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## **500 SERIES**

### **Installation and Operating Instructions**

#### **For Revision G systems**

**(For earlier revisions, contact Electro-Guard Technical Support for correct hook up instructions.)**

### **Theory of Operation**

Electro-Guard 500 series systems are automatically controlled sacrificial anode cathodic protection systems. There are five basic components: the anodes, the reference cell, the electronic controller, the monitoring station, and the vessel's underwater metal structures.

The anodes produce electrical current through ELECTROCHEMICAL action with the water surrounding the hull. They are usually composed of special alloys of zinc, aluminum or magnesium.

Electrical current generated by the anodes is delivered by wire to the electronic controller which regulates the output of current to the vessel's underwater metal structures. The amount of current (in amperes) delivered to the underwater metals is controlled by an electronic circuit that measures the voltage difference between a stable external reference electrode (reference cell) and the structures being protected by the controller. The controller regulates the current being delivered to the metal structures so that the external reference voltage matches a calibrated internal reference voltage. The internal reference voltage is calibrated for the type of metal the system is designed to protect.

As long as sufficient anode current is available and there are no strong external electrical influences -- such as stray electrical currents -- the controller will always supply the amount of anode current necessary to match the solution potential of the metal structures being protected to that of the internal calibrated reference voltage. As stated above, the term "solution potential" refers to the voltage difference between the stable reference electrode and the protected metal structures.

The controller is calibrated to maintain a solution potential for a boat's metal structures at which all electrochemical reactions will be cathodic -- hence the term "cathodic protection". Cathodic reactions are reduction reactions which are noncorrosive. Anodic reactions are oxidation reactions and are corrosive. By applying electrical current (from the anodes) the controller changes the solution potential of a boat's metals from their natural potential, where the electrochemical reactions are both anodic and cathodic, to the calibrated internal reference potential at which all reactions are cathodic. Since there are no longer any anodic (oxidation) reactions occurring on the boat's underwater metal surfaces, corrosion is prevented.

### **Operating Instructions**

Electro-Guard Series 500 cathodic protection systems are completely automatic in operation. No adjustments to either the meters or the electronic circuitry is necessary or appropriate. Under normal operating conditions the potential meter in the Model 601 monitoring station -- the meter with the colored scale -- should read in the green "SAFE" zone. The anode current meter, the other meter in the Model 601, may indicate anywhere between just above zero amperes and full scale.

The potential meter indicates the solution voltage (potential) of the vessel's underwater metal structures relative to a stable reference electrode. This measurement is the key parameter that indicates whether these structures are in an electrochemical condition at which they can corrode. It is important that the potential meter reading be checked frequently. Check this meter's indication at least several times a day when aboard the boat, more often when under way.

The green "SAFE" zone is the desirable reading under all operating conditions. In corrosion control terms, if the vessel is in the water it is operating, regardless of whether it is sitting still at its mooring or at cruising speed.

The red "UNDER" zone is a danger zone. A reading in this zone indicates insufficient corrosion protection. The farther the indicator needle progresses into this zone the more rapid the expected corrosion attack. An indication in this zone calls for immediate attention to and correction of the problem that is causing it.

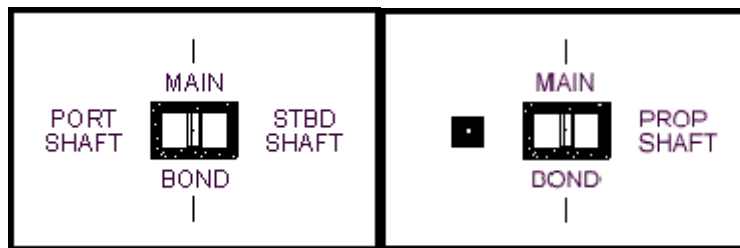
The red "OVER" zone, while not indicating a condition that will lead to as rapid corrosion attack, calls for the same corrective action as a reading in the "UNDER" zone. Undesirable effects of overprotection may occur if the vessel's underwater structures are left in the over protected range continuously. Some of these effects include moderate to severe damage to the wood surrounding through-hull fittings and fasteners in wooden hulled vessels, loss of paint coatings on underwater metal structures and brittle fracture of highly stressed stainless steel structures such as propeller and rudder shafts. If an underwater structure or the hull is made of aluminum, the red "OVER" zone indicates a potential at which the aluminum may suffer severe caustic corrosion attack.

The potential meter in the 601B (for fiberglass and wooden vessels) has yellow zones to either side of the "SAFE" zone. These zones indicate the potential of the bonded metal structures is outside of the designated zone of safe protection but that the condition is not critical. These are warning zones. The interpretation of readings in these zones should be that something is preventing the system from maintaining a proper level of protection and that the condition should not be allowed to continue for a significant length of time. If the reading does not return to the "SAFE" zone within a short time (not more than an hour), trouble shooting procedures should be carried out.

The potential meter may make brief excursions out of the "SAFE" zone as the operating conditions of the vessel changes. Such excursions are especially likely to occur when changing from being still in the water to being under way. However, such excursions should only last for a short time with the meter indication returning to the "SAFE" zone within a few minutes. If the potential meter indicates a protection level other than "SAFE" for any significant period of time, the system should be checked to determine the cause of the unsafe protection level.

Indications outside the "SAFE" zone may be caused by many factors. Among them are: improper or inadequate DC engine or equipment grounding, improper AC electrical equipment installation, improper shoreline safety ground installation, loss of or contaminated sacrificial zinc anodes, coating failure on underwater structures, and corrosion system component or wiring failure. Refer to the trouble shooting guide section of these instructions for more detailed information.

The Model 601 monitoring station has a propeller and shaft isolating switch. Its purpose is to provide an independent, isolated potential reading for each propeller and shaft assembly. Periodic isolated readings are necessary to monitor the effectiveness of the somewhat tenuous contact to the propeller shafts through the shaft slip ring assemblies. These readings are taken by pressing the switch in the direction of the propeller shaft to be read according to the legend printed on the 601 panel face. The illustrations below shows this switch with the significance of each switch position explained. The illustration on the left depicts a 601 panel for a boat with twin propellers and shafts; the one on the right for a boat with a single propeller and shaft.



1. With the switch in the "MAIN BOND" (normal) position, the potential of the bonded underwater metal structures, or the underwater hull in the case of a metal hulled vessel, is indicated. This is a composite reading of all the underwater structures on the vessel that are connected to the system.
2. With the switch in the "PORT SHAFT" (momentary left) position, the potential of the port propeller and shaft assembly only is indicated -- for twin shaft boats. For single shaft boats, pressing the switch in the direction of the square (momentary left) will cause the meter to indicate the potential of the structure connected to the "M-SENSE 1" terminal in the controller. The use of this position of the switch is optional. If a connection is not made for this switch position, the meter will indicate its zero point when the switch is moved into the left position.
3. With the switch in the "STBD SHAFT" (momentary right) position, the potential of the starboard propeller and shaft assembly only is indicated.

For single shaft boats, pressing the switch in the "PROP SHAFT" (momentary right) position will cause the meter to indicate the potential of the propeller and shaft assembly only.

4. These isolated potential readings should indicate the same potential as that of the "MAIN BOND". Any consistent indication of a difference between the "MAIN BOND" protection level and that of a shaft and propeller is cause to investigate the effectiveness of the propeller shaft slip rings. They may need to be cleaned or brushes may need replacement.

