TECHNICAL SPECIAL PROVISION

FOR

ELECTRICAL CONSTRUCTION FOR MOVABLE BRIDGES

LOXAHATCHEE RIVER BRIDGE REHABILITATION
NS 282.58

The official record of this Technical Special Provision has been electronically signed and sealed using a Digital Signature as required by Rule 61G 15-23.004, F.A.C. Printed copies of this document are not considered signed and sealed and the signature must be verified on any electronic copies.

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SECTION T508
ELECTRICAL CONSTRUCTION FOR MOVABLE BRIDGES

T508-1. BASIC ELECTRICAL REQUIREMENTS

T508-1.1. Description

It is the intent of this Technical Special Provision that only individuals of high competence and experience perform the work of this Section. Unless otherwise specified, all manufactured items, fabrications, components, pieces, assemblies and appurtenances that are to be removed, salvaged, repaired, rehabilitated, furnished new, installed or reinstalled under these Contract documents is classified as electrical construction.

All work shall conform to the requirements of the current AREMA Manual for Railway Engineering (AREMA Manual) unless otherwise noted herein or on the contact drawings.

Provide Shop Drawings, including but not limited to:

Detailed electrical and control system designs as required for fabricating and furnishing the control equipment.

Define the installation and interconnection of the electrical equipment including all required interconnections with equipment furnished under other Sections.

Test and verify that the completed electrical system's installation and performance is satisfactory with respect to the requirements of this Specification.

A complete list of all Electrical materials and equipment to be used including manufacturers' catalog numbers, catalog data sheets, illustrations, and shop drawings, to the Engineer for approval.

Prepare detailed design plan drawings of electrical and control system conduit and wiring to provide the functionality specified in the Contract Documents. Provide signed and sealed drawings if proposed system differs from the Contract Documents.

Furnish and install all wire, cables, conduits, wiring, wiring devices, light fixtures, motors, controllers, motor control centers, panelboards, relays, control equipment, safety switches, and all other apparatus and accessories indicated, specified, or required for a complete power and lighting system for the bridge.

Furnish and install the connections to motors and to other equipment furnished and installed under other Sections of this Technical Special Provisions.

Wiring and Conduit work includes runs to all light fixtures, all Variable Speed Controllers, drive motors, stand-by generator and transfer switch, motor control equipment, air horns, navigation lights, limit switches, system grounding scheme, electrical room amenities, and any other component necessary for a complete operating system.

Locate operating and control equipment to provide easy access, and arrange entire electrical work with adequate access for operation and maintenance as per the latest adopted National Electrical Code (NEC) requirements.

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

T508-1.1.1. Protection of Electrical Equipment: Protect electrical equipment from water damage, rain, condensation, and water dripping or splashing on equipment and wiring, at all times during shipment, storage and construction (prior to final acceptance). Provide temporary electrical connections to equipment heaters, or provide temporary heaters, as required to prevent damage from moisture.

Provide climate-controlled environment for the storage of control equipment/ assemblies during construction.

Thoroughly dry out and put through special dielectric tests any apparatus subjected to possible injury by water or dampness (including the interiors of motor control equipment or any other electrical devices).

Protect equipment from damage from mishandling, dropping, or impact. Do not install

damaged equipment.

Provide spare parts in sealed, uniform-sized cartons, with typed and clearly varnished labels to indicate their contents, and stored in a portioned lockable box. Also, provide a directory of permanent type describing the parts including the name of each part, the manufacturers' number, 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.

Ensure spare parts are available at time of Functional Checkout. Replace spare parts used during Functional Checkout.

T508-1.1.2. Coordination of Electrical Work: The contract documents are diagrammatic in showing certain physical relationships within the electrical work, and must interface with other work including utilities and mechanical work.

T508-1.1.3. Materials and Equipment to be Installed: Use only new materials that conform to the standards of the UL in every case where such a standard has been established for the particular type of materials and its intended application.

Furnish and install all new conduit, wiring, disconnect switches, smoke detectors, panelboards, controls and relays, wiring devices, transformers, boxes, terminal blocks, electrical identification, motor controls, and supporting devices for a complete electrical installation on the bridge.

Ensure all electrical equipment used outside of the conditioned spaces of the electrical room is suitable for use in a marine (salt atmosphere) environment.

T508-1.1.4. Electrical Journeymen: Designation of Electrical Journeymen: Designate a listing of pre-qualified electrical journeymen to perform the electrical work in accordance with the provisions of this Section. Perform all such work either by, or under the immediate supervision of an electrical journeyman. For this project, "under the immediate supervision" means that the journeyman is in the immediate vicinity and physically involved in performing the electrical work. The Engineer will review and approve the journeyman's knowledge, talents, and skills in performing certain critical work, and then the journeyman will do the actual work utilizing those talents and skills. Helpers will aid the journeyman in the performance of the work and will not act as non-credentialed surrogates of a remote journeyman. Non-approved helpers may only perform tasks of a support nature that do not directly involve responsibility for the installation, connection, or adjustment of electrical materials.

T508-1.1.5. Control Systems Engineer: Designate an individual (such as the Control System Supplier) to act as the Project's Control Systems Engineer. To serve as sole representative for the detail design, development, coordination, and testing of the leaf drives, interface to the electrical control system, the electrical control system including the Motor Control Center (MCC), the Programmable Logic Controller (PLC), the control console, and interfacing with the leaf drive system. Ensure the Engineer approves the Control Systems Engineer as qualified in developing and coordinating these types of Specialty Items. He will serve as a single point of contact prior to, during, and after construction, and must be available for consultation during all phases of the project, including Shop Drawing submittal and review.

Ensure the Control Systems Engineer is on site, directing all testing and commissioning of the bridge operating equipment and systems.

The Engineer will review the pre-qualification submittal of the Control Systems Engineer, and will be the sole judge of the adequacy of the information submitted. Inadequate proof of this ability and experience, or insufficient details, may be cause for disqualification.

T508-1.1.6. Tools and Procedures: Manufacturer Requirements: Install, apply, or adjust all electrical equipment and materials in accordance with the manufacturers' recommendations including the usage of the manufacturer specified tooling. When such materials are UL, or other third party, listed or recognized, the tooling used for field installation must be the same as, or the manufacturers'' approved equivalent to, the tooling utilized in the approval testing.

Quality Assurance:

A. Tooling Identification: When applicable, the approved tooling will provide a suitable identification to the work to allow verification that the appropriate tool was used to perform the

work. For example, use crimping dies that contain identification marks that emboss the crimps made with them with an identification embossment.

B. Quality Isolation: Where possible, the requirement to provide a level of workmanship quality is transferred to the tooling rather than the skills of the worker. As examples, but not limited to:

1. Conductor Stripping: Depend upon the use of approved non-nicking strippers rather than the operator's skill with knife edged stripping tools to prevent wire nicking.

2. Crimp Tightness: Proper crimping will depend upon the exclusive use of controlled cycle crimping tools that require the proper degree of compression before releasing the work rather than upon the operator's judgment in squeezing the tool handle.

3. Tie Tightness: Determine proper tensioning of cable and wrap ties by the use of the manufacturers' specified calibrated tensioning tool rather than the operator's judgment of what is "tight enough."

4. Fastener Torque: Tighten fasteners with a recommended torque, where the proper tightness is important to the performance of the function (which includes all electrical terminals), with a calibrated torque (limiting) screwdriver or other torque-indicating tool.

T508-1.1.7. Tool Verification: Whenever any other Article of this Section requires material submittals, when tooling is associated therewith, submit the manufacturers' tooling requirements and procedures, including catalog and calibration information, on the tooling that is proposed.

Document all tooling used as to the method of use and the calibration requirements and procedures. Provide calibrations that are traceable to the National Institute of Standards and Technology (NIST) or other recognized standards laboratory. Equipment that requires repetitive calibration (e.g., terminal crimpers often require daily verification by pull testing sample crimps) must be supported, on site, by the required calibration verification instruments. Ensure that operating manuals for all specialized tooling are available on the site for reference by the Engineer at any time.

T508-1.1.8. Tool Application: The journeyman electrician intending to operate a specialized tool must demonstrate his knowledge of, and skill in using, the tool including the knowledge and ability to judge the results produced by the tool and to recognize failure of the tool to perform satisfactorily.

T508-1.1.9. Verification Testing: Whenever verification testing is required in the performance of the work of other Sections, perform the tests and measurements in accordance with these requirements.

T508-1.1.10. Test Equipment: Provide test and measurement instruments suitable to perform the required tests including ratings and measurement accuracy as specified by the manufacturer. Clearly indicate the exact make and model of instrument used and include manufacturers' specification data indicating the suitability of the instrument's specifications in all procedure submittals.

Only use test instruments calibrated and certified by an independent certification laboratory to the required accuracy and in accordance with the instrument manufacturers' requirements within a maximum interval of the preceding 12 months. Certify all calibrations as traceable to the National Institute of Standards and Technology (NIST) or other recognized standardization authority.

Test instrument operating manuals and certification certificates must be available on the project site for reference by the Engineer whenever the instrument is being used or evaluated.

T508-1.1.11. Test Result Reporting: Where this Technical Special Provision requires test or inspection data submittal, obtain approval of the form(s) used for recording and submitting the data prior to performing the tests. While performing the tests, record the test results directly upon the approved forms, recopying the data onto the forms from informal field notes is not acceptable. Record all data with ballpoint pen or other non-erasable and non-water-soluble writing media, strike-thru and initial errors or corrections in such a manner that the original is still readable.

Identify each measurement item or group of items with the measurement date and approximate measurement time to the nearest quarter hour.

Where the environment has an effect upon the measurements, such as insulation measurements, record the weather conditions including approximate temperature, rain/fair, and approximate relative humidity, on the form at appropriate intervals as determined by the changing

meteorological conditions. Record wind velocity and direction for leaf related tests where the wind loading is a factor in the performance or results.

Identify each measurement item or group of items with the signature or initials of the approved measurement technician performing the tests. A separate sheet cross-referencing the signatures or initials to the printed name of the technician will accompany the submittal of the test results to identify the technician. The use of manuscript initials will be treated the same as the full signature and will constitute the technicians certification that the tests were performed in accordance with the submitted and approved procedures, utilizing approved test instruments, and that the results recorded are a true and accurate representation of the test conditions and results.

Record test instrument identification, including traceable serial number, for each measurement group. Include a copy of the Certificate of Calibration for the particular instrument in the submittal.

Have the Control Systems Engineer review and approve all test data submittals prior to submittal to the Engineer.

T508-1.1.12. Test Performance: The journeyman electrician, or other proposed test equipment operator, must demonstrate knowledge of the test equipment operating and testing procedures to the Engineer's satisfaction before performing tests. Only test results signed by such approved testing technician will be acceptable under the requirements of this Section.

T508-1.1.13. Submittals: Submit qualification information for Control Systems Engineer, qualification information for Electrical Journeymen and Certificates of Calibration for test instruments.

T508-2. WORKING PLANS AND SHOP DRAWINGS

T508-2.1. Description

Submit working plans and shop drawings as expanded in this Section. Clearly mark manufacturers' standard drawings that indicate dimensions and options for more than one piece of equipment clearly indicating what data applies.

Provide a separate submittal each major electrical system (e.g., drives, control panels, generator, etc.) unless otherwise indicated in this Section. Label data sheets for individual components such as motors, limit switches, etc. with the identification numbers shown in the Contract Documents.

Submit all electrical submittal items electronically in PDF format. Include title sheet as first page having names of job and Contractor with second page as table of contents listing each submittal item in same sequence as specified.

Do not submit piece-by-piece submissions of individual components; submit all components of an assembly at the same time. Include shop drawings drawn to scale and certified by the manufacturer for major electrical equipment. Where one-line diagrams, wiring diagrams, schematic diagrams, interconnection diagrams, etc. are called for, they are to be site specific. Submittal approval will be on an "all or none" basis.

Provide complete resubmittals even if some items on the original submittals have not been marked deficient. Provide sufficient time in project schedule to allow for the possibility of repetitious submittals without creating delays to the project. Delays caused by repetitious submittals are not the responsibility of the Owner.

T508-2.1.1. Shop Drawings: Submit complete conduit layout drawings for conduit and wiring, including details of all conduit penetrations through structural elements, for review and approval of the Engineer. Include details of reinforcement in the penetration area on conduit penetration drawings. Submit full-size drawings showing all conduit runs between all pieces of equipment. Ensure the approval of these drawings before installing any conduit.

Submit shop drawings for new power services detailing routing with dimensions, pull box locations, expansion joint fitting type and locations, and conduit support assembly details. Include drawing showing electric meter detail and location. Provide documentation showing coordination with the electrical utility company.

Use a set of approved shop drawings (incorporate all review comments if Approved as

Noted) and mark, in red, all circuit changes made in the field.

Maintain these construction shop drawings as working drawings for the duration of construction. Required working drawings include conduit routing plans, schematic diagrams, interconnection wiring diagrams, and conduit and cable schedules. Make working drawings available to the Engineer, on request, for review of construction issues.

Maintain a full set of working drawings on the jobsite at all times.

The working drawings must be available at the time of the Functional Checkout. Unavailability of the working drawings is sufficient reason to cancel the Functional Checkout.

T508-2.1.2. Electrical Material Submittals:

A. Manufacturers' standard descriptive leaflets or catalog sheets are acceptable for "off the shelf" items which require no modification for application on this project unless noted otherwise, including control house and pier items such as heat pump/air conditioning, smoke detection and fire alarm panel, leak detection, marine radio, disconnect switches, wiring devices, etc. For fused disconnect switches include outline drawings with dimensions, equipment ratings for voltage, capacity, horsepower, and short-circuit. Provide manufacturers fuse curves (time/current on log/log graph) for each rating of fuse supplied.

B. Provide a submittal for each type of motor. Include a motor data sheet indicating horsepower, voltage, FLA and LRA current, motor speed, NEMA frame size, insulation class, temperature rise, service factor, and any optional equipment or attachments such as tach-generator, encoder, thermal switch, or space heater in the motor submittals. Provide a motor torque-speed performance graph. Provide dimensioned outline, plan/elevation and wiring interconnection drawings. Include installation instructions, operation, and maintenance data with instructions for storage, handling, protection and starting of motors. Include assembly drawings, bearing data with replacement sizes, and lubrication instructions. Provide certified motor drawings to the machinery fabricator for coordination.

C. Provide catalog data, including dimensions and drawings, for each type of ground rod, clamp, well, and associated hardware.

D. Provide catalog data for each type of strut, clamp, insert, and associated hardware; dimensional data for struts; and pullout data for anchors.

E. Provide catalog data sheets for each type of conduit and fitting and conduit layout drawings, showing routing and penetrations. Coordinate structural block outs and embedded conduits with concrete lift drawings.

F. Provide catalog data sheets for each type and rating of terminal blocks. Include voltage and ampere ratings, materials, and dimensioned outline drawings.

G. Provide catalog data for each type of identification device. Provide an engraving schedule for all laminated nameplates.

H. Provide catalog data sheets for dry-type transformers including voltage, ampere, and kVA ratings, materials, and weight; dimensional data and outline drawings; and electrical connection diagrams.

I. Provide catalog data for panelboard and circuit breakers including dimensioned drawing for panel enclosure, detailing mountings and door hardware, voltage, ampere, and short circuit ratings for all circuit breakers and the overall panel board assembly. Provide a circuit directory listing each branch circuit and the circuit breaker rating. Submit load balance calculations showing even distribution of proposed load currents across the phases. Provide replacement parts list.

J. Provide catalog data sheets for each type of wiring device. Include voltage and ampere ratings, dimensions and outline drawing or photograph in the catalog data.

K. Provide catalog data, installation instructions, and replacement parts list for each type disconnect switch. Include voltage and ampere ratings, construction material, NEMA classification, and dimensioned outline drawing in the catalog data. Include, as part of the installation instructions, a replacement parts list.

L. Provide catalog data including dimensioned drawings, materials, application (indoor, outdoor, marine, etc.) voltage, and wattage ratings. Provide photometric data including the IES file

number for all fixtures except restroom and emergency lighting.

