CONSTANT VOLTAGE MANUAL TYPE CATHODIC PROTECTION RECTIFIER

INSTALLATION, OPERATION, & MAINTENANCE MANUAL

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INDEX

INTRODUCTION

Corrosion of underground structures (pipelines, well casings, etc.) is a process that occurs every minute of every day. As such, continuous protection is required to effectively prevent damage that could cost a company significantly in lost revenues, manpower, and equipment. The proper selection, installation, and operation of a suitable corrosion prevention system can be crucial to ensure that this costly damage does not occur. For well-coated structures, structures with small surface areas, or where minimal Cathodic Protection is required, a “sacrificial” type corrosion prevention system may be used. For poorly coated structures, structures with large surface areas, or where a larger amount of Cathodic Protection is required, an “impressed current” type corrosion prevention system is required. One key component of an impressed current corrosion protection system is a Cathodic Protection rectifier. A rectifier is a device that is used to convert “alternating current” (AC), as provided by the power utility, to “direct current” (DC), as is required for Cathodic Protection. The rectifier should be selected based on the type of control required for the specific application, the amount of Cathodic Protection required to provide effective protection, and the reliability of operation in the subject environment. IRT Integrated Rectifier Technologies, Inc. manufactures Cathodic Protection rectifiers that exceed industry standards for superior corrosion prevention and, as such, an IRT rectifier unit is a smart investment for any company.

IRT Integrated Rectifier Technologies, Inc. Cathodic Protection rectifiers and associated products are designed by a knowledgeable engineering team with years of experience in the corrosion field and manufactured by skilled technicians with a dedication to quality. The IRT units are designed with superior components to provide a high quality, reliable rectifier with an economic cost for your application. IRT maintains a large volume of in-stock components and sub-assemblies to ensure that orders can be shipped to you in the shortest time frame possible.

IRT products are sold and serviced by leading corrosion prevention engineering companies throughout North America and Internationally. These companies have superior expertise in the corrosion industry and have the personnel to meet all of your corrosion prevention system requirements including design, installation, and maintenance. IRT products are also available through leading material supply companies throughout North America.

Rectifiers manufactured by Integrated Rectifier Technologies, Inc. are guaranteed against defects in design, workmanship, or material for a period of one year from the time of shipment from our facility. Please refer to our warranty statement for further details.

DELIVERY INSPECTION

Although the rectifier unit may not be scheduled for immediate installation, we recommend that it be thoroughly inspected, both externally and internally, upon receipt to ensure that no damage has occurred during shipment. Please remember that although the outside of the rectifier packaging may not show any signs of damage, there may be internal damage that will not be apparent until the outer packaging is removed. Any damage, whether internal or external, must be reported to the freight carrier immediately. If any damage has occurred during shipment; an indication of this should made on the freight paperwork, the shipment should then be accepted, and a claim filed with the freight carrier. Please ensure to retain the original packaging that may indicate how the damage occurred.

If damage has occurred during shipment and repairs or a return to the factory is required, please contact us, or your local IRT distributor, with the Serial Number and the Model Number of the rectifier. This information is crucial for us to determine the rectifier unit in question and to be able to provide suitable assistance. An RMA number must be obtained from the factory prior to return of any damaged rectifier units.

PRE-INSTALLATION STORAGE

If the rectifier unit is to be stored prior to installation, it is recommended that it be stored in a dry area, preferably indoors. If the unit is to be stored outdoors for an extended period of time, it is recommended that it be placed on a raised surface (pallet or platform) and covered with a protective sheet or tarp to ensure the packaging does not deteriorate due to rain or snow. Whether stored indoors or outdoors, the unit should be placed in an area where it is protected from accidental damage from moving vehicles or equipment. Ensure that the rectifier unit is transferred to and from the storage facility using proper handling techniques.

SAFETY PRACTICES

As Cathodic Protection rectifiers are connected to the AC utility power, electrical shock hazards are present within the rectifier units. It is recommended that only qualified electronic or electrical personnel operate and maintain these units and that those personnel familiarize themselves with the areas of possible hazard within the unit. Following these practices can enhance the safety of personnel.

