Electric Shock Drowning … The Invisible Killer – Marina Electrical Safety – Part II
Overview – Topics to Cover

• What is an Electric Shock Drowning?
• Basics of Marina Electrical Systems and Causes of an Electric Shock Drowning
• NEC 555.3 – Ground-Fault Protection
  • Where can protection be located?
• What can be done to lessen the chances of an Electric Shock Drowning?
  • General Marina Rules
  • Ground Fault Circuit Breakers
  • Ground Fault Monitoring
    • Single Point Monitoring
    • Multiple Point Monitoring
• NFPA 303-5.20 – Maintenance of Electrical Wiring and Equipment
Instructor Bio – Michel Rivas

- Product Engineer – Marina Electrical Design
- B.S. in Electrical Engineering
- Concentration in Power Systems and Distribution
- Working with Eaton MP&L for 2 strong years
- Oversees more than 700 electrical designs a year
- Experienced in power pedestals and distribution, and electrical safety and efficiency
Electric Shock Drowning and the Causes
What is Electric Shock Drowning?

• Electric Shock Drowning occurs when faulty wiring on a boat or in a marina causes underwater metals to become energized.
  • Examples of underwater metals that could become energized:
    • Boat Props
    • Dock Frames
  • This creates an electrical field in the water.
  • The magnitude and intensity of the electrical field is determined by how much current is being leaked into the water.
What is Electric Shock Drowning?

• A swimmer enters the electrical field and completes the electrical circuit to ground.
  
  • The swimmer becomes a target for the electrical current leakage because the human body is a better conductor of electricity than fresh water

  • Fresh water is close to 70 times more resistive than salt water. This makes electric current leakage in fresh water marinas a major concern.

• Depending on the amount of current in the water and a swimmer’s location relative to the electrical field, a person may experience effects ranging from a slight tingle, to complete loss of muscle control, to ventricular fibrillation.
Dangers of Electrical Leakage – Freshwater vs. Saltwater

EFFECTS OF SALT CONTENT ON SWIMMER:
FRESHWATER

- SALT IN HUMAN BODY
- SALT IN WATER

FLOW OF ELECTRICAL CURRENT

THE HUMAN BODY CONTAINS A LARGE AMOUNT OF SALT. IN A BODY OF FRESHWATER, A SWIMMER BECOMES THE PATH OF LESS RESISTANCE FOR ELECTRICAL CURRENT DUE TO THE SALT IN THE BODY. EFFECTS OF THIS CURRENT COULD RANGE FROM A SLIGHT TINGLE TO COMPLETE MUSCLE LOSS TO A HEART ATTACK.
Dangers of Electrical Leakage – Freshwater vs. Saltwater

<table>
<thead>
<tr>
<th>EFFECTS OF SALT CONTENT ON SWIMMER: SALTWATER</th>
</tr>
</thead>
<tbody>
<tr>
<td>• SALT IN HUMAN BODY</td>
</tr>
<tr>
<td>• SALT IN WATER</td>
</tr>
</tbody>
</table>

FLOW OF ELECTRICAL CURRENT

SALT IS A VERY GOOD CONDUCTOR OF ELECTRICITY. A SWIMMER IN A BODY OF SALT WATER IS LESS LIKELY TO FEEL THE EFFECTS OF ELECTRICAL CURRENT IN THE WATER AS THE SALT WILL MOVE THE ELECTRICITY PAST THE SWIMMER.
Underwater Electrical Field

- 5mA of Leakage
- 20mA of Leakage
- 50mA of Leakage
# Electric Shock Drowning Medical Facts

