

# **CAPAC<sup>®</sup> MANUAL FOR MODEL 90W12D SYSTEM**



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FOR MODEL 90W12D SYSTEM**



**eVOQUA**

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# INTRODUCTION

You now have the finest system for the elimination of corrosion on under water metal parts. CAPAC<sup>®</sup>, the electrical system which stops the corrosive attack on metal is designed and built with the boat owner in mind. The system is permanent and fully automatic with nothing to be used up or wear out. The system achieves optimum protection by continuously adjusting the current supplied from its anode(s) under the varying water conditions encountered, just as on the systems which protect giant ocean going ships. The through-hull anodes and reference electrode are streamlined to minimize any power consuming drag or turbulence. The controller is rugged and built of corrosion resistant materials for long trouble-free operation.

The corrosion of metals is an electrolyte (water, either fresh or salt) is an electrochemical reaction. This means that the corrosion or rusting of the metal is dependent upon, and inseparable from, the flow of electricity. Where corrosion exists, the metal is at a slightly higher electric potential than the adjacent metal, which is not corroding. This is due to differences in composition, stresses, impurities in the metal itself, differences in the temperature and salinity of water or rate of flow of the water. It is the nature of this type of corrosion that if a flow of electric current is forced into all underwater metal areas, corrosion will be stopped. Your CAPAC<sup>®</sup> system does this using platinum surfaces anodes, which do not deteriorate when current is released from them. The current flowing from these anodes travels through the water to enter all grounded areas of the submerged hull. The reference electrode is sensitive to the effect of protection achieved by the metal and supplies an electric signal to the controller, which automatically insures that the optimum current flows from the anode. This is done by solid-state circuitry specifically designed for this purpose.

Your CAPAC<sup>®</sup> system is on continuous duty all the time your boat is in the water, silently prevent corrosion. Familiarize yourself with its operation and relax, secure in the knowledge that corrosion is being-stopped.

## SPECIAL INSTRUCTIONS TO OWNER

Check to see that the Capastic epoxy plastic shield has been applied to metal and wood hulls around each anode as described on page 9. This shield must be properly installed for proper operation of the CAPAC<sup>®</sup> system and to prevent damage to the hull.

### CAUTION NOTICE

- A. The CAPAC<sup>®</sup> Monitor is an accessory panel mounted meter assembly, which serves as a means of checking the operation of the 90W12D system. One of the design features of the monitor is a push button switch located on its front panel. The purpose of this switch is to connect the meter to reference electrode **only** when a check of the system is being made. Do not disable this switch and wire the meter directly to the reference electrode. To do so would cause the reference electrode signal to be gradually attenuated resulting in excessive current being impressed upon the hull causing possible damage due to overprotection.
- B. On vessels equipped to receive shore power, the vessel's hull and or ground system is electrically connected to the shore-based grounding system by way of the shore power grounding conductor. On a vessel without either sacrificial anodes or an impressed current cathodic protection system corrosion of the hull and appendages will be increased according to the metallic composition of the shore-based grounds. If the vessel is equipped with sacrificial anodes their effectiveness is greatly reduced and they are rapidly consumed. If the vessel is equipped with an impress current cathodic protection system such as CAPAC<sup>®</sup> the impressed current cathodic protection system will probably be overloaded in an attempt to protect the shore-based ground system. This can result in, 1) overprotection of the hull near the anodes(s), 2) under protection of the hull areas remote from the anode(s) and 3) damage to the vessel's paint and /or hull near the anode(s). Under these conditions the hull potential readings taken by a reference electrode in the system or a portable hull potential meter will not be truly representative of the hull potential over the entire surface of the hull due to the distortion of the current distribution field on the surface of the hull. If the vessel receives shore power, measures must be taken to isolate the hull from the shore-based ground system. Such isolation may be provided by either an isolation transformer or a galvanic isolator such as a Capac<sup>®</sup> Galvanic Isolator P/N50830. Refer to the American Boat and Yacht Council publication (latest revision) "Safety Standards for Small Craft", sections E-2 and #-8, for additional information concerning cathodic protection hull grounding practices

# **Section I**

## **System Description**

### **Components**

The 90W 12D system consists of four (4) major components, the controller, the anode(s), the reference electrode and the CAPAC<sup>®</sup> Monitor. The controller consists of an enclosure housing transistor control circuitry used to establish and maintain the protection of the under water metal. These models of controllers are available to protect the following metals:

37810-1 Potential control setting set by factory to protect STEEL.

37810-3 Potential control setting set by factory to protect BRONZE.

The anode is mounted on the under water surface of the hull and consists of a platinum surface disc which emits protective current to the other submerged metal surfaces. A Capastic epoxy compound is furnished with anodes for use on metal and wood hulls for application as a dielectric shield around each anode. Application instructions are printed on Capastic container label.

The reference electrode is also mounted on the underwater surface of the hull and consists of an insulated silver-silver chloride element, which is used to indicate the amount of protection on the underwater metal.

The CAPAC<sup>®</sup> Monitor is a panel mounted meter to be used as a monitor to check the level of cathodic protection on a submerged metallic surface. It is designed to be attached to the "monitor" terminals of the 90W12D controller. This accessory is not essential to the operation of the CAPAC<sup>®</sup> system but serves as a means of checking the operation of the system.

### **Components – Optional**

Dee Cee Tran Voltage Converter

The 90W12D controller requires a power source of 12V DC (negative ground) in order to operate. If the boat utilizes a different power source such as a 24 or 32 volt system, this voltage converter is available which will convert this voltage to 12 V DC.

\

### **Function**

When the system is installed and the hull is afloat, the controller will deliver current from the 12V DC source in the boat to the anode. This current will

flow through the water to the underwater metal through the ground wire and back to the negative battery terminal. Wherever current enters a submerged metal surface, the corrosion is eliminated. Once the corrosion is stopped, the metal or hull is said to be “polarized”.

The reference electrode is insulated from the hull and the anode, and does not receive any anode current. Since it is not “polarized”, it can be used to monitor the amount of protection or “polarization” obtained on the hull or metal fittings.



## Section II

### Application

The 90W12D system is designed to deliver an automatically controlled anode current of up to 7.5 amperes to the anode(s) from a 12-volt DC source with the negative terminal grounded to the hull or fittings.

**NOTE: UNDER NO CONDITION SHOULD CAPAC<sup>®</sup> BE OPERATED FROM OTHER THAN A NEGATIVELY GROUNDED SOURCE.**

It is primarily intended for installation on wood or fiberglass hulls of up to 100 feet; however, it will also protect well-painted metal hulls of up to 65 feet. These hull lengths are merely a practical guide, since the capability of the system to protect any metal is determined by the area of the bare metal surface under water.

Each metal requires a different amount of current for protection or “polarization”. Table 2.1 below gives the number of square feet of each metal, which the system will protect. The table below is not meant to imply that the CAPAC<sup>®</sup> system can be used on a non-painted hull but is given to illustrate the protection current requirements of different metals.

TABLE 2.1		
METAL	NUMBER OF SQUARE FEET	CURRENT DENSITY AMPERES PER SQUARE FEET
Bare Bronze	185	0.04
Bare Steel	750	0.01
Bare Aluminum	500	0.015
Bare Stainless Steel	250	0.03

When the metal surfaces are painted, the current requirement may be reduced by as much as a factor of 10. Therefore, the system would protect as much as 7500 square feet of newly painted steel.

On a newly painted hull protection current requirements will be minimal and as the hull coating deteriorates or is damaged, current requirements will increase.

If the system is installed on wood or fiberglass hulls, all of the submerged metal appendages must be bonded to the common ground in order to obtain protection.

When a variety of metals are used on the underwater hull, the CAPAC system will be set in the factory to protect whichever metal has the highest protected reading and no adjustment should be necessary.

For example: when a wood hull has a monel shaft, bronze propeller and steel rudder, the CAPAC<sup>®</sup> system will be set in the factory to protect steel regardless of the fact that the bronze and monel will be over-protected.

