

AASHTO-AGC-ARTBA Joint Committee

Subcommittee On New Highway Materials

Task Force 29 Report



Guide Specification for Cathodic Protection of Concrete Bridge Decks



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Guide Specification for Cathodic Protection of Concrete Bridge Decks

**AASHTO-AGC-ARTBA
TASK FORCE #29**

July, 1994



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INTRODUCTION

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**American Association of State Highway
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**AASHTO-AGC-ARTBA
TASK FORCE #29**

GUIDE SPECIFICATION FOR CATHODIC PROTECTION OF CONCRETE BRIDGE DECKS

650. BRIDGE DECK CATHODIC PROTECTION

650.10 DESCRIPTION: This document was prepared by the AASHTO-AGC-ARTBA Joint Committee Task Force 29 of the Subcommittee on New Highway Materials. The goal of the Task Force is to delineate concise guidelines which can be used by highway agencies as standard specifications for Cathodic Protection of Reinforced Concrete Bridge Decks. The task force members dedicate this document and our efforts to the late Richard F. Stratfull. Dick worked for many years for the California Department of Transportation and was a pioneer in the areas of corrosion detection and prediction, and cathodic protection of concrete bridge decks.

The intent of this document is to define standard specifications applicable to the Nation's bridges. It is recognized there are bridge structures which do not match the standard and would be subject to special study and design. The standard bridge deck is a reinforced, double mat rebar structure with a 6- to 9-inch thick slab. Standardization is expected to permit contractors to install these systems efficiently and, hence, provide an economic system to the bridge owner.

It is important to recognize that a concrete and corrosion condition survey should be conducted on each structure to assess the need for and applicability of cathodic protection. The continued monitoring and maintenance requirements for cathodic protection systems should also be considered. Proper monitoring and maintenance is required for the successful long-term performance of all cathodic protection systems.

Cathodic Protection (CP) is the only known fully developed means of mitigating the corrosion of reinforcing steel in existing bridge decks caused by the presence of chloride ions. The routine use of CP for pipeline protection and underground structures prompted development of new technologies which would allow the successful application and operation of CP on bridge decks. The first installation of an impressed current CP system on a bridge deck took place in California in 1973, using high silicon cast iron anodes affixed to the deck and covered with a 2-inch lift of conductive coke breeze asphalt and topped with a 2-inch wearing course of asphaltic concrete. Since that pioneering effort, the field of cathodic protection for reinforced concrete bridge decks has matured into a proven technology with several design options available. It should be considered as an engineering alternative for rehabilitation of salt-contaminated bridge decks.

As in any new technology, advancement of state-of-the-art of bridge deck CP involves interaction among Federal and State government agencies, researchers, contractors, and private industry and governmental research agencies. In 1982, the Federal Highway Administration (FHWA) issued a position paper on Cathodic Protection Systems which promoted widespread implementation of CP as a rehabilitation technique for bridge decks. The intensive research and product development by private industry and governmental research agencies which followed, has led to a new generation of anodes and a substantial reduction in the cost of materials and installation. The final determinant for any technology, however, must be generated by successful performance under field conditions. Satisfactory operation of more than 350 systems in 37 States and eight provinces in Canada give suitable testimony to the viability of CP.



The specifications listed below are the product of this ongoing effort to advance the reliability and refine the design, construction, and operation of CP on bridge decks. Those components specified have been subjected to extensive and exhaustive laboratory testing and have also provided a minimum of at least two years of adequate field performance. The specifications cover three different types of anode systems, but no recommendations as to the proper system for a given structure, either direct or implied, are intended. The available systems are:

- Coke-breeze asphalt conductive overlay system
- Conductive polymer systems
 - Slotted
 - Mounded in conjunction with an overlay
- Tack-down, manufactured anode systems
 - Catalytic titanium anode mesh with concrete overlay

At present, only one catalytic titanium anode mesh is included in these specifications. Similar systems by other manufacturers have been installed and are being evaluated. These systems will be considered by this task group in the near future for inclusion into these specifications.

Other anode systems, such as sprayed zinc with asphaltic concrete overlays and catalyzed titanium ribbon slotted systems, are under development. Although these may become standards in the future, at present, the task force considers them experimental, and, thus, they are not included herein. We hope, however, that all possible alternatives will continue to be studied and that these standards will be updated as appropriate.

General specifications for other components such as reference cells, rectifier, etc., are also included, as well as recommended installation and activation procedures. At present, a saturable reactor type rectifier is specified. Silicon controlled rectifiers (SCR's) have also been successful in some installations. These will be further considered by this task group in the near future for inclusion into these specifications. Items which were used in the research phase of cathodic protection of bridge decks, such as rebar probes, corrosometers, and multi-control mode rectifiers are not listed as they are not deemed necessary for routine operation.

In developing the specifications important reference materials were used. Several of the most pertinent documents are listed in the Bridge Deck Cathodic Protection Annex (650A.50) on page 51.

The use of cathodic protection on the following structures is not recommended at this time:

- Prestressed or posttensioned bridge decks,
- Coke-breeze systems on bridge decks whose concrete air void system has a spacing factor of less than 0.008 inches (ASTM C-457). Concrete overlay CP systems have been used successfully on decks with inadequate air void systems and thus are recommended.
- Bridge decks with alkali-reactive aggregate concrete.