<table>
<thead>
<tr>
<th>Current</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mA to 8 mA</td>
<td>Tingle, sensation of shock, not painful, muscle control not lost</td>
</tr>
<tr>
<td>8 mA to 15 mA</td>
<td>Painful shock, muscle control not lost</td>
</tr>
<tr>
<td>15 mA to 20 mA</td>
<td>Pain shock, muscle control is lost, paralysis / inability to swim occurs, labored breathing</td>
</tr>
<tr>
<td>50 mA to 100 mA</td>
<td>Ventricular Fibrillation possible</td>
</tr>
<tr>
<td>100 mA to 200 mA</td>
<td>Ventricular Fibrillation occurs</td>
</tr>
<tr>
<td>200+ mA</td>
<td>Burn marks may appear, chest muscles clamp heart</td>
</tr>
</tbody>
</table>

- **Current**
- **not Voltage**
- **Light Bulb**
  - 100 mA
Basics of the Electrical System

Line 1 (Black) – current carrying conductor
Line 2 (Red) – current carrying conductor
Neutral (White) – returns current to complete circuit
Ground (Green) – offers current another path to complete circuit if short or overload occurs
Basics of the Electrical System
Perfect Electrical Circuit

• Example:
  • 30 amps out on line to the receptacle
  • 29.5 amps returned via the neutral
  • Grounding conductor picks up the remaining 0.5 amps before it can leak into the water
Inadequate Electrical Circuit

Example:

- 30 amps out on line to the receptacle
- 29.0 amps returned via the neutral
- Faulty ground only picks up 0.5 amps
- 0.5 amps are leaked into water, presenting a potential problem.

30A OUT - 29A IN - 0.5A PICKED UP BY THE GROUND = 0.5A
Brief Review – Two Keys to Remember

• Two things are required for Electric Shock Drowning:

  1. An electrical fault to ground – either in the marina or on a boat

  2. An incomplete circuit caused by a faulty or nonexistent circuit back to the dock’s grounding system.
NEC 555.3 – Ground-Fault Protection
NEC 555.3 – Ground Fault Protection

• New to the 2011 National Electrical Code

• “The main overcurrent protective device that feeds the marina shall have ground fault protection not exceeding 100mA. Ground-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.

• There is a similar code that applies to floating buildings also requiring no less than 100mA protection for floating buildings – NEC 553.4.
Where can 100mA Ground-Fault Protection be Located?
Protection at the Utility Entrance

• Circuit breaker protection can be located where the incoming power enters the facility from the utility company.

• While this is a very economical solution, it may be difficult to pinpoint the exact cause or causes of the current leakage.

• Leakage grouping will also be a drawback for this solution.
Protection at the Head of Each Dock

• Circuit breaker protection can be located at the head of each dock within a disconnect or distribution panel.

• Comparatively, this is also an economical solution.

• Identifying the cause or causes of the leakage depends on **how the system is wired**.

• The effects of leakage grouping will depend on the number of boats powered by each piece of equipment.
Protection on Each Dock

• Circuit breaker protection can be located on each dock within a distribution panel or through a ground fault monitoring system with shunt trip circuit breakers.

• While this is a more costly solution, it is relatively easy to identify the cause or causes of the leakage.

• The effects of leakage grouping will again depend on the number of boats powered by each piece of equipment.
Protection in Each Power Pedestal

• Circuit breaker protection can be located in each power pedestal through ground-fault circuit breakers.

• This is a very costly solution, but is very easy to identify the cause of current leakage. If the circuit breaker trips, the boat or piece of equipment plugged in is experiencing a problem.

• Leakage grouping is mitigated with this solution as each circuit breaker is monitored individually.
Leakage Grouping
Leakage Grouping - Example

BOAT A
4mA LEAKAGE

BOAT B
5mA LEAKAGE

BOAT C
6mA LEAKAGE
# 15mA of Current Produced by the Three Boats

<table>
<thead>
<tr>
<th>Current</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 mA to 8 mA</td>
<td>Tingle, sensation of shock, not painful, muscle control not lost</td>
</tr>
<tr>
<td>8 mA to 15 mA</td>
<td>Painful shock, muscle control not lost</td>
</tr>
<tr>
<td>15 mA to 20 mA</td>
<td>Pain shock, muscle control is lost, paralysis / inability to swim occurs, labored breathing</td>
</tr>
<tr>
<td>50 mA to 100 mA</td>
<td>Ventricular Fibrillation possible</td>
</tr>
<tr>
<td>100 mA to 200 mA</td>
<td>Ventricular Fibrillation occurs</td>
</tr>
<tr>
<td>200+ mA</td>
<td>Burn marks may appear, chest muscles clamp heart</td>
</tr>
</tbody>
</table>
Loop Feed System

