

Stray and Contact Voltage Investigation Methodologies and Resource Estimates

Because being shocked in or around in-ground swimming pools can have adverse and even fatal consequences, reports of such events must be investigated by trained professionals knowledgeable in both electrical testing protocols and methods for constructing swimming pools. It is difficult to find publicly available statistics on the number of investigations into complaints of swimming-pool shocks conducted annually. However, EPRI has obtained anecdotal insights over the past 25 years, based on field visits and interviews with subject-matter experts who conduct such investigations. Based on these insights, EPRI estimates that the number of investigations into complaints of shocks around swimming pools and other wet areas in the United State ranges from 500 to 1000 per year. The typical cost of such an investigation ranges from \$10,000 to \$20,000 dollars, and the follow-on costs to implement equipotential remediation are in a similar cost range, depending on the original decking construction. To support these estimates, this document provides a discussion of the types of diagnostic tests required for such investigations.

One logical way to determine the overall cost of inadequate equipotential bonding could be to multiply the average cost for an investigation into a shock complaint by the average number of investigations done per year. This approach, however, significantly understates the problem. The real problem is that every in-ground swimming pool constructed to the 2008 NEC or any newer code versions is a pool “at risk” of becoming a shock hazard for pool users. Just because a shock complaint has not yet been registered is not a relevant method for understanding the overall cost/benefit of ensuring equipotential during the original pool construction.

A more thoughtful method to determine the overall cost to investigate a shock hazard at in-ground pools would be to assume that any pool constructed after the 2008 code adoption are “at risk” and are in need of an equipotential bonding and remediation assessment—regardless of whether or not a shock complaint has yet been registered. Given the fixed cost to eliminate the shock hazard in the upfront design, a reasonable model for the cost/benefit analysis would assume that the upfront cost of building the pool with no future equipotential and shock risk is definable, and that cost is between one and two orders of magnitude lower than the cost of having to conduct a future investigation and initiate remediation project. The differential between these costs can be defined on a per-pool basis and then extended to statewide or nationwide cost savings.

According to IEEE 2016 (*Guide to Understanding, Diagnosing, and Mitigating Stray and Contact Voltage*) and EPRI report 1020096 (*Guidebook for Evaluating Elevated Neutral-to-Earth and Contact Voltages in Distribution Systems*), understanding the reason for a shock complaint at an in-ground swimming pool requires five considerations:

1. Any utility-side contributions to stray and contact voltage conditions at the location of the shock complaint.
2. Any customer-side contributions to stray and contact voltage conditions at the location.
3. The electrical-side grounding and bonding scenarios at the location.
4. Compliance with National Electrical Code (NEC) article 680.26.
5. Equipotential bonding at the subject swimming pool.

Each of these unique investigation components has its own objectives, qualifications, and investigation criteria of a subject-matter expert. The following table includes the objective, required equipment and

resources, and estimates of the manhours and other costs required for each component of an investigation of shock complaints at a swimming pool.

Investigation Component	Objective	Required Equipment and Resources	Time and Resource Cost Estimates
Utility Wiring and Neutral-to-Earth Voltage Characterization	Determine the voltage drop on the primary power-distribution system over time as the system loading varies.	Bucket Truck, Line Crew, Data Logger or PQ Monitor, and Stray Voltage Expert	Ranges from minimum of 32 manhours to over 100 manhours plus truck roll cost.
Customer Wiring and Bonding Integrity and Neutral-to-Earth Voltage Characterization	Validate wiring and bonding integrity and determine the voltage drop on the customer power system over time as the system loading varies.	Stray Voltage Expert, Data Loggers, Voltage and Current Meters, Water Gradient Tester, and Assorted Accessories	This work can generally be accomplished in one half to one full day, depending on facility and circuit complexity.
Pool-Area Bonding Integrity Characterization	Validate the bonding means and condition of the bonding network at the pool area and at the circulating equipment.	Stray Voltage Expert, Backup Safety Person, Multimeter, 100-ft Wire Spool, and Other Specialized Accessories	This work can generally be accomplished in 2 to 4 manhours.
Energized Water and Equipotential Surfaces Characterization	Understand the potential for human body shock hazard between water and poolside walking or sitting surfaces.	Stray Voltage Expert, Backup Safety Person, Multimeter, Copper or Stainless-Steel Plates, and Other Specialized Accessories	This work can generally be accomplished in 2 to 4 manhours.
Current Flow Characterization	Understand the potential for in-water voltage gradients and swimmer paralysis.	Floating Gradient Meters or Specialized Equipment for Subject Assessment	This work can generally be accomplished in 2 to 4 manhours.
Reporting and Documentation	Create industry standard documentation to summarize findings and promote understanding of all findings and proposed next steps.	Camera, Meter, Logger Charts and Graphs, and Related Documentation Forms and Checklists	A comprehensive report with detailed findings requires an average of 40 manhours. Follow-up site visits for retrieval of data loggers may add an extra 8 hours of labor.

As previously mentioned, sparse are publicly available statistics on the number of investigations into complaints of swimming-pool shocks conducted annually. However, a few conclusions from EPRI member surveys, interviews, and actual field experiences are as follows:

1. Across North America, every province, state, and service territory tends to be aware of shock or perception complaints associated with in-ground swimming pools. Although the number of in-ground swimming pools varies quite a bit geographically, the shock and perception events can potentially be present at any geographic location if the equipotential bonding between the water and the decking is inadequate.
2. Considering the potential consequences associated with swimming-pool shock complaints, a conservative estimate of time for such investigations and reporting is 80 labor hours per investigation and the allocation of at least one bucket truck for at least one day.
3. Utilities in the Southern United States such as Texas, Florida, and Georgia report four to five times as many shock complaints per year as compared to states further North, which likely corresponds to more weather-friendly swimming and outdoor months per year in those regions.
4. The number of investigations into complaints about getting shocked at an in-ground swimming pool or wet area annually in the United State is estimated to be between 500 and 1000 per year. The typical costs associated with such investigations ranges between \$10,000 and \$20,000 dollars.