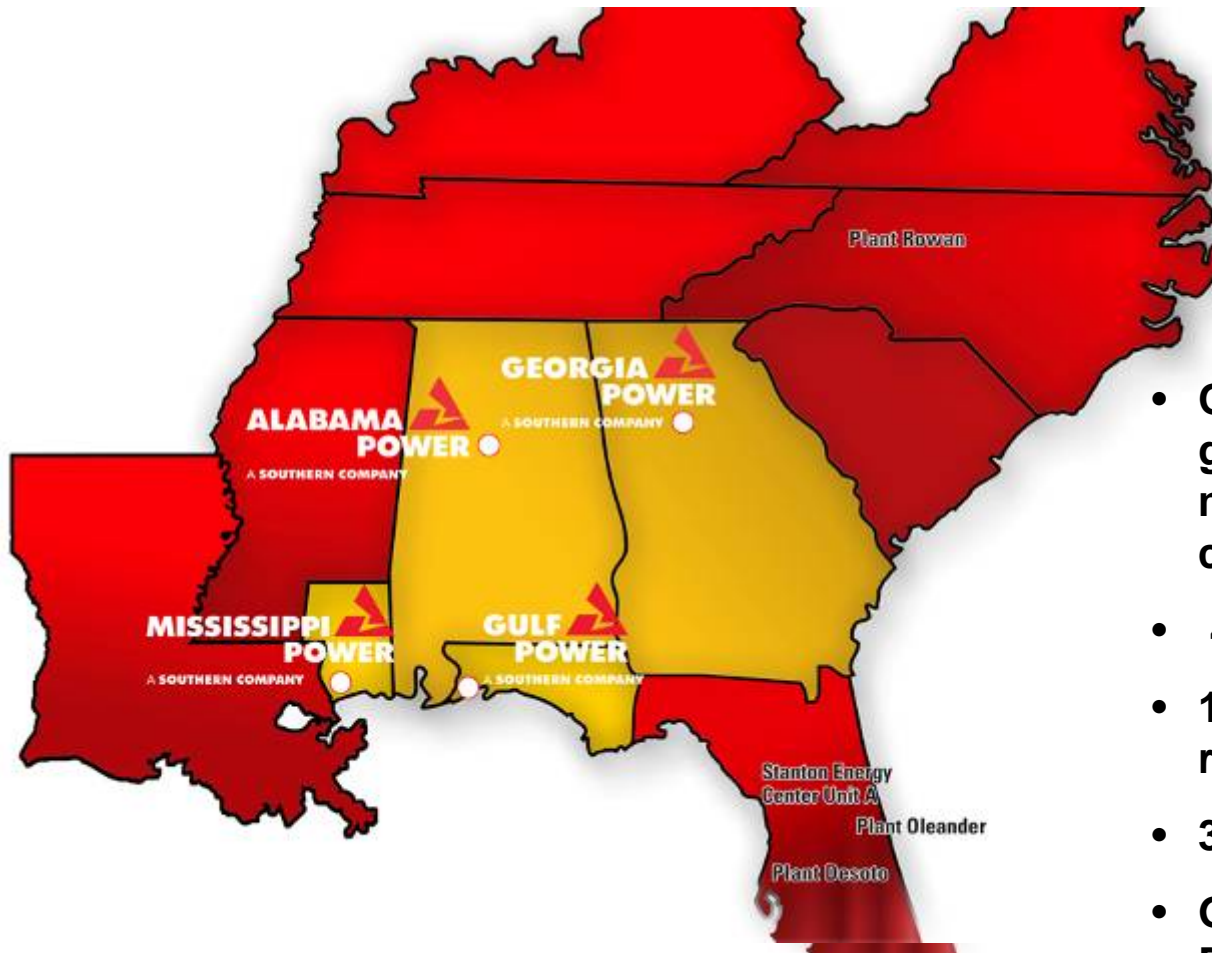




# Stray Voltage and Swimming Pools

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# Southern Company



- SouthernLINC Wireless
- Southern Power
- Southern Nuclear
- Southern Telecom

- One of the largest electricity generators in the nation with more than 42,000 MW of capacity
- 4.3 million Customers
- 120,000 square miles in 4-state region
- 3,400 substations
- Grid of Transmission and Distribution lines that would circle the earth



# Presentation Roadmap

- IEEE Working Group effort regarding “exposure voltages”
- What is stray voltage (in the classical sense)
- The National Electric Code and pool safety
- How can a pool have stray voltage
- EPRI 2009 Pool Tests
- Vision for the results of the testing

# IEEE Working Group

- IEEE “Working Group on Voltages at Publicly and Privately Accessible Locations”
- IEEE WG is writing a trial-use guide for assessing voltages at publicly and privately accessible locations.
- Topics include: Definitions, Causes, Testing Protocols, Measurement Equipment, Mitigation Options, Levels of Concern
- One desired outcome is clear distinction of “stray voltage”

# Proposed IEEE Working Group Definitions:

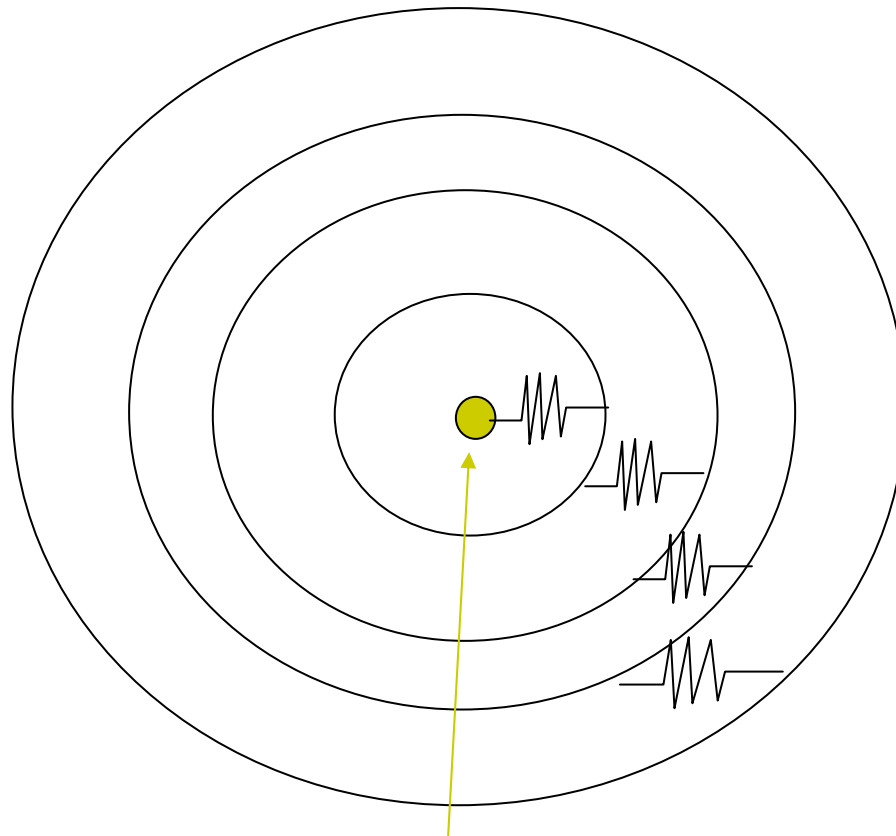
- Stray Voltage: A voltage resulting from the **normal delivery and/or use of electricity (usually smaller than 10 volts)** that may be present between two conductive surfaces that can be simultaneously contacted by members of the general public and/or their animals.  
.....**Stray voltage is not related to power system faults, and is generally not considered hazardous.**
- Contact Voltage: A voltage resulting from **abnormal power system conditions** that may be present between two conductive surfaces.....

