YOUR BOATING
DOLLARS AT WORK

Produced under a grant from the Sport Fish Restoration and Boating Trust Fund, administered by the U.S. Coast Guard.

USCG FY2006 Grant
In-Water Shock Hazard Mitigation Strategies
Final Report October 1, 2008

ABYC
Setting Standards for Safer Boating

Authored by James D. Shafer and Capt. David E. Rifkin (USN, Ret)

James D. Shafer, Harbor Marine Consultants, Inc, Vero Beach, FL, 772-284-0855, kp2r@bellsouth.net, www.marinaguard.net

David E. Rifkin, Quality Marine Services, LLC, Jacksonville, FL, 904-382-7868, qualitymarinesvcs@comcast.net, www.qualitymarineservices.net

The authors and principal researchers for this USCG Safety Grant began their fieldwork in the area of Electric Shock Drowning nearly eight years ago. Jim gained extensive experience in marine electrical application and troubleshooting through his former service business and worldwide cruising experiences. Dave gained his electrical experience in the Navy's nuclear power program in submarines. They are ABYC certified in Marine Electrical, Corrosion and Standards. Both Jim and Dave hold Accredited Marine Surveyors (AMS®) certifications with the Society of Accredited Marine Surveyors (SAMS®), and both have authored numerous technical publications in the marine electrical field.

Recognizing a need for more information in quantifying the problem, they began searching for accident information in an effort to better understand the causes of the injuries and deaths associated with the use of electricity in and around freshwater bodies of water.

Along with compiling the database included in this study, they began field experimentation leading to the development of some basic troubleshooting procedures used to identify potentially dangerous or even deadly situations around marinas supplied with electrical power. These procedures are routinely presented in lectures and seminars given by both authors at various venues including Marina Electrical Seminars, ABYC Certification Courses, Boating Group Seminars, and at the International Boat Builder's Exhibition (IBEX).

During the year-long USCG study, the authors visited more than a dozen marina sites (listed elsewhere in the study) across the country. At each location, a series of experiments was conducted, analyzed, and reported. The focus of the study was to reproduce accident conditions in a safe, controlled manner, and to indentify the underlying causes of each. This was done in a wide variety of geographical settings with a broad range of water, temperature and topographical conditions. The data and analysis in this report are the result of this effort.

A number of recommendations for improving electrical safety in the marine environment are presented near the end of the report. Each one will have a positive impact in reducing the number of accidents occurring at freshwater marinas across the country. The authors will be happy to answer questions related to this study, and discuss issues in this area that may come to the attention of any readers.

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Grant Contact Information:

Setting Standards for Safer Boating

American Boat & Yacht Council, Inc.
613 Third Street, Suite 10
Annapolis, MD 21403
Phone (410) 990-4460
Fax (410) 990-4466
Web: www.abycinc.org
E-Mail: comments@abycinc.org

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1. Forward & Executive Summary

Background

In FY 2003 & 2004 the American Boat & Yacht Council, ABYC, was awarded grants that studied the theory of AC electric shock in water. The purpose of these grants was to make a recommendation, after intense study, on how a person should react in the event of an encounter with an electrical situation. The laboratory based research that was conducted under these grants was concise, and repeatable in a lab situation. The problem arose when the lab set-up was to be tested in a real life situation; the parameters of the experiment could not be transferred to an environment with infinite variables (e.g. salinity, plant life, current, etc.). Currently this grant exists as a reference for future projects and has not been able to aid in the production of mitigation strategies for boats or people. In-water shock drownings are a reality and can be prevented by the use of off-the-shelf devices used in the correct manner and installations.

Problem

Since our inception in the 1950's, ABYC and its technical committees have been wrestling with requirements surrounding the installation of Alternating Current electrical systems on board boats. AC power and water are a dangerous combination. From the standpoint of NFPA 70, the National Electrical Code (NEC), ground fault circuit interrupters (GFCI) have been required since 1971.

In 1977, ABYC introduced the use of GFCI's in E-8 AC Electrical Systems. At that time, their use was limited to convenience outlets in heads. Currently, ABYC standard E-11, AC & DC Electrical Systems on Boats, 2003 requires GFCI outlets in heads, galleys, machinery spaces and weather decks. While we have followed the NEC's continued expansion of GFCI use, we have not entered into the "whole boat" protection concept like the European market. ISO 13297 "Small craft – Electrical systems – Alternating current installations" gives the boat builder the option of installing a "whole boat" GFCI or Residual Current Device defined as "electromechanical switching device, or association of devices, designed to make, carry and break currents under normal service conditions and to cause the opening of contacts when the residual current attains a given value under specified conditions. *NOTE RCD/GFCI serve to reduce the risk of injury to people from electrical shock.*" The text of 13297 also states: "The craft shall be provided with earth-leakage protection in the main supply circuit by a) a double-pole RCD having a maximum nominal trip sensitivity of 30 mA and 100 ms maximum trip time" or "b) each receptacle located in the galley, toilet, machinery space or weather deck shall be protected by a GFCI (RCD) having a maximum sensitivity of 10mA." The land based electrical codes in much of Europe also specify the use of an RCD as a main breaker.

The question of cost/benefit is always raised in situations like this. Purely academic arguments are not worth funding or spending significant committee time discussing, however, in this case there is a quantifiable problem. Appendix A is a list compiled by an industry expert [1] during his dealings with shock-induced drownings. These accidents may not show up in the early BAR data because they involved swimming from a boat or near a dock. ABYC documented a case surrounding an in-water shock death in our newsletter recently. This is an issue where a possible solution already exists through existing technology.

While on the surface, this seems like a simple argument that all boats should be fitted with "whole boat" GFCI's, it is not as simple as that. Many industry experts have documented a large number of "nuisance" trips involving GFCI's where larger appliances such as washers, dryers, microwaves and ranges create enough of an imbalance to trip a 5mA GFCI. The European solution with an RCD is quite effective but has a 30mA trip level with a max trip time of 100 ms. ABYC requires 5 mA with an average trip time listed in UL 94 of 30ms, quite a difference. We are also dealing with 2 different types of power, 110 60hz here in the US and 220 50hz in Europe.

The crux of this problem is the lack of testing and information. There are an equal number of arguments on each side of the "whole boat" protection scheme. What is needed is a definite answer to the feasibility of a device that will satisfy both the power needs of the boat and the life-safety needs of the occupants.

<u>Summary</u>

The Body of this grant report will explain in great detail the electrical testing, field mapping and mitigation strategies used on a number of test boats during the execution of this grant. A fault was introduced, mapped and then tested against possible preventive devices.

Included at the end of this report is a summary of timely actions on behalf of the American Boat & Yacht Council in their standard E-11 AC & DC Electrical Systems on Boats to mitigate this type of accident on board the boat. Also included is a brief report that outlines the practical application of the suggested device that uncovered a problem that a builder would otherwise been unaware.

There is much work still to be done. The ABYC has a standards jurisdiction over the boat side of this equation; the dock side is under the purview of the National Fire Protection Association (NFPA) in its document NFPA *303 Marinas and Boatyards*. This organization will be contacted as well for discussions on accident mitigation from the dock perspective.

2. Test Procedure

1. Methodology:

A. General: In order to study the effects of ground faults on boats connected to shore power, a process to "inject" such a ground fault, and thereby cause current to flow into the water was developed. Voltage gradients were measured around the boat and were compared to those known to be potentially lethal. Based on this approach, we have recommended strategies which will minimize the likelihood of lethal voltage gradients in the water. Since the freshwater situation is of the greatest concern, our recommendations were based primarily on freshwater data. However, the recommendations are also applicable to the saltwater case because even though lethal gradients are not normally achieved in salt water, low-level fault currents may cause heating and should be considered a potential fire hazard.

To make the testing and simulations of possible accident scenarios as realistic as possible, we endeavored to examine fault conditions under a variety of conditions and vessels, as is discussed further in this section. Vessels with different hull material, water conductivity (from fresh to salt), and different mooring arrangements were included in the testing. Since the highest risk (i.e. worst case) is associated with a defective vessel bonding system, all of the tests were carried out with the shore cord disconnected to simulate this. The bonding system was then energized with special test equipment to introduce current flow into the water back and to the source.

We effectively simulated virtually all of the conditions listed as accident causes in Table __ (in the preliminary section of the report).

B. Ground Fault Simulation: Simulating a ground fault situation involves the use of a variable AC voltage source (variac) connected to a vessel's bonding system with the normal ground return path to the shore service eliminated (worst case fault scenario). Using the variac, a controlled amount of current was allowed to flow into the water via a boat's underwater metals. The return path back to the source at the service is through the water from the faulted boat. This return path may also include any grounded dock structures and the grounded metals of nearby boats. Information on the levels of voltages and currents used is discussed in paragraph 1.E.v. below. The boats were physically disconnected from the from all shore services during the testing.

C. Testing Locations: We were predominantly interested in the freshwater environment where all of the accidents known to us have occurred. One saltwater location and two brackish water locations were included in the study to demonstrate whether or not electric shock drowning concern is limited to freshwater situations. The following locations were used for the testing as indicated:

- Beach Marine (BCH), Jacksonville, FL, saltwater,
  Sheet 1 series; boat testing
- Buffalo Launch Club, Niagara River, Buffalo (BLC), NY, freshwater
  Sheet 2 series; boat testing
- Callville Bay Marina (CBM), Lake Meade, Henderson, NV freshwater
  Sheet 3 series; boat testing, voltage vs. current testing
- Conley Bottom Resort (CBR), Lake Cumberland, Monticello KY, freshwater
  Sheet 4 series; boat testing
- Doctor's Lake Marina (DOC), Jacksonville, FL, mildly brackish water

Sheet 5 series; boat testing
- Lake Ocoee Marina (LOM), Benton, TN, freshwater
  Sheet 6 series; boat testing
- Mentor Harbor YC (MHY), Lake Erie, Mentor, OH, freshwater
  Sheet 7 series; boat testing
- Paradise Cove Marina (PCM), Austin, TX, freshwater
  Sheet 8 series; boat testing
- Queens Harbor (QHA), Jacksonville, FL, brackish water
  Sheet 9 series; boat testing
- Silver Lake Marina (SLM), Dallas, TX, freshwater
  Sheet 10 series, boat testing
- Stuart Yacht Builders (SYB), Stuart, FL, freshwater
  Sheet 11 series; voltage vs. current/gradient testing
- Texas Sailing School (TSS), Austin, TX, freshwater
  Sheet 12 series; boat testing
- Tropic Resort and Marina (TRM), Deland, FL, freshwater
  Sheet 13 series; voltage gradient vs. distance testing, voltage vs. distance testing, broken cable insulation testing
- Grand Island (GIN), Niagara River, NY, freshwater
  Sheet 14 series; dockside accident recreation testing

D. Qualifying the Bonding System and Electric Service: Prior to testing a particular boat the bonding (grounding) system was checked to ensure there was a valid path from the grounding wire to the underwater metals, and from the water back to the service grounding connection. The exact resistance of this system is not critical since the voltage was adjusted to obtain the desired current flow into the water, however the system had to be intact to the extent that the target current is achieved. Since only the grounding conductor was involved in the circuit path, the boat's shore cord was not plugged in during testing. This eliminates any problems associated with a ground-neutral connection that may be present on the boat.

E. Measurements: Measurements were be taken as outlined below. For each voltage measurement, a background voltage reading was taken so the actual reading could be corrected as necessary.

i. Equipment: The following equipment was be used to support testing:

- Voltage gradient measuring device ("Test Rig") with probes 2 feet apart (see photos at end of this section)
- Digital Voltmeter, Ideal Model 61-481
- Digital Current Leakage Tester, Ideal Model 61-452
- Circuit Tester, Ideal, Suretest Model 61-164
- Variac, Powerstat, Superior Electric Co., 900VA
- Conductivity, TDS, Temp, pH meter, Extech EC510
- Salinity tester, Hannah HI 98203
- Isolation transformer, Precision Electronics, Cat# 6634, 500VA
- Assorted cabling, plugs, receptacles, adapters
- Variable Ground Fault Protection Cable, Northshore Safety Systems

ii. Measurements/observations: For the basic testing, voltage and voltage gradient measurements were taken at each of 8 points around each vessel at varying depths, as accessible. Other tests and measurements were conducted for each vessel as described in paragraphs v-viii below. A test for the effects of broken insulation in the water is discussed in paragraph ix below. Additionally, measurements were taken to establish the relationship between voltage, voltage gradient, current and distance from an electrical source during the study as described in paragraph x below. A dockside accident recreation test is described in paragraph xi below. Finally, at each location data was collected to characterize the conditions where testing was conducted. Specific measurements and data recorded are listed below:

- Maximum horizontal field strength at depths of 1, 3, and 5ft around each vessel. Appears as HV1ft(V), HV3ft(V) and HV5ft(V) on the data sheets.
- Maximum vertical field strength at 3ft depth (in the longitudinal direction of maximum horizontal field strength) around each vessel. Appears as VF3ft(V). If the field strength weakened as the test rig was articulated away from horizontal, the words "less" are recorded in the VF3ft(V) block. The number of degrees from horizontal appears as VF3ft (deg from hor.). The letters "d a" indicate the direction of the vertical component of the field was down and away from the boat. The letters "u a" indicate up and away from the boat.
- Direction of maximum horizontal and vertical field strengths at 3ft. Appears as red arrows on the data sheets.
- Voltages, voltage gradients, and currents using field test rig and measuring equipment (see section E.x below for details).
- Water conductivity, salinity, pH, TDS, and temperature
- Water path impedance (includes portions of dock and boat bonding systems, and water path).
- Physical water current at the boat during testing
- Meteorological data at the test location
- Description of each marina and its electrical service
- Photographic record of each vessel and testing location
- Satellite image of each testing location

iii. Boat Orientation: A variety of boat orientations were used, as practical, in the study. This is important since any voltage gradients are dependent on the orientation of the grounding paths available to the fault current. The following orientations were included in the study:

- Bow in
- Bow out
- Alongside dock/pier/wharf

iv. Test Identification: Each test was given a unique identification number for ease of reference and analysis. The following format was used:
WWW (3 letter designator for marina, see 1.c above) – XXX (3 letter designation for hull material and coating) – YY (2 letter designation for propulsion type) - ZZ (2 letter designation for boat orientation) – Date – Time.

- **Hull Material:** FRP = Fiberglass, ALU (C) = Coated Aluminum, ALU(UC) = Uncoated Aluminum, STL(C) = Coated Steel, STL(UC) = Uncoated Steel.
- **Propulsion Type:** OB = Outboard, IB = Inboard, SD = Stern drive
- **Boat Orientation:** BI = Bow-in, BO = Bow-out, AP = Alongside port, AS = Alongside starboard.

Example: Test # SYB-ALU(C)-IB-BI, 12-13-06, 1300hrs: means that a coated aluminum boat was tested at Stuart Yacht Builders on December 13th, 2006 at 1PM. The boat had inboard power and was moored bow-in at the marina.

v. General Testing:

(a) Basic Testing: Based on preliminary testing, a 3A fault current was used as a baseline for all boats at all locations. This consistently provided a voltage gradient sufficiently above any background levels to allow meaningful measurements to be made. Voltages that approached full system voltage were used on a boat's bonding system in one special test described in paragraph (b) below. However, in some cases, full system voltage was needed to achieve the 3A current due to the relatively low conductivity of the marina water.

Using the relatively low 3amp test current also had the advantage of maximizing safety during the study. The primary concern was the risk associated with putting a high current in a bonding system that we couldn't quantify completely. At levels which could trip a shore supply breaker, significant heat could have been generated, increasing the risk of fire or (or explosion in gasoline-powered boats). Additionally, minimizing the actual current in the water enhanced safety during the testing (to both people and wildlife).

The linear relationships between voltage and current in the water (see test description in paragraph x below) allow extrapolating the results using any level of test current contemplated.

See Drawing 1, Data Sheets 1-10,12, Data Analysis Section 3.A.

Note: The first number of the Sheet Number is unique to the particular marina. The second number indicates the first, second, or third boat tested at that marina, and the third number indicates the data page number for the particular boat being tested (e.g. 3-1-2 means Callville Bay Marina, first boat tested, 2nd page of data for the first boat).

(b) High Current Testing: Two boats were deliberately tested using the highest possible test current consistent with safety considerations. On one boat, a fault current of 80% of the nominal current rating for the pedestal circuit breaker supplying the power was achieved. On the second boat only 11% of the nominal rating could be achieved. These tests were performed at the boat's location which resulted in the highest voltage gradient from the 3 amp testing described in paragraph v. above. The data from this test were used as additional confirmation to establish the relationship between applied voltage and resulting current and voltage gradients in the water.

See Drawing 2, Data Sheets 3-1-2, 3-2-2, Data Analysis Section 3.B.

vi. Isolated Ground Testing: In an effort to identify the worst case scenario for electric field strength, a setup was used which ensured all the fault current traveled back to a single known location in the water as it returned to the source. This was accomplished using a 500 VA isolation transformer. The hot side of the transformer was connected to the boat's grounding system through a variac. The neutral side consisted of a 180 square inch aluminum plate electrode placed in the water at depths of about 1 and 5 feet. The field strengths (horizontal and vertical) were measured to determine the maximum voltage gradient between the source (the boat) and the electrode in the water (maintaining at least 2" from the electrode). It was presumed that the strongest gradient would be measured near the plate electrode.

The same level of current (3A) was used as in the general measurements for each boat tested.

See Drawing 3, Data Sheets 1-10,12, Data Analysis Section 3.C.

vii. AC Leakage Testing: On each boat, the amount of AC current leaking into the water was determined with AC loads operating as practical. This was measured by clamping the whole shore cord with an AC clamp meter and then subtracting any background current that might be present (coming from other faulty boats or ground-neutral currents from the electrical distribution system).

See Drawing 4, Data Sheets 1-10,12, Data Analysis Section 3.D.

viii. Split Current Testing: On each boat, a nominal 10amp load was applied to the boats bonding system with the shore grounding connection intact. This was done to reveal the percentages of current split between the grounding conductor and the water return paths to the service ashore in the event of an electrical fault to ground. Any background current (coming from sources other than the boat being tested) was measured with the pedestal breaker open. This was subtracted from the measured water leakage current coming from the boat's electrical system.

See Drawing 5, Data Sheets 1-10,12, Data Analysis Section 3.E.

ix. Broken Cable Insulation Testing: In an effort to determine the extent of potential danger associated with an electrical cable dangling in the water, electric field densities (voltage gradients) associated with this condition were evaluated. This situation has been documented as a possible cause of death in some shock drowning incidents. The effects of an insulation break (one inch of exposed 14 awg conductor) in the hot lead only, the hot and neutral together, and finally the hot, neutral, and grounding conductors together were measured. This test was conducted by using full line voltage applied between the hot conductor and the distributed marina grounding system. Voltage gradients were measured and evaluated.

See Drawing 6, Data Sheets 4, 6, 13A, Data Analysis Section 3.F.

x. Voltage, Current, and Electric Field (voltage gradient) Relationship Testing: At selected locations, tests were conducted to characterize the nature of the relationship between applied voltage, voltage gradient, and current in the water.

See Drawings 7-11, Data Sheets 3A, 11A-C, 13B & C, Data Analysis Section 3.G.

(a) Water current/gradients vs. applied voltage: These tests were conducted by changing the voltage applied while measuring voltage in the water, current in the water, and voltage gradient as follows:

(i) Water current vs. applied voltage-1: A single electrode was energized using the distributed marina grounding system as a return path. The resulting water current was measured as applied voltage was varied.

Data from testing at Callville Bay Marina, Lake Meade, NV was also used to study the voltage/current relationship using a real boat's underwater metals as electrodes.

(ii) Water current vs. applied voltage-2: A pair of electrodes was energized using an isolation transformer (which ensured all current entering the water at one electrode could only return to the source via the second electrode, and not the marina grounding system). Different size electrodes were used to further evaluate the effects of surface area on current flow in the water. Voltage across the electrodes was varied and the resulting water current measured. Additionally, the test rig was placed between the electrodes to evaluate its affect on water current during testing, if any.

(iii) Voltage gradient vs. applied voltage: A pair of electrodes was energized using an isolation transformer (which ensured all current entering the water at one electrode could only return to the source via the second electrode, and not the marina grounding system). Voltage gradient (2' between test probes) was measured at a point equidistant from each electrode as the voltage to the electrodes was varied.

(b) Voltage gradient vs. distance from source: This test was conducted using two 180 square inch plates (isolated from the distributed marina grounding system). This means that all the current that entered the water at one plate had to exit the water at the opposite plate. The plates were energized such that 3amps of current resulted in the water. Two-foot voltage gradients were measured incrementally over the distance from plate to plate.

(c) Water voltage vs. distance from source: This test was conducted by energizing a 18" bonze propeller and measuring the voltage in the water (with respect to marina ground voltage) as the distance from the source was varied. A voltage which generated 3amps of current in the water was applied to the propeller. The resulting curve can be used to predict the voltage (or voltage gradient) at any distance from the source using a single voltage (or voltage gradient) at a known distance from the source.

xi. Dockside accident recreation test: During the testing phase of the study we were made aware of an accident that took the life of a dog and nearly of its owner. The physical layout of the accident scene remained unaltered since the time of the accident in September 2000. The fault was recreated in a unique opportunity to compare voltage gradients with the physiological effects experienced by the near-miss victim.

See Data Sheets 14, 14A-C, Data Analysis Section 3.H.

F. Safety: Safety during the testing process was paramount during all activities. Each marina operator was provided with a brief summary of the testing process before testing began. Testing activities were pursued during the fall through early spring off season, when boating activities were minimal. We had full instant control of the test current during all testing in the event that a dangerous situation developed.

Personal flotation devices were worn at all times during testing on the boat where secure railings were not available around the perimeter of the boat.

G. Data Analysis: The data were entered into spreadsheets, tables and graphs for analysis. See Field Data Section of the report for this information.

2. Physical Parameters: The following parameters were used in this analysis:

-Nominal human body resistance-wet (references 1-4, 9-12): 1000 ohms

-Nominal body length: 6 feet (based on outstretched arms or head-to-toe length)

-Potentially lethal voltage gradient (references 1-4, 9-12): 2 volts AC per foot (this voltage results in 12 volts AC across a 6 foot body span which results in 12 milliamps of AC current flow in a person with the nominal 1000 ohm resistance). In the nominal person 12 milliamps may result in paralysis (which can lead to drowning). This is a generally accepted level and is only used as a guideline based on the literature, which suggests this value can vary widely based on the individual parameters and conditions involved.

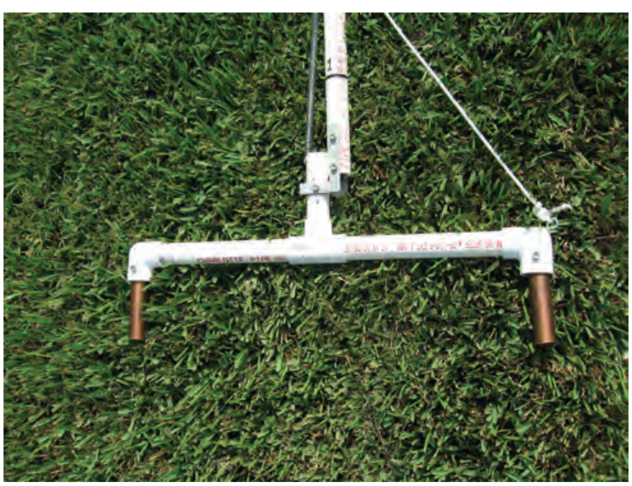
Various references suggest that current flowing through the body at levels above 10ma may cause paralysis (which leads to drowning). At levels above 60ma ventricular fibrillation is likely. At some intermediate levels between paralysis and fibrillation it is suggested that the cessation of breathing and loss of consciousness can occur (references 1-4, 9, 10, 12).

-Freshwater definition parameters: For the purpose of this study, “freshwater” is defined as water having about the same conductivity as drinking water (approx. 1.8 ms/cm or less).

Test Rig Photos

Complete Test Rig

Meter connected to Test Rig probes



Articulating base on Test Rig

One of 2 copper probes on Test Rig

3. FIELD DATA

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Sheet 1, Marina Data Testing Notes

Investigators: Jim Shafer, David Rifkin

Marina Name/Location: Beach Marine, Jacksonville, FL

Date: 3/1/2007 **Weather:** Sunny

Air Temperature: 72F **Wind:** E, 10kts **Clouds:** Scattered **Rain:** None

Electrical Service at Pedestals: 50A/240V, 30A/120V Water depth in marina: 7ft

Number piers/wharfs: 9/3 Bottom type: mud

Number vessels connected to shore power: 200 Vegetation present: none

Mooring arrangements/configurations: Bow in/out on fingers from main piers, alongside wharfs, alongside at Tee on end of piers.

Metallic structures that could infuence testing: Bonded aluminum docks.

Notes and comments on testing:

1. Brackish water, about 2/3 of full saltwater salinity. Located on intracoastal waterway approx 10 miles south of St. Johns River.
2. Docks are aluminum on plastic floats. Docks connected to marina bonding system.
3. Testing using an isolated ground, 5A was put into the saltwater between boat ground and large plate electrode.
   The maximum voltage gradient measured was 0.37V/ft.

Beach Marine, Jacksonville, FL, Saltwater

Sheet 1-1-1, Field Strength/Voltage Data Form

Test number: BCH-FRP-IB-BO-2/26/07-1400 Date: 2/26/2007 Marina/Location: Beach Marine, Jacksonville, FL

Vessel Name: Endurance Type: Trawler Hull Material/Coating, if metal: FRP

Make/Model: Albin Classic Cabin Dock #: 7 Slip #: 7 Pedestal #: 5/7 Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☐ Bow In/ ☑ Bow Out **Tee Dock:** ☐ S / ☐ P Side to, (small finger pier on port side)

Length/Beam: 43' / 14.5' ft **Prop:** ☑ Inboard ☐ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

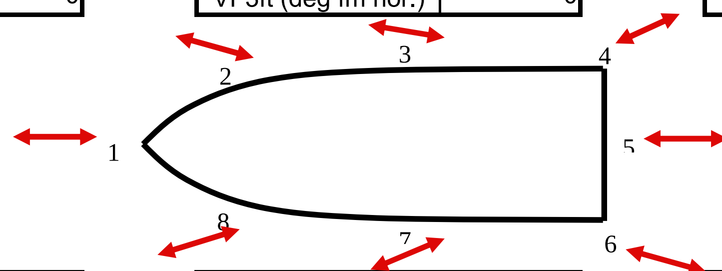
Power: ☑ 50A/240V ☐ 30A/120V ☐ 2-30A/120V ☐ 50A/240V to 2-30A Other: ______

2	Bkgd	Fault
HF1ft(V)	0.002	0.005
HF3ft(V)	0.002	0.004
HF5ft(V)	0.002	0.004
V3ft(V)	0.08	0.152
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.002	0.007
HF3ft(V)	0.002	0.007
HF5ft(V)	0.003	0.007
V3ft(V)	0.1	0.15
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)	0.002	0.022
HF3ft(V)	0.002	0.02
HF5ft(V)	0.002	0.014
V3ft(V)	0.111	0.25
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

1	Bkgd	Fault
HF1ft(V)	0.002	0.003
HF3ft(V)	0.002	0.003
HF5ft(V)	0.002	0.003
V3ft(V)	0.052	0.136
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.003	0.03
HF3ft(V)	0.002	0.027
HF5ft(V)	0.003	0.02
V3ft(V)	0.078	0.26
VF3ft(V)	0.003	0.031
VF3ft (deg fm hor.)		30 d a

8	Bkgd	Fault
HF1ft(V)	0.003	0.004
HF3ft(V)	0.003	0.004
HF5ft(V)	0.003	0.004
V3ft(V)	0.084	0.204
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.002	0.006
HF3ft(V)	0.003	0.006
HF5ft(V)	0.003	0.006
V3ft(V)	0.076	0.182
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.002	0.023
HF3ft(V)	0.003	0.022
HF5ft(V)	0.002	0.019
V3ft(V)	0.07	0.218
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

Calculated Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	0.0005	0.0015	0.0025	0.01	0.0135	0.0105	0.002	0.0005
HF3ft(V/ft)	0.0005	0.001	0.0025	0.009	0.0125	0.0095	0.0015	0.0005
HF5ft(V/ft)	0.0005	0.001	0.002	0.006	0.0085	0.0085	0.0015	0.0005
V3ft(V)	0.084	0.072	0.05	0.139	0.182	0.148	0.106	0.12
VF3ft(V/ft)	less	less	less	less	0.014	less	less	less

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.08 N 0.07 G 0.06 ohms

Test Current: 5 A Voltage for Test Current 2.5 V Water Type: ☑ Salt ☐ Brackish ☐ Fresh

Salinity: 24 g/l TDS: OL ppt pH: 7.2 Temp: 70.7 F

Conductivity: OL ms/cm@1ft OL ms/cm@3ft OL ms/cm@5ft Water path (Ω): 0.50

Sheet 1-1-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: BCH-FRP-IB-BO-2/26/07-1400 Marina/Location: Beach Marine, Jacksonville, FL

Date: 2/26/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	0.74
Bkgd(V)	0.003
Difference(V)	0.737
HF1ft(V/ft)	0.369
MaxVF1ft(V)	0.740
Bkgd(V)	0.003
Difference(V)	0.737
MaxVF1ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	2.740

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	
Bkgd(V)	
Difference(V)	
HF5ft(V/ft)	
MaxVF5ft(V)	
Bkgd(V)	
Difference(V)	
MaxVF5ft(V/ft)	
Deg from Hor.	
Hull V @ 3A	

AC Clamp Test (Amps)	
Ped CB open	0.006
Ped CB Shut Loaded	0.006
Net Water (A)	0.000

Current Split Test	
Test Load Current (A)	13.100
Bkgd, Ped CB Open (A)	0.006
Water Path (A), w/Load	10.520
1. Brackish water, about 2/3	10.514
2. Docks are aluminum on p	2.960
Net Ground Wire (A)	2.954
% Split Water	78.1%
% Split Ground Wire	21.9%

Testing Remarks:

1. Neutral and ground were connected on the boat. The boat was tested with shore cord removed so there was no interference from this connection.

Endurance (Sheet 1-1-1,2)

Sheet 2, Marina Data Testing Notes

Marina Name/Location: Buffalo Launch Club, Buff. NY, Niagara River

Date: 7/24/2007 Weather: Overcast

Air Temperature: 68F Wind: 2-5kts Clouds: 100% Rain: none

Electrical Service at Pedestals: 50A/240V, 30A/120V Water depth in marina: 12 feet

Number piers/wharfs: 4/3 Bottom type: mud, silt

Number vessels connected to shore power: 85 Vegetation present: grass where <8' deep

Mooring arrangements/configurations: Wooden docks with fixed wooden pilings along with some floating docks (coated steel tanks).

Metallic structures that could infuence testing: Sheet pile and associated structure reinforced the river side of marina. This metal was connected to the marina bonding system.

Notes and comments on marina aspects of testing:

None

Buffalo Launch Club, Buffalo, NY, Niagara River, Freshwater

Sheet 2-1-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: BLC-FRP-IB-AS, 7/24/07, 0800hrs Date: 7/24/2007 Marina/Location: Buffalo Launch Club, Buff. NY, Niagara River

Vessel Name: Why Knot Type: Cruiser Hull Material/Coating, if metal: FRP

Make/Model: 2006 Carver 45Voy. Dock #: F Slip #: 83 Pedestal #: 83 Water flow at dock: 1 kts

Mooring: **Wharf:** ☐ S / ☑ P Side to **Slip:** ☐ Bow In/ ☐ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 45'/15' ft **Prop:** ☑ Inboard ☐ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

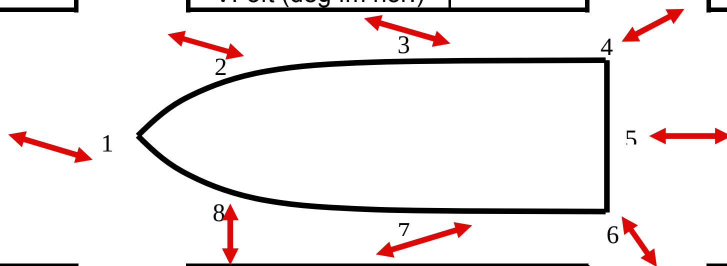
Power: ☑ 50A/240V ☐ 30A/120V ☐ 2-30A/120V ☐ 50A/240V to 2-30A Other: ______

2	Bkgd	Fault
HF1ft(V)	0.003	0.136
HF3ft(V)	0.003	0.132
HF5ft(V)	0.003	0.117
V3ft(V)	0.005	0.946
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.003	0.460
HF3ft(V)	0.003	0.490
HF5ft(V)	0.003	0.470
V3ft(V)	0.008	2.160
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)	0.012	1.800
HF3ft(V)	0.010	1.600
HF5ft(V)	0.005	1.170
V3ft(V)	0.015	4.600
VF3ft(V)	0.005	1.790
VF3ft (deg fm hor.)		25 u a

1	Bkgd	Fault
HF1ft(V)	0.002	0.060
HF3ft(V)	0.002	0.070
HF5ft(V)	0.003	0.066
V3ft(V)	0.003	0.312
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.003	2.000
HF3ft(V)	0.009	1.850
HF5ft(V)	0.008	1.400
V3ft(V)	0.029	6.600
VF3ft(V)	0.009	less
VF3ft (deg fm hor.)		0

8	Bkgd	Fault
HF1ft(V)	0.002	0.144
HF3ft(V)	0.002	0.148
HF5ft(V)	0.002	0.152
V3ft(V)	0.003	0.512
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.003	0.570
HF3ft(V)	0.003	0.640
HF5ft(V)	0.003	0.630
V3ft(V)	0.004	1.120
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.003	1.550
HF3ft(V)	0.003	1.600
HF5ft(V)	0.003	1.630
V3ft(V)	0.018	3.100
VF3ft(V)	0.003	1.900
VF3ft (deg fm hor.)		30 u a

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	0.029	0.067	0.229	0.894	0.999	0.774	0.284	0.071
HF3ft(V/ft)	0.034	0.065	0.244	0.795	0.921	0.799	0.319	0.073
HF5ft(V/ft)	0.032	0.057	0.234	0.583	0.696	0.814	0.314	0.075
V3ft(V)	0.309	0.941	2.152	4.585	6.571	3.082	1.116	0.509
VF3ft(V/ft)	less	less	less	0.893	less	0.949	less	less

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.03 N 0.08 G 0.12 ohms

Test Current: 3 A Voltage for Test Current 17.7 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.139 g/l TDS: 0.198 ppt pH: 8.35 Temp: 71F

Conductivity: 0.282 ms/cm@1ft 0.279 ms/cm@3ft 0.28 ms/cm@5ft Water path (Ω): 5.90

Why Knot (Sheet 2-1-1,2)

Sheet 2-1-2, Field Strength/Voltage Data Form

Additional Data and Remarks

Test number: BLC-FRP-IB-AS, 7/24/07, 0800hrs   Marina/Location: Buffalo Launch Club, Buff. NY, Niagara River

Date: 7/24/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	48.000
Bkgd(V)	0.003
Difference(V)	47.997
HF1ft(V/ft)	23.999
MaxVF1ft(V)	48.000
Bkgd(V)	0.003
Difference(V)	47.997
MaxVF1ft(V/ft)	23.999
Deg from Hor.	0
Hull V @ 3A	114.800

Note current actual: 2.79A

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	
Bkgd(V)	
Difference(V)	0.000
HF5ft(V/ft)	0.000
MaxVF5ft(V)	
Bkgd(V)	
Difference(V)	0.000
MaxVF5ft(V/ft)	0.000
Deg from Hor.	
Hull V @ 3A	

AC Clamp Test (Amps)	
Ped CB open	0.001
Ped CB Shut Loaded	0.001
Net Water (A)	0.000

Current Split Test	
Test Load Current (A)	12.300
Bkgd, Ped CB Open (A)	0.002
Water Path (A), w/Load	0.480
Net Water Path (A)	0.478
Ground Wire (A), w/Load	12.000
Net Ground Wire (A)	11.998
% Split Water	3.8%
% Split Ground Wire	96.2%

Testing Remarks:

1. Boat had an isolation transformer. The transformer was bypassed and the voltage source was applied directly to the bonding system on the secondary side of the transformer.

2. 5 foot isolation test not done due to water motion at test site at this depth.

3. Boat located on the outboard wharf paralleling the river. This structure is reinforced with a significant amount of bonded steel.

Sheet 3, Marina Data Testing Notes

Marina Name/Location: Callville Bay Marina/Henderson, NV

Date: 4/12/2011 Weather: Sunny, clear

Air Temperature: 74 Wind: 5kts Clouds: 0% Rain: None

Electrical Service at Pedestals: 50A/240V, 30A/120V Water depth in marina: 10-12'

Number piers/wharfs: 20/2 Bottom type: Rock/Sand

Number vessels connected to shore power: 120 Vegetation present: None

Mooring arrangements/configurations: Fingers off many piers/wharfs. Wood and composite-coated metal planks on foam/plastic floats.

Metallic structures that could infuence testing: Large metal houseboat hulls throughout marina

Notes and comments on marina aspects of testing:

1. This marina was the location of the high hull voltage/current test to verify the linearity of voltage vs. current in the water.
2. The many large metal-hulled house boats can provide a good ground return path for water currents back to the source. This large grounding surface are may have an effect on the testing data (moreso than a marina with mostly FRP hulls and significantly less underwater metal surface area).