Waterproofing (membranes mainly in the form of thin traffic toppings) has been used recently in concert with cathodic protection. The task group believes that such use of waterproofing should still be considered experimental.

Equally important to proper specifications is the selection of a qualified and experienced corrosion engineer to develop the final design details, and to provide quality control and assessment during construction and proper system activation. Guidelines are provided within the specifications that indicate the minimum qualifications recommended.

Section 650 is the main cathodic protection specification, and includes an Annex covering the qualification of new materials and systems, the recommended rectifier warranty check, test methods, and a glossary of terms. It is followed by sections relating to each anode system (651: *Conductive Coke Asphalt*; 652: *Non-Overlay Slotted*; and 653: *Distributed Anode CP Systems with Concrete Overlays*).

To implement this specification, it is necessary that the specifier complete the Design Specifics Checklist in section 650.30.01 on page 14. Detailed plans beyond those normally used on rehabilitation projects are not required. The detailed anode design and layout will be performed by the contractor and submitted as shop drawings prepared and signed by the Corrosion Engineer.

650.20 CATHODIC PROTECTION MATERIALS

650.20.01 Cathodic Protection Rectifier

Description: This specification defines the requirements for manufacturing cathodic protection rectifiers for bridge deck protection. *The rectifier shall be the saturable reactor constant current type with the ability to change control to constant voltage.* The rated DC output of each circuit shall be 24 volts, 10 amperes. The rectifier shall be designed and constructed in accordance with the schematic shown in Figure 650-1 and the following

specifications. Load (DC circuit) resistance will be variable and is expected to range from 0.25 ohms to 2.5 ohms. If the zone to be protected is smaller than 1,000 square feet, the DC output current specified (10 amperes) should be reduced.

Materials and equipment shall be designed, manufactured, and tested in accordance with the minimum applicable requirements of the latest editions of the following codes and standards:

- National Electrical Code (NEC)
- National Electrical Manufacturers' Assoc. (NEMA)
- American Society for Testing and Materials (ASTM)
- Military Specifications (Mil Spec)
- American National Standards Institute (ANSI)

The materials shall be installed outdoors and subjected to varying corrosive atmospheres with an ambient temperature of up to 50 °C and relative humidity up to 100 percent. The expected operating life shall be in excess of 20 years.

Each rectifier supplied shall include two sets of the following as a minimum: a wiring schematic drawing, parts list, test results, and an operation and maintenance manual.

The rectifier shall be warranted for one full year after installation or 18 months after delivery (whichever comes first) against defects in design or workmanship.

The rectifier shall be supplied by a company established in and presently involved in the design and manufacture of cathodic protection rectifiers.

Enclosure: The enclosure shall be designed to meet NEMA type 3R, 4 or 4X requirements as outlined in NEMA Publication No. 250 and selected by the designer. It shall be constructed of 11-gauge minimum thickness material and shall provide for adequate convection cooling of internal components. The enclosure shall be designed for either pole, wall, or base mounting as required. Any opening designed for cooling and over 1/8 inch shall be screened to prevent entry of nest-building insects. NEMA 3R enclosures shall have hinged removable front and side doors with bolts on adjustable stainless steel heavy-duty latches. NEMA 4 air cooled rectifiers shall have a single hinged front door with heavy duty, stainless steel latches. NEMA 4 air cooled enclosures shall include a thermostatically controlled fan with filter to provide adequate cooling. The fan and filter may be omitted if the designer can show that the rectifier will cool

properly when operated at maximum output voltage and current and the maximum ambient temperature. When a NEMA type 4 oil cooled enclosure is specified the transformer and rectifier stack shall be mounted on separate removable racks. The enclosure shall have provisions for locking and protection of the interior components from weather and vandalism. Entry for wiring shall be located in the bottom of the enclosure and shall be of adequate number and size to provide for input and output connections. A grounding lug shall be provided on the outside of the enclosure to accommodate a #6 AWG copper ground wire. A permanent manual holder shall be provided and attached to the inside of the cabinet door.

Transformer: The transformer shall be specifically designed for use in a cathodic protection rectifier, have separate, isolated primary and secondary copper windings, and a grounded copper Faraday shield between primary and secondary windings. The transformer shall be designed to operate continuously at rated load and will supply rated output at 5 percent low, 10 percent high line voltage without damage. The wire size of both windings shall be based on a minimum of 750 circular mils per amp. The transformer regulation shall not exceed 3 percent when measured at 1/4 load and full load. The transformer and materials shall be designed and manufactured to meet the requirements of MIL E 917. The secondary will have a sufficient number of coarse and fine taps to allow adjustment of the output in 1/2-volt increments. All tap leads shall be sized for a minimum of 500 circular mils per ampere. These taps shall be brought out to link bar arrangements or a terminal block for adjusting the output of the rectifier and shall be located on the instrument panel.

The transformer shall be vacuum impregnated or preheated and immersed in Class F (150 °C) transformer varnish until all tapes, insulating materials, outer wrapping and coil windings have been completely saturated and then oven baked until dry. When completed and before installation into a rectifier, the transformer shall be tested and must be able to withstand 2000 volts for one minute without breakdown between the primary and core, secondary and core, and primary to secondary.

Each circuit shall have its own isolated secondary winding or individual transformer designed per the above requirements.