# Definitions in this presentation:

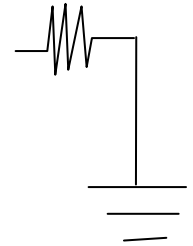
- Stray Voltage is a small open-circuit voltage (usually less than 10 volts) measured between any two points that can be simultaneously contacted by a human or an animal.
- Neutral to earth voltage (NEV) is the voltage measured between any point on a neutral or its extension and an isolated reference electrode placed in earth with “zero” or “nearly zero” potential (remote earth).
- Grounding Electrode Resistance ( $R_g$ ) is the resistance of a grounding electrode system with respect to remote earth.
- Grounding Electrode Current ( $I_g$ ) is the total current flowing in the surrounding earth via the grounding electrode system.

$$NEV = I_g \times R_g$$

$$NEV = 0.05A \times 25 \text{ ohms} = 1.25V$$

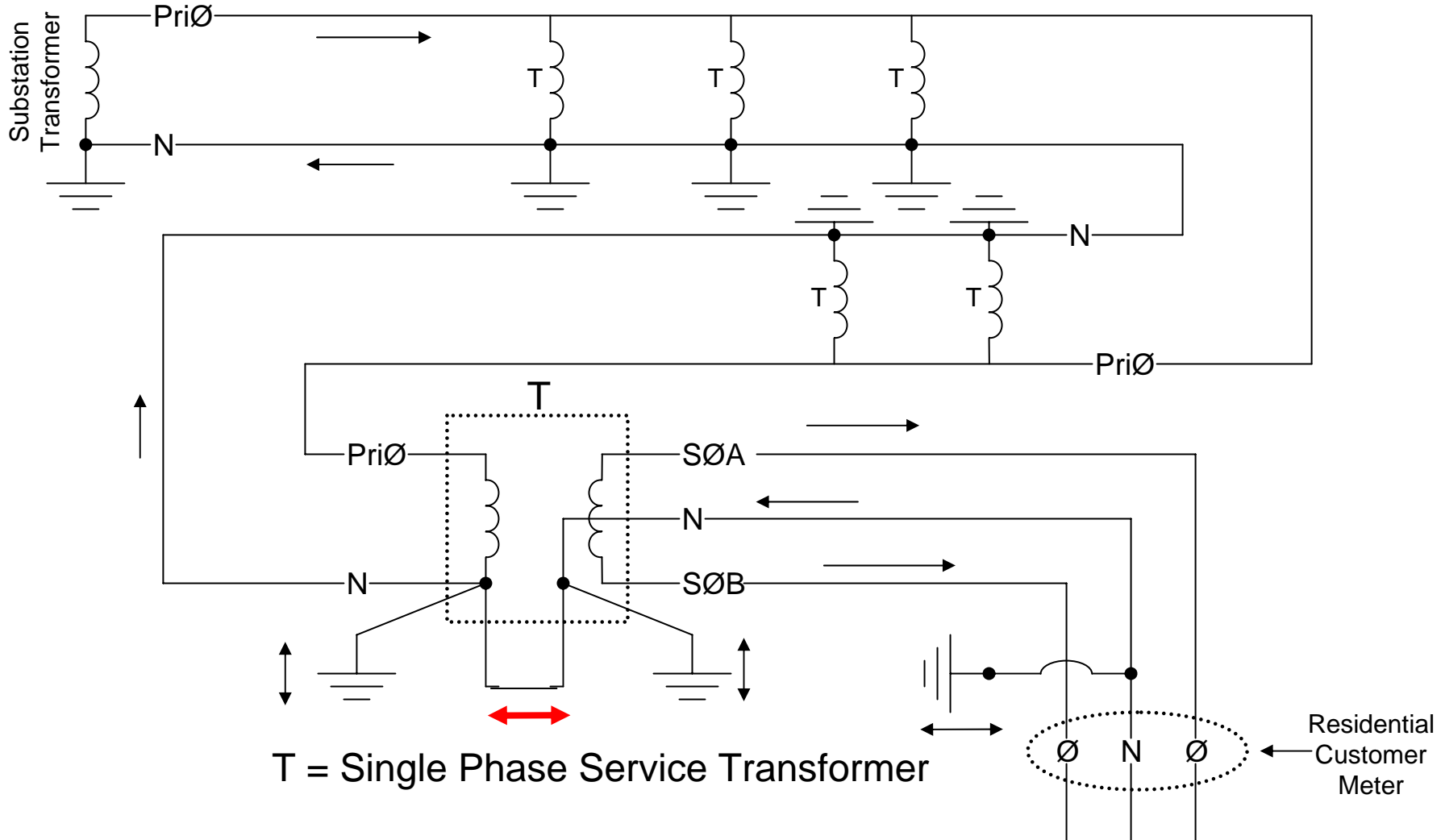


Ground Rod



Remote Earth

# Multi-grounded neutral distribution line




PriØ = Primary Phase Conductor

SØA,B = Secondary Conductor

N = Neutral





Just balance the loads and cancel out the neutral current ... right?

The distribution neutral current will usually be a combination of 60hz and triplen harmonics. Triplen order harmonics do not cancel.