SNWS Raw Water Inorganics

2006

Source		Alfred Merritt Smith WTF					River Mountains WTF			
Analyte	**Units**	**13-Jan-10**	**18-Apr-10**	**14-Jul-10**	**13-Nov-10**		**13-Jan-10**	**18-Apr-10**	**14-Jul-10**	**13-Nov-10**
Chlorine, Free	mg/L	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1
Color, Total	PCU	10	7.5	7.5	5		10	5	5	5
Conductivity	µs/cm	1077	1047	1043	1024		1074	1063	1042	1035
pH	pH units	8.14	8.01	7.95	7.91		8.16	8.17	8.02	7.88
Temperature	°C	14.4	13.4	14.1	15.2		14.5	13.2	14.4	16.4
Turbidity	NTU	0.98	0.64	0.48	0.34		0.64	0.37	0.59	0.40
Total Hardness	mg/L	350	330	330	340		320	290	310	340
Non-Carbonate Hardness	mg/L	216	190	192	201		187	152	172	202
Calcium	mg/L	87	84	83	86		80	72	80	85
Magnesium	mg/L	33	29	29	30		30	26	28	30
Potassium	mg/L	7.7	6.6	6.0	6.4		6.9	5.7	5.7	6.4
Sodium	mg/L	110	100	100	100		110	92	95	100
Alkalinity, HCO_3	mg/L	134	140	138	139		133	138	138	138
Aggressive Index		12.6	12.5	12.4	12.4		12.6	12.6	12.5	12.3
Bromide	mg/L	0.10	0.091	0.089	0.092		0.094	0.095	0.088	0.092
Carbon Dioxide	mg/L	1.6	2.2	2.5	2.7		1.5	1.5	2.1	2.9
Chloride	mg/L	100	90	99	91		100	92	99	92
Cyanide	mg/L	<0.025	<0.12	<0.025	<0.025		<0.025	<0.12	<0.025	<0.025
Fluoride	mg/L	0.36	0.33	0.34	0.32		0.36	0.34	0.34	0.33
Langelier Index		0.508	0.377	0.308	0.286		0.488	0.47	0.361	0.251
MBAS	mg/L	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05
Nitrate	mg/L	0.74	0.5	0.52	0.47		0.69	0.57	0.52	0.47
Nitrite	mg/L	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05
Perchlorate	µg/L	5.3	2.6	2.4	2.0		5.3	3.2	2.3	2.1
Silica	mg/L	7.5	7.6	7.4	7.2		7.3	7.7	7.8	7
Sulfate	mg/L	280	260	300	270		280	270	300	270
TDS - 180	mg/L	694	654	654	642		696	666	670	642
TOC	mg/L	2.3	2.6	2.5	2.5		2.4	2.6	2.6	2.5
Aluminum	mg/L	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005
Antimony	mg/L	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Arsenic	mg/L	0.0032	0.0025	0.0025	0.0028		0.0032	0.0027	0.0025	0.0028
Barium	mg/L	0.13	0.16	0.12	0.15		0.14	0.12	0.13	0.15
Beryllium	mg/L	<0.002	<0.002	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002
Cadmium	mg/L	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Chromium	mg/L	0.003	<0.002	<0.002	0.003		0.003	<0.002	<0.002	0.003
Copper	mg/L	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005
Iron	mg/L	<0.05	<0.05	<0.1	<0.1		<0.05	<0.05	<0.1	<0.1
Lead	mg/L	<0.002	<0.002	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002
Manganese	mg/L	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005
Mercury	mg/L	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Molybdenum	mg/L	0.006	0.0054	0.0053	0.0055		0.0057	0.0055	0.0054	0.0056
Nickel	mg/L	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005
Selenium	mg/L	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005
Silver	mg/L	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02	<0.02
Thallium	mg/L	<0.002	<0.002	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002
Vanadium	mg/L	0.003	<0.002	<0.002	0.003		0.003	<0.002	<0.002	0.003
Zinc	mg/L	<0.1	<0.1	<0.1	<0.1		<0.1	<0.1	<0.1	<0.1

N/A = Not Analyzed

SNWS Finished Water Inorganics

2006

Source		Alfred Merritt Smith WTF					River Mountains WTF			
Analyte	**Units**	**13-Jan-10**	**18-Apr-10**	**14-Jul-10**	**13-Oct-10**		**13-Jan-10**	**18-Apr-10**	**14-Jul-10**	**13-Oct-10**
Chlorine, Free	mg/L	1.91	1.74	1.44	1.51		1.69	1.75	1.71	1.72
Color, Total	PCU	5	5	5	2.5		7.5	2.5	5	2.5
Conductivity	μs/cm	1087	1050	1053	1033		1099	1080	1078	1058
pH	pH units	7.71	7.66	7.62	7.58		8.02	8.0	7.86	7.80
Temperature	^0C	14.9	13.4	15.0	15.2		14.5	13.6	14.9	16.8
Turbidity	NTU	0.06	0.05	0.05	0.05		0.05	0.06	0.04	0.05
Total Hardness	mg/L	320	310	320	330		320	290	320	330
Non-Carbonate Hardness	mg/L	191	177	187	196		189	151	183	191
Calcium	mg/L	79	79	80	85		77	74	80	84
Magnesium	mg/L	30	27	28	29		30	26	28	29
Potassium	mg/L	6.9	6.2	5.7	6.3		6.7	5.9	5.7	6.4
Sodium	mg/L	100	97	96	100		110	97	100	110
Alkalinity, HCO_3	mg/L	129	133	133	134		131	139	137	139
Aggressive Index		12.1	12.1	12.0	12		12.4	12.4	12.3	12.3
Bromide	mg/L	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05
Carbon Dioxide	mg/L	4.02	4.67	5.10	5.64		2.00	2.22	3.03	3.53
Chloride	mg/L	110	94	100	94		110	99	110	100
Cyanide	mg/L	<0.025	<0.12	<0.025	<0.025		<0.025	<0.025	<0.025	<0.025
Fluoride	mg/L	0.84	0.81	0.85	0.82		0.76	0.84	0.83	0.76
Langelier Index		0.017	-0.019	-0.053	-0.0658		0.323	0.31	0.201	0.168
MBAS	mg/L	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05
Nitrate	mg/L	0.78	0.52	0.53	0.48		0.66	0.56	0.54	0.50
Nitrite	mg/L	<0.05	<0.05	<0.05	<0.05		<0.05	<0.05	<0.05	<0.05
Perchlorate	μg/L	4.7	2.7	2.8	2.2		5.2	3.0	2.7	2.1
ortho-Phosphate	mg/L	0.06	0.05	0.04	0.05		0.06	0.06	0.06	0.06
Silica	mg/L	7.6	8.0	7.9	7.3		7.3	8.1	8	7.1
Sulfate	mg/L	280	260	300	270		280	270	300	270
TDS - 180	mg/L	702	660	656	644		700	670	674	650
TOC	mg/L	2.3	2.4	2.4	2.3		2.3	2.4	2.4	2.4
Aluminum	mg/L	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005
Antimony	mg/L	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Arsenic	mg/L	0.0022	<0.002	<0.002	0.0020		0.0027	0.0022	<0.002	0.0022
Barium	mg/L	0.13	0.13	0.13	0.15		0.12	0.13	0.12	0.15
Beryllium	mg/L	<0.002	<0.002	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002
Cadmium	mg/L	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Chromium	mg/L	0.0035	<0.002	<0.002	0.0027		0.0022	<0.002	<0.002	0.0024
Copper	mg/L	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005
Iron	mg/L	<0.05	<0.05	<0.1	<0.1		<0.05	<0.05	<0.1	<0.1
Lead	mg/L	<0.002	<0.002	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002
Manganese	mg/L	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005
Mercury	mg/L	<0.001	<0.001	<0.001	<0.001		<0.001	<0.001	<0.001	<0.001
Molybdenum	mg/L	0.0058	0.0055	0.0054	0.0054		0.0057	0.0054	0.0053	0.0055
Nickel	mg/L	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005
Selenium	mg/L	<0.005	<0.005	<0.005	<0.005		<0.005	<0.005	<0.005	<0.005
Silver	mg/L	<0.02	<0.02	<0.02	<0.02		<0.02	<0.02	<0.02	<0.02
Thallium	mg/L	<0.002	<0.002	<0.002	<0.002		<0.002	<0.002	<0.002	<0.002
Vanadium	mg/L	0.0021	<0.002	<0.002	0.002		0.0020	<0.002	<0.002	0.002
Zinc	mg/L	0.13	0.1	0.1	0.12		0.14	0.12	0.12	0.16

N/A = Not Analyzed

Revised 9/23/2008

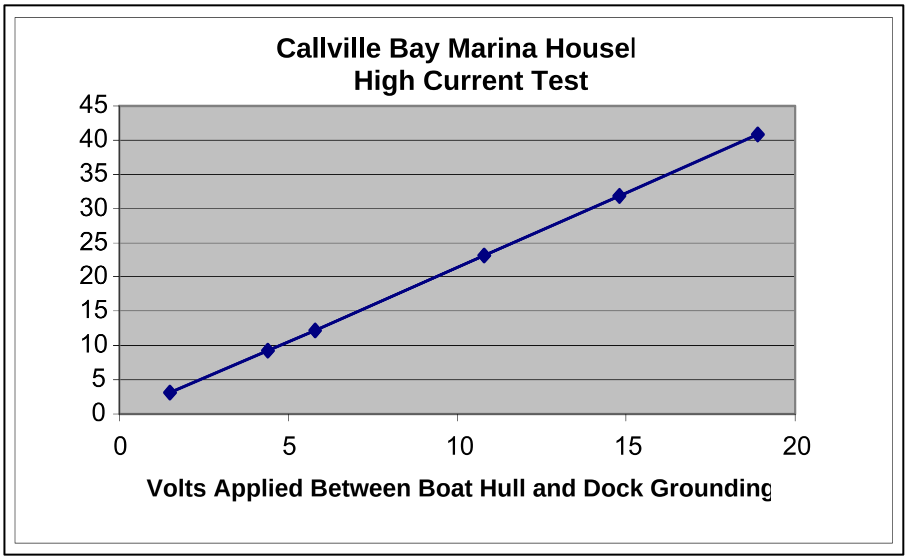
Callvillle Bay Marina, Henderson, NV, Lake Meade, Freshwater

Sheet 3A, CBM Linearity Data

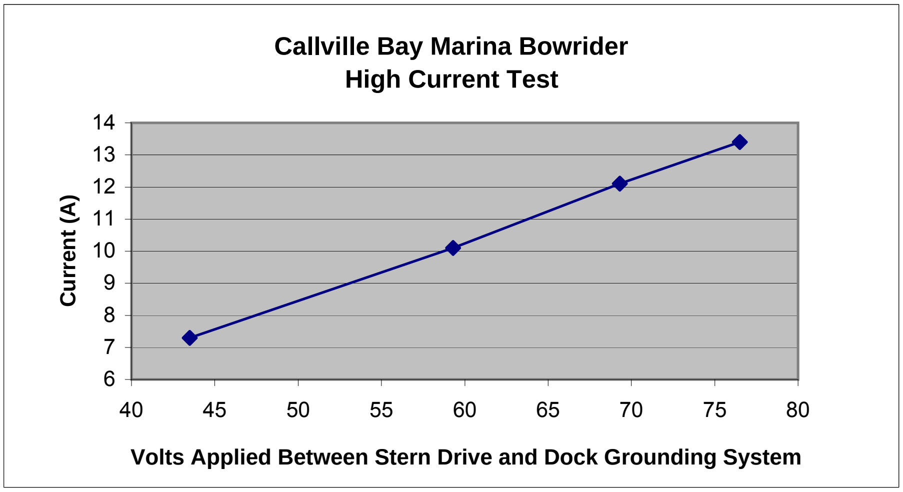
Investigators: Jim Shafer, David Rifkin

Calville Bay Marina, 4/11/07. Voltage was applied to the hull (top) and outdrive (bottom) and the resultin
water current measured.
Four electric hair dryers were used as ballast to prevent an uncontrolled overcurrent situation.
Using the linear relationship between voltage and current, the current for any voltage can be extrapolate

Hull Volts	Water Amps
1.5	3.1
4.4	9.3
5.8	12.2
10.8	23.2
14.8	31.9
18.9	40.8



Hull Volts	Water Amps
43.5	7.3
59.3	10.1
69.3	12.1
76.5	13.4



Sheet 3-1-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: CBM-ALU(UC)-IO-BI, 4-11-07, 0800 Date: 4/12/2011 Marina/Location: Callville Bay Marina/Henderson, NV

Vessel Name: #23 Type: Houseboat Hull Material/Coating, if metal: Aluminum/No Coating

Make/Model: FunCountryMarine 65' Dock #: O-dock Slip #: N/A Pedestal #: N/A Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☑ Bow In/ ☐ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 65'/14' ft **Prop:** ☐ Inboard ☑ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

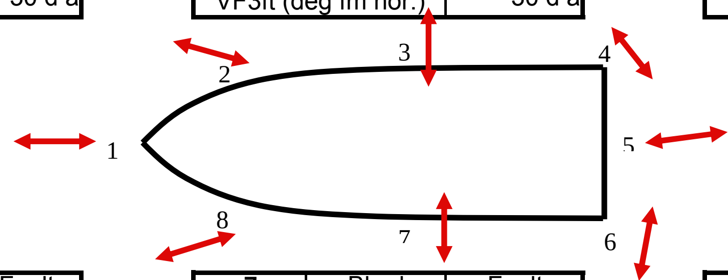
Power: ☑ 50A/240V ☐ 30A/120V ☐ 2-30A/120V ☐ 50A/240V to 2-30A Other: ______

2	Bkgd	Fault
HF1ft(V)	0.002	0.176
HF3ft(V)	0.002	0.118
HF5ft(V)	0.002	0.071
V3ft(V)	0.023	0.590
VF3ft(V)	0.002	0.158
VF3ft (deg fm hor.)		30 d a

3	Bkgd	Fault
HF1ft(V)	0.002	0.193
HF3ft(V)	0.002	0.130
HF5ft(V)	0.002	0.098
V3ft(V)	0.023	0.810
VF3ft(V)	0.002	0.167
VF3ft (deg fm hor.)		30 d a

4	Bkgd	Fault
HF1ft(V)	0.003	0.277
HF3ft(V)	0.003	0.140
HF5ft(V)	0.003	0.095
V3ft(V)	0.040	0.800
VF3ft(V)	0.003	0.225
VF3ft (deg fm hor.)		45 d a

1	Bkgd	Fault
HF1ft(V)	0.002	0.059
HF3ft(V)	0.002	0.056
HF5ft(V)	0.002	0.047
V3ft(V)	0.008	0.390
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.003	0.270
HF3ft(V)	0.003	0.137
HF5ft(V)	0.003	0.097
V3ft(V)	0.050	0.728
VF3ft(V)	0.003	0.190
VF3ft (deg fm hor.)		30 d a

8	Bkgd	Fault
HF1ft(V)	0.003	0.112
HF3ft(V)	0.003	0.100
HF5ft(V)	0.003	0.071
V3ft(V)	0.012	0.540
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.003	0.206
HF3ft(V)	0.003	0.112
HF5ft(V)	0.003	0.074
V3ft(V)	0.012	1.008
VF3ft(V)	0.003	0.156
VF3ft (deg fm hor.)		60 d a

6	Bkgd	Fault
HF1ft(V)	0.003	0.266
HF3ft(V)	0.003	0.126
HF5ft(V)	0.003	0.077
V3ft(V)	0.030	1.002
VF3ft(V)	0.003	0.167
VF3ft (deg fm hor.)		45 d a

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	0.029	0.087	0.096	0.137	0.134	0.132	0.102	0.055
HF3ft(V/ft)	0.027	0.058	0.064	0.069	0.067	0.062	0.055	0.049
HF5ft(V/ft)	0.023	0.035	0.048	0.046	0.047	0.037	0.036	0.034
V3ft(V)	0.382	0.567	0.787	0.760	0.678	0.972	0.996	0.528
VF3ft(V/ft)	less	0.078	0.083	0.111	0.094	0.082	0.077	less

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.05 N 0.05 G 0.11 ohms

Test Current: 3 A Voltage for Test Current 3.1 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.538 g/l TDS: 0.76 ppt pH: 8.18 Temp: 72F

Conductivity: 1.03 ms/cm@1ft 1.05 ms/cm@3ft Not Meas. ms/cm@5ft Water path (Ω): 1.03

#23 (Sheet 3-1-1,2)

Sheet 3-1-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: CBM-ALU(UC)-IO-BI, 4-11-07, 0800 Marina/Location: Callville Bay Marina/Henderson, NV

Date: 4/12/2011

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	15.000
Bkgd(V)	0.002
Difference(V)	14.998
HF1ft(V/ft)	7.499
MaxVF1ft(V)	15.000
Bkgd(V)	0.002
Difference(V)	14.998
MaxVF1ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	29.700

Isolation Test 2" from plate, 5' deep	
	9.000
Bkgd(V)	0.002
Difference(V)	8.998
HF5ft(V/ft)	4.499
MaxVF5ft(V)	16.000
Bkgd(V)	0.002
Difference(V)	15.998
MaxVF5ft(V/ft)	7.999
Deg from Hor.	30 u a
Hull V @ 3A	29.700

AC Clamp Test (Amps)	
Ped CB open	0.084
Ped CB Shut Loaded	0.162
Net Water (A)	0.078

Current Split Test	
Test Load Current (A)	12.560
Bkgd, Ped CB Open (A)	0.019
Water Path (A), w/Load	1.240
Net Water Path (A)	1.221
Ground Wire (A), w/Load	11.300
Net Ground Wire (A)	11.281
% Split Water	9.8%
% Split Ground Wire	90.2%

Testing Remarks:

1. A neutral to ground bond was detected on the boat. This did not affect the testing since the shore cord was unplugged.

Sheet 3-1-2, Field Strength/Voltage Data Form

2. High current/high hull voltage test. Only accomplished at this marina.

Water Amps	Hull Voltage
3.1	1.5
9.3	4.4
12.2	5.8
23.2	10.8
31.9	14.8
40.8	18.9

HV1ft(V) @ 40.8amps water current = 2.25v (or 1.12v/ft gradient)
Gradient measurement taken at starboard quarter (highest location measured in basic test using 3 amps).

Sheet 3-2-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: CBM-FRP-IO-AP, 4-11-07, 1300hrs Date: 4/12/2011 Marina/Location Callville Bay Marina/Henderson, NV

Vessel Name: #53 Type: Bowrider Hull Material/Coating, if metal: FRP

Make/Model: FourWinns Horizon 200 Dock #: O-dock Slip #: N/A Pedestal #: N/A Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☑ P Side to **Slip:** ☐ Bow In/ ☐ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 20'/7' ft **Prop:** ☐ Inboard ☑ Inboard Outboard ☐ Outboard ☐ Sail : ☑ Single ☐ Double

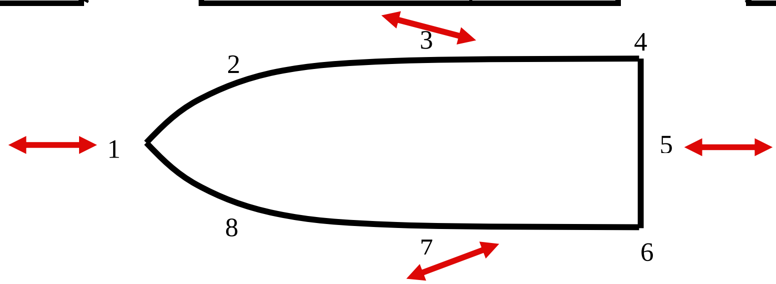
Power: ☐ 50A/240V ☐ 30A/120V ☐ 2-30A/120V ☐ 50A/240V to 2-30A Other: ______

2	Bkgd	Fault
HF1ft(V)		
HF3ft(V)		
HF5ft(V)		
V3ft(V)		
VF3ft(V)		
VF3ft (deg fm hor.)		

3	Bkgd	Fault
HF1ft(V)	0.002	0.276
HF3ft(V)	0.002	0.227
HF5ft(V)	0.002	0.205
V3ft(V)	0.037	1.429
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)		
HF3ft(V)		
HF5ft(V)		
V3ft(V)		
VF3ft(V)		
VF3ft (deg fm hor.)		

1	Bkgd	Fault
HF1ft(V)	0.002	0.070
HF3ft(V)	0.002	0.069
HF5ft(V)	0.002	0.064
V3ft(V)	0.030	0.097
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.003	4.400
HF3ft(V)	0.003	3.050
HF5ft(V)	0.002	0.628
V3ft(V)	0.039	6.100
VF3ft(V)	0.003	3.290
VF3ft (deg fm hor.)		25 d a

8	Bkgd	Fault
HF1ft(V)		
HF3ft(V)		
HF5ft(V)		
V3ft(V)		
VF3ft(V)		
VF3ft (deg fm hor.)		

7	Bkgd	Fault
HF1ft(V)	0.002	0.350
HF3ft(V)	0.002	0.300
HF5ft(V)	0.002	0.265
V3ft(V)	0.027	1.700
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)		
HF3ft(V)		
HF5ft(V)		
V3ft(V)		
VF3ft(V)		
VF3ft (deg fm hor.)		

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	0.034	0.000	0.137	0.000	2.199	0.000	0.174	0.000
HF3ft(V/ft)	0.034	0.000	0.113	0.000	1.524	0.000	0.149	0.000
HF5ft(V/ft)	0.031	0.000	0.102	0.000	0.313	0.000	0.132	0.000
V3ft(V)	0.067	0.000	1.392	0.000	6.061	0.000	1.673	0.000
VF3ft(V/ft)	less	0.000	less	0.000	1.644	0.000	less	0.000

Bonding system: ☐ Intact Pedestal Impedances w/SureTest: H No Power N No Power G No Power ohms

Test Current: 3 A Voltage for Test Current 22.5 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.538 g/l TDS: 0.76 ppt pH: 8.18 Temp: 72F

Conductivity: 1.03 ms/cm@1ft 1.05 ms/cm@3ft Not Meas. ms/cm@5ft Water path (Ω): 7.50

#53 (Sheet 3-2-1,2)

Sheet 3-2-2, Field Strength/Voltage Data Form

Additional Data and Remarks

Test number: CBM-FRP-IO-AP, 4-11-07, 1300hrs Marina/Location: Callville Bay Marina/Henderson, NV

Date: 4/12/2011

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	12.000
Bkgd(V)	0.002
Difference(V)	11.998
HF1ft(V/ft)	5.999
MaxVF1ft(V)	16.000
Bkgd(V)	0.002
Difference(V)	15.998
MaxVF1ft(V/ft)	7.999
Deg from Hor.	30 u a
Hull V @ 3A	50.000

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	8.300
Bkgd(V)	0.002
Difference(V)	8.298
HF5ft(V/ft)	4.149
MaxVF5ft(V)	14.000
Bkgd(V)	0.002
Difference(V)	13.998
MaxVF5ft(V/ft)	6.999
Deg from Hor.	25 u a
Hull V @ 3A	50.000

AC Clamp Test (Amps)	
Ped CB open	N/A
Ped CB Shut Loaded	N/A
Net Water (A)	N/A

Current Split Test, Not Performed, No AC	
Test Load Current (A)	
Bkgd, Ped CB Open (A)	
Water Path (A), w/Load	
Net Water Path (A)	
Ground Wire (A), w/Load	
Net Ground Wire (A)	
% Split Water	
% Split Ground Wire	

Testing Remarks:

1. This boat had no AC electrical system. The voltage source was hooked directly to the battery negative to establish water path .
2. This was an opportunity to look at a singe stern drive boat in freshwater, many of which have an AC electrical systems.

Sheet 3-2-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

3. High current/high hull voltage test. Only accomplished at this marina.

Water Amps	Hull Voltage
7.3	43.5
10.1	59.3
12.1	69.3
13.4	76.5

a. HV1ft(V) @ 13.4amps water current =12v (or 6v/ft gradient)

b. 6v/ft gradient measurement taken at stern (highest location measured in basic test using 3amp fault current) with test probe within two inches of drive housing.

c. Due to the small size of the boat, only bow, stern, and beam measurements were taken.

4. Current split test and AC clamp test not performed due to no AC system installed.

Sheet 4, Marina Data Testing Notes

Marina Name/Location: Conley Bottom Resort, Lake Cumberland, Monticello KY

Date: 5/17/2007 Weather: Overcast

Air Temperature: 68F Wind: 10kts Clouds: 100% Rain: Intermittent

Electrical Service at Pedestals: 50A/208V, 30A/120V Water depth in marina: 30ft

Number piers/wharfs: 12/1 Bottom type: Mud, rock

Number vessels connected to shore power: Approx. 800 Vegetation present: None

Mooring arrangements/configurations: Wooden docks on steel floats, most bonded to marina grounding system.

Metallic structures that could infuence testing: Steel floats bonded to the grounding system. 390 mooring cable winches, some bonded.

Notes and comments on marina aspects of testing:

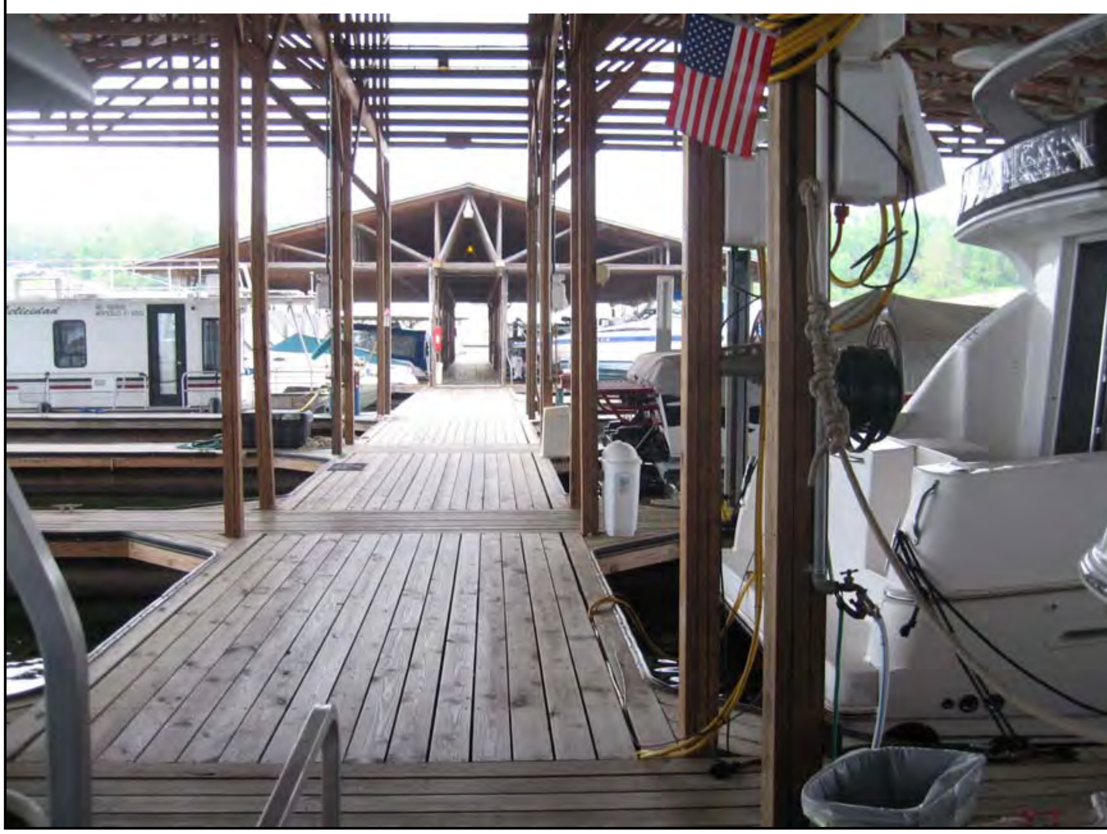
1. Broken cable insulation test:
Using isolation and non isolation, 3 conditions of bare wires in the water were tested. One inch of insulation was removed on each conductor with standard line voltage used as the source. The return ground was to a plate suspended in the water (isolation case). Field gradient was measured between the plate and the bare wire which were approx. 3 feet apart, representing a worst case situation where all current leaving the bare wires had to return to the plate nearby. Current is water current.
For the non isolation case, the distributed marina gounding system (instead of the plate) was used as the return path and the closest probe from the test rig was placed approx. 6" from the faulted conductors. In each case, the faulted conductors were in close proximity (less than 3") to each other. Data located on next page.

Sheet 4, Marina Data Testing Notes

Investigators: Jim Shafer, David Rifkin

	Isolation Transformer		No Isolation Transformer	
Hot only:	Bkgd (V):	0.003	Bkgd (V):	0.003
	Fault (V)	4.800	Fault (V)	1.600
	Current (A)	0.145	Current (A	0.144
	Volts/Foot	2.399	Volts/Foot	0.799
H + N:	Bkgd (V):	0.003	Bkgd (V):	0.003
	Fault (V)	3.000	Fault (V)	1.000
	Current (A)	0.108	Current (A	0.116
	Volts/Foot	1.499	Volts/Foot	0.499
H+N+G:	Bkgd (V):	0.003	Bkgd (V):	0.003
	Fault (V)	2.700	Fault (V)	0.870
	Current (A)	0.087	Current (A	0.087
	Volts/Foot	1.349	Volts/Foot	0.434

Conley Bottom Resort, Monticello, KY, Lake Cumberland, Freshwater



Sheet 4-1-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: CBR-FRP-IB-BO, 5-16-07, 0800hrs Date: 5/16/2007 Marina/Location: Conley Bottom Resort, Monticello KY

Vessel Name: Incommunicado Type: Trawler Hull Material/Coating, if metal: FRP

Make/Model: Carver 325 Dock #: AA Slip #: 8 Pedestal #: 8 Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☐ Bow In/ ☑ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 32'/12' ft **Prop:** ☑ Inboard ☐ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

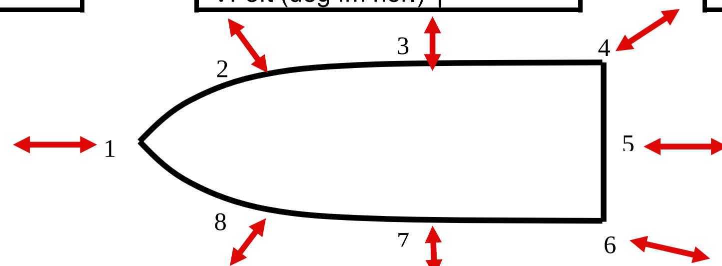
Power: ☐ 50A/240V ☐ 30A/120V ☑ 2-30A/120V ☐ 50A/240V to 2-30A Other: ______

2	Bkgd	Fault
HF1ft(V)	0.003	0.450
HF3ft(V)	0.003	0.370
HF5ft(V)	0.003	0.280
V3ft(V)	0.005	0.970
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.003	1.800
HF3ft(V)	0.003	1.470
HF5ft(V)	0.003	1.080
V3ft(V)	0.005	1.800
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		15

4	Bkgd	Fault
HF1ft(V)	0.003	2.400
HF3ft(V)	0.003	1.850
HF5ft(V)	0.003	1.420
V3ft(V)	0.005	1.750
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

1	Bkgd	Fault
HF1ft(V)	0.003	0.083
HF3ft(V)	0.003	0.081
HF5ft(V)	0.003	0.087
V3ft(V)	0.006	0.455
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.003	3.000
HF3ft(V)	0.003	2.300
HF5ft(V)	0.003	2.000
V3ft(V)	0.005	1.900
VF3ft(V)	0.003	6.000
VF3ft (deg fm hor.)		25 d a

8	Bkgd	Fault
HF1ft(V)	0.003	0.300
HF3ft(V)	0.003	0.300
HF5ft(V)	0.003	0.260
V3ft(V)	0.006	0.790
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.003	2.000
HF3ft(V)	0.003	1.600
HF5ft(V)	0.003	1.200
V3ft(V)	0.005	2.400
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.003	2.100
HF3ft(V)	0.003	1.600
HF5ft(V)	0.003	1.400
V3ft(V)	0.005	1.600
VF3ft(V)	0.003	3.900
VF3ft (deg fm hor.)		20 d a

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	0.040	0.224	0.899	1.199	1.499	1.049	0.999	0.149
HF3ft(V/ft)	0.039	0.184	0.734	0.924	1.149	0.799	0.799	0.149
HF5ft(V/ft)	0.042	0.139	0.539	0.709	0.999	0.699	0.599	0.129
V3ft(V)	0.449	0.965	1.795	1.745	1.895	1.595	2.395	0.784
VF3ft(V/ft)	less	less	less	less	2.999	1.949	less	less

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.1 N 0.15 G 0.3 ohms

Test Current: 3 A Voltage for Test Current 28.4 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.15 g/l TDS: 0.21 ppt pH: 8.4 Temp: 70.5F

Conductivity: 0.156 ms/cm@1ft 0.156 ms/cm@3ft 0.153 ms/cm@5ft Water path (Ω): 9.47

Incommunicado (Sheet 4-1-

Sheet 4-1-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: CBR-FRP-IB-BO, 5-16-07, 0800hrs Marina/Location: Conley Bottom Resort, Monticello KY

Date: 5/16/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	65.000
Bkgd(V)	0.003
Difference(V)	64.997
HF1ft(V/ft)	32.499
MaxVF1ft(V)	82.000
Bkgd(V)	0.003
Difference(V)	81.997
MaxVF1ft(V/ft)	40.999
Deg from Hor.	15 d a
Hull V @ 2.6A	117.000

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	32.000
Bkgd(V)	0.003
Difference(V)	31.997
HF5ft(V/ft)	15.999
MaxVF5ft(V)	83.000
Bkgd(V)	0.003
Difference(V)	82.997
MaxVF5ft(V/ft)	41.499
Deg from Hor.	30 d a
Hull V @ 3A	115.000

AC Clamp Test (Amps)	
Ped CB open	0.000
Ped CB Shut Loaded	0.002
Net Water (A)	0.002

Current Split Test	
Test Load Current (A)	12.340
Bkgd, Ped CB Open (A)	0.000
Water Path (A), w/Load	0.760
Net Water Path (A)	0.760
Ground Wire (A), w/Load	12.310
Net Ground Wire (A)	12.310
% Split Water	5.8%
% Split Ground Wire	94.2%

Testing Remarks:

1. In the 1' isolation test, could only achieve 2.6A of water current with full line voltage. This is due to the small size of the ground return which was essentially a small metal plate instead of tremendous number of ground paths available throughout the marina.
2. In the isolation test with the plate at 5', the following voltage and current was also collected:

Current (A)	Voltage (V)
1.000	39.400
2.000	76.800
3.000	115.000

Sheet 5, Marina Data Testing Notes

Investigators: Jim Shafer, David Rifkin

Marina Name/Location: Doctors Lake Marina, Jacksonville, FL

Date: 4/17/2007 Weather: Clear, partly sunny

Air Temperature: 65 Wind: 5kts Clouds: 50% Rain: None

Electrical Service at Pedestals: 50A/240V, 30A/120V Water depth in marina: 5'

Number piers/wharfs: 4/1 Bottom type: Mud

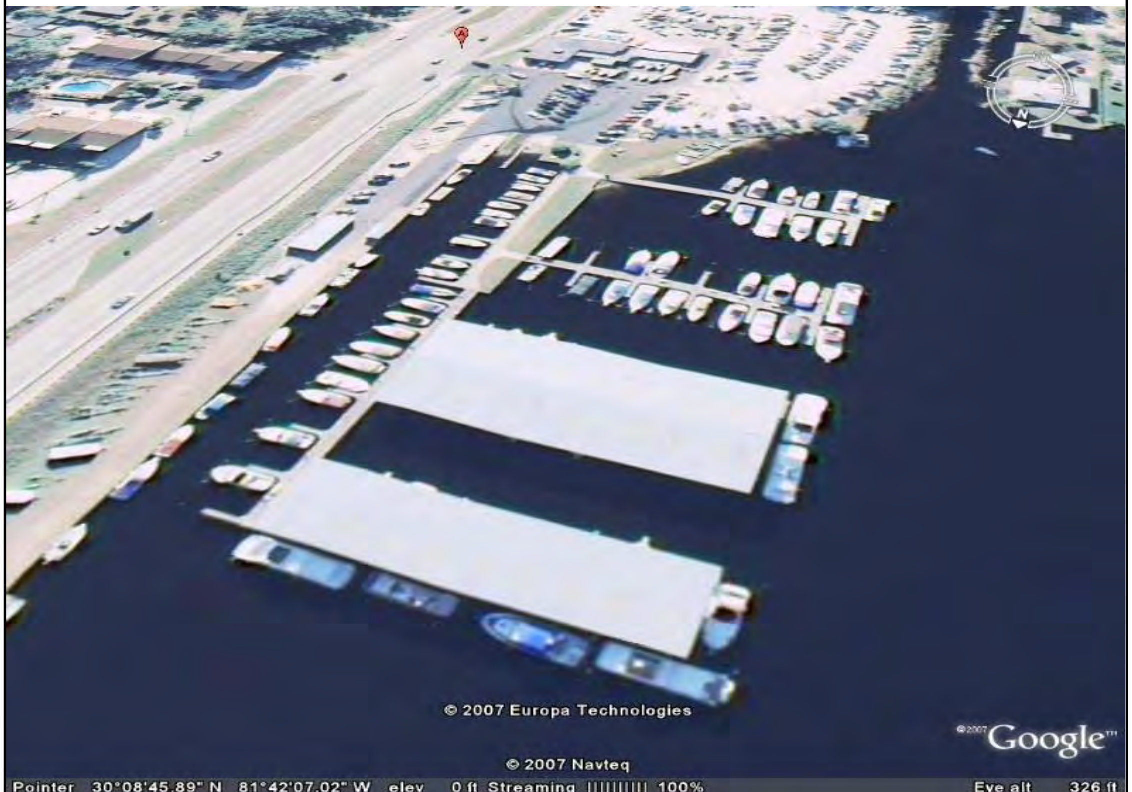
Number vessels connected to shore power: 95 Vegetation present: None

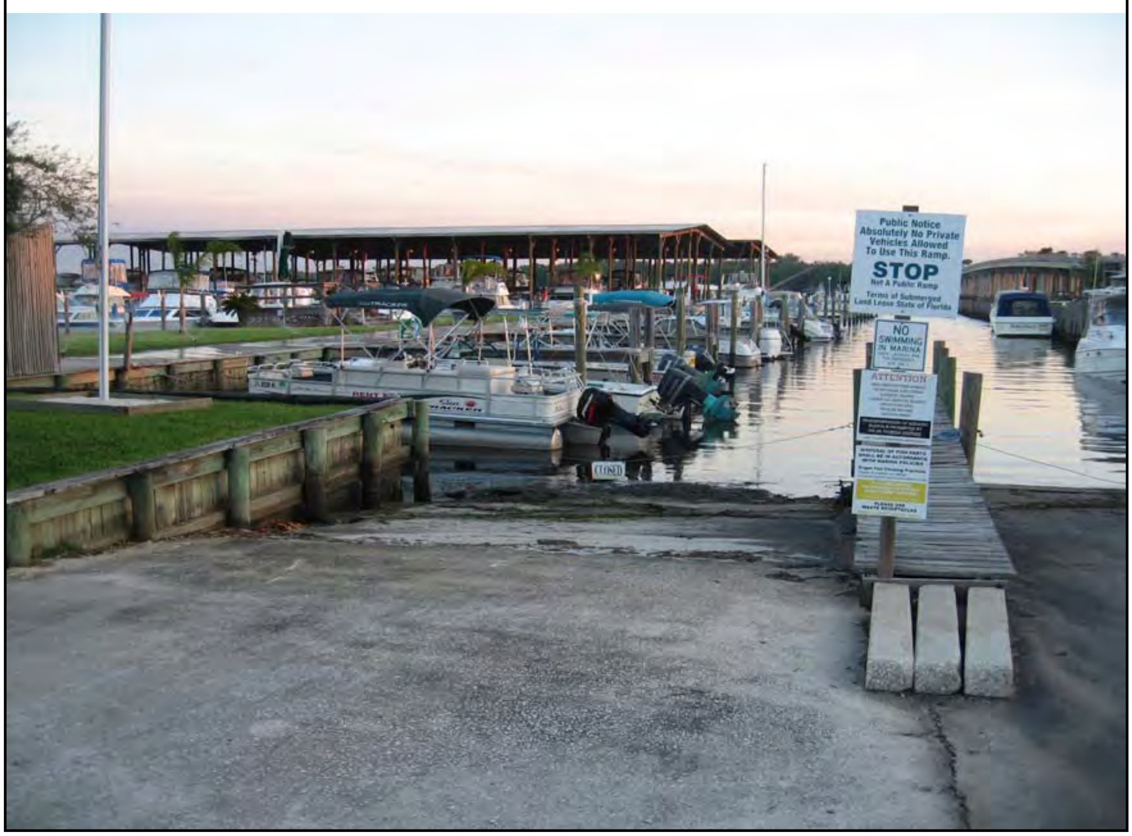
Mooring arrangements/configurations: Wooden plank docks attached to wooden pilings, no floating docks.