Table 2.2 below provides a listing of “freely corroding” and “protected” meter readings for various metals and also indicates which model of controller is to be used to combat corrosion on the metal indicated.

<b>TABLE 2.2</b>			
<b>CAPAC Monitor Meter Reading</b>			
<b>METAL</b>	<b>Freely Corroding</b>	<b>Protected</b>	<b>Controller Model to be used</b>
Carbon Steel 1020	0.61	0.85	37810-1
Stainless Steel 304 (active)	0.53	0.77	
Yellow Brass 268	0.36	0.69	37810-3
Aluminum Bronze	0.32	0.65	
Commercial Bronze	0.31	0.64	
Monel 400	0.075	0.405	

## Section III INSTALLATION

### ANODE INSTALLATION & PARTS LIST

#### Parts List

#### Anode Assembly Complete – 37792

Item # (Fig. 3.1)	Quantity	Part Number	Description
1	1	37786	Anode Assembly
2	1	37795-9-1	Flat Washer
3	1	37344-13	Lock Washer
4	1	37791-25-1	Hex Nut
5-10	1	37798	Encased splice
	10 feet	36282	Butyl Bead
	1 lb.	37020	Capastic Kit (When furnished)

#### Anode Installation (See Figure 3.1)

The anode platinum coated disc is 2-1/2 inches in diameter and is supported and electroically insulated from the hull by the black plastic structure which surrounds it. The threaded stem serves to mount the anode as a through-hull fitting. Water tightness is insured by the butyl sealant and the electrical connection is protected by the clear plastic encased splice provided. The anode is supplied with 10 inches of *black* cable and must be installed while the boat is out of the water.

Before commencing the anode installation, read all the instructions and check the parts with the parts list at the beginning of this section.

A Capastic epoxy compound is furnished with anodes for use on metal and wood hulls for application as a dielectric shield around each anode. Application instructions are printed on Capastic container label.

In order to function properly, the exposed metallic disc must not be painted. The black plastic holder may be painted as shown in Figure 3.3.

## **LOCATION (See drawing SK220B – Figure 3.2)**

### **Single Anode Installations**

For single anode installations it is recommended that the anode be mounted as close as possible to the keel line, approximately  $\frac{1}{4}$  the length of the hull, as measured from the stern. On wood hulls where a ground plate is mounted on the keel, the anode should be placed away from the keel by approximately  $\frac{1}{4}$  the width of the boat at that section.

### **Multiple Anode Installations**

Additional anodes may be installed as shown on drawing SK220B (Figure 3.2)

**Although these recommended positions insure uniform hull protection, the exact anode location is not critical, but should take into consideration the following factors:**

- 1. The Anode must not interfere with existing installations. A location which may be clear in the bilge is not necessarily clear on the outside hull surface and vice versa.**
- 2. The anode should be reasonably accessible so that inspection of the electrical connection can be made conveniently.**
- 3. The hull area where the anode is to be mounted should be virtually flat.**
- 4. Avoid locations which would interfere with lifting slings.**
- 5. Mount the anode at least 2 feet from the propeller shaft.**
- 6. Do Not install the anode adjacent to depth sounder or sonar transducers.**

## **Installation Instructions (Refer to Figure 3.1)**

**NOTE:** The anode assembly is identified by its black wire. It must be handled carefully so as not to abrade or scuff the platinized surface nor damage the threaded stem. Installation is accomplished as follow:

**Cable Needed: #14 gauge THW single conductor – to connect anode to CAPAC Controller.  
(Cable Not Furnished With CAPAC System)**

- 1. Drill a ½ inch diameter clearance hole through the hull from inside the bilge making certain that nothing on the inside or outside of the hull interferes with the chosen location. Alter position as needed to avoid obstructions.**
- 2. Prepare metal or wood hulls to receive Capastic epoxy shields around anodes. Apply Capastic shields in accordance with instructions on containers before installation of anode.**
- 3. Strip the waxed paper from the gray rubber (butyl) bead sealing compound and wrap three turns of the butyl bead around the outer edge on the back of the anode holder (item 1) and one turn around the brass hub. Then place anode in a warm (at least 70°F) place to keep bead soft until installed.**
- 4. Insert the warm anode hub through the hole in the hull and press the anode in place.**
- 5. On the inside of the hull, wrap three turns of butyl bead around the anode gland and against the hull and place items 2, 3, and 4 over the threaded stem of the anode. Tighten item 4 but do not apply more than 30 ft. – lbs. of torque.**
- 6. Strip ends of #14 gauge single conductor and 9 inch anode cables approximately 5/16” and insert the**

stripped end of 9 inch anode cable through items 5, 6 and 8 of clear plastic encased splice. NOTE – either end of encased splice can be used since both ends are identical.

7. Insert the stripped end of #14 gauge, single conductor wire going to the CAPAC<sup>®</sup> Controller through items 9 and 10 of clear plastic encased splice.
8. Butt splice anode wire to #14 gauge single conductor wire going to the CAPAC<sup>®</sup> controller using butt connector (item 7). Crimp and soft solder connector as shown in Figure 3.1. Thread the ribbed nuts (items 5 and 10) onto the treaded tube (item 8) and tighten.

## REFERENCE ELECTRODE INSTALLATION & PARTS LIST

Parts List			
Reference Electrode Assembly Complete -37800			
Item# Fig. 3.1	Quantity	Part Number	Description
1	1	37802	Reference Electrode Assembly
2	1	37795-9-1	Flat Washer
3	1	37344-13	Lock Washer
4	1	37791-25-1	Hex Nut
5-10	1	37798	Encased Splice
	10 feet	37292	Butyl Bead

### Reference Electrode Installation (See Figure 3.1)

The reference electrode silver-silver chloride element is 2-1/2 inches in diameter and is supported and electrically insulated from the hull by the back plastic structure, which surrounds it. The treaded stem serves to mount the reference electrode as a through-hull fitting. Water tightness is insured by the butyl sealant and the electrical connection is protected by the clear plastic

encased splice provided. The reference electrode is supplied with 10 inches of white cable and must be installed while the boat is out of the water.

Before commencing the reference electrode installation, read all the instructions and check the parts holder may be painted as shown in Figure 3.3.

## **Location (See drawing SD 220B Figure 3.2)**

On a wood hull, the reference electrode should be located as close as practical to a bonded metallic appendage. The following factors should also be taken into consideration:

1. The reference electrode must not interfere with existing installations. A location which may be clear in the bilge is not necessarily clear on the outside hull surface and vice versa.
2. The reference electrode should be reasonably accessible so that inspection of the electrical connection can be made conveniently.
3. The hull area where the reference electrode is to be mounted should be virtually flat.
4. Avoid locations, which would interfere with lifting slings.

## **Installation Instructions (Refer to figure 3.1)**

**Note:** The reference electrode assembly is identified by the letter “ R “ in the center area and its white lead wire. It must be handled carefully so as not to abrade or scuff the element nor damage the threaded stem.

Installation is accomplished as follows:

Cable Needed: #14 gauge THW single conductor-to connect reference electrode to CAPAC<sup>®</sup> Monitor. (Cable not furnished with CAPAC<sup>®</sup> system).

1. Drill a ½ inch diameter clearance hole through the hull from inside the bilge making certain that nothing on the inside or outside of the hull interferes with the chosen location Alter position as needed to avoid obstructions.
2. Strip the waxed paper from the gray rubber (butyl) bead sealing compound and wrap three turns of the butyl bead around the outer edge on the back of the reference electrode holder (item 1) and one turn around

the brass hub. Then place reference electrode in a warm (at least 70° F) place to keep bead soft until installed.

3. Insert the warm reference electrode hub through the hole in the hull and press it in place.
4. On the inside of the hull, wrap three turns of butyl bead around the gland and against the hull and place items 2, 3, and 4 over the treaded stem of the reference electrode. Tighten item 4 but do not apply more than 30 ft.-lbs. of torque.
5. Strip ends of #14 gauge single conductor and 9 inch reference electrode cables approximately 5/16" and insert the stripped end of 9 inch reference electrode through items 5, 6, and 8 of clear plastic encased splice.

