Remove Electric Shock Drowning Hazard at Residential Docks

: 2701.1.1 (New)

Proponents: James Erler (jim@erlerdesign.com); John Lane (redcloudjl@aol.com); Neil Harrington, Smith Mountain Lake Marine Volunteer Fire Rescue (neil.r.harrington@gmail.com)

2015 Virginia Construction Code

Revise as follows:

2701.1.1 Add to 2701.1.1 Changes to NFPA 70.
3. Change Section 555.15(E) of NFPA 70 to read:

(E) **Feeder Equipment Grounding Conductors.** Where a feeder supplies a remote panelboard, an insulated equipment grounding conductor shall extend from a grounding terminal in the service equipment to a grounding terminal in the remote panelboard.

Exception: Private, noncommercial docking facilities constructed or occupied for the use of the owner or residents of the associated single-family dwelling shall not have a grounding conductor between the grounding terminal in the service equipment and the grounding terminal in the remote panelboard.

Reason Statement:

1. Introduction

Death and injury by Electric Shock Drowning (ESD) due to intermittent voltages delivered by the ground conductor between the house service panel and the dock service panel was documented by Donald Johnson in 2009 (Ref 1: "The Case of Stray Voltage in a Lake", Donald R. Johnson, P.E., Johnson Engineering, Nov 01, 2009.).

"Seeing the swimmers' plight, the remaining teenagers standing on the dock called to the adults in the house for help. Several of them came running out, called 911, and dove into the water, trying to retrieve the kids who were underwater. (Note: It was determined later during testing that the currents in the water were intermittent, thus not causing any harm to the adults.) After multiple dives, the adults retrieved the two boys and one girl who had been submerged for some time.

"At the hospital, one boy was pronounced dead (cause of death was drowning), and the other two received brain damage due to lack of oxygen caused by the near-drowning experience.

"After going to trial, a jury awarded the plaintiffs a total judgment of $2,325,000. No appeal was filed by the electric utility defendant."

The green ground wire connected to the neutral wire is an unprotected path for lethal electrical voltages/currents to flow to/through the body of a swimmer at a dock. There is no protection on the green ground wire. Removing the green wire ground eliminates this risk and leaves only GFCI protected circuits at the dock. The proposed exception to the National Electric Code (NEC/NFPA 70) is to remove the requirement for an ground conductor between the house service panel and the dock service panel.

2. Proposed Exception:

a. Changes in the NEC/NFPA 70 between 2014 and 2017

The presently approved code in Virginia is the 2014 edition. Residential docks are covered by Article 225, Outside Branch Circuits and Feeders and Section 250.32(B) concerning grounding. In the 2017 edition, residential docks are covered by Article 555, Marinas, Boatyards, and Commercial and Noncommercial Docking Facilities.

b. Location within the NEC/NFPA 70:

We assume that the 2017 edition of Article 555 will be approved in this review of the VCC (Virginia Constuction Code), and therefore we have placed the proposed exception in Article 555. If single-family residential docks are excluded from Article 555 in the present review (as in the presently approved code), the proposed exception would need to be moved to Article 225, Outside Branch Circuits and Feeders, and a new Section covering single-family residential docks.

c. Present Code:

Section 555.15(E) requires a ground conductor between the house service panel (Feeder Equipment) and the sub-panel at the dock (dock service panel/remote panelboard) and the ground conductor is to be connected to the neutral conductor in the house service panel (Article 250), but not in the dock service panel. GCFIs are required on all circuits in the dock service panel and on the circuit that feeds the dock service panel in the house service panel.

d. Variance/Exception:

There shall be no ground conductor between the house service (feeder equipment) and the dock service panel. The ground conductor at the dock shall not be connected to the neutral conductor at the sub-panel at the dock (as in the present code) GCFIs are required on all circuits in the sub-panel at the dock and on the circuit that feeds the sub-panel in the primary panel at the house (as in the present code) and all GFCIs must be present if the ground wire between the primary panel and sub-panel is being removed in an existing installation.

e. Suggestion:

While GFCIs include a warning that they should be tested at regular intervals by homeowners/leaseholders, regular testing at docks is especially critical for safety whether the ground conductor between the house and dock is removed or not. It is also suggested that docks at short-term rentals be required to satisfy the latest electrical code as part of the county permitting process (e.g. A statement from a licensed electrician that the dock has been inspected and is up to present code). Furthermore, owners/property managers are to self-report to the county, testing of GFCIs at intervals required by the manufacturer (e.g. This could be a checkbox on the monthly short-term occupancy tax form) .