Metallic structures that could infuence testing: None

Notes and comments on marina aspects of testing:
1. This marina is located approx. 30 miles up St. Johns River (from ocean). It is brackish in the winter and very fresh during the rainy months of May through July. Water was barely brackish at about 4 times the conductivity of freshwater. It behaved like brackish water in the testing.
2. This marina experienced fluctuating ground-neutral currents in the range of 50-120ma. This caused slight voltage fluctuations (plus or minus 10mv during testing).

Doctors Lake Marina, Jacksonville, FL, Doctors Lake, Brackish Water





Sheet 5-1-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: DOC-FRP-IB-BO, 4-17-07, 0715hrs Date: 4/17/2007 Marina/Location Doctors Lake Marina, Jacksonville, FL

Vessel Name: Highlander Type: Houseboat Hull Material/Coating, if metal: FRP

Make/Model: Gibson 47 Classic 2003 Dock #: D Slip #: 1North Pedestal #: N/A Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☐ Bow In/ ☑ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 47'/14' ft **Prop:** ☑ Inboard ☐ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

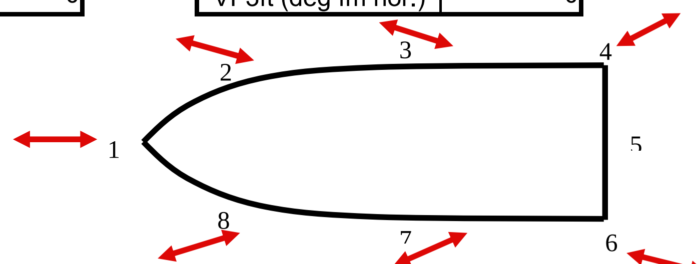
Power: ☐ 50A/240V ☐ 30A/120V ☑ 2-30A/120V ☐ 50A/240V to 2-30A Other:

2	Bkgd	Fault
HF1ft(V)	0.003	0.010
HF3ft(V)	0.003	0.010
HF5ft(V)	0.003	0.012
V3ft(V)	0.071	0.292
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.003	0.025
HF3ft(V)	0.003	0.027
HF5ft(V)	0.003	0.027
V3ft(V)	0.074	0.476
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)	0.003	0.108
HF3ft(V)	0.003	0.105
HF5ft(V)	0.003	0.103
V3ft(V)	0.129	0.700
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

1	Bkgd	Fault
HF1ft(V)	0.003	0.010
HF3ft(V)	0.003	0.010
HF5ft(V)	0.003	0.010
V3ft(V)	0.070	0.284
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.003	
HF3ft(V)	0.003	
HF5ft(V)	0.003	
V3ft(V)	0.003	
VF3ft(V)	0.003	
VF3ft (deg fm hor.)		

8	Bkgd	Fault
HF1ft(V)	0.003	0.013
HF3ft(V)	0.003	0.013
HF5ft(V)	0.003	0.014
V3ft(V)	0.052	0.252
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.003	0.027
HF3ft(V)	0.003	0.029
HF5ft(V)	0.003	0.028
V3ft(V)	0.054	0.368
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.003	0.120
HF3ft(V)	0.003	0.118
HF5ft(V)	0.003	0.103
V3ft(V)	0.052	0.652
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	0.004	0.004	0.011	0.053	0.002	0.059	0.012	0.005
HF3ft(V/ft)	0.004	0.004	0.012	0.051	0.002	0.058	0.013	0.005
HF5ft(V/ft)	0.004	0.005	0.012	0.050	0.002	0.050	0.013	0.006
V3ft(V)	0.214	0.221	0.402	0.571	0.003	0.600	0.314	0.200
VF3ft(V/ft)	less	less	less	less	less	less	less	less

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.1 N 0.07 G 0.34 ohms

Test Current: 3 A Voltage for Test Current 4 V Water Type: ☐ Salt ☑ Brackish ☐ Fresh

Salinity: 2.7 g/l TDS: 3.8 ppt pH: 8.1 Temp: 64F

Conductivity: 5.4 ms/cm@1ft 5.44 ms/cm@3ft 5.35 ms/cm@5ft Water path (Ω): 1.33

Highlander (Sheet 5-1-1,2)

Sheet 5-1-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: DOC-FRP-IB-BO, 4-17-07, 0715hrs Marina/Location: Doctors Lake Marina, Jacksonville, FL

Date: 4/17/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	1.900
Bkgd(V)	0.003
Difference(V)	1.897
HF1ft(V/ft)	0.949
MaxVF1ft(V)	3.000
Bkgd(V)	0.003
Difference(V)	2.997
MaxVF1ft(V/ft)	1.499
Deg from Hor.	30 d a
Hull V @ 3A	8.100

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	
Bkgd(V)	
Difference(V)	
HF5ft(V/ft)	
MaxVF5ft(V)	
Bkgd(V)	
Difference(V)	
MaxVF5ft(V/ft)	
Deg from Hor.	
Hull V @ 3A	

AC Clamp Test (Amps)	
Ped CB open	0.085
Ped CB Shut Loaded	0.085
Net Water (A)	0.000

Current Split Test	
Test Load Current (A)	12.440
Bkgd, Ped CB Open (A)	0.091
Water Path (A), w/Load	1.610
Net Water Path (A)	1.519
Ground Wire (A), w/Load	10.810
Net Ground Wire (A)	10.719
% Split Water	12.4%
% Split Ground Wire	87.6%

Testing Remarks:
1. Stern position not tested due to inaccessibility (large platform with rubber dinghy attached across stern).
2. Isolation test at 5' not done due to limited water depth for plate/probes.

USCG FY 2007 Safety Grant
In-Water Shock Mitigation

Sheet 5-2-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: DOC-FRP-IB-BO, 4-17-07, 1030hrs Date: 4/17/2007 Marina/Location: Doctors Lake Marina, Jacksonville, FL

Vessel Name: Lady Barb Type: Sportfish Hull Material/Coating, if metal: FRP

Make/Model: Bertram 33, 1985 Dock #: C Slip #: 5South Pedestal #: N/A Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☐ Bow In/ ☑ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 33'/12' ft **Prop:** ☑ Inboard ☐ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

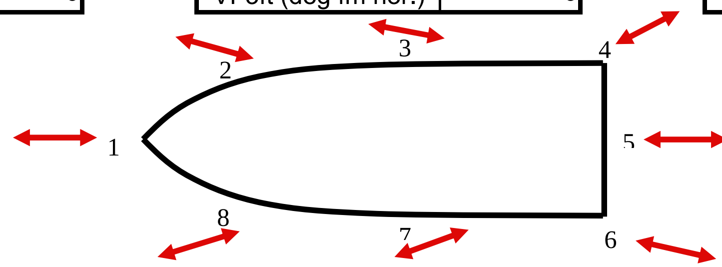
Power: ☐ 50A/240V ☐ 30A/120V ☑ 2-30A/120V ☐ 50A/240V to 2-30A Other: ______

2	Bkgd	Fault
HF1ft(V)	0.003	0.032
HF3ft(V)	0.003	0.032
HF5ft(V)	N/A	N/A
V3ft(V)	0.014	0.340
VF3ft(V)	0.003	0.032
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.003	0.086
HF3ft(V)	0.003	0.090
HF5ft(V)	N/A	N/A
V3ft(V)	0.018	0.744
VF3ft(V)	0.003	0.090
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)	0.003	0.146
HF3ft(V)	0.003	0.130
HF5ft(V)	N/A	N/A
V3ft(V)	0.018	0.814
VF3ft(V)	0.003	0.130
VF3ft (deg fm hor.)		0

1	Bkgd	Fault
HF1ft(V)	0.003	0.020
HF3ft(V)	0.003	0.020
HF5ft(V)	N/A	N/A
V3ft(V)	0.017	0.247
VF3ft(V)	0.003	0.020
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.005	0.134
HF3ft(V)	0.003	0.146
HF5ft(V)	N/A	N/A
V3ft(V)	0.012	0.883
VF3ft(V)	0.003	0.146
VF3ft (deg fm hor.)		0

8	Bkgd	Fault
HF1ft(V)	0.003	0.032
HF3ft(V)	0.003	0.023
HF5ft(V)	N/A	N/A
V3ft(V)	0.020	0.303
VF3ft(V)	0.003	0.023
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.003	0.078
HF3ft(V)	0.003	0.092
HF5ft(V)	N/A	N/A
V3ft(V)	0.010	0.510
VF3ft(V)	0.003	0.092
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.003	0.218
HF3ft(V)	0.003	0.184
HF5ft(V)	N/A	N/A
V3ft(V)	0.049	0.860
VF3ft(V)	0.003	0.184
VF3ft (deg fm hor.)		0

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	0.009	0.015	0.042	0.072	0.065	0.108	0.038	0.015
HF3ft(V/ft)	0.009	0.015	0.044	0.064	0.072	0.091	0.045	0.010
HF5ft(V/ft)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
V3ft(V)	0.230	0.326	0.726	0.796	0.871	0.811	0.500	0.283
VF3ft(V/ft)	0.009	0.015	0.044	0.064	0.072	0.091	0.045	0.010

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.16 N 0.12 G 0.4 ohms

Test Current: 3 A Voltage for Test Current 4.7 V Water Type: ☐ Salt ☑ Brackish ☐ Fresh

Salinity: 2.7 g/l TDS: 3.8 ppt pH: 8.1 Temp: 64F

Conductivity: 5.4 ms/cm@1ft 5.44 ms/cm@3ft 5.35 ms/cm@5ft Water path (Ω): 1.57

Lady Barb (Sheet 5-2-1,2)

Sheet 5-2-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: DOC-FRP-IB-BO, 4-17-07, 1030hrs   Marina/Location: Doctors Lake Marina, Jacksonville, FL

Date: 4/17/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	2.240
Bkgd(V)	0.003
Difference(V)	2.237
HF1ft(V/ft)	1.119
MaxVF1ft(V)	2.400
Bkgd(V)	0.003
Difference(V)	2.397
MaxVF1ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	8.030

Isolation Test 2" from plate, 5' deep (crossed out)	
MaxHF(V)	
Bkgd(V)	
Difference(V)	
HF5ft(V/ft)	
MaxVF5ft(V)	
Bkgd(V)	
Difference(V)	
MaxVF5ft(V/ft)	
Deg from Hor.	
Hull V @ 3A	

AC Clamp Test (Amps)	
Ped CB open	0.012
Ped CB Shut Loaded	0.012
Net Water (A)	0.000

Current Split Test	
Test Load Current (A)	12.300
Bkgd, Ped CB Open (A)	0.013
Water Path (A), w/Load	1.700
Net Water Path (A)	1.687
Ground Wire (A), w/Load	10.570
Net Ground Wire (A)	10.557
% Split Water	13.8%
% Split Ground Wire	86.2%

Testing Remarks:

1. Isolation test at 5' not done due to limited water depth.

Sheet 6, Marina Data Testing Notes

Marina Name/Location: Lake Ocoee Inn and Marina, Benton TN

Date: 5/17/2007 Weather: Clear

Air Temperature: 60F Wind: 3kts Clouds: 0% Rain: None

Electrical Service at Pedestals: 50A/208V, 30A/120V Water depth in marina: 30ft

Number piers/wharfs: 2 piers Bottom type: Mud, sediment

Number vessels connected to shore power: 75 Vegetation present: None

Mooring arrangements/configurations: Piers with fingers. Plastic encased styrofoam floats and styrofoam floats with wooden decks.

Metallic structures that could infuence testing: Winches and mooring cables, finger pier braces connecting the ends of each finger pier together.

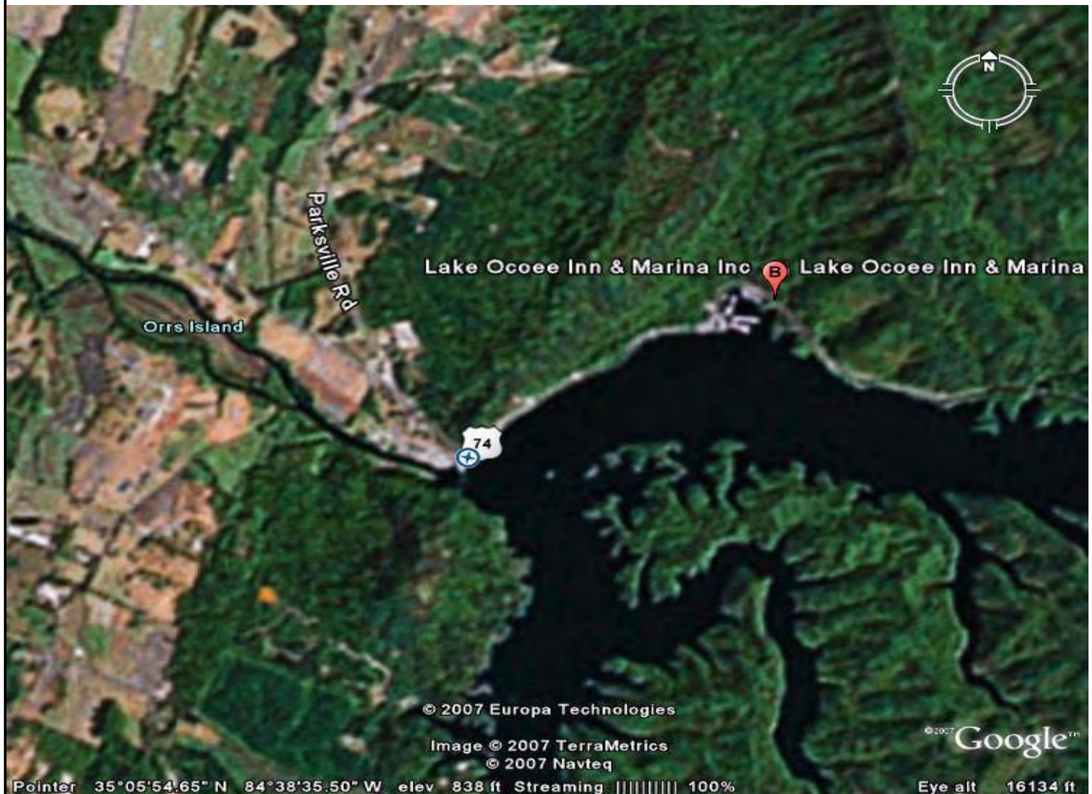
Notes and comments on marina aspects of testing:
See next page.

Sheet 6, Marina Data Testing Notes

1. Broken cable insulation test:
Using isolation, 3 conditions of bare wires in the water were tested. One inch of insulation was removed on each conductor with standard line voltage used as the source. The return ground was to a plate suspended in the water. Highest field gradient was measured between the plate and the bare wire (approx. 3 feet apart). This represented a worst case situation where all current leaving the bare wires had to return to the plate nearby. Current is water current.

	Isolation Transformer	
Hot only:	Bkgd (V):	0.003
	Fault grad (V)	4.500
	Current (A)	0.039
	V/ft	2.250
H + N:	Bkgd (V):	0.003
	Fault grad (V)	4.000
	Current (A)	0.031
	V/ft	2.000
H+N+G:	Bkgd (V):	0.003
	Fault grad (V)	3.800
	Current (A)	0.027
	V/ft	1.900

Lake Ocoee Marina, Benton, TN, Lake Ocoee, Freshwater



Sheet 6-1-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: LOM-FRP-IB-BI, 5/17/07, 0800 Date: 5/17/2007 Marina/Location Lake Ocoee Inn and Marina, Benton TN

Vessel Name: Diamond Jim Type: Houseboat Hull Material/Coating, if metal: FRP

Make/Model: 1979 Carlcraft Dock #: A Slip #: 42 Pedestal #: 42 Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☑ Bow In/ ☐ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 40'/12' ft **Prop:** ☑ Inboard ☐ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

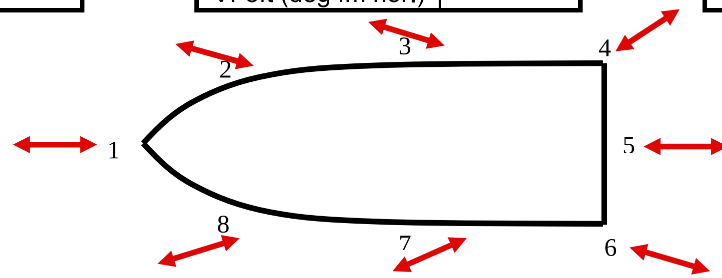
Power: ☐ 50A/240V ☐ 30A/120V ☑ 2-30A/120V ☐ 50A/240V to 2-30A Other: ______

2	Bkgd	Fault
HF1ft(V)	0.003	0.288
HF3ft(V)	0.003	0.280
HF5ft(V)	0.003	0.270
V3ft(V)	0.027	1.700
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.003	0.740
HF3ft(V)	0.003	0.750
HF5ft(V)	0.003	0.743
V3ft(V)	0.032	4.900
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)	0.003	7.200
HF3ft(V)	0.003	8.300
HF5ft(V)	0.003	5.600
V3ft(V)	0.020	17.800
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

1	Bkgd	Fault
HF1ft(V)	0.003	0.173
HF3ft(V)	0.002	0.177
HF5ft(V)	0.002	0.164
V3ft(V)	0.026	1.150
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.003	13.500
HF3ft(V)	0.003	14.700
HF5ft(V)	0.003	7.800
V3ft(V)	0.014	22.000
VF3ft(V)	0.003	15.400
VF3ft (deg fm hor.)		30 d a

8	Bkgd	Fault
HF1ft(V)	0.002	0.232
HF3ft(V)	0.002	0.224
HF5ft(V)	0.002	0.216
V3ft(V)	0.023	1.820
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.002	0.846
HF3ft(V)	0.002	0.830
HF5ft(V)	0.003	0.750
V3ft(V)	0.025	5.800
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.003	9.000
HF3ft(V)	0.003	8.500
HF5ft(V)	0.003	5.600
V3ft(V)	0.021	19.000
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	0.085	0.143	0.369	3.599	6.749	4.499	0.422	0.115
HF3ft(V/ft)	0.088	0.139	0.374	4.149	7.349	4.249	0.414	0.111
HF5ft(V/ft)	0.081	0.134	0.370	2.799	3.899	2.799	0.374	0.107
V3ft(V)	1.124	1.673	4.868	17.780	21.986	18.979	5.775	1.797
VF3ft(V/ft)	less	less	less	less	7.699	less	less	less

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.03 N 0.1 G 0.03 ohms

Test Current: 2.2 A Voltage for Test Current 117.5 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.029 g/l TDS: 0.046 ppt pH: 8 Temp: 70F

Conductivity: 0.064 ms/cm@1ft 0.058 ms/cm@3ft 0.057 ms/cm@5ft Water path (Ω): 53.41

Diamond Jim (Sheet 6-1-1,2)

Sheet 6-1-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: LOM-FRP-IB-BI, 5/17/07, 0800 Marina/Location: Lake Ocoee Inn and Marina, Benton TN

Date: 5/17/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	59.000
Bkgd(V)	0.003
Difference(V)	58.997
HF1ft(V/ft)	29.499
MaxVF1ft(V)	59.000
Bkgd(V)	0.003
Difference(V)	58.997
MaxVF1ft(V/ft)	less
Deg from Hor.	0
Hull V@ .59A	123.000

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	50.000
Bkgd(V)	0.003
Difference(V)	49.997
HF5ft(V/ft)	24.999
MaxVF5ft(V)	70.000
Bkgd(V)	0.003
Difference(V)	69.997
MaxVF5ft(V/ft)	34.999
Deg from Hor.	25 u a
Hull V @ .75A	123.000

AC Clamp Test	(MA)
Ped CB open	0.450
Ped CB Shut Loaded	0.750
Net Water (A)	0.300

Current Split Test	
Test Load Current (A)	13.400
Bkgd, Ped CB Open (A)	0.000
Water Path (A), w/Load	0.010
Net Water Path (A)	0.010
Ground Wire (A), w/Load	13.400
Net Ground Wire (A)	13.400
% Split Water	0.1%
% Split Ground Wire	99.9%

Testing Remarks:

1. Maximum fault current achieved for gradient testing was 2.2A at full line voltage.

Sheet 6-1-2, Field Strength/Voltage Data Form

2. Linearity data was taken using vessel bonded metals and distributed marina ground system. This was accomplished since full line voltage was used to get the maximum test current possible. Current is water current.

Hull Volt (V)	Current (A)
117.50	2.200
100.00	1.850
75.00	1.390
50.00	0.900
25.00	0.460
10.00	0.190

3. With probe placed under boat within a foot of underwater running gear, a gradient of 14v/ft was measured.
4. The bonded finger pier braces had a dramatic effect on the water current path since they represented a good ground return path.
5. One shore cord grounding conductor was not connected to bonding system aboard boat; no effect on testing.

Sheet 6-2-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: LOM-ALU(C)-IB-BI, 5/17/07, 1300 Date: 5/17/2007 Marina/Location Lake Ocoee Inn and Marina, Benton TN

Vessel Name: For Pete Sake Type: Houseboat Hull Material/Coating, if metal: Aluminum/unknown coating

Make/Model: 2002 James Towner Dock #: A Slip #: 60 Pedestal #: 60 Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☑ Bow In/ ☐ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 65'/14' ft **Prop:** ☐ Inboard ☑ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

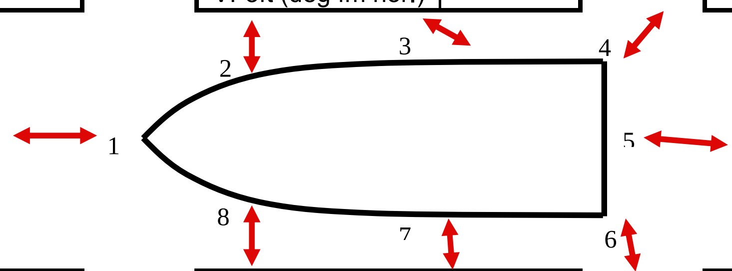
Power: ☐ 50A/240V ☐ 30A/120V ☑ 2-30A/120V ☑ 50A/240V to 2-30A Other: ____

2	Bkgd	Fault
HF1ft(V)	0.003	2.300
HF3ft(V)	0.003	1.830
HF5ft(V)	0.003	1.240
V3ft(V)	0.017	8.100
VF3ft(V)	0.003	2.600
VF3ft (deg fm hor.)		45 d a

3	Bkgd	Fault
HF1ft(V)	0.003	2.090
HF3ft(V)	0.003	1.690
HF5ft(V)	0.003	1.290
V3ft(V)	0.017	8.800
VF3ft(V)	0.003	1.800
VF3ft (deg fm hor.)		25 d a

4	Bkgd	Fault
HF1ft(V)	0.005	3.800
HF3ft(V)	0.005	2.300
HF5ft(V)	0.005	1.520
V3ft(V)	0.012	7.000
VF3ft(V)	0.003	3.100
VF3ft (deg fm hor.)		45 d a

1	Bkgd	Fault
HF1ft(V)	0.003	1.250
HF3ft(V)	0.003	1.210
HF5ft(V)	0.003	0.650
V3ft(V)	0.016	4.000
VF3ft(V)	0.003	1.600
VF3ft (deg fm hor.)		25 d a



5	Bkgd	Fault
HF1ft(V)	0.005	7.000
HF3ft(V)	0.003	3.300
HF5ft(V)	0.003	2.400
V3ft(V)	0.023	11.300
VF3ft(V)	0.003	7.800
VF3ft (deg fm hor.)		60 d a

8	Bkgd	Fault
HF1ft(V)	0.004	2.400
HF3ft(V)	0.004	1.900
HF5ft(V)	0.003	1.100
V3ft(V)	0.025	6.700
VF3ft(V)	0.004	2.300
VF3ft (deg fm hor.)		45 d a

7	Bkgd	Fault
HF1ft(V)	0.005	2.700
HF3ft(V)	0.004	1.800
HF5ft(V)	0.003	1.160
V3ft(V)	0.031	10.600
VF3ft(V)	0.004	2.500
VF3ft (deg fm hor.)		30 d a

6	Bkgd	Fault
HF1ft(V)	0.005	2.700
HF3ft(V)	0.005	2.080
HF5ft(V)	0.004	1.350
V3ft(V)	0.018	6.900
VF3ft(V)	0.004	2.900
VF3ft (deg fm hor.)		60 d a

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	0.624	1.149	1.044	1.898	3.498	1.348	1.348	1.198
HF3ft(V/ft)	0.604	0.914	0.844	1.148	1.649	1.038	0.898	0.948
HF5ft(V/ft)	0.324	0.619	0.644	0.758	1.199	0.673	0.579	0.549
V3ft(V)	3.984	8.083	8.783	6.988	11.277	6.882	10.569	6.675
VF3ft(V/ft)	0.799	1.299	0.899	1.549	3.899	1.448	1.248	1.148

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.04 N 0.07 G 0.04 ohms

Test Current: 3 A Voltage for Test Current 22 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.029 g/l TDS: 0.046 ppt pH: 8 Temp: 70F

Conductivity: 0.064 ms/cm@1ft 0.058 ms/cm@3ft 0.057 ms/cm@5ft Water path (Ω): 7.33

For Pete Sake (Sheet 6-2-1,2)

Sheet 6-2-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: LOM-ALU(C)-IB-BI, 5/17/07, 1300 Marina/Location: Lake Ocoee Inn and Marina, Benton TN

Date: 5/17/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	70.000
Bkgd(V)	0.003
Difference(V)	69.997
HF1ft(V/ft)	34.999
MaxVF1ft(V)	70.000
Bkgd(V)	0.003
Difference(V)	69.997
MaxVF1ft(V/ft)	less
Deg from Hor.	0
Hull V@ .83A	124.400

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	70.000
Bkgd(V)	0.004
Difference(V)	69.996
HF5ft(V/ft)	34.998
MaxVF5ft(V)	80.000
Bkgd(V)	0.004
Difference(V)	79.996
MaxVF5ft(V/ft)	39.998
Deg from Hor.	25 d a
Hull V@ 1.05A	124.400

AC Clamp Test	(A)
Ped CB open	0.000
Ped CB Shut Loaded	0.020
Net Water (A)	0.020

Current Split Test	
Test Load Current (A)	13.530
Bkgd, Ped CB Open (A)	0.002
Water Path (A), w/Load	0.008
Net Water Path (A)	0.006
Ground Wire (A), w/Load	13.520
Net Ground Wire (A)	13.518
% Split Water	0.05%
% Split Ground Wire	99.95%

Testing Remarks:

1. Boat had large stainless swim ladder in the water at the transom.
2. Neutral was bonded on the boat; no effect on testing.

Sheet 7, Marina Data Testing Notes

Investigators: Jim Shafer, David Rifkin

Marina Name/Location: Mentor Yacht Club, Lake Erie, Mentor OH

Date: 6/5/2007 Weather: Overcast, windy

Air Temperature: 60F Wind: 15kts Clouds: 100% Rain: Intermittent

Electrical Service at Pedestals: 50A/240V, 30A/120V Water depth in marina: 10-15 ft

Number piers/wharfs: 4/1 Bottom type: Mud

Number vessels connected to shore power: 120 Vegetation present: None

Mooring arrangements/configurations: Warves with finger piers, and piers with finger piers. Wooden docks on plastic floats.

Metallic structures that could infuence testing: Sheet pile sea wall along road/parking lot

Notes and comments on marina aspects of testing:

1. During the testing, there was ground swell in the marina coming off Lake Erie. This made steadying of the testing probe difficult at times. In some cases the measurements indicate an average reading due to the motion.

Mentor Yacht Club, Mentor, OH, Lake Erie, Freshwater

Sheet 7-1-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: MHY-FRP-IB-BI, 6-5-07, 0800hrs   Date: 6/5/2007   Marina/Location: Mentor Yacht Club, Lake Erie, Mentor OH

Vessel Name: White Spray, 2005   Type: Sailboat   Hull Material/Coating, if metal: FRP

Make/Model: Beneteau Oceanis 352   Dock #: None   Slip #: None   Pedestal #: None   Water flow at dock: 2 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to   **Slip:** ☑ Bow In/ ☐ Bow Out   **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 35'/12.8' ft   **Prop:** ☑ Inboard ☐ Inboard Outboard ☐ Outboard ☑ Sail : ☑ Single ☐ Double

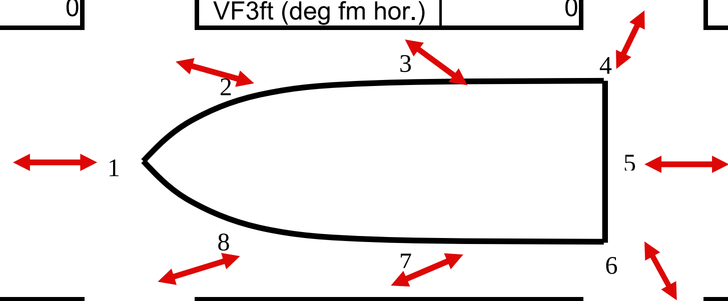
Power: ☐ 50A/240V ☑ 30A/120V ☐ 2-30A/120V ☐ 50A/240V to 2-30A   Other:

2	Bkgd	Fault
HF1ft(V)	0.003	0.183
HF3ft(V)	0.003	0.187
HF5ft(V)	0.003	0.183
V3ft(V)	0.210	0.890
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.003	0.186
HF3ft(V)	0.003	0.269
HF5ft(V)	0.003	0.300
V3ft(V)	0.186	1.790
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)	0.007	0.430
HF3ft(V)	0.007	0.550
HF5ft(V)	0.003	0.320
V3ft(V)	0.184	2.700
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

1	Bkgd	Fault
HF1ft(V)	0.003	0.167
HF3ft(V)	0.003	0.174
HF5ft(V)	0.003	0.168
V3ft(V)	0.196	0.370
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.004	0.570
HF3ft(V)	0.004	0.495
HF5ft(V)	0.003	0.327
V3ft(V)	0.197	1.920
VF3ft(V)	0.003	0.570
VF3ft (deg fm hor.)		30 d a

8	Bkgd	Fault
HF1ft(V)	0.003	0.206
HF3ft(V)	0.003	0.220
HF5ft(V)	0.003	0.208
V3ft(V)	0.190	1.000
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.003	0.218
HF3ft(V)	0.003	0.270
HF5ft(V)	0.003	0.267
V3ft(V)	0.206	1.590
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.003	0.350
HF3ft(V)	0.004	0.330
HF5ft(V)	0.003	0.255
V3ft(V)	0.176	1.800
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	0.082	0.090	0.092	0.212	0.283	0.174	0.108	0.102
HF3ft(V/ft)	0.086	0.092	0.133	0.272	0.246	0.163	0.134	0.109
HF5ft(V/ft)	0.083	0.090	0.149	0.159	0.162	0.126	0.132	0.103
V3ft(V)	0.174	0.680	1.604	2.516	1.723	1.624	1.384	0.810
VF3ft(V/ft)	less	less	less	less	0.284	less	less	less

Bonding system: ☑ Intact   Pedestal Impedances w/SureTest: H 0.02 N 0.08 G 0.04 ohms

Test Current: 3 A   Voltage for Test Current 15.9 V   Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.501 g/l   TDS: 0.696 ppt   pH: 8.3   Temp: 70F

Conductivity: 0.999 ms/cm@1ft   0.999 ms/cm@3ft   1.01 ms/cm@5ft   Water path (Ω): 5.30

White Spray (Sheet 7-1-1,2)

Sheet 7-1-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: MHY-FRP-IB-BI, 6-5-07, 0800hrs   Marina/Location: Mentor Yacht Club, Lake Erie, Mentor OH

Date: 6/5/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	9.000
Bkgd(V)	0.003
Difference(V)	8.997
HF1ft(V/ft)	4.499
MaxVF1ft(V)	9.000
Bkgd(V)	0.003
Difference(V)	8.997
MaxVF1ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	30.700

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	8.500
Bkgd(V)	0.002
Difference(V)	8.498
HF5ft(V/ft)	4.249
MaxVF5ft(V)	8.500
Bkgd(V)	0.002
Difference(V)	8.498
MaxVF5ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	34.000

AC Clamp Test (Amps)	
Ped CB open	0.028
Ped CB Shut Loaded	0.028
Net Water (A)	0.000

Current Split Test	
Test Load Current (A)	13.170
Bkgd, Ped CB Open (A)	0.027
Water Path (A), w/Load	0.245
Net Water Path (A)	0.218
Ground Wire (A), w/Load	12.890
Net Ground Wire (A)	12.863
% Split Water	1.7%
% Split Ground Wire	98.3%

Testing Remarks:

1. This boat was on a finger pier directly off of the sheet pile sea wall with the bow approx. 4 ft from the wall. The sea wall, being bonded, most likely reduced the field strengths around this boat during testing since the the grounding path was very large on the bow end of the boat.

Sheet 7-2-1, Field Strength/Voltage Data Form

Test number: MHY-FRP-BI-IB, 6-5-07, 1300hrs Date: 6/5/2007 Marina/Location: Mentor Yacht Club, Lake Erie, Mentor OH

Vessel Name: Back Track Type: Cruiser Hull Material/Coating, if metal: FRP

Make/Model: Meridian 368, 2005 Dock #: None Slip #: None Pedestal #: None Water flow at dock: 2 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☐ Bow In/ ☑ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 36'/13.5' ft **Prop:** ☑ Inboard ☐ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

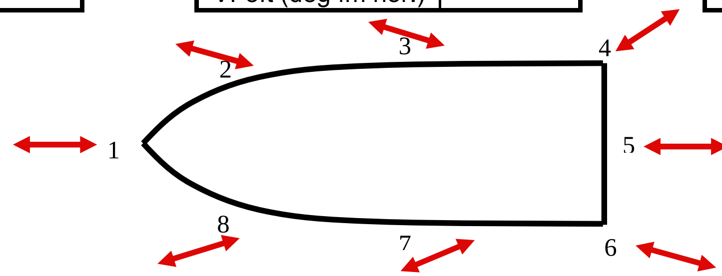
Power: ☑ 50A/240V ☐ 30A/120V ☐ 2-30A/120V ☐ 50A/240V to 2-30A Other: ______

2	Bkgd	Fault
HF1ft(V)	0.003	0.108
HF3ft(V)	0.003	0.109
HF5ft(V)	0.002	0.106
V3ft(V)	0.120	1.490
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.003	0.195
HF3ft(V)	0.003	0.205
HF5ft(V)	0.003	0.202
V3ft(V)	0.107	2.360
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)	0.003	0.450
HF3ft(V)	0.002	0.530
HF5ft(V)	0.002	0.420
V3ft(V)	0.108	3.128
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

1	Bkgd	Fault
HF1ft(V)	0.003	0.063
HF3ft(V)	0.003	0.061
HF5ft(V)	0.003	0.063
V3ft(V)	0.097	1.180
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.002	0.640
HF3ft(V)	0.002	0.602
HF5ft(V)	0.003	0.436
V3ft(V)	0.079	2.860
VF3ft(V)	0.002	0.670
VF3ft (deg fm hor.)		25 d a

8	Bkgd	Fault
HF1ft(V)	0.003	0.090
HF3ft(V)	0.003	0.100
HF5ft(V)	0.002	0.105
V3ft(V)	0.130	1.470
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.002	0.201
HF3ft(V)	0.002	0.220
HF5ft(V)	0.002	0.205
V3ft(V)	0.120	2.000
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.002	0.550
HF3ft(V)	0.002	0.720
HF5ft(V)	0.003	0.423
V3ft(V)	0.122	2.830
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft(V/ft)	0.030	0.053	0.096	0.224	0.319	0.274	0.100	0.044
HF3ft(V/ft)	0.029	0.053	0.101	0.264	0.300	0.359	0.109	0.049
HF5ft(V/ft)	0.030	0.052	0.100	0.209	0.217	0.210	0.102	0.052
V3ft(V)	1.083	1.370	2.253	3.020	2.781	2.708	1.880	1.340
VF3ft(V/ft)	less	less	less	less	0.334	less	less	less

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.04 N 0.08 G 0.08 ohms

Test Current: 3 A Voltage for Test Current 10.16 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.501 g/l TDS: 0.696 ppt pH: 8.3 Temp: 70F

Conductivity: 0.999 ms/cm@1ft 0.999 ms/cm@3ft 1.01 ms/cm@5ft Water path (Ω): 3.39

Back Track (Sheet 7-2-1,2)

Sheet 7-2-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: MHY-FRP-BI-IB, 6-5-07, 1300hrs Marina/Location: Mentor Yacht Club, Lake Erie, Mentor OH

Date: 6/5/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	17.000
Bkgd(V)	0.003
Difference(V)	16.997
HF1ft(V/ft)	8.499
MaxVF1ft(V)	17.000
Bkgd(V)	0.003
Difference(V)	16.997
MaxVF1ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	31.400

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	7.000
Bkgd(V)	0.003
Difference(V)	6.997
HF5ft(V/ft)	3.499
MaxVF5ft(V)	7.000
Bkgd(V)	0.003
Difference(V)	6.997
MaxVF5ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	37.400

AC Clamp Test (Amps)	
Ped CB open	0.001
Ped CB Shut Loaded	0.001
Net Water (A)	0.000

Current Split Test	
Test Load Current (A)	13.030
Bkgd, Ped CB Open (A)	0.001
Water Path (A), w/Load	0.018
Net Water Path (A)	0.017
Ground Wire (A), w/Load	13.000
Net Ground Wire (A)	12.999
% Split Water	0.1%
% Split Ground Wire	99.9%

Testing Remarks:

None

Sheet 8, Marina Data Testing Notes

Investigators: Jim Shafer, David Rifkin

Marina Name/Location: Paradise Cove Marina/Austin TX

Date: 3/29/2007 Weather: Overcast

Air Temperature: 74F Wind: 12kts Clouds: 100% Rain: Intermittant

Electrical Service at Pedestals: 50A/240V, 30A/120V Water depth in marina: 25' or more

Number piers/wharfs: 7/1 Bottom type: Rocks, mud

Number vessels connected to shore power: 200 Vegetation present: none

Mooring arrangements/configurations: Single long wharf moored to bottom/shore. 7 long finger piers connected to main wharf. Docks were concrete/gravel mix panels on plastic floats.

