CE RoHS compliant

BOAT & YACHT CORROSION CONTROL

2010

THE QUEEN'S AWARDS FOR ENTERPRISE: INNOVATION 2005

Revised for European use by

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CORROSION CONTROL IS AN EXACT SCIENCE

There are no mysteries in corrosion control. Since the early eighteen hundreds, scientists have been solving the problems of corrosion.

We are zeroing in on boat and yacht corrosion and can use the methods and reference tables that have been developed.

- ◯ FAMILIARIZE YOURSELF WITH THE CORROSION TERMS USED.

- ◯ FOLLOW THE STEP BY STEP BASIC SOLUTIONS TO CORROSION CONTROL

- ◯ STUDY THE SURVEY REPORTS OF THE ACTUAL BOATS TAKEN FROM OUR FILES.

Within a few hours you will be able to solve the so called “mysteries” of corrosion.

CHAPTERS

CORROSION

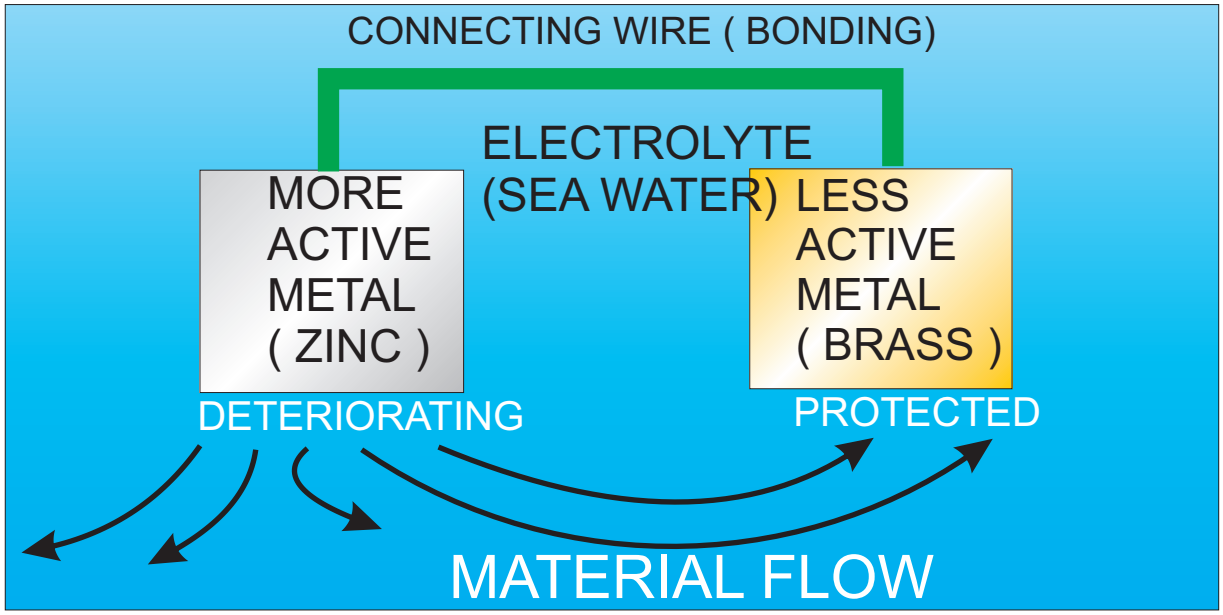
CORROSION – The destruction of metal or alloy by chemical or electrochemical reaction with its environment.

It is fairly difficult to glance at a failed metal boat part and tell immediately what caused that particular failure. Most likely the failure was caused by a combination of reasons including wrong choice of alloy by the manufacturer, manufacturing error such as overheating, contamination or wrong coating, error in application by boat builder, water velocity, impurities or pollution in the electrolyte, temperature, vibration, stress, crevice, galvanic or stray current corrosion.

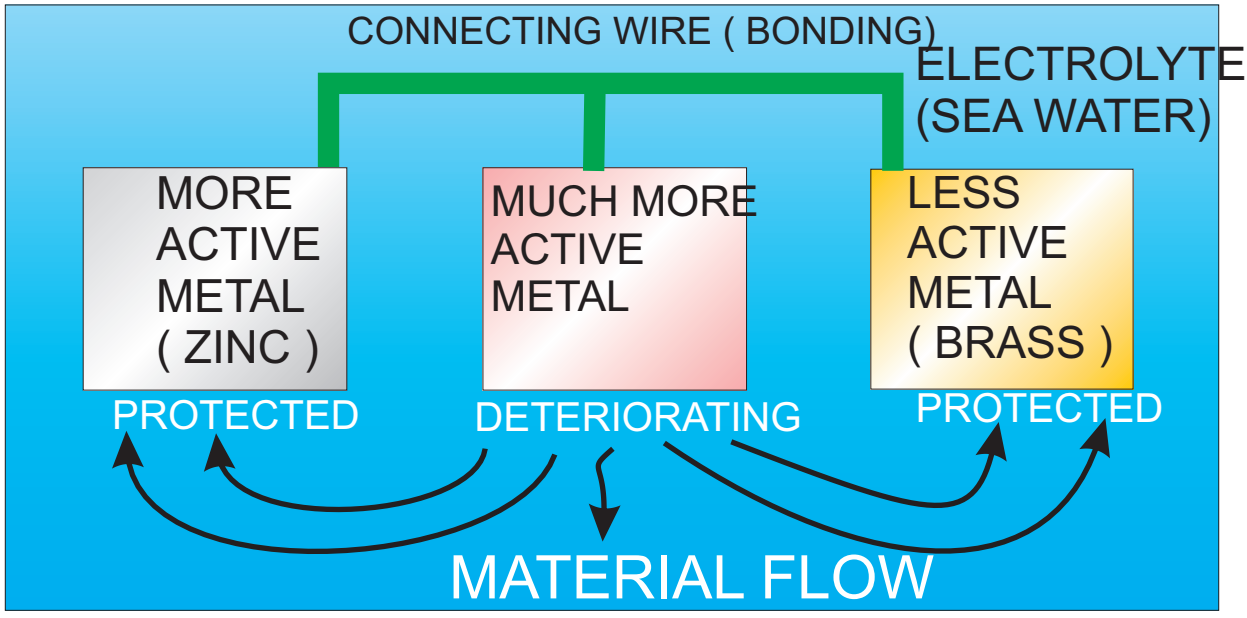
In well designed boats, the main cause of failure (galvanic, stray current, and to a large extent vibration, stress, and velocity corrosion) can be controlled by following these easy directions.

GALVANIC CORROSION

One of nature's phenomena is the fact that two different connected metals immersed in an ELECTROLYTE (in our case sea water / polluted fresh water) develop electrical voltage and current, the result of which is the loss of the most active metal.



If both the above metals were important to us, we could attach a third metal say magnesium to the bonding wire this would mean that all the magnesium would deteriorate before the zinc, then the brass.



If we know that the metal that is most active electrically will deteriorate while protecting the metal that is less active it is important that the most active metal is not an important part of the boat.

If both these metals are important to us, we must attach a more active each of them , which will deteriorate and protect them, and in so doing protect the boats EXPENSIVE AND IMPORTANT metallic parts.

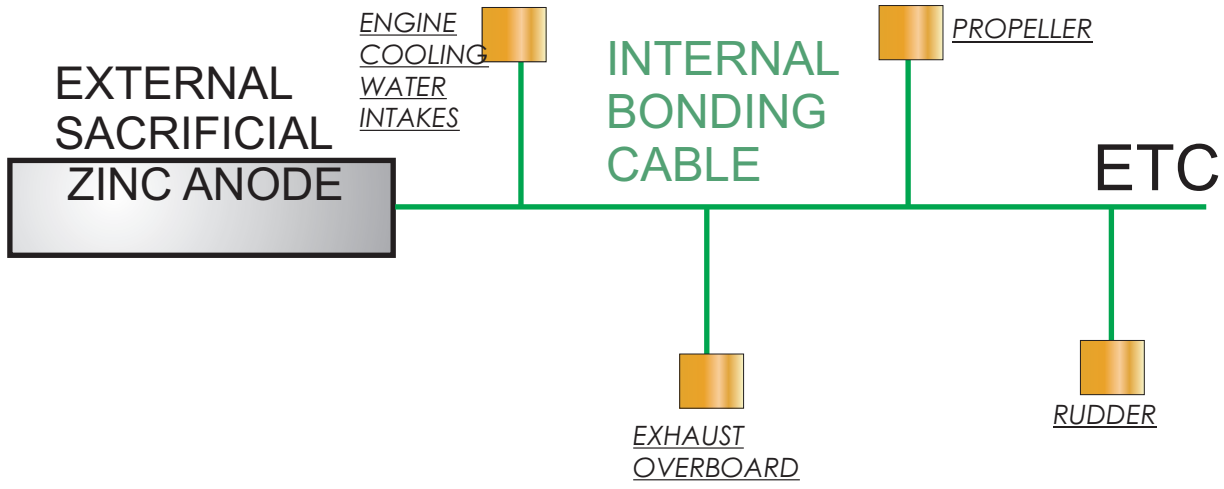
The metals we use on boats are normally alloys (several metals mixed together). The higher potential (more active) metals will deteriorate out of the alloys destroying our boat fittings and so endangering our lives and property. For example a brass propeller is 60% copper and about 30% zinc, if this deteriorates, all the zinc comes out of the brass (de-zincification)leaving only copper, this is noticeable because the brass turns from a bright gold to a dull reddish colour - copper. As a result the propeller becomes weak and fails.

Please note that when two metals are combined ie zinc and copper to make brass, the brass does not assume the worst case metals position on the noble scale. I.e. zinc would be the most active metal in brass, but by looking at pure zinc on the noble scale it can be seen that brass is lower down the scale form zinc, but further up the scale from copper, so a zinc anode will protect the zinc in the brass.

To protect boat fittings, attach a more active metal that will sacrifice itself .before the important metal fails

As it is not feasible to attach pieces of more active metal to each piece of underwater boat metal. Connect inside the hull all of the boat metal that is immersed (see BONDING) and connect a large piece of immersed more active metal into the system.

The sacrificial metal will erode, protecting the boat metal that is bonded to it and exposed to the same body of water. (The water inside the engine is usually a different body of water). (See ENGINE ZINCS)



WHICH METALS ARE MORE ACTIVE?

A list has been developed that shows us which metal or alloy is more active. This list is called the Noble scale. Each metal is more active than the metal listed beneath it.

Least Noble

Magnesium - freshwater anodes
Galvanized Iron
Zinc - seawater anodes
Cadmium
Aluminum - boats, pontoons and some anodes
Mild Steel - boats, steel hulls
Alloy Steel - boats, special steel
Aluminum (Formed Alloy) - outboards, propellers, z drives, pontoons etc.
Active Stainless Steel - hand rails, above water stainless
Tin
Manganese Bronze
Naval Brass (60% Copper, 30% Zinc) - Skin fittings
Yellow Brass
Admiralty Brass
Copper
Brass (60% Copper, 40% Zinc)
Silicon Bronze
Tin Bronze
Copper-Nickel (70/30 Alloy)
Passive Stainless Steel - Propeller shafts
Monel
Titanium
Silver
Platinum
Gold - G.P.S / V.H.F. Ground Plates

Most Noble

This is a partial list - alloys will have a different position on the list depending on composition.

Pick any two metals. Connect and immerse in sea water. The metal that is higher on the list is more active and will deteriorate while protecting the metal lower on the list.

A lower voltage metal will last forever if it's normal freely eroding voltage is raised by 225 to 250 millivolts.

The further metals are apart on the list, the greater the activity. Magnesium connected to Platinum would deteriorate faster than Magnesium attached to Copper.

This is why it is important not to connect any GOLD ground plate for V.H.F. ect to the bonding system, leave this isolated.(if used)

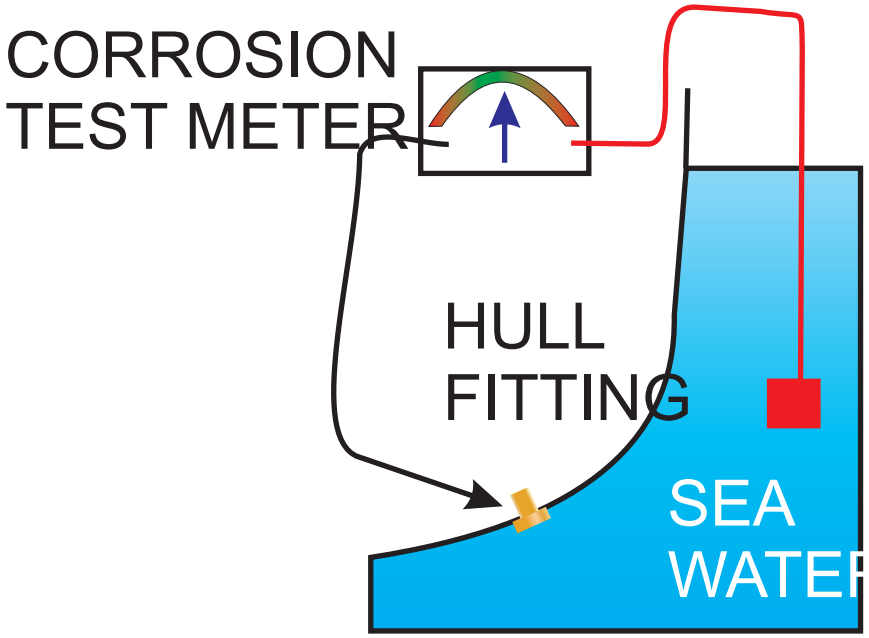
In electronics, the more active is called the ANODE and the less active the CATHODE. A SACRIFICIAL ANODE would be the metal we attached to the bonding system to protect our boat.

Normally the Marine industry uses ZINC as the sacrificial anode as it is high on the Noble scale and relatively inexpensive. Magnesium and Aluminum are used extensively in related industries. Magnesium voltages are high and can damage Steel and Aluminum in sea water, however this is sometimes used in freshwater.

TESTING FOR CORROSION

From reference books, we find that a method has been developed to show the voltage difference between metals in sea water. Our 'Corrosion Test Meter' is colour coded to more easily protect the common metals we use aboard most boats Bronze, Steel and Aluminum, and has a millivolt scale to read almost the entire spectrum of metals.

In a matter of seconds we can observe whether or not our boat metal is eroding or being protected. **With no guesswork.**



The 'Corrosion Test Meter' consists of a highly accurate millivolt meter, a probe and a silver/silver chloride half cell. Other less expensive half cells could be used but they do not have the stability or the reliable readings of silver/silver chloride.

It is not necessary to be a technician to use our corrosion test meter but for the technically minded, the full scale voltage of our meter is 1200 millivolts (1.2 volts).

Metals freely erode at the following approximate voltages depending on their composition.

	Erode	Protect
Bronze	300 millivolts	600 `100 millivolts
Steel	500 millivolts	850 `100 millivolts
Aluminum	650 millivolts	800 to 1050 millivolts

At approximately 1200 millivolts, Steel and some paints are damaged by over protection.

Aluminum can be damaged at 1075 to 1100 millivolts.

The more Noble the metal (lower on the Noble scale) the lower the voltage and the more resistant to galvanic corrosion

There is the Noble scale again with the approximate voltages you can expect to read on the 'Corrosion Test Meter' at 75ºF sea water temperature.

Composition of metals, water temperature, salinity, velocity and oxygen content will vary the meter readings slightly.

NOTE: Stainless Steel may read from 0 to 575 depending on composition and oxygen content of the seawater.