Under normal operating conditions, as stated above, the 601 potential meter should indicate somewhere in the green "SAFE" zone. Since the amount of anode current required to maintain

this "SAFE" potential will vary significantly from one boat to another, there is no particular anode current that can be predicted without knowing the true wetted metal surface for each type of metal being protected by the controller. The extent to which the underwater metal structures have been coated, the type of coatings and the condition of these coatings are the major variables that ultimately determine the true wetted metal surface exposed and, therefore, the required anode current for a particular boat. A large vessel that is very well coated with high quality anticorrosion coatings may require far less anode current than a smaller vessel that is less well coated. In addition, the amount of current required for protection will change with changes in the velocity, temperature and salinity of the water surrounding the boat's hull. An increase in any of these three factors will require a corresponding increase in current to maintain the calibrated protection level.

However, as complex as this may seem, each boat will establish a typical anode current for each operating condition. The expected anode current requirement while the vessel is shut down at the dock, moving slowly through the water, at cruising speed or operating in any other mode can be determined over time by observation. Any sharp departure from the established current levels is reason to check the system for proper operation.

## **500 SERIES**

### **SYSTEM INSTALLATION INSTRUCTIONS**

#### **Choosing the Correct Controller Type**

The 500 Series controller is set at the factory to protect a specific Electro-Guard designated metal group. Except for the 300 series alloys of stainless steel, metals belonging to different metal groups should never be included in the same bonding system. This rule must absolutely be adhered to for boats of fiberglass or wood hull construction utilizing a 500 series controller calibrated for "Group 1" metals. Any underwater metal structure belonging to the "Group 2" or "Group 3" designation that is connected (being protected by) a controller calibrated to protect "Group 1" metals will be damaged or destroyed. Similarly, any underwater metal structure belonging to the "Group 3" designation that is connected to a controller calibrated to protect "Group 2" metals will be damaged or destroyed.

The following table designates the three major metal groups and assigns the metals and metal alloys commonly used for underwater structures, fastenings and fittings:

**TABLE OF METAL GROUPS**

<b>Group Number</b>	<b>Typical Metal and Alloys</b>	<b>Protected Range*</b>
1	copper & copper alloys such as bronzes, cupro-nickels, nickel-coppers(monel, etc.), lead, 300 series stainless steel alloys	480-640 mV
2	iron, mild steel & 300 series stainless steel alloys**	50-250 mV
3	marine aluminum alloys & 300 series stainless	50-150 mV

	steel alloys**	
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\* Solution potentials as indicated by the "Protected Range" column are relative to a USN Mil-A18001J Zn reference electrode and in standard seawater.

\*\* It is common practice to protect 300 series stainless steel propeller shafts and stainless steel or bronze propellers at the same protected potential as the hull on steel and aluminum hulled vessels. However, especially on larger vessels, this is not the preferred technique. From a corrosion engineering viewpoint, the more rational and ultimately more economic procedure is to electrically isolate the shafts and propellers and to protect them with a separate controller. Contact your Electro-Guard dealer or the factory for details for the application of multi-potential systems.

The letter in the fifth position of the model number of the controller, immediately following the dash, designates what metal group it has been set to protect. If the letter is a "B", the controller is set to protect group 1 metals; if the letter is an "S", it is set protect group 2 metals; if the letter is an "A", it is set to protect group 3 metals. It is extremely important that the installer verify that the correct controller type is being used for the metal structures being connected to it. If there is any doubt as to what metal group a specific fitting or structure belongs to, contact your authorized Electro-Guard dealer or the factory for advice.

### **Controller Location & Installation**

The following considerations should be used when selecting a location for the controller:

1. Environment: The controller is an electronic device and, as with most electronic devices, a clean, dry location is desirable. The controller should not be exposed to the weather, water sprays or located in a very humid, poorly ventilated area. An engine space, electrical space or electrical panel is usually a good controller location.
2. Access: If possible, try to locate the controller in an area with good access. This not only makes installation easier, but makes any maintenance that may be required after installation much easier to accomplish.
3. Availability of 12 volt DC power: The controller requires a special 12 VDC branch circuit. This circuit should be fused -- it *should not* be on a circuit breaker. There should be no way to turn off the controller other than by removing the branch circuit fuse or the fuse in the controller.
4. Visibility: The controller should be located where the indicator lights & legend can be easily seen.

Use the controller mounting screw pattern template attached to these instructions to locate mounting screw positions. Three #10x1" pan head stainless steel sheet metal screws have been provided for this purpose. After marking and drilling the screw holes, install the upper mounting screw on the bulkhead or panel leaving enough clearance between the screw head and the surface so as to allow the molded mounting pad on the controller housing to be retained by the screw. Set the controller in place on the upper mounting screw and install and tighten the lower mounting screws.

### **Monitor Installation**

The Model 601 dual meter monitoring station that is supplied with the system is factory calibrated to indicate the appropriate solution potentials for the metal group for which its associated controller is calibrated. To verify this, check the model number on the unit's model/serial number tag. The letter in the fifth position of the model number, immediately following the dash, indicates the metal group for which the monitor is calibrated. If the letter is a "B", the monitor is set to indicate potentials for "Group 1" metals; if the letter is an "S", it is set to indicate potentials for "Group 2" metals; if the letter is an "A", it is set to indicate potentials for "Group 3" metals. It is extremely important that the installer verify that the correct monitor type is being used for the metal structures being connected to it. If there is any doubt as to what metal group a specific fitting or structure belongs to, contact your authorized Electro-Guard dealer or the factory for advice.

Locate the monitor in a clean, dry, highly visible location. Do not install in a location that is exposed to the weather. It is important that the monitor be visible to the vessel operator when the vessel is underway. Because of this, the monitoring station is most frequently located on the bridge in the vicinity of the helm or a nearby accessible, visible location.

Make sure that the location chosen allows access to route the multi-conductor signal cable supplied from the monitor to the controller. Mark the panel for the monitor cut out and mounting hole pattern utilizing the template attached to these instructions. Carefully cut a hole in the panel or bulkhead according to the marks transferred from the template. Drill the appropriate size mounting holes to accept either the black oxide coated stainless tapping screws or machine screws (supplied with installation kit).

Route the signal cable from the monitor location to the controller location. Be sure to leave enough slack cable at the monitor end of the cable so that the monitor can be removed from the panel before the cable connector is disconnected. Connect the signal cable by plugging in and turning the locking ring until it is snug. Secure the monitoring station to the panel with the appropriate mounting screws.

### **Anode Installation**

The preferred anode configuration for vessels using this controller should be determined by filling in the appropriate information on the attached "Vessel Data Acquisition Sheet" and returning it to your Electro-Guard dealer. Your dealer will, in turn, send it to the Electro-Guard engineering department where anode type, size and quantity will be calculated based on the information supplied. The resulting recommendations will be returned to you as part of the System Installation Plan through your dealer. The turn around time should be no more than seventy-two hours if FAX data transmission is used.

Each anode plate should be installed on Electro-Guard ZI-1 insulated anode mounting bolts. See the instructions attached to the bolts for proper installation.

No anode should be located closer than sixty inches to the reference cell.