3. Reason for Proposed Exception:

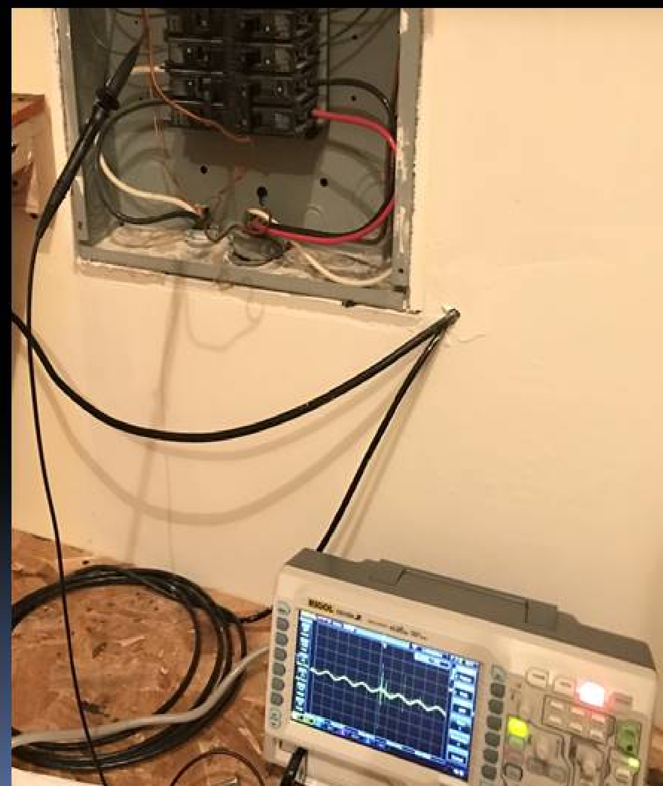
a. Electric Shock Drowning and Injury Caused due to the presence of the ground conductor between the primary panel at the house and the sub-panel at the dock