Millivolts	**Metal or Alloy**
1580	Magnesium
1140	Galvanized Iron
1050	Zinc
860	Cadmium
790	Mild Steel
740	Alloy Steel
625	Aluminum-Marine Grade
550	Active Stainless Steel
500	Tin
450	Manganese Bronze
450	Naval Brass
450	Yellow Brass
420	Lead
340	Copper
330	Brass (60/40)
260	Silicone Bronze
260	Tin Bronze
240	Lead
200	Copper/Nickel(70/30 Alloy)
150	Passive Stainless Steel (302,4,16,17,21,47)
110	Monel
100	Titanium
80	Silver
Zero	Platinum
Zero	Gold

A good rule of thumb for designers is to select metals to be connected together, or close in wet wood, that are within 200 millivolts of each other to reduce galvanic corrosion.

By placing the silver/silver chloride half cell of our meter in the water and probing the immersed metal inside our hull with the probe of our meter (through hulls, shafts, etc.) the readings on the 'Corrosion Test Meter' will tell us whether or not the metal is freely eroding, being protected or excessively protected, or there is a problem with the bonding wire (e.g. the wire is loose, broken or not making good contact through hull).

Excessive protection, while using up zinc anodes faster, can also destroy wood, lift paint and create gasses. (See wood, steel, ferro-cement, and aluminum hulls).

With the half cell in the water, we touch the probe to the metal in our bilge. The readings will be low in the yellow if the metal is unprotected. The readings for all the different pieces will be slightly different if the boat is not BONDED.

WHEN WE BOND OUR BOAT, THE READING SHOULD BE EXACTLY THE SAME.

After bonding, we add a SACRIFICIAL ANODE to our bonding system. This will raise the voltage of the system up into or over the green on our meter, depending on its size. It sometimes takes 5 to 24 hours for the hull to polarize. The voltage will continue to rise until polarization is reached. The amount of boat metal to be protected, type of metal and size of zinc determines polarization time.

With a permanently installed 'Corrosion Controller' we can monitor our system at all times and can adjust the output of the zinc up or down as the zinc erodes to keep in the green section of our meter.

OTHER PROBLEMS SUCH AS STRAY CURRENT CORROSION BROKEN BONDING WIRE OR LOSS OF ZINC ARE INSTANTLY RECOGNIZED ON OUR METER. Our ability to observe and control the output of the zinc appreciably lengthens its service life, saving pounds not only in zinc but in zinc installation labor, reduces the possibility of damage from over protection and allows us to detect stray current problems immediately. When we can no longer adjust our 'Corrosion Controller' test meter needle into the green, we must replace the sacrificial anode.

Under way, the boat normally needs more protective current so the voltage readings will be lower.

Shaft zincs expend themselves faster because of their greater velocity. This material loss does not go to protect the boat metal as the loss is through abrasion rather than electrical output, because of this it is best to fit a shaft brush and connect the shaft

brush to the bonding system.

SUMMARY

A permanently installed Corrosion Controller is a valuable piece of equipment, not only extending the life of the zincs but also notifying immediately of any stray current problems from the boat's D.C. system, the boat's A.C. system, the dock's A.C. system, other boats on the dock or problems with your bonding system.

Connected dissimilar metals immersed in an electrolyte generate a voltage and the most active metal deteriorates. This is called GALVANIC CORROSION.

Metal dissolves from the ANODE (more active) and protects the CATHODE (less active).

Metal can be protected by attaching a more active (higher on the Noble scale) piece of metal.

The metal that is sacrificed is called the SACRIFICIAL ANODE.

The 'Corrosion Test Meter' tells us the relative voltage of immersed metals.

Bonding, in effect, makes all the immersed metal into one piece of metal. The voltage throughout the bonding system will be the same and will average out depending on the size and voltage of each metal.

One piece of zinc, of the appropriate size, attached to our bonding system as the sacrificial anode, will protect all the bonded metal as long as the zinc keeps the needle of the meter in the green section. (green is 200 to 300 millivolts increase in voltage from 'freely eroding' voltage).

Monel freely eroding at 110 would be protected at 310 to 410 millivolts – tin (500mV.) would be protected at 700 to 800 millivolts. On a wood boat with bronze fittings, normal voltage and current flow could destroy wood.

CORROSION SURVEY

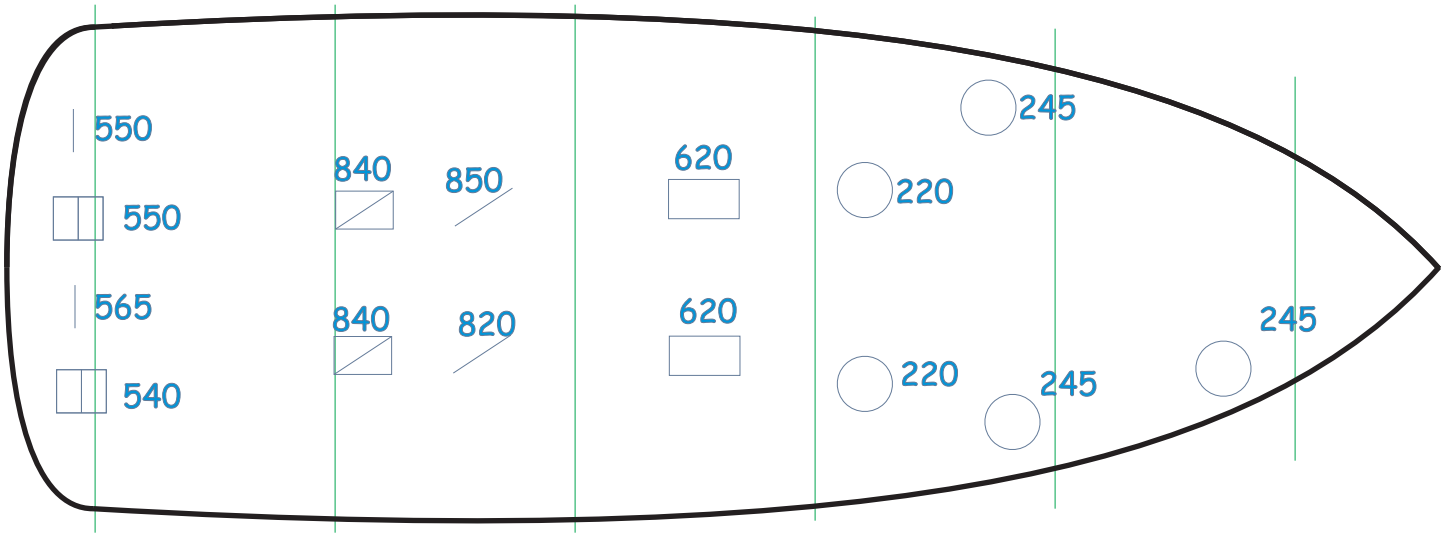
You are now ready to 'check out' or survey a boat for galvanic corrosion problems. The necessary tools are a PORTABLE CORROSION TEST METER and a notepad.

Draw a simple outline of a boat.

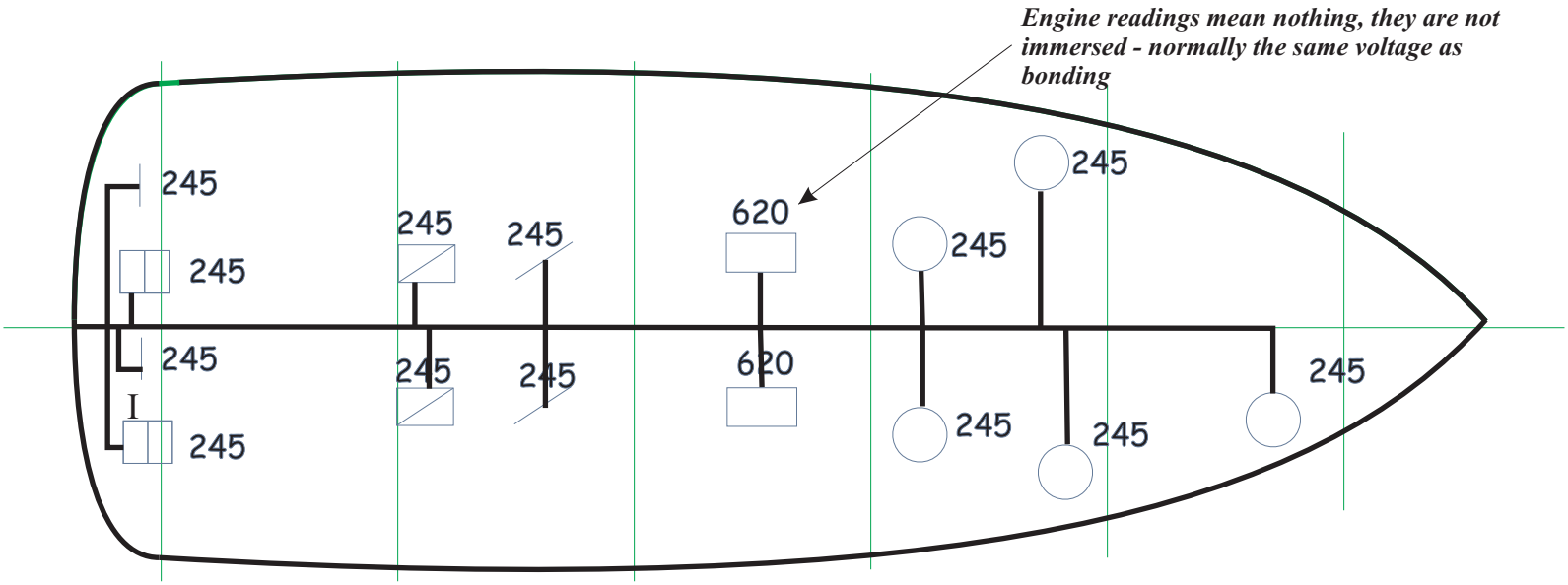
With your corrosion test meter, probe each metal fitting connected to the water.

Write these readings at the location of each on your outline and identify each with symbols.

Read each fitting even though the boat is already bonded. A different reading at any fitting means the bonding wire is not correct.

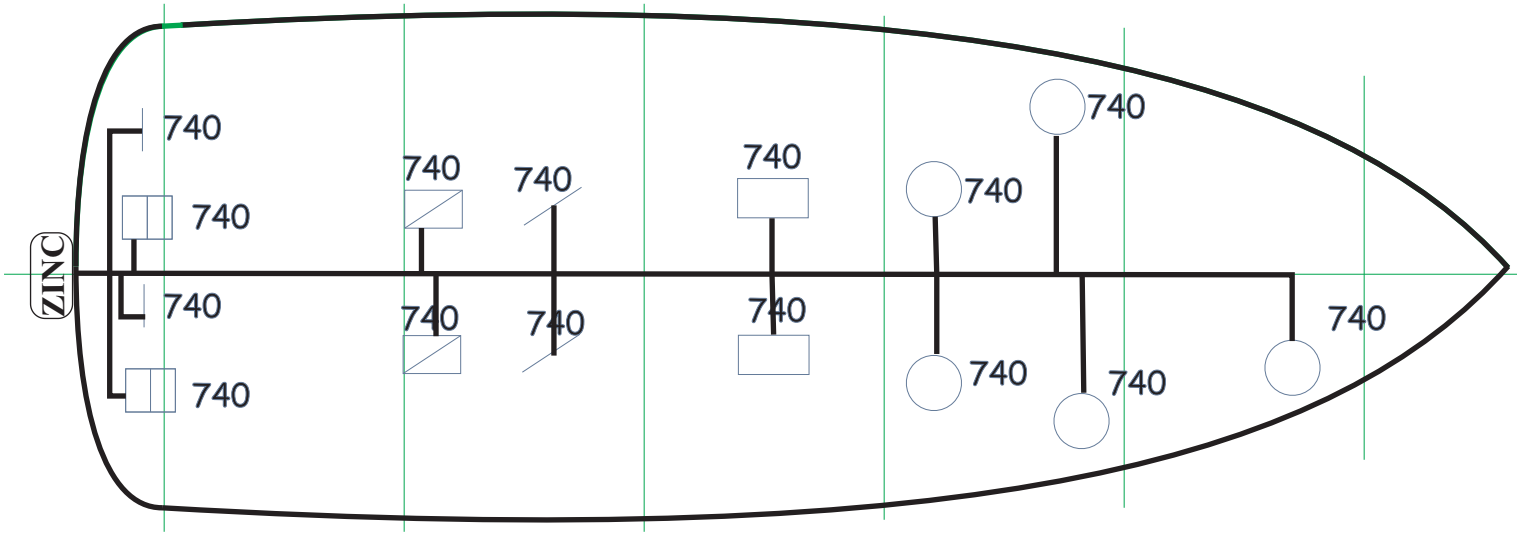


Remember the engine has its own body of water andprotection. your half cell is not in its body of water so engine readings do not reflect conditions inside the engine,
Check the engine zincs visually. All the bronze fittings are in the 'freely eroding' range. After bonding, the readings at each piece should be the same.



Install a sacrificial anode (normally zinc) to the bonded boat.

Read the voltage. The voltage should be considerably above its 'freely eroding' range and will continue to rise for 5 to 24 hours, depending on the size of the zinc and the area of metal to be protected, until the boat has polarized.



If the zinc is large enough, the voltage will be in the green or higher (500 to 900 millivolts on bronze) and will protect the boat metal until the voltage drops to within 200 millivolts of its 'freely eroding' voltage

If voltage is too high, zinc is being wasted and wood could be damaged. A 'Corrosion Controller' can be installed in the system to control the output of the system and guard against stray current corrosion.

A.C. or D.C. equipment not designed for boats can do serious damage in a short period of time eg, – battery chargers designed for automotive use. Use only marine quality chargers. (Such as the band we manufacture, Sterling Mariner).

A.C. problems could be insulation breakdown, immersed wiring, incorrect wiring or equipment failure. Also, the A.C. system has a 3rd or 'safety ground' wire. If this 3rd (green) wire is connected to your bonding system, corrosion, excessive zinc loss and stray current problems could result. e.g. Corroded wiring on the dock could put 30 to 40 V.A.C. down this green wire without tripping the A.C. Breaker.

BOAT EARTHING

This tends to be a very emotive point with a lot of boat designers and would be electrical engineers picking a corner and arguing the point intensely.
The truth of the matter is that both ways work (boat earth connected to shore earth and boat earth isolated to shore earth.) the reasons for the different approaches tends to be as much political as technical.

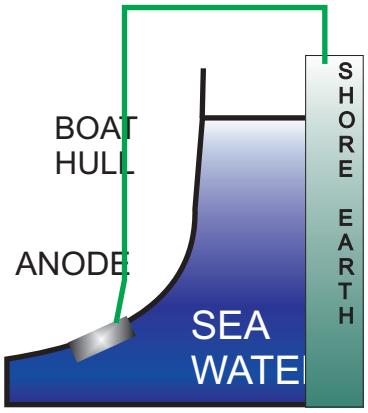
The American system of bonding the shore earth to the boat is actually a legal requirement.

The America Boat and Yacht Council (ABYC) recommends that the green wire be attached to the bonding system and most boat builders comply.

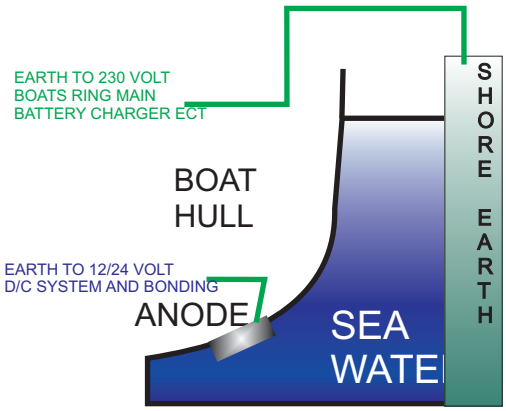
This on the surface appears to be the easiest and most obvious choice. However the shore earth will have a different potential from the sea water earth, thus the boats anodes can be subjected to all sorts of stray currents etc. (see A.C. and D.C. stray currents) . On top of this the Americans tend to use earth leakage detectors rather than the Residual Current Breakers which are adopted by the Europeans. Earth leakage detectors in them selves pose two main problems, 1) they require a earth wire (which a lot of Americas do not fit because to the problems it causes) and 2) if the wire falls off

of becomes degraded, the detector will not work.

