinets.** Power and control signals will be routed over the navigable channel by means of plastic jacketed aerial cables attached to stainless steel messenger cables. The layout and conductor counts of the aerial cables will be as detailed on the plans. The cables will be manufactured in the United States by a company that specializes in the manufacture of specialized cable assemblies. New aerial cables will be furnished and installed from the east tower to the west tower as shown on the plans. The

aerial cables, terminal cabinets, cable supports, strain relief fittings, cable terminators, brackets, and hardware will be provided as needed for installation, and are included under this item.

The aerial cable will be obtained from a manufacturer that is experienced in producing flexible aerial cable. Before cable orders are placed with any manufacturer, the Contractor will determine the true length of each cable between the aerial cable terminal cabinets. Splicing or joining of conductors between these points will not be permitted. In addition, the Contractor will verify the conductor count of each cable with the vendor of the bridge control system to ensure a minimum of 15% of the specified number of conductors are spare conductors.

The Contractor will be responsible for ascertaining and procuring the correct continuous length of aerial cables, including sufficient excess length to accommodate pulling eyes, cable clamping, connections, and for test samples.

The Contractor will be responsible for ascertaining and ordering the correct conductor counts based on his approved working drawings supplied by the control system vendor, including 15% spare conductors. In no case, will the conductor counts be less than those hereinbefore specified.

The aerial cables will be 600 V multiple conductor power and control cables suitable for a vertical riser/droop installation. The cables will be suitable for installation in a vertical position while being supported at intervals along its length. They will be designed to accommodate movement due to vibration. The cables will be suitable for use in wet locations and will be sunlight (UV) and weather resistant.

2.27.1. **Specification.**

All cables will be designed and manufactured in accordance with ICEA S-73-532 / NEMA WC-57 (22-16 AWG); and ANSI/NEMA WC70 / ICEA S-95-658 (14 AWG & larger).

Standard Test Methods are in accordance with ICEA T-27-581 / NEMA WC 53.

General configuration consists of multiple conductor extra flexible copper conductors, ethylene propylene rubber (EPR) insulation, cabled with fillers as necessary, binder tape, aramid (Kevlar®) fiber reinforcement, and a weather resistant polyethylene jacket.

2.27.2. **Construction.**

2.27.2.1. **Conductors.**

Conductors will be annealed copper in accordance with ASTM B-174 for #10 AWG and smaller, and ASTM B-172 for #9 AWG and larger.

Conductors will be stranded in accordance with ASTM B-174 or ASTM-172, class “K” stranding, and Section 2 of ANSI/NEMA WC70 / ICEA S-95-658, as applicable.

2.27.2.2. **Insulation.**

Conductor insulation will be an ethylene propylene rubber (EPR) compound meeting the requirements for ethylene propylene rubber – Type E-2 insulation; ICEA S-73-532 / NEMA WC-57, Table 3-2 (22-16 AWG), 600V; ANSI/NEMA WC70 / ICEA S-95-658, Table 3-8 (14 AWG & larger), EP Rubber; and Class E-2.

2.27.2.3. **Physical and Aging Requirements.**

The EPR insulation will meet the following physical and thermal aging requirements:

2.27.2.3.1. UNAGED

- Tensile Strength – minimum, psi 1200

- Elongation – minimum, % 150
- Tensile Stress @100% elongation, minimum, psi. 500

2.27.2.3.2. AGED

- After air oven 168 hrs. @121°C
- Tensile Strength and Elongation at rupture, min. % of unaged 75
- Hot Creep at 150°C, Hot Creep elongation, max. % 50
- Set, max. % 5

2.27.2.4. **Water Absorption Requirements.**

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

- Dielectric Constant after 1 day, max. 6.0
- Increase in Capacitance, max. %, 1 to 14 days 5.0
- Increase in Capacitance, max. %, 7 to 14 days 3.0
- Stability Factor after 14 days, max. 1.0
- Stability Factor Difference, 1 to 14 days, max. 0.5

2.27.2.5. **Insulation Thickness.**

The insulation thickness will comply with ICEA S-73-532 / NEMA WC57, paragraph 3.2 and Table 3-1 and ANSI/NEMA WC70 / ICEA S-95-658, paragraph 3.3 and Table 3-4 for cables as follows:

600 V

Conductor Size	Insulation Average
AWG or kcmil	Thickness – mils
22 - 16	25
14 - 9	30
8 - 2	45
1 - 4/0	65
225 - 500	80
525 – 1000	95

2.27.3. **Stripability.**

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

2.27.4. **Color Coding.**

- Color Coding of the insulated conductors will be accomplished by surface printed legends consisting of numbers and words (1-One, 2-Two, 3-Three…19-Nineteen… 37-Thirty Seven, etc.).
- Color coding sequence will be in accordance with ICEA S-73-532/NEMA WC 57, Appendix E, Method No.4.
- Sequence will begin from the inner conductor layer and progress to the outer conductor layer.
- For ease of identification during installation, number sequence may be reset to 1-One for each group of different size conductors.
- Contrasting color print will be employed and be legible after normal handling during installation.

2.27.5. **Cable Assembly.**

2.27.5.1. **Cabling.**

The cable components will be cabled into a tight concentric configuration. The direction of lay for adjacent layers of cable conductors will be reversed. The maximum lay length will be 12 X OD of the cabled layer. A central flexible preformed stainless steel 302 or 304 aircraft cable may be included as a strength member for heavy cables and/or long vertical installations.

2.27.5.2. **Fillers.**

Fillers will be employed as necessary within the cable core to produce a substantially circular cross Section. Fillers will be non-hygroscopic.

2.27.5.3. **Binder.**

The cabled conductors will be covered with a rubber/fabric binder tape. The tape will be applied helically with a minimum overlap of 25%.