Rectifying Elements: The rectifying bridge shall have a forward average current rating of 25 amps minimum. Each diode shall have a minimum peak reverse voltage rating of 800 volts. Heat sinks shall be sized to provide continuous rectifier operation at rated ambient temperature and rated output. When block style rectifying

Figure 650-1 (Sheet 1 of 3)

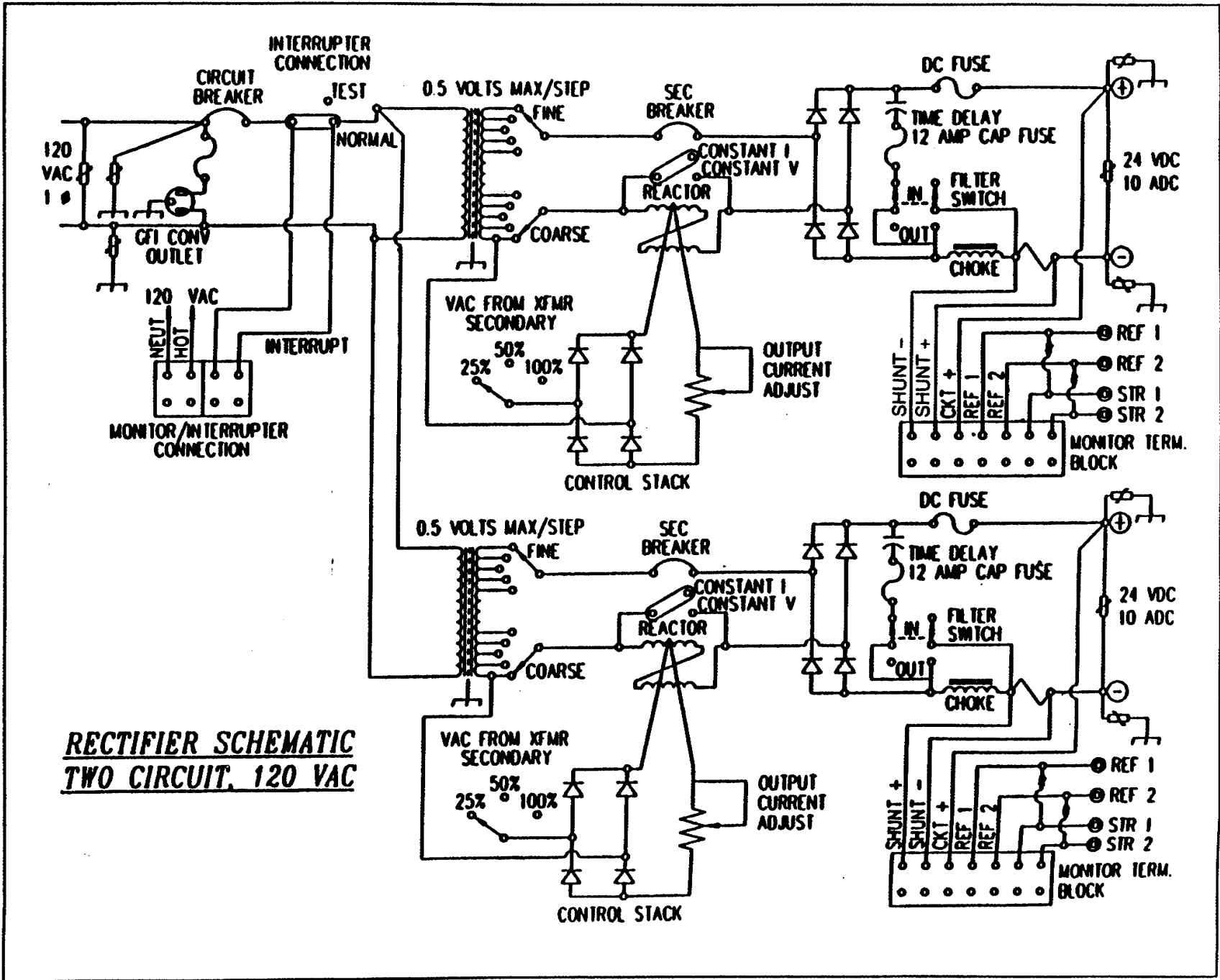
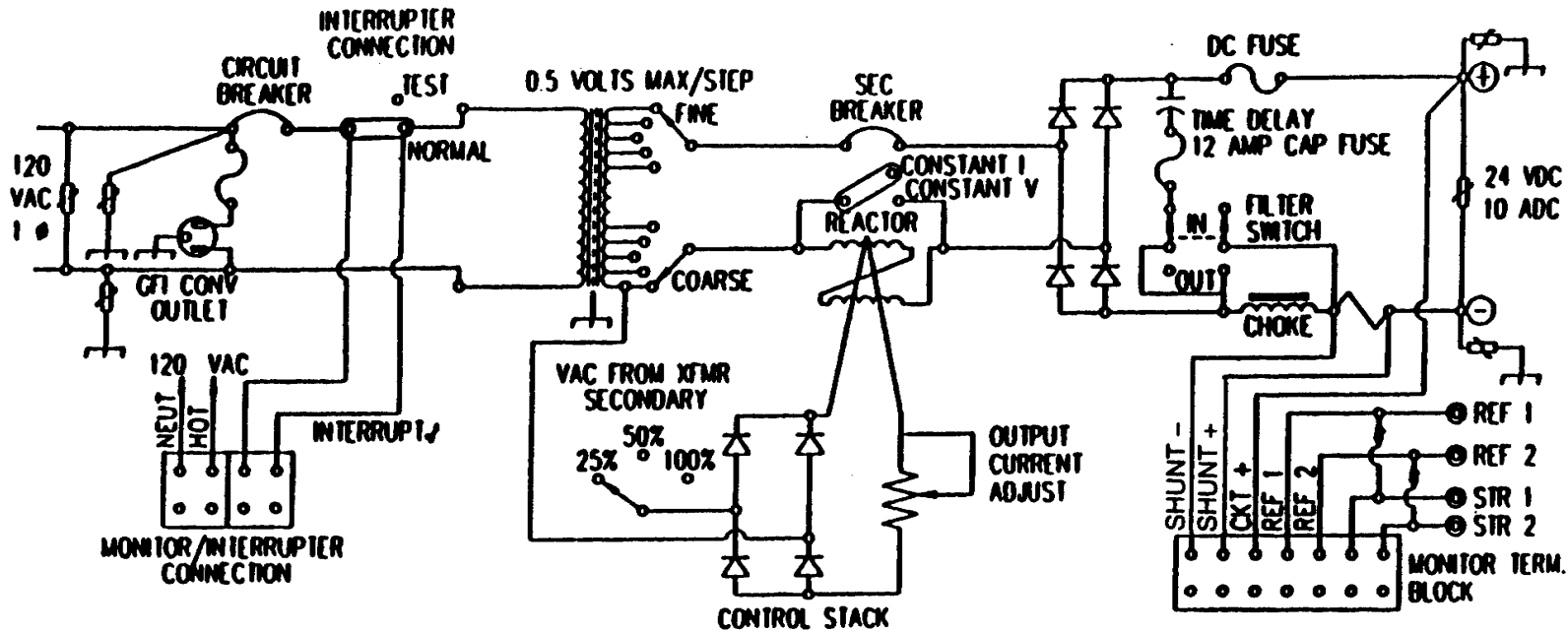
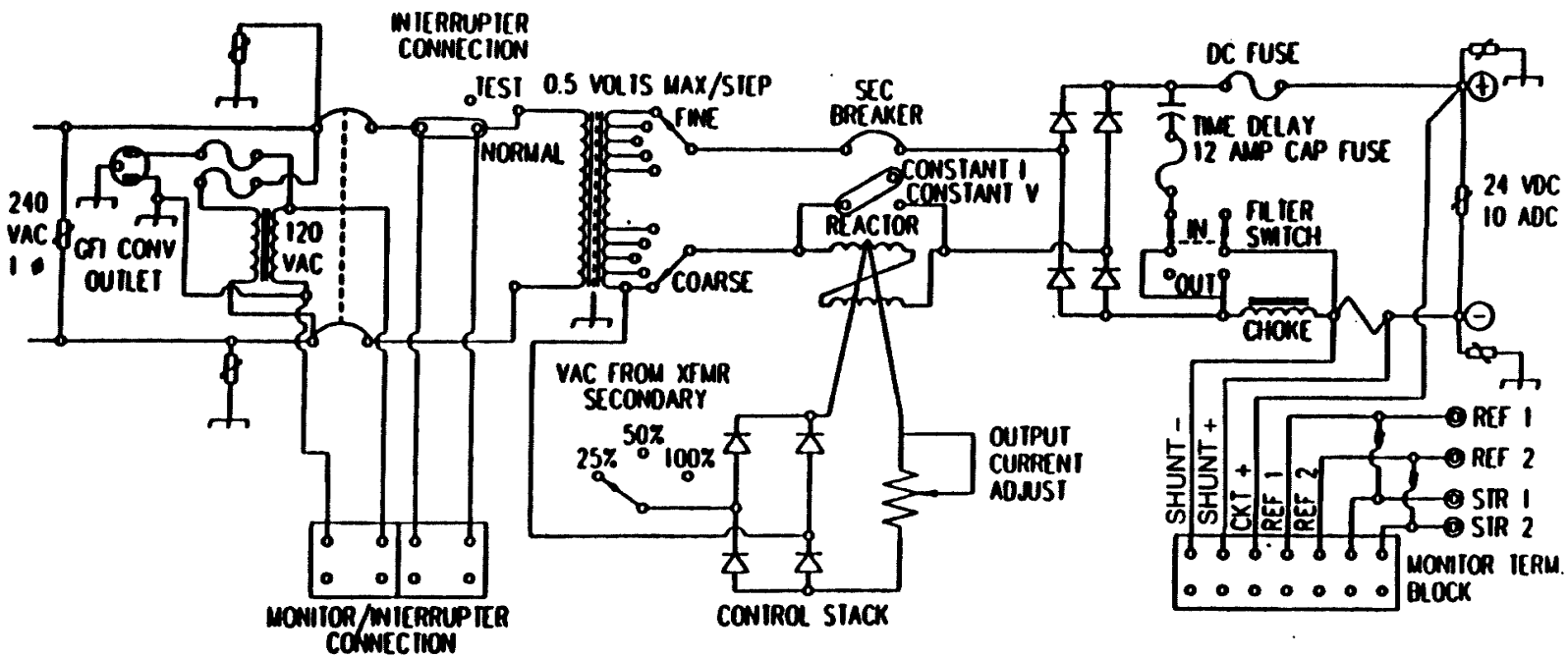


Figure 650-1 (Sheet 2 of 3)



RECTIFIER SCHEMATIC
SINGLE CIRCUIT, 120 VAC



RECTIFIER SCHEMATIC
SINGLE CIRCUIT, 240 VAC

Figure 650-1 (Sheet 3 of 3)

elements are used, in addition to the above, they shall have 1200 volt minimum isolation.