Conclusion : because the Americas use earth leakage detectors rather than RCBs, the above system suits their purposes , in short they cause a problem (having to bond the boat to shore earth) then they have to fix the problem with zinc savers and isolation transformers etc.



AMERICAN SYSTEM
THE SHORE EARTH IS CONNECTED
TO THE BONDING/ZNODE ON THE BOAT



EUROPEAN SYSTEM
THE SHORE EARTH IS TOTALLY
ISOLATED FROM THE BOAT
BONDING SYSTEM

There are several ways to protect against

1) excessive loss of zinc,
2) stray currents originating off the boat and
3) stray current originating on the boat.

A) A CORROSION CONTROLLER to monitor zinc protection and all stray currents wherever they originate and to control zinc consumption, plus a **ZINC SAVER** to stop zinc loss to the dock (if shore earth is connected to the boats bonding system). Our **ZINC SAVER** is also certified as a galvanic isolator.

B) On metal boats the surface area of the zinc controls consumption. A **CORROSION MONITOR** will identify all stray currents and their source. A ZINC SAVER will stop zinc loss to the dock

C) An Isolation Transformer. (if the shore earth is connected to the boats bonding system) The green wire terminates at the transformer cage. Zinc loss to the dock and

dock stray currents are eliminated.

IMPORTANT NOTE:

Cutting or disconnecting the 'Green Wire' in the shore cord is **up to you, in Aamerica you must not in Europe you still have the option.** This will stop the loss of zinc or ships' metal to the dock or to other boats. It will also stop A.C. and D.C. currents from coming aboard and destroying your boat metal as these currents exit into the water.

ZINC SAVER

If the dock cord green wire is attached to your bonding system (an A.B.Y.C. recommended connection) and another boat in the area has an A.C. green to bonding connection, you have formed a battery. The higher voltage boat (yours 800-900 millivolts) will lose zinc towards the dock (200 millivolts) and to all other lower bonding system voltage boats in the general area with the green A.C. to their bonding systems.

A ZINC SAVER installed between A.C. green wire system and D.C. bonding system stops zinc loss to other boats and to the dock while maintaining A.C. safety ground protection. This product is part of the Sterling Range.

STRAY CURRENT CORROSION

(Commonly called Electrolysis – a misnomer)

As you have learned in the section about Galvanic Corrosion, the metal that is more active (higher in voltage) loses its material to the metal that is less active. Stray current corrosion is similar except that the voltage and current flow is created by an outside electrical source rather than spontaneously in nature, normally with much more force than galvanic action and could deteriorate our valuable metal in a very short period of time.

A problem with the boat's own d.c. system, own a.c. system, the dock's a.c. system or other boats on the dock could cause stray current corrosion.

HOW TO CHECK FOR STRAY CURRENT PROBLEMS

The 'Corrosion Survey Checklist is easy to follow and is all the information needed to survey a vessel.

If the boat is properly bonded, attach the Portable Corrosion Test Meter probe to

one fitting with the sensor in the water. The meter will now show the hull potential. Turn on and off all A.C. & D.C. circuit breakers and master switches including the ship-shore power transfer switch. Unplug the shore cord from the boat.

Note the hull potential

Plug in the shore cord – check meter for change.

If the meter changes (sustained change, not just a pulse) there is stray current or zinc loss down the ground wire or between the power inlet and the master switch or breaker. Find and fix the problem.

If there is no meter change, turn on the first switch or breaker in line (usually ship-shore or shore power breaker). If meter changes find problem.

If no meter change, go on to next switch or breaker in line. Removing problems as they are encountered or note them and correct after survey is completed.

Each problem circuit must be checked by tracing the wire from the output side of the breaker on down to the appliance or appliances involved and on back to the neutral bus.

Every time there is a branch in the circuit, the wires can be separated, one at a time in each case checking the meter to see which branch contains the problem. By process of elimination, the faulty appliance or part or wire will be located.

After all the A.C. breaker circuits have been checked, then the D.C. panel can be checked the same way starting by disconnecting the batteries from the boat system, read the system voltage on your PORTABLE CORROSION TEST METER then reconnect the batteries. Check each D.C. circuit and run all D.C. equipment including engines.

It is important that as each circuit is turned on the equipment actually controlled by the circuit should actually turn on. (I.E: If the water is hot in a water heater one must run the hot faucet until cold to turn on the element).

Common stray current sources are.

A.C, polarity reversals.

Improperly installed polarity alarms (low resistance polarity indicator circuits

should include a normally off, momentary test switch).

A.C. shorts from live to case

Frayed, cut or waterlogged insulation
.
Wire in bilge water.

Salt bridges on terminal strips or junction blocks.

Staples, nails or screws through wires
.
Improperly grounded equipment
.
D.C. equipment using bonding system for return wire negative.

Loose connections, etc., etc,, etc.

MECHANICAL CORROSION

Turbulent water, high velocity water (especially at bends in cooler tubing) and silt laden water will all cause erosion of metals. Increased velocity inside a tube or across metal surfaces of boats in tidal water or drifting will also cause increased erosion,

Propellers have several special problems besides the normal problems of bronze (dezincification, galvanic and stray current corrosion) in that they have large uneven surfaces exposed to tidal currents which causes electrical differences on different areas of surface and also differences in voltage due to the different speed between the hub and blades. Turbulence and pounding cause erosion also. Besides balancing the shaft and propellers, bonding using shaft straps and zinc systems will normally keep prop erosion to a minimum by evening out the voltage over the entire prop surface.

Metals not suited for the purpose such as manganese bronze bolts used on a wood boat hull structural application will break as the wood works (especially if the metal dezincifies).

Water flowing across a metal surface can produce positive and negative areas on the same surface. Corrosion results. A zinc system will even out the voltage.

CORROSION CONTROL SYSTEMS

Below are systems listed in order of complexity and expense.

Galvanic corrosion can be controlled by:

✎A) Bonded system with zinc

Advantages: Protects against Galvanic Corrosion
Adds to lightening protection and radio ground

Disadvantages: No control over zinc output
Stray current corrosion can not be tested or observed
Wide range of zinc voltages Decreased voltage when boat is moving Normal voltage can destroy wood hulls

✎B) Bonded system with zinc and manual zinc controller

Advantages: Protects against Galvanic corrosion and wood damage
Adds to lightning protection and radio ground
Zinc can be controlled (with aid of portable test meter).

Disadvantages: Daily zinc voltage or stray current corrosion can not be tested or observed
Decreased voltage when boat is moving

C) Bonded system with zinc and manual controller with built in corrosion test raider

Advantages: Protects against Galvanic Corrosion
Adds to lightning protection and radio ground
Zinc output & voltage can be controlled
Stray current corrosion can be tested and observed

Disadvantages: None – The boat captain must monitor any system and a slight adjustment of the control knob once or twice a month will keep protection at exact levels.

D) Bonded system with zinc and automatic zinc controller.

Advantages: Protects against Galvanic corrosion
Zinc output voltage automatically controlled
Stray current corrosion can be tested and observed
Increased current when boat is moving

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Decreased voltage when boat is moving

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Zinc can be controlled (with aid of portable test meter)

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Decreased voltage when boat is moving

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Bonded system with zinc and automatic zinc controller.

Advantages: Protects against Galvanic corrosion

Zinc output voltage automatically controlled

Stray current corrosion can be tested and observed

Increased current when boat is moving

Disadvantages: Does not automatically protect against stray current corrosion.

Meter must be observed.

More complex

More expensive

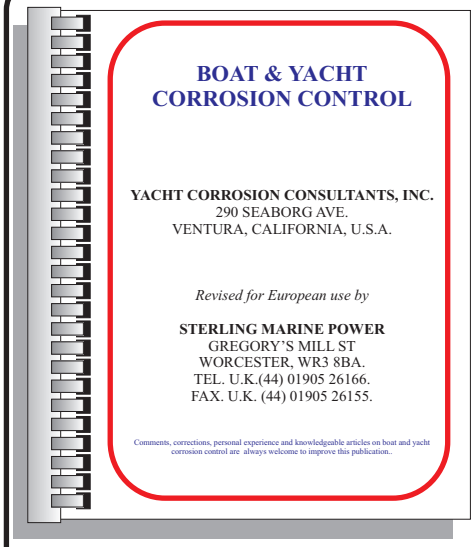
Can cover up beginning of problems or small stray currents

Impressed Current System

Advantages:	All of zinc system advantages plus exact output voltages and some stray current corrosion protection
Disadvantages:	Does not automatically protect against all stray current corrosion (Meter must be observed)
	High initial equipment and installation cost and more complicated to repair
	Bonded fittings must be very well done and checked often
	System failure could destroy metal

Each system has its pro's and con's.

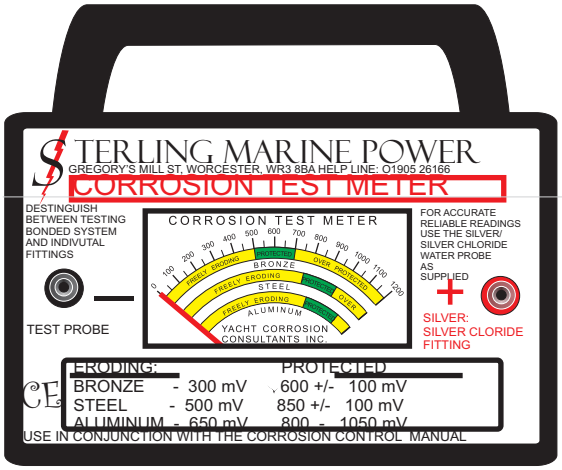
If an automatic zinc controller is used the Corrosion Controller test meter should be viewed each time one goes on board. A simple adjustment of the corrosion control knob will adjust protection up or down and should not vary substantially over several weeks. Voltage and current change slightly with the salinity, temperature and flow of the electrolyte (sea water). Stray current corrosion can strike at any time through several sources including your D.C. system, your A.C. system, the dock's A.C. system and other boats on your dock and a daily check is warranted.



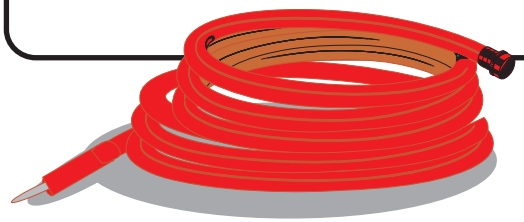
YACHT CORROSION TEST METER AND WORKBOOK

- *Sterling Part No. CTMB*

Within one hour, this easy to understand workbook and Test Meter will enable you to perform full corrosion surveys.
This workbook takes all the guesswork out of corrosion control -
Written for the non-technical person, this book answers questions and corrects misunderstandings about galvanic corrosion.
It explains in detail - with worked examples - how to survey your boat to prevent corrosion, and also how to easily identify and prevent any stray A.C or D.C. currents which can quickly cause unseen - but major damage to your boat
This workbook and test meter are all you need to solve corrosion problems on any vessel



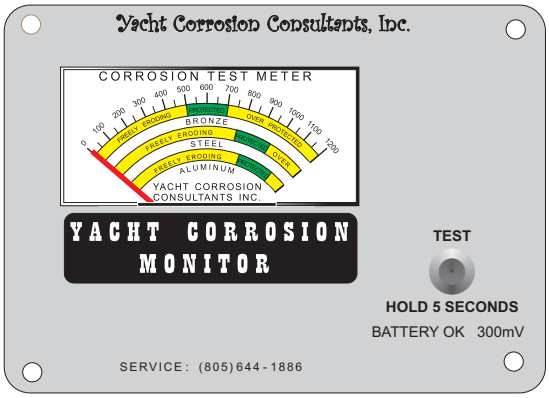
The Analog Corrosion Test Meter is supplied complete with:-
20ft red lead with essential Silver/Silver chloride half cell
10ft black lead test probe
This easy to read meter finds all corrosion problems instantly.



20ft EXTENSION LEAD For above TEST METER

Sterling Part No. TCRT20

Where larger boats are being surveyed the standard 20ft lead will need to be



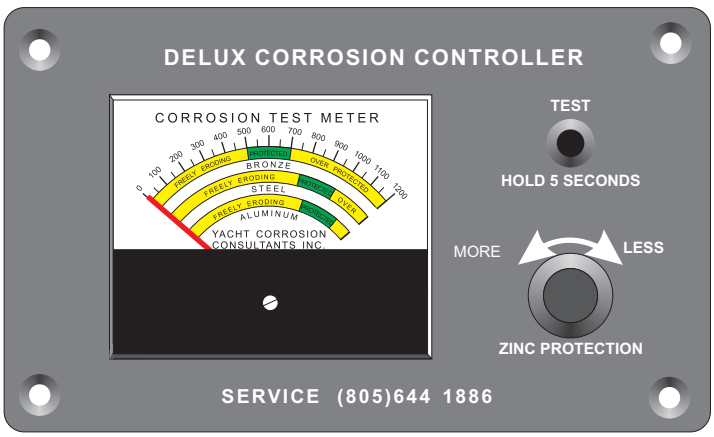
YACHT CORROSION MONITOR -

Sterling Part No. CYM

This on board, panel mounted meter, monitors galvanic voltage and is suitable for boats up to 65ft
It instantly confirms adequate protection or identifies damaging corrosion voltages.
Simple YELLOW and GREEN scale monitors the voltage.
Supplied with Silver/Silver Chloride half cell sensor
Gives clear indication if anodes need to be replaced and instantly

DELUX CORROSION CONTROLLER & MONITOR - *Sterling Part No.CYMPLUS*

This attractive panel mounted unit monitors galvanic voltage and by simply adjusting the control minimises zinc consumption and ensures maximum anode life.
Suitable for all boats up to 65ft
Instant adjustment ensures adequate protection at all times by correcting any damaging corrosion voltages.
Prevents wooden hull damage by lowering normal zinc voltages.
Simple YELLOW and GREEN scale monitors the voltage.
Best for salt water use
Supplied with Silver/Silver Chloride half cell sensor



BONDING.

Bonding provides a low-resistance electrical path between metals in contact with sea water. This path protects against self-generated galvanic corrosion, is helpful against, other types of corrosion and lightning and also acts as a radio ground.

Before bonding water turbulence and velocity should be minimized and any stray current problems should be detected and corrected at source.

Although the bonding system normally will only carry the protective current of the sacrificial anode, (usually under 1 amp) we recommend using a 2.5mmý wire or larger in order to insure a low resistance path. Over 20' length, use 4mmý wire over 40' length use 6mmý wire.

If the wire is insulated, the insulation should be of a green colour to designate its purpose. Solid or heavy stranded wire is best to resist corrosion but will break if allowed to flex. Stranded wire does not break as easily as solid but care must be taken with sealing connections as stranded wire corrodes much more easily. Copper braid is not recommended.

Bonding may be painted as long as non-metalic paint is used.

HOW TO BOND.

Inside the hull, connect all metallic parts touching water, including bilge pumps, intake strainer, etc. together in a neat, short route, all connections secure, with a 2.5mmý or larger copper wire, copper strap or similar bonding conductor. Connect this system to the engine block and to sacrificial anode. One method is to run a wire fore and aft, branching off to the individual metal parts.

This bonding, if bare metal, should be insulated from contact with wood, especially if the wood is damp. Electricity attempting to flow through the dampness reacts with the wood causing a foamy white substance and softening of the wood. (White substance around large metal fittings such as shaft log or rudder logs can be controlled by improving bonding system and lowering the voltage and current flow with the Corrosion Controller). Keep the bonding wire from being immersed as the water will corrode the conductor.

Soldering is a good method to secure the bonding wire to metal fittings but is rarely possible as the water acts as a heat sink. Another method is to thoroughly clean a spot

on a metal surface, use an all-stainless hose clamp to mechanically secure the wire and seal the connection against the environment with a long lasting, low water absorbing two-part dielectric removable epoxy. All connections should be soldered and sealed and wiring under clamps should have a heavy solder piece or wire end affixed to provide a secure grip for clamps.