Metallic structures that could infuence testing: See below

Notes and comments on marina aspects of testing:

1. Large metal ballast structure attached to west side of main wharf. Unknown if connected to dock bonding system. This large ballast did not appear to have any affect on the voltage gradient directions or magnitude.
An RC network (1k resistor in parallel with 1000uf capactor) was placed across the probes for one test point. This was as requested by one of the peer review group during test procedure meeting. Position 6 was used and the results were HF1ft(V)=0.910, HF3ft(V)=1.03, HF5ft(V)=0.670. These were slightly less than those measurements taken without the RC network. This did not add any stability to the readings as was suggested. Accordingly, this network was not used for future measurements.

Paradise Cove Marina, Austin, TX, Lake Travis, Freshwater

USCG FY 2007 Safety Grant
In-Water Shock Mitigation

Sheet 8-1-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: PCM-FRP-IB-BO, 3-29-07 0800hrs Date: 3/29/2007 Marina/Location Paradise Cove Marina/Dallas TX

Vessel Name: Texas Martini Type: Cruiser Hull Material/Coating, if metal: FRP

Make/Model: SeaRay Sundancer 240 Dock #: C Slip #: C9 Pedestal #: C9 Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☐ Bow In/ ☑ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 34'/10' ft **Prop:** ☑ Inboard ☐ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

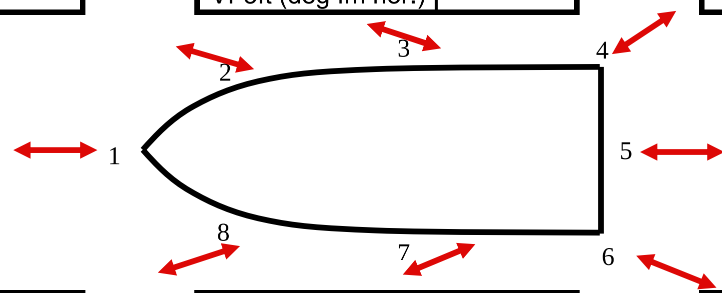
Power: ☐ 50A/240V ☐ 30A/120V ☑ 2-30A/120V ☐ 50A/240V to 2-30A Other:

2	Bkgd	Fault
HF1ft(V)	0.003	0.105
HF3ft(V)	0.003	0.110
HF5ft(V)	0.003	0.121
V3ft(V)	0.003	0.390
VF3ft(V)	0.003	0.110
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.003	0.230
HF3ft(V)	0.003	0.216
HF5ft(V)	0.003	0.214
V3ft(V)	0.005	1.300
VF3ft(V)	0.003	0.216
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)	0.003	1.330
HF3ft(V)	0.003	1.220
HF5ft(V)	0.002	0.893
V3ft(V)	0.003	3.300
VF3ft(V)	0.003	1.220
VF3ft (deg fm hor.)		0

1	Bkgd	Fault
HF1ft(V)	0.003	0.015
HF3ft(V)	0.003	0.010
HF5ft(V)	0.004	0.005
V3ft(V)	0.003	0.145
VF3ft(V)	0.003	0.010
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.003	2.500
HF3ft(V)	0.003	2.000
HF5ft(V)	0.003	1.190
V3ft(V)	0.061	3.950
VF3ft(V)	0.003	2.000
VF3ft (deg fm hor.)		0

8	Bkgd	Fault
HF1ft(V)	0.003	0.119
HF3ft(V)	0.003	0.122
HF5ft(V)	0.003	0.129
V3ft(V)	0.004	0.200
VF3ft(V)	0.003	0.122
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.003	0.250
HF3ft(V)	0.003	0.230
HF5ft(V)	0.003	0.213
V3ft(V)	0.008	1.240
VF3ft(V)	0.003	0.230
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.003	1.080
HF3ft(V)	0.003	1.070
HF5ft(V)	0.003	0.760
V3ft(V)	0.005	2.810
VF3ft(V)	0.003	0.950
VF3ft (deg fm hor.)		0

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft(V/ft)	0.006	0.051	0.114	0.664	1.249	0.539	0.124	0.058
HF3ft(V/ft)	0.004	0.054	0.107	0.609	0.999	0.534	0.114	0.060
HF5ft(V/ft)	0.001	0.059	0.106	0.446	0.594	0.379	0.105	0.063
V3ft(V)	0.142	0.387	1.295	3.297	3.889	2.805	1.232	0.196
VF3ft(V/ft)	0.004	0.054	0.107	0.609	0.999	0.474	0.114	0.060

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.05 N 0.04 G 0.08 ohms

Test Current: 3 A Voltage for Test Current 19 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.237 g/l TDS: 0.333 ppt pH: 8.6 Temp: 67

Conductivity: 0.462 ms/cm@1ft 0.452 ms/cm@3ft 0.447 ms/cm@5ft Water path (Ω): 6.33

Texas Martini (Sheet 8-1-1,2)

Sheet 8-1-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: PCM-FRP-IB-BO, 3-29-07 0800hrs Marina/Location: Paradise Cove Marina/Dallas TX

Date: 3/29/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	30.000
Bkgd(V)	0.003
Difference(V)	29.997
HF1ft(V/ft)	14.999
MaxVF1ft(V)	40.000
Bkgd(V)	0.003
Difference(V)	39.997
MaxVF1ft(V/ft)	19.999
Deg from Hor.	15 d a
Hull V @ 3A	66.500

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	13.000
Bkgd(V)	0.003
Difference(V)	12.997
HF5ft(V/ft)	6.499
MaxVF5ft(V)	32.000
Bkgd(V)	0.003
Difference(V)	31.997
MaxVF5ft(V/ft)	15.999
Deg from Hor.	30 d a
Hull V @ 3A	Not Meas.

AC Clamp Test (Amps)	
Ped CB open	0.000
Ped CB Shut Loaded	0.000
Net Water (A)	0.000

Current Split Test	
Test Load Current (A)	11.900
Bkgd, Ped CB Open (A)	0.000
Water Path (A), w/Load	0.660
Net Water Path (A)	0.660
Ground Wire (A), w/Load	11.260
Net Ground Wire (A)	11.260
% Split Water	5.5%
% Split Ground Wire	94.5%

Testing Remarks:

None

Sheet 9, Marina Data Testing Notes

Investigators: Jim Shafer, David Rifkin

Marina Name/Location: Queens Harbor Marina, Jacksonville FL

Date: 4/16/2007 Weather: Clear, sunny

Air Temperature: 75 Wind: 20kts Clouds: 0% Rain: None

Electrical Service at Pedestals: 50A/240V, 30A/120V Water depth in marina: 10'

Number piers/wharfs: 3 piers Bottom type: Mud

Number vessels connected to shore power: 38 Vegetation present: None

Mooring arrangements/configurations: 3 piers with fingers. Concrete pilings with poured concrete decks (non floating).

Metallic structures that could infuence testing: None

Notes and comments on marina aspects of testing:

1. Queens Harbor is a spring fed reservoir with a lock separating it from the Intracoastal Waterway.
2. The water was brackish with about half the salinity and conductivity of saltwater.

Queens Harbor Marina, Jacksonville, FL, Brackish Water

Sheet 9-1-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: QHA-FRP-IB-BO, 4-16-07, 1200 Date: 4/16/2007 Marina/Location Queens Harbor Marina, Jacksonville, FL

Vessel Name: Total Blarney Type: Cruiser Hull Material/Coating, if metal: FRP

Make/Model: Carver 370, 1995 Dock #: 1 Slip #: north end Pedestal #: N/A Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☐ Bow In/ ☑ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 37'/13' ft **Prop:** ☑ Inboard ☐ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

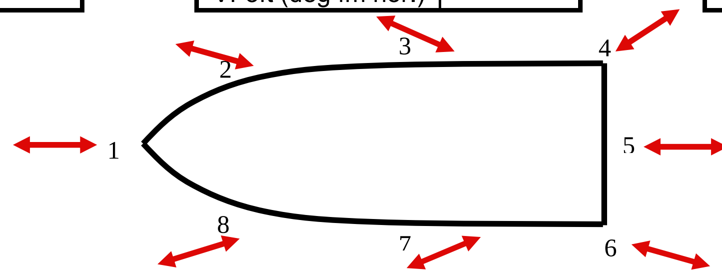
Power: ☑ 50A/240V ☐ 30A/120V ☐ 2-30A/120V ☐ 50A/240V to 2-30A Other:

2	Bkgd	Fault
HF1ft(V)	0.002	0.005
HF3ft(V)	0.002	0.005
HF5ft(V)	0.002	0.004
V3ft(V)	0.028	0.300
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.002	0.009
HF3ft(V)	0.002	0.010
HF5ft(V)	0.002	0.008
V3ft(V)	0.023	0.335
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)	0.002	0.020
HF3ft(V)	0.002	0.018
HF5ft(V)	0.002	0.020
V3ft(V)	0.024	0.384
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

1	Bkgd	Fault
HF1ft(V)	0.002	0.003
HF3ft(V)	0.002	0.003
HF5ft(V)	0.002	0.003
V3ft(V)	0.024	0.287
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.002	0.027
HF3ft(V)	0.002	0.022
HF5ft(V)	0.002	0.015
V3ft(V)	0.026	0.343
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

8	Bkgd	Fault
HF1ft(V)	0.002	0.005
HF3ft(V)	0.002	0.005
HF5ft(V)	0.002	0.005
V3ft(V)	0.026	0.298
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.002	0.009
HF3ft(V)	0.002	0.009
HF5ft(V)	0.002	0.009
V3ft(V)	0.027	0.314
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.002	0.018
HF3ft(V)	0.002	0.017
HF5ft(V)	0.002	0.014
V3ft(V)	0.027	0.306
VF3ft(V)	0.002	less
VF3ft (deg fm hor.)		10

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft(V/ft)	0.001	0.002	0.004	0.009	0.013	0.008	0.004	0.002
HF3ft(V/ft)	0.001	0.002	0.004	0.008	0.010	0.008	0.004	0.002
HF5ft(V/ft)	0.001	0.001	0.003	0.009	0.007	0.006	0.004	0.002
V3ft(V)	0.263	0.272	0.312	0.360	0.317	0.279	0.287	0.272
VF3ft(V/ft)	less	less	less	less	less	less	less	less

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.22 N 0.08 G 0.34 ohms

Test Current: 3 A Voltage for Test Current 4.17 V Water Type: ☐ Salt ☑ Brackish ☐ Fresh

Salinity: 24 g/l TDS: >20 ppt pH: 8 Temp: 72F

Conductivity: 19.8 ms/cm@1ft 19.5 ms/cm@3ft 19.7 ms/cm@5ft Water path (Ω): 1.39

Total Blarney (Sheet 9-1-1,2)

Sheet 9-1-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: QHA-FRP-IB-BO, 4-16-07, 1200 Marina/Location: Queens Harbor Marina, Jacksonville, FL

Date: 4/16/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	0.750
Bkgd(V)	0.002
Difference(V)	0.748
HF1ft(V/ft)	0.374
MaxVF1ft(V)	0.750
Bkgd(V)	0.002
Difference(V)	0.748
MaxVF1ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	12.000

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	0.692
Bkgd(V)	0.002
Difference(V)	0.690
HF5ft(V/ft)	0.345
MaxVF5ft(V)	0.900
Bkgd(V)	0.002
Difference(V)	0.898
MaxVF5ft(V/ft)	0.449
Deg from Hor.	10 d a
Hull V @ 3A	12.000

AC Clamp Test (Amps)	
Ped CB open	0.003
Ped CB Shut Loaded	0.100
Net Water (A)	0.097

Current Split Test	
Test Load Current (A)	12.700
Bkgd, Ped CB Open (A)	0.003
Water Path (A), w/Load	7.860
Net Water Path (A)	7.857
Ground Wire (A), w/Load	4.830
Net Ground Wire (A)	4.827
% Split Water	61.9%
% Split Ground Wire	38.1%

Testing Remarks:

None

Sheet 10, Marina Data Testing Notes

Investigators: Jim Shafer, David Rifkin

Marina Name/Location: Silver Lake Marina / Dallas, TX

Date: 3/27/2007 Weather: Overcast

Air Temperature: 65F Wind: calm Clouds: 100% Rain: Intermittent

Electrical Service at Pedestals: 50A/240V, 30A/120V Water depth in marina: 25"+

Number piers/wharfs: 5 piers Bottom type: Rocks, mud

Number vessels connected to shore power: approx. 150 Vegetation present: None

Mooring arrangements/configurations: Finger piers off main docks. Most slips covered.
Concrete docks on foam floats.

Metallic structures that could infuence testing: None

Notes and comments on marina aspects of testing:

1. Lake level was approx. 18ft below normal.

Silver Lake Marina, Dallas, TX, Silver Lake, Freshwater

Sheet 10-1-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: SLM-FRP-IB-BO, 3-27-07,0800hrs Date: 3/27/2007 Marina/Location Silver Lake Marina, Dallas, TX

Vessel Name: No Name Type: Cruiser Hull Material/Coating, if metal: FRP

Make/Model: Carver, 1981 Dock #: 100 Slip #: 123 Pedestal #: 123 Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☐ Bow In/ ☑ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 28'/10' ft **Prop:** ☑ Inboard ☐ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

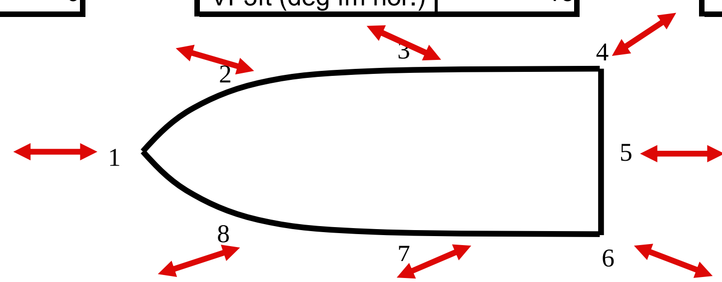
Power: ☐ 50A/240V ☐ 30A/120V ☑ 2-30A/120V ☐ 50A/240V to 2-30A Other: ____

2	Bkgd	Fault
HF1ft(V)	0.003	0.130
HF3ft(V)	0.003	0.120
HF5ft(V)	0.003	0.110
V3ft(V)	0.039	0.930
VF3ft(V)	0.003	0.120
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.003	0.410
HF3ft(V)	0.003	0.386
HF5ft(V)	0.003	0.323
V3ft(V)	0.039	1.800
VF3ft(V)	0.003	0.313
VF3ft (deg fm hor.)		15

4	Bkgd	Fault
HF1ft(V)	0.007	2.900
HF3ft(V)	0.007	2.000
HF5ft(V)	0.006	1.300
V3ft(V)	0.220	7.200
VF3ft(V)	0.007	2.900
VF3ft (deg fm hor.)		0.000

1	Bkgd	Fault
HF1ft(V)	0.003	0.061
HF3ft(V)	0.003	0.062
HF5ft(V)	0.003	0.062
V3ft(V)	0.036	0.620
VF3ft(V)	0.003	0.062
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.009	2.400
HF3ft(V)	0.009	2.500
HF5ft(V)	0.005	1.370
V3ft(V)	0.020	5.380
VF3ft(V)	0.009	2.500
VF3ft (deg fm hor.)		0

8	Bkgd	Fault
HF1ft(V)	0.003	0.084
HF3ft(V)	0.003	0.087
HF5ft(V)	0.003	0.084
V3ft(V)	0.020	0.620
VF3ft(V)	0.003	0.087
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.003	0.600
HF3ft(V)	0.003	0.650
HF5ft(V)	0.003	0.550
V3ft(V)	0.022	2.000
VF3ft(V)	0.003	0.650
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.007	2.380
HF3ft(V)	0.006	2.500
HF5ft(V)	0.003	1.270
V3ft(V)	0.024	4.100
VF3ft(V)	0.006	2.500
VF3ft (deg fm hor.)		0

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft(V/ft)	0.029	0.064	0.204	1.447	1.196	1.187	0.299	0.041
HF3ft(V/ft)	0.030	0.059	0.192	0.997	1.246	1.247	0.324	0.042
HF5ft(V/ft)	0.030	0.054	0.160	0.647	0.683	0.634	0.274	0.041
V3ft(V)	0.584	0.891	1.761	6.980	5.360	4.076	1.978	0.600
VF3ft(V/ft)	0.030	0.059	0.155	1.447	1.246	1.247	0.324	0.042

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.07 N 0.06 G 0.04 ohms

Test Current: 3 A Voltage for Test Current 22.7 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.298 g/l TDS: 0.422 ppt pH: 7.28 Temp: 63F

Conductivity: 0.525 ms/cm@1ft 0.605 ms/cm@3ft 0.459 ms/cm@5ft Water path (Ω): 7.57

No Name (Sheet 10-1-1,2)

Sheet 10-1-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: SLM-FRP-IB-BO, 3-27-07,0800hrs   Marina/Location: Silver Lake Marina, Dallas, TX

Date: 3/27/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	45.000
Bkgd(V)	0.003
Difference(V)	44.997
HF1ft(V/ft)	22.499
MaxVF1ft(V)	45.000
Bkgd(V)	0.003
Difference(V)	44.997
MaxVF1ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	80.000

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	21.000
Bkgd(V)	0.003
Difference(V)	20.997
HF5ft(V/ft)	10.499
MaxVF5ft(V)	21.000
Bkgd(V)	0.003
Difference(V)	20.997
MaxVF5ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	Not Meas.

AC Clamp Test (Amps)	
Ped CB open	0.000
Ped CB Shut Loaded	0.000
Net Water (A)	0.000

Current Split Test	
Test Load Current (A)	12.390
Bkgd, Ped CB Open (A)	0.023
Water Path (A), w/Load	0.015
Net Water Path (A)	0.008
Ground Wire (A), w/Load	12.330
Net Ground Wire (A)	12.307
% Split Water	0.1%
% Split Ground Wire	99.9%

Testing Remarks:

1. One of 2 shore inlets did not function (no power when connected), no effect on testing.

Sheet 10-2-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: SLM-STL(C)-IO-BI,3-27-07,1300hrs Date: 3/27/2007 Marina/Location Silver Lake Marine / Dallas, TX

Vessel Name: USS Rustoleum Type: Houseboat Hull Material/Coating, if metal: Steel, unknown coating

Make/Model: River Queen 40' (1980s) Dock #: 100 Slip #: 127 Pedestal #: 127 Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☑ Bow In/ ☐ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 40'/12' ft **Prop:** ☐ Inboard ☑ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

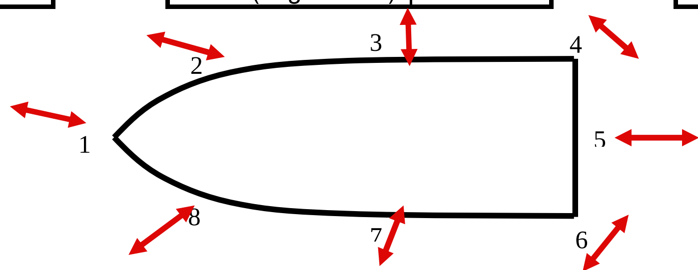
Power: ☑ 50A/240V ☐ 30A/120V ☐ 2-30A/120V ☐ 50A/240V to 2-30A Other: ______

2	Bkgd	Fault
HF1ft(V)	0.003	0.201
HF3ft(V)	0.003	0.173
HF5ft(V)	0.003	0.133
V3ft(V)	0.013	0.610
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.003	0.145
HF3ft(V)	0.003	0.155
HF5ft(V)	0.003	0.115
V3ft(V)	0.010	1.100
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)	0.003	0.570
HF3ft(V)	0.003	0.660
HF5ft(V)	0.003	0.400
V3ft(V)	0.030	2.000
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

1	Bkgd	Fault
HF1ft(V)	0.003	0.101
HF3ft(V)	0.003	0.092
HF5ft(V)	0.003	0.077
V3ft(V)	0.010	0.620
VF3ft(V)	0.003	0.104
VF3ft (deg fm hor.)		15 d a



5	Bkgd	Fault
HF1ft(V)	0.015	2.000
HF3ft(V)	0.008	0.980
HF5ft(V)	0.025	2.300
V3ft(V)	0.046	5.000
VF3ft(V)	0.010	2.000
VF3ft (deg fm hor.)		75 d a

8	Bkgd	Fault
HF1ft(V)	0.003	0.240
HF3ft(V)	0.003	0.188
HF5ft(V)	0.003	0.029
V3ft(V)	0.010	0.814
VF3ft(V)	0.003	0.217
VF3ft (deg fm hor.)		30 d a

7	Bkgd	Fault
HF1ft(V)	0.003	0.140
HF3ft(V)	0.003	0.141
HF5ft(V)	0.003	0.105
V3ft(V)	0.015	1.060
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.006	0.960
HF3ft(V)	0.006	0.950
HF5ft(V)	0.003	0.380
V3ft(V)	0.019	1.600
VF3ft(V)	0.006	less
VF3ft (deg fm hor.)		0

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	0.049	0.099	0.071	0.284	0.993	0.477	0.069	0.119
HF3ft(V/ft)	0.045	0.085	0.076	0.329	0.486	0.472	0.069	0.093
HF5ft(V/ft)	0.037	0.065	0.056	0.199	1.138	0.189	0.051	0.013
V3ft(V)	0.610	0.597	1.090	1.970	4.954	1.581	1.045	0.804
VF3ft(V/ft)	0.051	less	less	less	0.995	less	less	0.107

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.12 N 0.05 G 0.04 ohms

Test Current: 3 A Voltage for Test Current 13.4 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.298 g/l TDS: 0.422 ppt pH: 7.28 Temp: 63F

Conductivity: 0.525 ms/cm@1ft 0.605 ms/cm@3ft 0.459 ms/cm@5ft Water path (Ω): 4.47

USS Rustoleum (Sheet 10-2-1,2)

Sheet 10-2-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: SLM-STL(C)-IO-BI,3-27-07,1300hrs   Marina/Location: Silver Lake Marine / Dallas, TX

Date: 3/27/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	30.000
Bkgd(V)	0.003
Difference(V)	29.997
HF1ft(V/ft)	14.999
MaxVF1ft(V)	30.000
Bkgd(V)	0.003
Difference(V)	29.997
MaxVF1ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	74.000

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	20.000
Bkgd(V)	0.003
Difference(V)	19.997
HF5ft(V/ft)	9.999
MaxVF5ft(V)	20.000
Bkgd(V)	0.003
Difference(V)	19.997
MaxVF5ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	Not Meas.

AC Clamp Test (Amps)	
Ped CB open	0.000
Ped CB Shut Loaded	0.480
Net Water (A)	0.480

Current Split Test	
Test Load Current (A)	13.000
Bkgd, Ped CB Open (A)	0.000
Water Path (A), w/Load	0.280
Net Water Path (A)	0.280
Ground Wire (A), w/Load	12.700
Net Ground Wire (A)	12.700
% Split Water	2.2%
% Split Ground Wire	97.8%

Testing Remarks:

1. No continuity between shore cord and boat bonding system. Reached boat grounding system through an AC receptacle on board.
2. Boat had atleast one reverse polarity situation, detected at receptacle used for testing.

Sheet 10-3-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: SLM-ALU(UC)-IO-AS, 3-27-07,1600hrs Date: 3/27/2007 Marina/Location Silver Lake Marina, Dallas, TX

Vessel Name: Marine International Type: Houseboat Hull Material/Coating, if metal: Aluminum/No Coating

Make/Model: Somerset 2004 Dock #: Fuel Dk Slip #: Fuel Dk Pedestal #: N/A Water flow at dock: 0 kts

Mooring: **Wharf:** ☑ S / ☐ P Side to **Slip:** ☐ Bow In/ ☐ Bow Out **Tee Dock:** ☐ S / ☐ P Side to

Length/Beam: 90'/20' ft **Prop:** ☐ Inboard ☑ Inboard Outboard ☐ Outboard ☐ Sail : ☐ Single ☑ Double

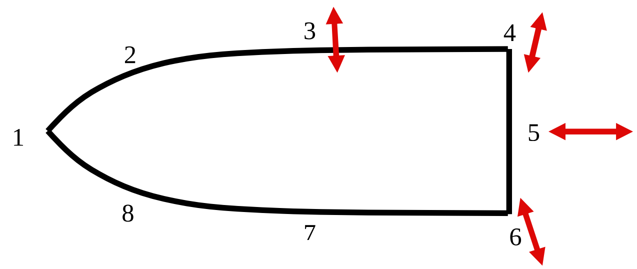
Power: ☑ 50A/240V ☐ 30A/120V ☐ 2-30A/120V ☐ 50A/240V to 2-30A Other: x2

2	Bkgd	Fault
HF1ft(V)		
HF3ft(V)		
HF5ft(V)		
V3ft(V)		
VF3ft(V)		
VF3ft (deg fm hor.)		

3	Bkgd	Fault
HF1ft(V)	0.010	0.378
HF3ft(V)	0.006	0.220
HF5ft(V)	0.006	0.158
V3ft(V)	0.098	1.700
VF3ft(V)	0.006	0.292
VF3ft (deg fm hor.)		45 d a

4	Bkgd	Fault
HF1ft(V)	0.008	0.404
HF3ft(V)	0.005	0.213
HF5ft(V)	0.004	0.145
V3ft(V)	0.081	1.610
VF3ft(V)	0.005	0.313
VF3ft (deg fm hor.)		45 d a

1	Bkgd	Fault
HF1ft(V)		
HF3ft(V)		
HF5ft(V)		
V3ft(V)		
VF3ft(V)		
VF3ft (deg fm hor.)		



5	Bkgd	Fault
HF1ft(V)	0.005	0.186
HF3ft(V)	0.004	0.163
HF5ft(V)	0.003	0.139
V3ft(V)	0.087	1.320
VF3ft(V)	0.004	0.188
VF3ft (deg fm hor.)		40 d a

8	Bkgd	Fault
HF1ft(V)		
HF3ft(V)		
HF5ft(V)		
V3ft(V)		
VF3ft(V)		
VF3ft (deg fm hor.)		

7	Bkgd	Fault
HF1ft(V)		
HF3ft(V)		
HF5ft(V)		
V3ft(V)		
VF3ft(V)		
VF3ft (deg fm hor.)		

6	Bkgd	Fault
HF1ft(V)	0.004	0.290
HF3ft(V)	0.004	0.221
HF5ft(V)	0.003	0.132
V3ft(V)	0.094	1.000
VF3ft(V)	0.004	less
VF3ft (deg fm hor.)		0

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	n/a	n/a	0.184	0.198	0.091	0.143	n/a	n/a
HF3ft(V/ft)	n/a	n/a	0.107	0.104	0.080	0.109	n/a	n/a
HF5ft(V/ft)	n/a	n/a	0.076	0.071	0.068	0.065	n/a	n/a
V3ft(V)	n/a	n/a	1.602	1.529	1.233	0.906	n/a	n/a
VF3ft(V/ft)	n/a	n/a	0.143	0.154	0.092	less	n/a	n/a

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H N/A N N/A G N/A ohms

Test Current: 3 A Voltage for Test Current 3.3 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.298 g/l TDS: 0.422 ppt pH: 7.28 Temp: 63F

Conductivity: 0.525 ms/cm@1ft 0.605 ms/cm@3ft 0.459 ms/cm@5ft Water path (Ω): 1.10

Marine International (Sheet 10-3-1,2)

Sheet 10-3-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: SLM-ALU(UC)-IO-AS, 3-27-07,1600hrs Marina/Location: Silver Lake Marina, Dallas, TX

Date: 3/27/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	31.000
Bkgd(V)	0.002
Difference(V)	30.998
HF1ft(V/ft)	15.499
MaxVF1ft(V)	31.000
Bkgd(V)	0.002
Difference(V)	30.998
MaxVF1ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	57.000

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	25.000
Bkgd(V)	0.002
Difference(V)	24.998
HF5ft(V/ft)	12.499
MaxVF5ft(V)	25.000
Bkgd(V)	0.002
Difference(V)	24.998
MaxVF5ft(V/ft)	less
Deg from Hor.	0
Hull V @ 3A	Not Meas.

AC Clamp Test (Amps)	
Ped CB open	
Ped CB Shut Loaded	
Net Water (A)	

Current Split Test	
Test Load Current (A)	12.390
Bkgd, Ped CB Open (A)	0.023
Water Path (A), w/Load	0.015
Net Water Path (A)	0.008
Ground Wire (A), w/Load	12.330
Net Ground Wire (A)	12.307
% Split Water	0.1%
% Split Ground Wire	99.9%

Testing Remarks:

1. No shore power available.
2. Vessel moored at fuel dock (not normal location). Marina store moored across dock.
3. AC clamp test not performed due to no shore power available.
4. All locations not available for testing due to size and configuration of boat and mooring location.

Sheet 11, Marina Data Testing Notes

Investigators: Jim Shafer, David Rifkin

Marina Name/Location: Stuart Yacht, Stuart FL

Dates: 12/14-12/15/2007 Weather: Sunny/Cloudy

Air Temperature: 74/70F Wind: 12kt Clouds: 40% Rain: None

Electrical Service at Pedestals: 50A/240V, 30A/120V Water depth in marina: 12ft

Number piers/wharfs: 0/2 Bottom type: Mud

Number vessels connected to shore power: Approx. 25 Vegetation present: None

Mooring arrangements/configurations: Wooden warves (pilings and planks) along seawalls.

Metallic structures that could infuence testing: None

Notes and comments on marina aspects of testing:

1. None

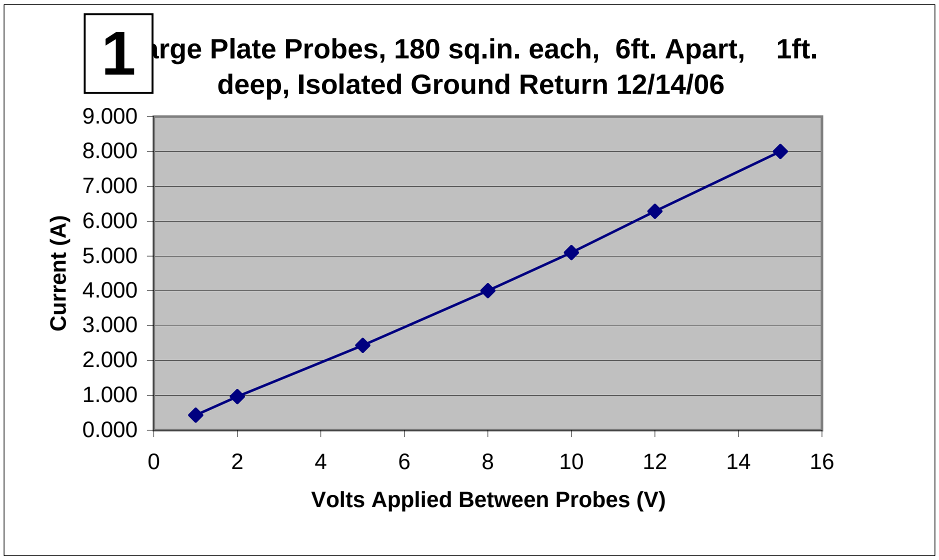
Stuart Yacht, Stuart, FL, Freshwater

Sheet 11A, Voltage vs. Water Current/Gradient

Stuart Yacht, Stuart FL, 12/14/06, brackish water
These tests were conducted to analyze the relationship between voltage applied, water current and voltage gradi

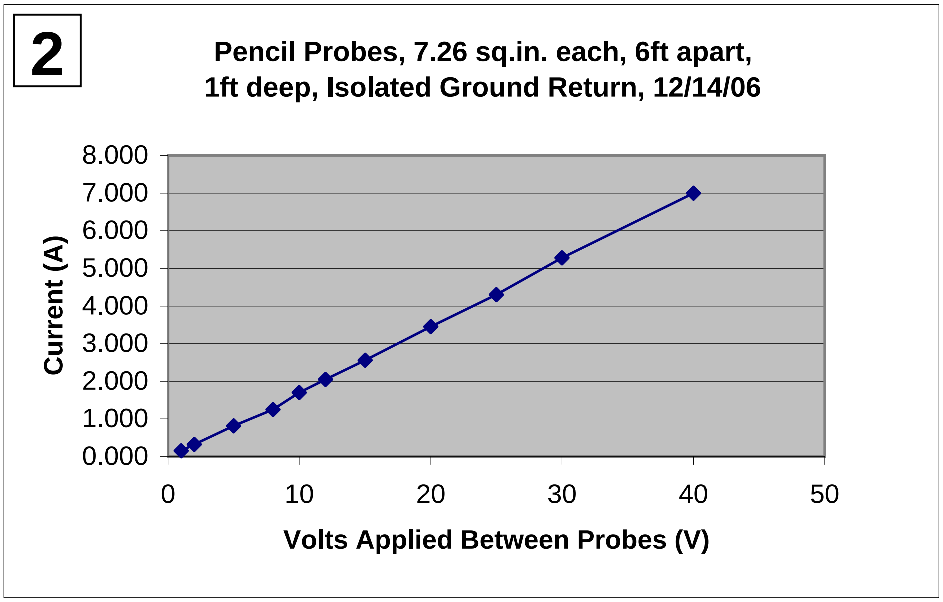
Large plate probes

Volts	Amps
1	0.430
2	0.960
5	2.430
8	4.000
10	5.100
12	6.280
15	8.000



Pencil probes fully immersed

Volts	Amps
1	0.150
2	0.320
5	0.820
8	1.250
10	1.700
12	2.050
15	2.560
20	3.450
25	4.300
30	5.280
40	7.000



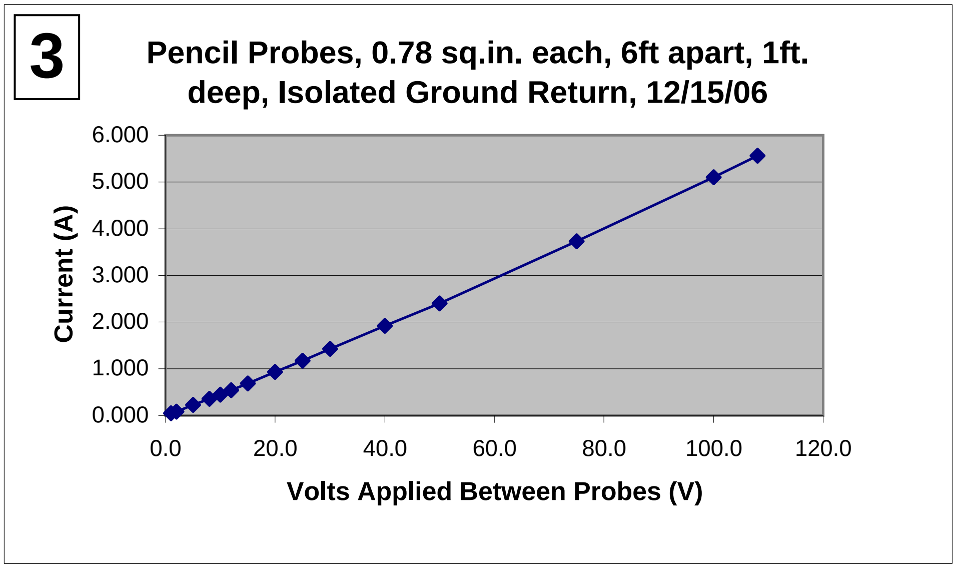
Water conditions (1ft)
Conductivity: 11 ms/cm
Salinity: 5.55 g/l
TDS: 7.627 ppt
pH: 7.64
Temp: 74.3 F

Sheet 11B, Voltage vs. Water Current/Gradient

Stuart Yacht, Stuart FL, 12/15/06, brackish water
These tests used to analyze the relationship between voltage applied, water current and voltage gradients.

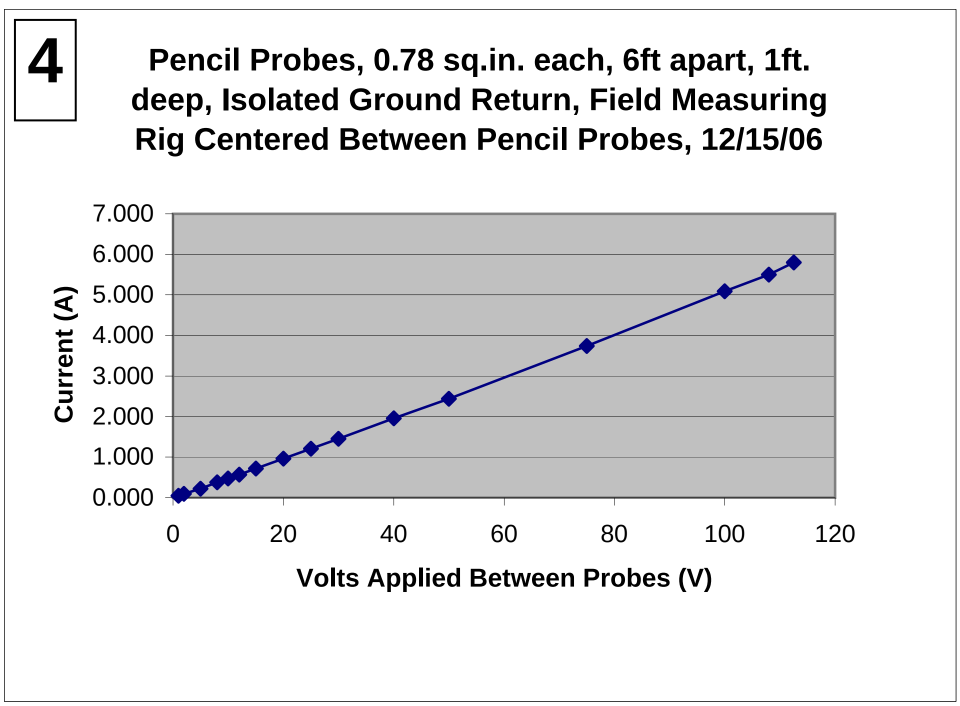
1in. of pencil probes exposed

Volts	Amps
1.0	0.045
2.0	0.085
5.0	0.223
8.0	0.356
10.0	0.448
12.0	0.544
15.0	0.686
20.0	0.934
25.0	1.170
30.0	1.423
40.0	1.920
50.0	2.400
75.0	3.730
100.0	5.100
108.0	5.560



1in. of pencil probes exposed. 2ft wide test rig probes between pencil probes.