M. Provide catalog data including dimensional data, ratings, and approvals; installation instructions for each type of smoke/heat detection device; and a detailed connection diagram for the overall installation.

N. Provide the following for the Motor Control Centers:

1. One-line and three line diagrams.
2. Schematic diagrams (including field wiring with wire numbers).
3. Wire and interconnection diagrams including terminals. Assign wire numbers for each wire.
4. Elevation and dimensioned outline drawings detailing arrangement of sections, cubicles, wireway and conduit entry.
5. Equipment schedule (Bill of Materials) detailing all components (with manufacturers' part no.) for each controller (cubicle).
6. Engraving schedule for nameplates.
7. Descriptive data for all components (CBs, starters, OL relays, HOA, lights, etc.).
8. Furnish instruction manuals describing theory of operation, maintenance information and schematics of motor starter units.

O. Provide the following for the AC Motors:

1. Catalog sheets with descriptive data.
2. Plan and elevation drawings with dimensional data.
3. Nameplate data.
4. Performance data including torque-speed and current graphs.
5. Schematic diagrams.
6. Provide certified motor drawings to the machinery fabricator for coordination.

P. Provide the following for the Variable Frequency Drive:

1. One-line, three line, and schematic diagrams (including field wiring with wire numbers).
2. Wire and interconnection diagrams including terminals. Assign wire numbers to each wire.
3. Elevation and dimensioned outline drawings detailing arrangement of sections, cubicles, wireway and conduit entry.
4. Manufacturers' Field Reports: Indicate start-up inspection findings.
5. Operation Data: Include instructions for starting and operating controllers, a listing of drive parameters, and describe operating limits that may result in hazardous or unsafe conditions.
6. Maintenance Data: Include routine preventive maintenance schedule.
7. Instruction Manuals: Furnish instruction manuals with manufacturers' information and recommendation covering.
8. Vector controlled drive characteristics such as ratings, conditions for applications and service, control functions, protective functions, and options available or included.
9. Safety precautions and procedures before and during installation, starting adjustments, and maintenance.
10. External control and power wiring, including grounding.
11. Recommendations to optimize immunity to electrical noise.
12. Listings of phenomena external to the Variable Frequency Drive that can cause malfunctions or dangerous conditions, with suggested corrective actions.
13. Troubleshooting procedures with symptom/cause-effect/and corrective recommendations, based on manufacturers' recommended SRUs (Smallest Replaceable Units).
14. Warning Labels: Include suitable warning labels inside and outside the enclosure in those cases where it is possible for the maintenance electrician to wire circuits into the enclosure that are not disconnected by the disconnect device.

Q. Provide the following for the DC Motors:

1. Catalog sheets with descriptive data.
2. Plan and elevation drawings with dimensional data.
3. Nameplate data.
4. Performance data including torque-speed and current graphs.
5. Schematic diagrams.
6. Provide certified motor drawings to the machinery fabricator for coordination.

R. Provide the following for the DC Drive:

1. One-line, three line, and schematic diagrams (including field wiring with wire numbers).
2. Wire and interconnection diagrams including terminals. Assign wire numbers to each wire.
3. Elevation and dimensioned outline drawings detailing arrangement of sections, cubicles, wireway and conduit entry.
4. Manufacturers' Field Reports: Indicate start-up inspection findings.
5. Operation Data: Include instructions for starting and operating controllers, and describe operating limits that may result in hazardous or unsafe conditions.
6. Maintenance Data: Include routine preventive maintenance schedule.
7. Instruction Manuals: Furnish instruction manuals with manufacturers' information and recommendation covering.
8. DC drive characteristics such as ratings, conditions for applications and service, control functions, protective functions, and options available or included.
9. Safety precautions and procedures before and during installation, starting adjustments, and maintenance.
10. External control and power wiring, including grounding.
11. Recommendations to optimize immunity to electrical noise.
12. Listings of phenomena external to the DC Drive that can cause malfunctions or dangerous conditions, with suggested corrective actions.
13. Troubleshooting procedures with symptom/cause-effect/and corrective recommendations, based on manufacturers' recommended SRUs (Smallest Replaceable Units).
14. Warning Labels: Include suitable warning labels inside and outside the enclosure in those cases where it is possible for the maintenance electrician to wire circuits into the enclosure that are not disconnected by the disconnect device.

S. Provide the following for the Integrated Bridge Control System:

1. Manufacturers' data sheets for all components (terminal blocks, relays, timers, fuses, circuit breakers, sensors, etc.). Provide instructions for adjusting and resetting time delay relays and timers. Provide all manufacturers' data and recommended preventative maintenance procedures and materials.
2. Dimensioned fabrication details for control desk, main control panel, and other enclosures including, to scale, equipment layouts, punch-outs, nameplate schedules, and bill of materials. Label all components, for which identification numbers have been provided in the Contract Documents, with that number.
3. A bill of materials. Provide some means of cross-referencing the item identification numbers to the materials list; either by schedule or labeling the applicable catalog data sheets.
4. Engraving schedule for nameplates.
5. Schematic diagrams including field wiring. Assign wire numbers for each wire and include in the schematic and wiring diagrams.
6. PLC topology, dipswitch settings, and input/output addresses.
7. PLC program listing.
8. Alarm message listing.
9. Dimensioned details for mounting of limit switches and field control devices.
10. Procedures for shop test and functional acceptance testing.

` T. Communications Equipment: Provide a submittal to the Engineer detailing the interfacing and testing of the PA/IC system.

U. Provide the following for the Navigation Lights and Aids:

1. Include manufacturers' data sheet for each new light, air horn, marine radio, and back-up power supplies (UPS).

2. Provide dimensioned outline drawings for mounting detail and any mounting/adapter assembly or component.

3. Submit battery sizing calculations and operation and maintenance data.

V. Provide the following for the Standby Generation System:

1. One-line, three-line, and schematic diagrams.

2. Wiring and Interconnection Diagrams for generator set, ATS, remote status panel, and auxiliary devices including batteries, charger, fuel supply monitor, and load bank. Include field wiring in the schematic diagrams. Assign wire numbers for each wire and show on both schematic and field wiring diagrams.

3. Elevations and dimensioned outline drawings detailing arrangement, wire way, conduit entry, panel layouts, fuel filling station piping, fittings and access locations.

4. Equipment Schedule detailing all components of the generator set, ATS, remote status panel, battery systems and fuel systems (and fuel tank).

5. Furnish a certified shop test report including all reactance values and other electrical parameters.

6. Listing of furnished spare parts.

7. Warranty.

8. Dimensioned drawings detailing shrouds and louvers.

W. Make a submittal for each type lighting fixture. Include catalog data sheets including outline and dimensions as well as product description with ballast, fuses, mounting adaptors, etc. identified. Submit lamp data sheets for each fixture including photometric data. Include submittal for lighting panel transformer and lighting panel with data sheets for each type circuit breaker. Submit calculations diagram with balanced load schedule.

X. Provide shop drawings showing outline and support point dimensions, voltage, main bus ampacity, integrated short-circuit ampere rating, circuit breaker arrangement and sizes. Provide manufacturers installation instructions, which indicate application conditions and limitations of use, stipulated by the product-testing agency. Include instructions for storage, handling, protection, examination, preparation, installation and starting of all products. Record actual locations of all products and indicate actual branch circuit arrangement.

Y. Make a submittal for the communication intercom/PA system. Include drawings for system routing with dimensions, speaker/amplifier/handset locations, system block diagram, wiring terminations and dimensioned mounting details for all devices. Submit manufacturers' data sheets for all communications equipment with documentation for system description and operation and maintenance procedures.

T508-3. MATERIALS AND EQUIPMENT

Furnish only new materials that conform to the standards of the UL, in every case where such a standard is established for the particular type of material and its intended application. Prior to purchase of any materials or equipment required to be furnished and installed, submit a complete list of all such materials and equipment including manufacturers' catalog numbers, catalog data sheets, illustrations, and shop drawings to the Engineer for approval.

T508-3.1. Wire and Cable

T508-3.1.1. Description: Wire and cable routing shown is approximate unless dimensioned. Route wire and cable, as required, to meet project conditions. Determine exact routing and lengths required where wire and cable routing is not shown, and destination only is indicated.

T508-3.1.1.1. Definitions: Power Conductor: Any wire that feeds power to a field device

(i.e. drive motors, brake motors, span lock motors, etc.).

Control Circuit Conductor: Any wire that goes to a pilot device (i.e. limit switches, pressure switches, etc.).

Field Wire: Any wire that leaves the electrical room. Consider the machinery platform to be outside the electrical room.

T508-3.1.2. Materials: Single conductor insulated wire. Provide XHHW-2 rated 600 V_{AC} unless otherwise noted. Provide SE, or RHW insulated wire for incoming services unless otherwise noted.

Use seven or nineteen strand copper, minimum 98% conductivity conductors for field wiring. Furnish connector accessories for copper in sufficient quantities for a complete installation. Do not use aluminum or solid copper conductors. In cases of low level audio or digital signals, use twisted shielded pairs when required.

Use no wire smaller than No. 12 AWG for power and lighting circuits and no smaller than No. 14 AWG for control wiring between cabinets, except that control wiring within a manufactured cabinet may be smaller. Use of wires smaller than No. 18 AWG requires approval by the Engineer. Multi conductor ribbon cables, between components within a cabinet, are allowed if approved by the Engineer. Install per the requirements of UL 508.

Minimum field wire size is No. 12 AWG for control conductors between cabinets and field devices and No. 10 AWG for motor loads. Use pigtails, no longer than 12 inch, for connection of field devices that cannot accommodate a No. 12 AWG wire. Use No. 10 AWG for 20 A, 120 V_{AC}, branch circuit home runs longer than 75 feet, and for 20 A, 277 V_{AC}, branch circuit home runs longer than 200 feet.

Maximum wire size allowed is 500 kcmil, use parallel runs as needed for larger loads.

T508-3.1.3. Construction Requirements: Installation includes placement, splicing, terminating, identifying, testing, and verifying each circuit and conductor. Do not splice wires (except for "pigtail" leads and lighting circuits), use insulated terminal blocks rated for 600 V_{AC} in enclosures.

Do not mix power and control conductors in the same conduit.

If more than three current carrying conductors are in a conduit, derate the conductors per Table 310.15(B)(2)(a) of the NEC. For derating purposes, consider all power conductors, other than the ground and neutral conductors, as current carrying, this requirement does not apply to control wires.

Tape uninsulated conductors and connectors with electrical tape to 150% of the insulation value of the conductor. Neatly train and lace wiring inside boxes, equipment, and panelboards. Place an equal number of conductors for each phase (three-phase system) of a circuit in same raceway or cable. Make conductor lengths for parallel circuits equal. Pull all conductors into a raceway at the same time.

Install two spare conductors, minimum, for long field runs to critical devices such as all movable span mounted devices, etc.

Use soap base wire pulling lubricant for pulling No. 4 AWG and larger wire. Take precautions to avoid "sawing" through PVC conduit. Use only braided pull ropes. Do not pull bare conductors through PVC conduits. Swab conduit with an approved lubricant prior to pulling the conductors.

Test each circuit for continuity and short-circuits for its complete length before connecting to load. Verify identification numbers for the entire length of the circuit. Inspect wire and cable for physical damage and proper connection.

Perform the insulation resistance test at 1,000 V_{DC} for 1/2 minute. Minimum insulation resistance for new cable will be 100 M-ohms or greater. When insulation resistance must be determined with all motor control centers, panelboards, switches, and over current devices in place, the insulation resistance when tested at 500 V_{DC} will be no less than 50 M-ohms. The Engineer will witness the test. Record the test results and submit to the Engineer for review prior to energizing the circuit. Include a Table of the test results with the "as-built" drawings with additional columns left blank for recording future readings.

T508-3.2. Grounding

T508-3.2.1. Description: Ground the electrical power and control system in accordance with

NEC requirements. Furnish and install ground rods, and grounding conductors as shown in the Plans. The requirements for the electrical grounding system do not apply to the Lightning Protection system grounding requirements.

T508-3.2.2. Materials: Use only insulated soft drawn annealed copper grounding conductors unless otherwise noted in the plans.

Use 1-inch diameter, 10 foot, copper clad steel ground rods.

Provide ground well 10 inches in diameter, 24 inches long, PVC, with a belled hub and a galvanized steel cover.

Use tin plated, high-pressure compression, one-hole lug connections for grounding equipment. Use only thermally welded connections to ground rods.

T508-3.2.3. Construction Requirements: Install a dedicated ground conductor, with green insulation in each conduit in which voltage of the current carrying conductors exceeds 50 V.

Size grounding conductors in any conduit in accordance with NEC Table 250.122, or the same AWG as the largest current carrying conductor in the conduit, whichever is larger.

Provide two ground rods and wells at the service entrance main disconnect switch in accordance with the NEC. Locate ground wells within 10 feet of the main disconnect switch mounting support. If the resistance between the two ground rods exceeds 25 ohms, add extensions and drive rods deeper if required.

Provide, as a minimum, a No. 2/0 AWG service entrance grounding conductor from the case ground to the well. Install the ground well so that the top of the well is 1/2 inch above the finished grade and drive the rod to just below the top. Fill well with gravel.

Bond the electrical system to the lightning protection system ground at the lightning grounding electrode (rod) closest to the motor control center in the bridge pier and the ground buss in the motor control center.

T508-3.3. Supporting Devices

T508-3.3.1. Description: Provide hangers and supporting devices as required by the NEC and this TSP.

T508-3.3.2. Materials:

A. Provide brass or stainless steel mounting bolts, nuts, washers, and other hardware used for fastening boxes, disconnect switches, devices, lighting outlet boxes, conduit clamps, and similar devices. Use hexagonal bolt heads and nuts. Do not use bolts smaller than 3/8 inch in diameter except as may be necessary to fit the mounting holes in small devices, outlet boxes, and similar standard equipment.

B. Provide PVC coated steel support struts and clamps to support PVC coated conduits.

C. Furnish products listed and classified by UL as suitable for purpose specified and shown. Provide adequate corrosion resistance and ensure that the material selected for the hardware is compatible with the material of the device supported.

D. Provide materials, sizes, and types of anchors, fasteners and supports to carry the loads of equipment and conduit. Consider weight of wire in conduit when selecting products. Minimum safety factor is 2.0. Provide stainless steel framework for supporting boxes, switches, and other externally mounted electrical devices.

E. Provide stainless steel, 12 gauge and 1-1/2 inch width minimum components from the same manufacturer for U-Channel strut systems utilizing bolted construction.

T508-3.3.3. Construction Requirements:

A. Do not use powder-actuated anchors, drill or weld structural steel members.

B. Use hexagonal bolt heads and nuts with spring lock washers under all nuts.

C. Fasten hanger rods, conduit clamps, and outlet and junction boxes to structure using proper fasteners. Use toggle bolts or hollow wall fasteners in hollow masonry, plaster, or gypsum board partitions and walls; expansion anchors or preset inserts in solid masonry walls; self-drilling anchors or expansion anchor on concrete surfaces; sheet metal screws in sheet metal studs; and wood screws in wood construction.

D. Use stainless steel straps or hangers held at not less than two points for attachment to steel or concrete. Provide 300 series stainless steel concrete inserts.

E. Install surface-mounted cabinets and panelboards with minimum of four anchors. Fasten device boxes to the mounting surface with not less than two anchors.

F. Do not fasten supports to piping, ductwork, mechanical equipment, or other conduit. In addition, do not allow piping, or other trades to fasten to electrical conduits and supports.

G. Fasten hanger rods, conduit clamps, and outlet and junction boxes to structure using proper fasteners.

H. Ensure that cut offs are cut square, ground smooth and de-burred. Where PVC coated steel has been cut or there is damage to the coating, coat the exposed steel with the manufacturers' touch up coating, to the same thickness as the original, prior to installation.

I. Use stainless steel cast in place inserts for overhead supports.

T508-3.4. Conduit and Raceways

T508-3.4.1. Description: Furnish and install conduit and raceways in the quantities and sizes required to complete the work as shown in the Plans. If conduit size is not shown in the Plans, determine the size as required by the NEC, minimum conduit size allowed is 3/4 inch. Furnish products listed and classified by UL for purpose specified and shown. Do not use non-metallic flexible conduit, aluminum conduit, or electrical metallic tubing (EMT). Recombine conduit and circuits indicated in the Plans, diagrams, and schedules where appropriate and as approved by the Engineer.