2.27.5.4. **Cable Jacket.**

2.27.5.4.1. **Cable Jacket Reinforcement.**

The jacket reinforcement will be aramid (Kevlar®) fibers. The reinforcement will be applied helically in two layers, reversing direction in each layer. This reinforcement will be applied directly over the binder tape, prior to application of the jacket.

2.27.5.4.2. **Cable Jacket Material.**

The cable jacket reinforcement will be covered with a homogeneous layer of black low density polyethylene (LDPE) in accordance with ANSI/NEMA WC70/ICEA S-95-658, paragraph 4.1.5 and Table 4-1 for LDPE jackets. The jacket will be sunlight (ultraviolet) and weather resistant.

The polyethylene jacket will meet the following physical and thermal aging requirements:

2.27.5.4.2.1. UNAGED

- Tensile Strength – minimum, psi 1400
- Elongation – minimum, % 350

2.27.5.4.2.2. AGED

- After air oven 48 hrs. @100C
- Tensile Strength and Elongation at rupture – min.% of unaged 75
- Heat Distortion @90C, max. % 25
- Absorption coefficient, Milli (absorbance/meter), min. 320

Certification by PE manufacture is acceptable.

2.27.5.5. **Cable Jacket Thickness.**

The cable jacket thickness will be in accordance with ANSI/NEMA WC70/ICEA S-95-658, paragraph 4.1.18, and Table 4-5, as follows:

Calculated Diameter of Cable Under Jacket – inches	Jacket Average Thickness – mils
0 - 0.425	45
0.426 - 0.700	60
0.701 - 1.500	80

1.501 - 2.500	110
2.501 and larger	140

2.27.6. **Packaging.**

2.27.6.1. **Reels.**

Packaging of the finished cable will be on suitable non-returnable reels capable of supporting the weight during transportation and normal handling.

2.27.6.2. **Cable Ends.**

Cable ends will be suitably sealed to prevent moisture from entering the conductor core area during shipment and storage only.

2.27.7. **Aerial cable terminal cabinets and junction boxes.**

Two aerial cable terminal cabinets will be furnished and installed, as shown on the plans, to provide termination for the aerial cables. Each cabinet will be of adequate size to mount all terminal blocks and to provide ample space between blocks for routing of the wires. Cabinets will be no smaller than 48 in. tall, 36 in. wide, and 12 in. deep.

Each aerial cable terminal cabinet enclosure will be a single door wall mount NEMA4X type enclosure, fabricated from No. 14 gauge sheet steel. The doors will be constructed of No. 14 gauge sheet steel, suitably reinforced, and will be provided with a three-point, vault-type latch. The doors will be provided with rubber gaskets.

Terminal blocks will be provided in each terminal cabinet for the connection of all conductors in the aerial cables. Sufficient terminals will be provided for termination of all spare conductors and other conductors to be terminated inside the cabinet. Terminal blocks will be one-piece blocks suitable for use in highly corrosive atmospheres and will conform to the requirements specified under section MM (junction boxes).

The ends of all conduits projecting into terminal cabinets and junction boxes will be provided with bronze insulated grounding bushings. The insulated portion will be of molded phenolic compound, and each fitting will have a screw type combination lug for bonding. Insulated bushings will be the O.Z./Gedney Type RBLG, or approved equal. All bushings in any box or enclosure will be bonded together with No. 8 AWG bare copper wire.

2.27.8. **Cable supports.**

Cables will be attached to stainless steel messenger cable per cable manufacturer's recommendation. All horizontal and vertical installations of aerial cable will be attached to bridge structure using adequately sized cable clamps.

2.27.9. **Construction details.**

2.27.9.1. **Conformance.**

All electrical equipment and its installation will conform to the requirements of the latest revision of the Standard Specifications for Movable Highway Bridges of the American Association of State Highway and Transportation Officials, except as may be otherwise provided herein.

Materials and construction will conform to the requirements of the NFPA 70/NEC latest revision, and to any applicable local rules and ordinances. The Contractor will obtain any required permits and approvals of all Departments or Agencies having jurisdiction. All work will be in conformance with the requirements of the United States Coast Guard.

2.27.10. **Submittals.**

2.27.10.1. **Factory Test Data.**

The Contractor will submit to the Engineer seven (7) certified copies of all the factory test data for approval before accepting shipment of cable from the manufacturer. The test data will 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.

2.27.10.2. **Insulation Data.**

The Contractor will submit to the Engineer typical published test data showing physical and electrical characteristics of the proposed cable insulating compound for approval before accepting shipment of cable from the manufacturer.

2.27.10.2.1. **Certificate of Compliance.**

The Contractor will submit to the Engineer seven (7) copies 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 Standards and Specifications in the Contract.

2.27.10.2.2. **Shop Drawings.**

The Contractor will prepare and submit to the Engineer for approval the following working drawings executed in accordance with the provisions of the Contract regarding the Aerial Cables:

- Manufacturer's construction drawings of all aerial cables showing the sizes of conductors, type and thickness of insulation, makeup of the cable layers, type and size of jackets and other components, the outer diameters of the finished cables, and the minimum bending radius of the finished cables.
- Detail drawings showing the construction of the aerial cable terminal cabinets and all equipment and components mounted therein.
- Detail drawings showing all aerial cable and conduit supports and any catalog cuts of any cable or conduit accessories or fittings.
- Aerial cable and conduit schematic routing drawing.