Volts	Amps
1	0.045
2	0.095
5	0.223
8	0.381
10	0.473
12	0.572
15	0.720
20	0.966
25	1.210
30	1.450
40	1.960
50	2.440
75	3.740
100	5.090
108	5.500
112.5	5.800



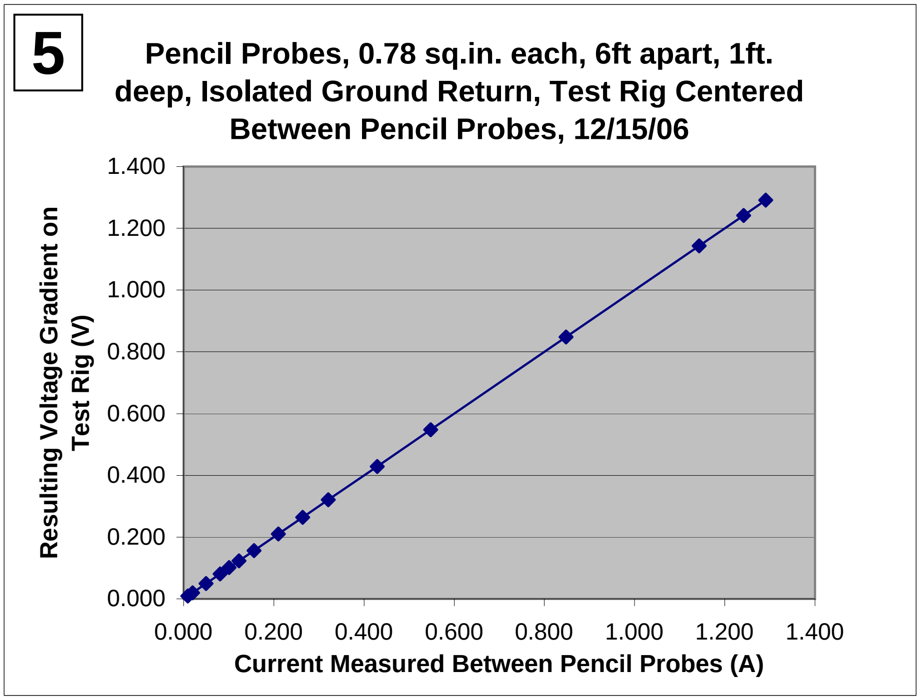
Water conditions (1ft)
Conductivity: 12.4 ms/cm
Salinity: 6.25 g/l
TDS: 8.7 ppt
pH: 7.61
Temp: 76.1 F

Sheet 11C, Voltage vs. Water Current/Gradient

Stuart Yacht, Stuart FL, 12/15/06, brackish water
These tests were conducted to analyze the relationship between voltage applied, water current and voltage gradients.

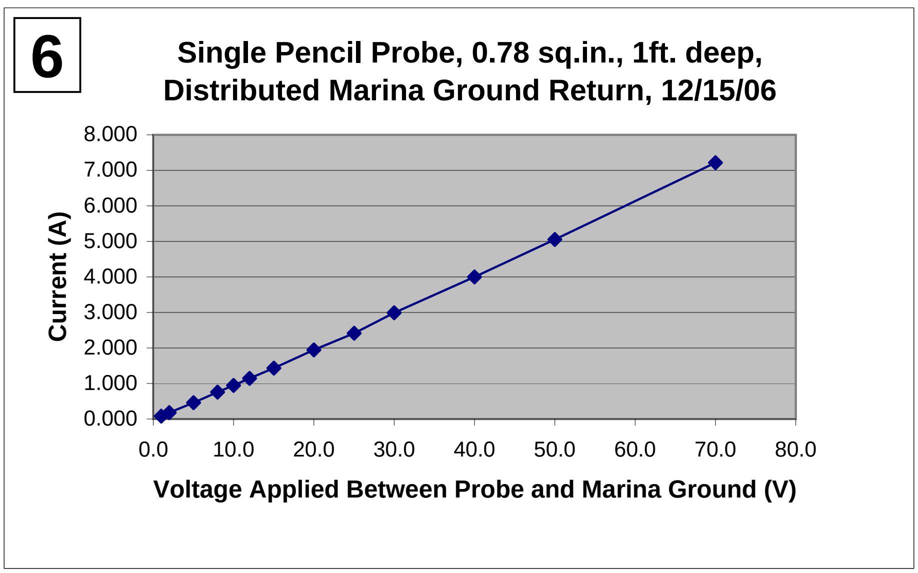
1in. of pencil probes exposed, 2ft wide field probes between probes.

Volts Applied	Amps	2ft Voltage Gradient Volts
1	0.05	0.009
2	0.10	0.020
5	0.22	0.050
8	0.38	0.081
10	0.47	0.101
12	0.57	0.123
15	0.72	0.156
20	0.97	0.210
25	1.21	0.264
30	1.45	0.321
40	1.96	0.429
50	2.44	0.548
75	3.74	0.848
100	5.09	1.143
108	5.50	1.242
112.5	5.77	1.291



Single pencil probe, 1" exposed, marina ground return

Volts	Amps
1.0	0.084
2.0	0.177
5.0	0.455
8.0	0.755
10.0	0.944
12.0	1.140
15.0	1.430
20.0	1.945
25.0	2.410
30.0	2.990
40.0	4.000
50.0	5.050
70.0	7.220



Water conditions (1ft)
Conductivity: 12.4 ms/cm
Salinity: 6.25 g/l
TDS: 8.7 ppt
pH: 7.61
Temp: 76.1 F

Sheet 12, Marina Data Testing Notes

Investigators: Jim Shafer, David Rifkin

Marina Name/Location: Texas Sailing, Lakewood Marina, Austin TX

Date: 3/28/2007 Weather: Partly Cloudy

Air Temperature: 74 Wind: 12kt Clouds: 40% Rain: None

Electrical Service at Pedestals: 50A/240V, 30A/120V Water depth in marina: 40'+

Number piers/wharfs: 14/1 Bottom type: Rocks, mud

Number vessels connected to shore power: Approx. 200 Vegetation present: None

Mooring arrangements/configurations: Moored piers, wharf with long fingers attached. Docks were composite/concrete on foam floats.

Metallic structures that could infuence testing: None

Notes and comments on marina aspects of testing:

1. Most boats were lifted out of the water by air pump lifts (except larger ones). Many of these were connected to shore power.

Texas Sailing School, Austin, TX, Lake Travis, Freshwater

Sheet 12-1-1, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Test number: TSS-FRP-IB-AS, 3-28-07, 1400hrs Date: 3/28/2007 Marina/Location Texas Sailing, Lakewood Marina, Austin, TX

Vessel Name: Lone Spar Type: Sailboat Hull Material/Coating, if metal: FRP

Make/Model: Beneteau 373, 2006 Dock #: D Slip #: 26 Pedestal #: None Water flow at dock: 0 kts

Mooring: **Wharf:** ☐ S / ☐ P Side to **Slip:** ☐ Bow In/ ☐ Bow Out **Tee Dock:** ☑ S / ☐ P Side to

Length/Beam: 38'/13.5 ft **Prop:** ☑ Inboard ☐ Inboard Outboard ☐ Outboard ☑ Sail : ☑ Single ☐ Double

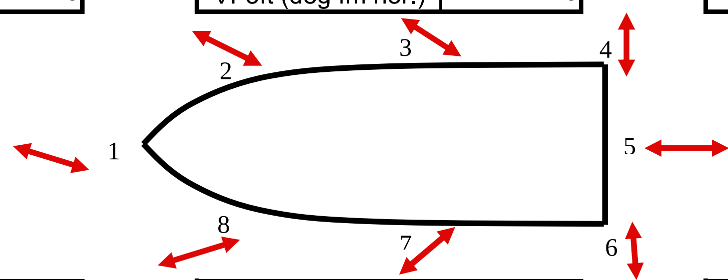
Power: ☐ 50A/240V ☑ 30A/120V ☐ 2-30A/120V ☐ 50A/240V to 2-30A Other: ______

2	Bkgd	Fault
HF1ft(V)	0.003	0.106
HF3ft(V)	0.003	0.110
HF5ft(V)	0.003	0.109
V3ft(V)	0.022	0.600
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.003	0.505
HF3ft(V)	0.003	0.461
HF5ft(V)	0.003	0.407
V3ft(V)	0.025	1.760
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)	0.003	1.530
HF3ft(V)	0.003	1.300
HF5ft(V)	0.003	0.962
V3ft(V)	0.025	3.750
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

1	Bkgd	Fault
HF1ft(V)	0.003	0.072
HF3ft(V)	0.003	0.070
HF5ft(V)	0.003	0.063
V3ft(V)	0.039	0.540
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.004	2.570
HF3ft(V)	0.004	2.230
HF5ft(V)	0.003	1.390
V3ft(V)	0.030	7.200
VF3ft(V)	0.003	2.780
VF3ft (deg fm hor.)		45 d a

8	Bkgd	Fault
HF1ft(V)	0.003	0.120
HF3ft(V)	0.003	0.117
HF5ft(V)	0.003	0.106
V3ft(V)	0.027	0.900
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.004	0.392
HF3ft(V)	0.004	0.380
HF5ft(V)	0.003	0.320
V3ft(V)	0.030	2.300
VF3ft(V)	0.004	less
VF3ft (deg fm hor.)		0

6	Bkgd	Fault
HF1ft(V)	0.005	1.660
HF3ft(V)	0.003	1.350
HF5ft(V)	0.003	1.000
V3ft(V)	0.039	5.600
VF3ft(V)	0.003	1.710
VF3ft (deg fm hor.)		30 d a

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	0.035	0.052	0.251	0.764	1.283	0.828	0.194	0.059
HF3ft(V/ft)	0.034	0.054	0.229	0.649	1.113	0.674	0.188	0.057
HF5ft(V/ft)	0.030	0.053	0.202	0.480	0.694	0.499	0.159	0.052
V3ft(V)	0.501	0.578	1.735	3.725	7.170	5.561	2.270	0.873
VF3ft(V/ft)	less	less	less	less	1.389	0.854	less	less

Bonding system: ☑ Intact Pedestal Impedances w/SureTest: H 0.05 N 0.39 G 0.09 ohms

Test Current: 3 A Voltage for Test Current 61.6 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.255 g/l TDS: 0.357 ppt pH: 8.5 Temp: 75F

Conductivity: 0.468 ms/cm@1ft 0.467 ms/cm@3ft 0.450 ms/cm@5ft Water path (Ω): 20.53

Lone Spar (Sheet 12-1-1,2)

Sheet 12-1-2, Field Strength/Voltage Data Form

Investigators: Jim Shafer, David Rifkin

Additional Data and Remarks

Test number: TSS-FRP-IB-AS, 3-28-07, 1400hrs

Marina/Location: Texas Sailing, Lakewood Marina, Austin, TX

Date: 3/28/2007

Isolation Test 2" from plate, 1' deep	
MaxHF(V)	25.000
Bkgd(V)	0.005
Difference(V)	24.995
HF1ft(V/ft)	12.498
MaxVF1ft(V)	36.000
Bkgd(V)	0.003
Difference(V)	35.997
MaxVF1ft(V/ft)	17.999
Deg from Hor.	15 d a
Hull V @ 3A	107.000

Isolation Test 2" from plate, 5' deep	
MaxHF(V)	14.600
Bkgd(V)	0.003
Difference(V)	14.597
HF5ft(V/ft)	7.299
MaxVF5ft(V)	32.000
Bkgd(V)	0.002
Difference(V)	31.998
MaxVF5ft(V/ft)	15.999
Deg from Hor.	30 d a
Hull V @ 3A	Not Meas.

AC Clamp Test (Amps)	
Ped CB open	0.002
Ped CB Shut Loaded	0.001
Net Water (A)	0.001

Current Split Test	
Test Load Current (A)	12.420
Bkgd, Ped CB Open (A)	0.000
Water Path (A), w/Load	0.035
Net Water Path (A)	0.035
Ground Wire (A), w/Load	12.300
Net Ground Wire (A)	12.300
% Split Water	0.3%
% Split Ground Wire	99.7%

Testing Remarks:

None

Sheet 13, Marina Data Testing Notes

Marina Name/Location: Tropic Resort and Marina, Deland FL

Dates: 9/7,10/4/07 Weather: Sunny/Cloudy

Air Temperature: 85/81F Wind: 6/10kt Clouds: 0% Rain: None

Electrical Service at Pedestals: 50A/240V, 30A/120V Water depth in marina: 10ft

Number piers/wharfs: 1/1 Bottom type: Mud

Number vessels connected to shore power: Approx. 15 Vegetation present: None

Mooring arrangements/configurations: Wood pilings with floating docks with wood planks.

Metallic structures that could infuence testing: None

Notes and comments on marina aspects of testing:

1. None

Tropic Resort and Marina, Deland, FL, St. JohnÕs River, Freshwater

Sheet 13A, Broken Cable Insulation Test

Tropic Resort and Marina, Deland FL, 10/4/07, Freshwater
In this test the resulting electric field was measured at various distances from the source using the marina distributed ground as the return path for fault current.
One inch of insulation was removed from ends of the hot, neutral and grounding conductors (12awg cable). Starting with the hot conductor in the water, voltage gradients were measured at 3', 5', and 7' from the source. This was repeated by adding an additional conductor until all 3 conductors were immersed. The probes on the test rig were 2' apart. Applied voltage was 125v.
The "Water Path" current in the data below represents the current that traveled through the water away from the vicinity of the bare conductors before entering the marina distributed grounding system.

See section of test procedure.

		Current in water as indicated (A)	Distance from source to center of test rig as indicated		
			1'	3'	5'
Hot only:	Bkgd (V):		0.003	0.003	0.003
	Fault (V)		11.000	0.750	0.290
	Volts/Foot		6.499	0.374	0.144
	Current (A) Hot	1.000			
	Water path (A)	1.000			
H + N:	Bkgd (V):		0.003	0.003	0.003
	Fault (V)		5.000	0.680	0.230
	Volts/Foot		2.499	0.339	0.114
	Current (A) Hot	1.030			
	Current (A) Neutral	0.100			
	Water Path (A)	0.920			
H+N+G:	Bkgd (V):		0.003	0.003	0.003
	Fault (V)		4.500	0.600	0.240
	Volts/Foot		2.249	0.299	0.119
	Current (A) Hot	1.040			
	Current (A) Neutral	0.090			
	Current (A) Grounding	0.087			
	Water Path (A)	0.879			

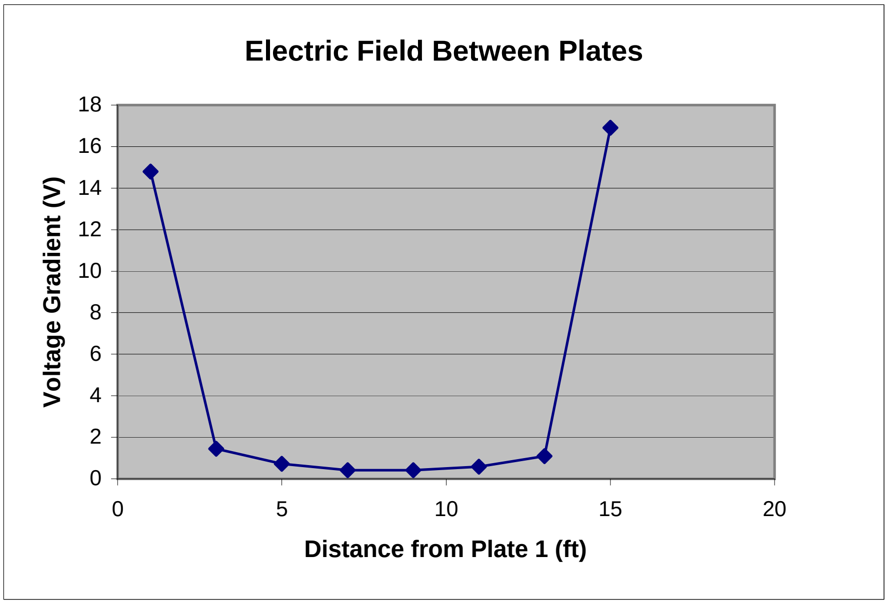
Water conditions (1ft)
Conductivity: 1.22 ms/cm
Salinity: 0.603 ppt
TDS: 0.847 ppt
pH: 8.16
Temp: 82 F

Sheet 13B, Voltage Gradient vs. Distance

Tropic Resort and Marina, Deland FL, 10/4/07, Freshwater
Voltage was applied between two 180 sq inch aluminum plates. Using the gradient test rig with probes 2' apart, voltage gradients were measured at intervals between the plates. Three amps of water current was used for this test. The plates were at the surface and spaced 16' apart.

Voltage applied to plates: 40VAC

Distance of test rig center from plate #1(ft)	2' Voltage Gradient (V)
1	14.8
3	1.45
5	0.73
7	0.42
9	0.41
11	0.59
13	1.100
15	16.90
Sum of voltages =	36.40

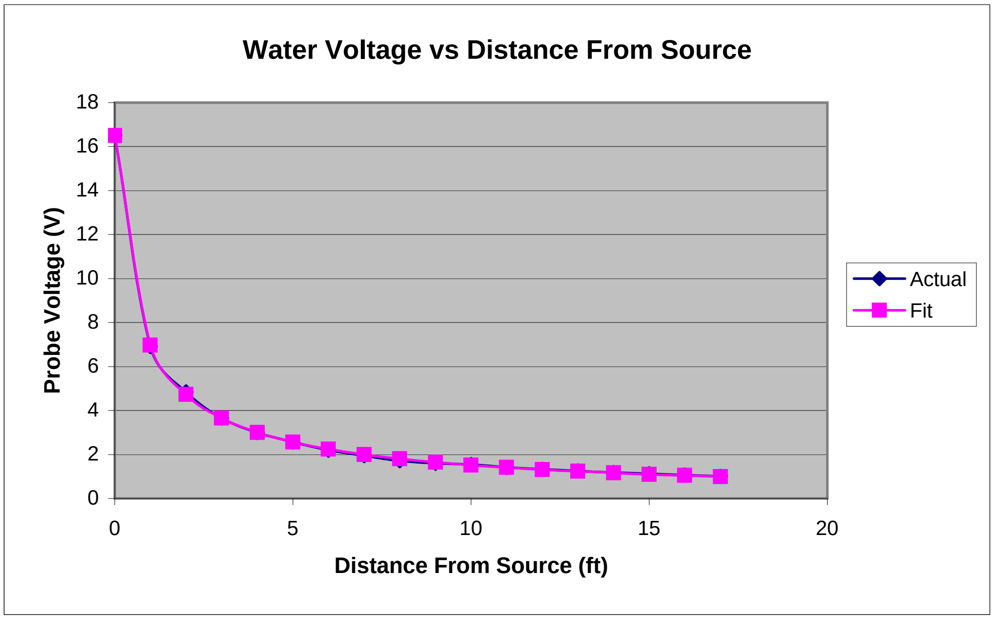


Water conditions (1ft)
Conductivity: 1.22 ms/cm
Salinity: 0.603 ppt
TDS: 0.847 ppt
pH: 8.16
Temp: 82 F

Sheet 13C, Water Voltage vs Source Distance

Tropic Resort and Marina, Deland FL, 9/7/07, Freshwater
This test was conducted by injecting 3amps AC into the water via a propellor suspended near the surface of the water. A probe was used to measure voltage between the water and the marina ground system as probe distance from the source was varied.
See section of test procedure.

Feet from Prop	Water Voltage (V)	Water Voltage Fit from Equation (V)
0	16.5	16.4981
1	6.91	6.9633
2	4.85	4.7362
3	3.65	3.6516
4	3.00	2.9972
5	2.56	2.5552
6	2.20	2.2349
7	1.95	1.9910
8	1.72	1.7986
9	1.60	1.6427
10	1.54	1.5134
11	1.41	1.4045
12	1.32	1.3113
13	1.25	1.2305
14	1.18	1.1599
15	1.12	1.0975
16	1.06	1.0419
17	1.00	0.9921



Water conditions (1ft)
Conductivity: 1.12 ms/cm
Salinity: 0.610 ppt
TDS: 0.825 ppt
pH: 8.14
Temp: 78 F

Sheet 14, Dockside Accident Recreation Test

Investigators: Jim Shafer, David Rifkin

Marina Name/Location: Grand Island, NY, Residence, Pete Schwabl

Date: 7/23/2007 Weather: Overcast, cool

Air Temperature: 68F Wind: clam Clouds: 80% Rain: none

Electrical Service at Pedestals: 120v, 30A Water depth in marina: 1-5 feet

Number piers/wharfs: Multiple along Niagara River Bottom type: mud

Number vessels connected to shore power: none Vegetation present: thick eel grass

Mooring arrangements/configurations: Wooden planked pier with unbonded round steel piles

Metallic structures that could infuence testing: Sheet pile seawall along shoreline

Notes and comments on marina aspects of testing:
See previous page.

Private Dock, Grand Island, NY, Niagara River, Freshwater

Sheet 14A, Dockside Accident Recreation Test

Investigators: Jim Shafer, David Rifkin

Test number: Accident Recreation, Schwabl Dock   Date: 7/23/2007   Dock Location Grand Island, NY, Residence, Pete Schwabl

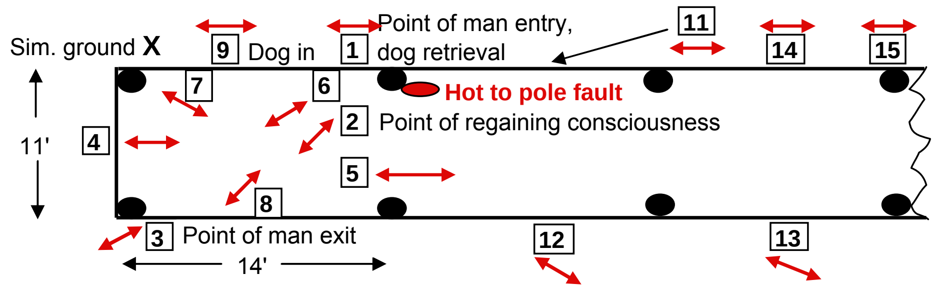
Power: ☐ 50A/240V ☑ 30A/120V ☐ 2-30A/120V ☐ 50A/240V to 2-30A   Other: ______   Water flow at dock: <2kts kts

2	Bkgd	Fault
HF1ft(V)	0.007	6.000
HF3ft(V)	0.007	6.000
Note:	3 feet from source	
V3ft(V)		
VF3ft(V)	0.007	less
VF3ft (deg fm hor.)		0

3	Bkgd	Fault
HF1ft(V)	0.004	3.600
HF3ft(V)	0.004	3.700
Note:	21 feet from source	
V3ft(V)		
VF3ft(V)	0.004	less
VF3ft (deg fm hor.)		0

4	Bkgd	Fault
HF1ft(V)	0.003	2.300
HF3ft(V)	0.003	2.300
Note:	16 feet from source	
V3ft(V)		
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

1	Bkgd	Fault
HF1ft(V)	0.012	20.100
HF3ft(V)	0.017	20.100
Note:	1 foot from source	
V3ft(V)	0.010	20.100
VF3ft(V)	0.017	less
VF3ft (deg fm hor.)		0



5	Bkgd	Fault
HF1ft(V)	0.003	4.800
HF3ft(V)	0.003	4.500
Note:	9 feet from source	
V3ft(V)		
VF3ft(V)	0.003	less
VF3ft (deg		0

8	Bkgd	Fault
HF1ft(V)	0.003	5.500
HF3ft(V)	0.003	5.700
Note:	13 feet from source	
V3ft(V)		
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

7	Bkgd	Fault
HF1ft(V)	0.004	10.700
HF3ft(V)	0.004	7.500
Note:	9 feet from source	
V3ft(V)		
VF3ft(V)	0.004	8.500
VF3ft (deg fm hor.)		25 u a

6	Bkgd	Fault
HF1ft(V)	0.003	12.500
HF3ft(V)	0.003	12.200
Note:	2 feet from source	
V3ft(V)		
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

Difference Voltages	1	2	3	4	5	6	7	8
HF1ft (V/ft)	10.044	2.997	1.798	1.149	2.399	6.249	5.348	2.749
HF3ft(V/ft)	10.042	2.997	1.848	1.149	2.249	6.099	3.748	2.849
HF5ft(V/ft)								
V3ft(V)	20.090							
VF3ft(V/ft)	less	less	less	less	less	less	4.248	less

Bonding system: ☑ Intact   Supply Impedances w/SureTest: H 0.45 N 0.28 G 0.24 ohms

Test Current: 38 A   Voltage for Test Current 106 V   Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.134 g/l   TDS: 0.184 ppt   pH: 8.4   Temp: 81F

Conductivity: 0.251 ms/cm@1ft   0.26 ms/cm@3ft   <5' deep ms/cm@5ft   Water path (Ω): 2.79

Sheet 14B, Dockside Accident Recreation Test

Investigators: Jim Shafer, David Rifkin

Test number: Accident Recreation, Schwabl Dock Date: 7/23/2007 Dock Location: Grand Island, NY, Residence, Pete Schwabl

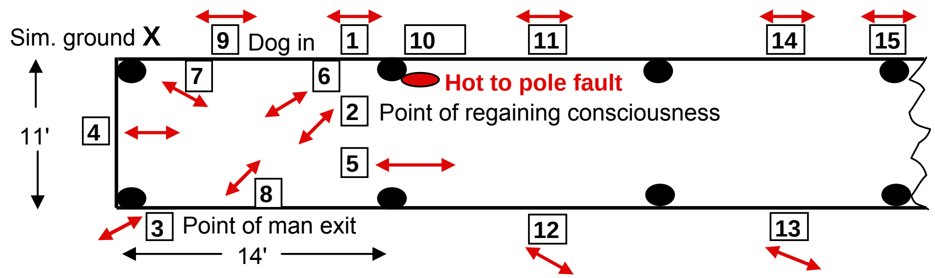
Power: ☐ 50A/240V ☑ 30A/120V ☐ 2-30A/120V ☐ 50A/240V to 2-30A Other: ______ Water flow at dock: <2kts kts

9B	Bkgd	Fault
HF1ft(V)	0.007	7.500
HF3ft(V)	0.007	7.700
Note:	10 feet from source	
Note:	No sim. ground plate	
VF3ft(V)	0.007	less
VF3ft (deg fm hor.)		0

10	Bkgd	Fault
HF1ft(V)	0.003	19.300
HF3ft(V)	0.003	19.600
Note:	1 foot from source	
V3ft(V)		
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

11	Bkgd	Fault
HF1ft(V)	0.003	5.900
HF3ft(V)	0.003	5.900
Note:	7 feet from source	
V3ft(V)		
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

9A	Bkgd	Fault
HF1ft(V)	0.007	9.200
HF3ft(V)	0.007	9.400
Note:	10 feet from source	
Note:	With sim. ground plate	
VF3ft(V)	0.007	less
VF3ft (deg fm hor.)		0



12	Bkgd	Fault
HF1ft(V)	0.003	5.480
HF3ft(V)	0.003	5.430
Note:	13 feet from source	
V3ft(V)		
VF3ft(V)	0.003	less
VF3ft (deg		0

15	Bkgd	Fault
HF1ft(V)	0.003	1.400
HF3ft(V)		
Note:	28 feet from source	
V3ft(V)		
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

14	Bkgd	Fault
HF1ft(V)	0.003	2.450
HF3ft(V)	0.003	3.600
Note:	21 feet from source	
V3ft(V)		
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

13	Bkgd	Fault
HF1ft(V)	0.003	1.960
HF3ft(V)	0.003	2.000
Note:	24 feet from source	
V3ft(V)		
VF3ft(V)	0.003	less
VF3ft (deg fm hor.)		0

Difference Voltages	9A	9B	10	11	12	13	14	15
HF1ft (V/ft)	4.597	3.747	9.649	2.949	2.739	0.979	1.224	0.699
HF3ft(V/ft)	4.697	3.847	9.799	2.949	2.714	0.999	1.799	0.000
HF5ft(V/ft)								
V3ft(V)								
VF3ft(V/ft)	less	less	less	less	less	less	less	less

Bonding system: ☑ Intact Supply Impedances w/SureTest: H 0.45 N 0.28 G 0.24 ohms

Test Current: 38 A Voltage for Test Current: 106 V Water Type: ☐ Salt ☐ Brackish ☑ Fresh

Salinity: 0.134 g/l TDS: 0.184 ppt pH: 8.4 Temp: 81F

Conductivity: 0.251 ms/cm@1ft 0.26 ms/cm@3ft <5' deep ms/cm@5ft Water path (Ω): 2.79

Sheet 14C, Dockside Accident Recreation Test

Investigators: Jim Shafer, David Rifkin

Test number: Accident Recreation, Schwabl Dock

Dock Location: Grand Island, NY, Residence, Pete Schwabl

Date: 7/23/2007

Testing Remarks:

This test recreated a near miss electric shock drowning event at a private residence in Grand Island, NY. The electrical conditions had not been altered since the accident in September of 2000 on the Niagra River a few miles upstream from the Falls. Two boats were present at the time of the accident and were not available for the recreation. A simulated grounding plate was used to determine the extent of the affect of the 2 boats. A romex-encased lighting conductor wore through the insulation and came in contact with a round steel pile supporting the dock. It may have welded itself to the pile causing a direct fault to the earth. The pile was not connected to the bonding system of the electrical service.

The pile was connected directly to the hot lead of the electrical service and the resulting electrical gradients were measured around the dock. The owner jumped into the water at the point indicated on the data sheet to retrieve his dog who had jumped in to the water to fetch something. The owner was instantly overwhelmed by electrical current and he knew what this was since he was a supervisor at the local power company. He clamped up and was sitting on the bottom of the river looking up. He couldn't breath or move. Next thing he knew he had moved to location no. 2 and was able to get his head above water and then move to exit water at location 3.

He was then able to exit the water by himself. The dog perished from the electrical shock. The slow moving water current moved him far enough away from the source to allow him to regain consciousness and muscle control.

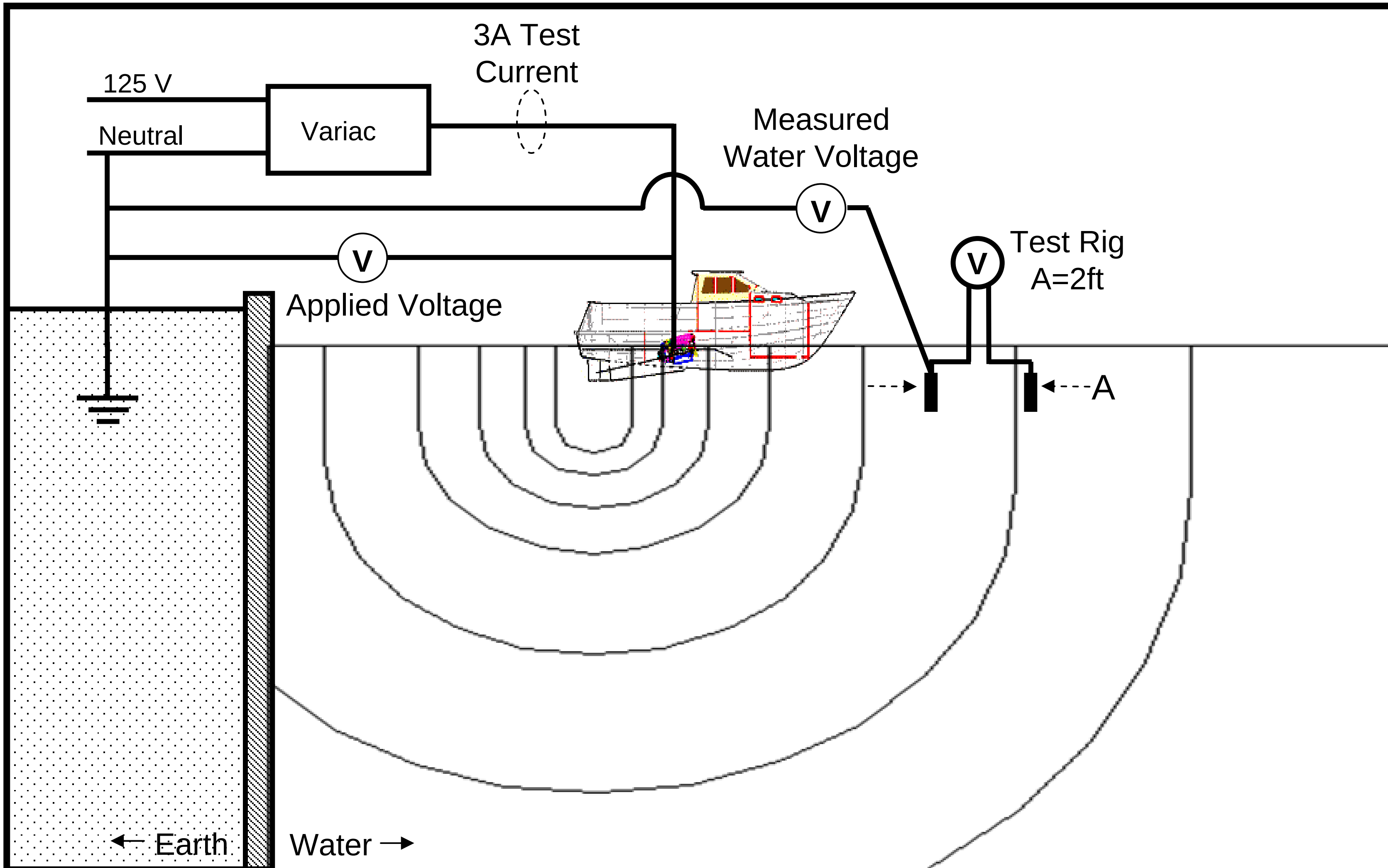
The data represent worst case voltage gradients since we did not know how good a connection the fault was making at the time of the accident. The owner was not wearing any type of rubber insulation suit.

Impedance of the water path is estimated at 2.7 ohms.

An 8 square foot plate was placed as marked on the diagram on the data page. Its effect on the total fault current was to raise it approx. 2amps to 39.4amps total. The loaded voltage was 106v, unloaded line voltage was 121v.

There was over 200 feet of sheet pile perpendicular to the piers in the back of the owner's and 3 other properties on the river nearby. These piles were connected to the electrical system's bonding system.

4. DRAWINGS



Constant voltage applied for 3A test current into bonding (grounding) system; water voltage and voltage gradients measured around boat

Note: See boat data sheets for test rig positions around each boat

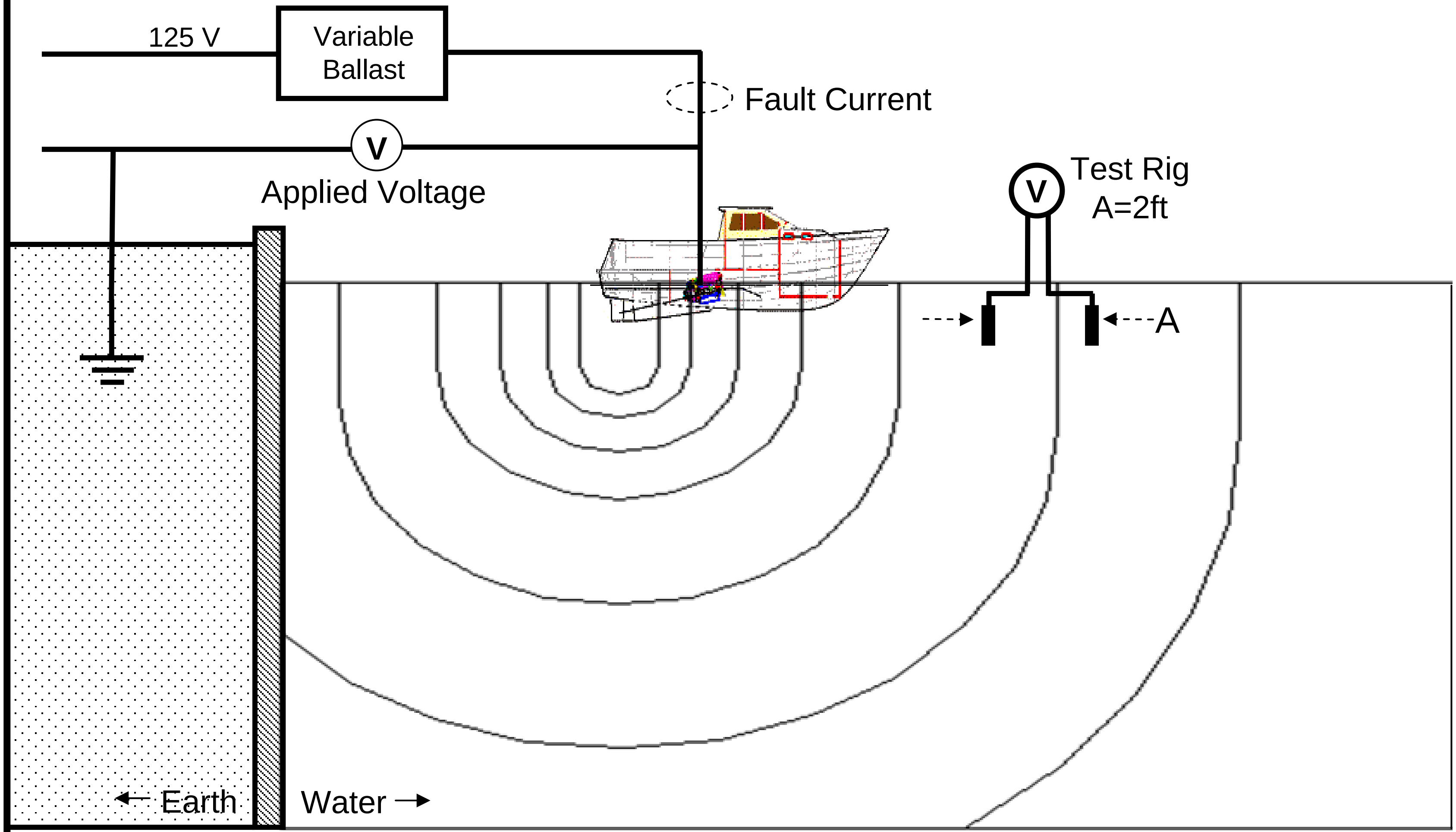
USCG Boating Safety Grant

In-Water Shock Hazard Mitigation Study

Basic Test

Investigators: James Shafer – David Rifkin

Drawing 1
See 1.E.v.(a) of Test Procedure



Constant voltage applied for max safe current into bonding (grounding) system; voltage gradient measured at point of highest gradient from basic test.

