Electric Shock Drowning

WHAT YOU NEED TO KNOW

Beth A. Leonard
February 25, 2014
IAMI ATS
Noah Dean Winstead, 10, and Nate Parker Lynam, 11, were swimming near a houseboat with Nate’s sister when she started to scream.

Nate’s maternal grandparents and another bystander tried to reach the two boys while Nate’s mother pulled her daughter from the water.

As soon as they hit the water, the rescuers realized the boys were being shocked.

Noah was unresponsive when pulled from the water; Nate was resuscitated but died in the hospital the next day; Nate’s sister was injured but recovered.
What killed Nate and Noah?

Electric Shock Drowning (ESD):

“ESD happens in fresh water where minute amounts of alternating current are present.”

– Kevin Ritz

Lucas Ritz
1991-1999
Notice the Purple Wire
An Electrocution, Not a Drowning
How big a problem is this?

- These are CONFIRMED incidents where the source of the electricity was identified
- Cannot tell from the body that electricity was involved
- Many more unexplained drownings go uninvestigated every year
- As awareness increases, the numbers will likely increase as well

<table>
<thead>
<tr>
<th>YEAR</th>
<th>FATALITIES</th>
<th>NEAR MISSES</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>2011</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2012</td>
<td>14</td>
<td>13</td>
</tr>
<tr>
<td>2013</td>
<td>6</td>
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More than 1,000 children (19 and under) die each year from drowning; only automobile accidents kill more.

- Michigan Public Health Institute
Objectives for this presentation

To help first responders and investigators recognize ESD, or the possibility of ESD, and respond appropriately. Specifically, this presentation will help you:

1. To understand what ESD is and why you need to know about it
2. To identify potential ESD victims
3. To know what to do – and not to do – as a first responder:
   1. To assist the victim
   2. To keep yourself and others safe
4. To know what to do as an investigator:
   1. To determine if electricity may have been involved
   2. To assist marinas and individuals to make their docks safe
Beth A. Leonard

- Director of Technical Services, BoatU.S.
- Editor, Seaworthy
- Technical Editor, BoatU.S. Magazine
- Two-time circumnavigator
- Author of *The Voyager’s Handbook* and hundreds of how-to articles on all aspects of boating
Two key questions

- Do you know or know of any strong swimmers who drowned near a dock in a way that was never satisfactorily explained?
  - “He wasn’t *that* drunk.”
  - “She must have cramped up.”
  - “The current didn’t seem that strong.”
  - “He swam off that dock all the time.”

- How has your boat/dock/marina changed?
  - How much AC equipment did your boat have in 1970? 1990? Last summer?
  - How many boats on your dock had AC equipment on them in 1970? 1990? Last summer?
  - How many docks had lifts, lights, outlets, or other AC-powered equipment in 1970? 1990? Last summer?
Electric Shock Drowning

- ESD basics
- Dealing with ESD victims
- Investigating potential ESD incidents
ESD Basics

- Fresh water + AC = Danger
- How electricity injures or kills in the water
- How electricity gets into the water
- How to keep electricity from getting into the water
Key points to remember

- Current always wants to return to its source; to complete the circuit
- Current will take all ways back to its source
- Most of the current will return to its source by the easiest path – the one with the least resistance
- You do not have to be grounded to become part of the circuit, but you do have to provide a path to ground
- A dangerous amount of current will pass through you only if you present an easier path to ground than the alternatives
Fresh water + AC = Danger

“ESD happens in fresh water where minute amounts of alternating current are present.”
– Kevin Ritz
### What exactly does “minute” mean?

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<td>Painful shock, begin to lose muscular control. Commonly referred to as the freezing current or let-go range.</td>
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<td>Extreme pain, respiratory arrest, severe muscular contractions. Individual cannot let go of an electrified object. Death is possible.</td>
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<td>Ventricular fibrillation (uneven, uncoordinated pumping of heart). Muscular contraction and nerve damage begin to occur. Death is likely.</td>
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<td>Cardiac arrest, internal organ damage, and severe burns. Death is probable.</td>
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Why fresh water and not salt?