2.27.11. **Aerial cable shop testing.**

All cable will be tested at the factory 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 aerial cables, the individual insulated conductors to be incorporated in the cables will be tested to demonstrate the quality of the production run. After each multi conductor cable is completely assembled, the following inspections, measurements, and tests will be performed as described below: high voltage testing, insulation resistance testing and conductor resistance testing. The tests will be performed on a 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 Specifications:

2.27.11.1. **Individual Conductors.**

The individual insulated conductors will be AC (rms) voltage spark tested in accordance with ANSI/NEMA WC70/ICEA S-95-658, Table 3-4, as follows:

- 600 V Cables

Conductor Size	AC Spark Test
AWG or kcmil	Voltage – kV
22 - 16	4.0
14 - 9	7.5

- 8 - 2 10.0
- 1 - 4/0 12.5
- 225 - 500 15.0
- 525 – 1000 17.5

2.27.11.2. **Finished Cable.**

2.27.11.2.1. **Voltage Test.**

2.27.11.2.1.1. The finished cable will withstand between each conductor and all other conductors, an AC (rms) voltage in accordance with ICEA S-73-532 / NEMA WC 57, table 3-3, paragraphs 3.4 &6.17.1 (22-16 AWG).

- 600 V Cables
- Conductor Size AC Test Voltage – kV
- AWG or kcmil (Five minute duration)
- 22 - 16 2.0
- 14 - 9 3.5
- 8 - 2 5.5
- 1 - 4/0 7.0
- 225 - 500 8.0
- 525 – 1000 10.0

2.27.11.3. **Insulation Resistance.**

2.27.11.3.1. The insulation resistance will be measured after the completed cable AC voltage tests.

The measurement method will be in accordance with ICEA S-73-532 / NEMA WC 57, paragraphs 3.5 &6.18 (22-16 AWG).

2.27.11.3.2. The insulation resistance constant (IRK) for EPR insulation will be 10,000 in accordance with ICEA S-95-658 / NEMA WC 70, paragraph 3.6.3, and Table 3-8 for insulation Class E-2.

IR = (IRK)log10(D/d)

IR = Insulation resistance in megohms-1000 feet
IRK = Constant for the Insulation
D = Diameter over the Insulation
d = Diameter under the insulation

2.27.11.4. **Conductor Resistance.**

2.27.11.4.1. The dc resistance of each conductor in the completed cable will be measured and comply with ICEA S-73-532 / NEMA WC 57, paragraph 2.3.4 (22-16 AWG).

2.27.12. **Aerial cable field testing.**

The test methods for measuring insulation resistance of cables installed in the field will be in accordance with the specified NEMA Publications.

The test equipment will include a megohm meter capable of generating a constant 1,000 V D.C. source, calibrated in a range legible from 0 to 1,000 megohms and up to infinity, with heavy-duty, rubber-insulated, alligator-clip leads, carrying case, and a guard-circuit terminal available for use if required.

Polarity for connecting the megohm meter to the cable under test and the duration of time for electrifying the cable before taking the resistance reading will be in accordance with the NEMA Publication.

The measured values of insulation resistance for each conductor in the aerial cables will be recorded for comparison with the test values determined at the factory and will be submitted as part of the approved copy

of certified test data. The failure of any conductor in an installed aerial cable to demonstrate satisfactory insulation resistance will be cause for the rejection of the aerial cable. If this should occur, the Contractor will promptly remove the rejected cable and replace it with a new cable, subject to all the aforementioned tests and acceptances, all without additional cost to the State.

The Contractor will record the measured insulation resistance for each cable, the cable length installed, cable and reel identifications, date of test, and ambient temperature. The test results and data will be submitted to the Engineer for approval. He will also submit a certificate identifying the test equipment used and stating it is accurate within limits as rated by the manufacturer.

2.28. **Heat Pump System.** The control house will be provided with a dual zone heat pump system providing both cooling and heating. It will comprise two wall mounted indoor units and an outdoor unit.

The outdoor unit will be an inverter-driven heat pump utilizing flash technology for extended heat output in low ambient conditions. It will deliver 100% of rated heating capacity at 5°F, and 80% at -13°F outdoor ambient temperatures. It will have a durable, aerodynamic fan design, and allow for quiet cooling operation down to 0°F. It will have an L-shape condenser coil features copper tubing and aluminum fins. It will be provided with a rugged housing, tough cabinet finish, and welded connections at all stress points. Cabinet mounting and construction will withstand 155 MPH. The indoor units will be powered by outdoor unit.

The indoor units will be wall-mounted ductless indoor units deigned for commercial applications. The indoor unit will be factory assembled, wired and tested, and will house all wiring, piping, fan motor and circuit board. The cabinet will have an adjustable four way grill fixed to the bottom, providing two, three or four way air flow. The evaporator fan will be a high performance, single motor, turbo type with four speeds. The coil will be of nonferrous construction with copper tubing. A condensate pan and drain will be provided under the coil with a built in condensate lift. The controls will include off/on, thermostat, timer, and high/low settings. A remote control will be provided. It will feature an easy to clean, washable filter, wide air flow pattern for better air distribution; independently adjustable vanes, self-check function with integrated diagnostics, and hot-start technology

It will have a limited warranty of five (5) yr. on parts and defects and seven (7) yr. on the compressor.

The system will be sized and installed by a licensed mechanical Contractor accustomed to the requirements of the bridges environment.

The heat pump system will be a Mitsubishi Mr Slim or approved equal by Carrier or Trane.

2.29. **Air Horn.** For giving the necessary boat signals, one compressed air horn with mounting brackets will be furnished and installed on the operator house, pointing parallel to the navigable channel.

The horn will be diaphragm type, 4 in. vibratory horn having a frequency of about 300 cycles per second. The horn will be of weatherproof construction with a projector bell of bronze. The horn will be provided with a stainless steel bracket for mounting on the machinery house as indicated on the Plans.