1.) Prior to site maintenance or inspection, familiarize yourself with the rectifier and conditions at the site.

2.) Prior to doing any maintenance or troubleshooting on a rectifier unit, familiarize yourself with any possible hazard points within the unit by reviewing the electrical schematic and the physical layout of the rectifier.

3.) Whenever possible, set the AC disconnect from the power utility to the “OFF” position prior to starting any work on the rectifier unit. Even with the rectifier AC input circuit breaker in the “OFF” position, hazardous voltages are still present at any terminals connected to the rectifier AC input terminals. Always tag and lock out the disconnect to ensure others do not energize it while you are completing the rectifier work.

4.) Prior to opening the rectifier enclosure door, lightly touch the back of your hand to the enclosure latch. If you feel an electrical tingle, set the fused AC disconnect to the “OFF” position and contact an electrician for assistance.

5.) When taking readings across the rectifier terminals, it is recommended to use only one hand, if possible.

GENERAL INSTALLATION TIPS

To ensure reliable, long-term operation of the Cathodic Protection rectifier, proper installation of the unit is required. Though most installation sites differ, there are several key guidelines that should be followed.

a) Prior to installation, check the connections (especially the electrical connections) on the rectifier unit to ensure that nothing has become loose during shipment. It is also recommended that if any scratches occur to the enclosure during installation, that these points be touched-up to prevent corrosion on the enclosure.

b) Selecting the site of installation is a very important factor. The rectifier should be installed in a location that is easily accessible by company personnel for regular adjustment and maintenance. However, it should not be located in areas where unauthorized personnel have easy access to the unit and may damage or vandalize it (i.e. residential areas, playgrounds, farm yards, etc.). The convenient access to AC power and the cathodic protection DC connections must also be considered when choosing the rectifier location.

c) Proper ventilation and cooling of the rectifier unit must be considered when choosing a suitable location. Air-cooled rectifiers are cooled by the natural convection of cool air drawn into the bottom of the rectifier enclosure, passing over the internal components, and the resultant warm air expelled from the top or sides of the enclosure. Oil-cooled rectifiers are cooled by the natural circulation of oil from the bottom to the top of the rectifier tank, over the internal components, and the resultant heat is radiated from the upper walls of the rectifier tank. As such, when choosing the installation site for the rectifier, adequate spacing should be allowed for around the sides of the rectifier unit. The rectifier should not be located near sources of heat such as exhaust vents, power generators, etc. If possible, place the rectifier unit in an area where it will be shaded during the hottest part of the day. If the rectifier is to be installed in an area with a high ambient temperature and minimal natural shading, a protective sunshade is recommended.

d) The rectifier unit should be mounted on a secure surface. Ensure that the wall, pole, frame, or mounting pad is designed to hold the full weight of the rectifier unit.

e) If the rectifier is to be installed in an area subject to frequent lightning activity, upgraded, high-energy type surge arrestors are recommended.

f) Do not install other equipment on or inside the rectifier enclosure without prior consent from the factory. Unauthorized equipment installation will invalidate the rectifier guarantee as IRT has no control of the equipment added or the resultant detrimental affect to proper rectifier cooling / operation.

AC & DC CONNECTION

After the rectifier has been installed in a suitable location, have a qualified electrician connect the rectifier unit to the AC supply following local and national codes. Please note that most electrical codes require a disconnect device between the AC power supply and the rectifier. Ensure that for dual input rectifiers (115 / 230 or 230 / 460 VAC), that the AC input terminal jumpers are properly configured for the actual AC input voltage being supplied and that the AC input wires are connected to the correct AC input terminals.

A grounding rod or rods should be installed as close as possible to the rectifier location but not too close to the AC input or DC output cables. The grounding rod(s) should be connected to the ground lug terminal adjacent to the AC input terminals within the rectifier.