- Dry skin is highly resistive but wet skin is not (~1,500 Ohms dry/300 Ohms wet according to OSHA)
- Saltwater is anywhere from 50 to 1,000 times more conductive than fresh water
- The conductivity of the human body when wet lies between the two, but much closer to saltwater than to fresh
- A voltage potential of just 2 volts AC per foot will put ~16mA through a swimmer and can be fatal

When travelling through:
- Saltwater - Most of the stray current will bypass a swimmer
- Fresh water - Most of the current will pass through a swimmer
Why AC and not DC?

- Cycling nature of AC disrupts the electrical signals in our nerves and muscles far more than DC.
- Would take an electrical potential of 6-8 volts per foot of DC to be dangerous (3-4 times that for AC).
- Lower voltage of DC makes it less likely that kind of voltage gradient would be generated by leaking DC.
- No recorded fatalities from DC even in fresh water.
But... what about brackish water?

- Some areas may normally be saltwater but may be fresh after a very hard rain or at certain times of the year.
- ESD can also occur in a layer of fresh water on top of saltwater.
- Too many variables to be able to say at what point brackish water becomes dangerous.

If in doubt, treat water as if it were fresh.
ESD Basics

- Fresh water + AC = Danger
- How electricity injures or kills in the water
- How electricity gets into the water
- How to keep electricity from getting into the water
Mechanisms of injury/mortality

Body has to bridge an electrical potential gradient such that current will flow through the body to return to its source

1. Grabbing hold of an electrified fitting on a dock or on a boat in fresh or saltwater
2. Swimming through an electrical field in fresh water

Electrocution

Drowning
## Injury/mortality: ESD in fresh water

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Stray current creates electrical field

Actual electrical current passing through a swimmer at any point depends upon a variety of factors including:

- Distance from source
- Salinity
- Temperature
- Depth
- Swimmer’s body mass and composition
- Swimmer’s orientation
- Swimmer’s sex
- Cuts and abrasions

Illustrative

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<tr>
<th>Current (mA)</th>
<th>Voltage (VAC/ft.)</th>
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<tr>
<td>50</td>
<td>~0.5</td>
</tr>
<tr>
<td>200</td>
<td>~1-2</td>
</tr>
<tr>
<td>500</td>
<td>~2+</td>
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If you want to know more...

- Detailed study of the electrical fields generated by specific faults on boats
- David Rifkin, one of the two authors, has been incredibly helpful in building my understanding of ESD
- He has investigated multiple ESD deaths and is generous in assisting others investigating deaths

Intuitive reactions can make the situation worse

- Distressed swimmer’s first reaction is to swim toward the dock, which almost always means swimming toward the source of the electricity.
- Diving in from the dock to assist someone may put rescuer in most dangerous part of the electrical field.
- If swimmer experiences mild discomfort and reaches the dock/boat, touching a metal fitting may result in electrocution.
ESD Basics

- Fresh water + AC = Danger
- How electricity injures or kills in the water
- **How electricity gets into the water**
- How to keep electricity from getting into the water
Three requirements to create stray current

1. An electrical fault on a boat or a dock
AC electrical fault

Electrical fault could be on the boat or on the dock

Note: The water carries some fault current depending on the resistances of the water and bonding conductors.
Three requirements to create stray current

1. An AC electrical fault on a boat or a dock: Electricity must be escaping from a circuit somewhere and trying to find its way back to its source

2. AC safety ground fault
AC electrical fault plus ground fault

Safety ground fault could be on the boat or on the dock.

Note: The water now carries ALL the fault current since the bonding conductor is broken.
Three requirements to create stray current

1. An AC electrical fault on a boat or a dock: Electricity must be escaping from a circuit somewhere and trying to find its way back to its source.

2. AC safety ground fault: The AC grounding system must be compromised so that stray current cannot easily return to ground through the ground safety wire. Any stray electricity then has only one path back to its source — through the water.

3. No ground fault protection
"No sane person would consider plugging a hair dryer into an AC outlet, turning it on, and stepping into the water with it. But that's essentially what we're doing with our boats."

- Kevin Ritz

In actuality, stepping into the bathtub with the hair dryer would be safer in most homes...
So what’s the difference between this...
…and this?
One big difference is this...