T508-3.4.2. Materials:

T508-3.4.2.1. PVC Coated Metal Conduit:

A. Hot dipped galvanized, inside and out, rigid steel conduit (ANSI C80.1) with hot galvanized threads and external PVC coating 40 mils thick; meeting the requirements of NEMA RN 1 and fittings and conduit bodies meeting the requirements of ANSI/NEMA FB 1 with steel fittings with internal and external PVC coatings to match conduit. Provide 40 mils thick PVC coating on the outside of conduit couplings and a series of raised longitudinal ribs to protect the coating from tool damage during installation.

B. Ensure the bond between the PVC coating and the conduit surface is greater than the tensile strength of the coating. Verify this bond by testing described in NEMA Standard RN-1, section 3.8.

C. Uniformly, and consistently, apply a nominal 2-mil thick urethane coating to the interior of all conduit and fittings. Conduit or fittings having pinholes or areas with thin or no coating are unacceptable. Protect all factory cut threads on conduit, elbows, nipples, and fittings by application of a urethane coating. The PVC exterior and urethane interior coatings applied to the conduit must afford sufficient flexibility to permit field bending without cracking or flaking at temperatures above 30°F.

D. Furnish right angle beam clamps and U-bolts specially formed and sized to fit the outside diameter of the PVC coated conduit. Supply all U-bolts with plastic encapsulated nuts that cover the exposed portions of the threads.

E. Ensure that only tools designed and approved by the conduit manufacturer for use on PVC coated materials are used and the workmen performing the installation are trained and certified in the installation and use of PVC coated conduit and fittings by the manufacturer.

F. Ensure that the same manufacturer supplies all PVC coated conduit, fittings, and accessories.

T508-3.4.2.2. Liquid-Tight Flexible Metal Conduit: UL 360 listed, interlocked galvanized steel construction, with integral ground continuity and PVC jacket. Use only PVC coated fittings, meeting the requirements of ANSI/NEMA FB 1.

T508-3.4.2.3. Non-Metallic Conduit: UL listed Schedule 80 PVC conduit meeting the requirements of NEMA TC 2 and Fittings and Conduit Bodies meeting the requirements of NEMA TC 3.

T508-3.4.2.4. HDPE Conduit: UL listed for electrical use Schedule 80 conduit meeting the requirements of NEMA TC 7. Use only UL listed fittings.

T508-3.4.3. Construction Requirements:

A. Use 1 inch minimum size Schedule 80 PVC or Reinforced Thermosetting Resin conduit for underground installations when installation is more than 5 feet from bascule pier wall. Use 1 inch minimum size Schedule 80 PVC conduit for underground installations when installation is within 5 feet from bascule pier wall.

B. Use 1 inch minimum size Schedule 80 PVC in slab above grade (embedded).

C. Use 1 inch minimum rigid galvanized steel (PVC coated) for outdoor locations, above grade, exposed (and on bascule leaf) and exposed in dry locations (in pier, control house).

D. Use 3/4 inch minimum size Schedule 80 PVC for wet and damp locations (fender).

E. Use 3/4 inch minimum size rigid galvanized steel (PVC coated) for lighting and receptacle circuits in bascule piers.

G. Install conduit in accordance with NECA Standard Practice and in accordance with manufacturers' instructions.

H. Do not use plastic straps or plastic hangers. Do not support conduit with wire or perforated pipe straps. Remove wire used for temporary support.

I. Group related conduits; support using conduit rack. Construct rack using stainless steel channel; provide space on each for 25% additional conduits.

J. Use pull boxes wherever necessary to facilitate the installation of the conductors. Use conduit hubs to fasten conduit to sheet metal boxes. Avoid moisture traps; provide junction box with drain fitting at low points in conduit system. Install all conduits so that they drain properly and provide drainage tees at low points where required.

K. Do not use condulets for pulling more than ten conductors or for making such turns in conduit runs or for branching conductors, except for indoor wiring to lighting fixtures and receptacles. Install bronze or alloy expansion fittings at any point where a conduit crosses an expansion joint, or where movement between adjacent sections of conduit is possible. Arrange conduit to maintain headroom and present neat appearance. Route exposed conduit parallel and perpendicular to walls. Maintain adequate clearance between conduit and piping. Maintain minimum 6 inch crossing and 12 inch paralleling clearance between conduit and surfaces with temperatures exceeding 40°C.

L. Use flexible metal conduit only for the connection of motors, limit switches, and other devices whose position has to be adjusted periodically. Make connections between the rigid conduit system and all movable motors and movable limit switches with flexible metal conduit with couplings and threaded terminal fittings. Use only fully interlocked flexible metal conduit. Do not use flexible metal conduit extensions longer than 2 feet in length and provide with bonding jumpers. Install flexible metal conduit as to drain away from the device it serves.

M. Provide both ends of each conduit run with a brass tag having a number stamped thereon in accordance with the conduit diagrams. Use bare copper wire to fasten these tags securely and permanently to the conduit ends.

N. Wherever possible, run conduits in the control room and bascule piers exposed and not concealed in the walls, ceiling, or floor. Where conduits pass through the floors or walls of the control room, provide Schedule 80 PVC conduit sleeves allowing free passage of the conduits. After installing couplings, caulk openings with an approved UL listed fire stop material for airtight fits. Provide escutcheon plates on the interior walls, ceilings, and floors.

O. Connect conduit sections to each other with approved couplings; do not use aluminum couplings. Install conduits to be continuous and watertight between boxes or equipment. Protect conduits at all times from the entrance of water and other foreign matter by being capped or well plugged overnight and when the work is temporarily suspended. Set conduits mounted exteriorly on parts of the steel work not less than 1-1/2 inch clear from the supporting structure to prevent accumulation of dirt. Space parallel horizontal conduit 1 inch apart and securely clamp to the steel work to prevent rattling and wear. Provide conduit supports at no more than 5 foot spacing between supports and no more than 12 inches from box or fixture, or as required by NEC, whichever is more stringent.

P. Cut conduit square using saw or pipecutter; de-burr cut ends. Clean and swab conduit after threading. Bring conduit to shoulder of fittings; fasten securely. Do not use long running threads.

Tighten conduits until all threads are concealed by the cuff of the PVC coated fitting or coupling.

Q. Join nonmetallic conduit using cement as recommended by manufacturer. Wipe nonmetallic conduit dry and clean before joining. Apply full even coat of cement to entire area inserted in fitting. Allow joint to cure for 20 minutes, minimum. Provide embedded conduit stub-outs with threaded 316 stainless steel couplings.

R. Install no more than the equivalent of three 90 degree bends between boxes. Use conduit bodies to make sharp changes in direction, as around beams. Use factory elbows for bends in metal conduit larger than 2 inches. All field bends will be long sweep, with a radius 12 times the diameter, and free of kinks to facilitate the drawing in of conductors without injury to the conductors. Make conduit runs with as few couplings as standard conduit lengths will permit.

S. Do not fill control wire conduits to more than 25% fill.

T. Use suitable caps to protect installed conduit against entrance of dirt and moisture. Upon completion of the conduit installation, clear each conduit with a tube cleaner equipped with a mandrel of a diameter not less than 80% of the nominal inside diameter of the conduit, and draw in the conductors. Provide suitable pull string in each empty conduit.

T508-3.5. Boxes

T508-3.5.1. Description: Provide pull boxes and junction boxes as shown in the plans, at locations where more than eight conductors are gathered, and as required by the NEC.

T508-3.5.2. Materials:

A. Provide PVC coated cast metal wall mounted boxes for wiring devices (toggle switches, duplex receptacles, GFCI receptacles).

B. Ensure pull boxes, junction boxes, and all other miscellaneous housings used for pulling wires, terminating wires, or otherwise used to install electrical equipment, are NEMA 4X stainless steel. Provide drip proof enclosure opening with a rolled edge and cover held closed with clamps.

C. Provide enclosures larger than 12 inch in any dimension with a continuous stainless steel hinged cover with a glued in neoprene gasket.

D. Provide sheet metal enclosures with O-ring sealing hub connectors, drain fittings, and not less than four mounting lugs.

T508-3.5.3. Construction Requirements:

A. Install insulated bushings on conduit ends projecting into all boxes and enclosures. Do not drill box or enclosure for more conduits than actually enter it.

B. In locations exposed to weather use side or bottom conduit entries boxes only.

C. Use of wireways (metallic or non-metallic) and/or sheet metal troughs with hinged or removable covers is not acceptable.

D. Size boxes per NEC requirements for the size and number of conduits. Additionally, size boxes to include provisions for terminal block wiring clearance. Do not use boxes smaller than 8 by 8 by 4 inches.

T508-3.6. Terminal Blocks

T508-3.6.1. Description: Provide terminal blocks for internal circuits; circuits crossing shipping splits; where it will facilitate equipment parts replacement and maintenance; and to connect the temporary systems to the permanent systems during phased construction. Provide disconnect type terminal blocks for conductors requiring connection to circuits external to the control house.

T508-3.6.2. Materials: Furnish and install terminal blocks rated at 600 V. Furnish channel mounted screw cage box clamp type terminal blocks for No. 8 AWG and smaller conductors, with vibration proof nonferrous screw. Provide terminal blocks in groups of 12 with interlocking “finger safe” type barriers with white marking strips.

Furnish power distribution terminal blocks for No. 6 AWG and larger conductors, three-pole, suitable for copper conductors, UL rated for amperage equal to the largest conductor it accommodates and made out of copper.

Provide all current carrying components with corrosion resistant plating on nonferrous hardware. Do not use aluminum components if installed outside of the conditioned spaces of the electrical

room.

Provide terminal blocks with wire protectors that physically isolate the conductor from the terminal screw.

Do not use terminal blocks that require special tools.

T508-3.6.3. Construction Requirements: Group terminal blocks for easy accessibility unrestricted by interference from structural members and instruments.

Provide 2 inches minimum on each side of each terminal block and between terminals and wire duct to allow an orderly arrangement of all leads terminated on the block and to allow for wire labels.

Do not terminate more than two wires on any one terminal position.

Permanently label each terminal block, device, fuse block, and both ends of each conductor to coincide with the identification indicated on the schematic and wiring diagrams. Ensure that terminal blocks and devices already numbered on the plans have the same numbers on the equipment supplied.

T508-3.7. Electrical Identification

T508-3.7.1. Description: Provide identification for each electrical component including, but not limited to, conduit, wire, panels, boxes, motors, motor controllers, disconnect switches, and control devices.

T508-3.7.2. Materials:

T508-3.7.2.1. Nameplates: Provide legend nameplates for all major pieces of equipment named on the plans, and for all control devices.

Provide legend nameplates for devices that show the device designation and name used on the schematic wiring diagram. Provide fuse legend nameplates that show the type, ampere, and voltage rating of the fuses.

Provide typewritten directories, with covers and directory pockets, for all panelboards. Provide identification for each branch circuit in a panelboard.

Provide nameplates of minimum letter height as scheduled below:

A. Panelboards, Switchboards, and Motor Control Centers: 1/4 inch; identify equipment designation. 1/8 inch; identify voltage rating and source.

B. Individual Circuit Breakers, Switches, and Motor Starters in Panelboards, Switchboards, and Motor Control Centers: 1/8 inch; identify circuit and load served, including location.

C. Individual Circuit Breakers, Enclosed Switches, and Motor Starters: 1/8 inch; identify load served.

D. Transformers: 1/4 inch; identify equipment designation. 1/8 inch; identify primary and secondary voltages, primary source, and secondary load and location.

E. Switches, control relays, timers and other control devices: 1/8 inch; identify load and source and tag identification number.

F. Control Panel switches, pushbuttons, indicating lights, meters: 1/8 inch; identify function (Raise, Lower, Pull, Drive, etc.). Provide these nameplates in addition to the lettering provided on the switch, button or light face.

T508-3.7.2.2. Conduit Markers: Provide adequate marking of primary conduits that are exposed or concealed in accessible spaces, to distinguish each run as either a power or a signal/communication conduit. Use orange banding with black lettering unless otherwise indicated.

Provide snap-on type plastic markers. Indicate voltage ratings of conductors where above 240 V. Locate markers at both ends of conduit runs, near switches and other control devices, near items of equipment served by the conductors, at points where conduits pass through walls, floors or into non-accessible construction, and at spacing of not more than 50 feet along each run of exposed conduit. Do not mark switch-leg conduit and short branches for power connections, except where conduit is larger than 1 inch.

Provide both ends of each marked conduit run with a brass tag having a number stamped thereon in accordance with the conduit diagrams. Fasten these tags to the conduit ends securely and permanently with bare copper or stainless steel wire.

T508-3.7.2.3. Conductor Identification: Furnish vinyl cloth labels, split sleeve, or tubing type wire and cable markers.

Use numbers as indicated in the approved shop drawings, if there are no numbers shown in the plans.

Provide wire labels on each conductor in panelboard gutters, pull boxes, outlet and junction boxes, and at load connection. Provide wire markers on each conductor at terminal blocks.

T508-3.7.2.4. Underground Warning Tape: Provide 4 inches wide plastic tape, colored yellow with suitable warning legend describing buried electrical lines in every conduit trench.

T508-3.7.3. Construction Requirements: Degrease and clean surfaces to receive nameplates and tape labels. Install nameplates and tape labels parallel to equipment lines. Secure nameplates to equipment fronts using stainless steel screws.

Secure nameplates to inside of recessed panelboard doors in finished locations. Use embossed tape only for identification of individual wall switches and receptacles, control device stations.

Provide wire markers on each conductor in panelboard gutters, pull boxes, outlet and junction boxes, and at load connection. Identify with branch circuit or feeder number for power and lighting circuits, and with control wire number as indicated on schematic and interconnection diagrams or equipment manufacturers' shop drawings for control wiring. Place plan wire number label adjacent to the manufacturers' number where equipment already has manufacturers' wire number.

T508-3.8. Dry-Type Transformers

T508-3.8.1. Description: Furnish and install dry type ventilated transformers as indicated in the Plans.

T508-3.8.1.1. Delivery, Storage, and Handling: Store in a warm, dry location with uniform temperature. Cover ventilating openings to keep out dust. Handle transformers using only lifting eyes and brackets provided for that purpose. Protect units against entrance of rain, sleet, or snow.

T508-3.8.2. Materials: Ventilated dry type transformers designed according to the latest revision of ANSI/NEMA ST-20 and for continuous operation at rated kVA, 24 hours a day, 365 days a year, with normal life expectancy. Ensure required performance is 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 not to exceed 220°C Provide transformers with proven 220°C UL tested insulation system. Use copper wound coils. Ensure that materials in the transformer are flame retardant and do not support combustion as defined in ASTM D635. Final insulation treatment will be total immersion in a 220°C insulating varnish that maintains superior bond strength, high dielectric strength, and power factors at temperatures normally associated with 220°C system. After immersion, cure the varnish thoroughly at normal operating temperatures to assure the scourging of all volatiles in the varnish solvent.

Provide transformers constructed with core materials of high quality and low loss characteristics to minimize exciting currents, no-load loss, and interlaminar vibrations. Incorporate built-in vibration dampening systems in the design to minimize and isolate sound transmission. Mechanically brace the core-coil assembly to withstand short circuit tests as defined in NEMA TR-27. Coil construction and mechanical bracing members must prevent mechanical degradation of the insulation structure during the short circuit. Provide self-bracing transformer enclosure with drip-proof and rodent-proof protection. Include convenient knockouts for conduit entrance. Locate terminal compartment in bottom of transformer, below the core-coil assembly, for side or bottom conduit entrance. Temperature rise in terminal compartment must not exceed 5°C above ambient.