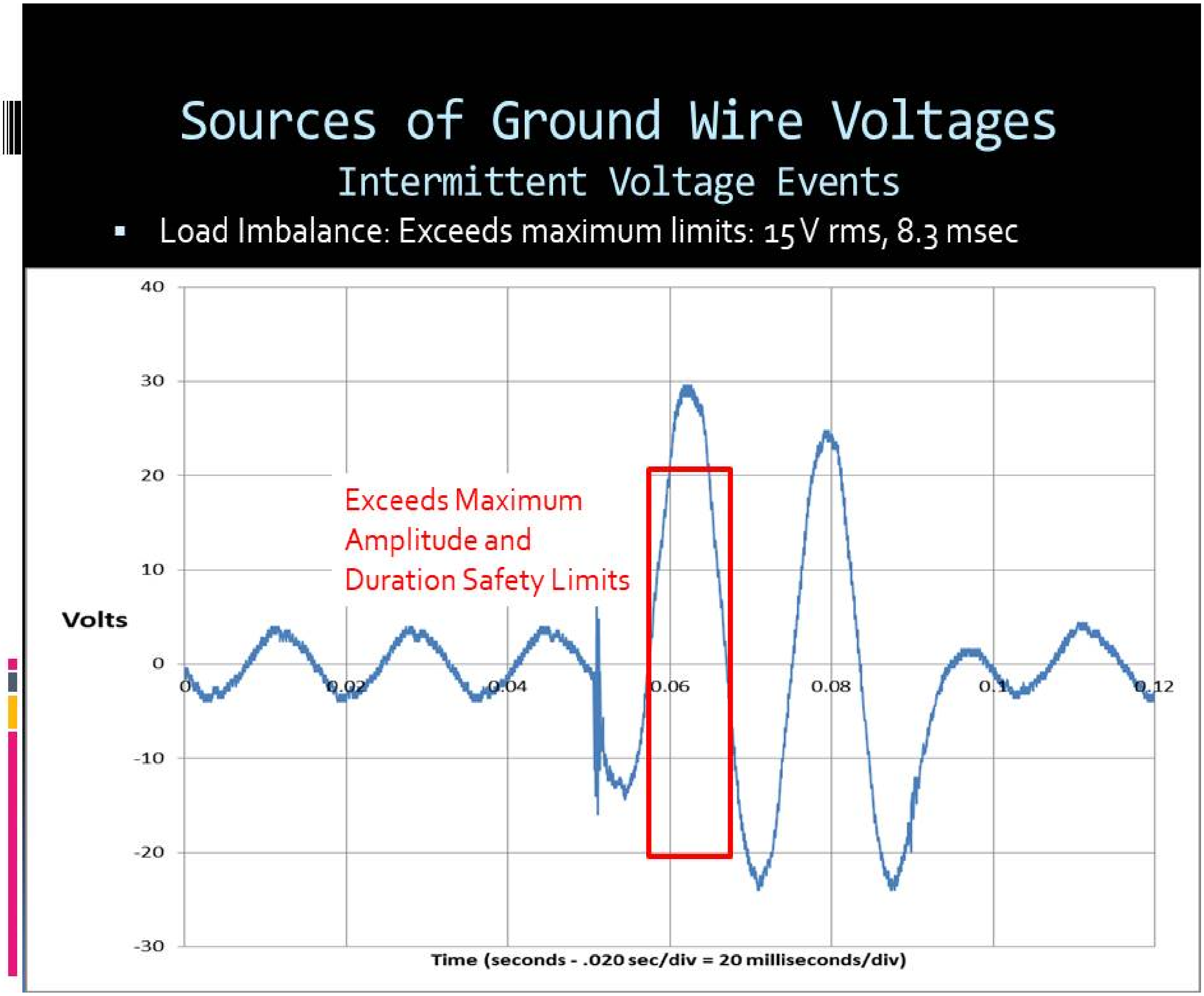
i. Intermittent lethal voltages

Intermittent lethal voltages between the neutral conductor and “remote” ground (the potential of the earth/body of water) have been measured and documented (Ref 2: “Electric Shock Drowning”, James Erler, July 2018, slides 52 - 63; Ref 1: “The Case of Stray Voltage in a Lake”, Donald R. Johnson, P.E., Johnson Engineering, Nov 01, 2009; Ref 3: "Boat Dock Exposure Voltage Mitigation," Frank Lambert and Shashi Patel, Georgia Tech/NEETRAC, January 2013, slides 4, 6, 8, 9).

Measurements

- Voltage between the neutral line and remote ground (1 k-ohm load)
- Multi-meter "jumpy" and unreliable
- Oscilloscope used to fully capture voltages delivered to the dock
- March through June, 2018 in Huddleston





These intermittent events are a normal part of the electrical power system. They are induced by several different events:

- Load imbalances when motors start and draw high currents (e.g. refrigerators, air conditioners, boat lift motors etc.)
- Arcing between high voltage and neutral/ground conductors
- Lightning strikes

These events may take place at the house associated with the dock or at neighboring properties that share the same neutral line.

ii. Continuous lethal voltages

Problems in the power delivery system can result with elevated neutral/ground conductor voltages. These include:

- Corrosion of neutral return conductors between a house panel and the power feed (Ref 1: "The Case of Stray Voltage in a Lake", Donald R. Johnson, P.E., Johnson Engineering, Nov 01, 2009; Ref 2: "Electric Shock Drowning", James Erler, July 2018, slide 51)
- Errors in repairs performed by the power company (neutral and power conductors reversed) (personal communication, Doug Dorr, Electric Power Research Institute)
- Nearby power usage causing regular load imbalances (Ref 3: "Boat Dock Exposure Voltage Mitigation", Frank Lambert and Shashi Patel, Georgia Tech/NEETRAC, January 2013, slide 9)

b. Death and Injury

While death by electrocution requires relatively high voltages, electric shock drowning may occur at modest voltages of 15 volts or less since it disables the swimmer (Ref 1: "The Case of Stray Voltage in a Lake", Donald R. Johnson, P.E., Johnson Engineering, Nov 01, 2009; Virginia Residential Code, Chapter 42, E4201.2 Definitions). Measurements and analysis by Mr. Erler (Ref 2: "Electric Shock Drowning", James Erler, July 2018, slides 52 - 63) clearly demonstrate that intermittent lethal voltages are delivered to docks by the presently required ground conductor. In June 2018 a girl was injured when she was shocked by an intermittent voltage event while sitting on a boat lift and dangling her feet in the water. She would have drowned if she had not been pulled from the water. She was hospitalized for 3 days following the injury. (personal communication, Neil Harrington, Smith Mountain Lake Marine Volunteer Fire/Rescue).