Note: See boat data sheets for test rig position on boats tested

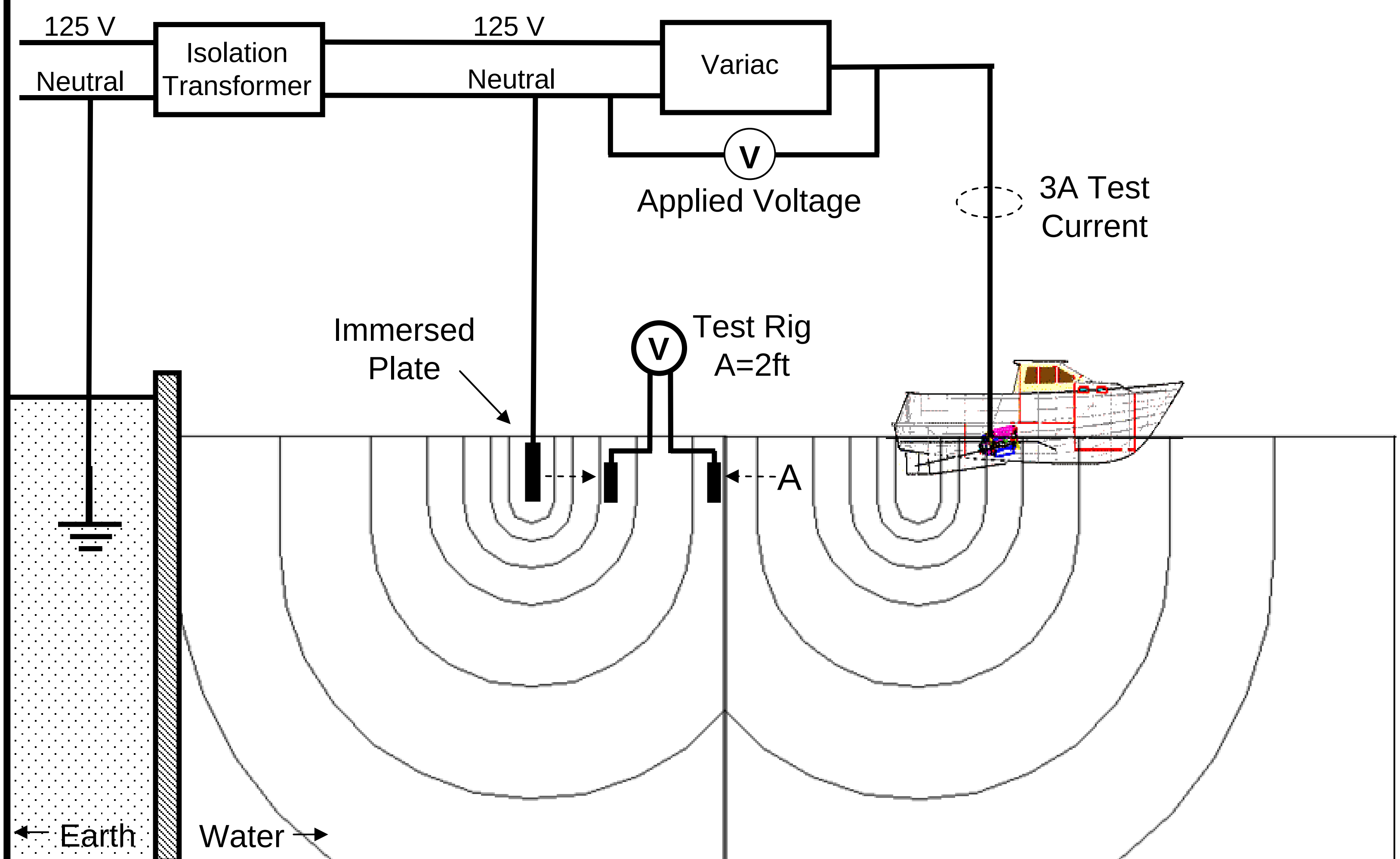
USCG Boating Safety Grant

In-Water Shock Hazard Mitigation Study

High Current Test

Investigators: James Shafer – David Rifkin

Drawing 2
See 1.E.v.(b) of Test Procedure



Constant voltage applied for 3A test current into bonding (grounding) system; voltage gradient at plate measured (isolated ground)

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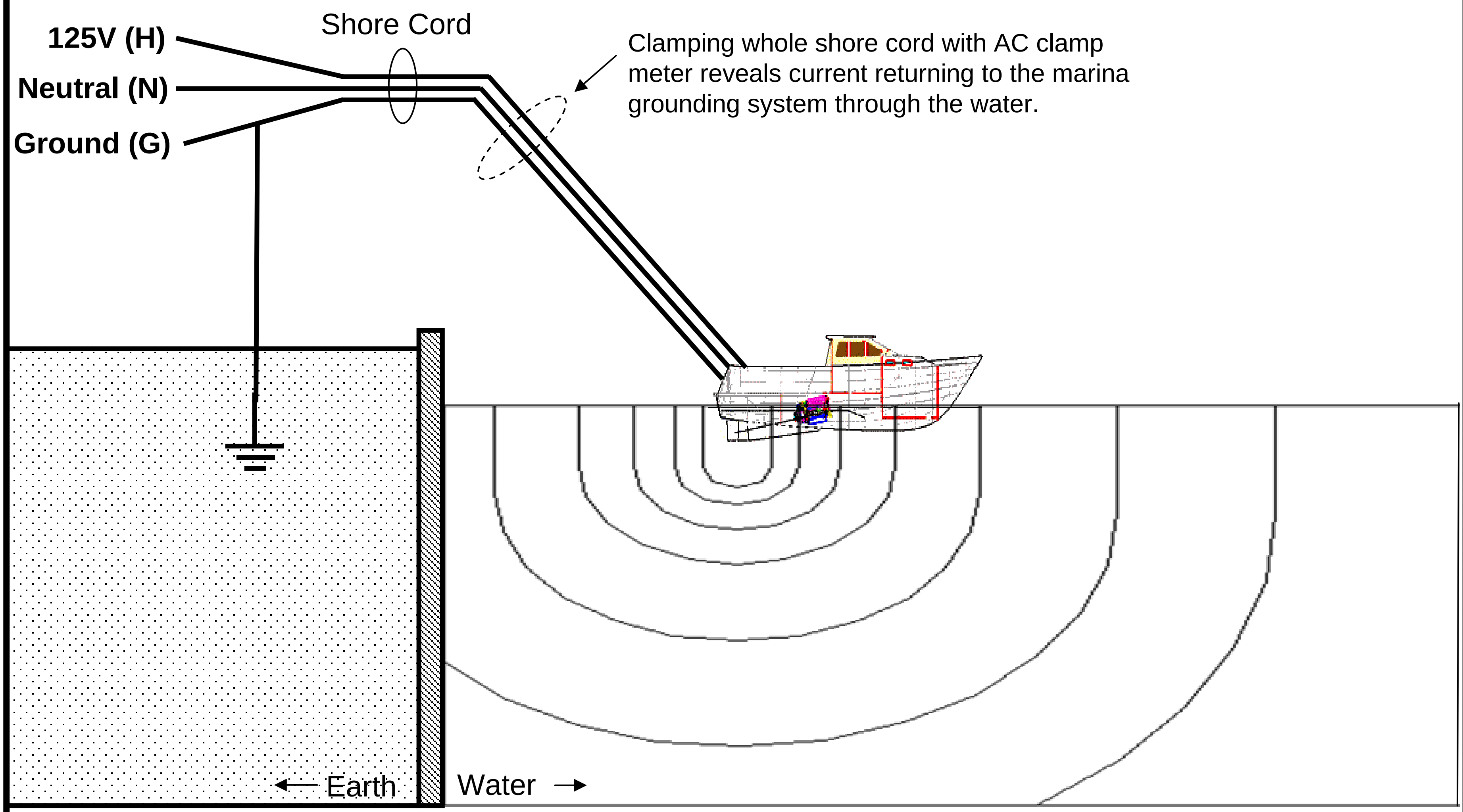
In-Water Shock Hazard Mitigation Study

Isolated Ground Test

Investigators: James Shafer – David Rifkin

Drawing 3
See 1.E.vi of Test Procedure



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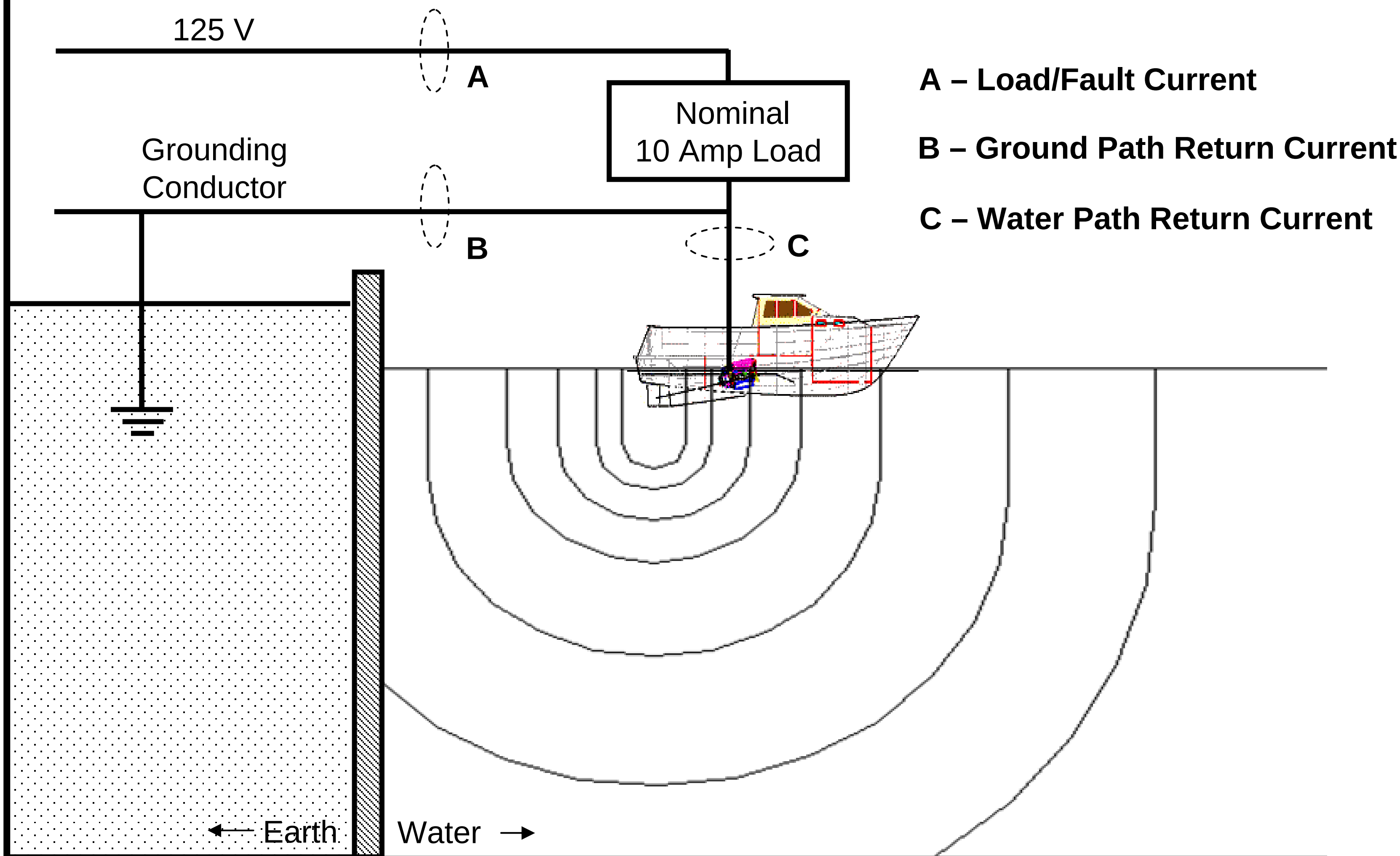
In-Water Shock Hazard Mitigation Study

AC Leakage Test

AC shore power on and loads running; current leaking into the water measured

Investigators: James Shafer – David Rifkin

Drawing 4
See 1.E.vii of Test Procedure



USCG Boating Safety Grant

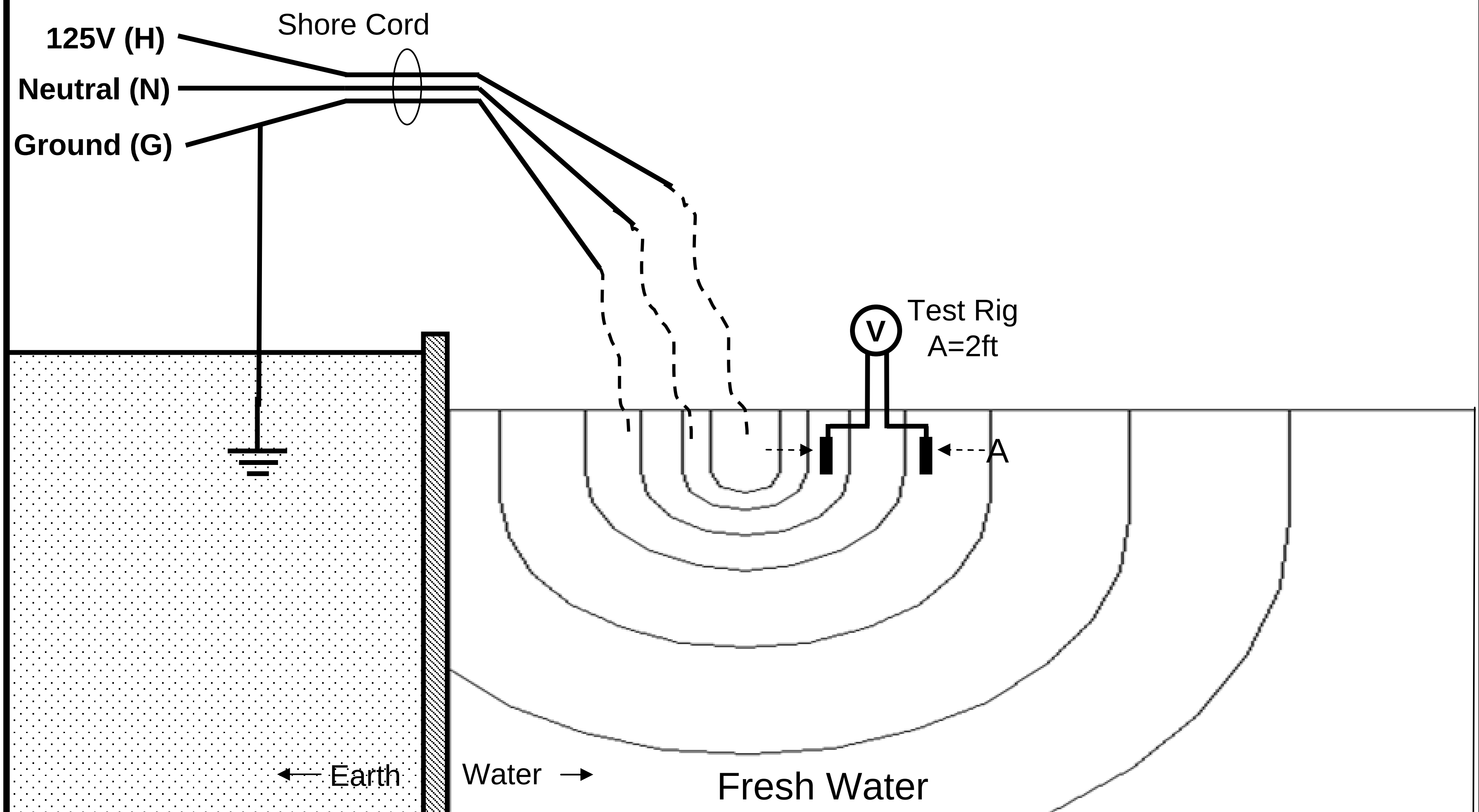
In-Water Shock Hazard Mitigation Study

Split Current Test

Nominal 10A fault into bonding system;
% current spit between ground path and water path determined

Investigators: James Shafer – David Rifkin

Drawing 5
See 1.E.viii of Test Procedure



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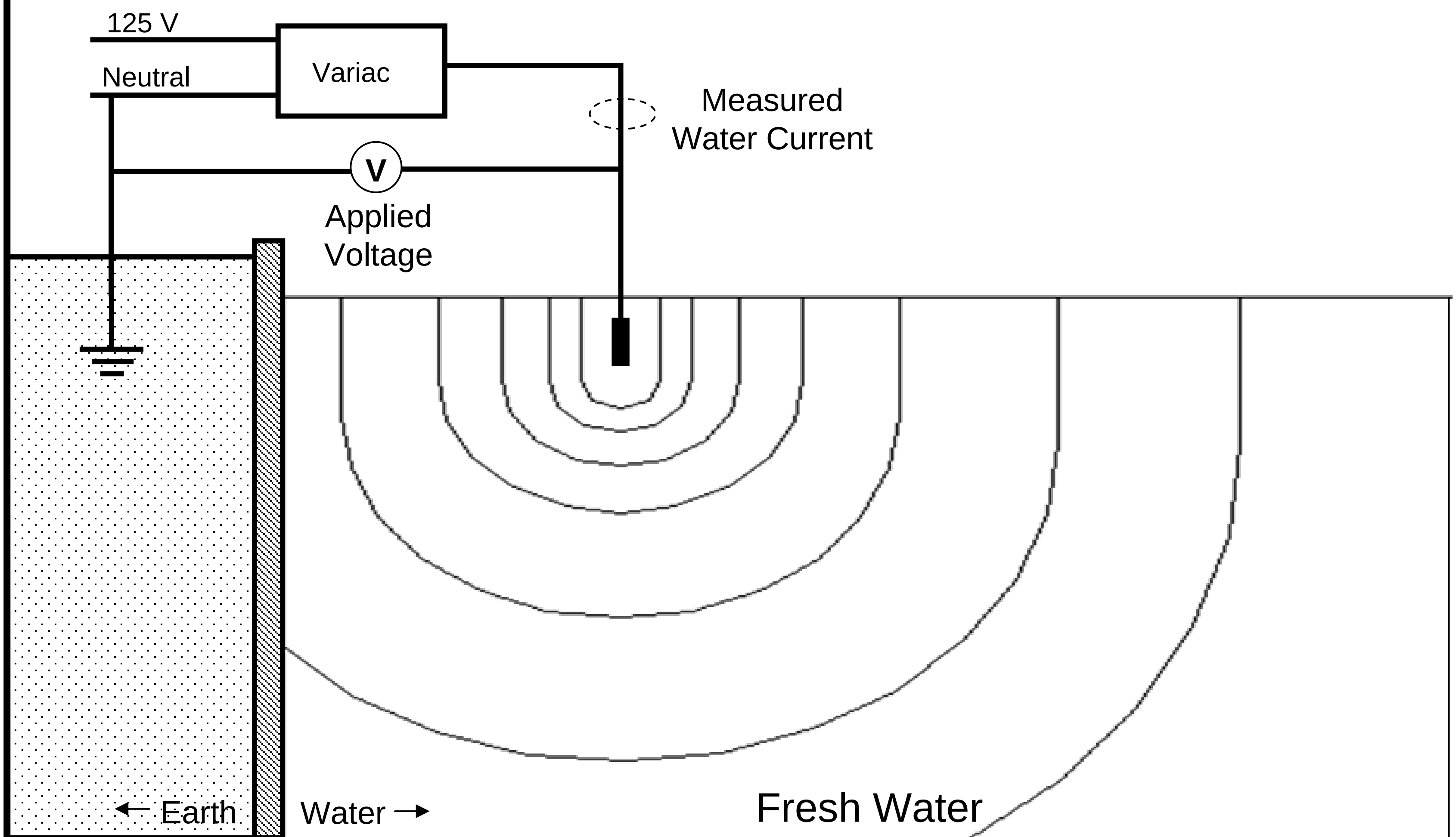
In-Water Shock Hazard Mitigation Study

Broken Cable Insulation Test

H, H+N, and H+N+G were immersed; conductor and water path currents, and voltage gradients were measured

Investigators: James Shafer – David Rifkin

Drawing 6
See 1.E.ix of Test Procedure



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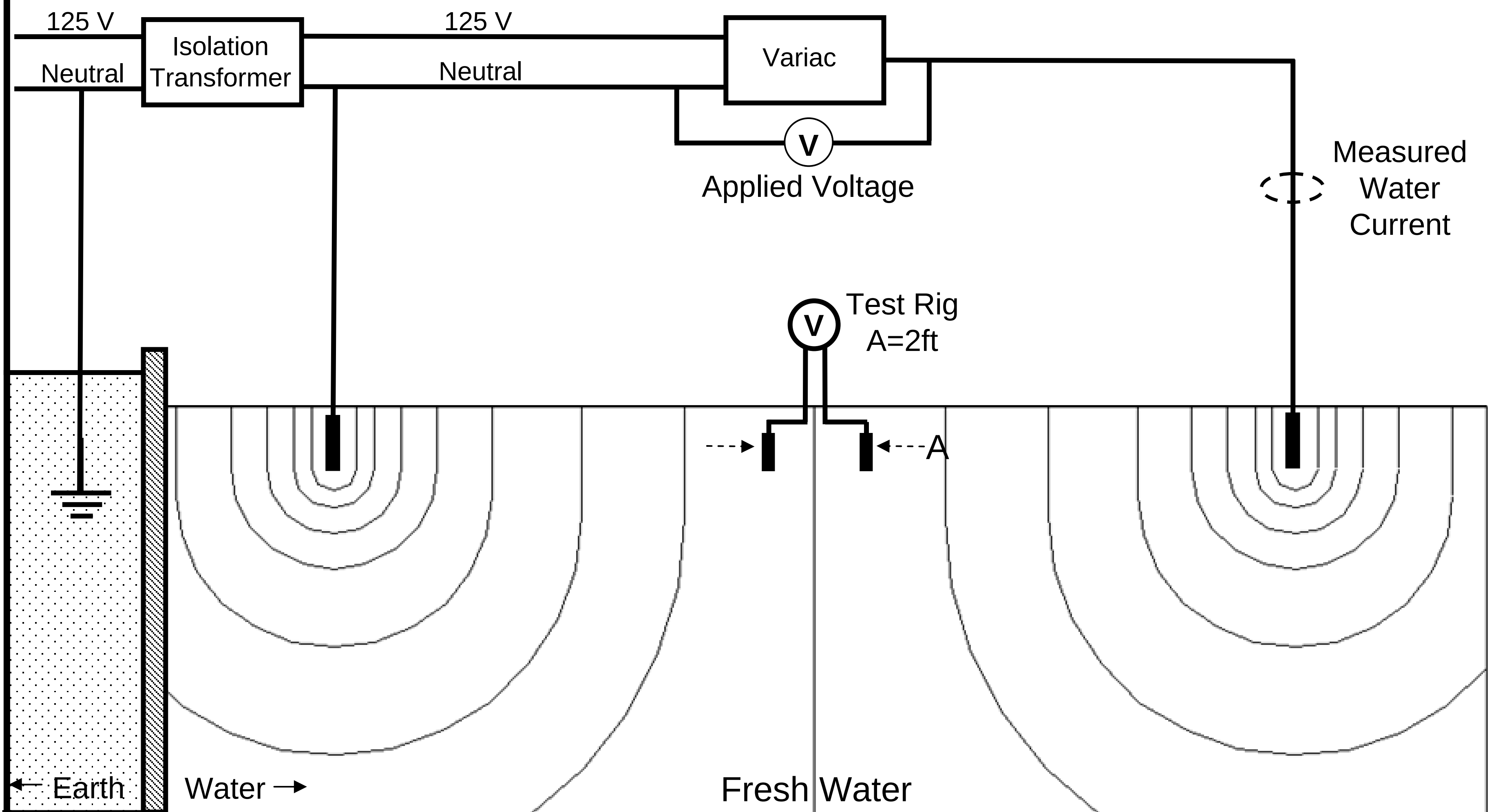
In-Water Shock Hazard Mitigation Study

Water Current vs. Applied Voltage-1

Applied voltage varied; water current measured (marina distributed ground)

Investigators: James Shafer – David Rifkin

Drawing 7
See 1.E.x.(a).(i) of Test Procedure



Note: Test rig placed only to determine effect on measurements (minimal effect)

Applied voltage across electrodes varied; water current measured (isolated ground)

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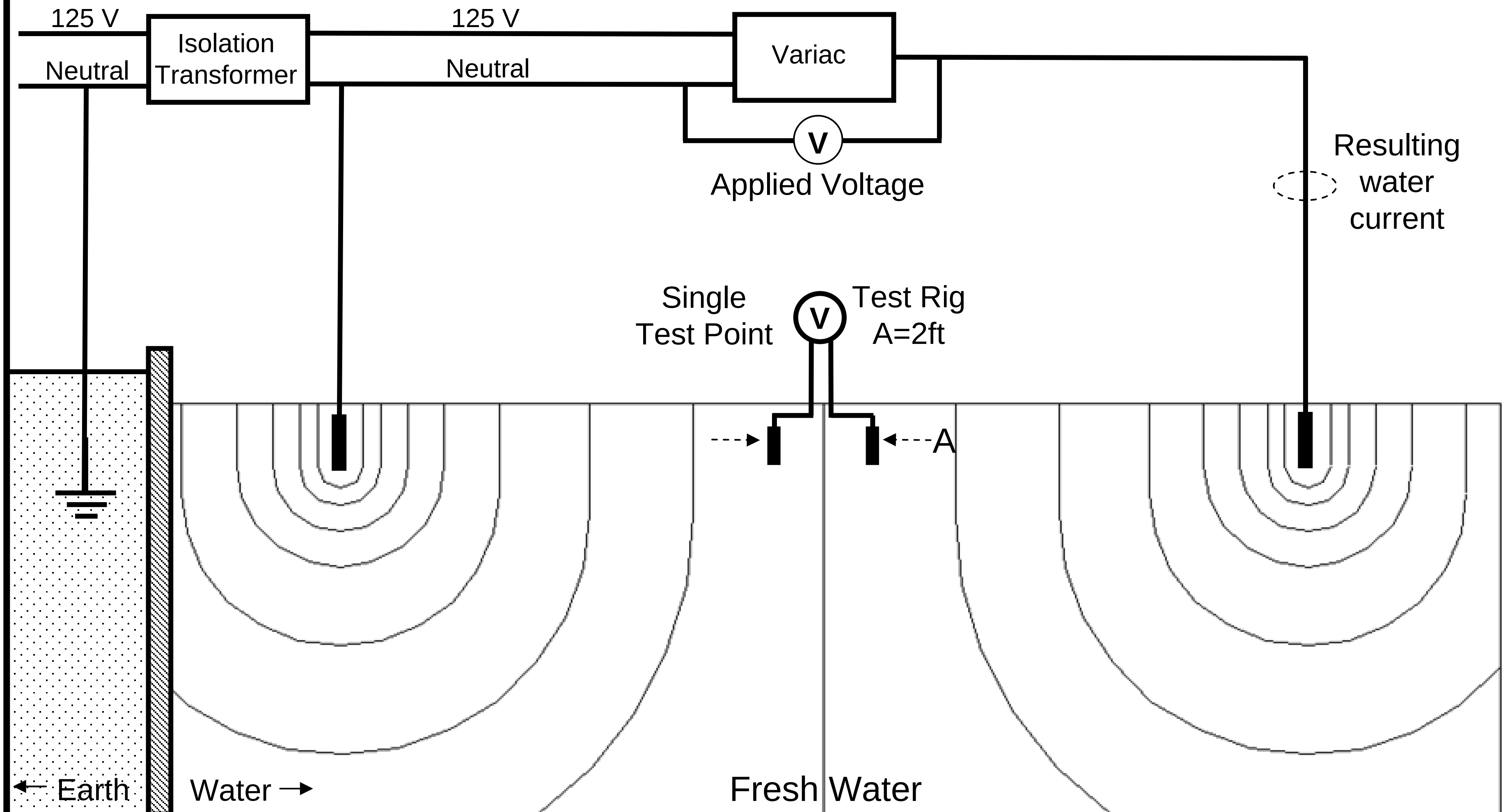
In-Water Shock Hazard Mitigation Study

Water Current vs. Applied Voltage-2

Investigators: James Shafer – David Rifkin

Drawing 8
See 1.E.x.(a).(ii) of Test Procedure



Applied voltage varied to vary water current; voltage gradient measured with test rig centered between electrodes (isolated ground)

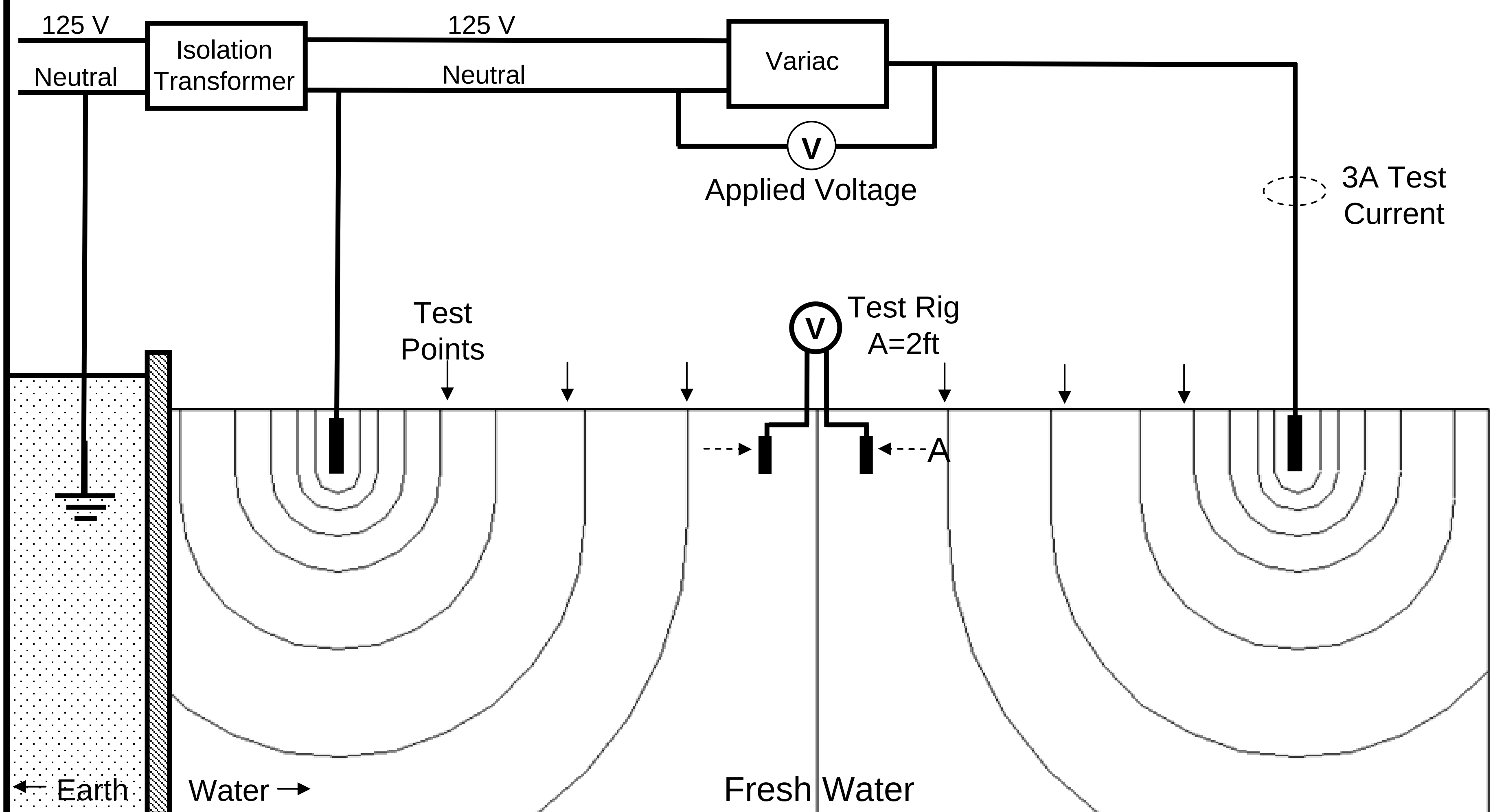
USCG Boating Safety Grant

In-Water Shock Hazard Mitigation Study

Voltage Gradient vs. Applied Voltage

Investigators: James Shafer – David Rifkin

Drawing 9
See 1.E.x.(a).(iii) of Test Procedure



Constant voltage applied for 3A test current into bonding (grounding) system; voltage gradient measured at test points (isolated ground)

USCG Boating Safety Grant

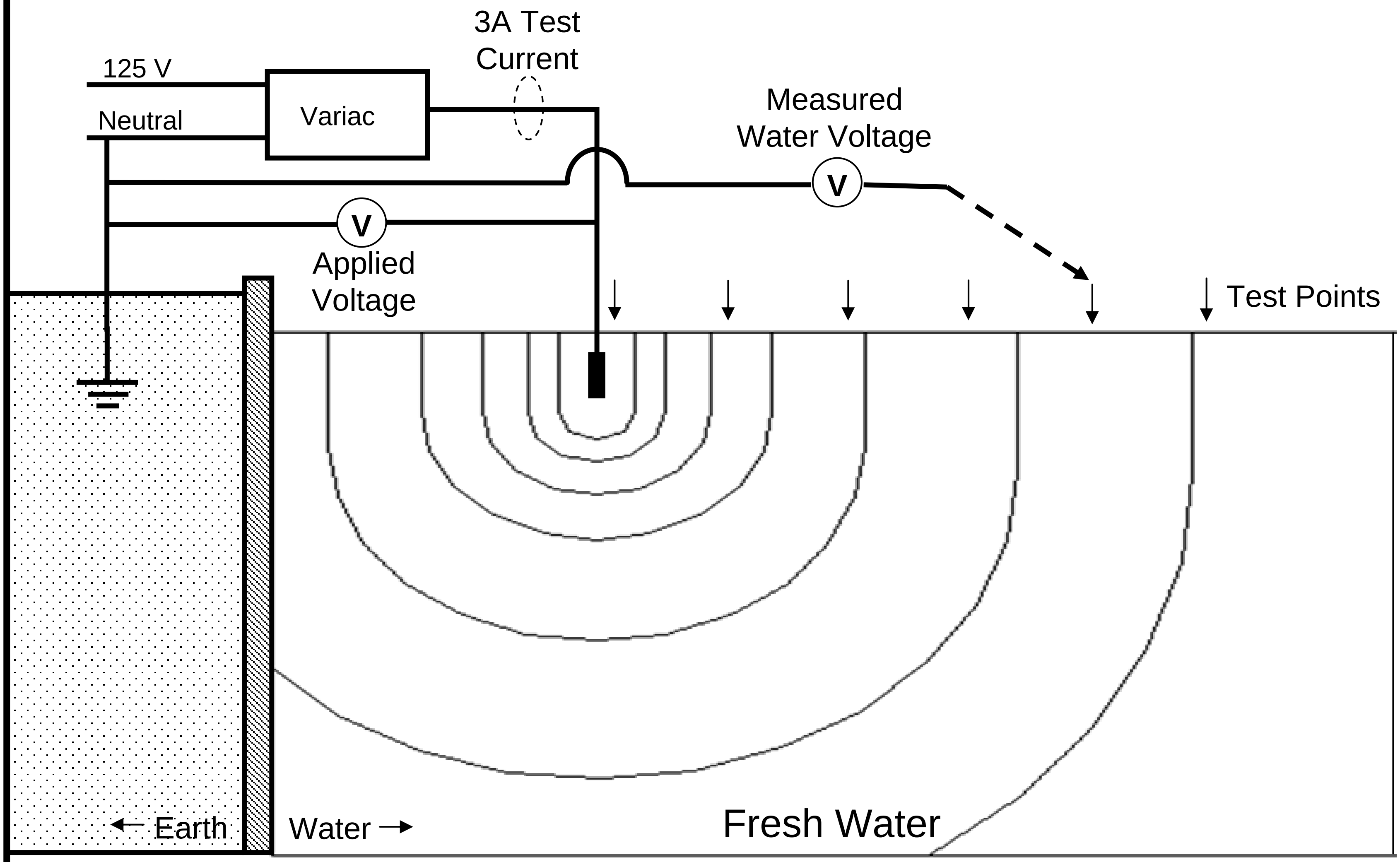
In-Water Shock Hazard Mitigation Study

Voltage Grad. vs. Dist. From Source

Investigators: James Shafer – David Rifkin

Drawing 10

See 1.E.x.(b) of Test Procedure



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In-Water Shock Hazard Mitigation Study

Water Voltage vs. Dist. From Source

Constant voltage applied for 3A test current into bonding (grounding) system; water voltage measured at test points

Investigators: James Shafer – David Rifkin

Drawing 11
See 1.E.x.(c) of Test Procedure

5. Data Analysis

1. General: The data from the study are analyzed in conjunction with the Test Procedure section of the report, with each test being addressed in its own section herein. The Data Analysis begins with a review of the incidents contained in the Electric Shock Drowning accident list (Table 1), and continues with the specific analyses of the data obtained in the field.

2. Electric Shock Drowning Accident List Analysis: The accidents listed in Table 1 were analyzed to determine the most common situations that result in Electric Shock Drownings, Electrocutions, or "near misses". A review of background information and the analysis are provided below:

A. Background: Providing power to yachts moored in a marina is a unique situation that has created a potential hazard not found when using AC power on shore. A person would not normally consider connecting AC power to an electric device and then climbing into a swimming pool with it – but that is exactly the situation that occurs when a moored boat is connected to shore power and a swimmer enters the water. This in itself is not a problem as long as everything is wired properly and functioning normally.

Because electric current takes all paths back to its source any AC leakage from the vessel or dock will return to the source through the water, and, in doing so, may create an electric shock hazard for anyone in the water. To further complicate matters a fault in an AC appliance can result in an electric current that is conducted into the water through the bonded underwater metals, and then back to the source.

Low-level ground fault leakage in the marina AC shore power system can cause lethal potentials to appear on any metal surface – either on a boat or on the dock. In fresh water the electric field in close proximity to this surface can paralyze a swimmer. There is no warning that this condition exists, and it has resulted in numerous drownings. Further, there is no post-mortem evidence that electric shock was the cause. Therefore, the fatalities listed below are only the *known* electric shock caused drownings, which were investigated because of circumstantial evidence, i.e., multiple deaths, eye witnesses, considerable distress, cries for help, shock sensation reported by rescuers, etc.

If a boat is properly wired and every appliance is functioning properly no hazard is created. For many reasons, however, current does get into the water. We have termed this type of fatality "Electric Shock Drowning".

B. Accident Summary: The data in Table 1 below categorizes a number of accidents, many fatal, which have occurred along with the causes listed in general categories. This table excludes accidents where a fault in the dock electrical system was the cause. This data has been collected over the last seven years from various sources including newspaper accounts and Internet searches. We are not aware of any National database listing this specific type of accident. The source of this information is Table 2 at the end of the Data Analysis section. Table 2 is an updated list of accidents since the grant proposal was submitted in late 2006,

Table 1, Categorized Accident Summary

Boats Only - Individuals Involved	Bonding Connection to Shore Missing	Workman -ship Wiring Error	In-service Wiring Failure	Neutral-Ground Bond	Fault in AC Appliance	Fault in AC/DC Appliance	Mfg. Wiring Error	Dock Wiring Error	Exiting Water
Near Miss 28	13	12	1	4	4	1	2	1	2
Fatality 21	17	12	0	3	2	4	4	1	3
Additional 17 Fatalities near docks -- 112 Total incidents, docks and boats – Approximately 15 yr. period									

C. General Conclusions:

i. Fault Conditions: In all the cases categorized above, two general conditions were necessary to cause the accidents. First there had to be an electrical fault (i.e. “short circuit”). Some examples included improperly wired appliances and electrical cords, electrical ground faults, and exposed conductors in contact with the water. The second condition is a lack of, or failure of the bonding system (which is designed to cause circuit protective action or reduce touch voltages to non-lethal levels in the event of an electrical fault). When both these conditions occur at the same time, potentially lethal or injurious conditions resulted.

Given that electrical ground faults may occur in any electrical equipment (under normal or abnormal conditions), the vital link to protect personnel in this situation is a properly installed and maintained bonding system.

ii. Environmental Conditions: In all the cases categorized above, not a single incident was caused in a saltwater or brackish water environment. All fatalities and injuries occurred in freshwater. Due to the low conductivity in most freshwater environments, voltage gradients in the water are significantly higher when compared to the gradients caused by a like amount of current in saltwater or brackish water.