Multiple pedestals looped together on a single circuit
## Loop Feed System (cont.)

<table>
<thead>
<tr>
<th>Design Characteristic</th>
<th>Effect of Wiring Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Vessels or Equipment on Each Circuit</td>
<td>High – multiple vessels of pieces of equipment are looped together on one circuit.</td>
</tr>
<tr>
<td>Leakage Grouping Effect</td>
<td>High – more devices powered by a single circuit produce a high likelihood of leakage grouping.</td>
</tr>
<tr>
<td>Ease of Detecting the Cause or Causes of Leakage Sources</td>
<td>Difficult – pinpointing the device or devices producing the leakage can be problematic due to the number of devices on each circuit.</td>
</tr>
</tbody>
</table>
“Homerun” System

Individual circuit for each boat. Most common in areas that require on-shore meter reading.
<table>
<thead>
<tr>
<th>Design Characteristic</th>
<th>Effect of Wiring Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Vessels or Equipment on Each Circuit</td>
<td>Low – each boat or piece of equipment is on an individual circuit.</td>
</tr>
<tr>
<td>Leakage Grouping Effect</td>
<td>Low - each device is powered by a single circuit breaker.</td>
</tr>
<tr>
<td>Ease of Detecting the Cause or Causes of Leakage Sources</td>
<td>Easy – if a circuit breaker trips, the piece of equipment it is protecting is experiencing a problem.</td>
</tr>
</tbody>
</table>
What Can Be Done to Lessen the Chances of an Electrical Shock Drowning?
General Rules – No Swimming in the Marina

- Do not allow swimming in your marina.
- Post signs prohibiting swimming in the marina.
General Rules – Designated In-Water Work Times

• Set aside a window of time where people can work on boats in the water when the electricity will be turned off.

• Post dates and / or times.

• Inform customers and workers no power will be available on the docks.
  • Customers need to be aware their power will be turned off during these “working windows.”
  • Contractors will need to be aware that no electricity will be available for power tools.
General Rules – Electrical Work

• Electrical work should only be completed by certified electricians.
  • Marina work should comply with all NEC and NFPA codes.
  • Routine maintenance and inspections should be performed at least annually per NFPA 5.20 “Maintenance of Electrical Wiring and Equipment.”
    • Document inspections and maintenance for liability purposes.
  • Boat owners should have all electrical work completed by ABYC certified electricians.
    • Boat owners should also document inspections and maintenance for liability purposes.
Equipment – Ground Fault Circuit Breakers

• Installing ground fault circuit breakers in all pedestals can be expensive and lead to “customer renovations.”
  • “Nuisance tripping” can occur.

• Customer renovations – customers frustrated by circuit breakers that constantly trip bypass protection devices.
  • It is important to educate boat owners of the potential hazards associated with work performed by untrained professionals.

• Nuisance tripping – common phrase used by customers to deflect blame for faulty boat wiring and / or repairs.
  • If a circuit breaker is in good working condition and trips, there is a problem present.
Equipment – Ground Fault Circuit Breakers

- Different Types of Ground Fault Circuit Breakers
  - 5mA – People Protection
  - 30mA – Equipment Protection

- REMINDER: Current NEC Code requires 100mA protection somewhere within the electrical system for all new installations.