An autopsy after an electric shock drowning (ESD) cannot reveal that death was caused by an electric shock, so unless the cause is a continuous lethal voltage, there is no way to know the cause of death was ESD. Unexplained drownings at docks are not tabulated, so it is impossible to know the number of drownings that are caused by intermittent voltage events. There are numerous reports in the media of unexplained drownings of healthy and experienced swimmers at docks.

4. Removal of the ground conductor and dependence on GFCIs

a. Function of the ground conductor if there are no GFCIs

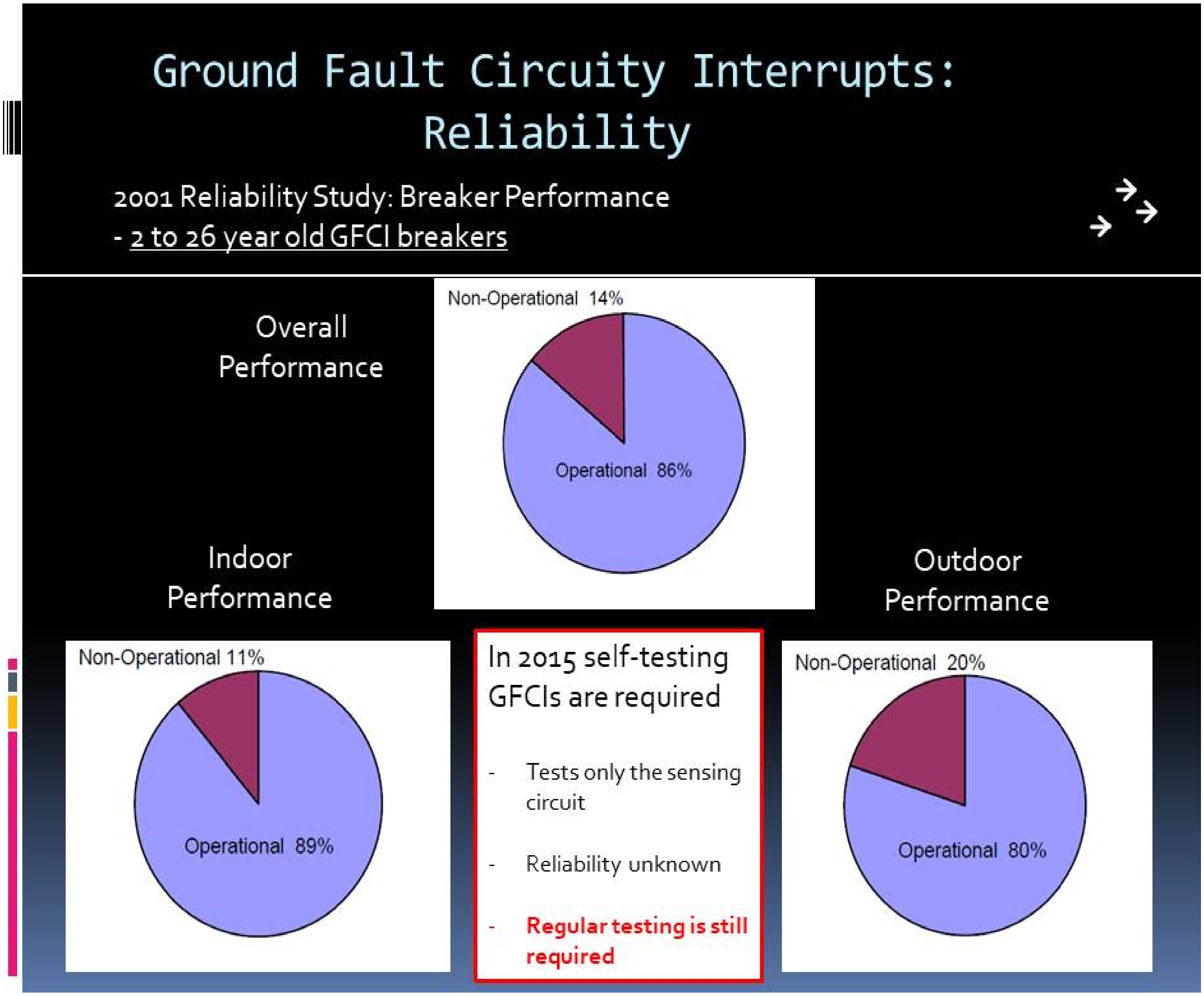
The ground conductor provides a return path to the breaker if there is a high-current fault to ground, enabling the breaker to trip if the current exceeds its rated current (typically 12 or 20 amps). It takes about 5 seconds for a breaker to trip. They are designed to trip if the load exceeds the rated current of the breaker. If a high-current fault occurs to a grounded dock component that is in contact with the water and swimmers are in the vicinity, they will be shocked and may drown, since the breaker is too slow to provide adequate protection. However, the tripped breaker will cut the power before an electrical fire could break out and provides protection for swimmers entering the water after the breaker has tripped. IMPORTANT NUMBERS: Exposure longer than 0.0083 seconds (8.3 milliseconds) can cause lethal ESD; standard breakers trip is ~5 seconds; GFCI breakers required at docks trip in 0.007 seconds (7 milliseconds) or less.