Props and shafts are not always electrically connected to the engine block as the transmission oil acts as an insulator. A high quality motor brush (preferably metal graphite) riding on the shaft with a wire attached to the bonding system is a good method of connecting the prop and shaft to the bonding system.

Some experts contend that the prop and shaft can have its own zinc collar and stay separate from the boat zinc system. For less installation and less turbulence to the prop and shaft, not even including the lightning protection and elimination of possible radio interference that the prop shaft could produce, we recommend a stern zinc and shaft brushes with no shaft zinc collar (or rudder buttons, etc).

Rudder shafts sometimes do not have a good electrical connection to the rudder bearing. A flexible loop of wire should connect the shaft and rudder to the bonding system.

On most power boats a place can be found on the stern under water to install sacrificial anode mounting bolts. On boats that are underway over 400 hours per year, the zinc anodes should be of streamlined configuration; with fairing block and be installed as to not disturb the smooth flow of water to props. Always remember to ensure that the zinc is underwater at all speeds.

Wood boat mounting bolts, zincs and bare metal bonding straps should be insulated from contact with the wood as electricity from a bonding system attempting to flow through the damp wood cause the wood to foam and soften much like wood rot.

On sailboats, concerned with the speed loss from drag of zinc, (although slight) a wing nut assembly can be installed on the cabin side. This wing nut is connected to the bonding system inside the boat and to an overboard zinc that can be detached while sailing.

The better the protective coating (paint, etc.) the less sacrificial anode needed.

Exterior mounted metal touching water must be bonded also, , (Such as swim step, trim tabs, etc.,) or have own zinc if difficult to put in bonding system.
The engine, containing a separate body of water will not be protected by the boat's

bonding system even though the bonding system is attached to the engine block. The engine voltage readings will be inaccurate as your half cell is reading from a different body of water. Engine zincs look like pipe plugs in your engine block. When the zinc pieces attached to these plugs deteriorate, a new zinc should be installed.

Most electrical installation manuals will recommend fuel tanks, fuel pumps, fuel fill fittings etc. be added to the bonding system as a spark deterrent.

Never use bonding wire or system as a current carrying wire on a D.C. System.

A positive ground D.C. system (unsual on boats) should be changed to a negative ground system. Shorts to seawater on a positive ground boat causes the entire grounding system to be anodic (more active) and the entire bonded system to quickly corrode.

In a twin engine boat system with a crossover (or emergency) starting method, be sure to attach the engines together with a heavy enough bonding cable to carry a starting current. If the common ground should fall off the battery, the engine would try to start through the fuel lines, etc.

Metallic base paints and preservatives can aggravate galvanic corrosion on a hull especially if the hull screws and fittings are far apart on the Noble scale. Current flows through metal in paint.

Fresh water systems may require a higher voltage and less current than saltwater systems. Pollution, minerals and current can all help to destroy metals in fresh water.

Sacrificial anodes not connected to a metal will not protect that metal.

METAL BOAT HULLS

The hull is part of the common bonding. Any part touching the water not connected to the hull must have a conductor attaching it to the hull.

Fittings that are more than 200 millivolts apart on the Noble scale from the hull material should be insulated from the hull.

Bronze fittings isolated from steel or aluminum hulls can have their own bonded systems to their own isolated zinc.
Metallic base paints can cause galvanic corrosion on metal hulls.

The better the protective coatings (paint, etc.) the less anodic protection needed.

Over voltage causes amphoeteric attack on aluminum(1100mV+) and hydrogen gas to form on steel(1200mV+). Damp wood mounting blocks will deteriorate with over voltage (550mV+).

FERRO CEMENT HULLS

Ferro cement hulls should be treated the same as metal hulls as corrosion in the metal mesh (armature) could seriously weaken the hull.

ALUMINUM HULLS

All metals parts more Noble (lower in voltage) then aluminum must be insulated from the aluminum.

Aluminum is amphoteric and can be easily damaged by over voltage (1100mV+) Zinc (1050mV) cannot hurt aluminum.

Aluminum anodes can be secured with type 300 stainless steel bolts,

Zinc anodes with aluminum core can be used.

Recent studies have proven that aluminum is protected within a range of 800mV to 1050mV. A good quality zinc of the proper size will keep aluminum in this range.

The surface area of the anode determines the voltage. One can hang anodes over the side electrically connected to the hull until the hull reaches the proper voltage.

If the anodes are welded to hull you lose surface area and the voltage will be less.

It is better to tape the surface which will be lost against the hull before you hang the anode over the side.

To be protected a metal must be connected to the zinc. When a boat is out of the water one can read between the zinc and all underwater fittings to determine bonding integrity. Use a digital type ammeter or a good anolog meter able to measure

50,000*p*. A reading of around 30*p* is acceptable.

On outdrives it is very common for pieces that are bolted together not to be connected to the zinc.

Also check the rams in down, mid and up positions.

ACTUAL SURVEY REPORTS.

Here a few survey reports of actual boats.

Make believe you are the surveyor on the reports.

There is a logical reason for each of the readings and evaluations.

After each survey there is a page of notes.

CORROSION SURVEY REPORT

Sterling Marine Power, Gregory's Mill St., Worcester. Help Line - Tel. 01905 26166 Fax 01905 26155

Ref. No.

Date

Name FOXTAIL II		Details of Vessel
Type	Length	Approx. year of construction
Builder & model		Hull material /construction WOOD

Title	Name	Details of Owner
Address		
		Daytime Phone No.
Post Code		Home Phone No.

Reason for survey/suspected problems etc.

OWNER REPORTS SNOW LIKE FOAM AT SHAFT LOGS STRUTS AND RUDDERPOSTS.

Propeller Shafts		Engine	
Stern Tubes		Filter	
Rudder Shafts		Bow Thruster	
Rudder Shaft Tubes		Transducer	
Shaft Brushes		Through Hull Fittings	No.?
	1	Anode Zinc	
	2		3

USE THIS TABLE IS FOR METALLIC FITTINGS ONLY

ANY A.C. STRAY CURRENT PRESENT?	NO
ANY D.C. STRAY CURRENT PRESENT?	NO

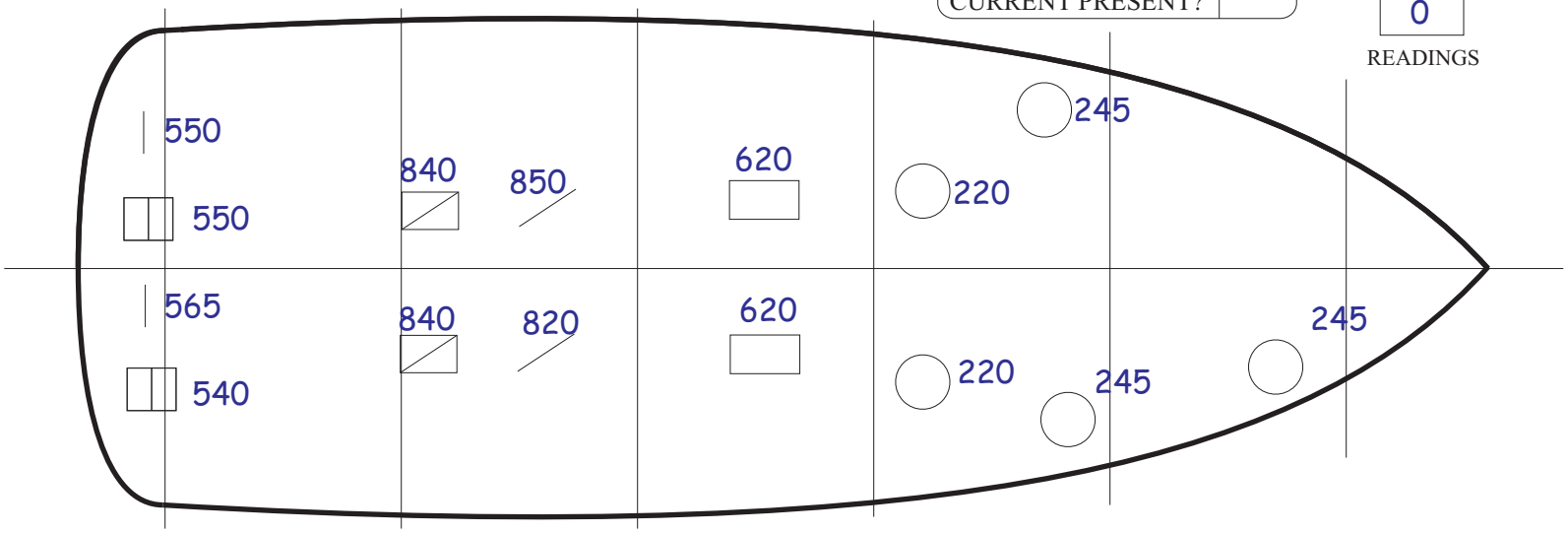
A.C. INLET

0 0

N L E

0

READINGS



Results

NO BONDING / SEPARATE ZINCS ON SHAFTS AND RUDDERS / WOOD BURNING FROM UNCONTROLLED OVER ZINCING / WOOD WET

Remedial work required

BOND BOAT AND INSTALL SHAFT BRUSHES / REMOVE INDIVIDUAL ZINCS INSTALL ZINC AT STERN / INSTALL ZINC CONTROLLER / KEEP BILGES DRY BOAT A.C. IS NOT GROUNDED TO HULL. INSTALL ZINC SAVER AND GROUND A.C. GREEN WIRE TO BONDING SYSTEM.

Signed/Surveyor.. T.M.

NOTES ON FOXTAIL II CORROSION SURVEY

| 850 & | 565 mean the rubber shafts are being protected by their own zincs.

(Bronze - 500 - 700 protected)

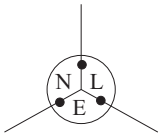
|| 540 means rubber shaft log has a poor connection to rudder shaft . should be the same voltage if connections were good.

/ 850 & / 870 & - the props and shafts have own zincs and are being

⊘ 840 to ⊘ 860 - the shaft logs are being protected but have a poor connection to shaft. higher than necessary voltage is burning wood. (Bronze 500 - 700 protected)

▭ 620 + 630 - the engine has own body of water and own zincs. check zincs.

○ 220 to ○ 245 - all bronze through hulls are 'freely eroding' and should be protected.



Pins on boat receptacle have no adverse readings on corrosion test meter, but a.c. green wire is not grounded to the hull as recommended by ABYC ground system and install zinc saver.

CORROSION SURVEY REPORT

Sterling Marine Power, Gregory's Mill St., Worcester. Help Line - Tel. 01905 26166 Fax 01905 26155

Ref. No.	
Date	

Name SHOCKWAVE		**Details of Vessel**
Type	*Length*	*Approx. year of construction*
Builder & model		*Hull material /construction* FIBERGLASS

Title	*Name*	**Details of Owner**
Address		
		Daytime Phone No.
	Post Code	*Home Phone No.*

Reason for survey/suspected problems etc.

CORROSION ON THROUGH HULLS
HEAVY CORROSION ON SHAFT AND PROP

Propeller Shafts		Engine	
Stern Tubes		Filter	
Rudder Shafts		Bow Thruster	
Rudder Shaft Tubes		Transducer	
Shaft Brushes		Through Hull Fittings	No.?
	1		2
	3	Anode Zinc	

USE THIS TABLE IS FOR METALLIC FITTINGS ONLY

ANY A.C. STRAY CURRENT PRESENT?	YES
ANY D.C. STRAY CURRENT PRESENT?	NO

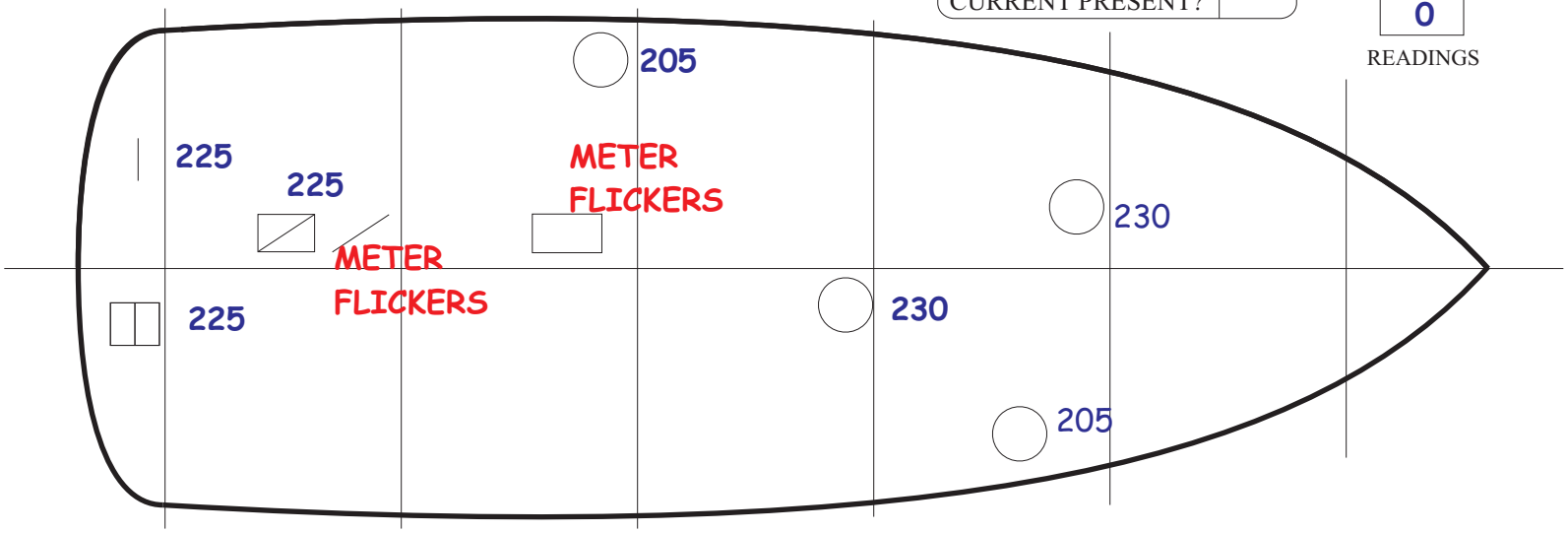
A.C. INLET

800 0

N L E

0

READINGS



Results

NO BONDING / HOT WIRE ON A.C. SHORE CORD CONNECTED TO ENGINE AND PROPSHAFTS

Remedial work required

TRACE AND CORRECT A.C. WIRING/ REPLACE SHAFT AND PROP/ INSTALL SHAFT BRUSH, BONDING, ZINC CONTROLLER AND LEAVE OFF ZINC COLLAR FROM SHAFT. CONNECT A.C. GROUND BONDING PER. ABYC - CONNECT & INSTALL ZINC SAVER

Signed/Surveyor..

NOTES ON ‘SHOCKWAVE’ CORROSION SURVEY.

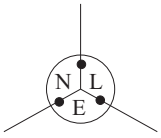
225 - No protection on bronze rudder and shaft.

205 - 230 - no protection on bronze thru hulls.

& - meter flickers - stray current problems

Pull shore cord and read boat receptacle pins - hot wire has 800 reading. (normal reading for uncontrolled shaft zinc.)

Find and remove the connection between hot wire and d.c. ground immediately.



Connect green a.c. ground to bonding system and install zinc saver.

CORROSION SURVEY REPORT

Sterling Marine Power, Gregory's Mill St., Worcester. Help Line - Tel. 01905 26166 Fax 01905 26155

Ref. No.	
Date	

Name CARAMIA		**Details of Vessel**
Type	*Length*	*Approx. year of construction*
Builder & model		*Hull material /construction* FIBERGLASS

Title	*Name*	**Details of Owner**
Address		
		Daytime Phone No.
Post Code		*Home Phone No.*

Reason for survey/suspected problems etc.