Next, connect the cable(s) from the anode bed to the rectifier positive output lug terminal(s) and the structure cable(s) to the rectifier's negative output lug terminal(s). Ensure that these cables are suitably sized for the expected current and the length of the cable run. Also, it is absolutely imperative that the polarity of DC connections is correct. A reversal of the DC cables can actually cause accelerated corrosion and eventually, severe damage to the structure to be protected.

GENERAL COMPONENT DESCRIPTION

When operating any instrument, it is a good practice to become familiar with the key components and the general operation of that instrument. As such, the key components of a rectifier shall now be reviewed.

The **AC Input Surge Arrestor** is a device that protects the rectifier components from voltage surges that may occur across the AC input of the rectifier. It does this by providing a bypass circuit for the resultant current from these high voltage surges after a specific voltage threshold has been reached. Most surge arrestors are designed to handle a certain number or energy value of surges prior to failing.

The rectifier **AC Input Circuit Breaker** (CB1) is a fully magnetic type that serves three key functions. It is used as an "OFF-ON" switch for the rectifier, it provides "short circuit" protection, and, to a lesser degree, provides input overload protection.

The rectifier **Main Transformer** (T1) provides full electrical isolation between the utility AC power and the Cathodic Protection DC circuit. It also steps the voltage up or down as required for the DC circuit and, for tap type units, provides a means of output adjustment.

The rectifier **AC Secondary Fuse** is a semiconductor or fast-blow type that provides protection from not only short-circuits or overloads in the DC output circuit but also in the diode bridge circuit.

The rectifier **Diode Bridge Assembly** is made up of silicon diodes configured into a full-wave bridge configuration. The diodes are supplied with suitably sized heatsinks to ensure that the diodes do not exceed 100°C at full rated output. The diode bridge is the device that converts the AC secondary voltage of the transformer into DC voltage that can be used for Cathodic Protection.

A **Varistor** is supplied across the AC input to the diode bridge to provide additional protection from any voltage surges that may pass the main AC surge arrestor or be developed by the main transformer. A second varistor may also be supplied across the DC output of the diode bridge at special request.

The **Current Monitoring Shunt** is a block style calibrated resistor with an accuracy of 0.25%. The DC current and voltage rating are stamped into the body of the shunt.

The rectifier **Metering** utilizes an analog, taut-band type movement that provides ±2% accuracy. The DC output amperage of the rectifier is monitored by a meter connection across the calibrated test screws of the above shunt. The DC output voltage of the rectifier is monitored by a meter connection across the DC output terminals of the rectifier.

The **DC Output Surge Arrestor** is a device that protects the rectifier components from voltage surges that may occur across the DC output of the rectifier. It's operation and characteristics are similar to the AC input surge arrestor.

As many optional features / components are available for our customers, it is not practical for this manual to describe all of the possible options in detail. As such, it is recommended that the rectifier data sheet and the electrical schematic be reviewed in detail to become familiar with any features not detailed in this manual.

INITIAL ENERGIZATION

After the rectifier has been properly connected to the AC supply and the DC output cables, it is ready to be energized. However, never take anything for granted. Before energizing, double-check both the AC and DC connections to ensure they are properly connected. Ensure that for dual input rectifiers (115 / 230 or 230 / 460 VAC), that the AC input terminal jumpers are properly configured for the actual AC input voltage being supplied and that the AC input wires are connected to the proper terminals. Also, make sure that the rectifier is at its lowest control setting. For tap-adjust type units, set the tap connections to “Coarse-A” & “Fine-1” and for variable transformer control type units, set the control knob to 0%. For three-phase input type units, ensure that all secondary tap connections are adjusted to the same setting.