Protective Devices: The entire unit shall be protected against overload and short circuit by a thermal magnetic type circuit breaker of the proper voltage rating and sized to hold 100 percent of the rated load current. It is to be connected between the AC supply and transformer primary. The circuit breaker shall be the manual reset type and must trip at between 110 percent and 125 percent of rated input current. The breaker shall be positioned and labelled to meet the requirements of the NEC article 240 sections 80 through 83C. In the case of multiple circuit rectifiers with individual transformers, each circuit shall have its individual AC supply protected by a properly sized fuse in addition to the breaker.

Rectifiers shall have a quick acting magnetic breaker rated at 120 percent of the circuit capacity placed in one leg of the AC secondary of each circuit.

Lightning and Surge Protection: The unit shall be equipped with properly sized AC and DC lightning protection. Each controlled output as well as every input to the rectifier shall be protected against voltage surges, using properly sized surge suppressors. Metal oxide varistors (MOVs) used to protect the AC input and DC output shall be rated at 500 joules and have a voltage rating which provides adequate protection to the internal circuitry. (See Table 650-1 below.)

Table 650-1

VAC INPUT	MOV RATING (max)	DC OUTPUT (max)	MOV RATING
120	250 VRMS	24	130 VRMS
240	480 VRMS		

DC Panel Meters: Meters are not required, but when specified, shall have a minimum 2 1/2-inch scale, d'-Arsonval pivot and jewel type movement, and have an accuracy of 2 percent of full scale. The meter circuit(s) shall include a switch, hermetically sealed, which removes the meter(s) from the circuit when not in use. The ammeter shall be connected to an external shunt plainly marked to show ampere rating and millivolt drop. A single ammeter may be used in conjunction with a hermetically sealed selector switch to read each circuit's output. When a combination volt/ammeter is specified, the volt scale and ampere scale shall be clearly labeled.

When a digital meter is specified, it shall monitor the voltage and current output of each circuit of the rectifier using hermetically sealed switches to select the reading required. The selector switch shall have an off position which removes all input signals from the meter sense leads. A meter power on/off switch shall be supplied. The meter shall have an LCD (or LED) three and one half digit (minimum) display with an accuracy of ± 0.05 percent, operate over a temperature range of -30°C to $+65^{\circ}\text{C}$; and a storage temperature range of -30°C to $+80^{\circ}\text{C}$. The input impedance shall be 10 megohms minimum.

Shunts: Each output circuit shall have a DC shunt readily accessible for meter accuracy checks. They shall be plainly marked and mounted on the control panel. The shunt(s) shall be placed in the negative circuit. The shunt shall be rated at 50 mV and 120 percent of circuit current (maximum), and have uninsulated ring tongue terminals, positioned for easy connection of test equipment or meters, fastened to the calibrated test points. The negative circuits shall not be connected together.

Convenience Outlet: Units shall be equipped with a 115 VAC, Ground Fault Interrupter (GFI), grounded AC outlet mounted on the panel face. The outlet shall be fused for 15 amperes and attached to the line side of the circuit breaker.

Terminals: A 600 volt AC input terminal block with "dead front" shall be located on the insulated control panel for connection of the input AC wiring. Solderless, compression lugs, spaced a minimum of 2 inches apart, sized to accommodate up to #6 AWG wire, shall be provided for the positive and negative output terminals of each circuit of the rectifier and mounted on the control panel. Binding posts, suitable for attaching No. 10 AWG wire, shall be provided for each zone to accommodate two reference electrodes and structure test leads. Test jacks shall be provided to enable external monitoring of each voltage, current, or potential reading being taken. All terminals shall be clearly identified on the panel.

Output Control: Saturable reactors shall be used to provide constant current output for each circuit. Each circuit shall have its own reactor and control stack with individual adjustment so that adjustment of one circuit's output will not affect the output of any other circuit. Adjustment shall be by means of a potentiometer and voltage taps to enable smooth circuit output adjustment from 10 percent of maximum circuit current up to maximum circuit design current. The potentiometer shall be sized to handle 115 percent of the maximum RMS control winding current. The minimum capacity control stack shall be sized to provide 110 percent of maximum RMS control winding current with a junction temperature of 100°C . Both the control stack and potentiometer must

be properly heatsinked as required to provide continuous operation at maximum control current and the ambient temperature specified. Current regulation from full load to short circuit may not exceed 115 percent on any circuit. The maximum hot spot temperature rise of any reactor must not exceed 75 °F.

The constant current output shall remain within a range of +/- 5 percent of the set value over a change of resistive loading from 0.25 ohms to 2.5 ohms with the input AC voltage remaining constant. The constant current output may vary in proportion to changes in the AC line voltage input to the rectifier.

A link bar arrangement shall be provided to allow operation in constant voltage mode. When connected, the link bar will bypass the reactor, disabling constant current operation. This arrangement shall be located on the instrument panel of the rectifier and shall be properly labeled as a function.