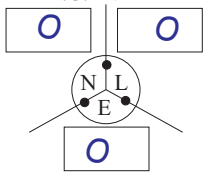
DIVER REPORTS ALL THROUGH HULL FITTINGS FORWARD OF ENGINE CORRODING

Propeller Shafts		Engine	
Stern Tubes		Filter	
Rudder Shafts		Bow Thruster	
Rudder Shaft Tubes		Transducer	
Shaft Brushes		Through Hull Fittings	No.?
	1		2
	3	Anode Zinc	

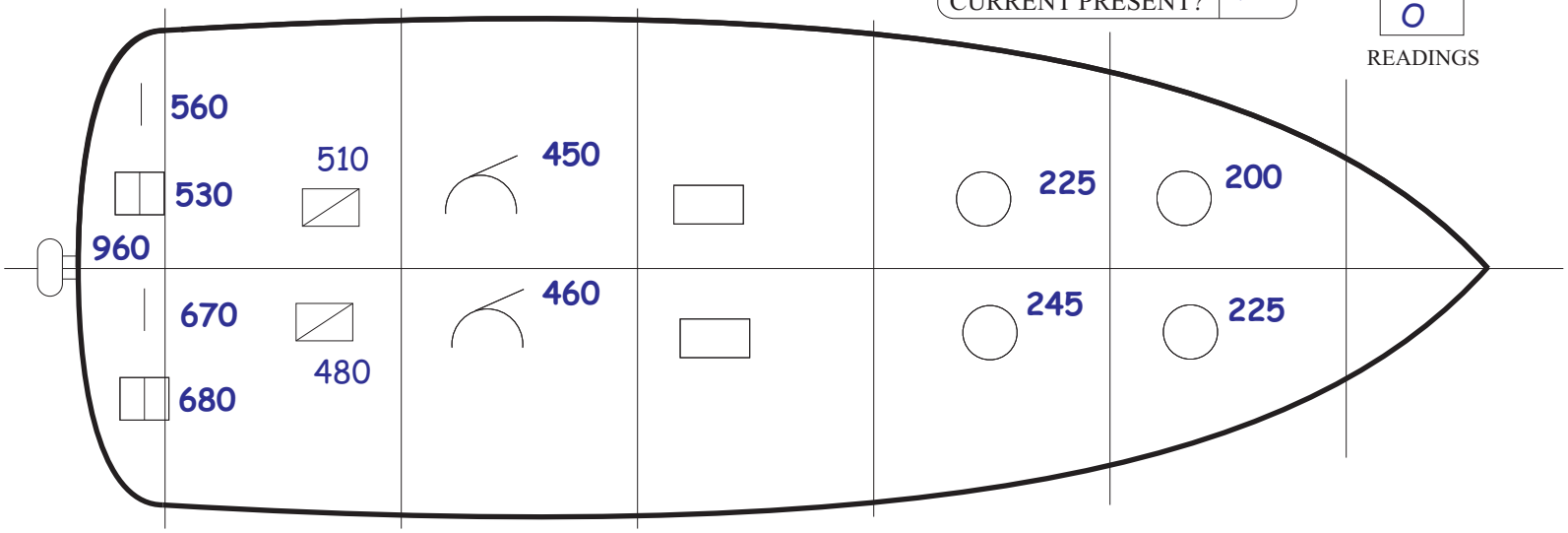
USE THIS TABLE IS FOR METALLIC FITTINGS ONLY

ANY A.C. STRAY CURRENT PRESENT?	NO
ANY D.C. STRAY CURRENT PRESENT?	NO

A.C. INLET



READINGS



Results

BONDING NOT SOLDERED OR SEALED AND HEAVILY CORRODED / BONDING WIRE BROKEN BETWEEN BOTH ENGINES AND COOLING INTAKES - 8" WATER IN BILGES - NO AUTO BILGE PUMP / STBD LOG LEAKING

Remedial work required

RE-BOND BOAT - SOLDER AND SEAL CONNECTIONS - TIGHTEN SHAFT PACKING INSTALL AUTO BILGE PUMP - INSTALL CORROSION CONTROLLER WIRE A.C GROUND TO BONDING SYSTEM INSTALL ZINC SAVER

Signed/Surveyor..

NOTES ON ‘CARAMIA’ CORROSION SURVEY.

Boat bonded but bonding damage by corrosion and stress resulting from poor installation. (Readings not the same at each bonded piece)

◯ 225 to ◯ 245 - Forward thru hulls not bonded.

CORROSION SURVEY REPORT

Sterling Marine Power, Gregory's Mill St., Worcester. Help Line - Tel. 01905 26166 Fax 01905 26155

Ref. No.	
Date	

Name GOIN HOME		**Details of Vessel**
Type	*Length*	*Approx. year of construction*
Builder & model		*Hull material /construction* FIBERGLASS

Title	*Name*	**Details of Owner**
Address		
		Daytime Phone No.
	Post Code	*Home Phone No.*

Reason for survey/suspected problems etc.

EXCESSIVE ZINC USE - DIVER REPORTS CORROSION ON ALL THROUGH HULL FITTINGS AND PROP

Propeller Shafts	Engine
Stern Tubes	Filter
Rudder Shafts	Bow Thruster
Rudder Shaft Tubes	Transducer
Shaft Brushes	Through Hull Fittings No.?
1	2
3	Anode Zinc

USE THIS TABLE IS FOR METALLIC FITTINGS ONLY

ANY A.C. STRAY CURRENT PRESENT?	YES
ANY D.C. STRAY CURRENT PRESENT?	NO

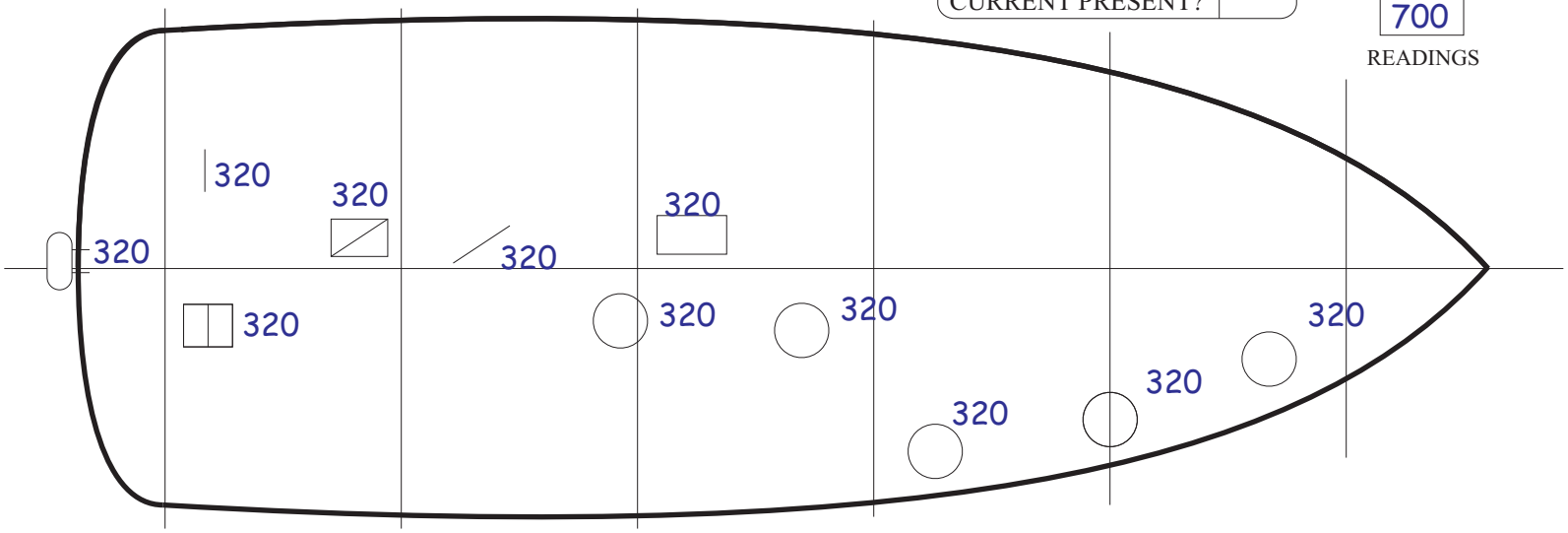
A.C. INLET

0	0

N L E

700

READINGS



Results

A.C. 'ON' READINGS 320- A.C. 'OFF' 770-A.C. RECEPTACLE ON DOCKS READS 30V A.C. BETWEEN NEUTRAL AND GROUND (SHOULD BE ZERO)

Remedial work required

INSTALL ZINC SAVER IN A.C. TO GREEN WIRE TO ENGINE BLOCK
INSTALL CORROSION TEST METER AND CONTROLLER - REPORT DOCK PROBLEM TO DOCK MASTER - REPLACE PROP. THROUGH HULL

Signed/Surveyor..

NOTES ON ‘GOIN HOME’ CORROSION SURVEY.

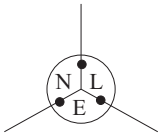
Boat well bonded - all readings are the same - 320 (freely eroding zone on meter).

Pull shore cord - Green wire pin on boat receptacle reads 770 - shore cord reads (with a.c. voltmeter) 30 volts between green and white wires (should be 0)

Checked one fitting again - reading 700 (only necessary to read one fitting - boat well bonded).

Serious A.C. stray current problem coming from dock.. Leave A.C.. cord unplugged and notify dock master.

Boat owner could have saved his prop and thru hulls with a corrosion test meter.



= A.C. Earth wire (green) is connected to the D.C.. ground system. Find wire and install zinc saver.

CORROSION SURVEY REPORT

Sterling Marine Power, Gregory's Mill St., Worcester. Help Line - Tel. 01905 26166 Fax 01905 26155

Ref. No.	
Date	

Name FUN TIME	**Details of Vessel**
Type / *Length*	*Approx. year of construction*
Builder & model	*Hull material /construction* FIBERGLASS

Title / *Name*	**Details of Owner**
Address	
	Daytime Phone No.
Post Code	*Home Phone No.*

Propeller Shafts		Engine	
Stern Tubes		Filter	
Rudder Shafts		Bow Thruster	
Rudder Shaft Tubes		Transducer	
Shaft Brushes		Through Hull Fittings	No.?
	1		2
	3	Anode Zinc	

Reason for survey/suspected problems etc.

DIVER REPORTS THROUGH HULL FITTINGS
CORRODING ON PORT SIDE

USE THIS TABLE IS FOR METALLIC FITTINGS ONLY

ANY A.C. STRAY CURRENT PRESENT?	NO
ANY D.C. STRAY CURRENT PRESENT?	NO

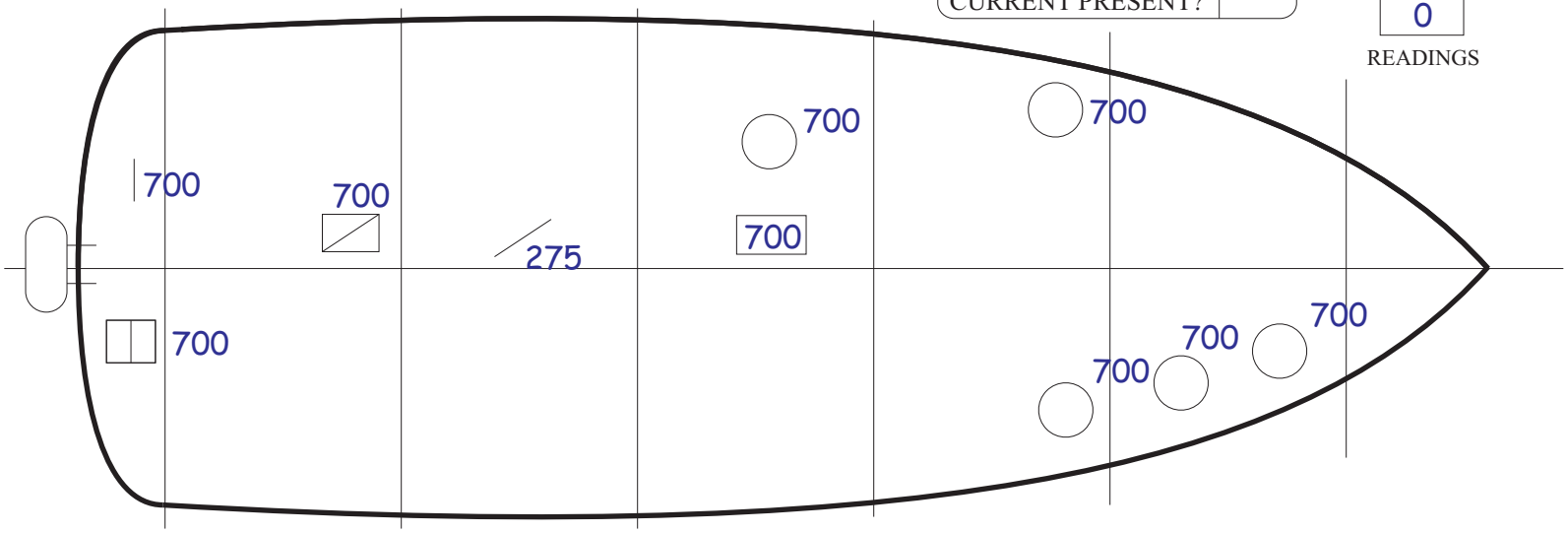
A.C. INLET

0 0

N L E

0

READINGS



Results

BONDING CONNECTIONS NOT SEALED - GALLEY SINK DRAIN CORRODING
SIX INCHES OF WATER IN BILGE - NO SHAFT BUSH

Remedial work required

RE-BOND GALLEY SINK THROUGH HULL FITTING - INSTALL SHAFT BRUSH
SEAL ALL CONNECTIONS - KEEP BILGE DRY - INSTALL CORROSION CONTROLLER

Signed/Surveyor.. T.W.

NOTES ON ‘FUN TIME’ CORROSION SURVEY.

Boat well bonded except for portside bronze through hull fitting and no shaft brush.

Portside through hull, prop shaft corroding.

Protect bonding connections.

Corrosion controller installation would make zinc last longer and allow boat owner to watch for problems.

CORROSION SURVEY REPORT

Sterling Marine Power, Gregory's Mill St., Worcester. Help Line - Tel. 01905 26166 Fax 01905 26155

Ref. No.	
Date	

Name LOTSALUCK	**Details of Vessel**
Type / *Length*	*Approx. year of construction*
Builder & model	*Hull material /construction* FIBERGLASS

Title / *Name*	**Details of Owner**
Address	
	Daytime Phone No.
Post Code	*Home Phone No.*

Reason for survey/suspected problems etc.