At this point, set the AC fused disconnect switch to the “ON” position and measure across the rectifier AC input terminals to ensure the voltage present is as expected. Then set the rectifier AC input circuit breaker also to the “ON” position and verify that there is some deflection on the panel meters (this deflection may be quite minimal). For units with a metering switch, ensure to set the switch to the “ON” position. Next, set the rectifier AC input circuit breaker to the "OFF" position and adjust the rectifier to a slightly higher output setting. For tap-adjust type units, moving the tap links bars or the AC wire on the adjustment terminal block to setting "Coarse-B" & "Fine-1" will suffice. For variable transformer control type units, setting the control knob to a 20-25% setting on the dial is adequate. Set the circuit breaker to the "ON" position and verify the metering has deflected to a suitable value. If either meter deflects fully to the right, immediately set the rectifier circuit breaker to the "OFF" position and adjust the rectifier to a lower output setting. Also, verify that the DC voltage and current shown on the metering is as expected for the subject output circuit (i.e. structure-to-anode bed resistance). If no problems are evident, the rectifier can be adjusted to the "target" current required to provide a sufficient cathodic protection potential on the output structure. Always set the rectifier circuit breaker to the "OFF" position before adjusting the rectifier.

After the "target" current has been achieved, verify the rectifier metering is showing accurate readings by comparing them to readings taken with an external Digital Volt Meter (DVM). The rectifier on-board voltmeter can be verified by simply measuring the DC voltage across the rectifier DC output lug terminals with the DVM. The rectifier on-board ammeter can be verified by measuring the voltage (in millivolts) across the calibrated test screws of the rectifier shunt (not across the connection bolts). To determine the current through the shunt from the millivolt reading taken, the following formula can be used:

$$\text{DC Current (I)} = \frac{\text{Measured Shunt Voltage (millivolts) X Rated Shunt Current}}{\text{Rated Shunt Voltage (50 millivolts typical)}}$$

Note: Rated shunt current and voltage values are stamped onto the body of the shunt and are also shown on the rectifier data page.

The ammeter can also be verified with an external DC clamp-on type meter, if available.

It is also useful to check the conversion efficiency percentage of the rectifier, which is defined as:

$$\text{Conversion Efficiency (\%)} = \frac{\text{DC Output Voltage X DC Output Amperage X 100\%}}{\text{AC Input Wattage}}$$

The AC input wattage can be obtained by connecting an AC Wattmeter to the AC input of the rectifier. The expected conversion efficiency for a single-phase rectifier with a full-wave silicon diode bridge is approximately 70-75%. For a three-phase rectifier, the expected efficiency would be approximately 90-95%. If the efficiency of the rectifier is significantly lower than these values, this may be an indication of a damaged diode bridge (refer to the "Troubleshooting" section).

It is recommended that all initial energization readings be recorded for future reference. Useful readings to record are structure potential levels prior to energization, AC input voltage & current, DC output voltage and current, tap or adjustment dial setting, conversion efficiency, structure potential levels after energization, as well as any observed problems or possible future concerns with the installation, in general.

After the structure potential readings have been taken and prior to leaving the site, it is recommended that the DC output connections to the rectifier be rechecked to ensure a secure connection. It is also beneficial to recheck the rectifier to ensure that all air inlet and outlet venting on the enclosure is not obstructed in any manner. The rectifier O&M manual should be securely set in it's holder (for small rectifiers without a manual holder, it is recommended that the manual be kept with the main operator or in the control room of the closest station). Also verify that all holes within the enclosure (other than the venting screens) are suitably plugged (such as unused conduit knockouts). For rectifier units with "OFF-ON" meter switches, ensure that the switch is in the "OFF" position prior to leaving the site.

REGULAR MAINTAINANCE & ADJUSTMENT

One of the fundamental formulas to remember when dealing with Cathodic Protection rectifiers is the "Ohm's Law" formula **"Current (I) = Voltage (V) / Resistance (R)"**. As you can see from the formula, if voltage stays constant and resistance varies (up or down), current will also vary (up or down). Now, as the description suggests, the output voltage of a "constant voltage" type rectifier is "constant" (this is true so long as the AC input to the rectifier is constant). As such, with changes in the output circuit (structure-to-anode bed) resistance, the DC output current of the rectifier will also vary. As the resistance between the structure and the anode bed typically varies during the year due to environmental conditions (rain, drought, frost, snow, etc.), if the rectifier DC voltage output is not periodically adjusted to compensate for this phenomenon, the DC output current will not remain at the desired "target" level. Therefore, dependant on the environmental conditions in your area, it is recommended that the rectifier be checked and adjusted as required at least twice per year. Some local regulatory bodies require a monthly or semi-monthly check to ensure proper protection levels are being maintained. These checks also allow you to ensure that the rectifier has not been damaged. When completing this maintenance and adjustment check, it is recommended that all readings and observations be recorded in the site file. With regular maintenance checks and by maintaining good records, future troubleshooting and repair costs can be reduced.