The compressed air horn will be actuated by a rotary air compressor driven by an integral 1-horsepower electric motor. The motor will be a 120V, single-phase, 60-cycle unit. The compressor unit will be mounted in the operator house, and a brass pipe will be extended through the house wall to the horn. The compressor unit will be a B&B Roadway Model 55-51, or engineer approved equal.

The air horn will produce a minimum 120 decibels.

2.30. **CCTV.** The CCTV system will be provided by a single vendor experienced in remote monitoring of CCTV and audio systems. Listed below is the equipment used to formulate the design, or equal substitution is acceptable on approval by the engineer. Additional equipment may be required to complete the system and will be provided by the Contractor at no additional cost to the state.

The head end unit will be an Xtralis Adpro Fasttrace 2E- hybrid, model 58111320 or approved equal. It will be a 19 in. rack mount, 4 ip channel, 4 analog channels, 20 inputs/8 outputs, 1 RS485 port, with 16 TB total of expansion modules.The software to be provided for remote and local interface of CCTV and audio system will be Xtralis Video Central Platinum with a secure key, two (2) copies required or equal. The Fast Trace 2E-Hybrid will be provided with a 4 channel ip license. Intrusion trace and loiter trace (or equal) licenses will be provided for implementation of the analytics zones as detailed sheet e43.An Adpro audio switcher (or equal) will be provided for interface with the field audio speakers and microphones. Provide dc power supply for audio switcher.The digital signal processing (DSP) megapixel super dynamic color MOS cameras will be Panasonic model WV-SP509 or equal. The WV-SP509 camera will incorporate a 1/3 in. progressive scan megapixel super dynamic MOS, [3.1 megapixel] pixels effective, with a microlens on each pixel for superior picture detail and clarity. The camera will have a minimum illumination of 0.5 lux in color. The WV-SP509 camera's megapixel super dynamic MOS will be charged with long and short charges, creating both standard shutter speeds and fast shutter speeds simultaneously, on a single image field. The megapixel super dynamic MOS will automatically apply each exposure pattern to bright and dark areas. The megapixel super dynamic MOS will feature images with a dynamic range of up to 128 times. The WV-SP509 camera will feature a black & white mode that may be automatically engaged on low light level and permit the use of an external infrared illuminator or manually selected. The camera will incorporate independent automatic color-to-black & white switching modes for switchover on light threshold and sensitivity to IR illumination in the 850 nm wavelength. Each color-to-black & white switching mode will incorporate two switching threshold light levels, high and low. Each color-to-black & white switching mode will incorporate three duration settings for automated switchover. The camera will feature a body-based automatic back focus mechanism (ABF) for automatic and remote back focus adjustment. The automatic back focus adjustment will engage and reposition the imaging assembly for optimal focus position for delicate megapixel camera focus adjustment on automatic or manual switchover from day to night mode and on manual activation at the camera or remote from a web browser. The camera will feature adaptive black stretch to transform shadows and dark areas into natural and crisp images in real time. The camera will reproduce the camera will also feature intelligent digital back light compensation, digital wide dynamic range circuit, digital noise reduction and electronic sensitivity-up for real surveillance purposes under severe conditions. For better picture quality, the camera will feature digital 2h enhancer, digital aperture correction, knee circuit and digital white detective ATW. The camera will also offer a user-configurable AWC setting for white balance at a manual setting. The camera will be able to support video motion detection (VMD) with 4 programmable detection areas, 15 steps sensitivity level and 10 steps detection size. The camera will feature face detection to enhance details of faces for better identification. The WV-SP509 camera will incorporate a CS-mount, 1/3 in. imager. The camera will incorporate 2x extra optical zoom at vga. The camera will have three external i/o terminals which can support alarm in/out or external day/night control or exposure out which is for external flash synchronizing. The camera's built-in shutter will feature 14 settings of: off, 1/30, 3/100, 3/120, 2/100, 1/100, 1/120, 1/250, 1/500, 1/1000, 1/2000, 1/4000 and 1/10000 sec. The camera will have full duplex two-way audio feature and be capable of transmitting and receiving the audio stream through the same Ethernet connection as the video. The audio will be encoded using the g.726 or equivalent ADPCM standard. The camera will provide an SD card (sdxc/sdhc/sd) slot which can support a maximum of a 64gbytes SDXC card that can cache images in the event of a network failure. The camera will also support manual recording to the optional SD memory card. The bandwidth limit will be adjustable to 128/256/512/768/1024/2049/3072/4096/8192/10240 /122800/14336kbps or frame priority mode (4096kbps/unlimited). Area (viqs) function that can decrease maximum network bandwidth. The camera will support audio input/output. The camera will support IPV4 and IPV6 network addressing. The power source for the WV-SP509 will be POE (IEEE 802.3af); 12v dc @ 750ma. All units must be UL listed. The camera lens will be 2.8 - 12 mm adjustable with auto iris, Panasonic Model PLAMP2812 or equal.The environmental camera housing to be used for all cameras will be a stainless steel tubular housing with 24 vac input, heater and blower and a sun shield. Model- Moog SSH10C2Y or equal. The housing will be wall mounted using a stainless steel bracket, Moog WM1000SS or equal. Power to each housing will be supplied by a 16 output rack mount CCTV power supply. 14 amp total current, individually selectable 24 vac or 28 vac fused outputs, 1U EIA 19 in. rack mount chassis, 115/230 VAC input UL listed. Model Altromix Vertline 166 or equal.
The IP cameras will be supplied with control and power over Ethernet (POE). An industrial Ethernet switch with 8, 10/100tx POE and 2 10/100/1000t or 100/1000 SFP combo ports will be used for this purpose, Antaira INP-1002G-T or equal.Communication across the channel will be over fiber optic using a 1.25 GBPS Ethernet sfp transceiver, multimode 550m/LC/850 nm., Antaira SFP-M-T or equal. Power supply will be 120 watt, industrial single output Antaira DR-120-48 or equal.