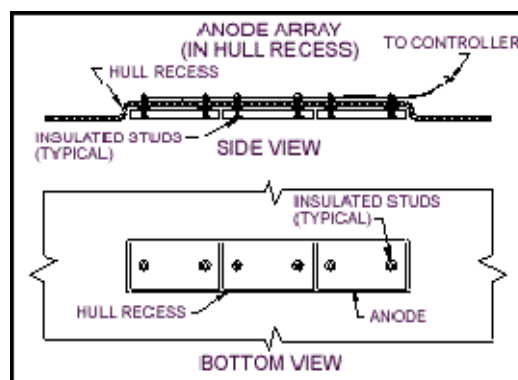
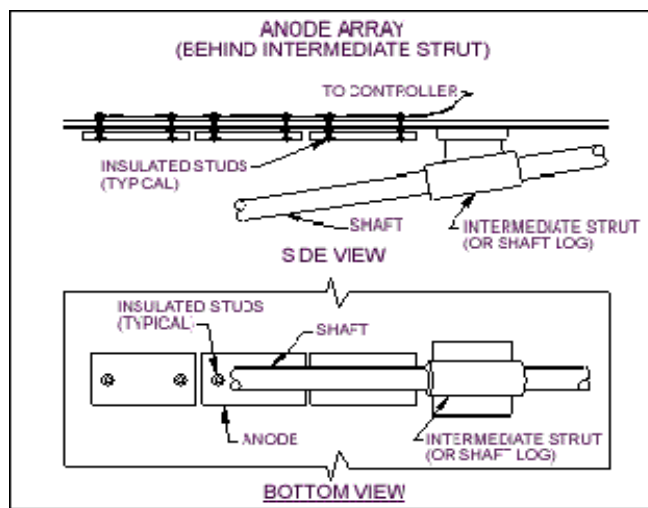
**ANODES SHOULD NEVER BE PAINTED OR HAVE ANY KIND OF COATING PUT ON THEM**

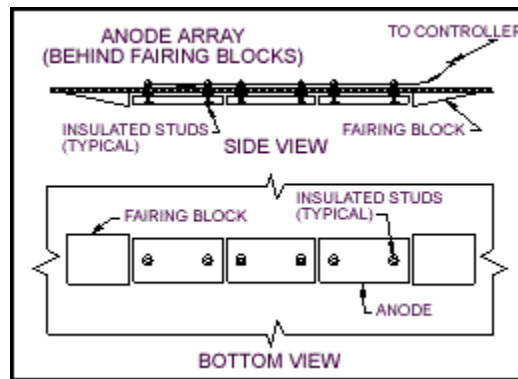
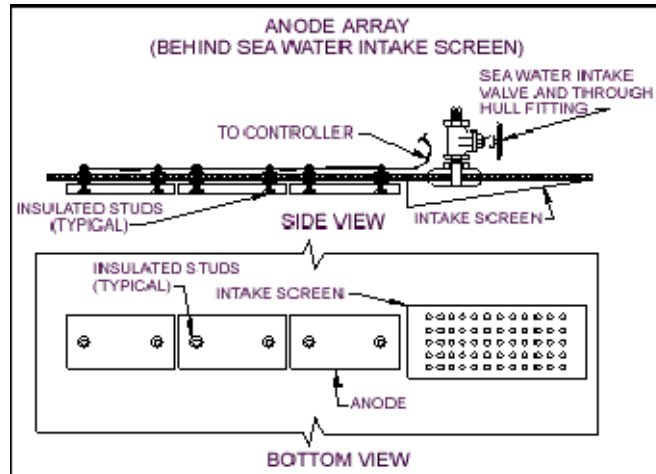
Cathodic protection anodes must be cast from specific, very high quality alloys. To assure proper system performance, follow the recommendations in the System Installation Plan for anode type.

If zinc anodes are recommended, only an alloy that meets or exceeds U.S. Navy military specification A18001J (or H) should be used. Ask your local factory authorized Electro-Guard dealer if you don't know or are in doubt about the quality of the zinc anodes available in your area. Using zinc anodes of inferior quality may result in inadequate anode current output. Insufficient anode current will cause the system to not maintain the "SAFE" protection level.

Remove all anodes which are affixed to or connected directly to any bonded underwater fittings - do not remove anodes that are on unbonded fittings or are installed in the machinery inside the boat.

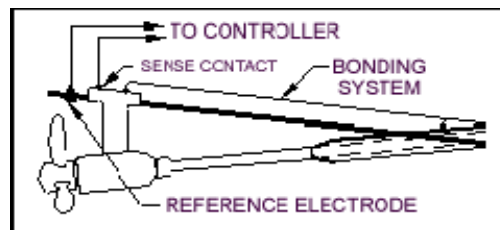
If an anode array is to be installed in an exposed location, where it possibly will catch or be damaged by debris in the water, a fairing block should be installed in front of it. Anodes can also be installed in pockets fabricated into the hull. The following illustrations show typical ways anodes can be installed.



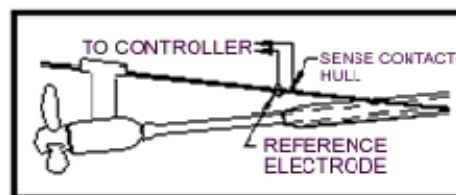


### Reference Cell Installation

The reference cell should be installed close to, but not touching, the metal fitting that is connected to the "SENSE" terminal of the controller. On all metal hulls, it should be located adjacent to the point on the hull where the sense hook up wire contacts the hull on the inside.



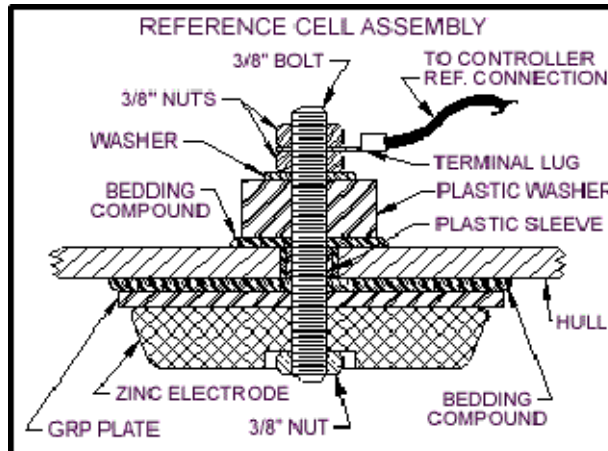
Typical Reference Cell Location on Fiberglass or Wood Hulled Vessels



Typical Reference Cell Location on Metal Hulled Vessels

On larger all metal vessels -- longer that 100' LWL -- it may be appropriate to install a second reference (and Sense) contact for the purpose of separately monitoring the potential forward of amidships. Consult with your authorized Electro-Guard dealer or the factory to determine if this is necessary on your vessel.

### **THE REFERENCE CELL SHOULD NEVER BE PAINTED**



1. Drill a 1/2" hole through the boat's hull at the location chosen for the reference cell. Remove the two stainless steel nuts, the 5/8" thick white plastic washer, and the plastic sleeve from the reference assembly. Do not disassemble the reference assembly further.
2. Use one part polysulfide rubber sealant (such as Boat Life) to bed the reference assembly. Cut the plastic sleeve slightly less than the depth of the hole. Make a donut of bedding compound around the stud and slide the plastic sleeve down the stud until it is against the green GRP shield.
3. Slide the reference assembly stud into the hole from the outside of the boat until the GRP shield is against the hull. With someone holding the assembly with a wrench on the outside put the already bedded white plastic washer over the stud against the hull. Follow this with the stainless steel washer and one nut. Tighten the nut to no more than 14 ft/lbs torque. The second nut is to be used to hold the wire termination in place.

### **Bonding Considerations**

The purpose of a bonding system is to connect all exposed under water metal fittings and structures that are compatible (that is, metals that are in the same metal group) into a common electrical distribution network. A 500 Series controller uses the bonding system to deliver electrical current to each fitting to provide cathodic protection.

### **Bonding for Metal Hulled Vessels**

Bonding in all metal hulled vessels concerns only those structures which are not in direct electrical contact with the welded hull structure. Such items as rudders and propeller shafts must be bonded in the same fashion as with wood or fiberglass hulls. The hull structure, itself, should have sufficient electrical integrity that no further bonding should be necessary.

### **General Bonding Considerations**

We do not "require" that a particular type or specification of wire be used for bonding with our system. The ultimate decision in this regard is up to the builder, owner or installer. However, we do make some strong recommendations as to the size and type of wire to be used.