Provide transformers with two 2-1/2% full capacity taps above rated voltage and two 2-1/2% full capacity taps below rated voltage. Minimum basic impulse level (BIL) allowed is 10 kV. Ground core and coil assembly to enclosure by means of a visible flexible copper grounding strap. Provide transformers 75 kVA and less suitable for wall, floor, or trapeze mounting; transformers larger than 75 kVA suitable for floor or trapeze mounting. Ensure coils are continuous windings with terminations brazed or welded. Include factory nameplate with transformer connection data and overload capacity based on rated allowable temperature rise.

Conduct the following tests at the factory: Applied voltage test (one minute) 4 kV; induced voltage test - two times normal for 7,200 cycles; and ratio and phase relation. Test reports on electrically duplicated units certify that the following tests were completed on the first rating of any design: no load losses, induced voltage, total losses, sound level, applied voltage, impulse test, and temperature rise. Submit copies of test results to the Engineer for approval.

T508-3.8.2.2. Dry Type Isolation Transformers: ANSI/NEMA ST 20; factory-assembled, air-cooled dry type shielded isolation transformers; ratings as shown on the Plans.

Ground core and coil assembly to enclosure by means of a visible flexible copper grounding strap. Provide electrostatic winding shield with separate insulated grounding connection. Isolate core and coil from enclosure using vibration-absorbing mounts.

Nameplate: Include transformer connection data.

T508-3.8.3. Construction Requirements: Run line and load conductors in separate conduits. Provide 2 inches high concrete sill pad for floor-mounted transformers. Provide wall or trapeze mounted units with sufficient space above and around the transformer for cooling per manufacturers' recommendations.

T508-3.9. Panelboards

T508-3.9.1. Description: Furnish and install, where indicated, a dead-front panelboard incorporating switching and protective devices of the number, rating, and type noted in the Contract Documents.

T508-3.9.2. Materials:

A. Provide only circuit breaker equipped panelboards. Except where noted provide panelboards with general-purpose, surface mounted, enclosures. Provide panelboards rated for the intended voltage and in accordance with NEMA PB 1. Provide a factory nameplate listing panel type and ratings. Label panelboards used as service entrance equipment.

B. Provide factory assembled interiors complete with switching and protective devices, wire connectors, etc. Use terminals suitable for copper wire of the sizes indicated. Design interiors so that switching and protective devices can be replaced without disturbing adjacent units and without removing the main bus connectors and that circuits may be changed without machining, drilling, or tapping. Arrange branch circuits using double row construction. Use copper bus bars for the mains and size in accordance with NEMA standards. Unless otherwise noted, include full size neutral bars. Arrange bus bar taps for panels with single pole branches for sequence phasing of the branch circuit devices. Furnish assembled panelboard rated for 22 kA minimum in accordance with NEMA standards and their test verification. Provide full height phase bussing without reduction. Use copper cross and center connectors. Provide neutral bussing with a suitable lug for each outgoing feeder requiring a neutral connection. Bus spaces for future switching and protective devices for the maximum device that fits into them.

C. Furnish boxes made from galvanized code gauge steel and of sufficient size to provide a minimum gutter space of 6 inches on all sides. Where feeder cables supplying the mains of a panel are carried through its box to supply other electrical equipment, size the box to include this wiring space. Provide this wiring space in addition to the minimum gutter space specified above and increase the limiting width accordingly. Provide at least four interior mounting studs.

D. Provide all panel trims with hinged doors covering all switching device handles, except that panelboards having individual metal clad externally operable deadfront units may be supplied without such doors. Ensure doors do not uncover any live parts when making switching device handles accessible. Provide doors with cylinder lock and catch, except that doors over 48 inches in height must have auxiliary fasteners at top and bottom of door in addition to cylinder lock and catch. Furnish keyed alike locks and directory frame and card with transparent cover on each door. Provide the trims fabricated from code-gauge sheet steel. Clean all exterior and interior steel surfaces of the panelboard trim and finish with gray ANSI-61 paint over a rust-inhibiting phosphatized coating. Provide trims for flush panels that overlap the box by at least 3/4 inch all around. Provide surface trims that have the same width and height as the box. Provide trims that are mountable by a screwdriver without the need for special tools.

E. Protect electrical circuits, excluding circuits shown on the plans, with molded case

circuit breakers. Each pole of these breakers must provide inverse time delay and instantaneous circuit protection. Provide breakers operated by a toggle type handle with a quick-make, quick-break over-center switching mechanism that is mechanically trip free from the handle. Include provisions so that the contacts will not stay closed against short circuits and abnormal currents. Show tripping because of overload or short circuit by the handle automatically assuming a position midway between the manual ON and OFF positions. Grind and polish all latch surfaces. On multi-pole breakers, construct all poles so that they open, close, and trip simultaneously.

F. Provide breakers completely enclosed in a molded case, bolt-on type construction. Plug-in type or tandem type circuit breakers are not acceptable.

G. Seal the covers of non-interchangeable trip breakers; seal the trip unit of interchangeable trip breakers to prevent tampering. Ensure ampere rating is evident and molded into the operating handle. Provide contacts made of non-welding silver alloy. Arc chutes, consisting of metal grids mounted in an insulating support, must accomplish arc extinction.

H. Provide circuit breakers that conform to the applicable requirements of NEMA Standards, and meet the appropriate classifications of Federal Specifications W-C-375b. Provide circuit breaker ratings, modifications, etc., as shown on the Plans. Provide molded case breakers as follows:

1. Thermal magnetic standard type that provides inverse time delay overload and instantaneous short circuit protection by a thermal-magnetic element.

2. Magnetic only standard MCP (Motor Circuit Protector) that provides instantaneous only short circuit protection by a front adjustable magnetic only element. The adjustment button(s) will have main setting points and mid-setting points following a linear scale so that each point has a significant value within calibration tolerance.

3. Ambient compensating standard that provides inverse time delay overload and instantaneous short circuit protection by a thermal magnetic element. Accomplish compensation by a secondary bi-metal that will allow the breaker to carry rated current between 25°C and 50°C. Provide with tripping characteristics that are uniform throughout this temperature range.

I. Provide multi-pole breakers with a single operating handle. Plate all copper parts to prevent corrosion. Provide all 100 A-frame breakers with an interrupting rating of 10 kA (minimum), all larger frame size breakers with an interrupting rating of 22 kA (minimum). Provide a main breaker section that includes a molded case circuit breaker with an adjustable trip unit. Furnish a breaker frame and trip rating as shown in the Plans.

T508-3.9.3. Construction Requirements: Install panelboards in accordance with NEMA PB 1.1. Install panelboards plumb. Install recessed panelboards flush with wall finishes. Height: 6 feet to top of panelboard; install panelboards taller than 6 feet with bottom no more than 6 inches above floor. Provide filler plates for unused spaces in panelboards. Provide typed circuit directory for each branch circuit panelboard. Revise directory to reflect circuiting changes required to balance phase loads. Identify each branch circuit in a panelboard. Provide panelboards with covers and directory pockets and typewritten directories. Identify mounted electronic components by marking with contrasting colored ink beside the component.

Provide engraved plastic nameplates.

Measure steady state load currents at each panelboard feeder; rearrange circuits in the panelboard to balance the running phase loads to within 10% of each other. Maintain proper phasing for multi-wire branch circuits. Inspect for physical damage, proper alignment, anchorage, and grounding. Check proper installation and tightness of connections for circuit breakers, fusible switches, and fuses. Take care to maintain proper phasing for multi-wire branch circuits. Prior to energization of the panelboard, Megger check phase-to-phase and phase-to-ground insulation for proper resistance levels and check panelboard electrical circuits for continuity and for short-circuit. The Engineer may witness this test.

T508-3.10. Wiring Devices

T508-3.10.1. Description: Provide wiring devices as required.

T508-3.10.2. Materials: Toggle Switches: Provide heavy-duty use, totally enclosed type with

bodies and handles of thermosetting plastic, supported on a metal mounting strap. Provide switches with screw type wiring terminals, side-wired. Do not use back-wired, clamp-type terminals. Provide snap type switches with toggle handle, rated quiet type, AC only, 20 A, 120/277 V, single pole.

Receptacles: Provide heavy-duty use, duplex grounding type rated 20 A and 125 V. Provide thermosetting plastic composition bodies, supported on a metal mounting strap. Provide side wired receptacles with binding-type terminals. Back-wired, clamp-type terminals are not allowable. Ensure that the grounded pole connects to the mounting strap.

Ground Fault Circuit Interrupter (GFCI) Receptacles: Provide duplex, feed-through type, convenience receptacle with integral ground fault current interrupter. Provide devices rated for 20 A and capable of detecting a current leak of 5 mA. Connect receptacles to protect the local load without disruption of the rest of the circuits.

T508-3.10.3. Construction Requirements: Install switches and receptacles as shown in the plans. Install switches 42 inch above the finished floor and receptacles 14 inches above floor unless otherwise noted. Install switches with OFF position down.

Furnish and install three-way switches as indicated in the Contract Documents.

Install surface mounted devices in weatherproof boxes. Inside the control house and other environmentally controlled rooms, provide 1/16 inch thick satin finished Type 302 stainless steel cover plates.

Use GFCI type receptacles in all outside locations, rest room, and sink area.

For exterior locations, provide weather proof, corrosion resistant, plates with spring loaded snap covers. Consider the machinery floor area as an outside location.

T508-3.11. Disconnect Switches

T508-3.11.1. Description: Furnish and install, where indicated, heavy-duty disconnect switches having electrical characteristics, ratings, and modifications shown on the drawings. Furnish and install fuses for fused disconnect switches.

T508-3.11.2. Materials:

A. NEMA Type 4X (stainless steel) enclosures. Units installed in the Operator Room or the Electrical Room can be NEMA 12.

B. Equip with metal factory nameplates, front cover mounted, that contain a permanent record of switch type, catalog number, and hp rating.

C. Equip with visible blades, reinforced fuse clips, non-teasible, positive, quick make-quick break mechanisms with a handle whose position is easily recognizable and is padlockable in the OFF position. Switch assembly plus operating handle as an integral part of the enclosure base. Provide switches that are hp rated and meet NEMA Specifications. Provide switches with defeatable door interlocks that prevent the door from opening when the operating handle is in the ON position. Provide heavy-duty switches with line terminal shields.

D. Fusible Switch Assemblies: NEMA KS 1; quick-make, quick-break, load interrupter enclosed knife switch. Handle lockable in OFF position. Fuse Clips: Designed to accommodate Class R fuses.

E. Non-fusible Switch Assemblies of NEMA KS 1 construction Type HD with quick-make, quick-break, load interrupter enclosed knife switch. Handle lockable in OFF position. Furnish non-fusible switches with one N.C. (normally closed) and one N.O. (normally open) set of auxiliary contacts.

F. Furnish time delay, current-limiting type fuses with 200 kA interrupting rating at 600 V_{AC}. Use only rejection type fuses, UL listed to minimize short circuit damage and applied as follows: UL Class RK1 - Service entrance, transformer feeder and panelboard feeder; UL Class RK5 - Motor branch circuit.

G. Service Entrance: Furnish service rated disconnect switch.

T508-3.11.3. Construction Requirements: Install disconnect switches where indicated in the plans or where required. Install switches plumb at a height with the top not exceeding 6 feet above the floor.

Do not use switch enclosure as a pull box for wiring other than the load it serves. Use

separate conduits for line and load conductors.

T508-4. MOTORS

T508-4.1. Description:

Furnish and install motors as indicated in the Contract Documents.

T508-4.2. Materials

A. Furnish motors designed for continuous operation in 40°C environment, and for temperature rise in accordance with ANSI/NEMA MG 1 limits for insulation class, service factor, and motor enclosure type.

B. Provide stamped, stainless steel nameplate indicating motor horsepower, voltage, phase, cycles, RPM, full load amps, locked rotor amps, frame size, manufacturers' name and model and serial number, design class and service factor.

C. Provide conduit connection boxes, threaded for conduit. For fractional horsepower motors, where connection is made directly, provide conduit connection in end frame.

D. Provide bolted compression lugs connections.

E. Provide double-ended shafts on all motors requiring motor brakes.

T508-4.2.2. Three Phase Motors:

A. Start-Ups: 12 per hour. 2 per ten-minute period.

B. Power Output, Locked Rotor Torque, Breakdown or Pullout Torque:

1. NEMA Design B Characteristics for pumps and span drive motors.
2. NEMA Design D for mechanical locks.

C. Insulation System: NEMA Class F or better.

D. Design, Construction, Testing, and Performance: Conform to NEMA MG 1 for Design B and D Motors.

E. Test in accordance with ANSI/IEEE 112, Test Method B. Load test motors to determine freedom from electrical or mechanical defects and compliance with performance data. Perform additional testing to determine speed/torque curve relationship. Do not exceed the motor full load characteristics during testing.

F. Motor Frames: NEMA Standard T-frames of steel or cast iron (no aluminum frames allowed) with end brackets of cast iron with steel inserts. Furnish totally enclosed fan cooled construction for motors 10 hp and larger.

G. Thermistor System (Motor Sizes 25 hp and Larger): Three PTC thermistors imbedded in motor windings and epoxy encapsulated solid-state control relay for wiring into motor starter.

H. Bearings: Grease lubricated anti-friction ball bearings with housings equipped with plugged provision for relubrication, rated for minimum AFBMA 9, L-10 life of 20,000 hours. Calculate bearing load with NEMA minimum V-belt pulley with belt centerline at end of NEMA standard shaft extension. Stamp bearing sizes on nameplate.

I. Sound Power Levels: To NEMA MG 1.

J. Nominal Efficiency: Meet or exceed values in Schedules at full load and rated voltage when tested in accordance with ANSI/IEEE 112.

K. Nominal Power Factor: Meet or exceed values in Schedules at full load and rated voltage when tested in accordance with ANSI/IEEE 112.

L. Service Factor: 1.0 for mechanical drives and 1.15 for hydraulic pump motors. Reference horsepower ratings from a 1.0 service factor.

T508-4.2.3. Storage: Provide temporary power connection to internal motor heaters, or provide external heater, to maintain constantly elevated internal temperature to assure prevention of condensation or moisture accumulation. Manually rotate the rotor every thirty days to prevent flattening of bearings. If the storage arrangement permits, rotate the entire housing 90 degrees every sixty days. The storage period continues after installation of the motors until they start actual repetitive service that will produce heat from operation.

T508-4.3. Construction Requirements

A. Provide auxiliary fans, for motors driven by variable speed drives or DC drives, if required to maintain temperature when running at less than full speed.

B. Install motors per manufacturers' instructions. Utilize millwright for field installations, base modifications, and shaft alignment with the machinery and the brakes.

C. Provide motor mounting bases as required for accommodating motors. Properly align motor shaft with speed reducer shaft before connecting motor coupling. Properly align brake drums with brakes. Align if required.

D. Coordinate motor shaft diameter and length with requirements for machine, service brakes, and tachometer. Verify alignment of motor shafts with machinery and brakes prior to installation of shaft couplings; correct as required to provide proper alignment within coupling misalignment tolerances.

T508-4.3.2. Quality Control: Perform a no-load spin test and megger tests on main drive motors to verify compliance with the manufacturers' specifications prior to make-up of machinery couplings.

T508-5. MOTOR CONTROL CENTER

T508-5.1. Description

Furnish and install a Motor Control Center (MCC) as shown in the Contract Documents and including adequate capacities for bus ampacity, three phase circuit breakers and contactors. Furnish the input circuit in the MCC complete with an ammeter, voltmeter, and all required instrument transformers.

Deliver MCC individually wrapped in factory fabricated fiberboard type containers and with lifting angles on each MCC supporting structure. Handle MCC carefully to prevent internal component damage, and denting or scoring of enclosure finish. Do not install damaged MCC. Store MCC in a clean and dry space. Protect units from dirt, fumes, water, construction debris.

Furnish and install, where indicated or required, motor controls having the electrical characteristics, ratings, and modifications shown in the Plans.

T508-5.1.2. Manufacturer: Furnish Motor Control Centers that are the product of an established manufacturing company. Do not use a value added reseller as a source.

T508-5.2. Materials

T508-5.2.1. MCC Sections:

A. Furnish NEMA Class II Type C category, 480 V_{AC}, 3-phase, four-wire type MCC. Enclosure may be a free standing NEMA 1 or NEMA 12 class, finished with ANSI 61 gray paint with appropriate rust inhibiting primer, composed of 20 inches vertical sections. Provide copper horizontal bus with 600 A rating and a vertical bus at 300 A, braced to withstand a 65 kA short circuit.