ENGINE COOLING SEACOCK DOES NOT CLOSE
NEW BATTERY LOSES CHARGE RAPIDLY

Propeller Shafts		Engine	
Stern Tubes		Filter	
Rudder Shafts		Bow Thruster	
Rudder Shaft Tubes		Transducer	
Shaft Brushes		Through Hull Fittings	No.?
Engine Intake	1		2
	3	Anode Zinc	

USE THIS TABLE IS FOR METALLIC FITTINGS ONLY

ANY A.C. STRAY CURRENT PRESENT?	NO
ANY D.C. STRAY CURRENT PRESENT?	YES

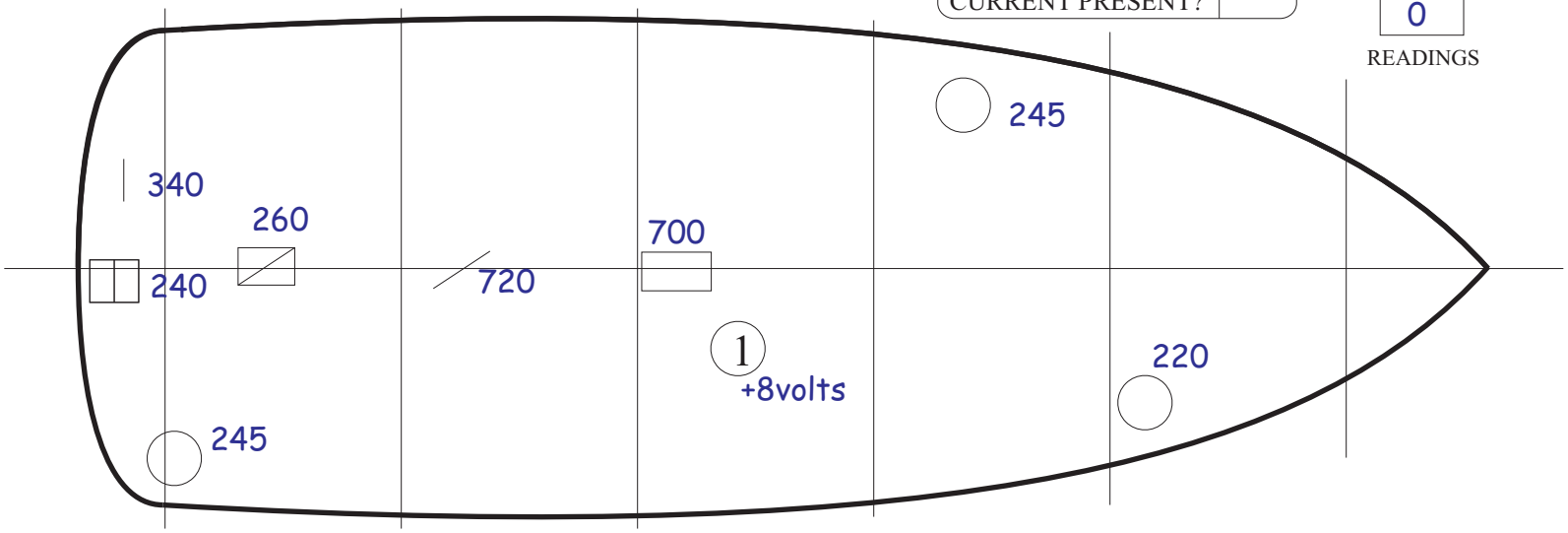
A.C. INLET

0	0

N L E

0

READINGS



Results

NO BONDING - RADIO GROUND WIRE ATTACHED TO POSITIVE BATTERY TERMINAL AND COOLING WATER INTAKE. A.C. GREEN NOT WIRED TO ENGINE/ BONDING SYSTEM AS RECOMMENDED BY ABYC.

Remedial work required

REMOVE GROUND WIRE FROM POSITIVE TERMINAL AND ATTACH TO NEGATIVE TERMINAL - REPLACE INTAKE VALVE - BOND BOAT, INSTALL SHAFT BRUSH AND CORROSION CONTROLLER - CONNECT A.C. GREEN WIRE TO BONDING SYSTEM AND INSTALL ZINC SAVER

Signed/Surveyor.. T.M.

NOTES ON ‘LOTSALUCK’ CORROSION SURVEY.

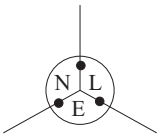
 340,  240,  260,  220,  245 - Freely eroding - Bronze not bonded.

 720 - Shaft has zinc collar.

 + 8 volts - Extremely serous D.C.. stray current problems.

Corrosion controller could have saved intake valve.

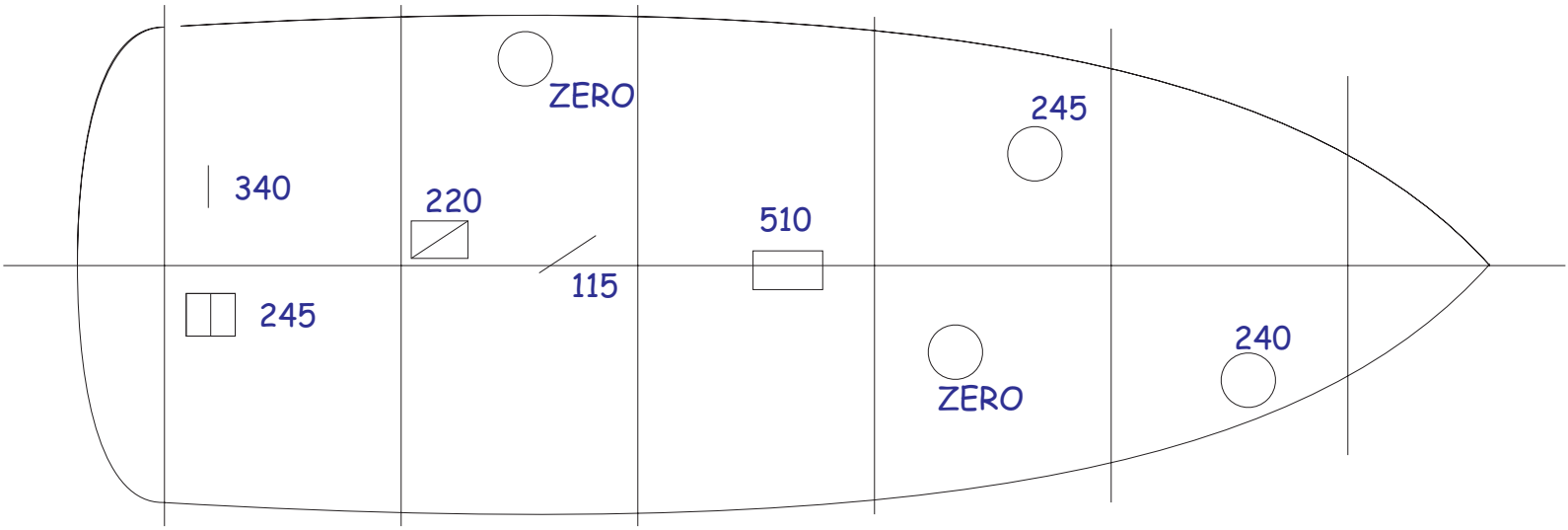
(If intake valve had failed (corroded away) - a week or two could do it - over 100 gallons an hour would have entered the boat)



0 readings no A.C. wiring connected to D.C. ground.

WHAT WOULD THESE READINGS MEAN

Voltages do not change when A.C. and D.C. are disconnected



EVALUATION

1. The boat is not bonded

2. No individual zincs are attached (bronze freely eroding - 250)

3. Boat has two plastic, or non metallic, through hulls (zero reading)

4. Monel shaft probably has no propellor attached (a bronze prop of any size would raise voltage over 200mV

RECOMMENDATIONS

1 Bond Boat

2. Attach zinc sacrificial anode (isolated from hull if wood boat.)

3. Install shaft strap to connect shaft and propellor to bonding system. (Oil in transmission often isolates engine from shaft

4. Install zinc controller and corrosion test meter.

5. Check engine zincs.

6. Verify A.C. ground wire to bonding system.

7. Install zinc saver.

GLOSSARY OF CORROSION TERMS.

AMPHOTERIC
Metals subject to attack by acids or alkalies. Aluminum is amphoteric and if over protected, is subject to severe corrosion.

ANODE
The more active - *less Noble, higher in voltage* - metal or area of metal in an electrolyte that protects the cathodic or less-active - *more Noble, lower in voltage* - metal or area by sacrificing itself. In an impressed current system the electrode that gives off current and sacrifices itself to protect the cathode.

CATHODE
The *more Noble, less active* area or metal in an electrolyte that is protected as the anode decays.

CAVITATION EROSION
The extreme turbulence created by a propeller in action, not only causes crystallization and fatigue of the metal, but also large localized pressure differences on the propeller's surface and in the surrounding water. Bubbles are formed and collapsed by the action and these areas of high stress become anodic - more positive - than other areas on the same surface and corrosion results. A zinc or impressed current system helps to even out the voltage and reduce the damaging effects.

CREVICE CORROSION
Some metals develop a film that protects against corrosion. In cracks and crevices this film is often broken and because of a lack of oxygen corrosion results. Stainless steel is very susceptible to crevice corrosion.

DEZINCIFICATION
Zinc is removed from the alloy thereby weakening the fitting. Bronze without zinc is very brittle. Some older boats with large fittings, get through hull fittings tested by striking them with a sledge hammer. If they shatter, they are replaced, if they do not, they are okay. Zinc anodes or an impressed current system will control dezincification.

DIELECTRIC SHIELD
Material that stops the flow of electricity such as plastic coatings on wiring, special epoxy sealants or non conductive paints.

ELECTROLYSIS
Chemical and/or electro mechanical changes in a solution due to the passage of an electrical current. Some boaters use this term incorrectly to mean galvanic corrosion or stray current corrosion.

ENGINE ZINCS
Small zinc anodes installed in the engine cooling system to protect the inside of the engine against galvanic corrosion. They resemble a pipe plug with a cylindrical piece of zinc threaded into it. The separate body of water inside the engine is not protected by the boats bonding and zinc system even though the bonding system is attached to the block of the engine. Engine zincs immersed in this body of water are its sole protection and should be checked regularly.

GALVANIC CORROSION
Corrosion resulting from electric current flow between dissimilar metals or dissimilar surfaces on one metal, in contact with the same electrolyte. This same natural phenomenon we see every day in flashlight batteries, automotive batteries, electroplating etc.

ION CONCENTRATION
When one area of the surface of a metal is exposed to higher velocity flow of electrolyte (seawater), metal ions of the electrolyte are washed away making this area anodic (more active) to an area of lesser flow in the same surface, corrosion results. Tidal currents can severely erode props, shafts and other exposed metal surfaces.

OXYGEN CONCENTRATION
When metal surfaces overlap, the water between the surfaces lacks oxygen making this surface more active (anodic) to the rest of the same metal. Galvanic corrosion results. A zinc or impressed current system would help to even out the voltage.

PITTING
Tiny areas on the surface of a metal where the protective film has broken allowing corrosion to take place. Stainless steel is very susceptible to pitting.

POLARIZATION
Initial current flow in a zinc system is high resulting in lower voltage readings until corrosion products (hydrogen gas, etc.) slow the current and the voltage stabilizes. From 5 to 24 hours depending on the size of the zinc and the area of metal to be protected is normal in boats and yachts.

SACRIFICIAL ANODE
The metal attached to a bonding system that is intentionally a higher voltage than the rest of the metal in the system so that this metal is sacrificial rather than the highest voltage boat metals and fittings.

SHAFT BRUSH
A device to connect the revolving shaft electrically to the bonding system.

STRAY CURRENT CORROSION
Similar to galvanic corrosion in that the more active areas lose material to the less active areas of metals in an electrolyte, but caused by an outside source rather than spontaneously. The boats D.C. system or A.C. system the docks A.C. system or other boats on the dock could be the source of stray current.

STRESS CORROSION
Heat transfer, 'working' of the metal and chemical attack all combine to cause brittleness and early failure.

WATER TEMPERATURE
Chemical activity is itself related to temperature. Corrosion will be greater where water is at elevated temperature. Sewer water can elevate the temperature of a tidal harbor up to a degree or more.

ZINC PAD
A mounting device to make zinc replacement easier and to insulate the zinc and current flow from the wooden or painted hull.

A mounting can be made by insulating threaded rod with heatshrink to the thickness of the hull and separating the nuts from the hull with non-current carrying washers (plastic, phenolic, etc.) - needed on wood hulls and metal hulls that need separate systems.

METALS.

These notes will not make you an expert on metals, but will give you a few tips on metal selection and what to be careful of in metal protection. An excellent handbook on the subject, is *Marine Metals Manual* by Roger Pretzer, International Marine Publishing Co., Camden, Maine.

When selecting boat metals that are going to touch each other or could be connected through moist wood, a good rule of thumb is, do not choose metals with over 200 millivolts difference in voltage. (see Noble scale with relative voltage reading).

A good example would be when an older hull, which has galvanized screws and bolts (1140 mV) and needs to be partially re-fastened. One should not use Monel (110 mV) or silicon bronze bolts (260 mV) side by side with the galvanized, as the galvanized bolts will quickly corrode away by galvanic action through the wet wood. Galvanized bolts would be a better choice, since over 550 millivolts damages wood - eventually the hull itself might have to be replaced!

There are quite a few imported Chinese junks which are fastened with handmade iron nails. Since these nails, composed of almost pure iron, are not in direct contact with the seawater and/or metallic based paints, they survive many years of service. To select a good companion fastener to these iron nails would be fairly easy with the corrosion control meter. First test a sample iron nail immersed in seawater and compare the voltage readings with available fasteners. Then select a suitable fastener within 200 millivolts of iron nail readings.

Never use a bolt or a screw that is lower on the Noble scale - *more active* - to fasten a metal fitting that is higher on the Noble scale - *less active*.

A mild steel bolt (700 mV) holding a bronze plate (260 mV) would quickly deteriorate.

When unsure of metals composition's, test each with the corrosion test meter. They should have approximately the same reading (within 200 mV). The further apart the two metals are on the Noble scale, the higher will be the voltage difference. The bigger the difference, the quicker the more active metal will deteriorate.

Monel 400 - (nickel/copper alloy) - Can be used under water even in contact with other metals. **Monel 500** is much stronger.

Silicon Bronze - (copper/silicon alloy). - Very corrosion resistant and not prone to de-zincification.

Aluminum Bronze - (copper/aluminum alloy). - is close to Silicon Bronze.

Phosphor Bronze. - Not quite as resistant as Aluminum or Silicon Bronze.

Manganese Bronze. - Very poor resistance to corrosion and stress. Manganese Bronze contains over 40% zinc. Bolts of this metal, holding working wood timbers together ,would de-zinc and any flexing would then break them.

Brass. - Never use in damp installations.

Naval Brass. - Tin content increases resistance to dezincification, but still is a poor substitute for a good bronze.

Aluminum alloys. - Used for hull and superstructures, but care should be taken, to keep them free of copper antifouling paint, and when attaching other metal parts directly to the surface.

Aluminum. - By itself aluminum is very stable in seawater. Corrosion takes place when other metals are attached. Any metals attached to aluminum must be very close on the Noble scale, even above decks, as in mast installations. If not, insulating separators can be used. A hard coating of protective aluminum oxide is quickly formed on exposed aluminum, so that even the pitting, which is common on aluminum, slows down after the first few months.

WHEN IS A ZINC ANODE NOT A ZINC ANODE?

Extreme care should be taken in the purchase of sacrificial zinc anodes. Military specifications are necessary for even voltages and proper protection. It is considerably less expensive to manufacture (or re-manufacture) poor quality anodes. It's easy to use die cast or junk zinc and then add some magnesium, so the zinc will erode. Good zinc anodes will corrode gradually and slough off any protective coating.

An anode made with poor quality zinc, may form it's own protective coating and may even not work at all. Ask your chandlery for the zinc's specifications - a good manufacturer will send specifications at your request.

The American Boat and Yacht Council recommends as follows:-

Zinc anodes should conform to military specification - MIL-A-18001.

- Lead (Maximum) - 0.006%
- Iron (Maximum) - 0.005%
- Cadmium (Range) - 0.25% to 0.15%
- Copper (Maximum) - 0.005%
- Aluminum (Range) - 0.1% to 0.05%
- Silicon (Maximum) - 0.125%
- Zinc - Remainder

Aluminum anodes should conform to B605 alloy or equivalent.

- Zinc (Range) - 5% to 6%
- Iron (Maximum) - 0.17%
- Copper (Maximum) - 0.2%
- Silicon (Maximum) - 0.1%
- Aluminum - Remainder

Magnesium anodes to military specification - MIL-A-21412 (Ships).

- Aluminum (Range) - 5% to 7%
- Zinc (Range) - 2% to 4%
- Manganese (Minimum) - 0.15%
- Silicon (Maximum) - 0.3%
- Iron (Maximum) - 0.003%
- Copper (Maximum) - 0.1%
- Nickel (Maximum) - 0.003%
- Other (Maximum) - 0.3%
- Magnesium - Remainder

STAINLESS STEEL.

Active & Passive .