Our recommendation of solid, insulated wire for those parts of the bonding system requiring wire of AWG 12 through AWG 10 is called into question from time to time. We believe the recommendation is justified for reasons to be explained shortly. We have never recommended solid conductor wire for sizes larger than AWG 10. Questions concerning our bonding recommendations are usually related to the recommended standards of the American Boat and Yacht Council (ABYC). Upon reading the ABYC specifications for direct current electrical systems and boat bonding systems closely, we do not find a specific recommendation in Section E-1, "Bonding of Direct Current Systems", as to whether bonding wire should be of stranded or solid construction. Section E-9, "Recommended Practices and Standards Covering Direct Current (DC) Electrical Systems on Boats", mentions bonding only once and refers the reader to Section E-1 for details.

Further, the use of the word bonding, itself, can be confusing when one considers ABYC's definition of a bonding system compared to the general understanding of bonding by boat owners, repair personnel and builders. If one considers the stated purpose of ABYC Standard E-1, along with the description of bonding system components and recommendations of items to be bonded, it is clear that objects that are DC electrical devices are what is to be interconnected by bonding conductors. Part E-1.4.c states that "Electrically isolated thru-hull fittings need not be connected to the bonding system." ABYC views bonding as a means to return any stray electrical current that may be leaking from a faulty DC electrical device to the negative contact of the electrical current source. Bonding for the purpose of facilitating cathodic protection is not well addressed. ABYC does reference corrosion prevention to bonding in Section E-2, "Cathodic Protection of Boats", where in E-2.4.a it states that stray current corrosion should essentially be controlled by minimizing electrical leakage and the use of a bonding system in accordance with E-1. Section E-2.4.1 also indicates that items to be cathodically protected should be connected to the bonding system, but since E-1.1 does not indicate cathodic protection as a purpose, it seems the E-2.4.1 section is essentially an afterthought.

It is neither common understanding nor practice in the small craft industry to separate the cathodic protection bonding system from what ABYC calls its direct current system bonding. In fact, there seems to be considerable confusion throughout our industry as to what should or should not be included in the bonding system. Because of this, we disagree with the concepts and/or wording of several of their recommended practices. We view the bonding system in a different light than ABYC. They refer to the bonding system as a normally non-current carrying wiring network that functions as a safety device which will safely return the current from a DC electrical fault (should one occur) to the source. We know the bonding system as a normally current carrying device that delivers protective electrical current to all the underwater metal structures connected to it for the purpose of cathodic protection. We do not agree with recommended practice E-2.4.1 of the ABYC Standards. To the extent possible, we believe that bonding for the purposes stated in E-1.1 should be kept separate from the wiring network that delivers cathodic protection current to a vessel's underwater structures.

In our opinion, the choice of the color green for cathodic protection bonding is unwise. Green is almost universally recognized as the color which indicates the associated electrical conductor is a ground. As indicated above, we believe that cathodic protection bonding should be a completely

separate wiring network from the DC safety bonding and therefore should have a different color. Giving the cathodic protection bonding a different color helps avoid inadvertent connections of conductors tying the frames of objects in the DC electrical system into the cathodic protection wiring. It is especially important that inexperienced personnel working on a boat's electrical system (as happens frequently) not be led to think that the cathodic protection bonding network is a "ground". If the direct current bonding and the cathodic protection bonding are installed as a common network, the conductors servicing the underwater metal structures for the purpose of cathodic protection should be insulated conductors, the color of the insulation for which should not be green.

Uninsulated bonding conductors are also undesirable. Besides giving the same visual message as a green, insulated conductor, bare conductors can lead to inadvertent bridging between different parts of the cathodic protection system which may result in inappropriate levels of protection to a vessel's underwater structures.

We recognize that a connection between the cathodic protection bonding and the DC electrical system bonding is desirable. Electrical contact to a vessel's underwater metal structures is an effective way to establish an earth ground for lightning protection for instance. Such an earth ground can also be used to improve the efficiency of certain low frequency radio devices such as Loran C and single sideband transceivers. One interconnection between the DC bonding and the cathodic protection bond is preferred. The point of contact between the two systems should be at the "Engine Negative Terminal" as defined in E-1.3.e. For multiple engine installations, each engine negative terminal should be connected to the cathodic protection bond.

Selecting solid or stranded conductor wire for a cathodic protection bonding conductor requires several considerations. The more important of these for our purposes are: flexibility (to facilitate installation), resistance to corrosion and fatigue resistance. Our experience indicates that using solid conductor wire of larger than AWG 10 for boat bonding is impractical because the stiffness of larger solid conductors makes installation difficult. For gages larger than AWG 10 we recommend the AC wiring types such as TW, THW, THHN and other similar types. The reason: these AC wire types have much larger individual strands than the same AWG wire gages of DC primary wire. The importance of the size (diameter) of the individual strands takes into account the same factors that indicate the desirability of solid conductors for sizes AWG 12 and 10.

If one compares the cross section of a AWG 12 or 10 solid conductor to that of the same wire gages of a stranded conductor, it is obvious that the diameter of the individual strands are far smaller than that of the single strand of the solid conductor. This difference in strand diameter can have a significant effect on the life expectancy and, therefore, reliability of cathodic protection bonding for each wire type. Our experience in over twenty years of cathodic protection of small vessels has shown a significantly shorter average life expectancy for stranded wire bonding and a corresponding lower reliability.

The cathodic protection bonding system is generally located in the most severe environmental conditions within the vessel -- in the bilge area. The conditions encountered include high humidity, high temperatures, wetting, high chemical activity (from salinity, cleaning agents and etc.) and physical abuse. Stranded conductors do not stand up as well under these conditions as solid conductors for several reasons. First, stranded wire takes up and transports moisture more readily. The small voids between the strands act as capillaries that will, given time, transport moisture taken in at breaks in the insulation throughout the length of the conductor. Since the

moisture entering the wire is frequently of very aggressive chemical composition (e.g.- water of very high salinity or chemical content), corrosion of the conductor material is to be expected.

Regardless of the corroding agent, the rate of corrosion attack to a metal is generally viewed as a measurement of the metal loss from the surface inward over a specified period of time. The larger the solid cross section of an electrical conductor the longer it will last in a corroding environment. Since the rate of corrosion penetration into each strand of a multi-stranded conductor is the same as that of the single strand of a solid conductor, failure will come at a much earlier point for the stranded conductor when both are subject to the same corroding conditions. Combining this factor with the capillary nature of stranded wire, and with its tendency to transport and retain moisture within the conductor, leads to accelerated attack, early failure and, therefore, a relative lower reliability.

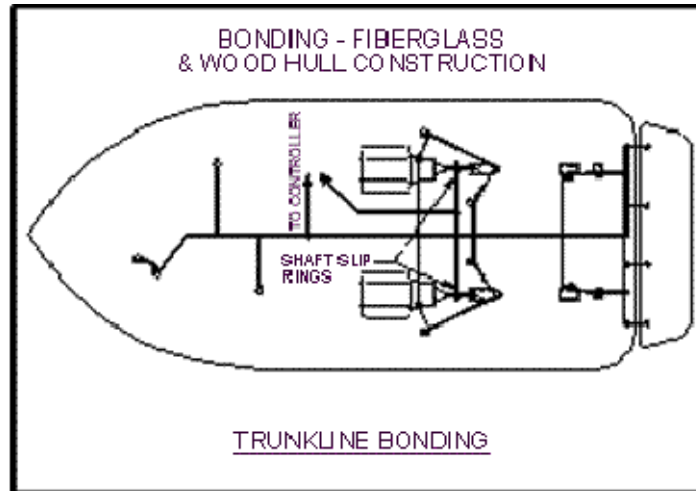
Fatigue resistance is the final consideration that needs to be addressed. Fatigue and fracture failure of the conductor is the most frequent objection we encounter when recommending solid conductor corrosion bonding wire. Our experience has shown that wire fracture failure (from fatigue) will occur only at points where the conductor is subject to frequent flexural movement. If the bonding conductor is properly installed and restrained, such movement can occur only where the bonding wire is bridging two structures within the vessel that are moving relative to one another. An example of this is a bonding conductor attached between the engine negative terminal and a main bonding wire restrained on an engine stringer. Another is a bonding conductor between a main bonding wire and a rudder post. In each of these cases or any other similar situation we recommend stranded wire of the DC primary type be used.