Ground Fault Protection (GFP) facts:

• GFPs trip, shutting off the electricity, if the current in the hot wire and neutral wire differ by a certain amount of mA

• GFCIs, like those in your bathroom, trip a tenth of a second or less at 6 mA difference

• The GFCI will trip if there is current returning along the safety ground wire even if no current is returning through the water
Not one, but two, GFCIs...
How ground-fault protection works

http://www.bluesea.com/
AC electrical fault

In this situation, the GFP at the pedestal would trip if the current returning through the safety ground and the water exceeded its threshold.

Note: The water carries some fault current depending on the resistances of the water and bonding conductors.
Three requirements to create stray current

1. **An AC electrical fault** on a boat or a dock: Electricity must be escaping from a circuit somewhere and trying to find its way back to its source.

2. **AC safety ground fault**: The AC grounding system must be compromised so that stray current cannot easily return to ground through the ground safety wire. Any stray electricity then has only one path back to its source — through the water.

3. **No ground fault protection**: Ground Fault Protection (GFP) devices, like Ground Fault Circuit Interrupters (GFCIs) required in bathrooms ashore, are designed to detect differences measured in milliamps and to shut down the electricity within a fraction of a second. If the circuit does not have one, then electricity will continue to flow into the water.
Not that unusual to have all three

1. AC electrical fault on a boat
   - Corrosion, wear, and tear
   - Complexities of marine wiring
   - DIY boaters

2. AC safety ground fault
   - Corrosion, wear, and tear
   - Critters

3. No ground-fault protection
   - Not required on docks historically
   - Only required on new boats today
Boat wiring ≠ house wiring (or why you need an ABYC certified tech)

- Boats have **AC and DC wiring** – confusing them can electrify the entire boat (on some boats AC hot and DC negative are black)
- The **AC system is tied into the system** (AC grounding bus tied into DC negative or engine negative) and underwater metals are bonded together; leakage in the AC system electrifies the underwater fittings on a boat
- If **neutral and ground are tied together**, as is common ashore, electricity can go into the water through the ground
- If **neutral-ground connection** on some appliances is not severed, electricity can go into the water through the ground
- If **neutral-ground connection** is severed on inverters, generators, and onboard transformers, an electrical fault may not trip the breaker
ESD Basics

- Fresh water + AC = Danger
- How electricity injures or kills in the water
- How electricity gets into the water
- How to keep electricity from getting into the water
A distinctly American problem...

- 240-volt power increases electrocution danger in other countries
- European, Australian, and New Zealand standards require ground fault protection on a marina’s main feeders and power pedestals
- No documented cases of ESD deaths we are aware of in those countries
Three requirements to create stray current

1. An **AC electrical fault** on a boat or a dock: Electricity must be escaping from a circuit somewhere and trying to find its way back to its source.

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Preventing ESD injuries/deaths

1. Prevent electrical or safety ground faults on all boats
2. Prevent faults in the safety ground wire on the dock
3. Install ground fault protection on the AC system on the docks
Preventing ESD injuries/deaths

Goal
1. Prevent electrical or safety ground faults on all boats
2. Prevent faults in the safety ground wire on the dock
3. Install ground fault protection on the AC system on the docks

Standard or code
1. ABYC E-11.11 – Ground Fault Protection – AC Systems
2. NFPA 303.5.20 – Maintenance of Electrical Wiring and Equipment
3. NEC 555.3 – Ground-Fault Protection
11.11.1 An Equipment Leakage Circuit Interrupter (ELCI) or Type A Residual Current Device (RCD) shall be installed with or in addition to the main 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 The trip level shall be a maximum of 30mA. The trip time shall be a maximum of 100ms.

11.13.3.5 If installed in a head, galley, machinery space, or on a weather deck, the receptacle shall be protected by a Type A (nominal 5 milliamperes) Ground Fault Circuit Interrupter (GFCI).
EXCEPTION: Installations where an isolation transformer is installed within 10 feet (3 meters) of the shore power inlet or the electrical attachment point of a permanently installed shore power cord and supported according to 11.14.6.3

Note: If the isolation transformer is more than 10 feet from the inlet, an ELCI must be installed within 10 feet of the inlet.
ABYC E-11.11.1 – Ground Fault Protection, AC Systems

- Effective as of 2013
- Only applies to new boats – vast majority of boats not affected by this standard
- But… can be easily refit to an older boat
- Isolation transformer is an acceptable alternative to ELCI/GFP

www.bluesea.com
Sample ELCI and GFCI layout
NEC 555.3 – Ground-Fault Protection

“The main overcurrent protective device that feeds the marina shall have ground fault protection not exceeding 100mA. Ground-fault protection of each individual circuit breaker or feeder circuit shall be permitted as a suitable alternative.”