NOTE – either end of encased splice can be used since both ends are identical.

6. Insert the stripped end of #14 gauge, single conductor wire going to the CAPAC Controller through items 9 and 10 of clear plastic encased splice.
7. Butt splice anode wire to #14 gauge single conductor wire going to the CAPAC Controller using butt connector (item 7). Crimp and soft solder connector as shown in Figure 3.1. Thread the ribbed nuts (items 5 and 10) onto the threaded tube (item 8) and tighten.

## Controller Installation

The controller is wired as shown in Figure 3.6. Any dry location in the bilge or the cabin will serve as a good mounting location. The unit is mounted with #10 screws or bolts through the four holes provided. To prevent damage to the Controller or Monitor remove the controller fuse until all wiring is complete.

## CAPAC® Monitor Installation

The CAPAC® Monitor is designed to be connected to the "Monitor(+)" terminal of the 90W12D controller. Strip and connect the cables according to Figure 3.6.

The connections to the CAPAC® Monitor are as follows:

**Plus (+) terminal – to 90W12D controller "Monitor (+)" terminals.**  
**Minus (-) terminal – to 90W12D controller "Monitor (-)" terminals.**



The side of the instrument control panel at the helm, Figure 3, 8, commonly serves as a convenient location for the monitor. This location is reasonably sheltered from excessive spray and is convenient for observation. The unit, however, should be located at least three feet from the magnetic compass if one is onboard. This will eliminate interaction between the compass and the CAPAC<sup>®</sup> meter.

Other suitable locations in the bilge or in various places in the cabin may be considered as alternates.

After a location has been selected for the unit, and an inspection has been made to ascertain that no interference will existing installations will be encountered, proceed to install the controller as follows:

1. Using the template supplied, Figure 3.7, locate the cutout for the "Monitor".
2. Pass the two cables to be connected to the Monitor (Figure 3.6), up through the cutout.
3. **Cut the cables so that approximately one foot of each protrudes from the helm and connect to CAPAC<sup>®</sup> Monitor.**

## **Dee Cee Tran Voltage Converter Installation (If furnished)**

The Dee Cee Tran is to be installed in the same manner as the controller. Strip and connect the cables according to Figure 1 in Dee Cee Tran Manual. The connections to the Dee Cee Tran are as follows:

Input Terminal – plus (+) lead from 24 or 32V DC source  
GND (ground) terminal – to hull or bonding system.  
Output Terminal – Plus (+) lead to 90W12D controller.

## **System Instructions**

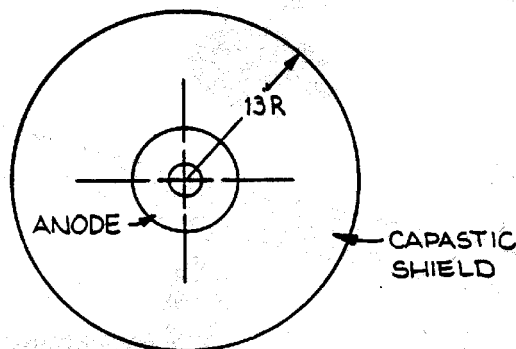
1. On wood hulls, it is necessary that all underwater appendages be bonded to from a common cathode which is, in turn, connected to the negative terminal of the 12V DC source which powers the CAPAC<sup>®</sup> unit. This bonding should be done with Number 8 gauge wire or larger. It is preferable that the fittings, including the rudder post, be soldered to the wire rather than only screwed or bolted to

the fitting. When ground plates are included in this common bond, the current drain on the battery will be higher. It may be desirable to disconnect the ground plate from the common bonding and reduce the battery drain. Radio frequency grounding for any electronic equipment is accomplished by connecting a capacitor (0.5 microfarads at 200 volts) between the common bonding and the ground plate. This will prevent unnecessary battery drain.

2. If the craft is equipped with an isolation coupling on the propeller shaft, it is recommended that it be removed. Unless the isolation feature is removed, the propeller and shaft will not receive protection. Engines equipped with hydraulic drives should be checked while in motion with an ohmmeter between the shaft and common ground. If not grounded, a grounding brush assembly should be installed.
3. Do not install thru-hull components adjacent to depth sounding transducers.

## Application of Capastic on Metal and Wood Hulls

A dielectric shield must be applied around the anodes in order to increase the distribution of anode current on metal and wood hulls and also provide protection for the metal or wood substrate against chemical attack by chlorine gas. The Capastic Kit (P/N 37020) supplied with your order contains a can of resin, a jar of hardener, mixing cups and sticks. If the Capastic Shield is correctly applied as per instructions container on label of resin can, it should eccentrically surround the anode as shown below.

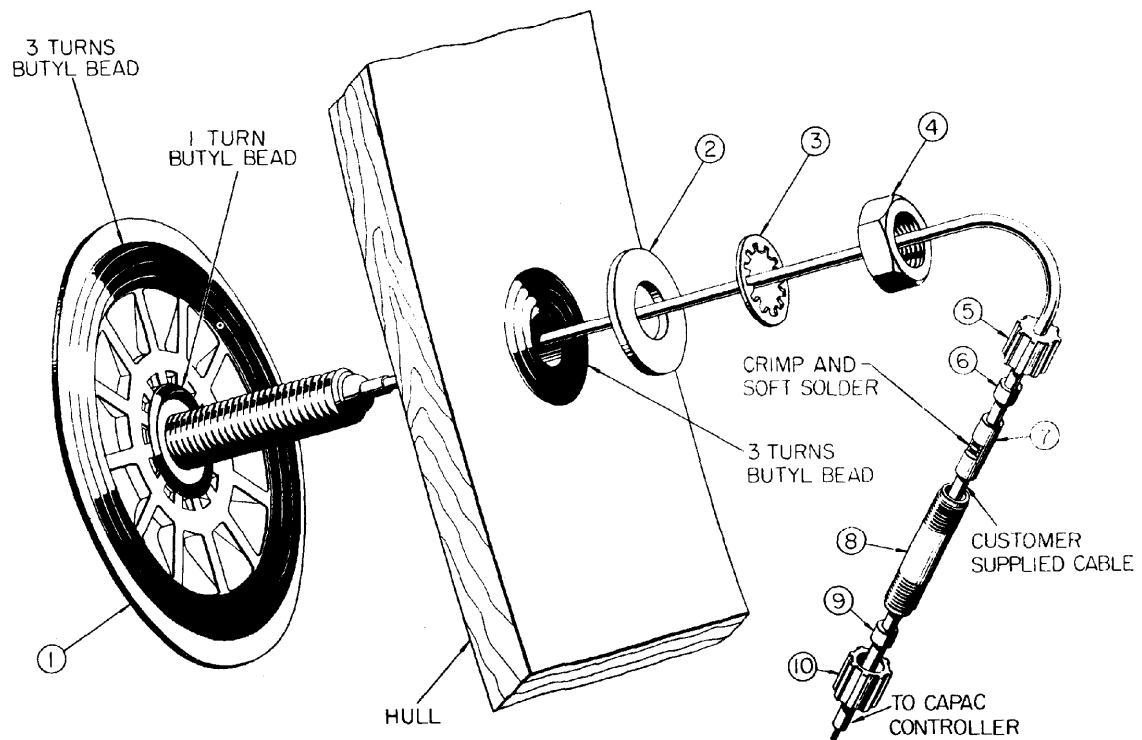


## **Painting**

The CAPAC<sup>®</sup> system is compatible with any paint system; however, certain steps can be taken to insure optimum results. The current demand for protection can be substantially reduced by painting the shaft and propeller. This procedure will reduce the initial current demand and will reduce the time required for polarization. Clear vinyl paint may be used. The plastic holder and Capastic dielectric shield (if needed) around the anode should be painted with antifouling paint; however, the center area of the anode must never be painted. (See Figure 3.3).

## **Electrical Power**

This CAPAC<sup>®</sup> system is operated from a 12 V DC source. If the boat is connected to 110-120V A.C. shore power, it is required that an isolation transformer or galvanic isolator of sufficient capacity be installed to prevent improper grounding or the hull or underwater appendages. See inside front cover Caution Notice B.