Interrupter Connection: Provision for interrupting the input power to the rectifier with a portable interrupter shall be included. The hot line coming from the load side of the circuit breaker shall be connected to a stud and link bar arrangement. The studs are to be spaced 3 inches apart. The stud and link bar arrangement shall be "dead fronted" and labeled.

Wiring: All wiring and current carrying studs within the rectifier, except for meter circuits, shall be sized for not less than 500 circular mils per ampere. All current carrying bolts, terminals and connections shall be made of copper, brass or bronze. Electrical connections made through the panel shall be either soldered to the bolt head or utilize the double nut method so as not to depend on the compression strength of the panel to maintain a tight connection. All connections shall be clear coated to prevent corrosion.

Nameplate: Each rectifier shall be provided with a stamped or engraved metal nameplate with the information shown in Figure 650-2:

Table 650-2

Name of Manufacturer	
Serial Number	Model Code
AC Input Volts	AC Input Amps
No. of Phases	Frequency
DC Output Volts	DC Output Amps
Maximum Ambient Temperature Designed to Operate In	

Enclosure Finish: All welds shall be sanded and all sharp edges rounded before finishing. The entire enclosure shall be galvanized according to ASTM specification A123 and shall have a minimum coating of 2.6 mils or 1.5 ounces of zinc per square foot of surface area. When painted, the enclosure shall first be hot dip galvanized, and then all bare metal shall be chemically or steam cleaned followed by an air dry vinyl wash etching primer and a uniform undercoat of 1/2-mil of epoxy-based primer. The epoxy-base primer shall be applied over the entire surface and oven dried before applying two top coats of paint. The first top coat shall be a base enamel paint applied in a uniform coverage over the entire surface without holidays, spatter, or runs. The dry film thickness (DFT) shall be 1/2-mil minimum. This coat shall be bake dried before applying the final top coat of baked enamel. The final coat shall be applied as above, bake dried and allowed to cool to room temperature before handling. The final DFT of all coats shall be no less than 1-1/2 mils.

Panel Material: The panel shall be constructed of 1/4-inch thick bakelite NEMA grade XX, or equal insulating material.

Panel Marking: All panel functions shall be legible and permanently labeled near the function being described using engraving techniques in the panel or bolt on engraved plates. Stick-on labels are not acceptable.

Remote Monitoring: A terminal block(s), suitable for connection of #18 AWG wire shall be provided to allow remote monitoring of output voltage, output current, and structure potentials of each circuit.

Filters: All single phase units shall include a filter. The output ripple of each circuit of the rectifier shall not exceed 5 percent of rated output voltage when measured at rated output voltage and current. The output ripple shall not exceed 5 percent of measured output voltage when measured at 25, 50, and 75 percent of rated output current. The filter shall be removable, using switches and/or link bar arrangements, unless the filter is discharged completely when connected to the rated load in less than 15 milliseconds after interruption of the input power. Choke designs shall meet the applicable requirements of the transformer specification (MIL E 917). The capacitor shall have a DC working voltage of twice the rated voltage output of the rectifier.

Disconnect Switch: The rectifier power input circuit shall be furnished with a switch and enclosure separate from the rectifier. The switch shall be a single-throw fuseable safety disconnect switch with solid copper neutral bus bar and shall be listed with the Underwriters Laboratory. The contractor shall determine the proper switch rating required to supply the maximum voltage and

current of the rectifier. The switch shall be lockable in both the on and the off positions. The switch enclosure shall be classified as a NEMA 3R type enclosure with a baked enamel finish.

Testing: Each completed rectifier shall be full load tested at low, high and nominal line voltage. The AC input voltage, current, ripple, watts, power factor, and the DC output voltage, current and efficiency shall be recorded at each input voltage. Each circuit shall be individually tested with all other circuits energized and loaded and the results recorded. Each circuit shall be tested for constant current at rated current output for expected variation in the load resistance (0.25 ohms to 2.5 ohms), but within the output voltage limits of the rectifier. Each rectifier or group of rectifiers shall be tested to show that they meet the requirements of this specification.

When required, testing shall be witnessed by the customer at the manufacturer's location. The manufacturer shall certify compliance with the above test procedures.

Solar Power Supply: When the Design Specifics Checklist in section 650.30.01 so notes, the solar power supply shall be designed using the latest information concerning solar insolation for the area in which the power supply is to be installed as published by the Solar Energy Research Institute. If information is not published for the exact location of installation, then the nearest location for which information is published shall be used. The array shall be sized using the least favorable mean daily direct normal insolation figures as the design parameter and shall be able to supply 120 percent of the maximum daily (24-hour) output ampere/hour rating of the power supply.

The unit shall include an electronic battery charge regulator set up to supply 2.35 volts per cell in series (lead acid type battery). The charge rate shall be temperature compensated at a rate of six millivolts per degree C per cell. Solderless pressure type terminals shall be provided for solar array and battery connection. The unit shall include an output regulator complete with solderless pressure type terminals. Separate 50 millivolt shunts shall be provided for charge current and output current measurements. A meter shall be provided to read output voltage and current. An on/off switch shall be provided to remove the load from the output of the power supply. A blocking diode shall be installed in series with the solar array output to prevent battery leakage through the solar panels during sunless periods.