B. Provide incoming feeders, load and control line entrances to MCC as indicated in the Plans. Provide a ground in each vertical section as well as a connecting horizontal bus.

C. Provide vertical sections with a vertical wireway and wireways on top and bottom with an insulated barrier with removable access covers to conceal vertical bus work.

D. Arrange motor starters in the MCC in a logical manner, group like devices together (locks, drives, etc.).

E. Provide a storage pocket on the inside of the cabinet door for the schematics. Furnish instruction manuals, including the theory of operation, maintenance information, and laminated plastic schematics on all units within the MCC.

F. Provide engraved nameplates for each cubicle (including blank nameplates for unused spaces, and blank nameplates for spare cubicles). Submit nameplate-engraving schedule for approval. Fasten nameplates using stainless steel screws.

T508-5.2.2. Circuit Breakers: Provide 3-pole, heavy duty, 600 V_{AC}, quick-make, quick-break molded case circuit breakers and MCPs. Provide a molded case type main breaker with an adjustable electronic trip unit. Furnish a 3-pole lighting panel circuit breaker as shown in the Plans. Provide an operating handle that always remains connected to the MCP or circuit breaker. Do not mount the operating handle on the door of the enclosure, but to the side of the door for safe "stand-aside" operation.

Position of the operating handle will indicate ON, OFF, or TRIPPED condition. Provide interlock to prevent unauthorized opening or closing of the cubicle door with the circuit breaker in the ON position as well as turning the circuit breaker ON with the door open.

T508-5.2.3. Magnetic Across the Line Starters:

A. Furnish 120 V_{AC} magnetic starter coils. Equip all magnetic starter coils with a combination R/C-MOV surge suppressor across the coil circuit to prevent inductive switching transients from damaging any connected circuitry.

B. Furnish motor starters of the Combination Motor Starters type (across-the-line non-reversing or reversing combination starters for motors up to 100 hp, 600 V_{AC}). Combine motor starters with disconnecting means, as indicated in the Contract Documents, in common enclosure. Provide a Motor Circuit Protector (MCP), or MCP with Current Limiter, as disconnecting means. Build and test motor starters in accordance with the latest NEMA standards. Equip combination motor starters with three NEMA Class 20 overload relays. Provide neatly typed label inside each motor starter enclosure door identifying motor served, nameplate horsepower, full load amperes, code letter, service factor, and voltage/phase rating. Provide quick-make, quick-break, and load interrupter enclosed knife switch with externally operable handle.

C. Furnish AC magnetic controllers designed for full voltage or across the line starting of induction motors rated in horsepower. Furnish starters with provision for field installation of up to 3 N.O. and 4 N.C., 10 A., auxiliary contacts in addition to the hold-in interlock. Supply a minimum of two Normally Open and two Normally Closed contacts with each magnetic motor starter. Provide additional contacts if required. Provide starters with encapsulated coils and enclosure as required to meet conditions of installation. Overload relays should be block-type with a push-to-test feature. Provide an isolated, field-mountable alarm contact.

D. Provide 3-pole, 480 V_{AC}, full voltage, NEMA type, magnetic combination type starters. Provide motor starters that are a combination circuit breaker and NEMA controller with overload relay protection. Connect to the bus with stab-type contacts, including ground, and a screw-type locking mechanism to hold the chassis firmly in place. Provide quantities as shown in the Plans. Where specified, provide control voltage transformers with fused secondary. Provide OL TRIPPED status and through-the-door overload RESET button.

E. Furnish Non-Reversing Starters (Across-the-line magnetic starters for motors up to 100 hp, 600 V_{AC}) built and tested in accordance with the latest NEMA standards. Equip non-reversing starters with three NEMA Class 20 overload relays. Provide a HAND-OFF-AUTO switch and pilot lights for OFF, RUN, and OL TRIPPED status. For FVR units provide a HAND-OFF-AUTO switch, a FORWARD-OFF-REVERSE switch and pilot lights for FORWARD, OFF, REVERSE, and OL TRIPPED status.

F. Provide reversing Starters (Reversing magnetic starters for motors up to 100 hp) built and tested in accordance with the latest NEMA standards. Equip reversing starters with three NEMA Class 20 overload relays.

T508-5.2.4. Reduced Voltage Starters:

A. Rated for operation in a 480 V_{AC}, 3 phase, and 60 Hz system.

B. Combination type with Motor Circuit Protector (MCP) feeder/disconnect (subject to manufacturers' recommendation for the protective device).

C. UL or CSA (Canadian Standards Association) certified and complying with the latest applicable ANSI, NEMA, IEEE, and NEC standards.

D. Include suitable warning labels inside and outside the enclosure in those cases where it is possible for maintenance personnel to wire circuits into the enclosure that are not disconnected by the disconnect device.

E. 460 V power controlling unit with features sized to meet the following operating requirements:

1. Operate in an ambient temperature of 0 to 40°C., an altitude of up to 3300 feet above sea level, and humidity of 0 to 95% non-condensing.

2. Have complete front accessibility with easily removable assemblies.

3. Feeder disconnect. Input AC circuit breaker (MCP) with an interlocked, padlockable handle mechanism.

4. Operate as a series controller with an electromechanical output contactor (starter) to provide isolation from the load circuit when not in operation. Input isolation contactor at manufacturers' recommendation.

F. Starting Characteristics:

1. Selectable starting mode: Soft Start, Current Limit Start, Full Voltage Start.

2. Input voltage (pedestal): 30% to 95% line voltage.

3. Initial (starting) torque: 10% to 90% full voltage starting torque.

4. Kick-start: 95% line voltage (90% full voltage starting torque) adjustable 0 to 999 milliseconds.

5. Full load motor current: 40% to 100% rated starter current.

6. Current limit: 100% to 450% motor full load current.

7. Linear acceleration ramp time: 0 to 60 seconds.

G. Stopping Characteristics: Coasting: Power removed from motor with no soft stop or DC brake.

H. Options:

1. Overload, alloy type overload relay complete with thermal elements.

2. Heat sink overheat sensor.

3. Transient protection.

4. Locked rotor and short circuit protection.

I. Factory Inspection Requirements: Supply test results of the starter test to substantiate design according to applicable ANSI and NEMA standards. Test to verify the performance of the starter and the suitability of the enclosure venting and rigidity. Factory test all units in accordance with ANSI standards.

J. Adjusting: Make final adjustments to installed starters in accordance with the Engineer's instructions to establish proper operation of the system.

K. Installation Verification Testing of Reduced Voltage Starters:

1. Operate each drive (starter/motor combination) through a complete starting/stopping cycle with the motor operating with its typical load and record the wattage and speed vs. time using a suitably accurate and fast Watt transducer (2.5 element minimum, plus or minus 0.5%, 10 inch/minute chart; or digital acquisition system of superior specifications).

2. Submit proposed test procedure, test equipment specifications and certifications (where applicable), and reporting forms.

3. Submit test results recorded on approved forms with the appropriate Functional Checkout documentation.

L. Overload Relays: Provide block-type with a push-to-test feature; isolated, field-mountable, alarm contact that closes on relay overload trip; and RESET pushbutton on front door that allows resetting without opening enclosure.

M. Non-fusible Switch Assemblies: Provide quick-make, quick-break, load interrupter enclosed knife switch with externally operable handle.

N. Motor Circuit Protector: Provide circuit breakers with integral instantaneous magnetic trip in each pole.

T508-5.3. Construction Requirements

A. Install MCC, where indicated, in accordance with applicable NEC standards, Manufacturers' written instructions and recognized industry practices, to comply with requirements and serve intended purposes. Install fuses, if any, in MCC units. Tighten bus connections and mechanical fasteners. Adjust operating mechanisms for free mechanical movement. Touch-up scratched or marred surfaces to match original finish.

B. Provide 2 inch concrete pad above finished floor elevation as shown in the Contract

Documents. Provide a reverse-phase and phase-failure relays at the load side of the Main Circuit Breaker.

C. Provide for external connections for remote display meter, on the control desk, for voltage, current, and kW.

D. Prior to energizing the MCC, Megger check phase-to-phase and phase-to-ground insulation for proper resistance levels. Prior to energizing the circuitry, check MCC electrical circuits for continuity and for short-circuits. Subsequent to wire and cable hook-ups, energize MCC and demonstrate functioning in accordance with requirements.

E. Provide overload relay heaters sized to the full load current of the actual motor nameplate.

T508-6. SPAN MOTOR AND VECTOR CONTROLLED VARIABLE FREQUENCY DRIVE

T508-6.1. Description

T508-6.1.1. General: Furnish and install a matched motor and drive system as described in this article. Furnish factory engineered span drive motors and vector controlled drives which are the end product of a single manufacturer. Do not use value added resellers or control system contractors as a source for this item.

T508-6.2. Materials

T508-6.2.1. Span Drive Motor:

A. To assure compatibility and drive system integration, ensure the drive manufacturer provides the motor.

B. Provide TEFC, NEMA Design A motors, stainless steel shaft, with auxiliary blower (if required).

C. Provide a closed keyway on the machinery end of the shaft. Coordinate motor coupling and installation details with the machinery manufacturer. Provide approved shop drawings to the machinery manufacturer for their use in the machinery assembly drawings.

D. Provide motors rated for inverter duty and suitable for use in a sensorless vector controlled variable speed drive application.

E. Start-Ups: 12 per hour, 2 per ten-minute period.

F. Power Output, Locked Rotor Torque, Breakdown or Pullout Torque: NEMA Design A Characteristics.

G. Insulation System: NEMA Class F or better.

H. Testing Procedure: In accordance with IEEE 112, Test Method B. Load test motors to determine freedom from electrical or mechanical defects and compliance with performance data. Perform additional testing to determine speed/torque curve relationship.

I. Motor Frames: NEMA Standard T-frames of steel or cast iron (no aluminum frames allowed) with end brackets of cast iron with steel inserts.

J. Thermistor System (Motor Sizes 25 hp and larger): Three PTC thermistors imbedded in motor windings and epoxy encapsulated solid-state control relay for wiring into motor starter.

K. Bearings: Grease lubricated anti-friction ball bearings with housings equipped with plugged provision for relubrication, rated for minimum AFBMA 9, L-10 life of 20,000 hours. Calculate bearing load with NEMA minimum V-belt pulley with belt centerline at end of NEMA standard shaft extension. Stamp bearing sizes on nameplate.

L. Sound Power Levels: To NEMA MG 1.

M. Nominal Efficiency: Meet or exceed values in Schedules at full load and rated voltage when tested in accordance with IEEE 112.

N. Ship motors to a facility for dynamometer testing with the variable speed drives.

T508-6.2.2. Variable Frequency Drives (VFD):

A. This is a functional specification; ensure that the manufacturer sizes the motors and drives to provide the torque and speed requirements as shown in the plans.

B. Design the VFD system to provide reversing, continuous speed adjustment with acceleration and deceleration control, of three-phase motors without exceeding the specified maximum motor and machinery torque. Provide an VFD system capable of supplying power to the motor(s) for the

required motor torques. Provide a control capable of providing selectable current limit settings. Provide a drive that is able to withstand output terminal line-to-line short circuits without component failure, be insensitive to input line rotation, and be capable of power ride-thru of 15 mS at full load.

C. Furnish the drive with internal over temperature protection.

D. 115 V_{AC} input control logic board option. Provide inputs that include, enable, forward, reverse, zero speed, full speed, and full torque. Provide a drive that responds to inputs with preset direction and speed to accelerate and decelerate the bridge leaf to follow a trapezoidal speed curve as shown in the Plans.

E. Contact outputs: 4 form "c" min. (functionally programmable). Provide outputs that include overload alarm, and drive fault.

F. Provide dynamic braking function (with power resistors) capable of 100% braking of full load motor torque for 3 minutes.

G. Provide drives capable of converting incoming three-phase, 460 V_{AC} (-10% of min. +10% of max.) and 60 Hz (plus or minus 2 Hz) power to a variable potential DC bus level. Invert the DC voltage to pulse width modulated waveform with an adjusted 0 to 420 Hz frequency output.

H. Ensure displacement power factor ranges between 1.0 and 0.95, lagging over the entire speed range.

I. Provide an VFD capable of operating, without derating, in an ambient temperature of 0 to 40°C, an altitude of up to 3,300 feet above sea level, and humidity of 5% to 95%, non-condensing.

J. Furnish a dry type isolation transformer, for external mounting, with "wye" connected secondaries, for each unit.

K. Provide VFDs in NEMA 12 enclosures with complete front accessibility with easily removable assemblies.

L. Include the following items in the VFD's enclosures:

1. Feeder disconnect. Input AC circuit breaker or fused switch with an interlocked, pad lockable handle mechanism accessible without opening the drive door and capable of breaking under load.
2. Isolated process follow input and output.
3. Motor mechanical brake contactor.
4. Brake chopper module for control of Dynamic Braking Resistors. Mount resistors externally.
5. Electronic over current trip for instantaneous and inverse time overload protection.
6. Human interface module with START-STOP pushbuttons, power ON indicating light, and speed control potentiometer, door mounted.
7. Human interface module with alphanumeric display of run, stop, forward, reverse, fault, over frequency, instantaneous over current, DC over voltage, AC under voltage/loss of phase, emergency stop, overload, Over temperature, inverter pole trip, and stand-by modes, door mounted.
8. Run, fault, and control power indicators, door mounted. Local/Remote operation indicating lights, door mounted.
9. Electrical isolation between the power and logic circuits, as well as between the 120 V_{AC} control power.
10. Line transient voltage protection.

M. Provide the following independent adjustments on the VFD:

1. Output frequency range: 0 to 400 Hz.
2. Programmable current limits from 20%-160% of rated current.
3. Acceleration time: 0-3600 sec. with two independently programmable timers.
4. Deceleration time: 0-3600 sec. with two independently programmable timers.
5. Start boost control.
6. Volts per Hertz - programmable for start boost, run boost, slope, and custom operation.
7. Slip compensation speed regulation to 0.5%.

8. Provide VFD run, fault, and control power indications visible with the controller door closed. Provide an VFD reset button as part of the human interface module. Provide remotely resettable faults from a “clear fault” input line of the VFD.

9. Enclosure Construction: Furnish two ground lugs, one for incoming line power and one for outgoing motor ground connections. Provide enclosures no less than 16-gauge steel and finished in standard manufacturers’ finish.

T508-6.2.2.1. Line Impedance and Isolation: Install, as a minimum, isolation transformers on the line side of the VFD drive controller. Install other passive filters and traps on the line side of the VFD drive controller to insure proper protective device coordination, harmonic damping, and compliance with IEEE 519.

T508-6.2.3. Extra Materials: Furnish the following additional parts and any other required parts for the Variable Frequency Drive motor controller:

1 main control board
1 power interface board
1 gate board driver
1 diode power block
3 incoming line fuses
3 control power fuses

T508-6.3. Construction Requirements

Factory Demonstration: Before shipping, conduct a factory Design Proof Test on the first assembly with a calibrated dynamometer to verify the performance requirements. The Engineer may witness the test. Provide 30 day advanced notice and submit description of the test stand to document the accuracy of the torque readings. This design verification operational test is required on one motor, chopper, resistor, and drive. The manufacturer must certify that all other units are reasonably similar.

Test the VFD and supply test results to substantiate designs according to applicable ANSI and NEMA Standards. The tests must verify not only the performance of the unit and integrated assembly, but also the suitability of the enclosure venting and rigidity.

T508-6.3.1. Shop Testing of Variable Frequency Drives: Perform shop testing on the variable frequency drives to insure compliance with the performance requirements of this Article before acceptance of Variable Frequency Drive-Motor combinations. The Engineer may witness the testing based on approved shop drawings and test procedures. The motor manufacturer's specifications shall not be exceeded during this test. Testing procedures will be as follows:

A. Apply load equal to the torque specified for T_{CV} (Maximum Constant Velocity Torque) to motor shaft. Run motor at 100% speed for 3 minutes (driving). Motor-drive combination should be capable of driving the load without excessive heating.