TYPICAL ASSEMBLY OF REFERENCE ELECTRODE ON  
METAL OR WOODEN HULL

Fig. 3.1

**TYPICAL ASSEMBLY OF REFERENCE ELECTRODE ON  
METAL OR WOODEN HULL**

**Figure 3.1**

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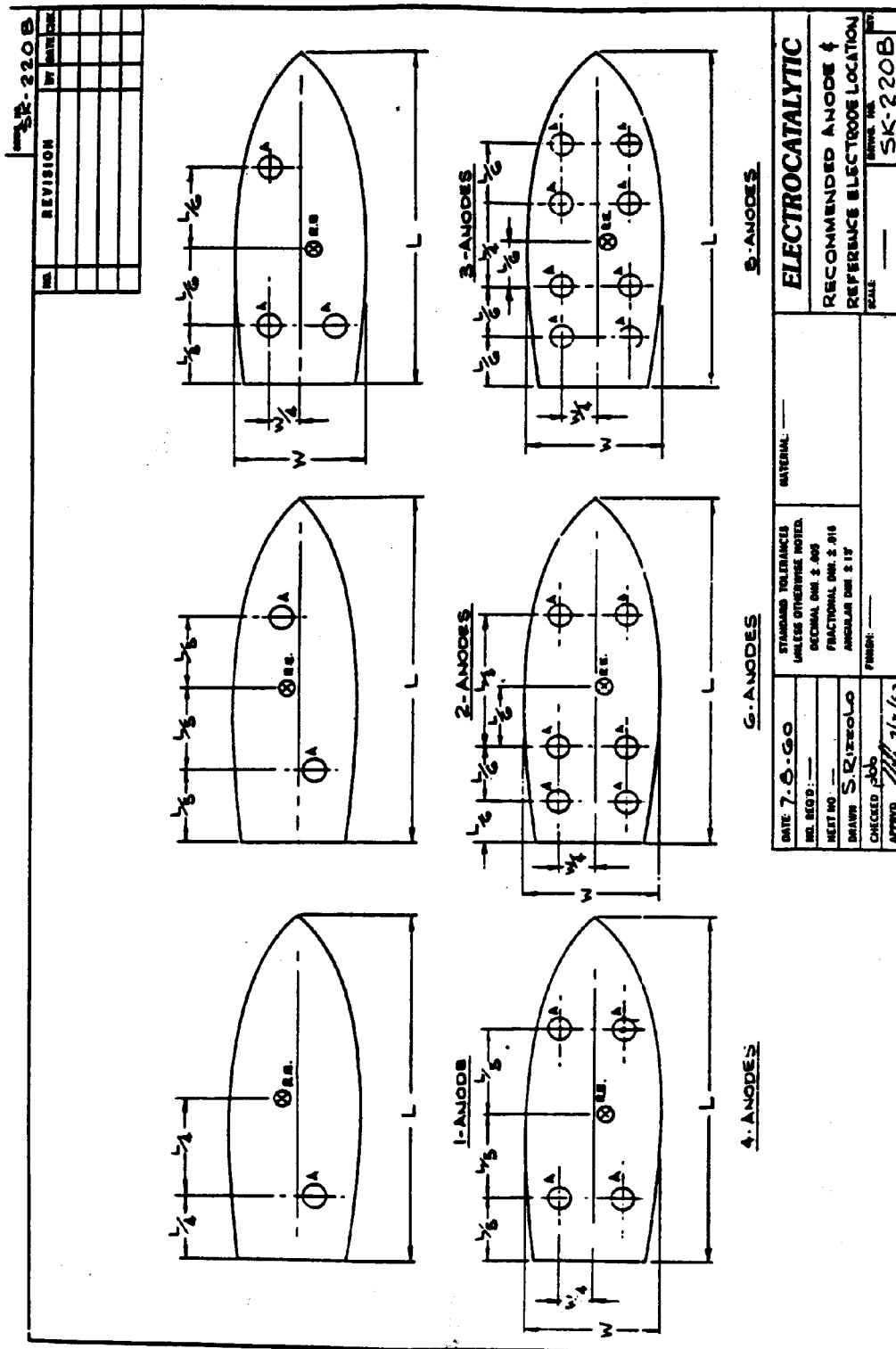
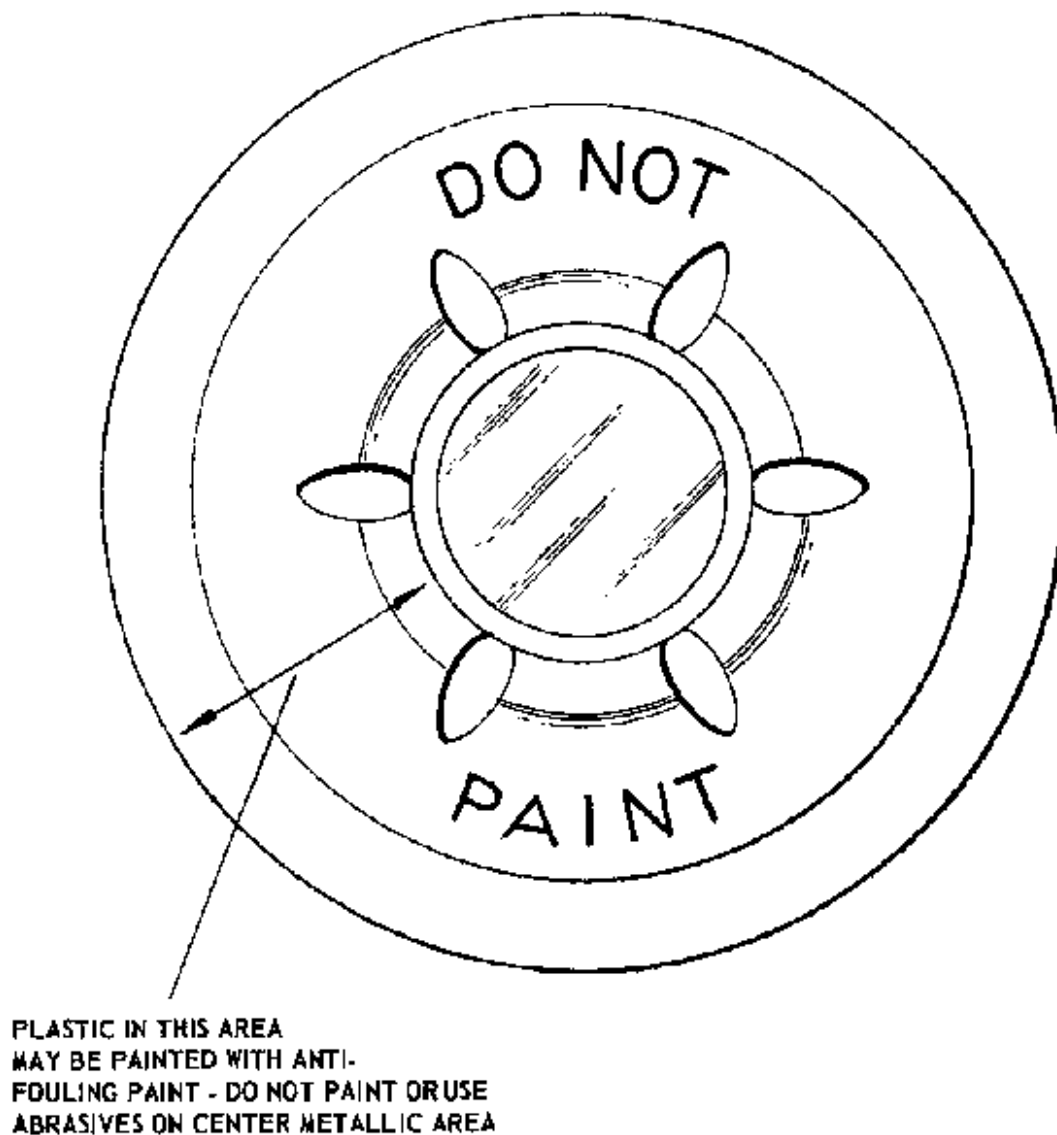