# NEC and Swimming Pools

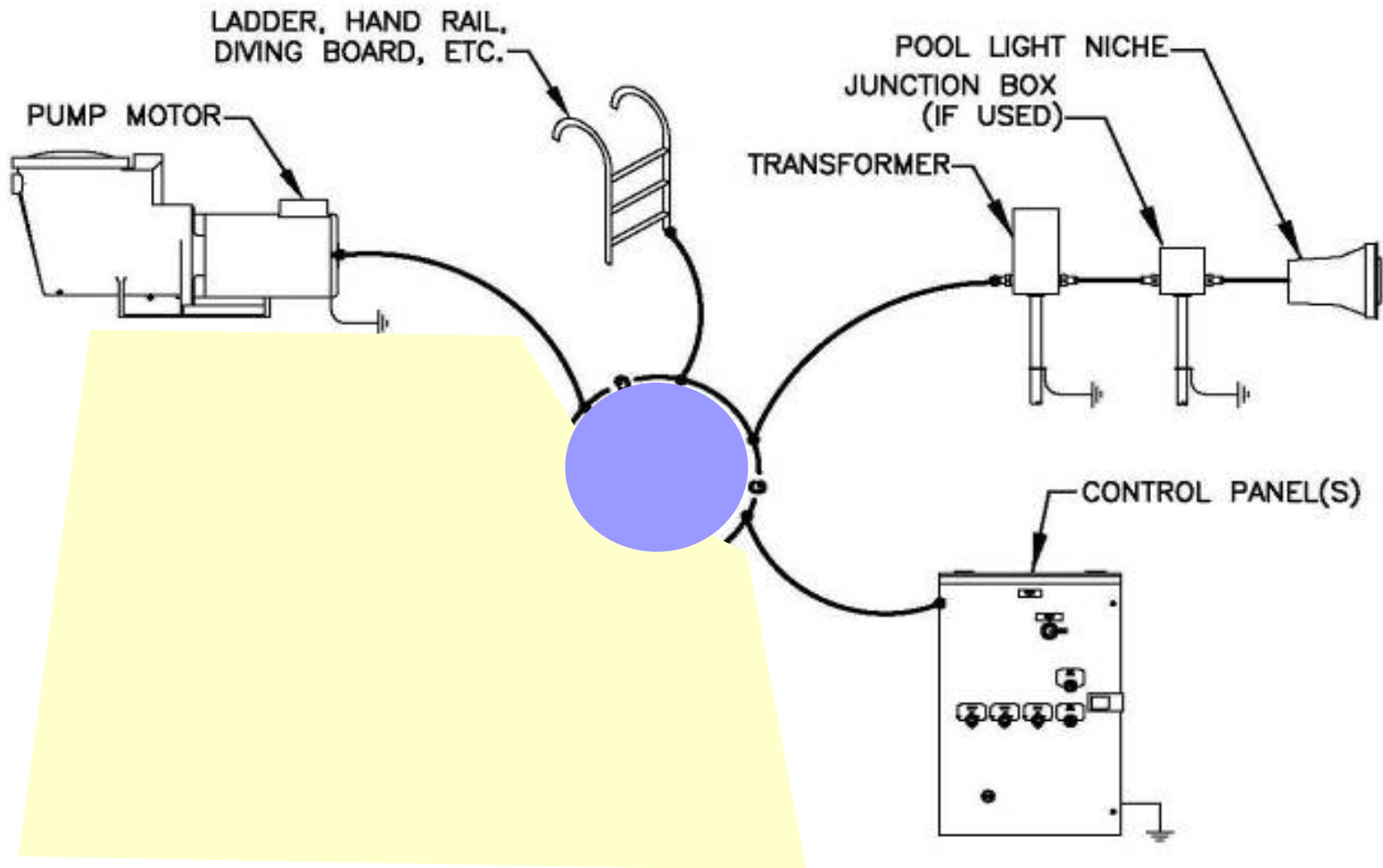
- **2008:** Requirement to “bond the pool water” included
- **2005:** Added Equipotential Bonding Grid (680.26C); also a TIA Tentative Interim Amendment allowing #8 copper encircling entire pool contour
- **1999:** The revised wording of the 1999 Code makes it clear that the No. 8 conductor is only for the elimination of the voltage gradient in the pool area and is not required to provide a path for fault currents
- **1984:** stressed eliminating voltage gradients as a FPN: “employed to eliminate voltage gradients in the pool area”
- **1975:** Common bonding grid defined as either 1) structural reinforcing steel 2) wall of welded metal pool 3) #8 solid copper
- **1962:** The first Article on Swimming Pools (requires bonding)

# 2005 NEC Section 680.26

## Equipotential Bonding

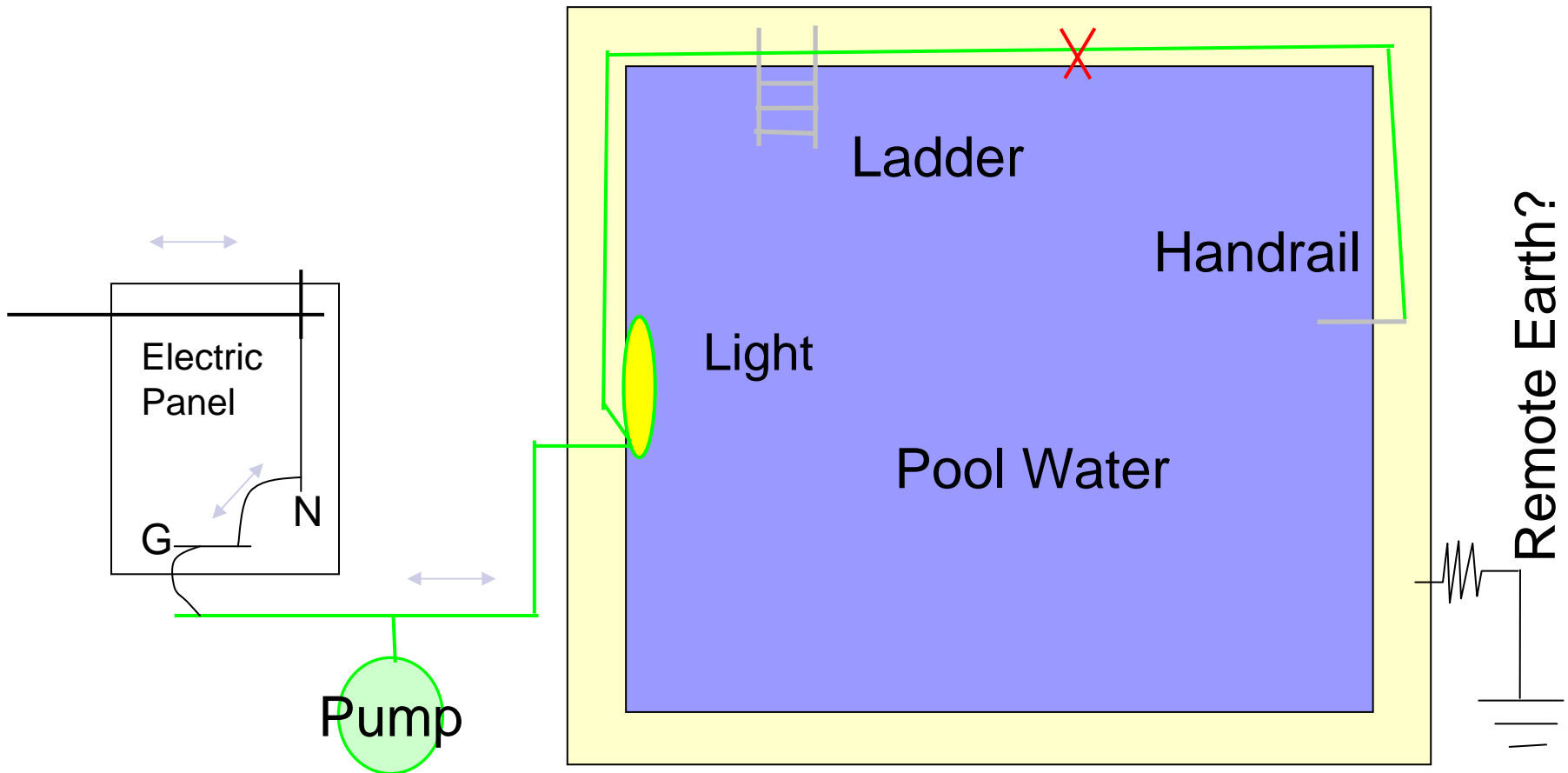
- **(A) Performance.** The purpose of equipotential bonding is to eliminate voltage gradients in the pool area. ...
- **(B) Bonded Parts.** The parts listed below shall be bonded together:
  - (1) Metallic Structural Components- all metal parts of the pool structure including reinforcing steel.
  - (2) Underwater Lighting- all no-niche luminaires unless of a listed low voltage lighting system with nonmetallic forming shells.
  - (3) Metal Fittings- all metal fittings within or attached to the pool structure.....