B. Apply overhauling load equal to T_{CV} (formerly Condition A) torque to motor shaft. Run motor at 100% speed for 3 minutes (dynamic braking). Motor-drive combination should be capable of dynamically braking the load without excessive heating.

Demonstrate that motor drive can produce T_S (Maximum Starting Torque) torque at no less than or equal to 50% speed for one minute.

Demonstrate that motor drive can dynamic brake T_S (formerly Condition C) torque at no less than or equal to 50% speed for one minute without excessive heating.

Demonstrate that motor drive cannot produce or exceed the Never-Exceed torque value at zero, defined as 10% of full speed.

T508-6.3.2. Installation: Install motors per manufacturers’ instructions.

Install motor mounting bases as required to accommodate motors. Properly align motor shaft with driven shaft before connecting motor coupling. Align if required. Megger motors before final connection. Record these readings and submit with “As-Built” drawings.

Adjusting: Make final adjustments to installed drive to assure proper operation of fan system if so equipped. Obtain performance requirements from installer of driven loads.

Cleaning: Touch up scratched or marred surfaces to match original finish.

Demonstration: Demonstrate operation of controllers in automatic and manual modes.

T508-6.4 Spare Components: Provide one complete Variable Frequency Drive, fully programmed.

T508-7. INTEGRATED BRIDGE CONTROL SYSTEM

T508-7.1. Description

T508-7.1.1. General: Furnish and install a PLC based integrated bridge control system comprising a main control panel (CP-1), two control stations (CP-2's), uninterruptible power supply, and field control devices. Perform the detailed design of the control system using information in the Contract Documents and AREMA Manual with adjustments as required for the equipment provided.

T508-7.2. Materials

T508-7.2.1. Cabinets: Control stations, CP-2's, wall mounted cast iron panel, NEMA 4.

Control Panel, CP-1, 12 gauge stainless steel enclosure with doors in the front. Provide enclosures that have body stiffeners for added strength and doors with heavy gauge stainless steel continuous hinge on one side and stainless steel screws and clamps on three sides with oil-resistant gasket all around.

For non stainless steel cabinets, clean and phosphatize internal and external surfaces prior to the application of high quality rust inhibiting primer. Furnish light gray ANSI No. 61 baked enamel or polyester powder finish coat. Furnish the back panel finished with gloss white lacquer applied over suitable primers.

Provide vents (louvers with filters) and interior fans to keep temperatures to reasonable operating limits within the cabinets. Provide a temperature switch to alarm when temperatures inside exceed 40°C. Fasten a fluorescent fixture with 20 Watt (min.) lamp to the inside of the drive panel and panel CP-1. Install an appropriate switch as indicated in the Plans. Install a duplex receptacle on the same circuit and mount inside the cabinet. Connect both light and receptacle to a common one-pole circuit breaker. Install ground lug in all panels for bonding of enclosures.

T508-7.2.2. Wiring: Provide interconnection wiring between all electrical devices mounted in the panels and enclosures. If the devices are to be connected to external equipment use terminal blocks. Install all interior wiring neatly and carefully, and terminate on UL approved terminal blocks as per manufacturers' instructions.

Individually bundle wiring to each control switch and install with a "drop loop" of sufficient length to allow its removal for maintenance without disconnecting the wiring. Use plastic wireways (open slot type) for routing all internal wiring in the control desk. Install internal wiring in factory prewired electronic system cabinets according to the Manufacturers' standard as to wire size, insulation, and method of termination on internal equipment. Segregate all low voltage signal wiring, such as data, audio, and video lines, from AC lines. Do not splice low voltage signal and data lines.

T508-7.2.3. Terminal Blocks: For internal circuits crossing shipping splits, and to facilitate equipment parts replacement and maintenance, provide terminal blocks for conductors requiring connection to circuits external to the specified equipment. Furnish rail mounted, tubular screw clamp type terminal blocks. Group terminal blocks for easy accessibility unrestricted by interference from structural members and instruments. Provide sufficient space (2 inch minimum) on each side of each terminal block to allow an orderly arrangement of all leads to be terminated on the block. Do not terminate more than two wires on any one terminal position.

Permanently label each terminal block, device, fuse block, terminal, and both ends of each conductor to coincide with the identification indicated on the manufacturers' wiring diagrams. Number terminal blocks and devices on the equipment supplied using the same numbers shown in the Contract Documents. Identify mounted electronic components by marking with contrasting colored ink beside the component. Permanently identify individual conductors using a sleeve not less than 1/2 inch long. Mark each sleeve so that the identifications are permanent and waterproof. Adhesive type labels are not acceptable.

T508-7.2.4. Programmable Logic Controller:

A. Furnish the PLC and all components in the PLC system manufactured by a single source and the product of a company with a minimum of five years of experience in the manufacture and service of this type of equipment. The PLC system includes all PLCs, Message Display (MD), cables, and associated peripheral equipment, software and documentation required to monitor the bridge control system as required. The PLC system includes PLC hardware and software, and bus controllers with distributed I/O racks.

B. The following minimum features are required in the PLC:

1. The PLC system includes a CPU, bus controller, power supplies, distributed Input/Output (I/O) blocks, and plug-in chassis.

2. Furnish a PLC system that uses industry standard ladder logic at all programming levels. Do not use Assembly Language, “C”, micro-code, or Function Blocks programming.

3. Furnish a PLC system that is internally capable of running auto-diagnostics on CPUs, I/O blocks, bus controllers, and other devices that are part of the PLC systems.

4. Include I/O blocks, interface module (if required) and power supply for system inputs and outputs (if required). Ensure that all I/O Blocks are compatible with the main PLC rack and Bus Controllers.

a. Inputs: As required plus 25% expansion capability at 120/240 V_{AC}, 4-20 mA and 0-10 V_{DC}. Furnish input modules that provide status lights indicating active inputs.

b. Outputs: As required plus 25% expansion capability at 2 A loads (fused with fault status light indicator on output) and 0-10 V_{DC}. Provide output modules that provide status lights indicating active outputs. Outputs for indicator lamps may be solid state. Use relay contact output modules for motor control functions.

c. Ensure that all functions have dedicated I/O assignments. Do not use BCD.

d. Use industry standard wire terminals.

5. Internal PLC Diagnostics: Log input faults in easy to understand English language message format with a date and time stamp for each fault. Include any corresponding address information (to determine location of the fault) in the fault message that gets logged. List faults in chronological order. In addition to fault logs of input faults, provide a fault bit for each I/O point that reflects the health of the I/O point and that is easily usable in a ladder logic application program in the form of relay contacts to allow the program to act on the diagnostic information. Ensure the fault bits are also be available to be read by a host or operator interface device. Provide diagnostic LED indicators viewable at each physical module (block). Input diagnostics include, but are not be limited to:

a. Input wiring error.
b. Input shorted.
c. Input open wire.
d. Input under range.
e. Input over range.
f. Input deviation (discrepancy).
g. Loss of input module (block).
h. Stuck on output circuit.
i. Stuck off output circuit.
j. Output-to-output short circuit.
k. Load shorted high.
l. Load shorted to 0 V.
m. Open circuit load.
n. Open circuit output leg.
o. Output circuit overload (greater than 2 A)
p. Output circuit over temperature
q. Output discrepancy.
r. Loss of Output module (block).

6. Main PLC Card Racks: Include processor, power supply, memory, bus controller,

spare slots, and terminators as required.

7. Memory: Non-volatile. Capability to program instructions from laptop PC. Provide minimum 25% spare memory capacity. Provide memory that requires no battery backup for memory retention.

8. Programming Instruction Set:

a. Language Characteristics: Ladder diagram.

b. Logic Operations: AND, OR, XOR, NOT.

c. Register Operations: Store, recall.

d. Math Operations: Addition, subtraction, multiplication, division.

e. Instruction Set: Relay coil; latch; bit follow; timer; counter; shift register; master control relay; skip; arithmetic; comparison; data move; block transfer; search matrix; AND; OR; XOR matrix; complement matrix; first-in stack; first-out fetch; last-out fetch; bit operate; n-bit serial register; I/O update immediate.

9. Electrical Interface: Provide the capability for 25% expansion of input/outputs and instructions by the connection of additional units of equipment.

10. Supply Voltage: 90-130 V_{AC}.

11. Spare Parts: One each of every type card, power supply, or module required. Quantity of four (4) of each I/O blocks required. One fully programmed PLC (main processor).

12. Compatibility: Wherever possible, all assemblies and sub-assemblies performing similar functions in separate controllers furnished under these Contract Documents are interchangeable without the need to reprogram.

13. Certification: Furnish manufacturers' certification that the PLC, as ordered and as used with any optional devices from the manufacturer, has been tested to successfully operate in the high electrical background noise environment of a large industrial plant.

14. Industry Standards: Provide PLC system components of normally recognized industry standards for use in heavy industry installations. House all components in structurally sound and finished metal cabinets or housings. Furnish switches and other operator-controlled devices of a size and durability for their intended use as is normally offered for industrial applications. Construct connecting cables constructed to withstand, without damage, all normal use and handling. Provide only "off-the-shelf" components from the PLC manufacturer. Do not use custom components.

15. Provide two (2) laptop PCs, each system with all required software (including any hardware "keys") and hardware to allow the programming and troubleshooting of the PLC. Provide, at a minimum, the following features:

a. Dual core or better processor, minimum 15.6 inch screen.

b. 1 10/100/1000 Ethernet, 2 USB 2.0 ports, IEEE 1394, external color VGA connector, and external keyboard connector.

c. Wireless LAN (802.11n) capability.

d. 8 Gig RAM expandable to at least 16 Gigs.

e. DVD/CD (DVD +/-RW) burner.

f. 1T hard drive.

g. Windows 7 64 bits with full compatibility with PLC programming software.

h. Carrying case.

16. Furnish a modular design PLC system with a plug-in processing unit, input-output frames or assemblies, and plug-in peripherals. Furnish components, including peripherals such as programming terminal and data type units, marketed and supported by one Vendor Company. Include all necessary cables.

17. Provide PLC system components that have been installed in industry applications for a minimum of 5 years and supported for a minimum of 10 years after installation.

18. Permanently mark all major assemblies, sub-assemblies, circuit cards, and devices with the manufacturers' part or identification number.

19. Provide PLC system components, except programming laptops, capable of

continuous operation at temperatures of 10 to 60°C, and humidity levels of 25 to 95% non-condensing. Provide programming laptops capable of continuous operation at temperatures of 10 to 40°C and humidity levels of 25 to 95%.

20. Provide programming and monitoring equipment that can be connected or disconnected with the PLC in operation.

21. Provide I/O blocks that are removable without disconnecting field wiring.

22. Include manuals (7 copies), showing the operation of all equipment. This includes plastic-laminated schematics of all cards or units within the system and interconnection wiring diagrams. Include maintenance information also.

T508-7.2.5. Message Display: Furnish panel-mount display for communication of visual alarm messages to the operator.

Provide MD with the following characteristics:

A. Utilizes bright tri-color LED technology to produce messages that are visible from at least 25 feet.

B. Communicates with the PLC via the remote I/O communication cable and have an RS232 serial port for programming by laptop PC.

C. Messages fonts are programmable to provide one line, 12 character of large text or four lines, 24 characters, of text in red, green, or amber. Be capable of storing alarm messages with time and date, scrollable on the display and the historical data stack downloadable via the RS232 port.

D. Operates on 120 V_{AC}.

E. Provided in a NEMA 12 enclosure with a bezel for panel mounting.

T508-7.2.6. Pushbuttons and Operator Interface: Indicating Lights: 120 V, bright LED type, 30 mm, corrosion resistant, heavy duty, oil-tight, NEMA 13. Lens color as indicated in the Plans and approved shop drawings.

Pushbuttons: Single button operator, contacts as required, 30.5 mm, corrosion resistant, heavy duty, oil-tight.

Bypass Switch: Two position, keyed operator, momentary contacts, 30.5 mm, corrosion resistant, heavy duty, oil-tight. All keyed alike.

Selector Switch: Number of positions as required, maintained, lever operator knob, one N.O. and one N.C. contact in each position, 30.5 mm, corrosion resistant, heavy duty, oil-tight. Contacts as indicated in the Plans and approved shop drawings.

Emergency Stop Button: Single button mushroom operator, 30.5 mm, corrosion resistant, heavy duty, oil tight. Maintained contacts, 3 contact (min), closed when button pulled out, open when button pushed in, 1 contact (min), open when button pulled out, closed when button pushed in. Red, 60 mm, jumbo mushroom button.

T508-7.2.7. Ammeter: If shown in plans, provide 3-1/2 digit LED rectangular, panel mount indicator for a 0-5 A input.

T508-7.2.8. Contact Blocks: Provide contact blocks rated at 10 A, NEMA Class A600. Use clear, oil-tight, blocks to allow visual inspection.

T508-7.2.9. Legend Plates: Square or rectangular, manufactured out of laminated plastic or any similar non-metal corrosion resistant material. Provide white plates with black lettering.

T508-7.2.10. Relays: Control Relays and Plug-In Relays.

A. Contacts: NEMA ICS 1, Form C. 2 or 4 pole.

B. Contact Ratings: NEMA ICS 1; Class C300, 7 amps.

C. Coil Voltage: 120 V_{AC}, 60 Hz.

D. Provide indicating lamp or LED across coil.

E. Provide push-to-test button.

F. Clear dust cover and spade terminals.

G. Socket mounted, provide track-mounted socket.

H. Furnish and install plug-in surge suppressor on each coil.

Industrial Control Relays: Contacts rated at 10 A, NEMA Class A600, with replaceable

contact cartridges. Coil voltage as indicated in the Plans. Furnish and install surge suppressor on each coil.

Contactors: Lighting type contactors, open type, and .electronically held. 20 A contacts min., (field convertible) other rating as show in Plans. Coil voltage as shown in Plans.

T508-7.2.11. Time Delay Relays: NEMA Class B600 solid-state time-delay relay with adjustable time delays as indicated in Plans with contacts rated 5 amps minimum, 600 V_{AC}. Coil voltage as indicated on the Plans. Furnish and install surge suppressor on each coil.

T508-7.2.12. Control Power Transformers: NEMA ST 1 rated machine tool transformer with isolated secondary winding with power rating as required for application. Voltage Rating: Line volts primary; 240/120 V_{AC} secondary, or secondary voltages as shown in the Plans or required by specific device.

T508-7.2.13. Control Fuses: Provide control fuses with current rating as shown in the Plans to isolate the individual control circuits and to provide selective overcurrent and short-circuit protection. Provide indicating type fuses for control circuits, ceramic or fiberglass body, midget type, rated 250 V_{AC}, 10 kA interrupting, UL listed for control circuit application. Automotive type, glass body fuses are not acceptable. Provide terminal block style, with isolating feature, fuse blocks to house the control fuses. Provide rail mounted fuse block, rated 600 V_{AC}, 30 A maximum for midget type fuses. Provide a hinge type cover for isolating and automatic fuse extraction from circuit when lifting the cover.

T508-7.2.14. Uninterruptible Power Supply: Provide backup power to the PLC by battery and on-line inverter systems. Provide Uninterruptible Power Supply (UPS) including a battery charger, battery bank, and inverter. Size batteries to provide power for load connected plus 25% for a total of 15 minutes minimum at 120 V_{AC}. Size inverters so that under normal full load conditions, the load will be no more than 75% of the output rating of the inverter. The UPS equipment includes a wall hung or floor mounted self-contained enclosure housing battery, charger, inverter and control electronics. Ensure UPSs are normally online and provide NO and NC contacts that are active during alarm conditions. Provide battery chargers that continuously monitor the charge level of the batteries, automatically correct the charge rate, and automatically recharge the batteries following a power outage. Size to provide a recharge time of 4-12 hours for 67% discharged batteries. Provide gel cell type batteries.

T508-7.2.15. Limit Switches: Provide Oil-tight, die-cast aluminum housing, double sealed limit switches.

Provide rotary cam limit switches for all Near Closed, Near Open, and Full Open leaf positions. Provide heavy duty, NEMA 4X construction for rotary cam housing.