b. Function of GFCI Breakers

GFCI breakers will trip if there is a low (or high) current fault to ground and are will trip within 0.007 seconds, which is less than the exposure time required to cause ESD. A GFCI breaker will trip more quickly and at lower currents (0.004 Amps) than a conventional breaker (12 or 20 Amps). Since a GFCI is tripped by a current imbalance between the hot and neutral conductor, *the ground conductor between the primary panel at the house and the sub-panel at the dock is not needed for GFCIs to trip properly.*

c. Reliability of GFCI Breakers

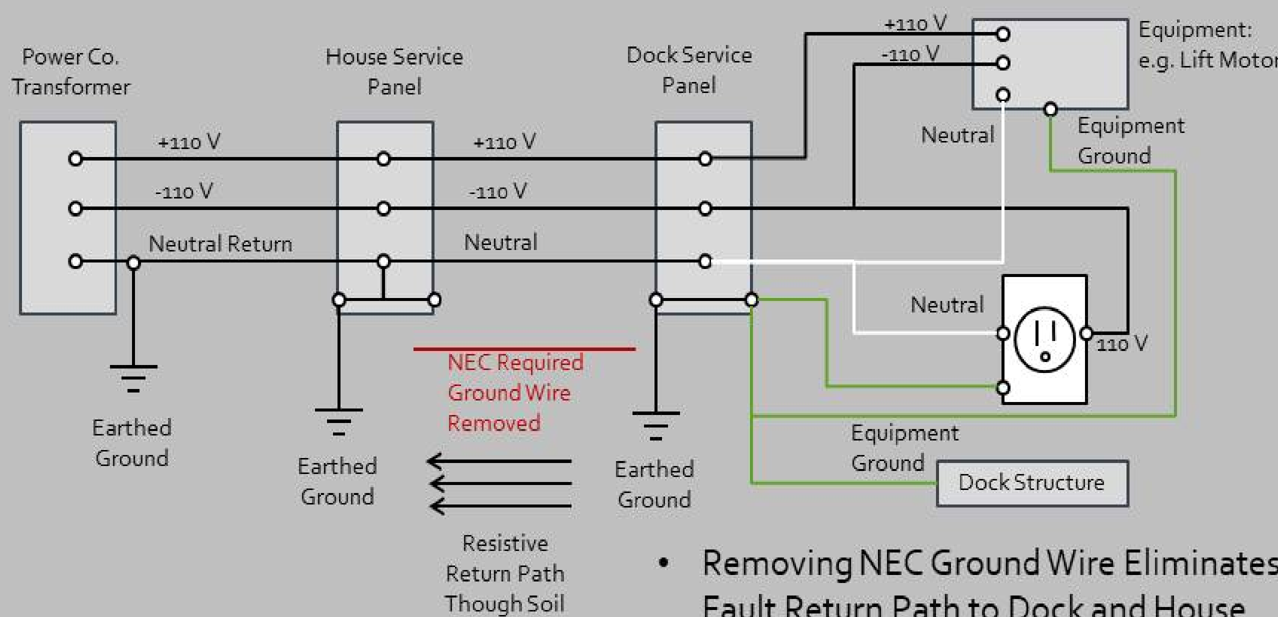
A study performed in 2001 Evaluated the reliability of installed GFCIs that were up to 26 years old. (Ref 4: "GFCI Field Test Survey Report," National Electrical Manufacturers Association, January 2001; Ref 2: "Electric Shock Drowning", James Erler, July 2018, slides 74 - 79) This led to the development of a self-testing design in 2015 (self-testing of only the sensing circuit but NOT the cutoff switch), but there is no known reliability data on the newer units. However, anecdotal reports from electricians indicate that there are still reliability issues with outlet GFCIs, especially in dirty environments (hair spray can cause the mechanism to stick). The 2001 data indicates a failure rate of ~20% in outdoor environments over a period of many years. Regular testing of GFCIs should help keep them operational by operating the cutoff switch, as well as detecting failures. The reliability of a post-2015 GFCI over a period of 30 days is likely to be very high.