# Typical NEC 680.26 Pool Bonding

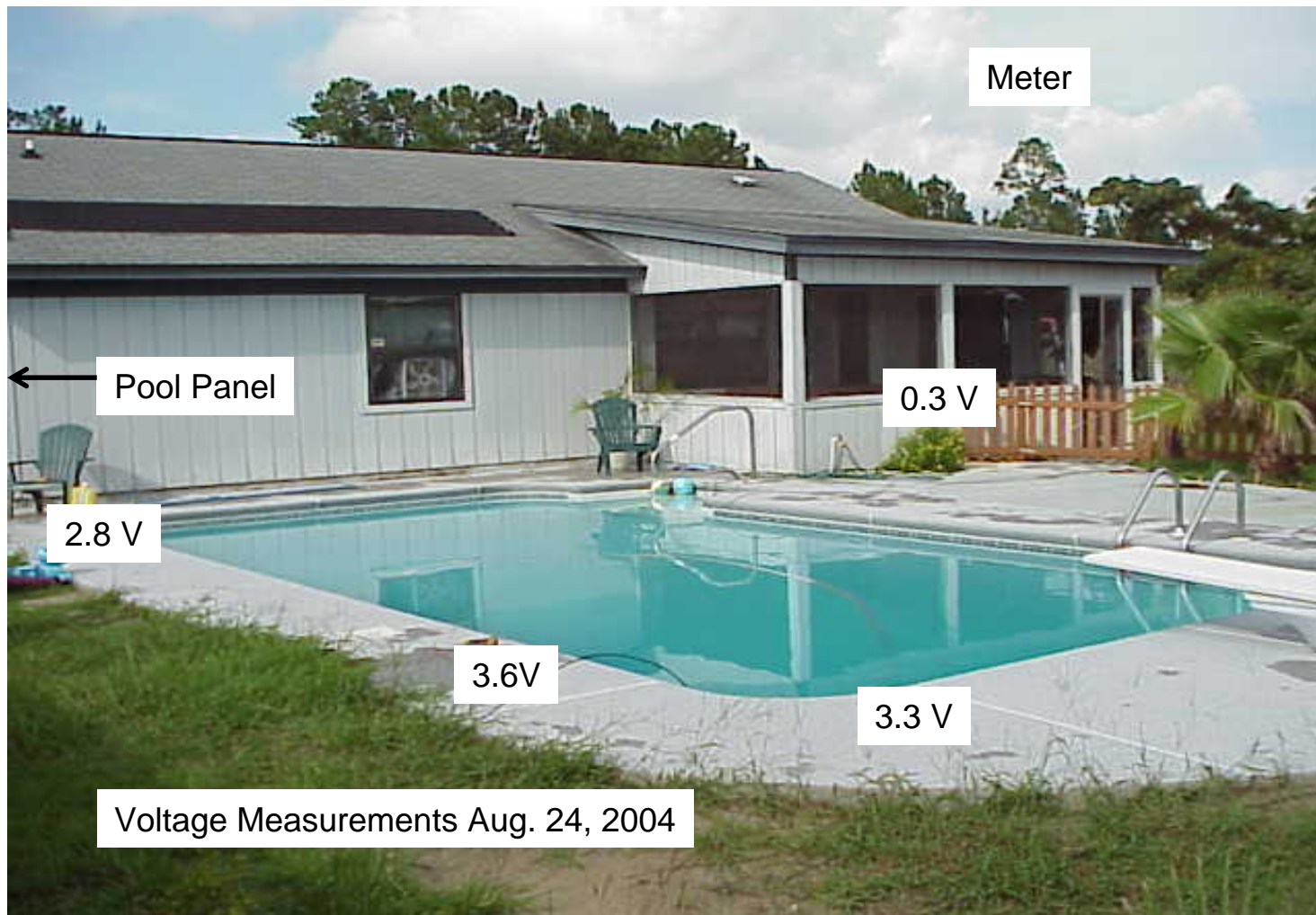


# How can a swimming pool have stray V?

There is an extension of the system neutral in the swimming pool environment.



# Swimming Pool with a significant voltage gradient only on one side of pool.



# EPRI Project “Evaluation of Bonding and Grounding Effects for Residential Swimming Pools and Spas”

- The purpose of this research project is to replicate a ‘wet area’ that allows for controlled measurements with variable NEV sources, variable grounding and bonding configurations, and **controlled fault setups**.
- Successful project results will benefit the public bringing a more comprehensive understanding of the suitability of different grounding configurations and supplemental mitigation techniques.

23,000 V Overhead Line  
~800 feet

23-kV Feed from Utility

EPRI Test Facility  
in Lenox, MA.

23-kV  
Substation

23-kV to  
4160 V  
stepdown  
bank

Stray Voltage  
Test Structure

4160 V Overhead Line  
~1200 feet





# 20 Simulated Residences and Variable NEV Source from Overhead and Underground Distribution



Previous Stray Voltage Testing Structure

New pool structure built beside existing stray voltage testing structure.