Normally, stainless steel protects itself from corrosion by a naturally generated oxidized surface. This condition is called it's 'passive' state.

When this film is removed and unable to regenerate itself, the stainless steel will become 'active' and may deteriorate rapidly. Lack of oxygen in cracks or scratches in the surface, bring stainless to an active state.

Since crustacean growth, chlorides, pollution, stagnant water, damp wood and crevices will turn stainless from a passive to an active state, it is not recommended for underwater use.

Stainless '316', which contains some molybdenum, is superior to most other steel alloys and is used for prop shafts. Other types, particularly '302' may deteriorate rapidly underwater or when used in unsuitable conditions.

Car polish or wax will coat and protect stainless steel railings..

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Builder & model		*Hull material /construction*

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Propeller Shafts		Engine	
Stern Tubes		Filter	
Rudder Shafts		Bow Thruster	
Rudder Shaft Tubes		Transducer	
Shaft Brushes		Through Hull Fittings	No.?
	1	Anode Zinc	
	2		3

Reason for survey/suspected problems etc.

USE THIS TABLE IS FOR METALLIC FITTINGS ONLY

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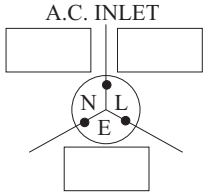

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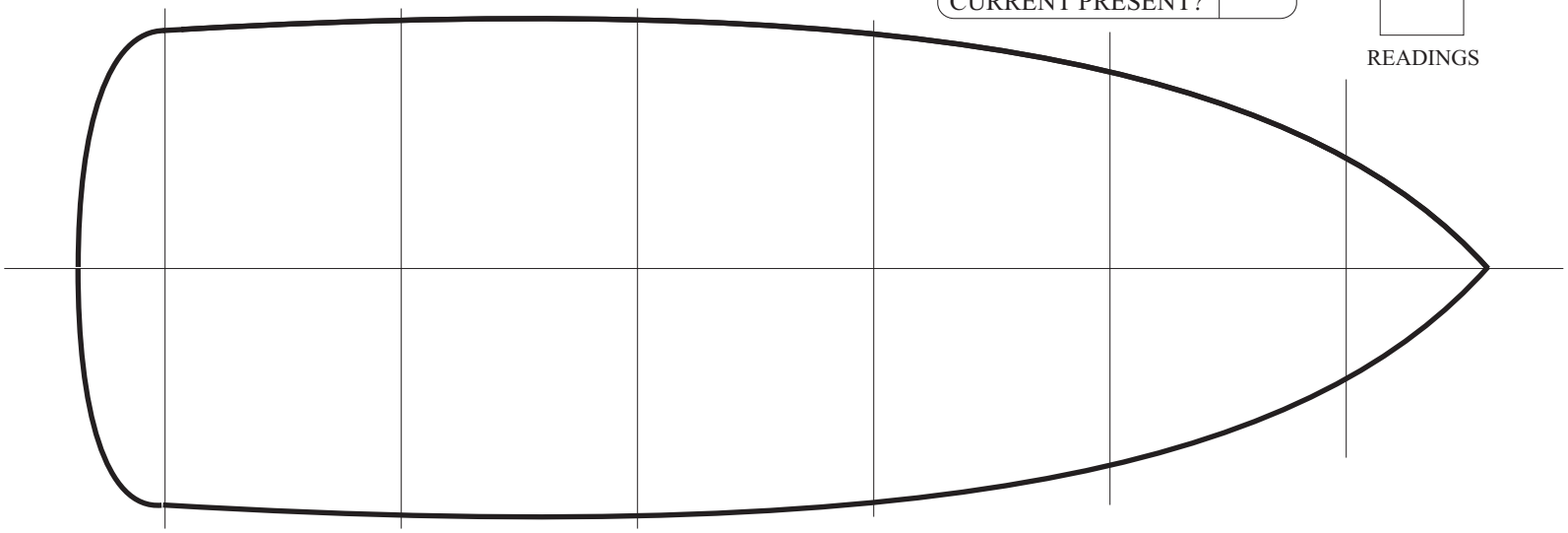

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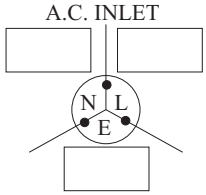

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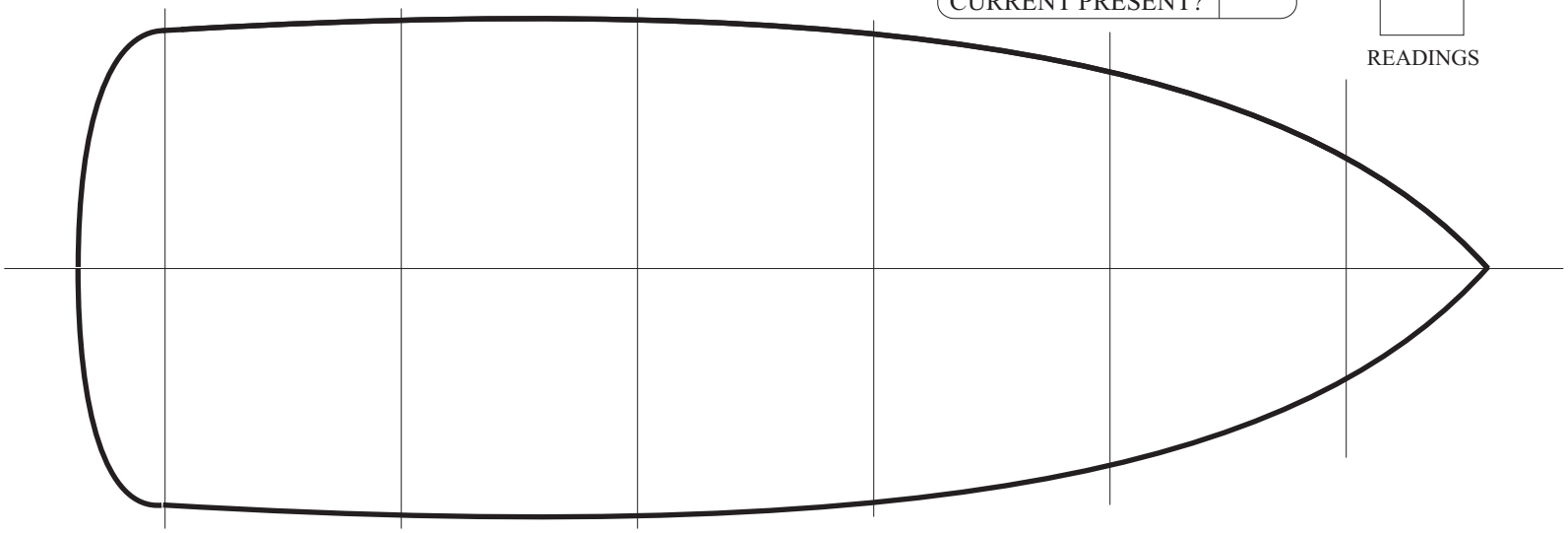

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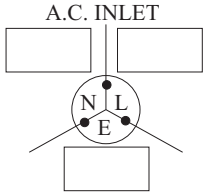

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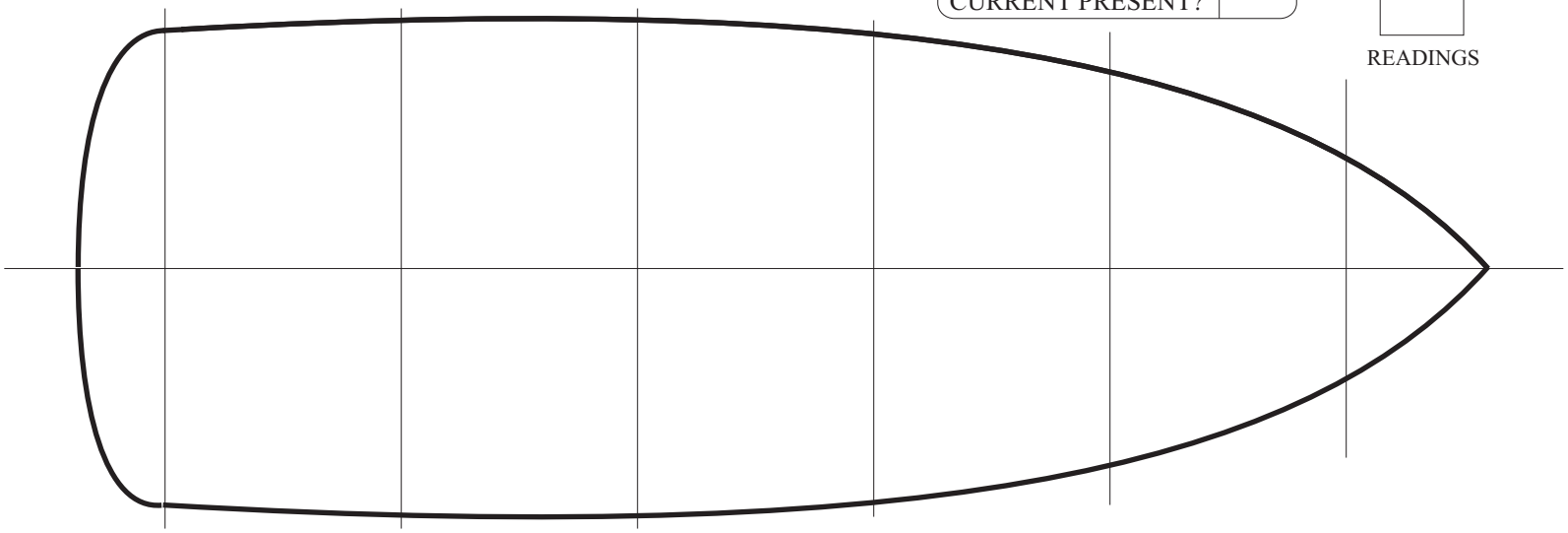

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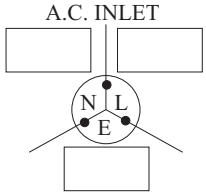

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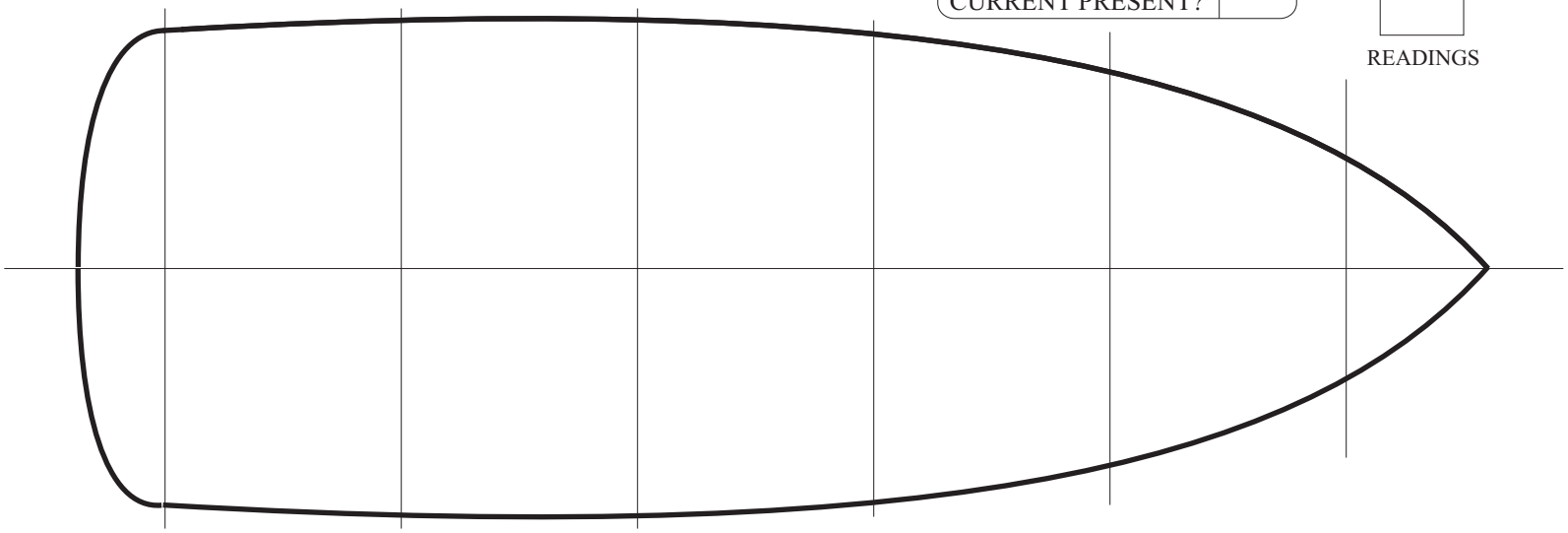

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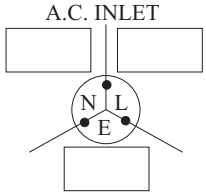

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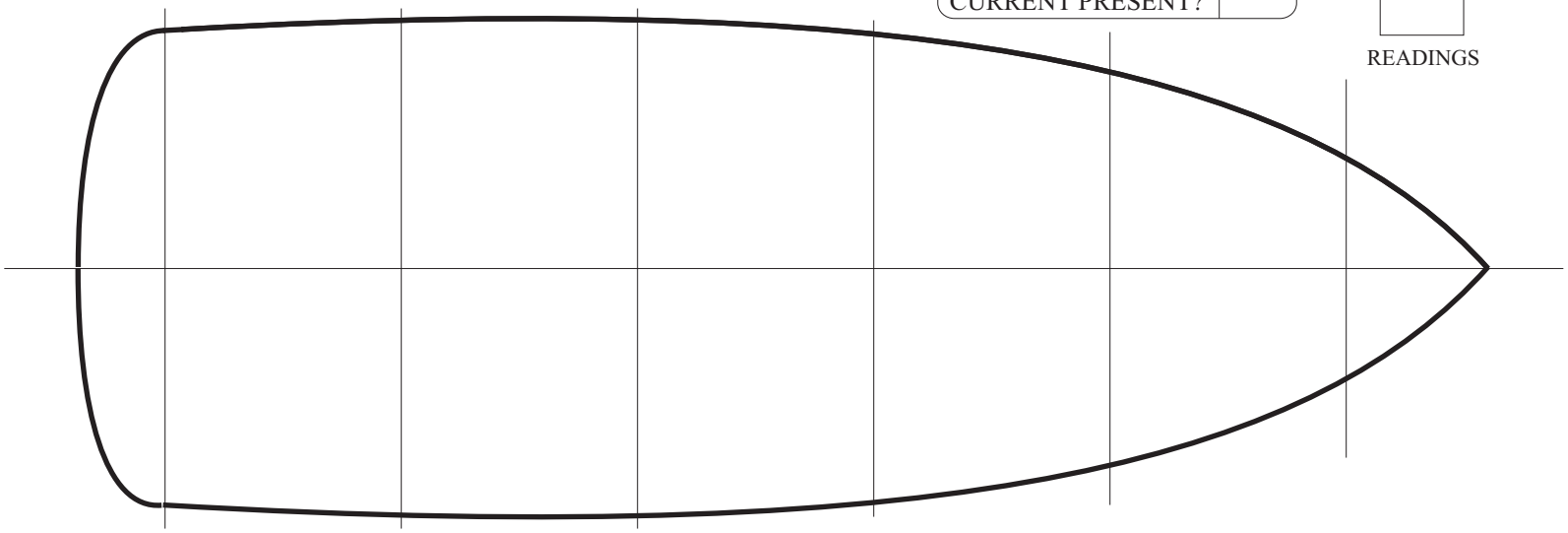

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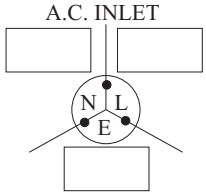