This does not mean that a brackish or saltwater environment should be considered absolutely safe. As water conductivity rises, the situation does become less injurious (for the same amount of current in the water). This is discussed further in the Field Data Analysis section below.

3. Field Data Analysis: This section contains observations from the data obtained in the field. Refer to the referenced Test Procedure Sections for procedural details and the Field Data Section for actual field data from any particular testing event.

A. Basic Testing: (Test Procedure 1.E.v.(a), Field Data Sheets 1-10, 12). This testing examined the danger levels associated fault current leaking into the water in a marina setting. Other general observations were made after analyzing the data from these basic tests.

i. In only three basic testing scenarios were lethal voltage gradients (above 2.0V/ft) measured around the perimeter of the boat (using 3A fault current). In some tests the voltage gradients approached potentially lethal levels (near approx. 1.5V/ft).

The first lethal scenario is found on Data Sheet 3-2-1 on a small runabout with a single sterndrive engine that was fully exposed at the transom (no swim platform). This boat was moored at Callville Bay Marina on Lake Meade in Nevada. Note that all other sterndrive boats tested had swim platforms that would have precluded casual close proximity to the drives themselves. The voltage gradient adjacent to this sterndrive was 2.2V/ft. The sterndrive itself was the only source of leakage on this boat, which acted to concentrate the field in the vicinity of the drive. The conductivity of the water was one of the more conductive in our freshwater testing. It was the proximity of the drive itself to personal access that increased the danger in this boat's configuration.

The second and third lethal voltage gradients were both observed at Lake Ocoee Inn and Marina on Lake Ocoee in Tennessee. This was by far the least conductive water of the testing venues with conductivity values below 0.1 ms/cm. This was the most significant factor in producing lethal conditions in the water.

The second lethal scenario is found on Data Sheet 6-1-1 on a fiberglass houseboat with conventional twin-screw propulsion. A maximum voltage gradient of 7.7V/ft was measured in the stern location (as close to the hull as practical). This maximum gradient was measured 30 degrees down and away from the vessel. It was clearly influenced by a grounded (bonded) steel finger pier brace located near the bottom several feet behind the boat. A higher voltage gradient may have existed in close proximity to the underwater water metals (props, struts, rudders, and shafts) but the point is moot for the purposes of the study. Any person reaching the perimeter of the hull in the stern and quarter positions would have been overcome by the lethal potentials in these areas well before they would have had the opportunity to reach the underwater metals themselves.

Additionally, it is likely that the voltage gradient directly adjacent to underwater metals may have actually been lower than measured near the hull. This is possible because the total current leaking into the water has to be divided by the total area energized. Therefore, at any specific location on the metals emitting current, the current density might have been fairly low, resulting in lower voltage gradients at those points. Based on the ground paths available in this specific scenario, we may have been measuring the lethal gradients at points where the current became concentrated as it sought a path back to the source.

The third lethal scenario is found on Data Sheet 6-2-1 on an aluminum houseboat with twin sterndrives. The primary contributor to the lethal gradient measured (3.9V/ft) directly astern is the extremely low conductivity of the water. Voltage gradients measured at the remaining test points around the boat were all relatively high for a metal-hulled boat and would have most likely resulted in severe discomfort for anyone approaching the boat in the water.

ii. It must be emphasized that the exact level of voltage gradient in the water necessary to incapacitate a person, or to cause a panic situation will vary among the population. The highest voltage gradient measured in basic testing was 7.7V/ft, a clearly lethal condition. And since the water was very non-conductive, the full test current of 3A could not be achieved, even at full line voltage. The test current at full line voltage in this situation was 2.2A. Recognizing the linear relationship of water current to applied voltage (see Section 3.G below), in this scenario 100ma will cause 0.35V/ft, and 30ma will result in 0.11V/ft. At these low current and voltage gradient levels (which can be limited by incorporating Residual Current Device technology), there should be no danger to anyone who may be in the water around a boat.

Using the nominal wet body resistance of 1000 ohms, and a person with a 6ft span, 0.35Vft and 0.11Vft would result in 2ma and 0.7ma of current through the body. This may, in fact, result in a tingling sensation or possibly some discomfort at the 2ma level, but it should not prove to be a lethal or injurious situation.

iii. The data revealed two interesting relationships (between voltage gradient and conductivity, and voltage gradient and surface area of energized metals). First, in general, lower water conductivity resulted in higher voltage gradients for the same amount of test current. The most lethal voltage gradients were measured at Lake Ocoee Inn and Marina (Data Sheet 6) where we measured the lowest water conductivity. And the smallest gradients were measured at Beach Marine (Data Sheet 1) in saltwater. A precise relationship between conductivity and voltage gradient could not be established because there was no practical way to measure the actual condition of the boat's or dock's bonding (grounding) system. We were able to measure the combined series/parallel impedance of the bonding systems and water paths in each test, and in most cases the highest voltage gradients are found where this overall impedance is the greatest. In fact, in the case of Beach Marine (saltwater), the test current was boosted to 5A in order to ensure we would see a measurable voltage gradient around the boat.

Second, the voltage gradients typically varied inversely to the surface area of the energized metals. While it would be difficult to accurately estimate the surface area of a boat's underwater metals, it is easy to recognize the difference in underwater metal surface area between a fiberglass vessel (with any propulsion arrangement) and a metal-hulled vessel. A perfect example of this can be seen in the Data Sheet 6 series of tests conducted at Callville Bay Marina on Lake Meade. The conductivity of the water, and the test current, were identical on both the large metal-hull houseboat and the small single sterndrive runabout. Yet, the highest gradient measured on the houseboat was 0.137V/ft, while the sterndrive measured 2.2V/ft. Since both boats were using the distributed marina ground paths back to the source the larger surface area of the houseboat proved to make it significantly less dangerous in the event of AC current leakage into the water.

iv. Summary: The Basic Testing identified the levels of AC fault current leakage that would prove to be potentially dangerous. Through analysis, it demonstrated that controlling leakage levels below certain values would provide the best opportunity to avoid dangerous conditions around boats using AC shorepower. The data also revealed that potential danger is higher in marinas where the water conductivity is the lowest, and that as the surface area of the energized metal increases (for the same leakage current), the danger is diminished. Or put another way, it takes a much larger leakage current to result in a potentially dangerous situation.

The directionality of voltage gradients was generally consistent with the location of the majority of underwater metals on a particular boat. In some cases, grounded dock structures did influence both the horizontal and vertical direction of the gradients. See Data Sheet 6 Series for examples of how gradients were affected by grounded dock structures.

In comparing the differences between the fresh and saltwater locations, it is clear that freshwater represents a significantly more dangerous situation for any person in the water around boats using AC shore power. However, since saltwater itself offers such a good grounding path, the same fault in saltwater will cause significantly higher fault current to flow at the fault itself. This results in increased risk of electrical fires on boats kept in saltwater.

While all bonding (grounding) systems on boats and docks should be maintained in a serviceable condition, marina operators should be aware of the relative in-water shock hazard associated with their particular environment and vessel population.

B. High Current Testing: (Test Procedure 1.E.v.(b), Field Data Sheets 3-1-2, 3-2-2)

i. These two tests were conducted at Callville Bay Marina on Lake Meade using the same setup as used in basic testing except that the fault current was deliberately increased to a higher level. An attempt was made to raise current incrementally to near the nominal rating of the shore pedestal circuit breaker to verify that the current vs. voltage linear relationship was still valid at higher current levels.

Full line voltage was applied to the bonding system and ordinary hair driers were used as ballast in order to raise the current level in a controlled, deliberate manner, and the resulting water current was recorded. The voltage gradient was measured at the location on the boat that exhibited the highest gradient during the basic testing (which used a test current of 3A).

ii. Two boats were subjected to the higher currents. In the case of the aluminum houseboat a test current of almost 41A was achieved (50A shore service) resulting in only 18.9V hull voltage (hull voltage measured between the hull and dock grounding system). Using the small sterndrive boat, 13.4A was measured with a resulting hull voltage of 76.5V. These tests were carried out, as with the basic tests, with the shore cord disconnected and the test current applied to the vessel bonding system.

In both cases the current in the water varied linearly with the voltage applied and validated our basic testing regimen using a conservative, safer current level of 3A.

At 40.8A on the houseboat, the voltage gradient at position 4 (starboard quarter) was 1.12V/ft. On the sterndrive boat, the 13.4A resulted in a voltage gradient of 6V/ft at the sterndrive itself. This lethal gradient (6V/ft) was no surprise since a lethal gradient was also measured at the same location using 3A of test current.

C. Isolated Ground Testing: (Test Procedure 1.E.vi, Field Data Sheets 1-10, 12)

i. These tests were done on each boat tested as part of the complete testing routine. The equipment setup and test current (3A) was essentially the same as in the basic testing. In this test, however, instead of using the marina distributed ground return paths, a 180 sq.in. aluminum plate was used as the sole return point for the test current (accomplished using an isolation transformer). In test planning, it was recognized that this would represent the near worst-case situation for developing dangerous voltage gradients in the water.

ii. The plate was suspended at a point on the dock close to the boat at both 1ft and 5 ft depths and the test rig was placed as close as possible to the plate without touching it. One electrode was positioned 1-2 in from the plate and the other electrode was oriented directly away from the plate toward the nearest point on the boat under test.

iii. The measured voltage gradients varied between the lowest of less than 1V/ft (@ 5A in saltwater) to the highest of 40V/ft (@ 1.05A in the least conductive freshwater on Lake Ocoee). This would suggest that 100ma, on Lake Ocoee, would result in a voltage gradient of 4V/ft, clearly in the lethal range. However, the actual size, and normal condition of the effective distributed marina grounding surface area would never permit actual voltage gradients to reach this level. In fact, in only 2 other testing locations was the resulting gradient at or near 2V/ft for this test (Sheets 2-1-2, 10-1-2). In both of these locations, a lethal gradient was never reached around the boat itself.

iv. This test only served to gain insight into the behavior of electric fields in a water environment. It reinforces the understanding that the field will concentrate significantly where there is a relative small surface area to conduct a given amount AC current. The situation created with the isolated ground return does not exist in the real world, and therefore, only the basic testing data should be used in analyzing the dangers caused by AC current leaking into the water.

D. AC Leakage Testing: (Test Procedure 1.E.vii, Field Data Sheets 1-10, 12)

i. This testing was done on each boat to reveal any AC leakage caused by ground faults onboard. The results are recorded on each data sheet and data was taken along with the basic testing. In two cases potentially dangerous current levels were detected leaking into the water (highest was 480MA, Sheet 10-2-2). In most cases it was not possible to energize a significant number of AC loads on the boats we tested, so some faulty equipment may not have been uncovered in the study.

Other field experience has confirmed that there are a number of boats leaking current into the water. These boats represent a potential danger to anyone who might be in the water nearby.

E. Split Current Testing: (Test Procedure 1.E.viii, Field Data Sheets 1-10, 12)

i. In this testing, a nominal 10A fault was introduced into the bonding system of each boat. The boat's bonding system remained connected to the dock bonding system for this test. The system was arranged such that any fault current had the opportunity to travel back to the source using 2 paths; the dock grounding system and the water path. The percentage of current in each path was measured to demonstrate the benefits of an intact bonding system.

ii. In the case of the saltwater testing (Sheet 1), the water path proved to be the lowest impedance path for the fault current to return to the source ashore. In fact, 78% of the current used the water path. The dock grounding system at this location was in very good condition (0.06 ohms) as measured at the boat's shore power pedestal. This demonstrated the effectiveness of the saltwater path as a ground return. Not only is this water path highly conductive in saltwater, but it has a tremendous cross sectional area compared to the relatively small gauge of the dock grounding conductor. This observation is consistent with testing in saltwater associated with other marine electrical projects.

In general, the current split in the freshwater testing areas clearly favored the dock grounding conductor over the water path. A precise correlation between water conductivity, dock ground impedance, and % current split could not be made due to the variability of the water path size in the various testing locations. In the least conductive water in Lake Ocoee (Sheet 6) more than 99.95% of the fault current returned in the dock grounding system.

iii. The data indicate that in a freshwater situation, the condition of the boat and dock bonding (grounding) systems is critical in providing a low impedance return path for any AC leakage introduced by ground faults in the marina. This low impedance path will either cause a circuit protective action to occur (e.g. circuit breaker trip) or, in cases where the fault current generated does not reach the levels necessary for a protective action, it will reduce "touch voltages" on metal surfaces to levels which will not cause personal injury.

F. **Broken Cable Insulation Testing:** (Test Procedure 1.E.ix, Field Data Sheets 4, 6, 13A)

i. This test was designed to determine if broken insulation on a shore cord conductor could produce dangerous conditions if the cord was hanging in the water. It is not uncommon to observe shore cords draped in the water, with electrical tape applied to repair insulation problems, and with actual cracks in the insulation jacket itself. Although compliant shore cords are rated for wet environments (meaning contact with the water will not result in fault current flow if the cord is in serviceable condition), they do deteriorate with age and exposure to the elements. Homemade repairs are commonplace due to the cost of replacement.

One inch of insulation was bared on a 14awg 3-wire extension cord. Sequentially each conductor was added to the water and the voltage gradients near the conductors were measured. The test was conducted using both an isolation transformer (water path only, worst case scenario) and the distributed marina grounding paths (which includes the water path as well).

ii. In the three locations where this testing was conducted (Sheets 4, 6, 13A), three of the four tests resulted in dangerous voltage gradients in the water (greater than 2V/ft). In one test the gradient approached 1V/ft, which would cause certain discomfort and possible injury.

The worst-case situation occurred when only the hot conductor was immersed. As the neutral and grounding conductors were introduced, the voltage gradients diminished since these additional conductors were acting as return paths for the fault current coming from the hot conductor (meaning less water current which resulted in the lower voltage gradients). However, the testing at Tropic Marina and Resort showed that even when all 3 conductors are immersed, lethal gradients might still occur. Even though Tropic Marina and Resort was the most conductive of all 3 locations, the return path geometry where this particular test was conducted was conducive to concentrating the voltage gradients in the water.

iii. The data in our basic testing show that lower conductivity will definitely increase the danger level in the water. However, the geometry of the grounding paths may trump higher conductivities and still produce dangerous levels of voltage gradients in the water, even when the neutral and grounding conductors are also immersed. The testing clearly demonstrated that shore cords (or any other conductor in the marina) hanging in the water clearly represent a potential in-water shock hazard.

G. Voltage, Current, and Electric Field (voltage gradient) Relationship Testing:
(Test Procedure 1.E.x., Field Data Sheets 3A, 11A-C, 13B,C)

i. This testing (conducted during the study) was designed to establish the relationships between voltage and current in the water. In all cases, the data showed that when a voltage applied to a metallic item in the water is changed, the current varies almost exactly linearly with this change (Field Data Sheets 3A, 11A-C). This is a very important concept that allowed testing to be done at moderate, relatively safe current levels. This linear relationship was true regardless of the path taken by the current (it made no difference whether the distributed marina ground path was used as a return or a dedicated plate in the water using an isolation transformer. The current resulting from any applied voltage to any metals in the water will vary linearly with changes in this applied voltage.

From a purely technical standpoint, the relationship discussed above did very slightly from being exactly linear. As voltage is raised between two metals, the current actually increases a bit faster than the voltage. This is most likely due to the local heating affect at the surface of the metals involved as chemical reactions occur at the metal-water interfaces (which are part of the natural process by which current gets into and out of the water). This heating tends to speed up the necessary chemical reactions, which effectively causes a slight reduction in overall circuit resistance. By Ohm's Law, a reduction in resistance will cause an increase in current.

For the purposes of the study and the data analysis, this small percentage variation from exact linearity is insignificant. Note that this relationship was demonstrated using real boats as well as using small metallic plates and probes as can be observed in the data sheets.

ii. The data show that if the current in the water is varied, the resulting voltage gradient varies linearly with this current in any given location (Field Data Sheet 11C). Since current in the water varies linearly with voltage applied, it can be concluded that the voltage gradient in the water varies linearly with voltage applied. This means that if hull voltage were to double (e.g. due to the worsening of an existing ground fault), the voltage gradients in the water around the boat would also double.

iii. It was also observed during the study that the surface area of the energized underwater metal(s) have a direct affect on the amount of current in the water, and hence the resulting voltage gradients developed (Field Data Sheets 3A, 11A-C). This was the case using various sized metal probes and plates as well as real boat's underwater metals.

The best illustration of this is seen on Field Data Sheet 3A at Callville Bay Marina on Lake Meade. In the case of the large, non-coated aluminum houseboat, approximately 5V of hull potential (measured with respect to the dock grounding system) resulted in 10A of current flow into the water. When the small bowrider was tested with it's single sterndrive, it required approximately 60V to get the same 10A of water current flow. These numbers come from analyzing the graphs on Field Data Sheet 3A.

This means that for a ground fault generating a given amount of water current, the danger level increases as the surface area of the underwater metals decrease. The reason for this is that the current density in the case of the smaller surface area is greater, meaning a stronger voltage gradient will result in the water. Using the data from the high current testing (see paragraph 3B above) on these same two boats, it was found that 40.8A of current resulted in a maximum voltage gradient of only 1.12V/ft at the houseboat. Using the linear relationships identified in the study, the same 40.8A, if it had been coming from the small sterndrive boat, would have produced approximately 18V/ft near the sterndrive. In most cases, the boats with the smallest bonded metal surface areas are potentially the most dangerous.

iv. Another interesting observation was made during the course of testing and data analysis. Using the data in Field Data Sheet 13B, it was observed that when 2ft-voltage gradients were added up between two energized immersed metals, the result was very close to the applied source voltage (the difference was attributed to the inability to achieve perfect alignment in the 2ft segments measured). This demonstrated that Kirchoff's Voltage Laws apply in this environment. Kirchoff's Law states that the sum of the voltage drops around any closed circuit will equal the source voltage.

v. Field Data Sheet 13C shows the results of voltage testing using an immersed propeller as the source and the distributed marina grounding system as the return. This was done to observe the magnitude of voltage gradient decay as the distance from the source increases. This test was designed to show what a representative decay might look like using a representative piece of typically immersed metal (18" bronze propeller).

The resulting graph of voltage vs. distance from the source shows that the drop in voltage is relatively steep as the distance is increased closest to the source. At 4ft from the source, the voltage is approximately 20% of the applied voltage, and is reduced to 10% at a distance of 10ft. As the distance increases further, the rate of drop in voltage continues to decrease until this rate of change is negligible at approximately 20ft away. Since voltage and voltage gradient both vary linearly with current flow, this graph can be used with either voltage or voltage gradient data (the shape of the curve is what is germane).

The graph on Field Data Sheet 13C can be used to predict what the voltage or voltage gradient would be at a particular distance. All that is needed is an actually measured voltage or voltage gradient, and the approximate distance this measurement was taken from the source.

As an example, suppose a voltage gradient of 0.5V/ft was measured 10ft behind a boat known to be the cause of producing this gradient. Assume that the closest a swimmer could casually get to the energized underwater metals at the stern is 3ft (e.g. boat has a swim platform). Using the graph on Field Data Sheet 13C, draw a horizontal line from the curve (starting at the 10ft point on the curve) to the Probe Voltage axis. Label this point on the axis as 0.5V/ft. Next, re-label the voltage axis in 2V increments starting at the 0.5V/ft. (essentially the curve is just being shifted directly downward to match the measured data). Now, simply read the voltage gradient (using the new axis numbers) associated with the curve for the given 3ft distance. The resulting voltage gradient would be approximately 2.5V/ft.

It must be recognized that this will only provide a rough approximation. Variables such as the nature of the distributed marina grounding system, the size of the underwater metals involved and the shapes and configurations of these metals will all have an affect on the rate of voltage decay. More research is needed in actual marina venues to more accurately characterize the decay of voltage/voltage gradient as the distance from the source is increased.

H. Dockside accident recreation test: (Test Procedure 1.E.xi, Field Data Sheet 14 Series)

i. This test is described in detail on Field Data Sheet 14C. The only unknown in the recreation was the exact amount of fault current flowing during the actual accident. From the electric bill received by the homeowner, the current levels were considerable but may have been less than the 38A measured by energizing the dock piling with full line voltage. We made a solid electrical connection to the steel piling, however the connection during the actual fault may have had a higher resistance value.

ii. The voltage gradient at the point of water entry (position 1 on Field Data Sheet 14A) was 10V/ft. This was certainly enough voltage to completely paralyze the homeowner (which is what he reported). Note that the entry point was at the same location as the energized piling which means the strongest gradients were in this area (as also seen by the data at positions 1 and 10). Apparently the slow moving current in the Niagara River moved the homeowner several feet under the dock and away from the energized piling, reducing the voltage gradient he was experiencing.

The voltage gradient at position 2, where consciousness was regained, was still close to 3V/ft. The homeowner was still partially paralyzed in this position and did not regain the full ability to move until he was closer to position 3. Either the voltage gradient that will cause paralysis in this particular individual is higher than the nominal 2V/ft, or the gradients at the time of the accident may have been lower.

In any event, the gradient at the point of entry was not enough cause ventricular fibrillation in this individual. Even with the 10V/ft gradient observed, if the length of the victim's body exposed to the gradient was only several feet, it is possible that the total current flow through his body could have been on the order of 30ma (less than the nominal levels associated with ventricular fibrillation). In fact, the levels were most likely great enough to cause cessation of breathing (30-40ma range) which may have helped prevent the homeowner from drowning before regaining consciousness.

iii. This accident is a classic case of an electrical installation without adequate bonding of a metallic object that could become energized (the lighting conductor was not properly installed which resulted in chafing against the oxidized steel piling). Had the steel piling been properly bonded (as required by the National Electric Code in this situation), the circuit breaker would have likely tripped and the accident avoided. While this accident did not occur on a boat per se, the underlying safety principles are still relevant to a boat's electrical system.

4. Summary:

A. It takes two faults to create a dangerous situation; an electrical fault to ground, and a break in the bonding (grounding) system back to the source.

B. If AC leakage current is kept to less than 100 milliamps, a dangerous condition should not result around boats connected to the shore power system.

C. Current in the water varies linearly with voltage applied to an underwater metal. Voltage gradient varies linearly as current in the water is varied.

D. A low-impedance bonding path will carry the majority of AC fault current back to the source (in freshwater). This will result in either a protective circuit action (to disrupt power to the fault), or significantly reduced touch voltages on metal surfaces (minimizing shock hazard). In saltwater, the water often offers a lower impedance than the bonding conductors themselves.

E. In general, the smaller the surface area of the energized metal, the more dangerous it will be (for the same AC leakage current). Additionally, it takes a much higher level of AC leakage current to cause dangerous conditions as the surface area of the energized metals increases. In other words, a small, single stern drive fiberglass boat is potentially more dangerous than a large metal-hulled houseboat.

F. The lower the water conductivity, the greater will be the shock hazard for anyone in the water around boats using AC shore power. As the conductivity increases, the shock hazard diminishes. In the case of saltwater, there is little danger to anyone in the water. However, in saltwater fault currents will be higher, representing an increased risk of onboard electrical fires.

Table 2. Electric Shock Drowning Incidents (updated 02/08/2008)

Low level ground fault leakage in the marina AC shore power system can cause lethal potentials to appear on any underwater metal surface – either on a boat or on the dock. In fresh water the electric field surrounding this surface can paralyze a swimmer. There is no warning that this condition exists, and it has resulted in a number of drownings. Further, there is no post-mortem evidence that electric shock was the cause. Therefore, the fatalities listed below are only the *known* electric shock caused drownings, which were investigated because of circumstantial evidence, i.e., multiple deaths, eye witnesses, considerable distress, cries for help, shock sensation reported by rescuers, etc.

We do not know the exact wiring errors or ground faults that created some of the incidents listed below, but it can be assumed that an energized AC conductor (L1 or L2) came in contact with a bonded (grounded) metal object, and coincidently, this object was *not* connected to the shore bonding (grounding) system. This caused a voltage to appear on the bonded under-water metal gear, creating a lethal field around the boat. This was true in every case that was investigated.

No database has been found that catalogs "Electric Shock Drowning" – our term for this phenomenon. The incidents listed below came from various sources, i.e., investigation, press, third party, and eyewitness reports. Dates and details are missing for some. There is no way to know what fraction of the total fatalities this listing represents, but it may be reasonable to assume that it could be small. We have no reports of fatalities in salt water.

ELECTRIC SHOCK DROWNINGS

1. July 28,2007 — Lake of The Ozarks, MO Twenty four year old female attempted to exit the water using a metal ladder at the end of a private dock. She apparently experienced a paralyzing electric shock which caused her to fall back into the water and drown. Several people had reported being shocked by the ladder and the dock owner had gone to shut the power off. The dock power wiring termination was found submerged under the dock near the exit point.

2.	July 24, 2006	Lake Lanier, Cumming, GA. Seventeen-year-old boy in water near a private dock, working on a jet ski with two friends, was overcome by electric shock. Extension cord with damaged insulation caused the metal dock to become energized. Friends also shocked, and partially disabled, could not help their friend. Father of victim fought paralyzing shock and pulled unconscious son away from dock – he could not be resuscitated. Investigation planned.
3.	July 14, 2006	River Street Marina, Port Huron, MI. A 20-year-old man jumped, or fell, into the water from the pier behind a 29' boat, moored stern too. He became disabled as he attempted to climb onto the swim platform. Two friends attempting to pull him onboard reported being shocked. He could not be resuscitated. The next day an inspector reported 107vac in the water behind the boat – measuring points not known at this time. Investigation in progress.
4.	June 24, 2006	Brady Mountain Resort, Lake Ouachita, AR. A 14-year-old boy died from electric shock while swimming near a houseboat. A friend was also shocked and taken to a hospital and released. A man jumped in to help and was rendered unconscious (reason unknown, he was unharmed after regaining consciousness). The cause appeared to be inserting a shore cord with a 30A/125V (L5-30) plug (with the grounding pin bent back) into a 50A-125/250V receptacle in such a way so as to energize the neutral, which was connected to the bonding system, thereby energizing the hull.
5.	June 10, 2006	Lake Michigan, Racine Harbor, WI. A 56-year-old man was killed when he went swimming from the stern platform of a boat. Inquest listed death as "Accidental Electrocution" and did not establish a root cause. Victim's wife stated that the Reverse Polarity light flickered on and went out when power applied to vessel. Comment: A reverse polarity situation along with a grounded neutral can energize underwater metals on a boat.
6.	May 22, 2006	Weiss Lake, Cherokee County, AL. A 24-year-old young man was killed while in the water near a pier. He was attempting to rescue his friend who had become paralyzed by an electric shock while trying to exit the water via a metal ladder. Another friend was also disabled by shock as he entered the water to assist. The two young men, who were shocked, were not seriously injured. There was an electric windmill on a metal tower attached to the ladder, and was apparently powered by an incorrectly modified extension cord, and which may have been connected to a non-functioning GFCI outlet. A bystander on the dock pulled the power cord just in time, or there may have been two more victims. Investigation underway.
7	Mar 19, 2006	Summerset Lake near Desoto, St. Louis, MO. A teenage boy was killed when he received an electrical shock while swimming toward a metal ladder at a dock on the lake. Three other teens (2 boys and a girl) were with him, and all received electric shocks in the same area. One teen was uninjured; while the other 2 were in critical condition at a hospital (these 2 were unconscious on the dock when rescuers arrived). There is an electric boat lift and lighting on the dock but the cause is not yet known. The water level may have risen up to an electrical junction box under the dock. A rep from the local utility found 10 amps of current running into the dock with no loads turned on. There was a chain leading into the water where arcing, a dead muskrat, and 10 dead minnows were observed.

8.	June 27, 2005	Scott's Creek Marina at Cave Run Lake, Moorhead, KY. A 19-year-old girl drowned while in the water near a houseboat due to electric shock caused by a faulty A/C system with an ungrounded system on the houseboat. Another girl sustained burns on her legs while reaching into the water to help the victim. A nearby rescuer swam toward the scene and was shocked and paralyzed by the electrical field. He turned around and swam out of the field and survived.
9.	Sept. 2004	Lake Of The Ozarks, MO 22-year-old male stepped on an electrical cable upon exiting the water after swimming behind a private residence – fell face down into water unconscious – could not be revived. No information on cable.
10.	Sept. 12, 2004	Ross Barnett Reservoir, Ridgeland, MS. A 16-year-old boy was swimming in the marina when he approached a houseboat. He screamed as if in pain and disappeared under the water. He could not be revived after divers recovered his body. A friend in the water also felt a shocking sensation. The cause was a home made shore cord, hard wired to the panel which was passed through a hole in sheet metal siding with no chafe protection. The insulation was cut by boat motion and shorted the hot conductor to the siding. The siding was not adequately grounded to the shore grounding system but was connected to the boat's bonding system, which caused the hull to go up in potential killing the boy.
11.	Aug 8, 2004	Lake Travis, Austin, TX. Young man, in good health, swimming, in evening, unobserved, between two sections of marina dock – disappeared. Came to surface two days later. No toxic substance found on post mortem, but Joule marks (electrical contact points) found on right wrist and left leg and shin. Suspected electric shock drowning. Accident under investigation. (See follow-up, last page)
12.	June 19, 2004	Lake Waccamaw, NC. Ten-year-old boy drowned while swimming with friends near a private dock boat lift that had just been raised from the water. An adult reported a heavy shock when touching the lift and several children in the water reported being shocked. Victim was noticed motionless face down nearby – could not be revived. Lift frame had become energized and the bonding conductor from the supply panel was not connected.
13.	June 5, 2004	Lake Wylie, Charlotte, NC. Two young boys swimming at bow of houseboat called for help. Father of victim and friend rushed forward – boy on ladder said he was being shocked, other boy in water not moving. Friend rushed aft to pull shore cord as father went onto water – his son could not be resuscitated. May not be exact sequence. Causes of energized hull were substantial errors in wiring on the dock as well as on the boat, apparently done by non-qualified individuals.
14.	Aug 3, 2003	Bull Shoals Lake, Bull Shoals, AR. Diver found Aug. 5 in shallow water 8 ft. from his dock, drowned. Incorrectly wired dock junction box caused 117 VAC to appear on metal dock components. Rescue diver reported feeling shock sensation 20 ft. from dock!
15.	June, 2003	Allatoona Lake, GA. Six wildlife fatalities (ducks!!) Houseboat pulled away from the dock and still connected shore power cord separated in middle and fell into water. Six dead ducks found floating nearby.

16.	May, 2003	Cape Coral, Florida. Double drowning, section of re-bar driven through power cable to back yard boat lift caused line potential to appear on lift frame, salt water.
17.	May 31, 2002	Lake Cumberland, Monticello, KY. Double drowning, fault on houseboat, fresh water. 125V plug at boat end of shore cord rewired by owner for 220V – L2 connected to "GR" pin - ground lead in 4 wire cord cut and taped off! Hull rose to line potential.
18.	March, 2002	Bay Marina Boat Works, Biloxi, MS. Some electrical work had recently been done at this yard, which resulted in reverse polarity connections at the shore cord receptacles for the stored boats. Over a short time period several boat owners reported being shocked as they worked on their boats, and one owner was electrocuted. The possibly of a missing ground combined with a ground- neutral connection on the lethal boat was not investigated.
19.	Sept.15, 2001	Farr Shores, Lake Hamilton, Hot Springs, AR. Girl in great distress, man attempting rescue drowns, ground fault on boat, fresh water.
20.	June 6, 2001	Residence, Timber Ridge Dr., Dumfries, VA, Lake Montclair. Two young boys entered water near pontoon boat. Battery chargers (2) connected to modified extension cord from house. Electric shock drowning – cause of energized hull not reported.
21.	May, 2001	New Orleans, Electrocution – Boy using conveyor to transfer shrimp – no ground, salt water.
22.	Apr 10, 2001	Norris Lake, Lafollette, TN. Two teenage boys swimming behind house boat. One boy climbed onto swim platform complaining of feeling severe shock – other boy fell back from ladder– his head *not* below water (ventricular fibrillation?). Could not be resuscitated. Damaged power cable to boat, black lead energized hull, ground wire burned in two – breaker did not trip due to incorrect connection (may not be exact sequence).
23.	2000 or 2001	Put-in-Bay, Ohio, Grand Banks 42. Owner's prescription sunglasses went overboard. Young bystander disappeared while trying to retrieve glasses, electric shock drowning.
24.	Sept.30, 2000	Tims Ford Lake, Winchester, TN. Two boys (21&22). Electric shock drowning. Rescue diver felt electric shock Live wire in water near dock.
25.	Aug 1, 1999	Multnomah Channel, Portland, OR. 8yr old boy tubing with friends in freshwater marina along slow moving river. Boy decides to swim to dock (was wearing type 3 life vest). Suddenly he rolled over on back near the stern of a boat. Mother enters water and helps get boy on dock (she felt tingle in water). Diagnosed as electrocution (head was above water almost all the time). Cause was AC to DC short on boat and no connection between AC ground and DC ground. 84vac measured behind stern upon subsequent investigation.
26.	July, 1999	Lake Mohave, AZ. Young man swimming toward stern of a houseboat became disabled and drowned, fresh water. Boat had a neutral-ground bond. Home made shore cord "Y" became partly disconnected causing hull to become energized. 17vac measured behind stern-drive.
27.	July18, 1999	Cedar hill Lake, Smithville, TN. Two young boys, with flotation devices, were discovered in water, face down, a few feet behind a houseboat. The 7 year old could not be revived. The 8 year old recovered. Electric shock drowning suspected.

28. July, 1999 — S. Carolina, single drowning – 3 feet of water, woman in great distress, husband attempts rescue and drowns, fresh water.

29. Approx. 1999 — Rio Vista, CA. Several boys reported a tingle while swimming in this fresh water marina and got out of the water. A short time later two other boys, 8 – 10 years old, drowned at the same spot. Forty-year-old power wiring running under moored boats found to have substantial fault to ground because of insulation failure.

30. Sept., 1998 — Lake Sonoma, CA. Single drowning, young girl in great distress, fault on dock, fresh water.

31. Approx. 1998 — AF Base, Washington, DC, boy walking on ice slipped and grabbed exposed wires on dock that were supposed to have been de-energized, electrocuted.

32. July, 1997 — Lake Mead, NV. Single drowning, fault on houseboat, freshwater.

33. Feb. 1995 — Bolling AFB, Washington, DC. Young boy reaches from water and grabs support structure for electrical junction boxes receiving lethal shock. Bare energized wires found touching metal case inside junction box. Grounding wire had been cut and never reattached to the junction boxes.

34. Approx. 1994 — Texas, single drowning, fault on boatlift, salt water.

35. Sept., 1993 — Oklahoma, single drowning, fault in submersible pump, fresh water.

36. August 1993 — Alexandria Bay, NY. Double drowning. Two teenage girls snorkeling near dock were paralyzed by electric shock and drowned. Fault thought to be in dock wiring, not confirmed. (Two bystanders attempted to enter water to lend assistance, but were unable to do so.)

37. July, 1993 — Oklahoma, single drowning, fault in dock lights – energized dock frame, fresh water.

38. May 11,1991 — Lake Hamilton, Hot Springs, AR. A canoe carrying four young boys tipped over a few dozen yards from a dock. As they swam toward the dock they felt a light tingle. Three of the boys diverted away from the dock while the fourth boy continued into the electric field and drowned. Cause was broken insulation on a dock wire hanging in the water.

39. July, 1991 — Oklahoma, single drowning, fault in dock wiring, fresh water.

40. Dec., 1989 — Oklahoma, single drowning, fault in submersible pump, fresh water

41. July, 1988 — Park Township, MI, Lake Macatawa, Bay Haven Marina. 18-year-old boy falls off dock, in great distress, two attempts to assist thwarted because of severe electric shock as rescuers entered water.

42. 1987 or 1988
    - A) Gross Pointe Yacht Club, single drowning, diver, fresh water
    - B) Petosky, MI, single drowning, diver, fresh water. NOTE: Both incidents relayed 3rd hand.

43. July 29, 1986 — Harrods Creek, Lexington, KY – Ohio River. About 2030 two dogs jump into water from owners 20 ft. runabout, and were observed to be in great distress. Owner's wife jumps in to help and was immediately in trouble. Husband goes in to save his wife – both drown. Rescuers felt strong electric shock and could not approach victims, but were able to rescue dogs later. Faulty light switch and missing ground on nearby houseboat determined to be the cause.

44.	June 8,1986	St Croix River, Prescott, Wisconsin. 44 year old swimmer dove off of the dock near his 28' power boat. As he approached the swim platform he said he felt like he was being shocked, and was becoming numb, and then disappeared below the surface. Recovery and attempted resuscitation in a matter of minutes were unsuccessful. Battery charger had faulted to its metal chassis, and the boat's manufacturer had deliberately not installed the AC grounding wire to the boats bonding system – as required – causing AC potential to appear on the underwater metal gear.
45.	Date Unknown	Community swimming pool in Oklahoma, 10 year old electrocuted while inserting coins in a soda vending machine. Power cord damaged by one of the 4 legs, grounding pin on plug missing, machine chassis later measured at nearly line voltage, NO GFCI.

ELECTRIC SHOCK – NEAR MISSES
(Additional ones included above)

1.	September, 2007	Franklin Lock Campground on the Caloosahatchee River, FL. Boat docked in freshwater marina receiving AC shore power. Owner was cleaning prop shaft under the boat using a metal scraper. As his foot touched the bottom and the scraper connected the shaft and the strut he felt an electric shock which caused his "teeth to clench and muscles to contract". He also saw blue sparks at the scraper. After the shock he was able to exit the water and observed that one of two 30amp shore power breakers had tripped. He was not wearing a wetsuit.
2.	August 28, 2007	Private pond, Eden, NY 22 year old male entered the pond in an attempt to rescue his dog, which was in great distress, and was thrown back and lay unresponsive. His father dragged him from the water and started CPR which was continued by the rescue squad on the way to the hospital, where he is still recovering as of 9/1. Submersible irrigation pump was considered likely cause.
3.	July 20, 2007	Lake Arcadia, Edmond, OK Adult male entered water at the end of a private dock and was immediately paralyzed by electric shock, and began to sink. His wife, reaching from the dock, kept his head above water. A bystander, entering the water from his boat was also shocked so he got back into the boat and assisted the wife in pulling the man onto the dock. High water had submerged the electrical outlets at the end of the dock.
4.	July 01, 2007	Collins Bay, Lake Ontario, Kingston, ON. As a SCUBA diver, with no wet suit, approached a moored sailboat he felt a tingling sensation. Approaching closer he experienced a moderate electric shock so he backed away. Later examination disclosed damage to a steel dock section at the boat's stern and the battery charger was found to have a "short circuit". The condition of the bonding system was not reported.