# 4 types of Decks to model various field conditions

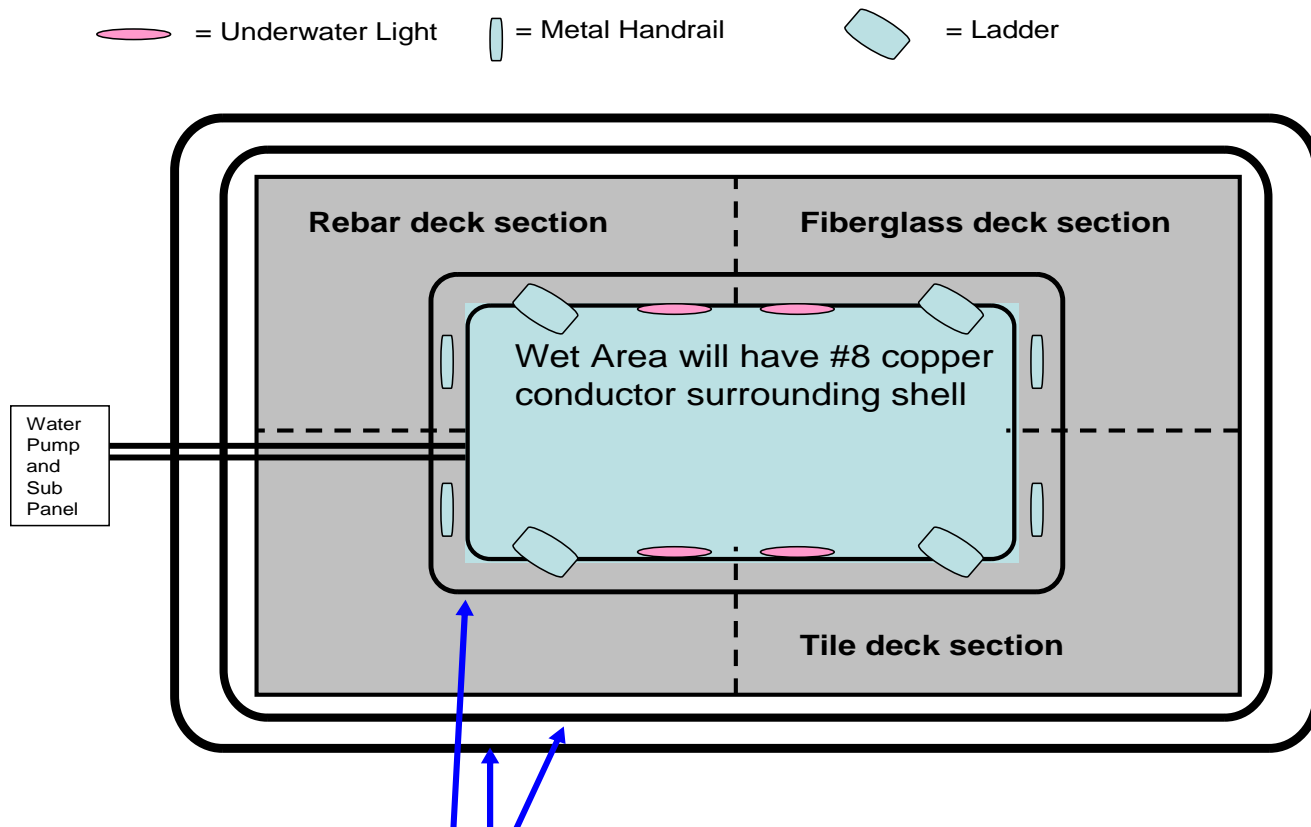
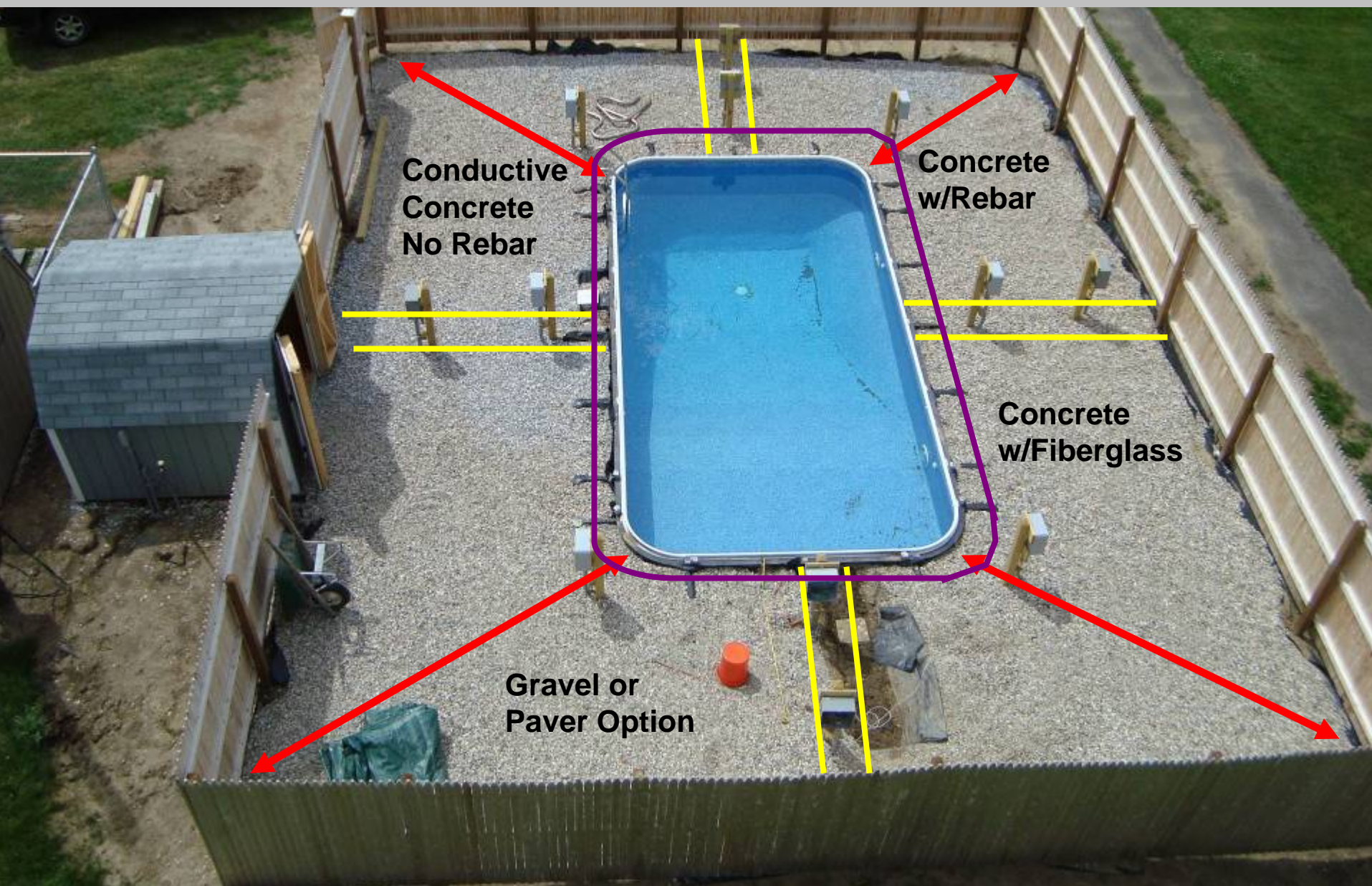