Our experience has shown that cathodic protection bonding systems installed according to our recommendations have a significantly longer effective life and higher overall reliability.

### **Bonding Fiberglass or Wood Hulled Vessels**

There are two acceptable bonding system schemes. The first scheme utilizes a trunk line that is routed from the most forward underwater thru-hull fitting to the last fitting aft -- usually in the area of the transom. Every under water fitting and structure is attached to the trunk line either directly or by a bonding branch circuit. In areas where many fittings are to be connected, such as in engine spaces or the lazarette, a branch circuit should be routed from the trunk line in a continuous, unbroken fashion to connect to every under water fitting in the area and then back to the trunk line completing a redundant loop.

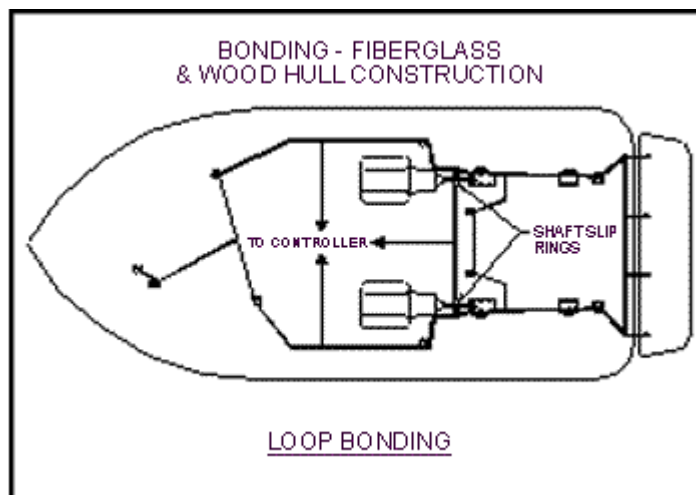
All bonding wire inter connections between the trunk line and branch circuits should be mechanically spliced, soldered and sealed with Electro-Guard Marine Wire Sealer. Except where bonding wire must flex, such as the wire connecting to a rudder, shaft wiper or engine, all bonding wire smaller than #8 AWG should be single solid conductor insulated type TW, THW, THHN or similar. Bonding wire #8 AWG and larger should be multi-strand TW, THW, THHN or similar. Multi-strand wire with fine strands is not recommended, except where wire must flex. Then use standard DC primary wire.



The second scheme uses a continuous loop of heavy bonding wire surrounding (that is routed to the outside of) the fittings to be connected. Branch circuits are then routed from the loop wire on one side of the vessel to connect to every fitting and structure within easy access going across the hull, finally connecting to the loop wire on the opposite side. The advantage of the continuous loop bonding method is redundancy. A bonding wire can be broken at any point and all fittings will still receive protective current. All bonding wire interconnections should be done in the same fashion as with the trunk line method.

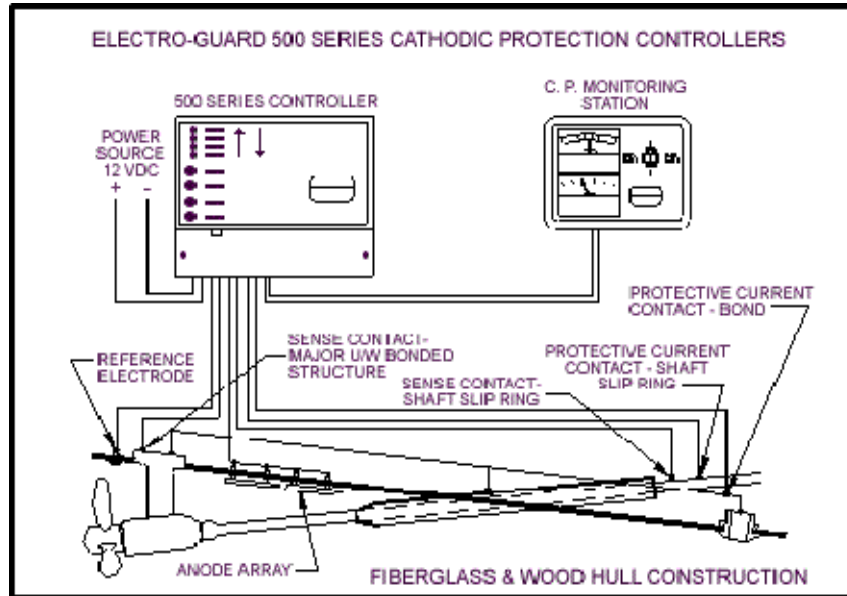
Except where bonding wire must flex, such as the wire connecting to a rudder or to a shaft wiper, all bonding wire smaller than #8 AWG should be single, solid conductor, insulated type. TW, THW, THHN or similar single conductor wire is acceptable. Bonding wire #8 AWG and larger should be multi-strand TW, THW, THHN or similar. Multi-strand wire with fine strands is not recommended.

Where wire must flex, use standard multi-stranded DC primary wire. Both the splice connections to the bonding system and terminals should be soldered and sealed with Electro-Guard Marine Wire Sealer.



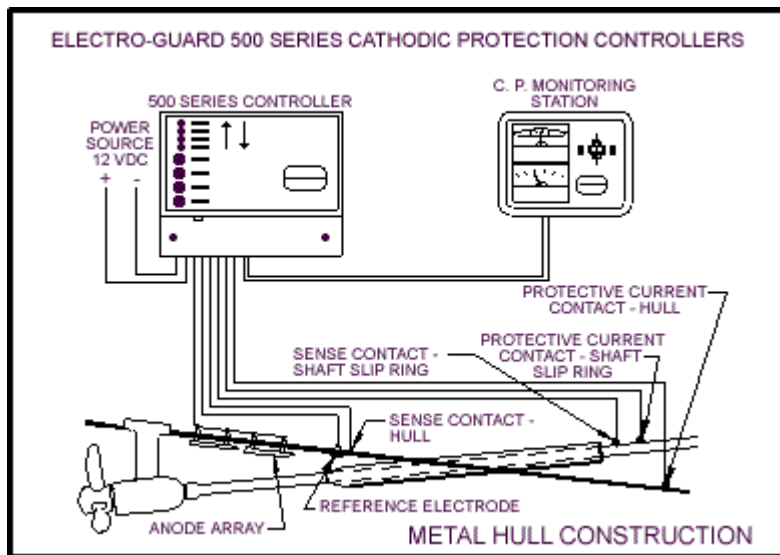
Slip rings provide electrical contact from the controller to rotating propeller shafts. Slip ring contacts are part of the bonding system.