Overcurrent protection device – the device that disrupts power to a circuit or piece of electrical equipment in the event of an electrical problem. Examples include circuit breakers and fuses. Circuit breakers are the most common form of ground-fault protection devices.

- Effective 2011
- A similar code applies to floating buildings – NEC 553.4
Dock GFP alternatives

At utility entrance
- Most economical
- Difficult to isolate problems

On each dock
- More costly
- Easier to isolate problem

On pedestal
- Most costly
- Easiest to isolate problem

Photos: Ed Sherman and Chris Dolan
NFPA 303-5.20 – Maintenance of Electrical Wiring and Equipment

“An inspection of all electrical wiring, ground connections, conduit, hangers, supports, connections, outlets, appliances, devices, and portable cables installed or used in a marina, boatyard, boat basin, or similar establishment shall be made at regular intervals to ensure a complete inspection at least annually.”
The new standards have faced challenges...

- Many boaters, marina owners, and others are not aware of the problem at all.
- A great deal of misinformation and misunderstanding still exists about ESD and what to do to prevent it.
- Not every jurisdiction has adopted NEC 555.3 or NFPA 303.
- ABYC E-11.11.1 only applies to new boats; keeping ELCIs from tripping would be a challenge on many old boats.
- Standards can be viewed as onerous:
  - Cost of GFP equipment for marinas/dock owners
  - Cost of annual inspections
  - Nuisance trips on docks and boats can be problematic
Preventing ESD injuries/deaths

Goal
1. Prevent electrical or safety ground faults on all boats
2. Prevent faults in the safety ground wire on the dock
3. Install ground fault protection on the AC system on the docks

Standard or code
1. ABYC E-11.11 – Ground Fault Protection – AC Systems
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3. NEC 555.3 – Ground-Fault Protection
Things can and do change…

1. AC electrical fault on a boat
   - Corrosion, wear, and tear
   - New equipment being added
   - New boats arriving all the time
   - DIY boaters

2. AC safety ground fault
   - Corrosion, wear, and tear
   - Storms, chafe, chop
   - Critters

3. No ground-fault protection
   - GFCIs need to be exercised to keep working
Goal
1. Prevent electrical or safety ground faults on all boats
2. Prevent faults in the safety ground wire on the dock
3. Install ground fault protection on the AC system on the docks
4. Make sure nobody swims of the dock

Standard or code
1. ABYC E-11.11 – Ground Fault Protection – AC Systems
2. NFPA 303.5.20 – Maintenance of Electrical Wiring and Equipment
3. NEC 555.3 – Ground-Fault Protection
4. Put up signs prohibiting swimming
In addition, states starting to regulate marinas

- West Virginia
  - Michael Cunningham Act
  - Enacted last year
- Tennessee
  - Noah Dean and Nate Act
  - Being considered now
- Kentucky
  - Chipley Act
  - Being considered now

All of these require:
- Regular dock inspections
- Ground fault protection on docks
- Posting of signs
Not just marinas... ANY electrified dock
Boat lifts can be particularly problematic
QUESTIONS?
Electric Shock Drowning

- ESD basics
- Dealing with ESD victims
- Investigating potential ESD incidents
Key points to remember

- Current always wants to return to its source; to complete the circuit
- Current will take all ways back to its source
- Most of the current will return to its source by the easiest path – the one with the least resistance
- You do not have to be grounded to become part of the circuit, but you do have to provide a path to ground
- A dangerous amount of current will pass through you only if you present an easier path to ground than the alternatives
# Drowning, ESD, or electrocution?