Audio communication to the bridge roadway will interface with the head end unit. The speaker will be 15 watt, one way, for marine use, Valcom V-1036M or equal. The intercom will be wall mount designed to interface with various modes of audio/video transmissions. It will be weather resistant and designed for outdoor use.

2.31. **Spare Parts.** Supply spare parts in accordance with AASHTO requirements and Contract Plans. The spare parts supplied for each bridge will include, but not be limited to, the following:

- Six (6) fuses of each kind and size installed.
- One (1) 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. For rotary limit switches, furnish eight contact assemblies.
- 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.
- One (1) coil for every five or less of each size relay, contactor, and motor starter installed.
- One (1) 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.
- Two (2) heaters for overload relays of each size installed.
- For the motor and machinery brakes:
  - One (1) spare thrustor of each size complete with heater and motor;
  - Two (2) limit switches for hand-release mechanism;
  - Two (2) limit switches - brake released;
  - Two (2) limit switches - brake set; and
  - Five (5) liters of thrustor oil.
- For the navigation lights:
  - One (1) each color and type lens;
  - Two (2) each color and type LED lamp; and
  - Six (6) lens gaskets.
- For the PLC system:
  - One (1) each of every type PLC and Flex I/O input and output card;
  - Four (4) discrete input cards;
  - Four (4) relay contact output cards;
  - One (1) PLC chassis power supply module; and
  - One (1) control switch contact unit of each type installed.
- For each drive provided:
  - Three (3) incoming line fuses; and
  - Three (3) control power fuses.
- For the Barrier Gates:
  - One (1) spare motor; and
  - Six (6) spare lamp assemblies.

Arrange the spare parts in uniform size cartons of substantial construction, with typed and clearly varnished labels to indicate their contents, and store them where directed by the engineer. Provide large spare parts with moisture-proof wrapping. Provide 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 indicated on the elementary wiring diagram.

3. CONSTRUCTION

3.1. **Electric Service.** The existing electrical service, generator and automatic transfer switch will remain to be reused. The existing conduit from the automatic transfer switch will be extended into the new MCC, and new conductors drawn in.

3.2. **Grounding.** Bridge steel work on each side of the navigation channels will be solidly bonded and grounded to 1 in. copper plated steel ground rods installed using No. 2/0 AWG bare, stranded, tinned copper cable.

The resistance to ground will be no higher than 25 ohms. Provide 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 aerial cable, navigation lighting units, all metal framing, cases, and enclosures of the electrical equipment, such as motors, control console, control cabinets, conduits, submarine cable armor (stripped of its jacket prior to clamping), and all other metal parts in the proximity of current carrying conductors or equipment. Extend a No. 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 No. 2/0 AWG grounding electrode conductors.

Provide 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. Ground system conductors will be continuous un-spliced 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.

Provide equipment ground conductors composed of seven-strand, soft-drawn, bare, tinned copper wire conforming to ASTM B33 and not smaller than No. 10 AWG.

3.3. **Painting.**

3.3.1. **General.** The requirements for painting structural steel also apply to painting electrical equipment, unless otherwise specified.

3.3.2. **Shop Painting.** Electrical equipment such as conduits, boxes, supports, and other devices which have a galvanized finish or are of stainless steel 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.

3.3.3. **Field Painting.** Electrical equipment, which is normally given a factory painted finish suitable to the engineer, need not be field painted. Give all other electrical equipment, such as conduits, boxes, device enclosures, supporting clips and brackets, and other devices, two field coats of paint as specified under the requirements for painting structural steel. Before applying the two field coats, clean galvanized surfaces free of all grease, oil, dirt, and foreign material and etch with copper sulfate solution, after which the solution will be applied. In lieu of etching and a coat of shop 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.

3.4. **PLC Programming and 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.

3.4.1. Step 1: Turn bridge control power on. PLC enables desk controls. Turn oncoming traffic signals from green, through yellow, to red.

3.4.2. Step 2: LC energizes the gate flashers and gongs. The Traffic gate lower permissive light will light. Lower the traffic gates, oncoming first, then offgoing. 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.

3.4.3. Step 3: Confirm that with all traffic gates lowered the barrier gate lower permissive light is lit. If not, the operation will be stopped and an alarm 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.

3.4.4. Step 4: Lower the barrier gates. The traffic gate raise permissive light goes out. 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. The barrier 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.

3.4.5. Step 5: Confirm that with all gates lowered the span lock pull permissive light it lit. If they are not, the operation will be stopped and an alarm sent to the HMI. PLC de-energizes gongs only. The barrier 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.

3.4.6. Step 6: Withdraw the span 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 lock takes longer than 30 seconds to withdraw, the operation will stop and an alarm will be sent to the HMI. If the span lock withdrawn limit switches fail to register, the span lock withdrawn bypass switch will allow the operation to continue and an alarm will be sent to the HMI.

3.4.7. Step 7: 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. One brake hand release will be permitted to be bypassed using the brake hand release bypass and an alarm will be sent to the HMI. Initiate span raise by turning the selector switch to raise. The drive will smoothly ramp to 5% speed at 100% 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% speed. If after 10 seconds the brakes do not release, the operation will cease and an alarm will be sent to the HMI. The PLC system will monitor the skew based on feedback from the absolute encoders and dynamically adjust the drives to maintain skew to within 6 in. If the skew should exceed 12 in. the span will stop and an alarm will be sent to the HMI.