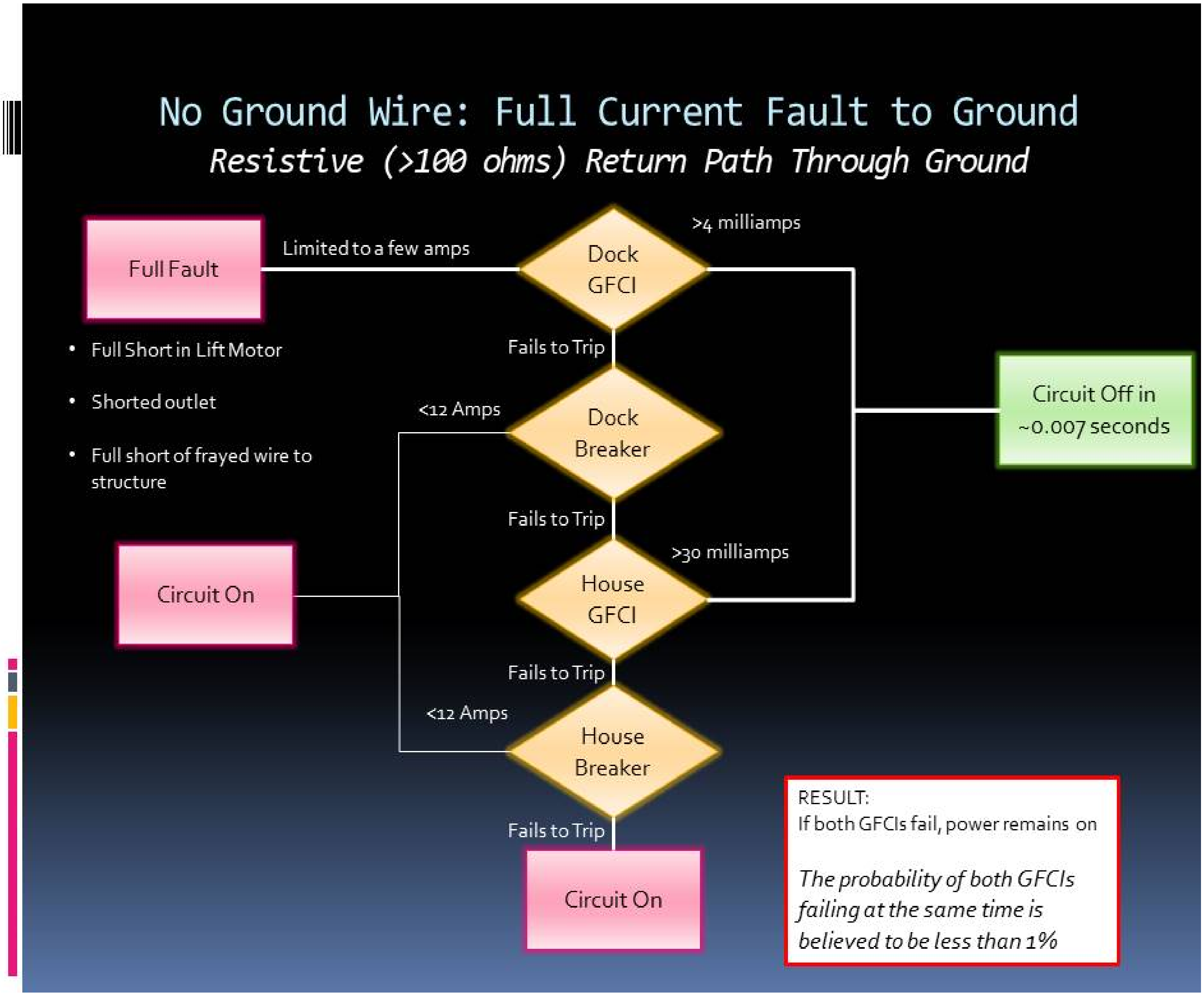
d. Safety Impact of Removing the Ground Wire