**SLIP RING HOOK UP GRAPHIC HERE**



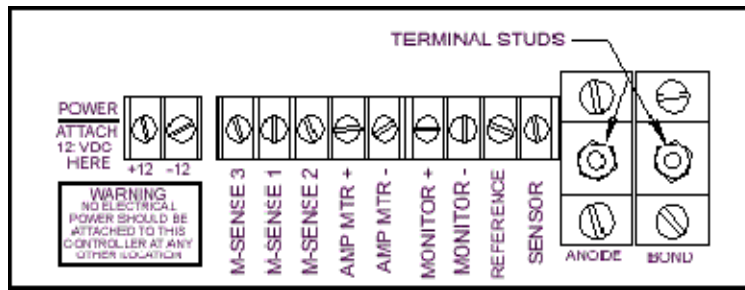
**ELECTRO-GUARD 500 SERIES CATHODIC PROTECTION CONTROLLERS**

**FIBERGLASS AND WOOD HULL CONSTRUCTION**

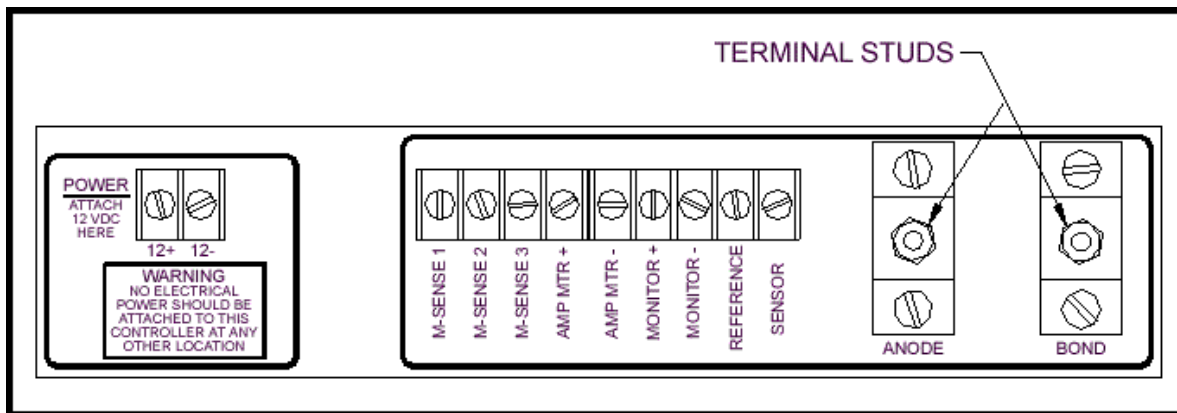


**ELECTRO-GUARD 500 SERIES CATHODIC PROTECTION CONTROLLERS**

**METAL HULL CONSTRUCTION**



**500 SYSTEM HOOK UP DIAGRAM**



**501/502 SYSTEM HOOK UP DIAGRAM**

**Connecting Hook Up Wires From Boat**

- Connect wire from reference cell to "REFERENCE" terminal -- wire should be green #14 AWG. See illustration on page 11.
- For fiberglass or wood hulled vessels connect wire from a separate contact to a major underwater fitting that is already in the general bonding system to the "SENSE" terminal -- wire should be yellow #14 AWG. This connection assures that the controller will sense the true solution potential of a major underwater fitting, which in turn represents the solution potential of all the bonded fittings.

For metal hulled vessels, connect wire from the hull to the "SENSE" terminal. Connect wire to hull near location where reference cell is located -- within twelve inches of reference cell through-hull fitting if possible. The actual connection can be to the shell plating, a frame or any other metal structure that is welded to the hull. The wire should be yellow #14 AWG. The metal should be clean & free of oil at the point of connection, and should be sanded to bright metal. A ring tongue terminal should be soldered to the end of the hook up wire, the wire attached to the hull & the wire end, terminal, & contact area sealed with Electro-Guard Marine Wire Sealer.

- For twin shaft boats, connect wire from port propeller shaft slip ring sense brushes (feed back) to "M-SENSE 1" terminal -- wire should be yellow #14 AWG with 1 black stripe (or tape ID - 1 black band).

For single shaft boats to use the optional switch position (left position), connect wire from the structure to be monitored to "M-SENSE 1" terminal -- wire should be yellow #14 AWG with 1 black stripe (or tape ID. - 1 black band). The connection to the structure should be at a different location from that of the bonding system. If, for example, the propeller shaft strut is to be monitored, make the contact for the switch on a strut bolt that does not have a bonding wire connected to it.

- For twin shaft boats, connect wire from port propeller shaft slip ring sense brushes (feed back) to "M-SENSE 1" terminal -- wire should be yellow #14 AWG with 1 black stripe (or tape ID - 1 black band).
- For twin shaft boats, connect wire from starboard propeller shaft slip ring sense brushes to "M-SENSE 2" terminal -- wire should be yellow #14 AWG with 2 black stripes (or tape ID. - 2 black bands).

For single shaft boats, connect wire from the propeller shaft slip ring sense brushes (feed back) to "M-SENSE 2" terminal -- wire should be yellow #14 AWG with 2 black stripes (or tape ID - 2 black bands).

- **USE MULTI-STRAND, TINNED DC PRIMARY WIRE** to hook up system components as described above. Crimp and solder all terminals. Seal all terminals that are exposed to moisture, especially in the bilge area, with Electro-Guard Marine Wire Sealer.
- **Wire gauge tables:**

**Table 1 - 2.5 Ampere Maximum Load**

Maximum Wire Length (Anode to Hull)	AWG Wire Size (Stranded)
20'	#6
32'	#4
52'	#2
65'	#1
82'	#1/0
103'	#2/0
163'	#4/0

**Table 2 - 5.0 Ampere Maximum Load**

Maximum Wire Length (Anode to Hull)	AWG Wire Size (Stranded)
10'	#6
16'	#4
26'	#2

33'	#1
41'	#1/0
53'	#2/0
82'	#4/0

**Table 3 - 10 Ampere Maximum Load**

Maximum Wire Length (Anode to Hull)	AWG Wire Size (Stranded)
5'	#6
8'	#4
13'	#2
16'	#1
20'	#1/0
26'	#2/0
41'	#4/0

**\* Use wire gauge tables 1, 2, and 3 to determine the appropriate wire sizes for connecting the anodes, hull and propeller shaft slip rings.**

- Connect wire from anodes to the brass "ANODE" terminal stud as shown on the above terminal board diagram -- wire color should be brown (or black). Use the appropriate wire gauge table according to the maximum possible system anode current. The maximum possible current for each Series 500 system is as follows: Model 500 - 2.5 amperes, Model 501 - 5.0 amperes, Model 502 - 10.0 amperes.
- Connect wire from hull to the brass "BOND" terminal stud as shown on the above diagram -- wire color should be red. A minimum of two separate contacts to the hull is preferred for redundancy. Use the appropriate wire gauge table according to the maximum possible system anode current.
- Connect wire from the propeller shaft slip ring current brushes to the "BOND" terminal stud -- wire color should be red. Use the appropriate wire gauge table according to the maximum possible system anode current. If a separate wire is to connect each shaft slip ring to the controller, divide the maximum possible system anode current by the number of propeller shafts to determine which wire gauge table to use.
- Appropriate sized insulated electrical terminal studs or buss bars should be installed immediately outside the controller enclosure to accommodate the large cables connecting the controller to the anodes, hull and propeller shaft slip rings. A single #6 AWG wire should then be used to connect each terminal stud or buss bar to its appropriate location inside the controller. Keep this wire as short as possible.