3.4.8. Step 8: Once the leaf reaches the nearly open position (to be field determined) the drives will ramp down to and remain at 5% speed until the span reaches fully open. The drive output torque will be limited to 80%, the brakes will set and then the drives will shut down. An independent electronic speed switch will verify deceleration and will emergency stop the span if deceleration does not occur. Should deceleration failure occur, an alarm will be sent to the HMI. If the time to open the span exceeds 120 seconds, the operation will stop and an alarm will be sent to the HMI.

3.4.9. Step 9: The span navigation lights will change from red to green based on the input from the span position limit switches.

3.4.10. Step 10: Allow navigation traffic to clear.

3.4.11. Step 11: Initiate span lower by momentarily turning the selector switch to lower. The drives will smoothly ramp to 5% speed at 100% 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% speed. If after 10 seconds the brakes do not release, the operation will cease and an alarm will be sent to the HMI.

3.4.12. Step 12: Once the leaf reaches the nearly closed position (to be field determined) the drives will ramp down to and remain at 5% speed until the span seats. The drive output torque will be limited to 80%, the brakes will set and then the drives will shut down. An independent electronic speed switch will verify deceleration and will emergency stop the span if deceleration does not occur. Should deceleration failure occur, an alarm will be sent to the HMI. If the time to close the span exceeds 120 seconds, the operation will stop and an alarm will be sent to the HMI.

3.4.13. Step 13: Drive the span locks. If the span is seated but the limit switches fail to provide proper indication, the span seated bypass switch will be used to allow the 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 lock takes longer than 30 seconds to drive, the operation will stop and an alarm will be sent to the HMI. If the span lock driven limit switches fail to register, the span lock driven bypass switch will allow the operation to continue and an alarm will be sent to the HMI.

3.4.14. Step 14: PLC energizes the gate gongs. Raise the barrier gates. If the barrier gates are raised but the proper indications are not given, the barrier gate raised bypass switch will allow the traffic gates to raise 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 gate takes longer than 30 seconds to raise the operation will stop and an alarm will be sent to the HMI.

3.4.15. Step 15: Raise the traffic gates. 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 barrier and traffic gate flashers and the gongs.

3.4.16. Step 16: Turn traffic signals to green. Turn bridge control power off. PLC disables desk controls.

3.4.17. Step 17: In general, any circuit breaker trip, any overload trip, any drive fault, any bypass switch, 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 switch can be enabled at any time, if more than one is enabled, the operation will stop.

3.5. **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 so as 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 particular 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.

3.6. **Field Testing.**

3.6.1. **General.** Furnish all labor, materials, plant, and equipment, maintenance and protection of traffic and perform all work necessary, such as adjustments or corrective measures, to properly test all systems included in the initial and final acceptance field testing for the bridge. Final acceptance testing will not commence until the Operations and Maintenance manuals have been submitted and approved.

All test results, parameters, data specified herein to be recorded will be presented in legible, tabular format, listing associated parameters and conditions. For example, motor current will reference speed (rpm), span height (feet-inches), raise or lower mode, drive control selector speed, etc. The results of the bridge electrical

systems tests will be presented in a matrix form on an Inspection Report Data Sheet. The proposed format of these sheets will be submitted to the engineer for acceptance 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 will have references to the specific sections of the testing procedure. The precision of the results will depend on the accuracy of recording equipment, the observer and weather conditions. For each stage of testing of the bridge control equipment, the name of the person who will perform the test, instruments used with calibration data if required, the exact date, time and weather conditions will be recorded.

Some devices such as the transfer switch, lamps, console indicator lights, brake function indicator lights, console controlled lighting, horn, etc. can be easily tested without performing any bridge opening operation.

The bridge main parameters will also be observed and visually compared to the control desk indicating meters. Any discrepancy between results should be recorded. A discrepancy between critical measurements like span position and speed will be resolved prior to continuing the tests.

The testing will be accomplished sequentially, following the bridge operation instructions for normal operation and emergency operation, as established in the new approved Operating and Maintenance (O&M) Manuals. A copy of the final, approved, O&M manuals will be on site during the testing. The major bridge systems will be monitored while each bridge operates. All monitored parameters will be kept for future reference, and a printout copy will be attached to the O&M Manuals for reference. Another printout copy will be provided to the engineer.

3.6.1.1. The testing of the bridge electrical equipment would necessitate the use of the following recording and testing devices:

3.6.1.1.1. 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 will stream to disk at a rate of 10 Hz. The data will be transferred to graphing software.

- Portable tachometer
- Portable ohmmeter
- Amp-probe
- Recording ammeter
- Recording voltmeter
- Infrared scanner
- Measuring tape
- Stop watch (Timer)
- All other necessary instrumentation and tools to monitor, adjust and/or replace items during the bridge testing procedure.

All meters will be calibrated per NIST guidelines within 6 months of the testing.

Arrange for and provide all the necessary field tests and provide a testing procedure subject to the approval of the engineer, to demonstrate that the entire electrical system is in proper working order and in accordance with the plans and specifications. The tests will include, but not be limited to operational testing of traffic signals, warning gates, movable span, navigation lights and signals and manual transfer switch.

Should the tests show that any piece of equipment or cable or wiring connection, in the judgment of the engineer, is defective or functions improperly, such adjustments and/or replacements will be made by the Contractor as to make the installation satisfactory to the engineer and at no extra cost.

It may be found that minor deviations from the performance specification are required for optimum bridge operation. All hardware required for these modifications will be included in the control system vendor scope of work at no additional cost to the department.

During the field testing period, arrange to have at the site representatives of the manufacturer of all major pieces of equipment or systems. The representatives will be capable of supervising 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.