The improvement is safety for swimmers at the dock is established above, but does the removal of the ground wire create added risks? The flow diagram in slide 89 of Mr. Erler's brief (Ref 2: "Electric Shock Drowning", James Erler, July 2018, slides 88 - 90) follows the electrical path logic sequence should there be a high current fault to ground.

Remove NEC Ground Wire



- Removing NEC Ground Wire Eliminates Fault Return Path to Dock and House Service Panels



Without the ground wire, the only return path to the neutral conductor is through the ground which is estimated to be greater than 100 ohms. This limits the current to a few amps which would be insufficient to trip the load side of the breaker. However, BOTH the dock GFCI and the house GFCI would have to fail for the circuit to remain on.

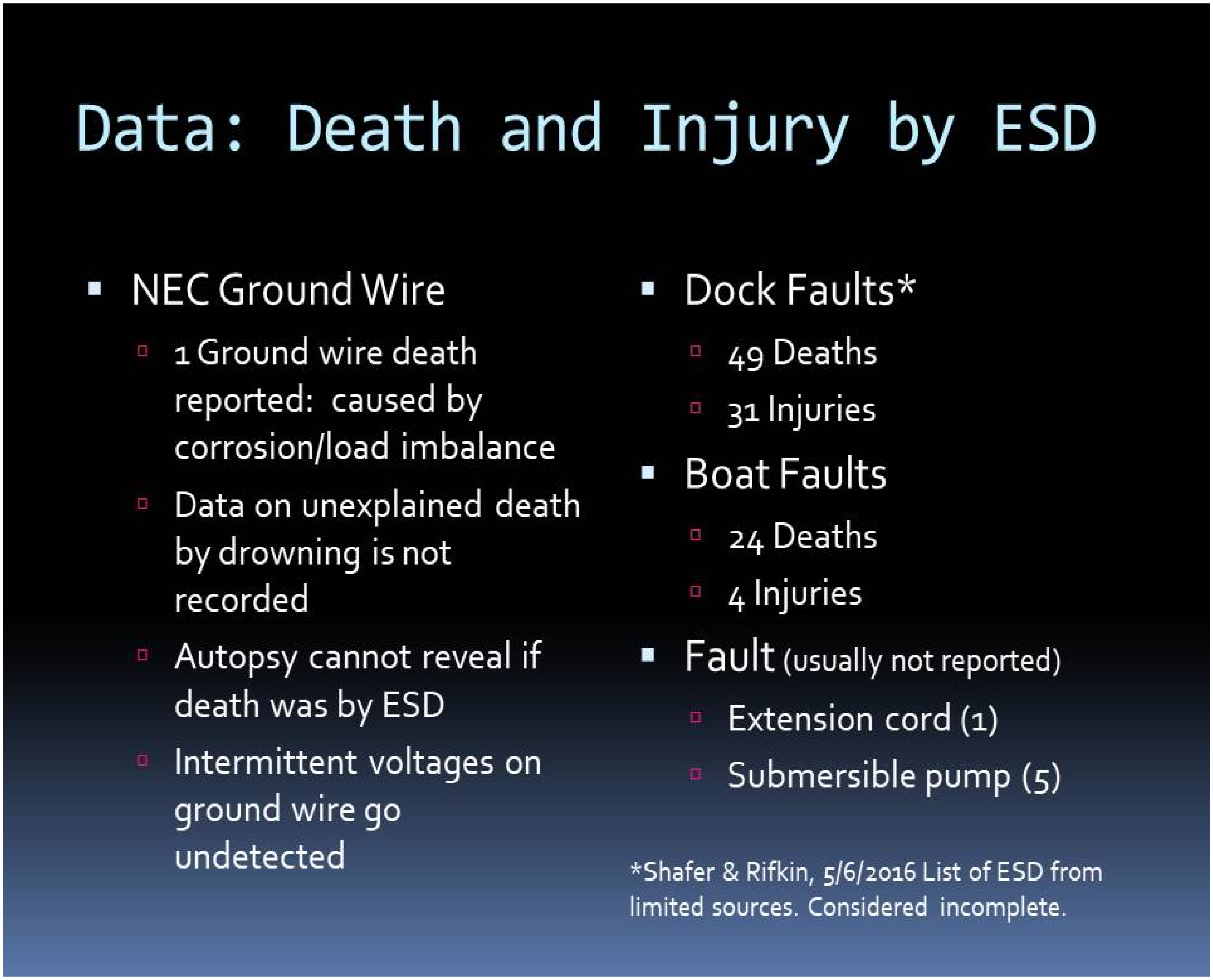
If the probability of failure of GFCIs is the same as the 2001 data, the probability of both failing at the same time drops to 4%. The newer GFCIs with regular testing will likely put this figure well below 1%.