Battery capacity shall be determined by the daily ampere per hour requirement of the load as well as the minimum ambient temperature of the area of installation. Batteries shall be sized to provide a minimum of five additional

days of reserve capacity and shall be maintenance free lead acid shallow discharge type. The total battery shall be sized using the 10-hour discharge rate as published by the battery manufacturer.

All current carrying power wiring shall be sized for a minimum of 1,000 circular mils per ampere.

650.20.02 Reference Cells: The reference cells may be either silver-silver chloride or graphite. The same type of reference cells shall be furnished throughout the project. The cells shall be approved by catalog and data (2 years stability in concrete) submittals before being furnished to the project.

Silver/Silver Chloride: A silver/silver chloride cell shall consist of a silver metal element covered in silver chloride electrolyte and encased in a concrete compatible jacket. A single conductor lead wire shall be factory attached to the silver element. The single conductor wire shall be #14 AWG meeting 650.20.04 and colored black. The black conductor shall be connected to the silver element and sealed against moisture. A separate ground wire shall be supplied. It shall be #14 AWG meeting 650.20.04 and white in color. Both cell and ground leads shall be long enough to be routed without splices (except those housed in junction boxes) from the selected location in the deck to the terminal points in the rectifier. The manufacturer shall define the conversion factor for converting cell voltages to copper-copper sulphate equivalents.

Graphite Cells: A graphite reference cell shall consist of a non-impregnated graphite bar with a square cross-section of 1.5 inches (38 mm) on a side and 6.0 inches (150 mm) long with a factory attached lead wire. The lead wire shall have a firm mechanical connection to the graphite. The connection shall consist of a 3/8-inch diameter 1/2-inch long threaded brass rod with a drilled hole in the center of the rod of sufficient size to insert the lead wire. The lead wire shall be soldered to the inside of the rod. The brass rod shall be screwed into the end of the graphite bar. The spaces between the lead wire, insulation and walls of the brass rod and hole shall be filled with a water tight flexible non-shrink seal. The cell shall be supplied with a #14 AWG wire meeting 650.20.04 and black in color. A separate ground wire shall be supplied. It shall be #14 AWG meeting 650.20.04 and white in color. Both cell and ground leads shall be long enough to be routed without splices (except those housed in junction boxes) from the selected location in the deck to the terminal points in the rectifier. The manufacturer shall define the conversion factor for converting cell voltages to copper-copper sulphate equivalents.

650.20.03 Ground Electrode: The grounding electrode and grounding conductor shall conform to the requirements of the NEC. In addition, the connection of

the conductor and electrode shall be made with an exothermic weld (650.20.07)

650.20.04 Wire: Wire for anodes and system negatives, ground wires, and continuity bond wire used with exothermic welds shall be stranded copper conductors insulated with cross linked polyethylene listed by UL as RHH/RHW/USE or high molecular weight polyethylene with a minimum insulation thickness of 3/32 inch. The conductor sizes of the anode and system negative wiring shall be as determined by the corrosion engineer in accordance with recommended practices of the NEC.

650.20.05 Conduit: The conduit for cathodic protection shall be either rigid ferrous metal or polyvinyl chloride (PVC) electrical conduit and shall include junction boxes, fittings, and attachment hardware. Rigid ferrous metal electrical conduit and fittings shall be galvanized steel and shall conform to ANSIC 80.1, C80.4, and UL 6 for Type I rigid steel conduit. Each length of conduit shall bear the UL label. PVC conduit or EPL-40-PVC shall conform to NEMA standards Publication No. TC2. Conduit fittings shall meet NEMA TC3. Solvent cement for attaching fittings to the conduit shall be supplied or recommended by the conduit manufacturer.

Junction boxes used in a rigid conduit system shall be iron castings and hot-dipped galvanized in accordance with ASTM A 123 and conforming to NEMA ICS-6-Type 4 and UL 50. Junction boxes in a PVC conduit system shall be polyvinyl chloride with gasketed covers held by four screws. Junction boxes shall have a square 6 inch minimum opening and be a minimum of 4 inches deep.

Attachment hardware to attach conduit to bridge decks and abutments shall consist of rigid clamps formed to fit over the conduit with tables that fit flat on the deck or abutment, having holes for concrete penetrating screws or pins. Attachment hardware on a rigid conduit system shall be stainless steel or hot-dipped galvanized steel or malleable iron. Attachment hardware on a PVC conduit system shall be polyvinyl chloride coated steel of sufficient size to allow movement of the conduit due to thermal expansion and contraction.

650.20.06 AC Service Equipment: The material to be installed shall meet the national, State and local codes and be acceptable to the local electric company.

650.20.07 Wire Connections to Rebar: Welding of reference cell ground wires and system negative wires to the reinforcing steel or other metal items shall be accomplished by a commercially available exothermic weld kit. Continuity bonding of discontinuous rebar shall

be accomplished by exothermic welding or resistance welding.

Exothermic Welding: The exothermic weld kit shall consist of a mold and powder charge of suitable size for the wire and reinforcing rod or item. The rod or item shall be cleaned before welding. The weld and wire shall be cleaned of oil and grease with a solvent and clean cloth. The mold shall rest on the rod or item and securely hold the wire in place. When ignited, the charge in the mold shall burn and result in a mechanically secure and electrically conductive weld of the wire to the reinforcing rod or item. The finished weld shall be cleaned of any slag. The weld and any exposed copper of the wire shall be coated with a non-conductive, 100 percent solid, moisture and chemical resistant two-part epoxy paste. The epoxy shall initially cure in 20 minutes at 70 °F and cure to an ultimate compressive strength of at least 8000 PSI in 24 hours at 70 °F.