3.6.2. **Initial Field Testing.** The initial field tests are intended to confirm that each major sub-component meets factory acceptance test criteria in its field installed condition and that each subsystem is operating properly as part of the completed system. Confirmation of correct operation of sub-components will be demonstrated through successful operation of the particular 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.

The initial field testing is intended for the Contractor to make the necessary adjustments and/or modifications such that the normal and emergency control and power systems are operational, trouble free, operating with all interlocks properly functioning, and in compliance with the requirements of the contract plans and specifications.

3.6.3. **Final Acceptance Field Testing.**

3.6.3.1. **General.** The bridge acceptance testing is intended to show and/or demonstrate that the normal and emergency control and power systems are operational, trouble free, operating with all interlocks properly functioning, and in compliance with the requirements of the contract plans and specifications.

The final acceptance tests are not intended to substitute each sub-component acceptance factory and field tests. Confirmation of correct operation of sub-components will be demonstrated through successful operation of the total control system. However, the Contractor is still responsible for the factory and initial field tests as required per contract specifications. For example, it is not the intent to manually operate and test each limit switch during Final Acceptance Field Testing. This will have been accomplished by the Contractor during Initial Field Testing. The Contractor will be able to prove that the results of the sub-component tests are in conformance with the contract plans and specifications. 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 will be verified through the successful completion of the entire bridge control and power systems tests.

The Final Acceptance Field Testing procedure will 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, traffic signals, traffic gates, barrier gates, span locks, brakes, the span drives and motors, bypass switches, etc. The Final Acceptance Field Testing procedure will demonstrate that the bridges can only be operated according to the “Sequence of Operation” as defined in the approved O&M Manuals. Visual inspections and physical measurements of some equipment are required for the purpose of recording valid parameter values. Bridge run printouts will be provided for each test, and kept for the record together with all other recorded data.

The department must be in possession of the approved operating and maintenance (O&M) manuals at least thirty days before Final Acceptance Field Testing may begin. Start approval submissions of the O&M manuals as soon as possible, as several revisions may be required.

There will be 90 consecutive days of nominal bridge operation using the new permanent systems, with a minimum of five successful openings per day in the last thirty days, before scheduling of the Final Acceptance Field Testing.

Results and observations will be carefully recorded throughout the various tests.

Prior to performance of these tests, all temporary PLC forces, bypasses, jumpers, switches, etc., installed during any previous testing must be removed. The control circuits will be in the state presented in the originally As-Built control wiring diagrams (restored to normal).

All tests and verifications will be for equipment at both the near and far sides. In addition to all devices listed below, all associated devices should also be tested.

3.6.3.2. **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:

- All limit switches
- Control cabinets contactors
- Traffic signals, traffic gates, barrier gates, interlocked heating and ventilating devices, etc.
- Control desk indicating lights
- Control Desk HMI screens
- Control Desk

The control desk devices (HMI, switches, pilot lights,) will be used throughout the tests, and all irregularities observed will be noted during and after the tests from the notes and printouts. Special attention will be given to the desk meters accuracy verification.

3.6.3.2.1. Provide one (1) desk multi-functional power monitor verification as follows:

3.6.3.2.1.1. For a determined bridge span opening, at an exact start recording [Time stamp] time from the PLC log information will be recorded.

3.6.3.2.1.2. The PLC recorded values will be filed. The results will be compared and the meter accuracy estimated.

3.6.3.3. **Air Horns.**

Test that the air horn produces a tone acceptable to the engineer.

3.6.3.4. **Traffic Signals Control.**

Test that the traffic signals change state upon activation of the desk selector switch. The duration time of the amber light will be of an acceptable time to the engineer. If necessary, the TR-RSR timing relay will be re-set to an acceptable time delay. Verify traffic signal interlocks are functioning correctly by showing transition from red to green is prevented when any of the following occur:

- Any gate not fully raised;
- Span Locks not driven; or
- Span not seated.

3.6.3.5. **Traffic Gate Control.**

Testing of the gates will demonstrate the balance condition of the gate arms such that a stationary arm remains in the same position when the brake is released. Demonstrate proper normal operation upon activation of the desk selector switches. Demonstrate proper manual operation.

Perform individual and group lower/raise commands and sequencing checks. Verify that the gates can only be lowered/raised in the proper sequence and the gongs activate/de-activate at the appropriate times.

3.6.3.5.1. Verify the gate interlocks are functioning properly by showing the following:

- Gate operation is prevented when any of the following occur:
  - Gate housing door opened;
  - Hand crank inserted;
  - Gate motor disconnect switch opened; or
  - Gate motor overloaded.

3.6.3.5.2. Gates cannot be lowered unless the traffic signals are red.

3.6.3.5.3. Gates cannot be raised unless the span is fully seated, span locks are driven and the barrier gates are raised.

Verify that the bypass is functioning properly such that when the “Barrier gate Raised Bypass” switch is enabled, interlocks 3 listed above are overridden.

3.6.3.6. **Barrier Gate Control.**

Perform individual lower/raise commands and sequencing checks. Verify that the gates can only be lowered/raised in the proper sequence.

3.6.3.6.1. Verify the gate interlocks are functioning properly by showing the following:

- Barrier gate operation is prevented when any of the following occur:
  - Hand crank inserted;
  - Gate motor disconnect switch opened;
  - Gate motor overloaded;
  - Gates cannot be lowered unless the traffic gates are lowered; or
  - Gates cannot be raised unless the span is seated and the span locks are driven.

Verify that the bypasses are functioning properly such that when the “Traffic Gate Lowered Bypass” switch is enabled, interlock 2 listed above is overridden, and when “Span Lock Driven Bypass” switch is enabled interlock 3 is overridden.