### **Connecting Cable From 601 Monitor**

- Black to "AMP MTR +" terminal
- Blue to "AMP MTR -" terminal
- Brown to "M-SENSE 1" terminal
- Red to "M-SENSE 2" terminal
- Yellow to "M-SENSE 3" terminal
- Orange to "MONITOR +" terminal
- Green to "MONITOR -" terminal
- White to "SENSOR" terminal
- Shield to -12 VDC POWER terminal -- shield is bare wire with black heat shrink tubing insulator

### Connecting Twelve Volt DC Power

- 12 volt positive connects to "+12" terminal.
- 12 volt negative connects to "-12" terminal.
- A 12 VDC branch circuit capable of delivering a minimum of two amperes is sufficient & should be fused. This branch circuit *SHOULD NOT* be on a circuit breaker -- there should be no method for turning the controller off other than by removing the branch circuit fuse or the fuse in the controller.

Notes:

1. Controller is reverse polarity protected -- connecting in reverse polarity will not cause damage, however, the controller will not work when so connected.
2. **CAUTION** - The two terminals labeled "POWER/ATTACH 12 VDC HERE" are the only terminals in the controller that should be attached to an electrical power source -- do not attach electrical power to any other terminal in the controller.
3. Replacement fuse for the controller should be a 5X20 MM fuse rated at 1 ampere.

## TROUBLE SHOOTING

### 500 Series System

In most cases where the meter readings on an Electro-Guard controller indicate an improper level of protection of the boat's underwater fittings, the problem lays not with the controller itself, but is due to some sort of system interference. This system interference can occur when one or both of two major conditions is present aboard the boat -- electrical interference and direct electrical contact between a highly reactive metal, such as zinc, and the bonded underwater fittings.

The first condition, electrical interference, is the result of an electrical fault circuit being present aboard the boat. The fault circuit may be in either the A.C. or D.C. electrical system. It is not uncommon for there to be several fault circuits occurring aboard a boat at once. Fault circuits are, specifically, electrical circuits that allow electrical current to flow through unintended pathways which can lead to serious damage to the boat's machinery and/or under water structures. Fault circuits can take many specific forms and can occur anywhere aboard a boat. In many instances a fault circuit will involve a non-electrical metallic pathway such as piping or metal framing. Electric fault circuits can occur due to electrical insulation failure in equipment or wiring; improper equipment installation or improper wiring; improper electrical system design; or inadvertent contact between an electrical conductor and non electrical equipment or structures.

If an electrical fault circuit occurs that is in contact with the corrosion control bonding system and if there is a significant amount of current flowing in the fault circuit it will result in an adverse effect on the bonded underwater fittings. This effect will be reflected by an undesirable indication on the system seawater potential (color coded) monitoring meter. If the reason for this undesirable meter reading is a fault circuit the only proper way to remedy the situation is to find the cause of the fault circuit and then eliminate it. Doing this usually requires the services of a qualified Electro-Guard corrosion technician or a competent marine electrician who understands that electrical system faults can lead to severe corrosion of any metallic structure of the boat that is in contact with the water.

Another potential source of electrical interference is the vessel's AC shoreline system. Most frequently when AC shoreline interference occurs, it is because the AC safety ground conductor of the dock or pier distribution system has electrical continuity through the shoreline to the vessel's bonded underwater metal structures or hull.

The significance of the connection between a boat's under water metals and the AC shoreline safety ground conductor is three fold. First, if a voltage drop exists in this conductor, electrical current will flow either into or out of the water via the connected metal parts. In either case, damage may occur to the vessel's structure. A voltage drop in the dock safety ground conductor indicates that electrical current is flowing in this conductor and that any boat that has its underwater metal fittings connected to the dock safety ground conductor via its own electrical system is subject to the flow of electrical and, therefore, corrosion currents.

Existence of electrical current flow in the marina AC safety ground system is to be expected, particularly on those docks where larger boats are being moored. Larger boats typically use significant amounts of electrical current to power on board systems such as lights, water heaters, space heaters, air conditioning and water circulation systems. The electrical current supplied by the "hot" conductor in the dock AC system is supposed to be returned by the "neutral" conductor. The AC "safety ground" conductor is provided to bleed off any leakage current from an AC device to prevent human exposure to dangerous AC electrical voltages that may appear on the non electrical parts of such a device. Because of the many unavoidable interconnections between the AC neutral and safety ground systems in a marina, some of the return current will nearly always flow through the safety ground system.

Second, the metals so connected are subject to severe corrosive attack should a major electrical failure occur aboard the boat or a neighboring boat that has its underwater metals electrically connected to the dock AC safety ground system. In this second condition, a loop circuit is formed between two or more boats. The safety ground conductor acts as a current pathway for one side of the circuit and the water the boats are moored in acts as the other side. These electrical currents may have no more effect than to increase the rate of sacrificial anode consumption on those vessels influenced by them. However, the potential for severe corrosion damage exists to boats so exposed.

Third, should two (or more) vessel's have underwater fittings made of galvanically incompatible metals and these metals are electrically connected through a common AC safety ground conductor, moderate to severe corrosion damage will occur to the fittings that are made of a more reactive (less noble) metal. An example of this phenomenon would be to have aluminum alloy stern drives on one boat connected electrically through the shore power system to the bronze and stainless steel propellers, shafts, struts and rudders on another nearby vessel. A

galvanic corrosion cell is formed between the aluminum structures (less noble) and the bronze and stainless steel structures (more noble) resulting in damage to the aluminum parts of the drives.

Though several organizations, such as the American Boat & Yacht Council, recommend connecting the AC safety ground aboard small vessels to both the dock safety grounding system and the boat's own underwater metals, the owners of these vessels should be aware of the significant corrosion hazard that results from following this practice. They should also be aware that nearly all boats being produced and/or sold in this country are wired according to these recommendations. Such recommendations are designed to prevent electrocution to humans, but do not consider the danger to the boat itself.

There are several solutions to the problem of exposure of a boat's underwater metals to influence by electrical currents passing through the AC shoreline distribution system. The most acceptable is the installation of a properly sized AC isolation transformer aboard the vessel. This transformer should be installed as the first device downstream of the AC shoreline receptacle, ahead of the ship to shore switch and the electrical distribution (circuit breaker) panel. The transformer should be installed on an electrically isolated mounting with the AC shoreline safety ground conductor connected to the metal housing of the transformer. The shoreline safety ground conductor *should not* be connected to any on board AC device that is being supplied power from the secondary side of the transformer and/or to the under water metal structures of the vessel. Use of a properly designed and installed isolation transformer *electronically isolates* the electrical power being used aboard the boat from that supplied by the shoreline. This will effectively prevent corrosion currents from using the shoreline as a conductive pathway between the boat with the device and any other vessel using the same dock power system.

Another solution, though not quite as effective as a transformer, is to install a galvanic isolator in the AC shoreline ground conductor between the boat's receptacle and the first AC device, such as a ship to shore switch or distribution panel. This device allows AC current to pass unimpeded while blocking low level (galvanic) DC currents. Mercury Marine's Quicksilver galvanic isolator is the only one we know of that is Underwriters Laboratories approved and listed at this time. A galvanic isolator will block approximately eighty-five percent of the potential problems that occur due to safety ground interconnection between boats.

If a vessel uses any amount of AC electrical power supplied through a shoreline, one of the devices just described should be installed. There should be no direct (low resistance) connection between any of the AC shoreline conductors and a vessel's underwater metal structures. Proper installation of an isolation transformer or a galvanic isolator is essential for the device to be effective. Whichever device is chosen, one should be certain that the specific model to be installed is rated for the anticipated electrical current load and that it has Underwriters Laboratories approval.

The second major condition that can lead to interference with the control system is direct contact between the any bonded fitting, and a highly reactive piece of metal, such as a zinc, aluminum or magnesium sacrificial anode or a metal structure that is not in the same major metal group. The most frequent material causing this problem is zinc. Once an Electro-Guard controlled system is put aboard a boat there can be no sacrificial anodes attached directly to any of the bonded underwater metals. To do so is, in essence, short circuiting the system and over protection may result.