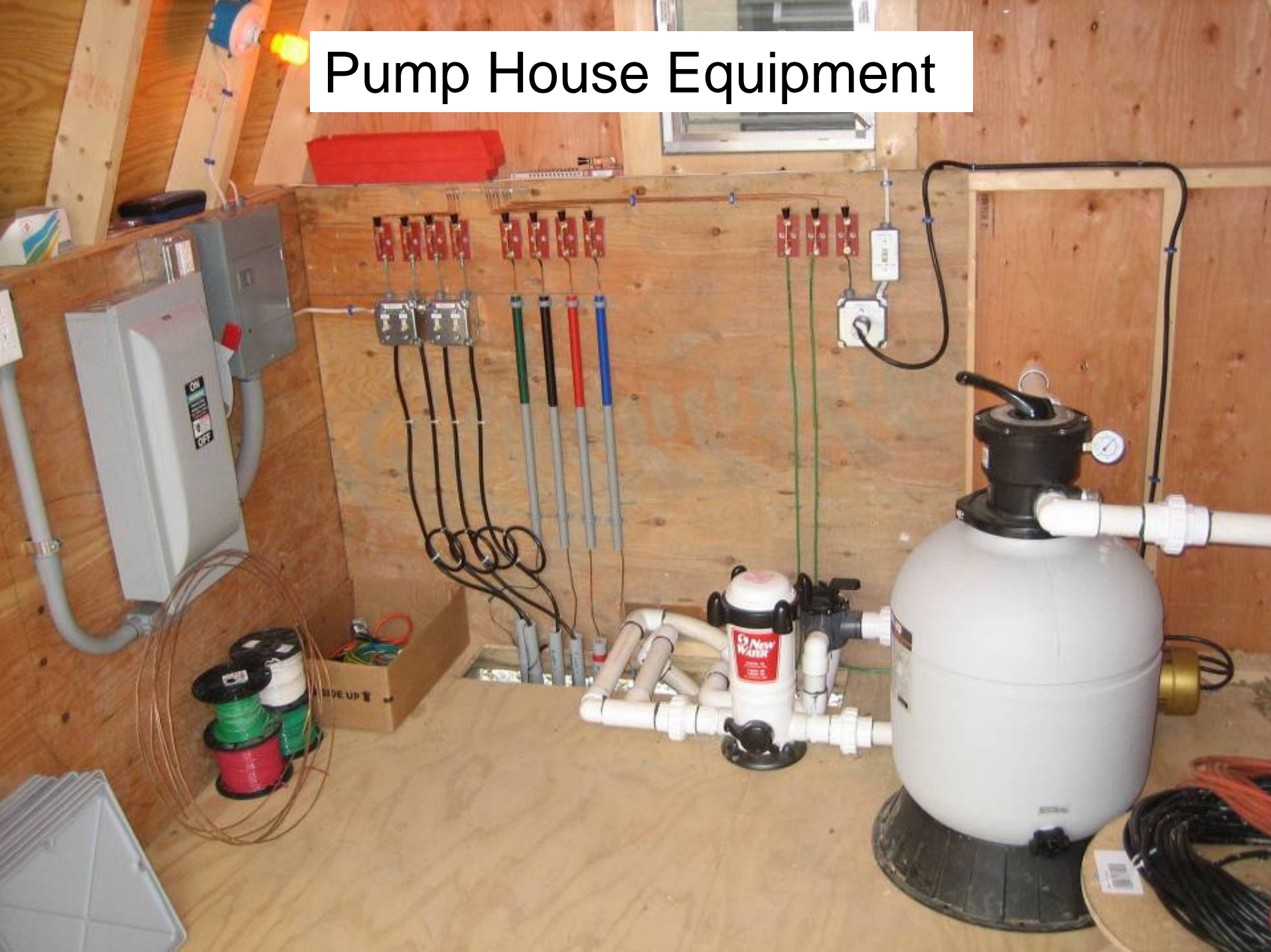
Diagram courtesy  
EPRI – D. Dorr


Three solid #8 bare copper ground rings are connectable. (18in from water at 6in depth, 7ft from water at 6in depth, 7ft from water at 36in depth)

**Red Lines** indicate location of measurement rods. **Yellow Lines** indicate 12inch spacing between deck sections to be backfilled with gravel. **Purple ring** is #8 bare copper to be laid on surface of gravel below concrete.