Prior to arriving at the site for the rectifier maintenance check, it is recommended that the technician review the existing rectifier site file to gain familiarization with the subject rectifier and site conditions. Upon arriving at the rectifier site, a visual check should be completed to determine if any changes have occurred. Things to look for are signs of new underground construction, buildings, pipeline tie-ins, bonds, etc. Prior to adjustment of the rectifier, it is recommended that structure potential readings be taken, to determine the adjustment level required. Even if the potential levels are within the required range, the rectifier should still be checked for proper operation.

When approaching the rectifier, ensure that no items have been placed near the rectifier enclosure in such a manner as to block the venting, either on the bottom or sides. As the vent openings on the rectifier enclosure are screened, there should be no refuse inside from birds or larger insects. However, after opening the door of the enclosure, ensure that there has been no significant accumulation of dirt, snow, or other small debris at the bottom of the enclosure, which may adversely affect proper venting.

Prior to any adjustment of the rectifier, measure and record the “As Found” readings of the rectifier (DC voltage, DC amperage, etc.). Next, set the rectifier circuit breaker and the utility disconnect to the “OFF” position to allow for a detailed rectifier inspection.

CAUTION: Please ensure that the utility disconnect is in the “OFF” position prior to any internal rectifier maintenance as hazardous voltages are still present within the rectifier even with the rectifier circuit breaker in the “OFF” position.

At least once a year the rectifier should be inspected for loose electrical connections that could eventually cause damage to the electrical panel, wiring, or rectifier components. If an electrical connection becomes loose, the resistance of the connection increases and causes it to heat up. This additional heat will cause the connection to oxidize and become even higher resistant until a failure occurs. The best way to check for a heated connection is with a temperature probe, however, as these are not typically standard issue for Cathodic field maintenance, the visual inspection method will suffice. First, visually inspect all of the main electrical connections within the rectifier for signs of discoloration on the connection terminal, the electrical panel, or the wire attached to the terminal. Key points to check are the DC output lug terminal connections and the fuse holder connections. If you see a suspect connection, use a wrench or other suitable tools to see if the connection is indeed loose. (Note: Be careful when touching these types of connections with your hand as the temperature of loose high current connections can cause a significant burn.) If you do find a loose connection, it should be secured with suitable tools (ensure to secure both the front and rear of panel connections). If a loose connection has already caused damage to the electrical panel, the panel should be repaired or replaced, as re-tightening a connection on a degraded panel will most likely still lead to a future failure.

Certain main components within the rectifier should also be inspected for signs of over-heating or other damage.

The main isolation transformer (T1) within the rectifier is designed to operate at a fairly high temperature and thus is usually somewhat discoloured. However, it should not be extremely dark or black. If it is, this could indicate insufficient / blocked venting or a problem within the transformer itself.

The AC primary, AC secondary, and the DC output surge arrestors should be checked to ensure that a significant voltage surge has not damaged them. Signs of damage to an arrestor device are usually visually noticeable by a blackened or cracked housing. Please note however that sometimes the operational status of an arrestor is not discernable visually and requires further checking (see Troubleshooting section).