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<th>ESD</th>
<th>Electrocution</th>
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<tbody>
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<td>• Victim cannot speak or shout</td>
<td>• Victim will feel tingling, numbness, pain, paralysis</td>
<td>• Possible victim will be able to scream once</td>
</tr>
<tr>
<td>• Reflexive “ladder climbing”</td>
<td>• Initially, victim may be able to shout</td>
<td>• Sudden cessation of all activity</td>
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<td>• Looks “playful”</td>
<td>• Looks distressed and not playful</td>
<td>• If wearing flotation, may roll on back with face out of the water and be unresponsive</td>
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<td>• Lasts ~60 seconds with an adult and as little as 20 seconds with a child</td>
<td>• May turn into drowning behavior once victim begins to get water in lungs</td>
<td>• If not wearing flotation, will likely roll onto face</td>
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<tr>
<td>• Slips below surface</td>
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If any possibility of electricity in the water... 

- Consider your own safety first
- Turn off ALL POWER to the area and VERIFY
- Listen to any and all first hand accounts
- Pay attention to environmental clues: floating fish, birds, etc.
- Secure area, including all vessels, within 100 ft. of the incident
- Follow all protocols
- Back out if experiencing tingling or shock
Retrieving the victim

- If there is any chance of ESD, turn off the shore power connection at the meter base and/or unplug shore power cords while getting the marina operator to turn off power to the docks.
- Tell anyone in the water to move away from the dock, not towards it – they should back out of the area in as upright an orientation as possible and exit the water 100 yards from any dock.
- Stop anyone else from entering the water.
- Reach, throw, row, but don’t go.
- If you are not sure whether the dock might still be energized:
  - Be careful reaching from the dock - If you are touching something metal, you may be a path to ground.
  - Do not use a metal ladder to enter the water.
## Treating the victim – what’s wrong?

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Treating the victim

In fact, it doesn’t matter whether the victim is suffering from drowning, ESD, or electrocution – in all cases you can do the following:

- CPR to restart breathing and heart function
- Artificial Electrical Defibrillator (AED) if you cannot detect a heartbeat*

*Newer AEDs will not operate if the victim’s heart is beating normally; make sure the victim’s chest is dry
If you are ever in fresh water and feel tingling or shocks...

- DO NOT follow your instinct to swim toward the dock!
- SHOUT! Drowning victims cannot speak, let alone shout. Let everyone know what's happening so they'll understand the danger and react appropriately.
- Try to stay upright and back out of the area the way you came, warn any other swimmers in the area of the danger, and then head for shore 100 yards or more from the dock.
- Alert the dock or marina owner and tell them to shut the power off to the dock until they locate the problem and correct it.
- Go to the hospital to make sure there are no lingering effects that could be dangerous.
Still don’t know...

- How salty is salty enough? Brackish water
- Are you protected in neoprene? In a drysuit?
Electric Shock Drowning

- ESD basics
- Dealing with ESD victims
- Investigating potential ESD incidents
Investigating potential ESD incidents

You won’t be able to tell by looking at the victim

- Often no bodily clues to suggest anything but “simple drowning” due to alcohol intoxication or heart attack
- No signs of burning because victim in water – no signs of electrocution
- Even if there is water in the lungs, electricity could still have been a factor

Clues that it could be ESD

- Tingling sensation reported by anyone swimming in the marina; multiple injured
- Reports of great distress, agitation, screaming
- No water in lungs
- Excessive damage to metal boat parts in the water – props, stern drives, etc.
To confirm an ESD death...

Need to find source of electricity
- Electrical fault on a boat or the dock
- Safety ground fault on the boat or the dock

Unfortunately, not as simple as putting a probe into the water and reading the display.

For a much more complete guide, download presentation by Ed Sherman and Chris Dolan:
Two tools to identify stray current

Sure Test circuit analyzer

Digital Clamp Meter

Ed Sherman and Chris Dolan

David Rifkin
Testing for stray current

1. Check that there is no fault in the dock wiring – ground, neutral, and hot wire integrity

2. Check that the boats near the accident site are not leaking electricity

- Find if there is an electrical fault or a ground safety problem on the dock
- Faults in dock wiring can give misleading readings when you test the boats
- Process of elimination
- Must test all AC equipment on board including cycling equipment
Checking dock wiring

- Like a simple circuit tester, lights on the front indicate where there is continuity and where there is not.
- Decoder on the back will help you to figure out what you see means.
- Certain things can be misleading, particularly neutral-ground connections.
- If you identify a problem, bring in a qualified electrician to evaluate the dock wiring and diagnose the problem.
Checking boat wiring

- If what goes in the “hot” conductor returns on the neutral or the safety, the meter will read zero.