# Pump House Equipment





Nearby distribution line to be faulted during testing

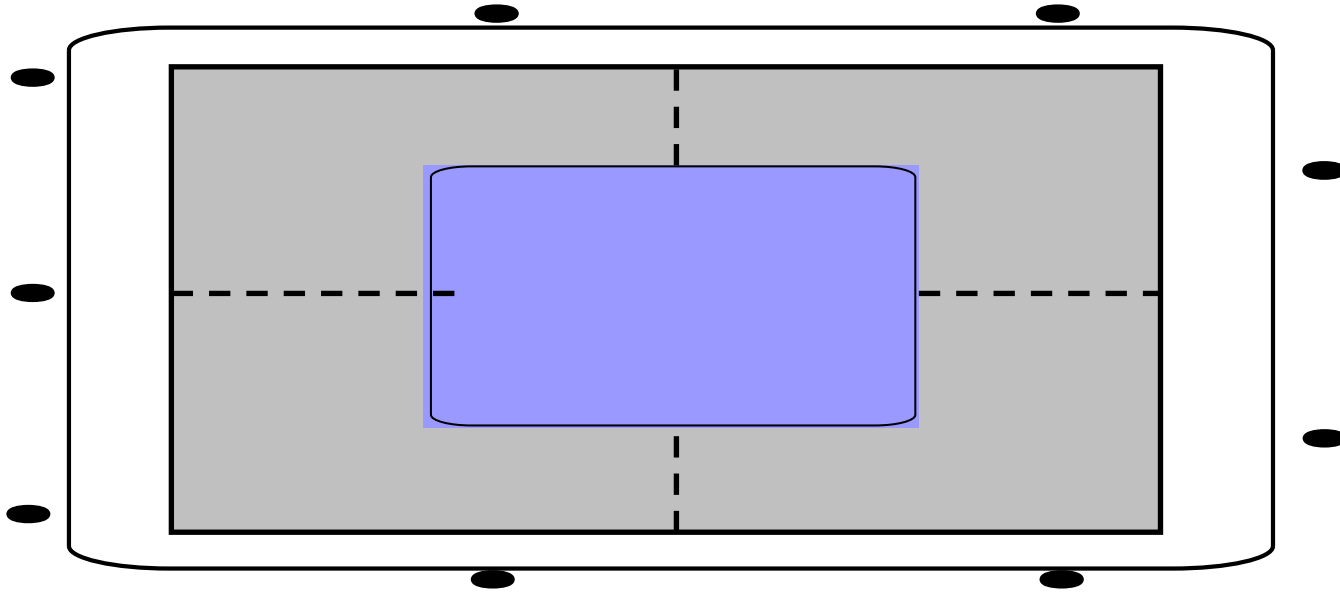




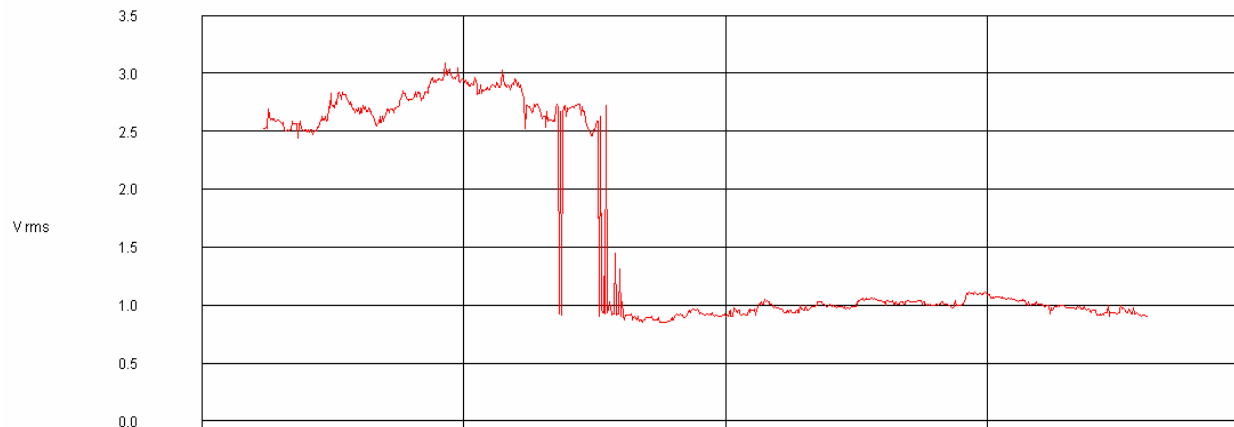
# NEV Mitigation Issues Include:

- Effect of inner ring vs outer ring
- Effect of ring combinations
- Effect of vertical vs angled ground rods
- Effect of multiple ground rods and spacing
- Effect of horseshoe vs full ring
- Effect of depth of ground ring

Preliminary results indicating outer ring reduces voltage around pool area by 50% or more.