Provide proximity type limit switches for the Fully Closed and Overtravel leaf positions, constructed of heavy die cast aluminum with stainless steel swing bolts, with vents and drains.

T508-7.2.16. Limit Switch Nomenclature: Near Open is defined as that position where the bascule leaf is approximately 8 degrees from Full Open. Near Closed is defined as that position where the bascule leaf is approximately 8 degrees from Full Close. Limit switches, as listed in AREMA Manual, are intended as a guide to their various functions and a means to determine the quantities required.

T508-7.2.17. Inclinometer - Span Position Transmitter: Mount dual leaf-angle position transmitters to the trunnion girder at suitable locations to the centerline of bridge rotation as practical. Furnish units powered with 120 V_{AC} and that provide a voltage or current output signal, 4 to 20 mA as required to properly interface with the PLC, relative to leaf angle. House position transmitters in NEMA 4X rated enclosures with terminal blocks, and power supply as required for connecting to power source and angle position meters. Provide position transmitter that can be adjusted and calibrated without having to physically move the NEMA enclosure. Provide position transmitter with temperature drift of no more than 0.01% per degree C. and have suitable vibration resistance and dampening for a bridge leaf application. Ensure Non-Linearity is less than $1x10^{-3}$ full scale and transverse sensitivity less than 1% 45 degrees tilt.

T508-7.3. Construction Requirements

T508-7.3.1. Control Station (CP-2):

A. Control stations (CP-2) shall be housed in NEMA 4 Cast Iron Enclosures as detailed on

the contract drawings.

T508-7.3.2. Programming of Programmable Logic Controller:

A. Have the manufacturer of the PLC, or his representative, review the operational sequence, flow diagrams, plans, and theory of operation of the bridge and write a program, under the direction of the Control Systems Engineer, for complete bridge monitoring as intended by the Contract Documents.

B. Prompt the bridge tender, by activating a lighted pushbutton on the control console, for all manual inputs.

C. Include the normal operation of interlocks for each event along with the capability of bypassing them on the control console. Provide non-latching contacts making it necessary to reactivate the by-pass switch each operation until repairing the external switches. Consider non-normal or "emergency" operations wherein the bascule leaf does not complete its normal sequence and alternative actions are required. Provide each permissive (function) with individual by-pass capabilities. Ensure the program includes operational/ maintenance functions, modes of operation, and all messages on the MD, as intended by the Contract Documents, flow diagrams and theory of operations.

D. Ensure the programmer consults with the equipment designer and the Engineer to determine all critical items to display on the MD display when a fault occurs. Display, at a minimum, the following indications:

1. All bridge control system failures.
2. All generator/ATS failures.
3. Navigation light failures (if applicable).
4. All span lock failures, including excessive time for an operation.
5. All leaf limit-switch failures (compare limit switch to analog span position).
6. All brake failures, including excessive time for an operation.
7. All drive failures.
    a. Hydraulics: All hydraulic system failures.
    b. Variable Speed or DC Drive: All drive failures.
8. All PLC failures.
9. All leaf openings (not an alarm but part of the monitoring function).
10. All uses of bypass functions, type, and time (not an alarm but part of the monitoring function).
11. Incoming voltage and current (not an alarm but part of the monitoring function).

E. If power is lost during an operation, the leaf will stop until the power is restored and the tender re-initiates the operation by depressing the flashing button on the console which indicates the next sequential operation.

F. Assemble the PLC program such that fault and event data may be stored in memory and downloaded on command to the MD historical stack, labeling the date and type of fault. Ensure bypass switch activation and date activated for, locks, etc., is recorded in memory and downloadable from the MD. Provide a Laptop PC connectable to the MD or PLC for download. Ensure the program also records the elapsed time for all the following operations: opening sequence, time bridge is open, and closing sequence. Store this elapsed time information for the last 100 openings (minimum) in databases located on the MD, to be downloaded to a removable memory device for examination at a remote location. Ensure the programming supplier also supplies the following documentation (hard copy and CD): Ladder diagram address, rung address, contact addresses and English contact description, Cross reference rungs that control contacts, cross reference of contact controlled by each rung, English comments before each series of rungs, and cross reference to relay numbers in the Contract Documents. Ensure applications programs and associated software development tools for PLC, MD screens, and other programmable devices are stored and backed up on the laptop.

G. Submit all documentation, including the electrical relay ladder logic, to the Engineer for review and approval. Provide clear documentation clear for easy understanding by Owner personnel. Do not password protect any portions of the program. Ensure hard copy printout of all programs installed and

operating on the PLC and MD are available on-site at all times. Note any program changes during start-up and the immediately update the printout.

T508-7.3.3. Training: Include in the bid the cost of a two-day training session for five Owner personnel. Include basic programming, interface with the PLC, as well as operation, trouble shooting and maintenance techniques related to the PLC topics. Furnish notebooks and manuals as required. Ensure manuals include all technical information covered in the class. Submit class outline to the Engineer for approval two weeks before holding the class. Ensure that a qualified manufacturers' representative conducts the class.

T508-7.3.4. Shop Inspection and Testing: Ensure that prior to shipment, the complete control system (including fully functional CP-1, fully functional CP-2, UPS, MCC, generator/ATS interface, VFD, primary and backup PLC, and navigation light interfaces) are functionally tested together to assure completeness and correct operation of the entire bridge control system. It is the responsibility of the Control Systems Engineer to coordinate the assembly and staging of equipment at one facility. The Engineer may witness the testing as a complete control system. Ensure testing includes simulation of all control, diagnostics, maintenance, and emergency functions. Simulate inputs with toggle switches and outputs with indicator lights. If a computer or PLC simulator is used, provide an I/O indicator panel that clearly identifies every simulated input and output. Perform simulations and sequencing; at a pace set by the Engineer or his representative. The forcing of contacts or use of unapproved jumpers during the witnessed test will be cause for rejection.

Prepare and submit a complete set of test procedures and schedules for approval. Give the Owner sufficient notice of 30 days prior to testing in order to make arrangements. The procedure includes a systematic description of all semi-automatic actions or simulations and the expected control response, output, or sequence of outputs.

Include exercising the entire control system and software, simulating failures including loss of utility power, equipment failures, and Emergency Stops in the procedures. Ensure the actual testing demonstrates conformance to the requirements and intent of the Contract Documents.

Correct all discrepancies or other non-conformance issues, as determined by the Engineer or his representative, at no cost to the Owner prior to shipment. Furnish a full set of "As-Shipped" schematic drawings and software listings to the Engineer prior to shipment to the Bridge site.

T508-7.3.5. Field Devices: Install limit switches in accordance with manufacturers' instructions. Provide all mounting hardware and supports as required. Install limit switches to allow for field adjustment at construction and for future maintenance. Terminate all limit switches on terminal blocks. Install drainage "T" below takeoff for limit switches on all applicable conduit runs. Submit limit switch target materials, shapes, and mounting methods to the Engineer, for review, prior to installation.

After installation, test switches, in the presence of the Engineer, to determine if operation is as intended. Switches should relay signal to the control console at intended "point of operation." Switches should provide positive indications with no intermittent signals or flickering of lights on control console. Adjust position of switches as required.

T508-7.4. Movable Bridge Functional Checkout

T508-7.4.1. General Requirements

A. Design and perform functional acceptance testing of the movable bridge operation as defined herein, to determine compliance with the requirements for construction, safety, maintenance, and operation of the facility as required in the contract documents. Include in the tests verification of all functions related to leaf operation, maintenance, and safety whether specifically defined herein or required of the contract.

B. Collect full documentation of the test requirements and provide in booklet form.

C. Submittals: Detail and submit in shop drawing format for approval by the Engineer, test procedures for specific tests to be performed and their criteria for acceptance.

T508-7.4.2. Material Requirements: Functional Acceptance Test Books: Integrate and assemble information required for Functional Test into a book (approximately 9 by 12 inches). Neatly label the book with a descriptive title, the name of the project, the location, year of the test, the Owner,

the Contractor and the Engineer. Provide black on white background, easily legible, copies of drawings, figures, and data. Bind the information into each instruction (test procedure) section between rigid plastic or cloth binding covers. Submit four (4) bound copies for review to the Engineer.

C508-7.4.3. Construction Requirements:

General:

A. The Functional Acceptance Testing will consists of two parts:

1. Functional Tests.
2. Operational Testing Period

B. Engineer Notification: Provide adequate notice (ten working days minimum) prior to all tests so that the Engineer can witness and accept the method and result of the testing.

C. Manufacturer Representatives: Arrange to have at the site, for each test, appropriate representatives of the bridge drive and electrical control equipment. These representatives must be prepared to make adjustments to the equipment, of locating faults or defects and correcting them, and of obtaining from the manufacturers, without delay, new parts or replacements of apparatus which, in the opinion of the Engineer, do not perform satisfactorily.

D. Field Tests: Arrange for and provide all necessary field tests, as indicated herein and as directed by the Engineer, to demonstrate that the entire modified or reworked area is in proper working order and is in accordance with the approved Plans and Special Provisions.

Testing:

A. The Functional Acceptance Tests: Present specific, step by step procedures to demonstrate and provide data for evaluation of each function of the movable bridge. Include for each test quantitative measurements (i.e., Watts, pressure, etc.), their method of measurement, and their method of recording.

B. Acceptance Criteria: Present Functional Acceptance criteria that is concise and void of ambiguities. State specific performance of each component or function with regards to the requirements of the design and each unique condition of performance. Include all normal and emergency operating conditions as defined in the Contract documents and AREMA specifications and all maintenance modes of operation.

Preliminary Checkout:

A. Prior to scheduling the Functional or Acceptance Test, perform preliminary checks and make adjustments on the new work, such that the system is in general working order. Insure that all control wiring has been completed and properly labeled. Coordinate this work with the maintenance such that any failure of the system being tested would not interfere with the scheduled use of the bridge.

B. Perform drive system tests during periods in which the span being tested is normally closed (i.e., closed to marine traffic). Provide backup means of lowering the leaf if a train is scheduled to use the bridge.

C. Run the bridge continuously in normal mode (not manual mode) for at least five (5) days before performing the Functional Checkout.

D. Record the following during the preliminary checkout (record using time as the base measurement):

1. Chart recorded wattmeter readings for each main drive motor and lock motor during their full cycle of operation
2. Chart recorded pressure readings for both ends of each cylinder during their full cycle of operation

Functional Tests:

Upon approval of the Engineer to proceed, conduct the Functional Acceptance Tests. The tests include the following functional tests and Acceptance Criteria:

Control Functions (testing both manual and automatic operations):

A. Bridge Sequence: Demonstrate the correct operation of the bridge as described in these Technical Special Provisions and in the drawings.

B. Demonstrate EMERGENCY STOP of the leaf at or during each phase of opening and closing the bridge (phases include ramping up or down, full speed, and creep speed).

C. Interlocks:

1. Demonstrate BYPASS operation for each failure for each required bypass (as listed in Section 508).

2. Provide comprehensive testing of interlocks to demonstrate that unsafe or out of sequence operations are prevented.

D. Position Indicator: Observe readings with bridge closed and full open to assure correct readings.

E. Span Locks:

1. Operate each span lock through one complete cycle and record, with chart recorder, motor power (Watts) throughout the operation, record lockbar-to-guide and lockbar-to-receiver, clearances.

2. Operate each lock with hand crank or manual pump for one complete cycle.

F. Emergency Power: Have test results from the tests specified in Section 508 available for inspection.

G. Automatic Transfer Switch:

1. Perform automatic transfer by simulating loss of normal power and return to normal power.

2. Monitor and verify correct operation and timing of: normal voltage sensing relays, engine start sequence, time delay upon transfer, alternate voltage sensing relays, automatic transfer operation, interlocks and limit switch function, timing delay and retransfer upon normal power restoration, and engine shut-down feature.

Bridge Operational Testing Period:

A. Upon successful completion of the Functional Checkout a 60 day a bridge operational testing period will start.

B. Train, during the latter 15 days of this 60-day period, Owner personnel in the maintenance and operation of the bridge.

C. Repair or replace, at no cost to the Owner, any mechanical or electrical component of the bridge that becomes inoperative during the 60-day period. Maintenance other than specified above will be accomplished by Owner forces during the 60-day period.

D. During this period, open the bridge a minimum of 4 times per day.

E. During this period, under observation by the Engineer, test all aspects of the bascule and its operation.

Contractor’s Warranty of Movable Bridges:

A. After the 60-day operation and training period, and as a condition precedent to final acceptance of all work under the Contract Documents in accordance with Section 5-11, provide a warranty for the repair or replacement of any defective mechanical or electrical components of the movable portions of the bridge which will be in effect for a one year period after final acceptance in accordance with Section 5-11.

B. At the end of the one-year warranty period, provided all previous warranty work and remedial work, if any, has been completed satisfactorily, the Engineer will issue a release from further warranty work and responsibility.

C. The contractor shall ensure that all warranties for all equipment installed are transferable to the Owner after final acceptance.

T508-8. BRAKES

T508-8.1. Description

Provide motor and machinery brakes of mill duty quality, manufactured to AISE-NEMA Standards, and conforming to the ratings, sizes and mounting arrangements shown on the Plans. Provide drum and shoe brakes of 460 V, 3 phase, 60 Hz, spring applied, electro hydraulic released thrustor type. All torques given are continuous AISE torque ratings, and dimensions conform to the AISE Standards.

T508-8.2. Materials

A. Provide all brakes from a single manufacturer, with a minimum of 10 years of experience supplying brakes to the movable bridge industry.

B. Provide a NEMA 4 brake actuator enclosure of cast aluminum alloy, fitted with double shaft seals. Ensure the thrustor motor is of ample capacity for the intended application. Ensure that the rated stalled thrust of each thrustor is not less than 135% of the thrust actually required to release the brake with the torque adjusted to the continuous rated value. Brakes are to set automatically when the thrustor motor is de-energized. Provide thrustor motors rated for inverter duty operation.

C. Use hydraulic oil specifically recommended by the thrustor manufacturer with a free operating temperature range between -10°F and +120°F.

D. Design brake for easy replacement of the shoes, from either side, without disassembling the brake.

E. Do not use brake wheel couplings.

F. Mount motor brakes on the input shaft extensions of the primary reducer, and the machinery brakes on the input shaft of the secondary reducers, unless otherwise indicated on Plans.

G. Provide the following features for all brakes:

1. Adjustable time delay for setting the brake - Provide thrustor actuator with an independent internal time delay valve constructed of stainless steel, adjustable between 0 and 5 seconds for setting the brake. Provide for step-less adjustment between the minimum and maximum settings, adjustable with the brake in full service.

2. Chrome plated brake wheels - Manufacture wheels from ASTM A 536 Grade 65-45-12 ductile iron, finish bored to provide the specified fit with shaft. Mount the brake wheels to the shafts with an FN2 fit and keys. Check, document and submit “run-out” measurements for all brake wheels. Dynamically balance all brake wheels 16 inch diameter and larger.

3. Shoes of special high torque molded linings.

4. Latching hand releases - Provide a manual release lever and a device for holding the brake in the released position. Mount the hand release attachment permanently on the brakes, arrange such that the brake is releasable manually without the use of apparatus not permanently attached to the brakes. Provide a hand release that is releasable without removing the brake cover. Ensure the mechanism latches in both the released and non-active positions, provides, at a minimum, 90% of the power release stroke, and not inhibit the working stroke of the actuator when fully retracted. Provide brakes that do not require more than 50 lbs of force to release the brake manually.

5. Limit switches - Three limit switches for each brake to indicate: brake set, brake released, and brake hand released.

6. Stainless steel pins and clips, or other approved corrosion resistant material.

7. Coat all items with the manufacturers’ special paint and application process required for corrosive atmospheres.

H. Provide nameplates on the brakes with the following information:

1. Manufacturer
2. Model number
3. Push capacity of the actuator
4. Stroke of the actuator
5. Volts, phase, Hz, watts
6. Braking torque (indicate both the recommended setting and the maximum torque - see Plans for the recommended setting and maximum torque)
7. Brake lining material
8. Type of fluid required in the reservoir

I. For each brake, provide a NEMA 3R enclosure with shaft seals, constructed of 12-gauge type 304 stainless steel. Provide hinged lids that permit easy inspection of all brake components and easy operation of the hand release. Use bolts to fasten the each enclosure to the brake support. Provide thermostatically controlled space heater.