- A reading other than zero means one of two things:
  - Current is leaking from the boat into the water.
  - Current from another boat is coming through the electrical fittings on the boat you are testing.

- To determine which, turn off the pedestal and re-check the cord – if now reads zero, the boat you are checking has the fault.

- If two cords, clamp them together.
How much current is dangerous?

- Clamping shore power cords for current in the water
- Readings of 100 milliamps or greater in fresh water present a dangerous condition and immediate action should be taken
- Readings less than 100 milliamps are still serious, should be considered a threat to someone in the water, and should be checked by an ABYC certified marine electrician

Kevin Ritz
Checking boat wiring

Even if you get a zero reading, you can’t be sure until you’ve tested all AC equipment aboard, especially cycling appliances. So, to be sure:

1. Start with all AC equipment on including refrigeration, water heater, air conditioning, microwave, etc.
2. If the clamp meter reads anything except zero, turn of equipment one at a time watching to see if the reading changes
3. When it changes, you’ve identified a problem
4. There may well be more than one problem on a boat
5. If you turn everything off and it still doesn’t read zero, try turning off the pedestal
6. If it still doesn’t read zero, the electricity is coming from another boat – assuming the dock wiring is sound
Two power cords?

- Clamp one, and then the other
- If you get a reading, clamp both together
- If you then still get a reading, you have a leak of that magnitude
- If you are unable to clamp both for some reason, record the two readings and subtract them; the result should be zero. If it is not, you have a leak of that magnitude
Note that a GFP could trip with a zero reading on the clamp meter...

http://www.bluesea.com/

...if some of the current is returning on the safety wire
In this case:
• GFP would trip
• Clamp meter would read zero

Ed Sherman and Chris Dolan
GFP vs. Clamp Meter

In this case:
- GFP would trip
- Clamp meter would read 0.5A

30A OUT - 29A IN - 0.5A PICKED UP BY THE GROUND = 0.5A
One more tool… AC voltage probe

- Once you have located likely boat, use this probe to sweep the water
- Looking for voltage in the water – not current
- May also be able to find voltage on above water metal fittings
Everything is hot... 24 Volts AC on stanchions
Unfortunately, this can all be a lot more complicated…

If you need advice with a possible ESD case, contact:

Capt. David Rifkin (USN, Ret.)
Telephone: 904-382-7868
Website: http://www.qualitymarineservices.net/
Email: qualitymarinesvcs@Comcast.net
Preventing ESD is a process and a program

At any time, conditions can change so that a safe marina is no longer

- GFPs need to be exercised or may not function
- Dock wiring can be compromised by movement, chafe, moisture, critters
- A new boat could come into the marina leaking electricity
- An old boat could have a new piece of equipment installed on it improperly and become “hot”
Elements of an ESD-prevention program

1. Installation of ground-fault protection for all docks
2. Pre-season check of all docks and pedestals
3. Inspection by qualified electrician
4. System to test EVERY boat that enters the marina simple enough it can be done by dock jockeys
5. Requirement to re-check any boat that has had AC electrical work done
6. Procedure for dealing with boats leaking electricity – one hour of qualified electrician to track down leak; not use AC
7. Regular dock maintenance
Objectives for this presentation

To help first responders and investigators recognize ESD, or the possibility of ESD, and respond appropriately. Specifically, this presentation will help you:

1. To understand what ESD is and why you need to know about it
2. To identify potential ESD victims
3. To know what to do – and not to do – as a first responder:
   1. To assist the victim
   2. To keep yourself and others safe
4. To know what to do as an investigator:
   1. To determine if electricity may have been involved
   2. To assist marinas and individuals to make their docks safe
Acknowledgements

- David Rifkin
  - In-Water Shock Mitigation Strategies
- Kevin Ritz
  - Electric Shock Drowning: The Invisible Killer
- Ed Sherman and Chris Dolan
  - Marina Dock Safety

These resources and others can be found at: www.boatus.com/seaworthy/ESD.asp

I want to thank all of these people for being willing to share these presentations as well as their time and hard-won experience.
Thank you for your attention!

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