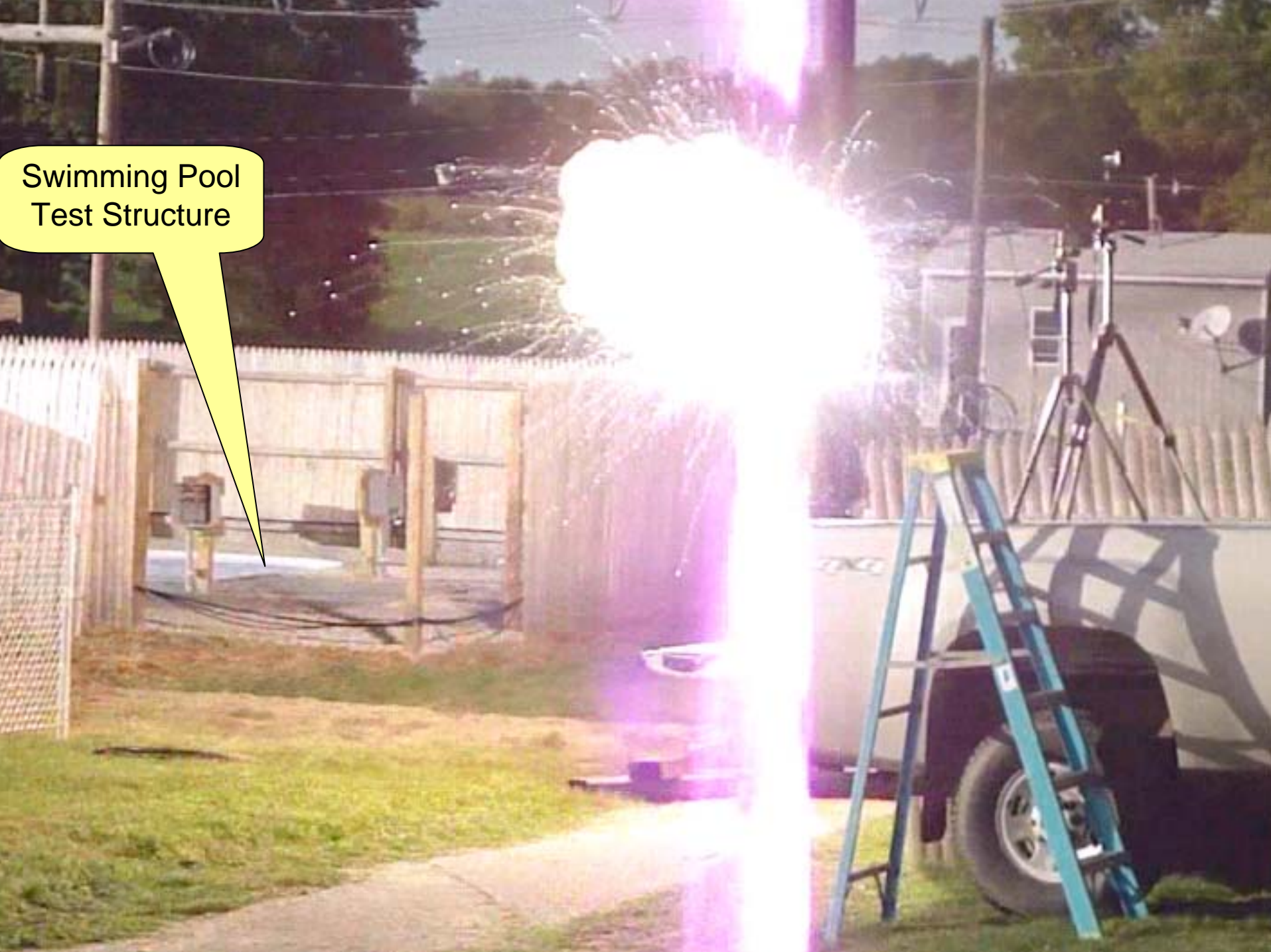
Pool 3 SGR Results

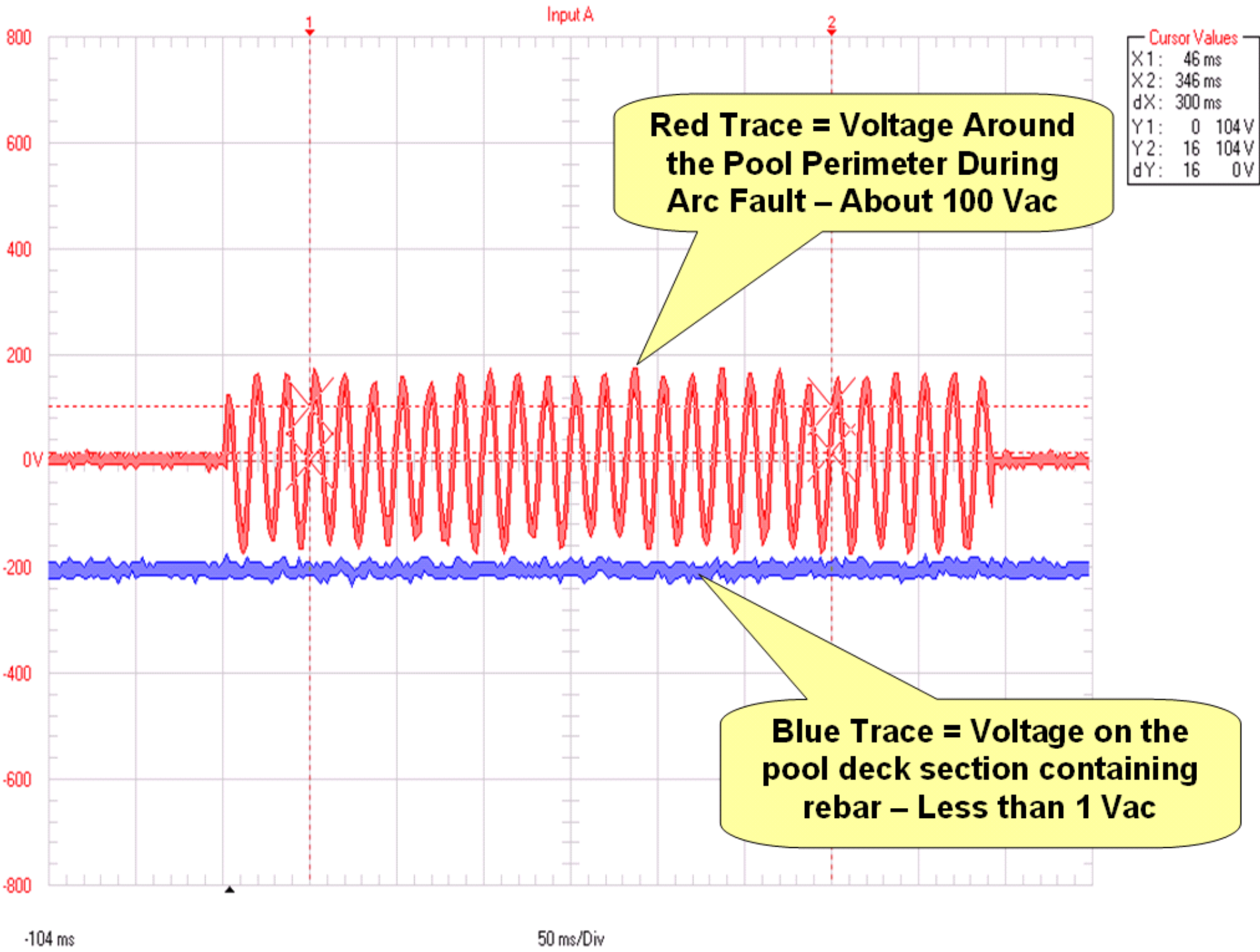






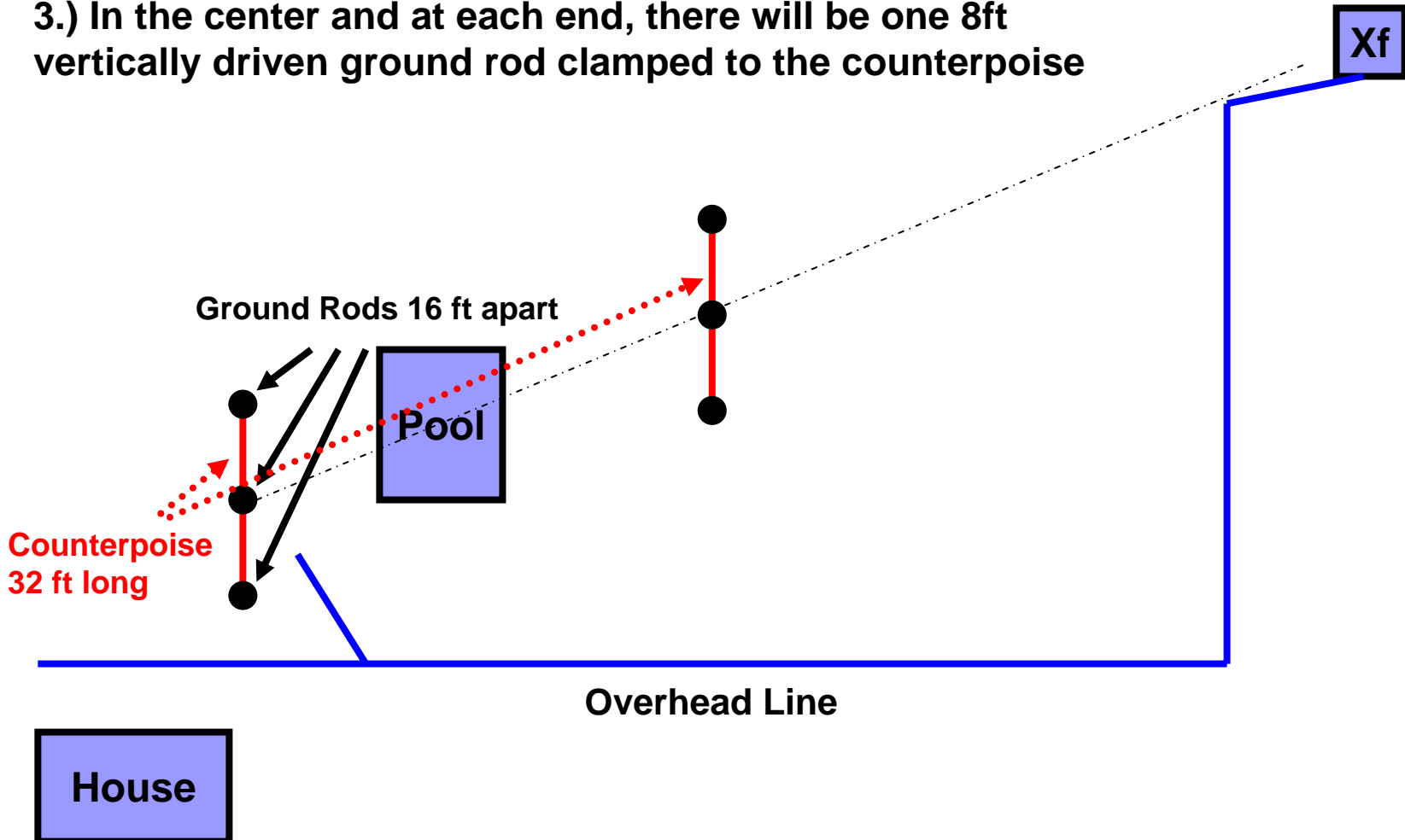
Swimming Pool  
Test Structure





# Fault Testing to force current thru pool

- 1.) Red Line indicates location of trench for counterpoise
- 2.) Specifications: 1 ft deep, 1 ft wide, 32 ft long
- 3.) In the center and at each end, there will be one 8ft vertically driven ground rod clamped to the counterpoise



# Power System Failures are predictable



# Vision applied to future pool complaints

- Develop Appropriate Investigation Procedure and Solutions
  - Identify whether a “break” or lack of proper Equipotential Grid exists
  - Present the findings to the pool owner with the pro’s and con’s of available solutions
  - Ensure that the safety of the public drives the solution and that risks are adequately identified



# Questions?

Breaks in swimming pool equipotential grids may cause voltages to be felt... what should the utility do?