C27 Swimming Pool Electrocutions Revisited

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The goal of this presentation is to attempt to verify reported experiments as outlined in a paper titled, “Point Source Electrocution in Swimming Pools and Spas,” presented at the 2002 AAFS meeting. The tests reported in the paper could not be duplicated and did not conform to theoretical results.

This presentation will impact the forensic community and/or humanity by demonstrating an understanding by which forensic engineers evaluate the nature of swimming pool electrocutions.

Since 1990, the U.S. Consumer Product Safety Commission (CPSC) recorded sixty deaths and fifty electrical shock incidents in or around swimming pools owing to defective or improperly installed electrical equipment. In most of these cases, GFCI devices were not included, and the predominating offending electrical appliances were 120 Volt AC pool lighting fixtures.

In either the home or industrial environment, the presence of water clearly serves to augment electrical shock and electrocution risk. The risk is produced by the reduction in human contact resistance brought about by improved contact coupling between the victim and the electrical source via the water. The National Institute for Occupational Safety and Health (NIOSH) observes that the presence of moisture from environmental conditions such as standing water, wet clothing, high humidity, or perspiration, increases the possibility of a low voltage electrocution.[1] However, despite a large amount of literature and research describing shock risk and the water environment, there is still much misconception among electrical engineers regarding the mechanics of shock in damp or waterwet environments.

Typically, the water used in swimming pools, hot tubs, or spas are not ionic fluids and are thus considered poor conductors. As such, it is not expected to see a substantial current flow between two poles immersed in pool water, as the water provides a relatively high resistance path.

Mathematically, the field produced by a live 120 VAC conductor immersed in a swimming pool is a boundary value problem and is best described though Poisson’s equation. The boundary value problem solution describes the field conditions. This equation is derived from Maxwell’s Divergence equation. Maxwell’s Divergence equation in point form is derived by the application of Gauss’ Law to an infinitesimal volume and is stated as:

Equation 1

$$\nabla \bullet \vec{D} = \rho$$

where D = flux density (coulombs/m^2)
ρ = charge density (coulombs/m^3)

Substituting into equation (1) for the electric field intensity **E** and electric potential V, we obtain Poisson’s equation

Equation 2

$$\nabla^2 V = -\frac{\rho}{\varepsilon}$$

where ε = permitivity of the medium (Farads/m)

In free space, $\rho = 0$ so that equation (2) reduces to Laplace’s equation. The nature of the flow of current through a material determines whether the material is a dielectric, conductor, or semiconductor. In liquids, both positive and negative charges are free to migrate. Generally, the conductivity of a liquid is given by

Equation 3

$$\sigma = \rho_- \mu_- + \rho_+ \mu_+$$

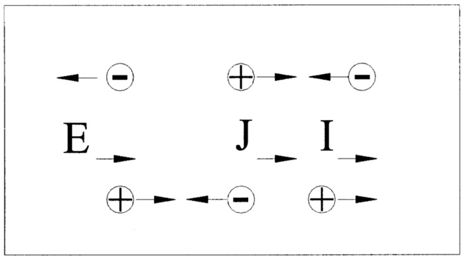
where ρ_-= density of negatively charged particles (coulombs/m^3)
μ_- = mobility of negatively charged particles (m^2/v•s)
+ = positively charged density and mobility

The first term represents the contribution to the conductivity from negatively charged particles moving opposite to the **E** field and the second term represents the contribution from positively charged particles moving with the **E** field.

According to Kraus[2] water has the following conductivities:

Distilled Water	σ ≈10^{-4}	**mhos/m**	**Insulator**
Fresh Water	σ ≈10^{-2}	**mhos/m**	**Poor Conductor**
Sea Water	σ ≈ **4**	**mhos/m**	**Conductor**

The conductivity of a liquid electrolyte is represented in the diagram below and explains the movement of charges and the relative direction of the fields with respect to the movements of the charges.



Swimming pool water has few electrolytes and is therefore at best an insulator or a poor insulator. Measurements of current flow through pool water should not indicate appeciable amounts. Ground fault circuit interrupters (GCFI) have a threshold current of five milliamperes. Currents above this value are recognized to pose a danger to humans in that they may produce a disruptive effect on the equivalent electric dipole of the heart. This effect can produce death.

The field configuration produced by a live conductor in a swimming pool is dependent on its boundaries. This type of problem may be solved by the application of Poisson's equation, graphically, experimentally, or with an analog or digital computer. Experimental tests were conducted in a 20-foot by 25-foot swimming pool standardized at neutral pH, requisite chlorine level, and room temperature. A voltage source was supplied by immersion of a two conductor energized extension cord near the sutface at a location near the submersible pool light fixture to simulate a failed and hazardous ixture. A 5-foot by 5-foot rectangular coordinate grid was formed. The grid provides voltages and current measurement distance targets to help explain a field map of the energy distribution in the x-y plane of the pool. A human model was simulated in accordance with IEC 479 and UL data to approximate a nominal human surface area. The model, constructed from a twenty-four guage galvanized steel sheet, buoyancy foam, insulators and resistors, was positioned at the various grid nodes while voltage and current measurements were recorded. The findings of the test show that for a substantive shock risk and injury to occur to an immersed human subject, certain physical contact must be made with an energized conductor, regardless of conductor immersion, conductor surface area, or water chemistry, and the water container must present a definite ground. The findings of this test could not reproduce the conclusions reached in a previous AAFS paper and show substantive flaws in the reasoning and the conclusions reached in that paper.

The voltage measurements along the pool grid were essentially insignificant until the probe was very near the source. Similarly, current measurements were in the microampere range under these conditions. Essentially in this case, the tests indicate that physical contact with the source and grounding of the individual is necessary to produce an electrical shock incident. The electric field produced in a water environment is dependent on the energized surface area, the water chemistry, and the characteristics of the ground.

References:

1. U.S. Department of Health and Human Services, Public Haelth Service, Centers for Disease and Prevention, National Institute for Occupational Safety and Health (NIOSH) Worker Deaths By Electrocution - A Summary of NIOSH Surveillance and Investigative Fingings, p.7.
2. Krauss, John D., Electromagnetics, Third Edition, McGraw-Hill, p 123.

Electric Field Intensity, Conductor, Poisson's Equation