The rectifier fusing should also be checked for overheating. If the fusing is a bolt-on type (for larger rectifier units), ensure that the fastening studs or bolts are secure on both the front and rear. Many smaller rectifier units utilize the “clip-type” fuse connectors that are very convenient for fuse replacement but are also infamous for becoming loose and oxidizing over time. However, with regular checks and maintenance, problems can be avoided. For this type of connection, if oxidation is apparent, the fuse should be removed and both the fuse and the fuse contact surface of the clips cleaned up with some very fine sand paper or emery cloth (only the oxidation layer should be removed, not the protective coating on the copper). If the fuse clips have lost tension, they should be replaced. If replacements are not immediately available, the clips can be “squeezed” together and should then provide a suitable short-term connection to the fuse. A notation should be made however, in the site inspection form for replacement on the next maintenance check. The connection hardware on each fuse clip should also be checked and re-tightened if necessary.

If, after completing the inspection on the rectifier unit, a problem is found other than just a loose connection, refer to the “Troubleshooting” section of this manual. If no problems have been found, the rectifier can be adjusted to a new DC output setting (if deemed required based on the “as-found” structure potential levels). As per the adjustment procedure indicated in the “Initial Energization” section, adjust the DC output of the rectifier to the level required to provide suitable protection to the structure. If the rectifier is adjusted to or near it’s maximum rated output, future replacement of the rectifier with a larger unit or the addition of anodes may need to be considered. If the required “target” DC output current from the rectifier varies significantly over the year due to soil resistance changes, maintenance checks should be done frequently. As an alternate to this, the rectifier could be replaced with an “automatic, constant current” type rectifier. This type of rectifier would automatically (electronically) adjust the DC output voltage to maintain a constant DC output current in accordance with DC circuit resistance changes.

TROUBLESHOOTING

If a problem is found with the rectifier during the maintenance inspection or reported by the local operator, the following troubleshooting procedure can be followed to determine the cause.

The only way to effectively determine the cause of a failure in any piece of equipment is to conduct a systematic analysis of the function and operation of the key components. For this troubleshooting procedure, we shall review the possible faults that may occur starting from the DC output and working back to the AC input. Please refer to the attached electrical schematic for component descriptions and test points.

CAUTION: Please be advised that hazardous voltages are present within the rectifier unit even with the rectifier AC input circuit breaker in the “OFF” position. Extreme care should be observed when taking measurements on the front of the instrument panel or the side AC input panel. Internal troubleshooting of the rectifier should only be attempted by qualified electronic or electrical technicians. The fused AC disconnect should be set to the “OFF” position prior to any internal rectifier maintenance or repair.

1.) If there is no reading on the rectifier ammeter, ensure to check that there is not a metering switch that must be activated to get a reading on the meter. If there isn’t a metering switch or if the metering switch is activated and there still is no current showing on the meter, the operational status of the ammeter should be verified. This can be done by measuring the DC voltage across the calibrated test screws of the rectifier shunt or by using an external DC clamp-on type meter, if available. If the shunt measurement or clamp-on indicates that there is no current, continue to the next step. If the measurement indicates that there is current, there is either a problem with the ammeter, the ammeter connection or, if supplied, the ammeter switch. With power to the rectifier “OFF”, trace the ammeter wires from the shunt to the meter itself. Use a Digital Volt Meter (DVM) on the resistance or diode check setting to determine if the wires are continuous from the shunt terminals to the meter terminals. If the DVM reads a high resistance, the subject wire or the crimp connection has gone high resistant and should either be repaired or replaced. If there is an ammeter switch, ensure to activate it during this test. If the DVM still shows a high resistance even after the ammeter switch is activated, the switch has most likely failed and should be replaced. If the wire connections and the ammeter switch are continuous, the ammeter has most likely failed and should be replaced.

2.) If there is no DC output current from the rectifier, as verified in the above step, but there is DC output voltage, verify that the DC output connections are secure and that the DC output cabling is continuous. A common misconception is that if there is DC voltage at the rectifier output terminals but no DC current, that there is a problem with the rectifier. This is incorrect. If there is DC voltage at the rectifier output terminals but no DC current, it is almost guaranteed that the DC output cabling to either the structure or the anode bed is discontinuous. As per Ohm’s Law, if the circuit resistance is infinitely high, the current will be infinitely low. To verify this, a temporary load resistor could be connected across the DC output terminals of the rectifier. If there is now DC output current, there is a problem with the DC output circuit or cabling.