Resistance Welding: Discontinuous rebar shall be bonded to continuous steel by resistance spot welding a 1/16-inch or 1/8-inch diameter steel tie wire to the steel. To make the weld, the rebar shall be clean of all rust and oil. After cleaning, the tie wire shall be wrapped around the rebar when possible or laid across the rebar, preferably on top of a rib. A resistance spot welder with modified hand tool shall be used to make the connection. The manufacturer's instructions shall be followed.

650.20.08 Anode System Materials

The anode system shall be one of the following (as defined by the owner):

- Coke asphalt: per Section 651
- Slotted system: per Section 652
- Distributed anode with overlay: per Section 653

650.20.09 Remote Monitoring System

General: Supply all labor, materials, and equipment necessary to furnish and install a remote monitoring system for the cathodic protection rectifier(s). The system shall consist of a remote monitoring unit (RMU), complete with integral telephone modem and operating software. The purpose of the remote monitoring system is to transfer rectifier operating data to a remote computer terminal, thus eliminating the need for monthly field inspections at the site.

The system shall monitor the status of the rectifier output voltage and current for each anode zone, and also have the capability of performing remote depolarization tests using each embedded reference cell (two per zone).

The system shall be designed for "real time monitoring" of the rectifier operating data, i.e. only the instantaneous data is transferred to the computer terminal at the time of the phone call.

The contractor shall be responsible for supplying and installing a dedicated telephone line to each RMU, installing the RMU equipment at the rectifier site(s), and supplying operating software at the receiving end.

The remote monitoring system shall be warranted for one full year after installation or 18 months after delivery (whichever comes first) against defects in design and workmanship.

The contractor shall furnish and install computer equipment for receiving rectifier data at an office facility designated by the owner (optional).

Submittals: Prior to the installation, the contractor shall submit to the Owner for approval, three sets of catalog cuts and material lists which completely detail the equipment to be supplied.

A typical block diagram for the RMU configuration is shown in Figure 650-2. The system hardware shall conform to the following requirements:

Environmental Parameters: The RMU equipment shall be capable of operating in temperatures from -40 °F to +185 °F, and humidity ranging from 5 percent to 95 percent non-condensing. Printed circuit boards shall be silicon conformal coated to prevent dust and moisture intrusion. All inputs and outputs shall be provided with lightning protection.

Analog Input Parameters: Analog input ranges for each zone shall be as follows:

- One input for measuring the anode current across a shunt capable of 0.1 amperes resolution;
- One input for measuring output voltage with a resolution of 0.1 V; and
- Two differential inputs for measuring reference cell potential data with 1 mV resolution. The input impedance for reference cell potential measurement shall be at least 10 megohms.

Digital Output: Should the RMU malfunction, the output current interrupt signal shall not interfere with normal operation of the rectifier.

Data Communications: A phone modem shall be provided with the RMU. The modem shall be capable of 1200 baud data transfer, with both answer and dial-up modes. The modem furnished shall have surge suppression and shall be fully compatible with the modem at the

receiving end. The RMU shall have an integral RS-232 communications port, 7-bit ASCII, even/odd parity, and one stop bit.

Analog to Digital Converter Resolution: The resolution of the analog to digital converter shall be at least 10 bits (0.39 percent) at 0.5 percent accuracy.

Timer: The RMU shall be equipped with a timer which shall be used for depolarization tests.

Interrupter: An on/off interrupt "switch" shall be provided for conducting depolarization tests. The interrupt "switch" shall be either electronic or electro-mechanical (relay) and shall open the circuit within 10 milliseconds after the interrupt signal is given.

The "switch" shall be capable of being driven by the monitoring unit microprocessor and shall be connected in the rectifier AC power supply as shown in Figure 650-1, Typical Rectifier Schematic.

Data Storage: The RMU shall have sufficient non-volatile CMOS RAM memory to store one set of depolarization values for each reference cell as specified under the "PC Software" Section below. Storage for 500 total reference cell potential readings shall be provided (4 Kb minimum). The default setting shall be one per hour for 24 hours.

RMU Software: The RMU shall be equipped with software which enables the RMU to respond to commands and queries from the remote computer terminal as specified under the "PC Software" Section.

AC Power: The RMU and phone modem shall be powered by the rectifier 120 VAC power supply. If 220 VAC is used, a step down transformer shall be supplied.

Enclosure: The RMU shall be mounted in the rectifier cabinet, if space is available, or installed in a separate RMU enclosure adjacent to the rectifier unit. The RMU enclosure shall have a NEMA 4 rating, with hinged gasketed cover and padlock feature. The enclosure shall be provided with mounting attachments and hardware. All exterior hardware shall be installed in conduit. Separate conduits shall be used for AC power and control wiring.

Wiring: All wiring interconnecting the RMU with the rectifier shall be Teflon insulated #18 AWG stranded copper wire. All other wiring used in the monitoring system shall be Teflon insulated #22 AWG. Cables providing AC power to the RMU shall be designed and installed to meet the National Electric Code. Wiring shall be neatly installed and secured within the enclosure using plastic wire ties.