Next in frequency to cause interference is electrical contact between a vessel's hull or bonded metals and an underwater metal structure nearby -- such as on another boat or a pier -- that is in a metal group which is either more or less reactive than the metals being protected by the system. If the vessel's hull or bonded fittings come into physical (or electrical) contact with a structure made of a metal from a different metal group, the protection level of the hull will shift out of the "SAFE" zone toward either the "OVER" or "UNDER" protection zone. If the vessel is allowed to remain in this condition for an extended period of time its hull or bonded metal fittings may be severely damaged or destroyed.

To cite an example of how this might happen, consider the following. A fiberglass boat with an aluminum stern drive (Group 3) is kept in a marina and is supplied with AC electrical power from the dock. A boat nearby on the same dock is also built of fiberglass, but its propulsion system uses a standard inboard engine driving through a stainless propeller shaft and a bronze propeller (Group 1). This boat also is supplied with AC power from the dock. Both boats, either purposefully or inadvertently, have electrical continuity between their on board AC safety ground systems and their underwater metal structures. Since both boats also have continuity between their AC safety ground systems and the dock safety ground system, there is electrical continuity between their underwater metal structures. Because the aluminum stern drive (Group 3) is more reactive than the bronze and stainless drive hardware (Group 1), the stern drive will corrode, acting as a sacrificial anode, and will deliver galvanic electrical current to the other boat's propeller and shaft via the AC safety ground system.

If each of these boats had an Electro-Guard system, the monitor meter on the stern drive boat would indicate in the "UNDER" zone and the monitor on the other boat would indicate in the "HIGH" or "OVER" zone.

While most instances where undesirable meter readings are observed will be the result of conditions as described above, the occurrence of a control system malfunction or failure should not be discounted. However, the possibility of system interference should be eliminated before an assumption of system malfunction is made.

In all cases, it will be better if a qualified Electro-Guard corrosion technician is called in to trouble shoot the system and take the appropriate corrective action. However, on the assumption that the vessel's owner or one of his crewmen may wish to attempt to correct an adverse condition in this system, the following trouble shooting procedures and guide is provided as assistance. Please be aware that the structure and electrical system of boats are, as a rule, quite complex and that the non-professional may find the combined complexities of these systems and the Electro-Guard system difficult to understand. Under such circumstances the trouble shooting guide may not guarantee success in resolving the problem. This guide should be considered as an emergency aid to assist in the correcting of an adverse condition in the absence of a qualified technician. If the vessel's owner or crew is successful in correcting the apparent problem in the control system, it is advisable, once the vessel has returned to an area where a trained Electro-Guard technician is available, to have the system checked out for proper operation.

## **Trouble Shooting Procedure**

### **500 Series Systems**

**A.** Before disconnecting any wire(s), shutting off the controller, or in any other way changing the way the system is operating when you start trouble shooting, make the following checks and record (write down) the results:

1. Look at the controller LED's. Note which are lighted and whether the four amber LED's next to the arrows are indicating that the controller is attempting to increase or decrease anode current. Record (that is, write down) the indications of these lights.
2. Look at the 601 monitor. Record the exact indication of the potential (color coded) meter and the anode current meter. Also, record the potential for isolated readings of each shaft by pressing the shaft selector switch to each shaft position.
3. If the vessel's AC shore line is connected, unplug it and test for continuity between each shore line conductor and the hull. Note the results.
4. Using a portable corrosion test meter, with an independent zinc reference probe in the water, take potential readings of all anodes at the anode mounting studs. Record the results.
5. Take potential reading of the system reference electrode. Record the results.
6. For metal hulled vessels, take potential readings of the hull at several locations. Record the results for each location.
7. Take potential readings of the propeller shafts and record each reading.
8. Remove the terminal access cover of the controller by unscrewing the fillips head screw at each end and lifting off. Record the potential readings of the terminal screws for the following Items: BOND, ANODE, SENSE, REFERENCE, MONITOR + AND MONITOR -.
9. Using a digital multimeter, read the REFERENCE to SENSE potential at the controller terminals.
10. Disconnect the anode wire from the anode terminal stud. Using a digital multimeter, take a resistance reading between the anode and bond studs at the lowest ohm setting of the instrument. Record the reading.
11. Take potential reading of the wire coming from the anodes. Record the reading.

**B.** Interpreting the results of the above checks:

1. The controller LED's indicate how it interprets the REFERENCE to SENSE potential. If the green power light is on and no other indicator is lighted, the REFERENCE to SENSE potential should be between 480 mV and 640 mV for Group 1 metals, 80mV and 250mV for Group 2 metals, and 70 mV and 150 mV for Group 3 metals.

If the red "REFERENCE CELL DISCONNECTED" light is on, the REFERENCE to SENSE potential should be less than 35 mV.

If the green "PROTECTION LEVEL TOO HIGH" LED is on, the potential should be between 36 mV and somewhat more than 480 mV for Group 1 metals, between 36 mV and somewhat more than 60 mV for Group 2 metals and between 36 mV and somewhat more than 50 mV for Group 3 metals. The four amber LED's next to the arrows should indicate that the controller is attempting to decrease anode current.

If the amber "PROTECTION LEVEL TOO LOW" LED is on, the potential should be more than 640 mV for Group 1 metals, more than 250 mV for Group 2 metals and more

than 150 mV for Group 3 metals. In this condition, the four amber LED's next to the arrows should indicate the controller is attempting to increase anode current.

2. If the 601 monitor indicates protection to be outside the "SAFE" zone for a substantial length of time (more than thirty minutes) and/or the controller LED indicators continue to show "PROTECTION LEVEL TOO LOW" or "PROTECTION LEVEL TOO HIGH" for more than the above indicated time, the following trouble shooting guide should assist in determining the source of the problem:

## TROUBLE SHOOTING GUIDE

Condition	Cause	Correction
Protection in "Under" zone and controller LED's showing "PROTECTION LEVEL TOO LOW"	Insufficient anode current. Anodes are: too small, passivated from iron contamination, loose or have bad connection to controller.	Install more anodes. Install new anodes of correct size that are made of USN Mil. A18001J (or H) specification alloy. Repair connection to anodes
	Anode current less than maximum	Bond has bad connection to controller.
		Anodes and/or bond wires too small gauge-- indicated by voltage drop over length of wire
Same condition as above, except anode current is at maximum	Load is too big for system. Usually caused by AC shore line interference. Can also result from significant coating failure, stray DC electrical current from on board fault circuit, or strong electrical current field in water (rare)	Reduce load by: Isolating AC system, repair coatings on underwater structures, eliminate electrical field at source, or move boat
Protection in "OVER" zone, anode current zero or near zero, controller red "REFERENCE CELL DISCONNECTED" LED on or green "PROTECTION LEVEL TOO HIGH" LED on and amber LEDs indicating controller is attempting to reduce current	Strong polarizing current is influencing the bonded fittings. Possible sources are: AC shore line interference, high energy aluminum or magnesium anodes attached directly to hull and/or shafts, stray DC electrical current from on board fault circuit, strong electrical current field in water (rare)	Eliminate polarizing current at its source or move boat, remove high energy anodes from direct contact with hull or shafts, correct fault circuit
	Reference cell or bond wire is disconnected	Reconnect reference cell or bond wire

If the person trouble shooting the system understands its principals of operation and the significance of the checks indicated above, he should be able to determine the reason for the system interference or malfunction and take appropriate action to correct the problem. If not, please contact an authorized Electro-Guard dealer for advice. If a dealer cannot be located or otherwise contacted, contact Electro-Guard, Inc