Fig. 3.2

FIGURE 3.2

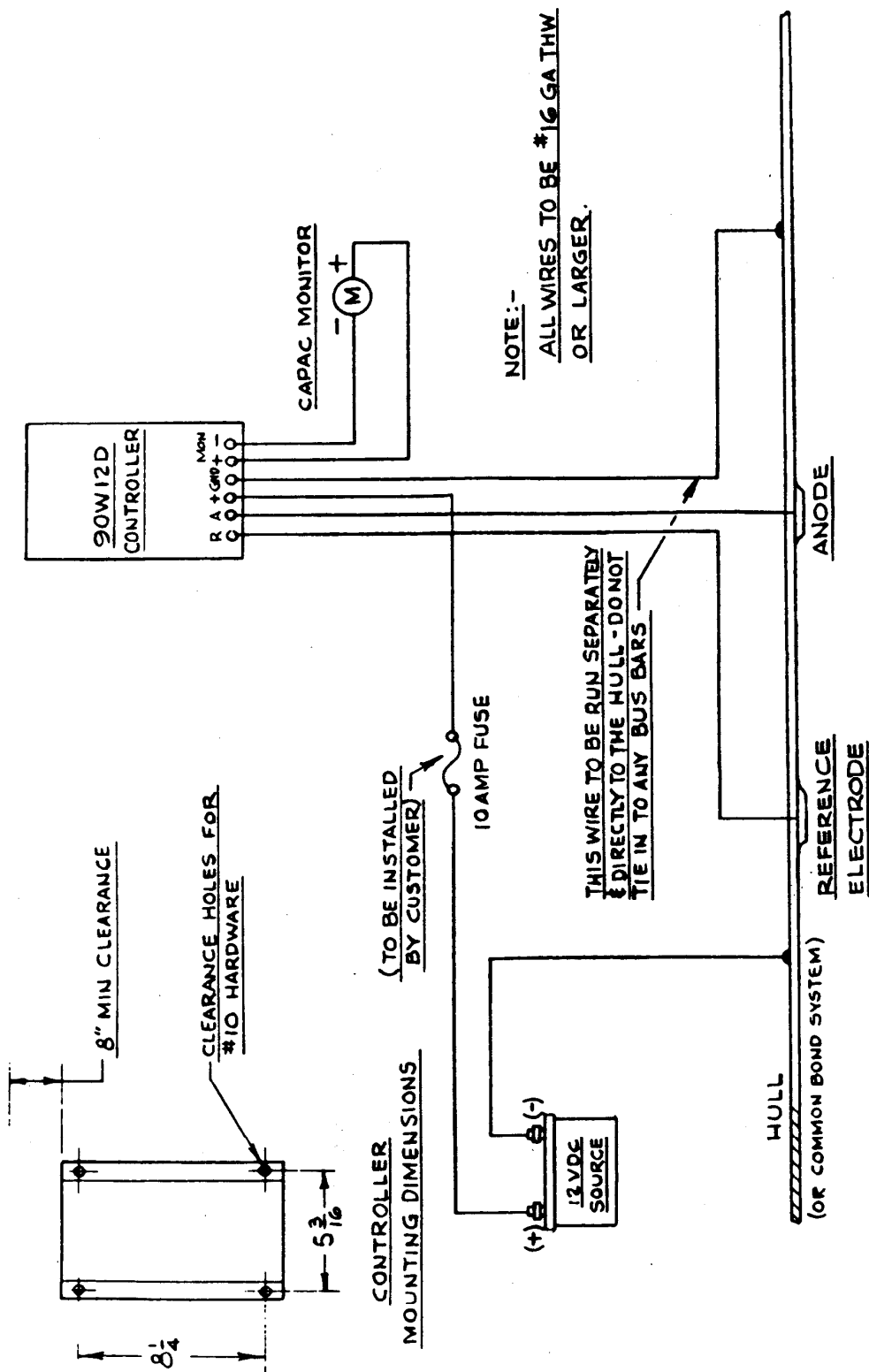
**THIS DRAWING PERTAINS TO ANODE**  
**AND REFERENCE ELECTRODE**



**FIGURE 3.3**



**Figure 3.4  
Controller  
&  
figure 3.5  
90W12D SYSTEM**

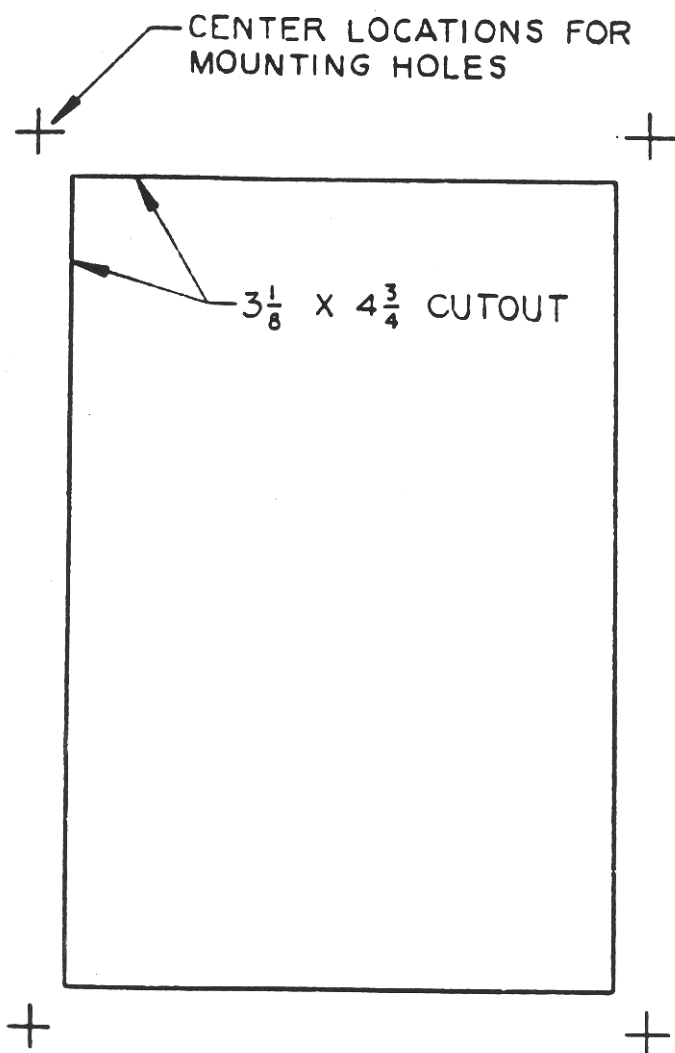


INSTALLATION DRAWING

Fig. 3.6

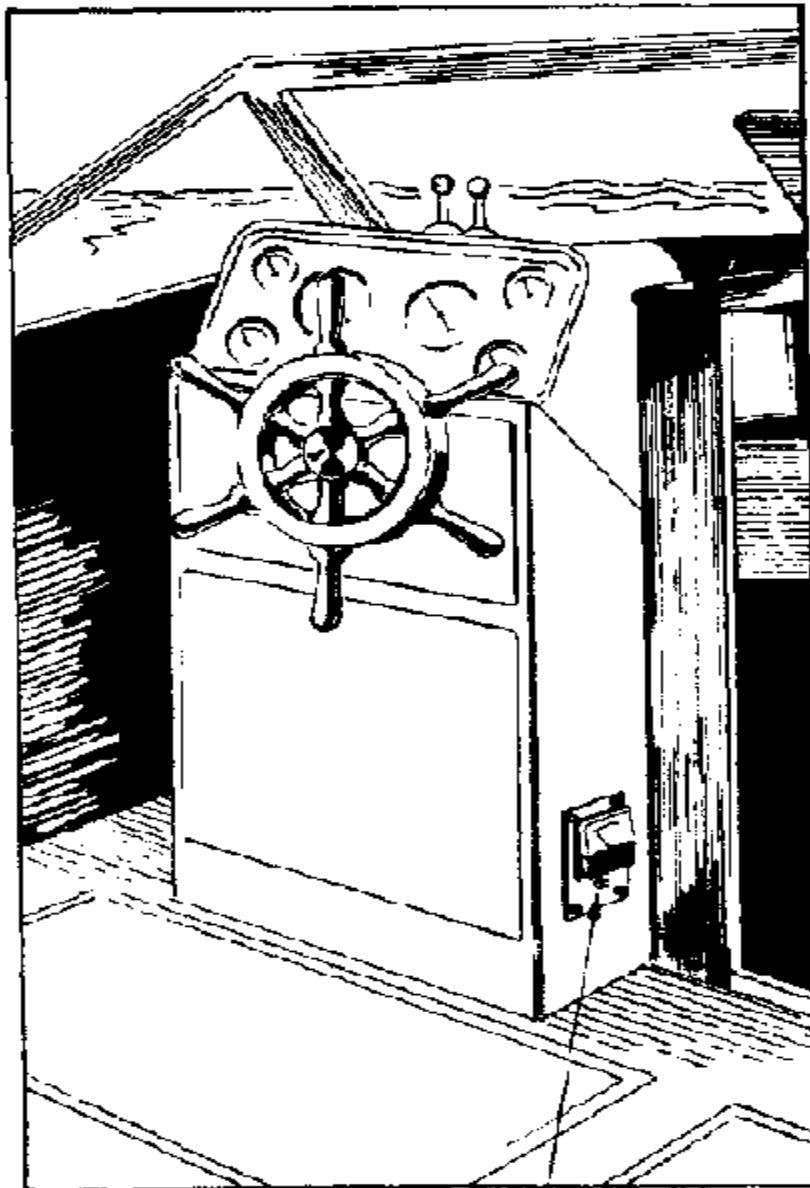
## INSTALLATION – DRAWING FIGURE 3.6





TEMPLATE  
CAPAC MONITOR  
50030

TEMPLATE  
CAPAC MONITOR  
50030



PUSH TO READ

**CAPAC<sup>®</sup> MONITOR AT HELM**  
**FIGURE 3.8**

## **Section IV Operation**

To achieve optimum results with CAPAC<sup>®</sup>, the equipment must operate continuously while the boat is in the water. Therefore, to prevent accidental de-energizing of the system, no on-off switch is provided on the controller.

As soon as the hull is afloat, the reference electrode creates a meter deflection on the CAPAC<sup>®</sup> Monitor (when the button is pushed) which is related to the degree of protection to the metal hull fittings regardless of whether the anode is emitting any current or not. Each type of metal (brass, monel, stainless, etc.) creates a different meter reading when it is freely corroding in sea water. Each type of metal has a correspondingly higher reading when it is protected or polarized. The metal for which the CAPAC<sup>®</sup> system is factory set is imprinted on the front of the 90W12D controller.

Operating Procedure is as follows:

After the system is installed according to Figure 3.6 and installation instructions in Section III, simply apply 12 V DC to input of controller and the system will function completely automatically. The hull potential should be periodically checked by depressing the button on the face of the panel of the CAPAC<sup>®</sup> Monitor. In fresh water, polarization of large bare metal areas is quite slow and it may take up to two weeks for the hull potential to reach the value indicated in Table 2.2 of the application section of this manual.

In salt water it may take several days to polarize large metal areas. When the bare metal areas have been coated, polarization usually occurs in a few minutes.

The anode current required for optimum protection changes with water salinity, speed of the hull, and aging of the paint system. The meter reading as read on the CAPAC<sup>®</sup> Monitor (when the button is pushed) created by the reference electrode is continuously monitored by the transistor control circuit and compared to the automatic control setting as set at the factory. The controller rapidly increases or decreases the current, as conditions demand in order to maintain the hull at the desired level of protection.

## **Section V**

### **Service**

#### **General Theory**

The Model 90W12D system is composed of four major components: The reference cell, the controller, the anode(s) and the CAPAC<sup>®</sup> Monitor. These units perform the following functions:

- A.** The reference electrode produces a voltage, which is related to the amount of protection received by the hull.
- B.** The controller compares the voltage produced by the reference cell with an internal voltage set by the factory. The output of the controller is automatically adjusted to keep the reference voltage at the same value as the factory set voltage.
- C.** The anode(s) is an electrically insulated element located outside the boat's hull through which current flows from the controller into the water and back into the hull or bonded fittings.

The amount of anode current delivered by the controller is dependent upon factors such as: The physical dimensions of the hull, the condition of the paint on the hull, conductivity of the sea water, and the speed of the boat. For this reason the operating current of the controller is difficult to predict.

- 1.** When the anodes fitted to the hull or fitting emit current, the protection given to the hull gradually increases and corrosion is reduced. This process is called polarization.