T508-8.2.1. Motor Brakes

Provide motor brakes with wheel diameter as shown and factory set to the torque values shown on the Plans. Field verify the motor brake torque setting is within +10% and -0% of the factory set torque. Adjust setting if needed and demonstrate conformance. In cases where break-away torque cannot be developed with a manually operated torque wrench, such as on large brakes, submit an alternative technique for review.

T508-8.2.2. Machinery Brakes

Provide machinery brakes with wheel diameter as shown and factory set to the torque values shown on the Plans. Physically field-verify the motor brake torque setting to be within +10% and -0% of the factory set torque. Adjust setting if needed and demonstrate conformance. In cases where break-away torque cannot be developed with a manually operated torque wrench, such as on large brakes, submit an alternative technique for review.

T508-8.3. Construction Requirements

Do not set brakes at torque values more than 90% of their continuous rated capacity for normal operation.

Sequence the brakes on each leaf using time delays set as follows (time delays may be adjusted in the field during operational testing based on leaf behavior and load testing data):

1. Motor brakes to set with 0 to 2 seconds delay.
2. Machinery brakes to set 2 to 4 seconds after the motor brakes set.

Coordinate hydraulic delays in the brake thrusters and electronic delays in the control system to provide the times noted above.

T508-9. STANDBY GENERATION SYSTEM

T508-9.1. Description

A. Furnish, install, and place in permanent operating condition one diesel engine-driven stand-by generation systems. Size the system as shown in the Plans. In the event of a power failure the generator is to furnish power for bridge all bridge operations.

B. Work includes engine-generator set, automatic regulator, automatic transfer switches, standard water cooling system, residential exhaust system, water circulating system, an electric starter with battery and battery charger, provision for remote monitoring and control by ATS (Automatic Transfer Switch) and PLC, exerciser and integral fuel tank.

C. Furnish and install an ATS as shown in the Plans. Furnish and install ATS with provisions for remote monitoring and control. Monitoring includes ATS status, and control includes Auto, Run, Off, Test at a minimum.

D. Furnish and install load bank as shown in the Plans. If the generator size is changed, change the load bank also. Provide a load bank that is at least 50% of the generator's kW rating.

E. Verify with the generator manufacturer that the available starting capacity of the proposed unit is adequate for the requirements of the connected load.

F. Furnish and install the exhaust systems in accordance with manufacturers' recommendations. Mount the engine-generator sets on vibration dampeners. Furnish and install load banks with aluminum duct and flex coupling as indicated on the Plans. Provide generator controllers that are compatible with ATS and remote operation as required.

G. Test and certify the performance of the particular system by the factory as to the full power rating, stability, voltage, and frequency regulation. Test unit at full load with a 0.80 power factor. Submit results of test.

H. The generator will be installed at an elevation of less than 600 feet above sea level, and ambient temperatures between 20 and 100°F; continuous rating using engine-mounted radiator. Furnish a system completely assembled by one manufacturer and supplied as a package.

T508-9.2. Materials

T508-9.2.1. Stand-by Generator Set:

A. Furnish a water-cooled in-line or V-type, four stroke cycle, compression ignition Diesel internal combustion engine, with an idle speed of 1,800 RPM. Provide an engine with enough capacity to operate at 10% overload for one hour at specified elevation and ambient limits and designed for use of No. 2 fuel oil. Provide unit with suitable spring-type vibration isolators and mounted on structural steel base. Provide isochronous type governor to maintain engine speed within 0.25%, steady state, and 0.25%, no load to full load, with recovery to steady state within 2 seconds following sudden load changes. Provide the engine with the following safety devices: engine shutdown on high water temperature, low oil pressure, over speed, and engine over crank. Set limits as recommended by the manufacturer.

B. Provide DC starting system with positive engagement starter motor. Include remote starting control circuit, with MANUAL-OFF-REMOTE selector switch on each local engine-generator control panel. If required by the manufacturer, provide a thermal circulation type water heater with integral thermostatic control, sized to maintain engine jacket water at 90°F, and suitable for operation on 120 V_{AC}. Provide radiator using glycol coolant, with blower type fan, sized to maintain safe engine temperature in ambient temperature of 110°F. Radiator air flow restriction of 0.5 inch of water maximum.

C. Ensure the system is equipped with an ANSI/NEMA MG 1; three phase, 4-pole, 12 lead, reconnectible brushless synchronous generator with brushless exciter, rated as shown in the Contract Documents, at 0.80 power factor, 60 Hz, with ANSI/NEMA MG 1, Class F insulation and Temperature Rise of 105°C. continuous. Directly connect the stator to the engine flywheel housing and drive the rotor through a semi-flexible driving flange to ensure permanent alignment. Include generator mounted volts-per-hertz exciter-regulator to match engine and generator characteristics, with voltage regulation plus or minus 1% from no load to full load. Ensure the instantaneous voltage dip is less than 13% of rated voltage when applying full-load and rated power factor to the alternator. Provide a 3 second recovery to stable operation. Include manual controls to adjust voltage drop, plus or minus 5% voltage level, and voltage gain.

D. Provide the engine exhaust system with a flexible connection near the engine, a metal thimble where the exhaust line passes through the wall, and a rain hood over exhaust pipe end. Provide a metal thimble with a diameter 6 inch larger than the exhaust line. Size the exhaust line per engine manufacturer recommendations. Furnish an exhaust muffler rated for residential service. Provide an exhaust system that is leakproof and properly flash the wall to prevent water from entering the control house where the exhaust line passes through the wall. Protect exhaust line inside the control house with approved heat shield to protect any object within 2 feet of the exhaust that may be damaged by fire or excessive heat.

E. Provide heavy duty, diesel starting type lead-acid storage batteries, 170 A/hour minimum capacity. Match battery voltage to starting system. Include necessary cables and clamps. Provide a plastic coated metal or wooden tray treated for electrolyte resistance, constructed to contain spillage of electrolyte. Current limiting type battery charger designed to float at 2.17 V per cell and equalize at 2.33 V per cell. Include overload protection, full wave rectifier, DC voltmeter and ammeter, and 120 V_{AC} fused input. Provide wall mounted NEMA Type 1 enclosure.

F. Provide a molded case circuit breaker on generator output with integral thermal and instantaneous magnetic trip in each pole sized as shown in the Plans. Include battery-voltage operated shunt trip and connection to open circuit breaker on engine failure. Mount unit in NEMA Type 1 enclosure.

T508-9.2.2. Automatic Transfer Switch (ATS):

A. Provide electrically operated, mechanically held in both normal power and stand-by position ATS with mechanically operated, mechanically held transfer switch connected to bypass automatic switch. Provide a unit that is capable of transfer under full load operation. Provide an ATS that is compatible with the engine generator. Provide a visual indicator to determine whether the main contacts are open or closed. Mount the ATS in a NEMA Type 1 gasketed cabinet with a key locking door. Mount controls in a dead front swing-out panel which, when opened, exposes all system components. Provide industrial type pilot devices and relays rated 10 A with self-cleaning contacts. Provide fully rated ATS to protect all types of loads, inductive and resistive, from loss of continuity of power, without de-rating,

either open or enclosed and have withstand, closing, and interrupting ratings sufficient for voltage of the system and the available short circuit at the point of application in the Plans.

B. Ensure the ATS provides complete protection with field adjustable solid-state voltage sensing logic to monitor each phase of the normal power supply. Provide a factory set close differential adjustment set to drop out when the monitored voltage drops below 70% of normal and initiate load transfer when the emergency source becomes available. Upon restoration of the normal source to a pickup level of 90%, the logic initiates automatic re-transfer of the load circuits to the normal power source provided a main drive motor is not energized. Inhibit the House ATS to not retransfer when operating on the Main generator. Wire the ATS so that it obtains its operating current from the source to which the load is being transferred. Provide mechanically and electrically interlocked ATS so that a neutral position is not possible when under electrical operation. Provide positive interlock so that it is not possible for load circuits to be connected to normal and emergency sources simultaneously, regardless of whether the switch is electrically or manually operated. Provide the ATS with a neutral position for load circuit maintenance.

C. Provide an Automatic Sequence of Operation as follows: Initiate Time Delay to start Stand-by Engine Generator upon initiation by normal source monitor. Provide an adjustable Time Delay to Start Stand-by Generator. Initiate Transfer of Load to Stand-by Source upon initiation by normal source monitor and permission by stand-by source monitor. Provide an adjustable Time Delay Before Transfer to Stand-by Power Source. Initiate Retransfer of Load to Normal Source when drive motors are de energized. Provide a Time Delay before Transfer to Normal Power with an adjustable bypass time delay in the event of stand-by source failure. Provide an adjustable Time Delay Before Engine Shut Down as per engine-generator manufacturers' recommendation.

D. Furnish and install an Engine-Generator Exerciser to Start engine-generator every seven days and run for 30 minutes before shutting down. By-pass exerciser control if normal power source fails during exercising period. Provide indicating lights and mount in cover of enclosure to indicate NORMAL SOURCE AVAILABLE, STAND-BY SOURCE AVAILABLE, and SWITCH POSITION and include a test switch to simulate failure of normal power source. Monitor each line of normal source voltage and frequency, initiate transfer when voltage drops below 90% or frequency varies more than 3% from rated nominal value. Monitor stand-by source voltage and frequency, inhibit transfer when voltage is below 85% or frequency varies more than 5% from rated nominal value.

E. Set and calibrate the ATS in accordance with the manufacturers' specifications. Adjust the following: voltage sensing relays, transfer time delay relay, and engine shutdown relay. To test, perform an automatic transfer by simulating loss of normal power and return to normal power. Monitor and verify correct operation and timing of: normal voltage sensing relays, engine start sequence, time delay upon transfer, alternate voltage sensing relays, automatic transfer operation, interlocks and limit switch function, timing delay and retransfer upon normal power restoration exerciser, and engine shut-down feature.

F. Provide ATS controllers capable of interfacing to the integrated bridge control system for remote monitoring and control as required in the Contract Documents.

T508-9.2.3. Panels: Provide a generator control panel, complete with: oil pressure gauge, water temperature gauge, low oil pressure alarm contacts, high water temperature alarm contacts, low oil pressure shut down contacts, high water temperature shut down contacts, overspeed shut down contacts, and cranking limiter relay.

Provide totally enclosed, ventilated, metal panel mounted on unit with channel or angle finished in enamel applied over corrosion resistant primer, complete with hinged door, ground bus, battery operated service light to illuminate panel under power outage condition, and incorporating: output circuit breaker; a digital control panel which can access the generator frequency, AC output voltage for each phase, AC output current for each phase, and engine runtime meter; output voltage adjustment rheostat; and an auxiliary relay, 3PDT, which operates when engine runs, with contact terminals pre-wired to terminal strip. Provide generator control panel complete with: Engine OFF-START-AUTO selector switch; cranking limiter; and trouble horn and double pole, double throw silencing switch with

red indicating light.

Provide illuminated annunciators with engraved nameplates reading: Low oil pressure alarm, high water temperature alarm, low oil pressure shut down, high water temperature shut down, overspeed shut down, over cranking shut down, low fuel, and fuel tank leak. Provide locking type annunciators with manual reset button for DC operation from battery bank incorporating contacts for remote indication. Provide contacts so that when shut down occurs from one set of shut down contacts, subsequent operation of shut down contacts are locked off from operating annunciators. Provide lamp test feature. Operation of the silencing switch silences the trouble alarm but does not turn the pilot light OFF. On return to normal and resetting of annunciators, trouble horn to sound again until switch is returned to normal position.

Provide a remote alarm panel in a NEMA 1 enclosure installed in the operator's room. Provide panel conforming to NFPA 110.

T508-9.2.4. Fuel Supply:

Provide skid mounted, under engine-generator set, fuel tank sized to hold enough fuel for a minimum of 24 hours of operation at full load.

Furnish all supports, guards, sunshades, loading valves, and other features required by local codes and ordinances.

Provide tank with a sight-level gauge. Furnish UL listed double walled tank. Provide a leak detector device with alarm contacts to detect leakage within the outer wall. Location of leak detector is to be approved by the Engineer. Provide a fuel level switch with contacts for remote alarm when 25% of fuel remains in the tank.

T508-9.2.5. Load Bank: Furnish and install a permanent engine radiator airflow cooled, resistive load bank for the engine generator system designed for automatic/manual control with the kW capacity indicated in the Plans with 4 equal load steps, continuous duty cycle, 60°C nominal air temperature rise, 0.25 to 0.50 inch water column air back pressure. Install the load bank by bolted attachment to radiator with duct and flex coupling to air outlet in wall. Provide a self-contained load bank which includes all resistive load elements, load control devices, load element branch circuit fuse protection, main load bus and terminals, control terminals, system protection devices and NEMA 3R enclosure.

The control section is to be physically and thermally isolated from both the hot load elements and the heated airflow. Supply mounting adapters, suitable for the installation method selected, with the load bank. Provide a screen on the exhaust of the load bank. Furnish UL listed load elements, labeled, totally enclosed, sealed and weatherproof with an electrically grounded outer sheath such that the element cannot be electrically short-circuited by external foreign objects and personnel are protected against accidental electrical shock. Provide the load bank with a comprehensive protection system to protect against overheating. The system will disconnect the load elements from the power source and activate an alarm upon sensing a loss of cooling airflow, or an exhaust air temperature greater than 150°C. Equip the load bank with an automatic controller.

In automatic mode, the load bank provides a component of the total power source load and is automatically variable in response to dynamic total load demands upon the power source. Ensure the automatic controller includes control logic, solid-state sensors, and time delays that act to apply/remove load bank components in multiple steps in response to dynamic load demands of the power source. Ensure the automatic controller includes a solid-state load sensor with level and time delay adjustment and output contacts for each load step. Provide a current transformer for external installation.

Provide a 12 gage aluminum duct (shroud), constructed to route the exhaust airflow from the radiator through the louvered opening. Provide 2 by 2 feet access opening in side of duct for inspection purposes. Provide gasketed cover plate for inspection port. Include provisions for vibration isolation by use of a flexible expansion fitting between the duct and the generator.

T508-9.2.6. Transient Protection and Grounding: Provide a regulator to protect the generator from transient spikes generated by SCR devices. Provide positive equipment ground for system components. Coordinate the VSD dynamic braking so that regeneration is not put back on line when the

generator is the power source.

T508-9.3. Construction Requirements

Initially start and check the complete installation for operational compliance by a factory-trained representative of the manufacturer of the generator set and the ATS. The supplier of the generator set, as recommended by the manufacturer for operation under environmental conditions specified, will provide the engine lubrication oil and antifreeze. Upon completion of initial start-up and system checkout, the supplier of the generator set will perform a field test, with the Engineer notified in advance, to demonstrate load carrying capability, stability, voltage, and frequency.

Perform a dielectric absorption test on generator winding with respect to ground. Determine and record a polarization index. Submit copies of test results to the Engineer. Perform a phase rotation test to determine compatibility with load requirements. Function test engine shutdown features: low oil pressure, over-temperature, over-speed, over-crank, and any other feature as applicable.

Perform, in the presence of the Engineer, resistive load bank test at 100% nameplate rating. Provide the following loading: 25% rated for 30 minutes, 50% rated for 30 minutes, 75% rated for 30 minutes, and 100% rated for 2 hours. Maintain records throughout this period to record water temperature, oil pressure, ambient air temperature, voltage, current, frequency, kilowatts, and power factor. Record the above data at 15 minute intervals throughout the test. Provide a twenty minute unloaded run at the conclusion of the test to allow engine to cool before shutdown. Perform, in the presence of the Engineer, full operational bridge control testing to demonstrate generator capability to operate the bridge through a minimum of three raise/lower cycles. Furnish three copies of the field test data to the Engineer. Make all necessary hook-ups to accomplish field tests and furnish all fuel necessary for field tests and startup. Perform this test prior to the Functional Checkout.