- REMINDER: 15mA can cause serious injury

<table>
<thead>
<tr>
<th>Current</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>15 mA to 20 mA</td>
<td>Pain shock, muscle control is lost, paralysis / inability to swim occurs, labored breathing</td>
</tr>
</tbody>
</table>
Equipment – Ground Fault Monitors

• Install a ground fault monitoring system in the marina.
• Usually consist of a control module and current transformer(s).
• Wires are run through the current transformer(s) and the electrical cycle is measured.

• Multiple models
  • Single Source Monitoring
    • One monitor for one major power source
  • Multiple Source Monitoring
    • One monitor for multiple power sources
Ground Fault Monitors
Ground Fault Monitors – Integral CT Model
Ground Fault Monitors – Single Source Monitoring

**Diagram Details:**
- **400A / 3P MCB w/ SHUNT TRIP**
- **150A 3P**
- **20A 1P**
- **400A BUS**
- **INTERNAL VISUAL DISPLAY**
  - **ALARM:** 4 / 12
  - **Differentiation:** 54mA
  - **Address:** 2
  - **Channel:** 12
- **EXTERNAL VISUAL DISPLAY**
  - **ALARM / STROBE ACTIVATED (RED)**
  - **TEST / RESET BUTTON**
  - **POWER ON (GREEN)**
## Ground Fault Monitors – Single Source Monitoring

<table>
<thead>
<tr>
<th>Design Characteristic</th>
<th>Effect of Monitoring Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>Low – Single CT units are relatively inexpensive and can be added to existing equipment.</td>
</tr>
<tr>
<td>Leakage Grouping Effect</td>
<td>High – more devices monitored by a single CT produce a high likelihood of leakage grouping.</td>
</tr>
<tr>
<td>Ease of Detecting the Cause or Causes of Leakage Sources</td>
<td>Difficult – pinpointing the device or devices producing the leakage can be problematic due to the number of devices on one monitor</td>
</tr>
</tbody>
</table>
Ground Fault Monitors – Multiple Source Monitoring
## Ground Fault Monitors – Multiple Source Monitoring

<table>
<thead>
<tr>
<th>Design Characteristic</th>
<th>Effect of Monitoring Method</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cost</strong></td>
<td>High – Multiple CT units can be expensive due to the number of CTs required for monitoring.</td>
</tr>
<tr>
<td><strong>Leakage Grouping Effect</strong></td>
<td>Low - each circuit is monitored by a single CT. Fewer vessels monitored on one CT limits the grouping effect.</td>
</tr>
<tr>
<td><strong>Ease of Detecting the Cause or Causes of Leakage Sources</strong></td>
<td>Easy – if an alarm is triggered, the piece of equipment it is monitoring is experiencing a problem.</td>
</tr>
</tbody>
</table>
First Aid for Electric Shock Victims

• If possible turn off all power sources that may come in contact with the water. Area should be deemed safe before any action is taken.

• Extreme caution should be taken when removing victim from the water.

• Call 911 immediately

• Begin artificial ventilation - victim with pulse, but not breathing

  • OR

• CPR - victim without pulse and not breathing

  • use (AED) Artificial Electrical Defibrillator if available
Signs of Electric Shock Drowning or Potential for Electrical Shock Drowning

• Often leaves no bodily clues to suggest anything but “simple drowning” due to alcohol intoxication or heart attack.
  • No signs of burning due to the victim being submerged in water – no signs of electrocution.
  • Often classified as electrical shock due to “evidence of great distress, multiple deaths…”

• Signs of a Potential Problem:
  • Tingling sensation reported by anyone swimming in the marina.
  • Excessive damage to metal boat parts in the water – props, etc…
NFPA 303-5.20 – Maintenance of Electrical Wiring and Equipment
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 inspection required in 5.20.1 shall include a test of the ground integrity and polarity.”

• “The use of grounding-type portable electrical equipment that is not properly and adequately grounded” shall be identified and removed from use or repaired.
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
Inspections – Signs of Potential Problems
We now welcome any questions you have on today’s topic.
Thank You