- 2.** As this anode current increases, the voltage between the reference electrode and hull increases gradually.
- 3.** Tests have shown that there is an optimum reference electrode voltage (hull potential). Increasing anode current to give a higher reference electrode voltage gives no further reduction in corrosion and wastes current. Excessive current, such as created by magnesium anodes, may even cause paint damage.

When the reference electrode voltage is below the optimum voltage set by the factory, output of the controller increases until the reference voltage equals the set voltage. A reference voltage greater than the set voltage causes a decrease in controller output.

## Determining the Difficulty

The following procedure will help to localize difficulties in a CAPAC<sup>®</sup> system.

- a) Check for 12 V DC voltage at controller input terminals.
  - b) Check reference electrode (Par. 1 or 2 below).
  - c) Check anode (Par. 1 or 2 below).
  - d) Check CAPAC<sup>®</sup> Monitor meter (Par. 3 below).
  - e) Check Dee Cee Tran Voltage Converter ( Par. 4 below) (if installed)
  - f) Check operation of the controller by determining if a variation in reference cell input voltage changes the anode current (Pat. 5 below).
1. With the hull afloat all of the cables disconnected from the controller: An unpainted reference electrode develops a voltage between its lead and the hull or fittings, which may be measured with a high impedance (20,000 ohms/volts) DC voltmeter. This voltage will usually lie between 9.1 and 1.0 volt depending on the type of hull material and the degree of protection provided to the hull, as listed in Section II. The hull will be negative (-) and the reference electrode positive(+). On some unprotected wooden hulls, the voltage may be zero or negative. The presence of this voltage shows that the reference electrode is not shorted and that the wire is not broken. An anode develops a voltage to the hull of 0.3 to 2.0 volts when disconnected from the controller. A properly installed anode will always develop a higher voltage than a reference electrode on the same hull.
  2. With the hull out of the water and dry, and all leads disconnected from the controller: An ohmmeter will indicate a high resistance (greater than 10,000 ohms) when connected between the anode or reference electrode lead wire and the hull or fittings. Lower reading will be observed if the anode, electrode, or cables are wet due to the voltage generated by these elements. The cables connecting the anode and reference electrode to the controller can be checked for continuity by shorting the controller ends of the cables to the hull and checking for continuity between the face of the anode or electrode and the bare hull. Proper installations will show a reading of 1 ohm or less. A higher reading indicates poor connections, or in the case of wood hulls, poor bonding of fittings to the negative terminals of the power source.
  3. The meter of the CAPAC<sup>®</sup> Monitor read 1.0 volt full scale between terminals (+) and (-). The meter can be checked by using 1-1/2 volt battery, dividing resistor, and another DC voltmeter.
  4. The Dee Cee Tran Voltage converter will produce 12.6 V DC at its output terminals when 24 to 32 V DC s applies to its input terminals.

5. To check the operation of the controller, disconnect the reference cell and anode leads and make the connections as shown in Figure 5.2A. The 1.5V dry cell should be connected with a 1000 ohm 2 watt potentiometer or variable resistor with dial knob. With this hook-up any desired potential can be set into the reference input by adjusting the potentiometer until the desired value is reached as read on the CAPAC<sup>®</sup> Monitor. The 10 ohm 20 watt resistor will act as a dummy load and represents the resistance of the anode. Vary the potentiometer according to the graph (Figure 5.2B) and note that output voltage for your model as read on voltmeter (V).