5. August, 2006 — Lake Michigan, Racine, WI. Owner decided to check underwater as he was having vibration on one engine. He donned scuba gear and jumped in water. When he touched the bronze prop he was hit with current that almost paralyzed him causing great difficulty in breathing. He was able to get away from the zone of danger. Cause is thought to be the boat in the next slip. A yellow barrel connector on the water heater Neutral #16 wire was loose, due to the terminal being the wrong size and not correctly crimped. It heated up which burnt terminal insulation and shorted the hot to the grounded case. As the phase did not see excessive current, the breaker did not trip. The neutral dock pedestal socket pins had corroded due to poor connection and the ensuing heating so that eventually only intermittent connection was made. The diver's wetsuit may have saved his life. He was only inches from the neighboring boat when touching the prop on his boat (which provided the path back to the source).
6. July 2, 2006 — Lake L'Homme Dieu, Douglas County, MN. Three men were nearing an aluminum dock in an outboard boat (aluminum hull?) when the prop caught on an extension cord laid under water (powered a boat lift), and were severely shocked as they entered the water. Possibly two of the three men entered the water to rescue the third man who had fallen face down into the water, half out of boat, and was not moving – exact sequence not known. A bystander unplugged the cord. The third man spent several days in the hospital. No investigation planned.
7. July, 2005 — Brooklyn, NY. A diver went into the water behind a boat in this small, private marina. He surfaced seconds later complaining about tingling and pain in his arm. A probe in the water measured 40vac to ground behind the boat. Cause was determined to be a neutral-ground short on a recently installed water heater (although there was most likely a bad ground too at that pedestal to cause this). He was wearing a short, spring wet suit.
8. July, 2004 — Sahauro Lake, AZ, a man-made, freshwater lake near Phoenix. A man was diving to perform maintenance on a dock structure. He left the water after feeling a tingling sensation in the water near a pontoon houseboat. The shore cable was disconnected from the boat and the diver resumed his work without further incident. The cause may have been an improperly wired battery charger on the boat.
9. July, 2004 — Sacramento River, CA. Man entering water around several boats (being supplied by genset power from one of the boats) receives shock in water. Two other men jump in to rescue man. One of the 2 rescuers became imperiled. Generator secured immediately. Incorrect wiring on one boat caused a ground fault which introduced current into the water between boats.
10. May 31, 2004 — Lake Barkley, Grand Rivers, KY. After receiving permission from marina two adult women went swimming near their rented houseboat. As they started back to the boat from the swim slide entry point both felt a strong electric shock sensation, and had the presence of mind to *swim away* from the boat! A relative entered the water and felt the same thing – which disappeared when the boat was disconnected from shore power. This close call was brushed off by staff so no action was taken to locate source of fault current (a fatality waiting to happen).

11.	August, 2003	Green River, Campbellsville, KY. Marina manager using Hioki clamp-on ammeter checking shore cords for leakage and discovered one houseboat with 4 amps on one of two shore cords. Hull potential to dock ground 8 VAC and owner commented that one of his children reported a tingle in the water!! Boat had just been reassembled after being trucked from Texas and problems were being experienced with 120 VAC deck light. Deck lights were rewired and neutral / ground fault in inverter was cleared – leakage current no longer exists.
12.	July, 2002	Allatoona Lake, GA. Three swimmers in great distress near houseboat, by-stander pulls shore cord, all saved, one spent several days in hospital, fresh water, and fault on boat.
13.	Fall, 2002	Lake Murray, SC. Swimmer reports strong tingle, hi-level fault currents in dock frame, fresh water.
14.	Date Unknown	Man jumps into water to rescue dog, feels high level tingle, cause unknown, fresh water.
15.	2002-2003	Florida, interviews with divers – many reports of high level tingle while cleaning bottoms, all salt water, and no fatalities.
16.	September, 2000	Niagara River, Grand island, NY – On the dock behind his home the owner watched his dog sink near a steel piling while retrieving a ball. He jumped into the water to rescue the dog and found himself sitting on the bottom in 5' of water completely paralyzed. In a few seconds he began getting tunnel vision and assumed he was going to die. Within the next few seconds a slight current moved him about 4' away from the steel pile. He was able to get his head above water and move another 8' to a ladder. A romex cable, which powered a light on top of the piling, had chaffed and caused the energized conductor to contact the pile. The dog was lost.
17.	Date & location Unknown	Swimmer feels a tingle as his hand enters the A/C discharge stream. Caused not determined, salt water.
18.	July 3, 1998	Lake Chelan, Chelan, WA. 21 year old exiting water – shocked on swim ladder – 48 hours in the hospital – rescuers shocked.
19.	August, 1995	Lake Cumberland, KY, Jamestown Resort and Marina. Seven children swimming behind houseboat received electrical shocks (no fatalities). Lights went out on boat and children immediately started screaming. Cause was loss of neutral, a neutral-ground connection on the air conditioning system and a poor grounding connection on the shore cord. The grounding connection deteriorated when cooking loads were energized causing a loss of return path to the source (reason lights went out).
20.	July, 1981	Brackish water on the Connecticut River in Essex, CT. Diver checking zincs felt strong "electric pulses" as he approached the boat so he backed away. After securing power to the boat, the electric pulses were gone (exact fault unknown)

CODE VIOLATIONS

1. January, 1994 — Oklahoma State Department of Health (OSDH) inspected eleven commercial docks and five private docks, and an earlier (1989) inspection of 116 commercial docks, found 96% not in NEC compliance; most common fault was *open* ground.

2. Aug 8, 2004 — Follow-up — Follow-up to #9 in the Electric Shock Drowning Section above: Lake Travis, Austin, TX. Because of this accident the manager of a neighboring marina now shuts down power to the docks whenever an employee enters the water to do any kind of service. In Nov., 2005, an employee who was in the water, to move the feeder cables that run near the pier access ramp, discovered badly damaged insulation. A fatality was likely prevented because the power had been turned off!

6. Recommendations

Based on the analysis of the data collected during the study, the following recommendations will reduce the likelihood of in-water shock hazard around boats connected to a shore electrical supply. In many cases these recommendations will also reduce the risk of fire aboard boats caused by electrical faults (i.e. short circuits).

1. Install a Residual Current Device (RCD) in the shore power supply of a boat's electrical system. This applies to all electrical systems that utilize shore power, including boats using transformers supplied by shore power. These RCD's respond to the imbalance of current between ungrounded and grounded conductors and cause a circuit protective action to quickly occur. Based on the data, this RCD should be set to trip at a maximum level of 100 milliamps (which would have prevented lethal voltage gradients for all scenarios in the Basic Testing series).

2. Require that all underwater metals be connected to the shore bonding (grounding) conductor if AC shore power is being supplied to the boat. This includes even those metals that are not part of the boat's electrical system since they still represent a potential fault current path back to the source through the water. This will protect anyone in the water in the event that any underwater metal becomes accidentally energized on the boat. This recommendation will also reduce the shock hazard for a boat's occupants.

The ABYC standards concerning installation of transformers and battery chargers should be reviewed in light of this recommendation.

3. Periodically test boats for AC leakage into the water. While none of the boats tested during the study demonstrated any significant AC leakage current, field experience has revealed many boats leaking current at potentially dangerous levels. The examination of past accidents shows that one of the two conditions necessary for an accident to occur is an electrical fault to the grounding system (i.e. short circuit). Another way this manifests itself is an improper connection between neutral and grounding (bonding) conductors on the boat. This connection always creates a parallel path for AC current to return to the source through the water. A periodic testing regimen could uncover faulty boats before an accident occurs.

Incorporation of periodic AC leakage testing guidelines should be considered for ABYC and NFPA standards (specifically NFPA 303, Fire Protection Standard for Marinas and Boatyards).

4. Periodically determine the integrity of a boat's bonding (grounding) system. The second condition (the first being an electrical fault) necessary for an accident is a break in the bonding system between a boat's underwater metals and the supply bonding conductor. Periodic testing could reveal those boats with bonding system faults (e.g. broken bonding conductors, failed open circuited galvanic isolators, corroded or damaged receptacle connections) so that repairs can be made before an electrical fault occurs.

Incorporation of periodic bonding system integrity testing guidelines should be considered for ABYC Standards along with expansion in NFPA 303 to include boat itself as an electrical appliance connected to the shore power system.

5. Prohibit swimming in any marina where AC shore power is being supplied to the docks for any purpose. Posting of warnings should be considered for the protection of occupants of boats at a dock or marina facility. This could in the form of a physical sign posted at a dock or marina, or a label near a boat's AC shore power main breaker.

Consideration should be given to establishing "diving windows" in freshwater marinas using AC shore power, where all AC power could be secured at specified times to facilitate diving operations.

Incorporation of swimming and posting guidelines should be considered for ABYC Standards and NFPA 303.

6. Replace any shore power cord with insulation damage, or any cord with electrical tape applied to repair damage. The study showed that broken insulation can cause dangerous conditions if a shore cord is allowed to enter the water.

Shore cord requirements are already included in NFPA 303. Consideration should be given to expanding requirements in the ABYC standards to include shore cord inspection and replacement criteria.

7. Revise the ***"Warning"*** NMMA brochure on Electrical Shock Hazards to include recommendations 3 through 6.

8. Create a category in data collection databases to include injury and deaths attributable to Electric Shock Drowning. This would expand visibility in this area and could prompt more research into improving boating and marina safety.

9. Disseminate an abstract of this report, with recommendations, in the form of a brochure (similar to the NMMA pamphlet) to the US Corps of Engineers, State Boating Law Administrators, State Fish and Wildlife administrators, and other entities having jurisdiction of recreational salt and fresh water lakes and rivers (including law enforcement, and fire and rescue). Trade groups like the Association of Marina Industries, American Boat Builders and Repairers Association, and local marine trades associations should also be included in this dissemination.

10. Conduct a review of the National Marine Manufacturers Association (NMMA) checklist for inspecting for ABYC Standards compliance to ensure that all grounding (bonding) requirements established in the standards are included. This would serve to increase compliance in an area that directly impacts personal safety around boats.

11. Establish a quality assurance standard requiring post-construction testing of the electrical systems of new boats. This testing could detect manufacturing defects in a boat's electrical system that could otherwise go undetected until an accident occurs in the field.

12. Conduct further research to better characterize the decay in voltage/voltage gradient as distance to a fault source increases. A wide of marina and private dock venues must be used as the basis for this study. The data from this research would be useful in establishing basic guidelines for the placement of swimming areas (or designation of no-swimming boundaries) in proximity to boats using AC shore power. A procedure to determine the effectiveness of this placement in any particular location could be determined based upon this research.

7. Post Research Evaluation

The American Boat & Yacht Council's Electrical Project Technical Committee initiated a "Grounding Subcommittee" in January of 2005. Recognizing the need for funding, this proposal was presented to the USCG under the non-profit Boating Safety grant process. Concurrently with the grant research work the Subcommittee continued to look for solutions to the issues identified in this report. Regular reporting to the ABYC Electrical Project Technical Committee assured that the goals of overall in-water electrical safety from both the grant perspective and the Technical Committee perspective were running a parallel course. The grant work influenced the Committee as much as the Committee influenced the grant work; it was a true team effort from a complete circle of influence and expertise.

The July 2008 version of ABYC E-11, *AC & DC Electrical Systems on Boats*[1] includes a requirement, effective July 31, 2009, for an Equipment Leakage Circuit Interrupter or ELCI to be installed on all boats equipped with AC dockside power. This piece of equipment has the same electrical properties as the European Residual Current Device (RCD) discussed in this report. This device was used throughout the grant testing as well as in the on-going post-grant practicality testing. The electrical and environmental properties of ELCI mitigate the risk situations researched and recreated in this grant. It is our understanding that many companies involved in the Committee work are planning on making this device available as an aftermarket add-on.. Specifications listed in ABYC E-11 for the ELCI are as follows:

11.11.1 An Equipment Leakage Circuit Interrupter (ELCI) shall be installed with or in addition to themain shore power disconnect circuit breaker(s) or at the additional overcurrent protection as required by E-11.10.2.8.3 whichever is closer to the shore power connection.

11.11.1.1 This device shall meet the requirements of UL 1053 Standard for Safety for Ground-Fault Sensing and Relaying Equipment and the requirements of UL 943 Ground Fault Circuit Interrupters with the exception of trip level and trip time. Trip level shall be a maximum of 30mA. The trip time shall be a maximum of 100ms.

NOTE: Trip levels of less than 30ma and times of less than 100ms may result in nuisance trips in certain environments.

11.11.1.2 The ELCI shall be readily accessible.[2]

Note that the ABYC E-11 requirement for a standard 5 miliampere Ground Fault Circuit Interrupter is still in place. The ELCI is not intended to replace this requirement. ABYC recommends that anyone interested in commenting or reporting on this report obtain a copy of E-11 for the complete requirements.

The remaining recommendations in this document will be presented to the ABYC Electrical Project Technical Committee for evaluation and consensus on the correct action or referral to the organizations with jurisdiction.

1. ABYC E-11 is available by contacting ABYC through their website at www.abycinc.org
2. ABYC E-11 *AC & DC Electrical Systems on Boats* July 2008

8. References

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2. IEC (International Technical Commission) standard 479-1 and IEEE Standard 80. Relative body impedance.

3. Electric-Current Induced Drowning Accidents - Bilal M. Ayyub, BMA Engineering, report 2004, for Office of Boating Safety, USCG. - - - Electric shock drowning - laboratory simulations only – extensive references on Pg. 120, and explanation of IEEE Standard 80.

4. Electric Shock Hazard of Underwater Swimming Pool Lighting Fixtures - A.W. Smoot & C.A. Bentel, sponsored by Underwriter's Laboratories, Inc. N.Y. Presented – IEEE Winter Power Meeting, NY Feb, 1964. - - - Electric shock scenarios set up in salt-water pool (22 ohm/cm resistivity) using volunteers to determine physiological effect of AC currents on humans.

5. Acceptance of Innovative Ground Wire Monitor Installation Schemes for Mining Operations. - W.M. Colley, W.J. Keefer, H.C. Verakis – US Dept of Labor, MSHA circa – mid 1990's. - - - Grounding and bonding requirements in mining.

6. Safe Measurement of Ground Resistance – Robert L. Casco, US Dept of Labor, MSHA. Presented Society for Mining, Metallurgy and Exploration (SME) Symposium Feb, 1992. - - - Grounding and bonding requirements for mining.

7 MSHA – Metal/Nonmetal Electrical Grounding Requirements - by W. J. Helfrich, MSHA, Pittsburg Safety & Health Technology Center – presented IEEE Cement Industry Technical Conference, May 1981.- - - Importance of machinery frame grounding.

8. Safety Grounding - A Performance Approach by W. J. Helfrich & R.L. Reynolds, MSHA, Pittsburgh Safety and Health Technology Center – presented 1985 Mining Industry Technical Conference. - - - Importance of bonding.

9. Electrical Safety in Industrial Plants. By R. H. Lee, E.I. duPont de Nemours & Co. Article III, AVO Training Institute, Inc. Circa – mid 1990's. - - - Body resistance and physiological effects of electric shock – discussion of lethal current levels.

10. Electrical Safety - Vol. II, Part 4, Environmental, Safety, and Health Manual, Nov. 1999 – Robert W. Kuchuck, Director ES&H Working Group. - - - Discusses body resistance and physiological effects of AC current on a human.

11. Investigation of Deaths Related to Electrical Injury by S. Vandenburg, G.M. McCormick, and D.B. Young. Southern Medical Journal, Sept 4, 1996. - - - Body resistance and physiological effects of current.

12. Principles of Biolectrical Impedance Analysis by Rudolph J. Liedtke, April 1, 1997 - - - Body resistance and physiological effects of AC current on humans.

9. Acknowledgements

Marina Facilities That Volunteered
For This
USCG Grant Study

An essential element of the Grant field testing was having available a selection of typical locations and various boat types. Through the long association of the Investigators with the marina industry we were able to select the venues needed. Not only were we invited to carry out our testing but the facilities and boats were graciously provided at no cost.

In recognition of the effort to support our project we wish to extend our sincere thanks to all of those individuals listed below:

1) Beach Marina 2315 Beach Blvd. Jacksonville Beach, FL 32250 Ken Taylor	2) Buffalo launch Club 503 East river Rd. Grand Island, NY 14072 Douglas Scheid
3) Callville Bay Marina Forever Resorts / Lake Mead Las Vegas, NV 81924 Bruce Rowe	4) Conley Bottom Resort & Marina Route 5 Monticello, KY Fried Piercy
5) Doctors Lake Marina 3108 U.S. Highway 17 South, Orange Park, FL 32003 Monty Murphy	6) Lake Ocoee Inn & Marina 2496 Hwy 64 Benton, TN 37307 Jerry Hamby
7) Mentor Harbor Yacht Club 5330 Coronada Dr. Mentor-On-The-Lake, OH John Gallagher	8) Paradise Cove Marina 17141 Rocky Ridge Rd. Austin, TX 78734 Ron Doll
9) Queen's Harbor Marina 1131 Queens Harbor Blvd, Jacksonville, FL, 32225-4909 David Cawton	10) Silver Lake Marina/ Marinas Int'l 11226 Indian Trail # 200 Dallas, TX 75229 Gilbert Welch
11) Stuart Yacht Builders 450 Salerno Rd Stuart, FL Gregg Burdick	12) Texas Sailing School 103 Lakeway Dr., Suit B Austin, TX 78734 Robert Barlow
13) Tropical Resort & Marina 1485 Lake View Dr. Deland, FL 32720 Rick Carr	14) Pete Schwabl 2063 E. River Rd. Grand Island, NY 14070

10. FY 2006 Grant Application

YOUR BOATING
DOLLARS AT WORK

The American Boat and Yacht Council, Inc.

Proposal to the
U. S. Coast Guard (USCG)
FY 2006 Boating Safety Grant Funds

Proposal on
FY 2006
In-Water Shock Hazard Mitigation Strategies

Project Administration:
Mr. Skip Burdon, President
American Boat & Yacht Council, Inc.
3069 Solomons Island Road
Edgewater, MD 21037
410-956-1050 Tel
410-956-2737 Fax
sburdon@abycinc.org
www.abycinc.org

January 23, 2006

A. Organization

The American Boat & Yacht Council, Inc. is a not-for-profit membership organization which was incorporated in 1954, in response to a recommendation by the Motorboat and Yacht Advisory Panel of the Coast Guard Merchant Marine Council, to provide a broad based standards development effort among public, government, and industry interests.

ABYC develops and publishes voluntary standards and technical information reports for the design and construction of recreational boats and related equipment. These standards and technical reports are widely recognized as both complementing and supplementing existing Federal regulations for recreational boats. The standards are published in the ABYC Standards and Technical Information Reports for Small Craft. The focus of these standards and technical reports is safety. The process by which these documents are developed is designed to achieve consensus among the various interests in boating including, but not limited to: consumers, manufacturers, marine surveyors, government representatives, insurance underwriters, designers, and boat repairers. The American Boat & Yacht Council also produces other publications which relate to boating safety issues and conducts an extensive education and certification program for industry and boating personnel.

B. Official Representative –

Skip Burdon, President, American Boat & Yacht Council Inc. (ABYC)

C. Not-for-Profit Service Organization

ABYC is an international not-for-profit public service organization which has been classified 501(c)(3) by the Internal Revenue Service (Federal ID number 13-1939929).

D. Project Description

IN-WATER SHOCK HAZARD MITIGATION STRATEGIES

Project Proposal

Background

In FY 2003 & 2004 the ABYC was awarded grants that studied the theory of AC electric shock in water. The purpose of these grants was to make a recommendation, after intense study, on how a person should react in the event of an encounter with an electrical situation. The laboratory based research that was conducted under these grants were concise, and repeatable in a lab situation. The problem arose when the lab set-up was to be tested in a real life situation; the parameters of the experiment could not be transferred to an environment with infinite variables (e.g. salinity, plant life, current, etc.). Currently this grant exists as a reference for future projects and has not been able to aid in the production of mitigation strategies for boats or people. In-water shock drownings are a reality and can be prevented by the use of off-the-shelf devices used in the correct manner and installations.

Problem

Since our inception in the 1950's ABYC and its technical committees have been wrestling with requirements surrounding the installation of Alternating Current electrical systems on board boats. AC power and water are a dangerous combination. From the standpoint of NFPA 70, the National Electrical Code (NEC), ground fault circuit interrupters (GFCI) have been required since 1971. Below is the evolution of the expanded use of GFCI technology from the NEC point of view:

DWELLING UNIT
120 volt GFCI Protected Outlets - REQUIRED LOCATIONS

DATE OF NEC EDITION	SWIMMING POOLS	SPAS / HOT TUBS	EXTERIOR	BATHROOMS	GARAGE	HYDRO MASSAGE TUB	BOATHOUSES	KITCHEN	UNFINISHED BASEMENTS	CRAWLSPACE	WET BAR
1971	X_{1a}		X_2								
1975	X_{1a}		X	X							
1978	X_{1a}		X_{3a}	X	X_4						
1981	X_{1a}	$X_{5a,b}$	X_{3a}	X	X_4						
1984	X_{1b}	X_{5b}	X_{3a}	X	X_4						
1987	X_{1b}	$X_{5b,c}$	X_{3a}	X	X_4	X_{5b}	X	X_{6a}	X_{7a}		
1990	X_{1b}	$X_{5b,c}$	X_{3a}	X	X_4	X_{5b}	X	X_{6a}	X_{7b}	X	
1993	X_{1b}	$X_{5b,c}$	X_{3a}	X	X_4	X_{5b}	X	X_{6a}	X_{7b}	X	X_8
1996	X_{1b}	$X_{5b,c}$	X_{3b}	X	$X_{4, 9a}$	X_{5b}	X	X_{6b}	$X_{7b,c}$	X	X_8
1999	X_{1b}	$X_{5b,c}$	X_{3b}	X	$X_{4, 9b}$	$X_{5b,10}$	X	X_{6b}	$X_{7b,c}$	X	X_8
2002	X_{1b}	$X_{5b,c}$	X_{3b}	X	$X_{4, 9b}$	$X_{5b.10}$	X	X_{6b}	$X_{7b,c}$	X	X_8

1a. All receptacles outlets within 15 feet of the water, in any direction, also see EXTERIOR.
1b. All receptacles outlets within 20 feet of the water, in any direction, also see EXTERIOR.
2. Effective January 1, 1973.
3a. Changed to 'with direct grade access to dwelling and outlets' in 1978. Direct grade access was defined in 1987 as 6 feet 6 inches or less above grade.
3b. Changed back to ALL dwelling unit exterior outlets in 1996; except an outlet for snow melting equipment IF on a dedicated circuit and NOT readily accessible.
4. All, except outlets not readily accessible (6 feet 8 inches? or higher) and outlets for dedicated appliances which are not easily movable (freezer, refrigerator, etc.).
5a. Outdoor spa, receptacles within 15 feet / Indoor spa, receptacles within 20 feet.
5b. Receptacles for motor and electrical equipment.
5c. Indoor spa or hot tub, receptacles within 10 feet for pump motor.
6.a Outlets within 6 feet of kitchen sink to serve as counter top outlets, outlets not to be installed face up in work surfaces and counter tops.
6b. All outlets which serve as counter top outlets, except outlets for refrigerator or freezer.
7a. At least one, which must be identified as being GFCI protected.
7b. Changed to all receptacles in unfinished basements and crawl spaces, except: laundry, sump pump, refrigerator or freezer.
7c. Except where not readily accessible.
8. Outlets within 6 feet of wet bar sink to serve as counter top outlets, outlets not to be installed face up in work surfaces and counter tops.
9a. Unfinished accessory buildings are treated like garage.
9b. Accessory buildings that have a floor located at or below grade and not intended as habitable rooms and limited to storage areas, work areas, and areas of similar use.
10. Receptacles within 5 feet.

WE RECOMMEND INSTALLING GFCI PROTECTION TO MEET, AT A MINIMUM, THE LATEST AND MOST CURRENT CODE, AND, ADDITIONALLY, AT ALL WET AREAS OR AREAS WHICH COULD POTENTIALLY BECOME WET AREAS.

In 1977 ABYC introduced the use of GFCI's in E-8 AC Electrical Systems. At that time, their use was limited to convenience outlets in heads. Currently in ABYC E-11 2003 requires GFCI outlets in heads, galleys, machinery spaces and weather decks. While we have followed the NEC's continued expansion of GFCI use, we have not entered into the "whole boat" protection concept like the European market. ISO 13297 "Small craft – Electrical systems – Alternating current installations" gives the boat builder the option of installing a "whole boat" GFCI or Residual Current Device defined as "electromechanical switching device, or association of devices, designed to make, carry and break currents under normal service conditions and to cause the opening of contacts when the residual current attains a given value under specified conditions. *NOTE RCD/GFCI serve to reduce the risk of injury to people from electrical shock.*" The text of 13297 also states: "The craft shall be provided with earth-leakage protection in the main supply circuit by a) a double-pole RCD having a maximum nominal trip sensitivity of 30 mA and 100 ms maximum trip time" or "b) each receptacle located in the galley, toilet, machinery space or weather deck shall be protected by a GFCI (RCD) having a maximum sensitivity of 10mA." The land based electrical codes in much of Europe also specify the use of an RCD as a main breaker.

The question of cost/benefit is always raised in situations like this. Purely academic arguments are not worth funding or spending significant committee time discussing, however, in this case there is a quantifiable problem. Appendix A is a list compiled by an industry expert [1] during his dealings with shock-induced drownings. These accidents may not show up in the early BAR data because they involved swimming from a boat or near a dock. ABYC documented a case surrounding an in-water shock death in our newsletter recently. This is an issue where a possible solution already exists through existing technology.

While on the surface, this seems like a simple argument that all boats should be fitted with "whole boat" GFCI's, it is not as simple as that. Many industry experts have documented a large number of "nuisance" trips involving GFCI's where larger appliances such as washers, dryers, microwaves and ranges create enough of an imbalance to trip a 5mA GFCI. The European solution with an RCD is quite effective but has a 30mA trip level with a max trip time of 100 ms. ABYC requires 5 mA with an average trip time listed in UL 94 of 30ms, quite a difference. We are also dealing with 2 different types of power, 110 60hz here in the US and 220 50hz in Europe.

The crux of this problem is the lack of testing and information. There are an equal number of arguments on each side of the "whole boat" protection scheme. What is needed is a definite answer to the feasibility of a device that will satisfy both the power needs of the boat and the life-safety needs of the occupants.

Objectives

This grant will investigate the dangers and occurrences of accidents and drownings related to in-water electrical shock hazards;
Through recreation and accident investigation this project will provide a better understanding of the elements surrounding in-water shock accidents;

[1] In-Water Shock Incident list provided by: Mr. James D. Shafer & Capt. David E. Rifkin

This grant will also provide information on the mitigation of in-water electrocution through recommendations to boat electrical safety standards, recommendations for aftermarket modification of boats with shore power, and;
a suggested brochure for the USCG "Your In Command" series.

Method

ABYC and identified industry experts propose to tackle this problem in 8 steps, 3 topics:

Topic 1 Investigate the scope of the problem:

1. Investigate documentation on known in-water shock accidents/deaths. (Both private and USCG BAR Data)

2. Determine similarities between accidents/deaths

3. Summarize top 5 contributing factors (e.g. boat type, installed equipment, fault mode(s), environmental factors)

Topic 2 Create & Solve the problem:

4. Create accident scenarios which incorporate the most common contributing factors as well other possible contributing factors.

5. Identify hardware, devices or actions that would have prevented these accidents.

6. Investigate the European RCD and compare to the issues faced in the US.

Topic 3 Summarize & Publicize Topics 1 & 2

6. Summarize accident scenarios, present to industry peer-group.

7. Provide comments to ABYC and industry on mitigation strategies.

8. Write USCG brochure.

Results Expected

Early research points to the very real possibility of a boat-based solution for leaking AC current. NFPA and the NEC have aggressively addressed the land-based counterparts of this problem (for example the NEC 2005 code has significantly tightened its requirements dealing with swimming pools and grounding). The ABYC needs data to discuss and possibly include a strategy for personnel protection from AC leakage current that results from faulty boat or shore-based systems. An additional likely result would be discussions with NFPA regarding additions to 303 “Marinas & Boatyards” regarding the use of some type of GFCI/RCD device on shore power supplies.

Benefits

The creation and analysis of accident scenarios has long been needed. Without empirical testing, the answer to mitigation of in-water shock hazard situations cannot be finalized. The possibility of finding a device or strategy that would eliminate AC current from entering the water from a boat is very real and needs to be investigated. Preventing sources of injury and death on-board boats is not always an easy or inexpensive task. Labeling, CO Detectors and propeller guards are all examples of strategies used to soften the hazard where elimination is close to impossible. Funding this grant may help in a solution, to be written in an industry standard, for a significant hazard on board boats.

IN-WATER SHOCK HAZARD MITIGATION - APPENDIX A

1.	June 30, 2005	Scott's Creek Marina at Cave Run Lake, Moorhead, KY. A 19 year old girl drowned while in the water near a houseboat due to electric shock caused by a faulty A/C system with an ungrounded system on the houseboat. Another girl sustained burns on her legs while reaching into the water to help the victim. A nearby rescuer swam toward the scene and was shocked and paralyzed by the electrical field. He turned around and swam out of the field and survived.
2.	Sep 12, 2004	Ross Barnett Reservoir, Ridgeland, MS. A 16 yr old boy was swimming in the marina when he approached a houseboat. He screamed as if in pain and disappeared under the water. He could not be revived after divers recovered his body. A friend in the water also felt a shocking sensation. Details pending outcome of legal action.
3.	August 8, 2004	Lake Travis, Austin, TX. Young man, in good health, swimming, in evening, unobserved, between two sections of marina dock – disappeared. Came to surface two days later. No injuries or toxic substance found on post mortem. Suspected electric shock drowning. Accident under investigation.
4.	June 5, 2004	Lake Wylie, Charlotte, NC. Two young boys swimming at bow of houseboat called for help. Father of victim and friend rushed forward – boy on ladder said he was being shocked, other boy in water not moving. Friend rushed aft to pull shore cord as father went onto water – his son could not be resuscitated. May not be exact sequence. Causes of energized hull were substantial errors in wiring on the dock as well as on the boat, apparently done by non qualified individuals.
5.	Aug 3, 2003	Bull Shoals Lake, Bull Shoals, AR. Diver found Aug. 5 in shallow water 8 ft. from his dock, drowned. Incorrectly wired dock junction box caused 117 VAC to appear on metal dock components. Rescue diver reported feeling shock sensation 20 ft. from dock!
6.	June, 2003	Allatoona Lake, GA. Six wildlife fatalities (ducks!!) Houseboat pulled away from the dock and still connected shore power cord separated in middle and fell into water. Six dead ducks found floating nearby.
7.	May, 2003	Cape Coral, Florida. Double drowning, section of re-bar driven through power cable to back yard boat lift caused line potential to appear on lift frame, salt water.

8.	May 31, 2002	Lake Cumberland, Monticello, KY. Double drowning, fault on houseboat, fresh water. 125V plug at boat end of shore cord rewired by owner for 220V – L2 connected to "GR" pin - ground lead in 4 wire cord cut and taped off! Hull rose to line potential.
9.	March, 2002	Bay Marina Boat Works, Biloxi, MS. Some electrical work had recently been done at this yard, which resulted in reverse polarity connections at the shore cord receptacles for the stored boats. Over a short time period several boat owners reported being shocked as they worked on their boats, and one owner was electrocuted. The possibly of a missing ground combined with a gnd/neu connection on the lethal boat was not investigated.
10.	Sept.15, 2001	Farr Shores, Lake Hamilton, Hot Springs, AR. Girl in great distress, man attempting rescue drowns, ground fault on boat, fresh water.
11.	June 6, 2001	Residence, Timber Ridge Dr., Dumfries, VA, Lake Montclair. Two young boys entered water near pontoon boat. Battery chargers (2) connected to modified extension cord from house. Electric shock drowning – cause of energized hull not reported.
12.	May, 2001	New Orleans, Electrocution – Boy using conveyor to transfer shrimp – no ground, salt water.
13.	April 10, 2001	Norris Lake, Lafollette, TN. Two teenage boys swimming behind house boat. One boy climbed onto swim platform complaining of feeling severe shock – other boy fell back from ladder– his head *not* below water (ventricular fibrillation?). Could not be resuscitated. Damaged power cable to boat, black lead energized hull, ground wire burned in two – breaker did not trip due to incorrect connection (may not be exact sequence).
14.	2000 or 2001	Put-in-Bay, Ohio, Grand Banks 42. Owner's prescription sunglasses went overboard. Young bystander disappeared while trying to retrieve glasses, electric shock drowning.
15.	Sept.30, 2000	Tims Ford Lake, Winchester, TN. Two boys (21&22). Electric shock drowning. Rescue diver felt electric shock Live wire in water near dock.
16.	August 1, 1999	Casselman's Marina, Portland, OR. 8yr old boy tubing with friends in freshwater marina along slow moving river. Boy decides to swim to dock (was wearing type 3 life vest). Suddenly he rolled over on back near the stern of a boat. Mother enters water and helps get boy on dock (she felt tingle in water). Diagnosed as electrocution (head was above water almost all the time). Cause was AC to DC short on boat and no connection between AC ground and DC ground.
17.	July, 1999	Lake Mohave, single drowning, fault on houseboat, missing ground, fresh water.

18.	July18, 1999	Cedar hill Lake, Smithville, TN. Two young boys, with flotation devices, were discovered in water, face down, a few feet behind a houseboat. 7 year old could not be revived. 8 year old recovered. Electric shock drowning suspected.
19.	July, 1999	S. Carolina, single drowning – 3 feet of water, woman in great distress, husband attempts rescue and drowns, fresh water.
20.	Approx. 1999	Rio Vista, CA. Several boys reported a tingle while swimming in this fresh water marina and got out of the water. A short time later two other boys, 8 – 10 years old, drowned at the same spot. Forty-year-old power wiring running under moored boats found to have substantial fault to ground because of insulation failure.
21.	Sept., 1998	Lake Sonoma, CA. Single drowning, young girl in great distress, fault on dock, fresh water.
22.	Approx. 1998	AF Base, Washington, DC, boy walking on ice slipped and grabbed exposed wires on dock that were supposed to have been de-energized, electrocuted.
23.	July, 1997	Lake Mead, NV. Single drowning, fault on houseboat, freshwater.
24.	Approx. 1994	Texas, single drowning, fault on boatlift, salt water.
25.	Sept., 1993	Oklahoma, single drowning, fault in submersible pump, fresh water.
26.	August 1993	Alexandria Bay, NY. Double drowning. Two teenage girls snorkeling near dock were paralyzed by electric shock and drowned. Fault thought to be in dock wiring, not confirmed. (Two bystanders attempted to enter water to lend assistance, but were unable to do so.)
27.	July, 1993	Oklahoma, single drowning, fault in dock lights – energized dock frame, fresh water.
28.	May 11,1991	Lake Hamilton, Hot Springs, AR. A canoe carrying four young boys tipped over a few dozen yards from a dock. As they swam toward the dock they felt a light tingle. Three of the boys diverted away from the dock while the fourth boy continued into the electric field and drowned. Cause was broken insulation on a dock wire hanging in the water.
29.	July, 1991	Oklahoma, single drowning, fault in dock wiring, fresh water.
30.	Dec., 1989	Oklahoma, single drowning, fault in submersible pump, fresh water
31.	July, 1988	Park Township, MI, Lake Macatawa, Bay Haven Marina. 18-year-old boy falls off dock, in great distress, two attempts to assist thwarted because of severe electric shock as rescuers entered water.

32.	1987 or 1988	A) Gross Pointe Yacht Club, single drowning, diver, fresh water B) Petosky, MI, single drowning, diver, fresh water. NOTE: Both incidents relayed 3rd hand.
33.	July 29, 1986	Harrods Creek, Lexington, KY – Ohio River. About 2030 two dogs jump into water from owners 20 ft. runabout, and were observed to be in great distress. Owner's wife jumps in to help and was immediately in trouble. Husband goes in to save his wife – both drown. Rescuers felt strong electric shock and could not approach victims, but were able to rescue dogs later. Faulty light switch and missing ground on nearby houseboat determined to be the cause.
34.	Date Unknown	Wisconsin, single drowning, felt tingle, disappeared, fault on boat, fresh water (from Boat US)
35.	Date Unknown	Community swimming pool in Oklahoma, 10 year old electrocuted while inserting coins in a soda vending machine. Power cord damaged by one of the 4 legs, grounding pin on plug missing, machine chassis later measured at nearly line voltage, NO GFCI.

ELECTRIC SHOCK – NEAR MISSES

(Additional ones included above)

1.	July 2005	Brooklyn, NY. A diver went into the water behind a boat in this small, private marina. He surfaced seconds later complaining about tingling and pain in his arm. A probe in the water measured 40vac to ground behind the boat. Cause was determined to be a neutral-ground short on a recently installed water heater (although there was most likely a bad ground too at that pedestal to cause this). He was wearing a short, spring wet suit.
2.	July 2004	Sacramento River, CA. Man entering water around several boats (being supplied by genset power from one of the boats) receives shock in water. Two other men jump in to rescue man. One of the 2 rescuers became imperiled. Generator secured immediately. Mis-wiring on one boat caused a ground fault which introduced current in water.

3.	May31, 2004	Lake Barkley, Grand Rivers, KY. After receiving permission from marina two adult women went swimming near their rented houseboat. As they started back to the boat from the swim slide entry point both felt a strong electric shock sensation, and had the presence of mind to *swim away* from the boat! A relative entered the water and felt the same thing – which disappeared when the boat was disconnected from shore power. Close call was brushed off by staff so no action was taken to locate source of fault current. A fatality waiting to happen!
4.	August, 2003	Green River, Campbellsville, KY. Marina manager using Hioki clamp-on ammeter checking shore cords for leakage and discovered one houseboat with 4 amps on one of two shore cords. Hull potential to dock ground 8 VAC and owner commented that one of his children reported a tingle in the water!! Boat had just been reassembled after being trucked from Texas and problems were being experienced with 120 VAC deck light. Deck lights were rewired and neutral / ground fault in inverter was cleared – leakage current no longer exists.
5.	July, 2002	Allatoona Lake, GA. Three swimmers in great distress near houseboat, by stander pulls shore cord, all saved, one spent several days in hospital, fresh water, and fault on boat.
6.	Fall, 2002	Lake Murray, SC. Swimmer reports strong tingle, hi-level fault currents in dock frame, fresh water.
7.	Date Unknown	Man jumps into water to rescue dog, feels high level tingle, cause unknown, fresh water.
8.	2002-2003	Florida, interviews with divers – many reports of high level tingle while cleaning bottoms, all salt water, and no fatalities.
9.	Date & location Unknown	Swimmer feels a tingle as his hand enters the A/C discharge stream. Caused not determined, salt water.
10.	July 3, 1998	Lake Chelan, Chelan, WA. 21 year old exiting water – shocked on swim ladder – 48 hours in the hospital – rescuers shocked.

CODE VIOLATIONS

1.	January, 1994	Oklahoma State Department of Health (OSDH) inspected eleven commercial docks and five private docks, and an earlier (1989) inspection of 116 commercial docks, found 96% not in NEC compliance; most common fault was ***open*** ground.