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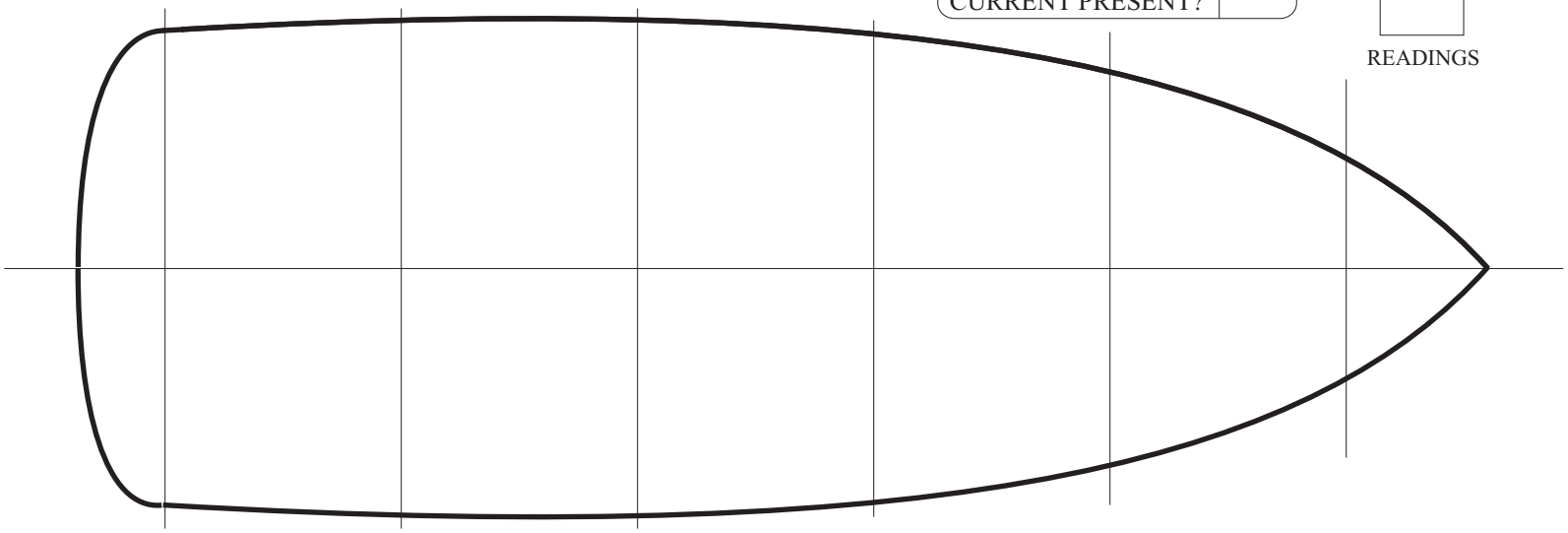

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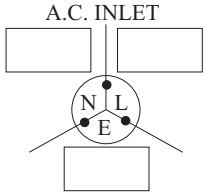

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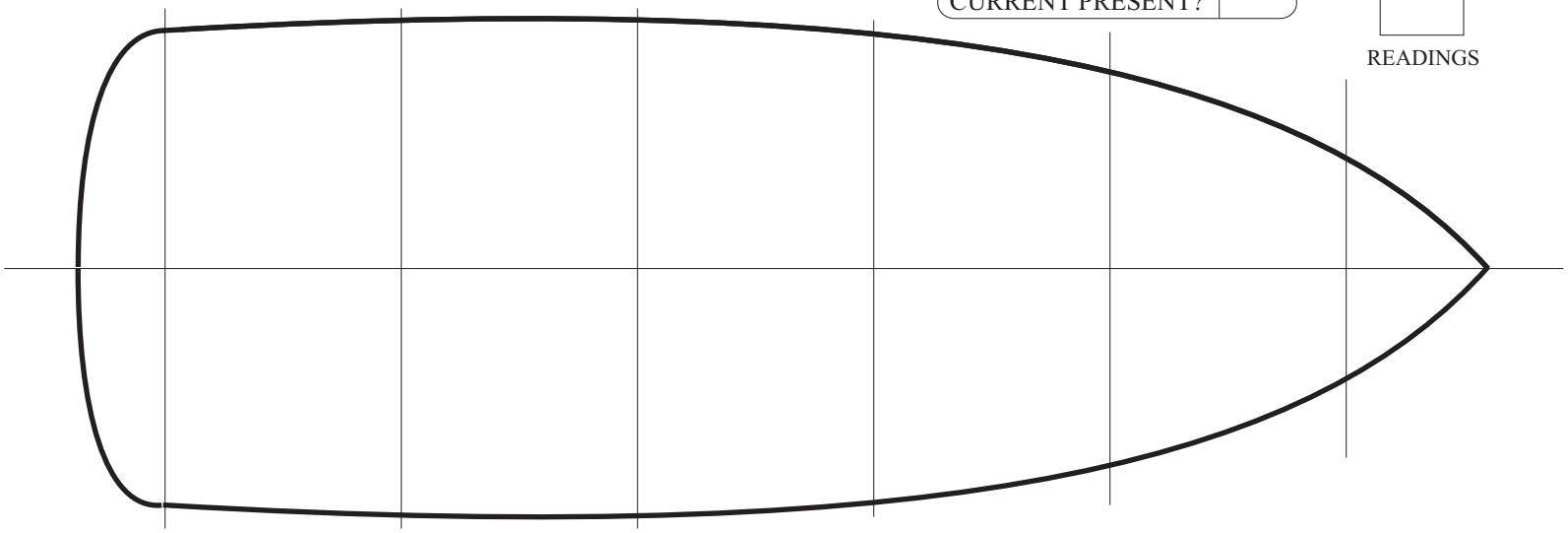

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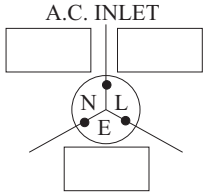

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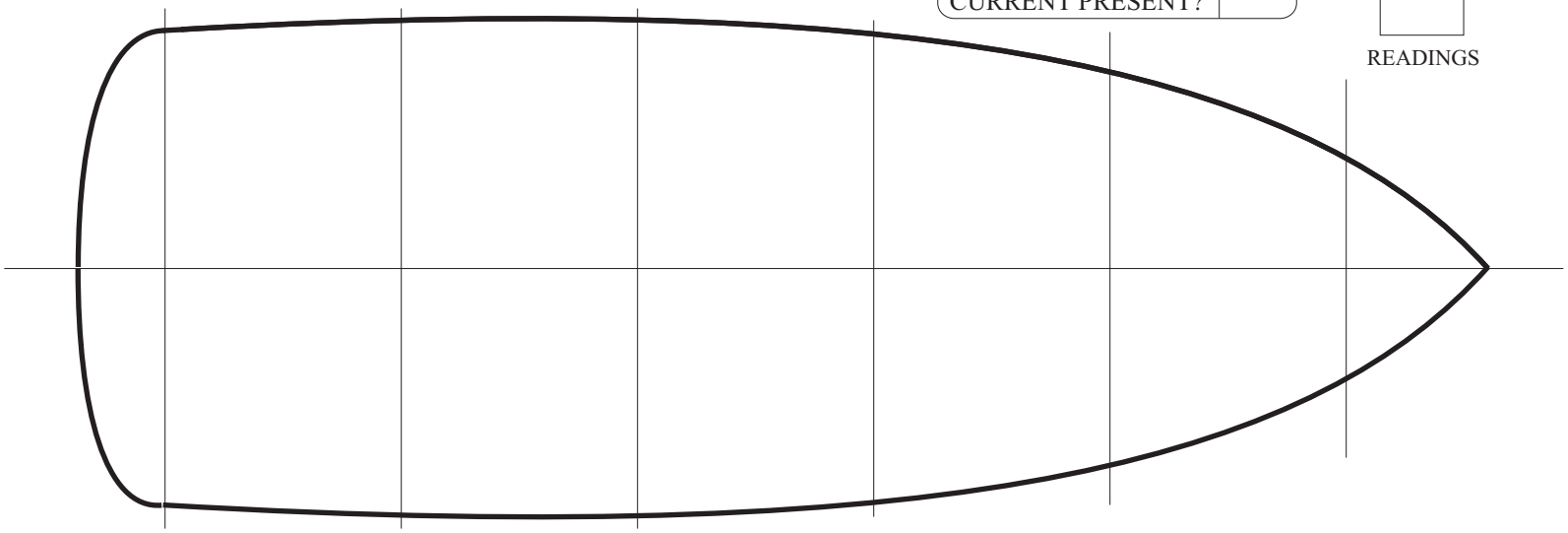

Results

Remedial work required

Signed/Surveyor..

CORROSION SURVEY CHECKLIST.

DATE_____
NAME OF BOAT_____
STYLE AND MAKE OF TEST EQUIPMENT_____
HIGHEST VOLTAGE METAL IN UNDERWATER SYSTEM_____
(METAL VOLTAGE (IN SEAWATER):- ALUMINUM-626, STEEL-425, BRONZE-200, S/STEEL-50/450
READ TEST ZINC BESIDE BOAT - VOLTAGE IS_____
ALL IMMERSED METAL IS ELECTRICALLY CONNECTED (BONDED) AND THE VOLTAGE IS:-_____
DISCONNECT BATTERIES - BONDING SYSTEM VOLTAGE IS:_____
FULL SHORE CORD-BONDING SYSTEM VOLTAGE IS:
DOCK A.C. GROUND READING IS:_____
PLACE MILLIAMMETER BETWEEN BOAT RECEPTACLE GROUND AND SHORE GROUND. AMPERAGE IS:-_____
CONNECT SHORE CORD-BONDING SYSTEM VOLTAGE IS:-_____
ALL D.C. EQUIPMENT OPERATED AND NO VOLTAGE CHANGE:-_____
ALL A.C. EQUIPMENT OPERATED AND NO VOLTAGE CHANGE:-_____

ZINC SAVER TEST (IF USED)

DISCONNECT WIRES ON ONE SIDE OF THE INSTALLED UNIT:-
READ CONTINUITY BETWEEN WIRES STILL CONNECTED TO DISCONNECTED WIRES. THERE SHOULD BE NO CIRCUIT.
CONTINUITY:_____;NO CONTINUITY:_____
READ CONTINUITY ACROSS ZINC SAVER. CHANGE LEADS AND READ OPPOSITE DIRECTION. BOTH READINGS SHOULD BE APPROXIMATELY THE SAME BOTH WAYS `5%. READINGS WILL VARY BETWEEN STYLES OF METERS AND DESIGN OF THE UNIT.
CONTINUITY - LEFT TO RIGHT_____RIGHT TO LEFT_____

BONDING CONTINUITY TEST (OUT OF WATER)

READ FROM ZINC TO ALL PROTECTED METAL PARTS IN BONDING SYSTEM
ALL PARTS CONNECTED - NO RESISTANCE:-_____
READ FROM ZINC(S) TO ALL BOLTED AND ASSOCIATED METAL PARTS OF I/O OR OUTBOARD MOTOR
ALL PARTS CONNECTED - NO RESISTANCE:-_____
USE DIGITAL OR 50,000 OHMS SENSITIVE ANALOGUE CONTINUITY METER ` 30 OHMS ACCEPTABLE

CORROSION SURVEY CHECKLIST.

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(METAL VOLTAGE (IN SEAWATER):- ALUMINUM-626, STEEL-425, BRONZE-200, S/STEEL-50/450
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CONTINUITY - LEFT TO RIGHT_____RIGHT TO LEFT_____

BONDING CONTINUITY TEST (OUT OF WATER)

READ FROM ZINC TO ALL PROTECTED METAL PARTS IN BONDING SYSTEM
ALL PARTS CONNECTED - NO RESISTANCE:-_____
READ FROM ZINC(S) TO ALL BOLTED AND ASSOCIATED METAL PARTS OF I/O OR OUTBOARD MOTOR
ALL PARTS CONNECTED - NO RESISTANCE:-_____
USE DIGITAL OR 50,000 OHMS SENSITIVE ANALOGUE CONTINUITY METER ` 30 OHMS ACCEPTABLE

CORROSION SURVEY CHECKLIST.

DATE_____
NAME OF BOAT_____
STYLE AND MAKE OF TEST EQUIPMENT_____
HIGHEST VOLTAGE METAL IN UNDERWATER SYSTEM_____
(METAL VOLTAGE (IN SEAWATER):- ALUMINUM-626, STEEL-425, BRONZE-200, S/STEEL-50/450
READ TEST ZINC BESIDE BOAT - VOLTAGE IS_____
ALL IMMERSED METAL IS ELECTRICALLY CONNECTED (BONDED) AND THE VOLTAGE IS:-_____
DISCONNECT BATTERIES - BONDING SYSTEM VOLTAGE IS:_____
FULL SHORE CORD-BONDING SYSTEM VOLTAGE IS:
DOCK A.C. GROUND READING IS:_____
PLACE MILLIAMMETER BETWEEN BOAT RECEPTACLE GROUND AND SHORE GROUND. AMPERAGE IS:-_____
CONNECT SHORE CORD-BONDING SYSTEM VOLTAGE IS:-_____
ALL D.C. EQUIPMENT OPERATED AND NO VOLTAGE CHANGE:-_____
ALL A.C. EQUIPMENT OPERATED AND NO VOLTAGE CHANGE:-_____

ZINC SAVER TEST (IF USED)

DISCONNECT WIRES ON ONE SIDE OF THE INSTALLED UNIT:-
READ CONTINUITY BETWEEN WIRES STILL CONNECTED TO DISCONNECTED WIRES. THERE SHOULD BE NO CIRCUIT.
CONTINUITY:_____;NO CONTINUITY:_____
READ CONTINUITY ACROSS ZINC SAVER. CHANGE LEADS AND READ OPPOSITE DIRECTION. BOTH READINGS SHOULD BE APPROXIMATELY THE SAME BOTH WAYS `5%. READINGS WILL VARY BETWEEN STYLES OF METERS AND DESIGN OF THE UNIT.
CONTINUITY - LEFT TO RIGHT_____RIGHT TO LEFT_____

BONDING CONTINUITY TEST (OUT OF WATER)

READ FROM ZINC TO ALL PROTECTED METAL PARTS IN BONDING SYSTEM
ALL PARTS CONNECTED - NO RESISTANCE:-_____
READ FROM ZINC(S) TO ALL BOLTED AND ASSOCIATED METAL PARTS OF I/O OR OUTBOARD MOTOR
ALL PARTS CONNECTED - NO RESISTANCE:-_____
USE DIGITAL OR 50,000 OHMS SENSITIVE ANALOGUE CONTINUITY METER ` 30 OHMS ACCEPTABLE

CORROSION SURVEY CHECKLIST.

DATE_____
NAME OF BOAT_____
STYLE AND MAKE OF TEST EQUIPMENT_____
HIGHEST VOLTAGE METAL IN UNDERWATER SYSTEM_____
(METAL VOLTAGE (IN SEAWATER):- ALUMINUM-626, STEEL-425, BRONZE-200, S/STEEL-50/450
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ALL IMMERSED METAL IS ELECTRICALLY CONNECTED (BONDED) AND THE VOLTAGE IS:-_____
DISCONNECT BATTERIES - BONDING SYSTEM VOLTAGE IS:_____
FULL SHORE CORD-BONDING SYSTEM VOLTAGE IS:
DOCK A.C. GROUND READING IS:_____
PLACE MILLIAMMETER BETWEEN BOAT RECEPTACLE GROUND AND SHORE GROUND. AMPERAGE IS:-_____
CONNECT SHORE CORD-BONDING SYSTEM VOLTAGE IS:-_____
ALL D.C. EQUIPMENT OPERATED AND NO VOLTAGE CHANGE:-_____
ALL A.C. EQUIPMENT OPERATED AND NO VOLTAGE CHANGE:-_____

ZINC SAVER TEST (IF USED)

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CONTINUITY - LEFT TO RIGHT_____RIGHT TO LEFT_____

BONDING CONTINUITY TEST (OUT OF WATER)

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ALL PARTS CONNECTED - NO RESISTANCE:-_____
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