3.6.3.7. **Span Locks Control.**

Perform pull/drive commands and sequence checks. Verify that the locks can only be pulled/ and driven in the proper sequence. Pull and drive locks using the control desk marked-up corresponding switches, and verify the locks are in the correct positions.

3.6.3.7.1. Verify the span lock interlocks are functioning properly by showing the following:

- Span lock operation is prevented when any of the following occur:
  - Auxiliary cover removed and/or manual hand crank inserted;
  - Span lock motor disconnect switch opened;
  - Span lock motor overloaded;
  - Span locks cannot be pulled unless the barrier gates are lowered; or
  - Span locks cannot be driven unless the span is fully seated.

Verify that the bypass is functioning properly such that when the “Barrier Gate Lowered Bypass” switch is enabled, interlock 2 listed above is overridden, and when “Span Seated Bypass” switch is enabled interlock 3 above is overridden.

3.6.3.8. **Span Brakes Control.**

The normal automatic set and released operation of the brakes will be visually recorded during the span raise and lower operations. Each brake will be hand released, one at a time, and the hand-released indication on the control desk verified.

With the span in non-permissive operation mode (span locks driven, drives not energized), the brake set and release switches can be activated manually and their set/released indication monitored on the control desk.

3.6.3.9. **Span Normal Operation.**

Several bridge openings will be required to demonstrate that all the operational parameters are acceptable and all interlocks and bypasses are functioning properly. 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 approved O&M *Manuals will be followed up to the indicated operational step of the* equipment to be tested. All tests will be performed for all span motors on all leafs.

3.6.3.9.1. Follow the full "Sequence of Operation." During the span "Raise" and "Lower" operation, the following parameters will be monitored and manually recorded:

- Span position [height in feet];
- Motor power [kilowatt];
- 3-phase current [amperes];
- 3-phase voltage [volts];
- Motor speed [rpm];
- Span skew;
- Manually record maximum height during the "Raise" [degrees]; and
- Manually record "Raise" and "Lower" times [seconds].

These parameters will also be recorded at the fully closed, nearly closed, nearly open and fully open position as indicated at the control desk by PLC HMI.

Verify that the span operated normally within the permissible position limits.

Verify that the recorded position, the control desk indicated position and the limit switches indicated position are equal or within the set design tolerances.

3.6.3.9.2. Verify the span operation interlocks are functioning properly by showing the following:

3.6.3.9.2.1. Verify that the span cannot be operated if more than one brake in any machinery room has been manually released.

3.6.3.9.2.2. Verify that the span cannot be operated if the span locks are not pulled.

Verify that when the "Brake Hand release Bypass" switch is enabled, interlocks 1 listed above is overridden, and when the "Span Lock Pulled Bypass" switch is enabled, interlock 2 listed above is overridden.

3.6.3.10. **Emergency Span Stops.**

Under normal opening procedures, push the "Emergency Stop" red mushroom head button. Verify that all motor and brake contactors drop out and the span brakes set properly.

3.7. **Bridge Operator.** Once the Contractor begins field operations he will be responsible for operating and maintaining the bridge as required by the United States Coast Guard USCG.

This includes bridge openings for navigation and resolving operational emergencies (i.e. marine collision, vehicular collision, etc.), as well as all operations required for construction scheduling and systems testing. The Contractor will be responsible for maintaining the bridge so it can be safely operated in a reliable and

timely fashion. The Contractor will keep a log of all marine traffic openings according to State and Coast Guard standards and regulations. The type and name of each vessel will be recorded, along with the date and time of opening. This log will become the property of the State, when the state operators gain control of bridge operations.

This responsibility will continue until final acceptance of the bridge by the Department. The Contractor will also provide persons to supervise the operation of the bridges and to train personnel for a period of thirty 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 are not limited to, representatives from manufacturers of the major equipment and a control engineer.

Provide operators who are skilled persons 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 required to be in attendance at the bridge for the normal working period of 8 hr. per day, in addition to those required to operate the bridge as mandated by the USCG.

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 hr. sessions to hardware and maintenance related topics. In addition, devote three 8 hr. 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 hr. session to training on the fire, security, and communications systems and equipment. Furnish all necessary instruction sheets, student training aids, books, paper, and booklets to supplement training. Submit to the department, a minimum of two weeks prior to training session, an outline of topics to be covered and training material for review. It is the Contractor's responsibility to coordinate with the department the location where training sessions will be held. Supplying of visual aid equipment and other miscellaneous items required for training will be the responsibility of the Contractor.

Make the instruction booklet that was specified above, “Operation and Maintenance Manual, Volume 1, Operation of Electrical Equipment,” available for use during the training period.

Training of the designated bridge operational personnel will commence three weeks prior to the official bridge opening date. This will allow training of personnel without interruption of normal traffic flow.

4. MEASUREMENT

The department will measure Bridge Electrical Work, acceptably completed, as a single complete unit of work.

5. PAYMENT

Payment is full compensation for all labor, materials, operation and maintenance manuals, training and equipment necessary for completely installed, ready for operation, movable bridge electrical systems; and for all incidental items necessary to complete the work as shown on the plans and included in the proposal and contract.

It is the intent and purpose of these special provisions 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 herein specified. 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 these specifications and without extra cost.

Submit to the engineer a detailed breakdown of the Contractor's costs under these items within 30 days of award of the contract. This breakdown will be evaluated by the engineer and utilized as the basis for monthly progress payments for work satisfactorily completed. A minimum of 10% of the bid price for this item will be retained by the department until final acceptance of the bridge electrical system, the Contractor and Control System vendor have completed all items on their punch-lists, and all aspects of bridge operation, operator and maintenance personnel testing, training, and control are complete. 5% of the bid price for this item will be retained until final approval of the operation and maintenance manuals is granted by the engineer.