3.) If there is no reading on the rectifier voltmeter, ensure to check that there is not a metering switch that must be activated to get a reading on the meter. If there isn’t a metering switch or if the metering switch is activated and there still is no voltage showing on the meter, the operational status of the voltmeter should be verified by measuring the DC voltage across the DC output terminals of the rectifier. If the measurement indicates that there is no voltage, continue to the next step. If the measurement indicates that there is a DC voltage, there is either a problem with the voltmeter, the voltmeter connection or, if supplied, the voltmeter switch. Follow the steps outlined in Step 1 above to determine where the fault lies.

4.) If it is found that there is no output voltage or current from the rectifier, there are five key items to check:

   a. Check the continuity of the AC secondary fusing (or DC output fusing, if supplied) by setting the DVM to the resistance or diode check mode and measure across the fuse(s). If a high resistance is measured, the fuse has opened and should be replaced (prior to replacement see Step 5). If a very low resistance is measured, the fuse is operational and other components should be checked.

b. Verify that the correct level of AC input voltage is present at the AC input terminals of the rectifier unit. Please note that this should be done with the rectifier AC input circuit breaker in the "ON" position to eliminate the possibility of a "static" voltage reading (as may occur if one AC line becomes discontinuous). If the correct AC input is not available, contact the local power utility company for assistance.

c. With the AC power and the rectifier input circuit breaker "ON", check the proper operation of the rectifier circuit breaker (CB1) by measuring the AC voltage at the input (top) terminal(s) and also at the output (bottom) terminal(s) of the breaker. The AC voltage at the output terminals of the circuit breaker should match the voltage at the input terminals. If the voltage doesn't match, the rectifier AC input circuit breaker has probably developed bad contacts and should be replaced.

d. Another possible cause could be a discontinuous wire connection in the rectifier. Do a visual check of all the electrical connections within the rectifier for a heated or burnt wire connection. Check all connections for tightness and do a slight pull test on all wire connectors. If a poor or discontinuous connection is found, it should be repaired or replaced. If replacement is required, ensure to use the same type of wire and/or connector.

e. With the rectifier input circuit breaker "ON", verify that there is an AC voltage out of the main transformer (T1) secondary by measuring across the tap link bars or terminals (for tap type units) or across the AC input to the diode bridge assembly (for variable transformer types). For this check, ensure that the rectifier is adjusted to at least 25% of rated output. If no AC voltage is measured at the secondary terminals, the main transformer has probably failed and should be replaced.

5.) If the rectifier fusing is found to have become discontinuous or high resistant, there are several possible causes for this that should be explored prior to fuse replacement. If the fuse is replaced before these possible causes are checked, the new fuse may fail immediately after replacement.

a. The AC secondary fuse may fail if the DC output circuit becomes low resistant or shorted. This is possible during very wet periods, if the rectifier has been adjusted to or over maximum rated output, or when the DC output cables are damaged during construction. To determine if this is the problem, the DC output cables can be checked with a soil resistance meter (a typical DVM will not work) to determine if they are shorted. As an alternate to this, the DC output cables could be disconnected from the rectifier and a temporary test load used. If the DC output cables are found to be shorted, they must be repaired prior to further operation of the rectifier. If a very low DC circuit resistance is suspected, after replacing the fuse, energize the rectifier at a very low setting to ensure an over-current situation doesn't occur.

b. The AC secondary fuse may fail during a DC output voltage surge situation when the DC surge arrestor acts as a bypass for the surge current. Though the DC surge arrestor protects the rectifier circuitry from the surge current, it also acts as a zero resistance bypass circuit for the rectifier current and thus the fuse will fail. As long as the DC surge arrestor doesn't fail in a shorted condition (zero resistance), the fuse can simply be replaced and the rectifier should operate properly. However, if the DC surge arrestor does fail in a shorted condition, any replacement fuses installed will fail immediately. To determine if the DC output arrestor has shorted, disconnect the DC output cables from the rectifier and measure across the rectifier DC output terminals with a Digital Volt Meter (DVM) on the resistance or diode check setting. If a very low resistance is measured, the arrestor has probably failed. Remove the arrestor from the circuit, re-check it, and replace as necessary.