For example, if a model 37180-3 is being tested, the output of the controller as read on Voltmeter (V) should be 5V DC when an input of 0.65 volts appears across the reference cell input terminals. If an input of 0.60 volts or less appears across the reference cell input terminals the output voltage of the controller should be  $10 \pm 2V$  DC. If an input of 0.709 volts or greater appears across the reference cell input terminals the output voltage of the controller should be 0 volts.

## Detailed Service and Theory of Operation

### Anode:

The anode is constructed of 1 2-1/2 inch diameter platinized titanium disc that is supported and electrically insulated from the hull by a fiberglass holder. The platinized titanium disc must never be painted. The current delivered by the anode depends upon the anode voltage and the resistance of the sea water. With 12 volts applied directly to the anode, it will deliver up to 5 amperes in warm seawater, 3 amperes in normal seawater, and as little as .01 ampere in fresh water. It is recommended that the anode voltage not exceed 12V DC.

If damage to the platinum surface of the anode is suspected the anode current can be compared to that of other anodes on the boat (when there are more than one) or to a new anode suspended in the water. Connect the anode directly to the 12 volt battery. If it's current is 80% or less than another anode it should be replaced.

NOTE: The anode may be identified from the inboard side by means of the 10 inches of black lead wire attached to the back of it.

### Reference Electrode

The reference electrode is constructed of a silver-silver chloride element that is supported and electrically insulated from the hull by a fiberglass holder. In order to assure accurate results, the silver screen must never be painted. If it should accidentally be painted, the paint should be removed with a chemical solvent.

CAUTION: **NEVER** use steel wool or any abrasive cleaner on an anode. If a reference electrode is connected as an anode, it will be destroyed within a few days. If it is connected as an anode for several minutes, it will subsequently develop an inaccurate voltage. These points should be remembered when checking a **CAPAC**<sup>®</sup> system.

The accuracy of this electrode is determined by comparing the CAPAC<sup>®</sup> Monitor meter reading with a portable silver-silver chloride reference electrode meter.

NOTE: The reference electrode may be identified from the inboard side by means of the 10 inches of white lead wire attached to the back of it.

## Controller

The 90W 12 D controller functions to provide the correct amount of output current to the anode so that the desired cathodic polarization potential is maintained on the metallic surfaces exposed under water. The controller operates on an input voltage of 12V DC, (i.e. batteries ore rectified or rectified and filtered direct current source) and consists of one integrated circuit, seven transistors and associated circuitry configured to provide the following functions:

- 1) Polarization level control.
- 2) Current limiting.
- 3) Automatic shutdown for open or short-circuited reference electrode.

Polarization level control is provided by integrated circuit I1, transistors Q3, Q4, Q5 and Q6. these devices are connected as a closed loop, gain-controlled amplifier/comparator whose output is connected to the anode. An adjustable reference set point voltage is connected to one input of the integrated circuit. This represents the desired polarization potential for the metal to be protected (i.e. 650 millivolts for bronze, 850 millivolts for steel and 950 millivolts for aluminum). The other input of the integrated circuit is connected to the reference electrode.

If the sensed reference electrode potential is below the set point potential, the amplifier output is increased thereby supplying current to the anode and increasing the polarization on the immersed metal. If the sensed reference electrode potential is above the set point potential, the amplifier output is decreased, reducing the anode current and the polarization on the immersed metal. In this manner, the correct polarization potential on the cathodic surface is automatically maintained.

Current limiting is achieved by means of transistor Q7 whose input is connected across current sensing shunt resistor R19. As the anode current through R19 increases and the voltage drop across it increases thereby turning on transistor Q7 which shunts the drive current to the darlington connected output stage comprised of Q5 and Q67 this reduces the output current from this accordingly so as to restrain it to a maximum of approximately 7.5 Amperes.

Automatic shutdown is achieved for open or shorted reference electrodes by two different means. If the reference electrode should become open-circuited, resistor, R2 causes the reference electrode terminal of the controller to increase in potential thus simulating an over-protection condition which causes the control amplifier to reduce the output current to the anode. If the reference electrode should become short circuited, transistors Q1 and Q2 are turned on, thereby shunting the drive signal at the input of transistor Q3. This action also turns off the controller output current fed to the anode.



<b>Controller Specifications</b>	
Operating voltage	12V DC
Automatic Control Range	380 Millivolts to 1.3 Volts
Current Output	0 to 7.5 Amperes
Control sensitivity	$\pm 9.929V$ from control point
Type of Control	Smoothly Varying
Weight	3.5 lb.s
Active Components	1-CA3130 Integrated Circuit 1-2N4037 Transistors 3-2N1711 Transistors 1-2N3054 Transistor 1-2N3771 Transistor

# Trouble Shooting

Some probable causes of failure and their symptoms are:

## Steel Hulls:

### 1) Symptoms:

CAPAC Monitor Meter reads higher than the correct value

- above 0.75 for bronze – above 0.95 for steel
- a. Anode and reference electrode cables may be reversed or shorted together. Remember that the reference electrode has a **white** lead wire attached to the back of it while the anode has a **black** lead wire attached to the back of it. Re check wiring as shown on Figure 3.7 and test as explained in the Service paragraph 1 and 2.
- b. Wire to negative terminal of controller is not securely connected to the hull.
- c. The craft may be receiving protection from “zincs” or another CAPAC<sup>®</sup> system. If the zincs are attached to the hull, noting can be done except to remove them. Their removal is not absolutely necessary, but in general, a reading above 1.05 indicates over protection and this condition is not recommended due to excessive calcareous deposits and possible paint damage.
- d. If the controller is faulty and the high reading is not caused by a, b, or c, the meter should gradually fall to 5 or 6 on steel hulls and 7 or 8 on aluminum hulls when the input power is disconnected.

### 2) Symptoms:

The CAPAC<sup>®</sup> Monitor Meter continually reads between 0.1 and 0.6

Check:

- a. Blown 10 ampere input fuse caused by a shorted anode or excessive current demand.
- b. Dead or discharged battery. Check for battery voltage on terminals (+) and (-).
- c. Open anode lead wire to anode. Check as described in Service.
- d. If the controller is defective, connecting a wire from terminal + to A will place the battery voltage on the anodes and will give an increase in hull potential.

The controller must then be repaired. Do not leave anode connected to battery.

3) Symptoms:

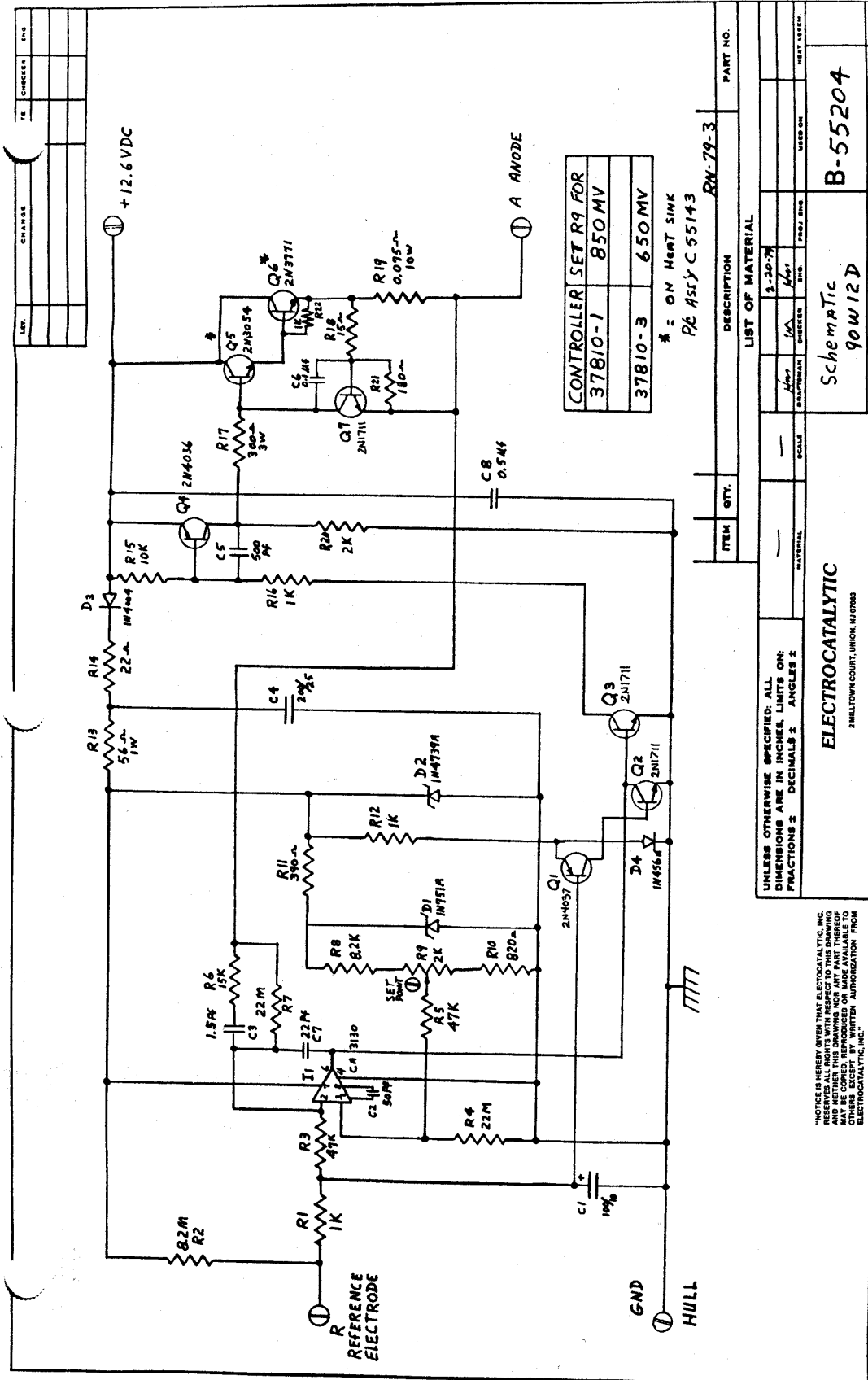
The meter reads zero.

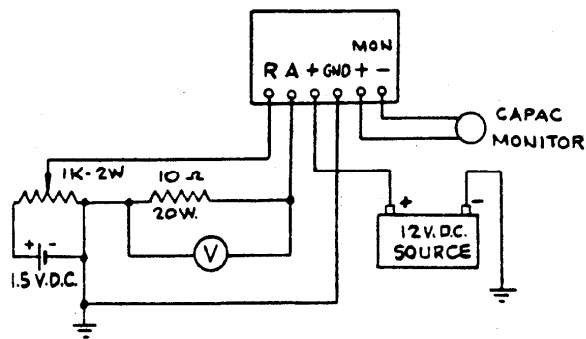
Check:

- a. Reference electrode for open or shorted wiring, as described in Service, Paragraph 1 and 2.
- b. CAPAC<sup>®</sup> meter, as described in Service, paragraph 3.

**Bronze Fittings:**

The Servicing procedure for bronze fittings is the same as for steel hulls except that the CAPAC<sup>®</sup> Monitor meter will read 0.55 to 0.75 when the hull is protected. This means that the checks given under Symptoms 2 for steel apply when the CAPAC<sup>®</sup> meter on a boat with bronze fittings reads 0.1 to 0.4.

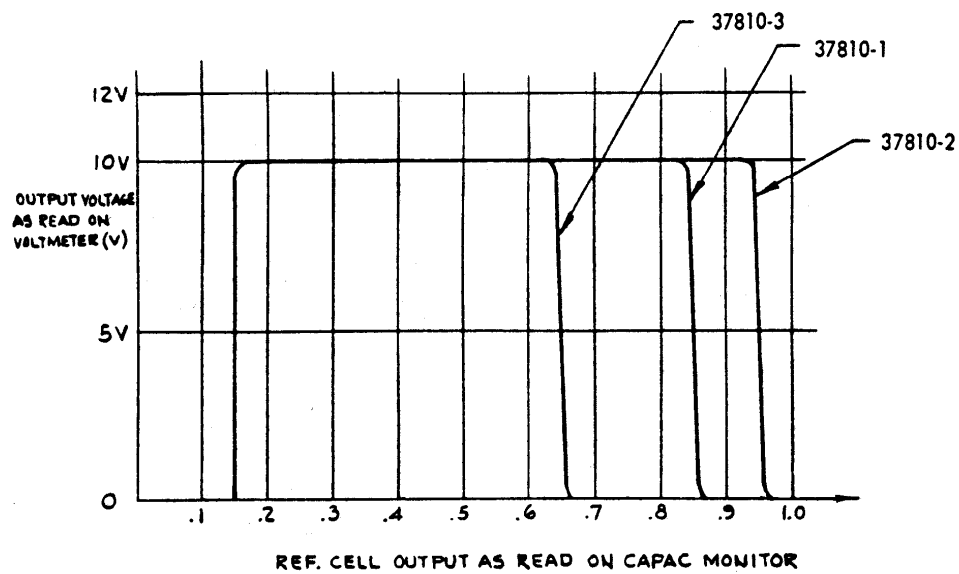




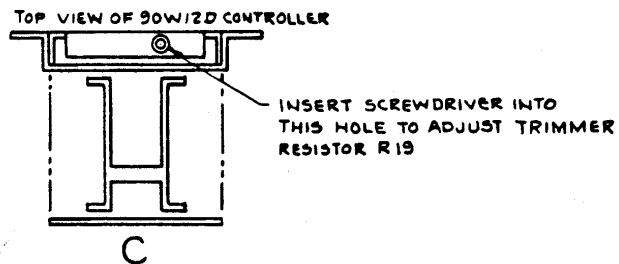
A

#### EQUIPMENT NEEDED

- 1- 1.5V BATTERY & DIVIDING RESISTOR
- 2- 10  $\Omega$ , 20 WATT RESISTOR
- 3- VOLTMETER, 20,000 OHMS/VOLT



B



C

Fig. 5.2

## WARRANTY

Evoqua Water Technologies warrants each new CAPAC<sup>®</sup> SYSTEM or part thereof manufactured by it, to be free from defects in workmanship or material, under normal use of service, for a period of one (1) year from the date of installation of such system or eighteen (18) months from date of shipment, which ever occurs first.

Our obligation under this warranty is limited to, at our option, the repair or replacement, f.o.b. our Union, New Jersey plant, of such systems or parts thereof which are found, after inspection by us, to be defective. We assume no liability for damages of any other kind whatsoever, and in no event shall we be liable for incidental and/or consequential damages.

**THIS WARRANTY IS EXCLUSIVE AND IS IN LIEU OF ANY AND ALL OTHER WARRANTIES, ARISING BY LAW OR CUSTOM, EXPRESSED OR IMPLIED, INCLUDING, BUT NOT BY WAY OF LIMITATION, THE IMPLIED WARRANTY OF MERCHANTABILITY AND THE IMPLIED WARRANTY OF FITNESS FOR PARTICULAR PURPOSE.**

EVOQUA CAPAC <sup>®</sup> WARRANTY VALIDATION		
THIS REGISTRATION CARD MUST BE COMPLETED IMMEDIATELY AFTER PURCHASE AND RETURNED TO MANUFACTURER.		
MAIL TO: SIEMENS WATER TECHNOLOGIES		
CAPAC <sup>®</sup> SECTION, 2 MILLTOWN COURT, UNION, NJ 07083		
NAME OF BOAT		
TYPE OF BOAT		
	HULL MATERIAL	LENGTH
OWNERS NAME		
ADDRESS		
TELEPHONE NO.		
PURCHASED FROM		
ADDRESS		
TELEPHONE NO.		
INSTALLEY BY		DATE:
ADDRESS		
TELEPHONE NO.		