Note: NEMA has not responded to requests for reliability data on newer GFCIs.

This risk is certainly much lower than the risk of death due to ESD caused by the ground conductor.

5. Public Interest and Concern

The introduction of devices that detect electricity in the water, such as the Shock Alert (Ref 5: "Shock Alert Owner's Manual"), made it possible to easily detect electricity around docks. Neil Harrington (Smith Mountain Lake Marine Volunteer Fire/Rescue) tested over 200 docks at Smith Mountain Lake, Virginia, and found that over 90% of them had electricity in the water (Ref 6: "Stray voltage common around docks," Laker Weekly, January 16, 2018). On June 2, 2018, a girl was injured by an intermittent electric shock at a dock on Smith Mountain Lake (Ref 7: "Teen injured after shock at dock," Laker Weekly, June 12, 2018; Ref 8: "Teen recovers after shock at dock," Laker Weekly June 6, 2018) further heightened public concern. Press releases and newspaper articles about ESD at Smith Mountain Lake reflect the growing public awareness and their desire for a safe environment at their docks (Ref 9: "Research Dock shock from home ground wire," Laker Weekly, July 18, 2018; Ref 10: "Stray voltage found around lake docks," Laker Weekly, June 12, 2018; Ref 11: "Use these tips to avoid shocks at docks," Laker Weekly, June 19, 2018; Ref 12: “Boat lifts a common source of stray voltage in water,” Laker Weekly, June 26, 2019; Ref 13 “WSC to combat stray voltage,” Smith Mountain Eagle, July 10, 2019)



Submitted August 1, 2019 by James Erler, Neil Harrington and John Lane

Resiliency Impact Statement: This proposal will neither increase nor decrease Resiliency
The proposed exception will neither increase nor decrease Resiliency as defined in COV Executive Order Twenty-Four.

Cost Impact Statement: The code change proposal will decrease the cost of construction

a. Existing Installations

Installations that followed all prior versions of the NEC present significant risks to swimmers at docks (Ref 2: “Electric Shock Drowning”, James Erler, July 2018, slides 22 - 23), as they either include the lethal ground conductor and/or may not include GFCIs on all dock circuits in the dock service panel and on the circuit feeding the dock in the house service panel. While the recommended code exception may not be retroactive, most homeowners with docks are highly motivated to eliminate the risk of ESD for themselves, their family and their guests (Ref 13: “WSC to combat stray voltage,” Smith Mountain Eagle, July 10, 2019; Ref 12: “Boat lifts a common source of stray voltage in water,” Laker Weekly, June 26, 2019; Ref 9: “Research: Dock shock from home ground wire,” Laker Weekly, July 18, 2018). The cost to upgrade these installations could range from ~$100 to inspect and remove the ground conductor to ~$1,000 or more to upgrade the house and dock service panels with GFCIs.

b. New Construction

In new construction the ground conductor between the house and dock service panels is no longer needed, and the ground conductor/bonding at the dock is no longer needed. The cost savings is either negligible or perhaps a few hundred dollars.