c. The AC secondary fuse may also fail if one or more of the diodes in the diode bridge assembly have shorted. To determine if this is the cause, the following diode bridge verification procedure should be followed.

   i. With the AC power "OFF", disconnect one of the two wires from the AC input of the diode bridge (BAC1). This can be easily done on tap type units by removing a tap link bar or tap wire. For three-phase input rectifiers, two of the three AC input wires to the diode bridge (BAC1 & BAC2) should be removed. The output cables should also be disconnected from the rectifier DC output lug terminals.

   ii. With the DVM set on the diode check range, place the positive (Red) meter lead on the bridge negative terminal (BDC-) and touch the negative (Black) meter lead to each of the bridge AC input terminals. An operational diode should measure approximately 0.4 to 0.6 volts on the diode check setting and the DVM may emit a single beep. An open or short circuit reading will indicate a faulty diode that requires replacement.

   iii. Next, place the negative meter lead on the bridge positive terminal (BDC+) and touch the positive (Red) meter lead to each of the bridge A.C. terminals.

   iv. When replacing the damaged diodes, ensure to replace them the same type and polarity (consult the rectifier data sheet or the factory for details). When installing the diodes, do not over-tighten them as the mounting studs may be easily damaged.

   v. A final check to complete on the diode bridge assembly is to determine if any of the components are shorted to a grounding point. With the DVM again set on the diode check range, attach the negative (Black) meter lead to the rectifier ground terminal or frame and touch each of the diodes and heatsinks with the positive (Red) meter lead. There should an infinite resistance reading on the meter. If the meter reads a low resistance or short, somewhere one of the diode bridge components or wires is contacting a grounding point and must be repaired.

6.) If the rectifier AC input circuit breaker continually trips to the "OFF" position when the rectifier is energized, there are several factors that may cause this.

   a. Visually inspect the rectifier AC input surge arrestor for damage (usually located adjacent to the AC input terminals). If the housing of the arrestor is cracked or blackened, the arrestor has failed and should be replaced. Always replace the arrestor with one of the same type. If an immediate replacement cannot be obtained, the rectifier can operate without this arrestor for a limited period, however, please remember that the rectifier then has no protection against surges. In certain circumstances, the arrestor may also fail without any external signs of damage. As such, to ensure that the AC arrestor is not the problem and with the AC power "OFF", disconnect the wires of the arrestor from the circuit breaker terminals. If the rectifier circuit breaker now remains in the "ON" position when energized, the arrestor has failed and should be replaced.

   b. If the breaker still trips to the "OFF" position, disconnect the wires between output (bottom) terminals of the rectifier circuit breaker (CB1) and the AC primary of the main transformer (T1). If the rectifier circuit breaker now remains in the "ON" position when energized, the main transformer has most likely failed and should be replaced (consult the factory for a replacement).

   c. Another possibility is that the AC configuration terminals of the main transformer (T1) (for dual input types only) are incorrectly set for the actual AC input voltage applied to the rectifier. Please confirm that these terminals are configured properly (refer to the electrical schematic) for the AC voltage being applied.

   d. If the breaker is still tripping to the "OFF" position after checking the above steps, it is most likely that the rectifier AC input circuit breaker itself has failed and will require replacement.

7.) If the DC output of the rectifier is intermittent, this could be caused by a loose or a high resistant connection. Refer to Step 4d above.

8.) If the efficiency of the rectifier is not as expected, one or more of the diodes in the bridge assembly may not be functioning. Follow the steps outlined in Step 5.c above to determine if this is the problem.

9.) If, by following the above troubleshooting steps, the rectifier problem cannot be solved, please feel free to contact the factory or your local supplier for technical assistance.