Evaluation of Ground Ring vs. Equipotential Mat at a Swimming Pool in Buford, Georgia

NEETRAC Project 08-132

August, 2008

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SUMMARY

The 2008 National Electric Code (NEC) allows installation of an alternate means 680.26(B)(2)(b) (ground ring) around nonconductive pools, nonstructural steel and encapsulated steel swimming pools in lieu of an equipotential copper bonding grid to mitigate abnormal water-to-deck voltages around swimming pools. This allowance was not present in the previous versions of the code. There have been cases where a ground ring did not provide adequate protection for the swimmers and the public.

Mr. Reuben Clark of Consolidated Manufacturing International (CMI) requested NEETRAC to investigate the effectiveness of a ground ring vs. equipotential copper bonding grid in mitigating water-to-deck voltages around a swimming pool during normal as well as abnormal operations of the power supply system. In accordance with the request, Shashi Patel and Barry Fairley of NEETRAC conducted tests around a residential swimming pool in Buford, Georgia on June 30, 2008.

The test consisted of electrically isolating the pool and associated equipment and supplying a current from a 120 volt outlet from the house. After energizing the pool to about 95 volts, several water-to-deck voltages were measured under two different grounding scenarios. In the first scenario, a ground ring was installed around the pool. The ring was removed and an equipotential copper bonding grid was installed in the second scenario.

The test data showed that the 3' wide equipotential copper bonding grid provided adequate protection to the swimmer and person walking on the deck by substantially reducing the water-to-deck voltages in the range of 70 to 93% compared to the alternate ground ring electrode, which may not provide adequate protection.

BACKGROUND

Bonding of metal parts in and around a swimming pool to an equipotential bonding grid is extensively covered in Article 680.26. The intent of this bonding is to equalize the voltages between the pool water and the deck including any attached metal structures or parts. Article 680.26(C) of the 2005 NEC has been an effective method in mitigating stray voltage problems by establishing an equipotential copper bonding grid. This is critical for fiberglass swimming pools or pools with insulated liners, concrete pools with no structural steel elements or fibercrete and encapsulated steel pools.

The 2008 NEC under 680.26(B)(2)(b) allows installation of an alternate means (ground ring) for perimeter surfaces in lieu of an equipotential copper bonding grid for mitigation of abnormal water-to-deck voltages. This allowance was not present in the previous versions of the code. There have been cases where a ground ring did not provide an adequate protection for the public and private pool users. For this reason, Mr. Reuben Clark of Consolidated Manufacturing International (CMI) requested NEETRAC to investigate the effectiveness of a ground ring compared to equipotential copper bonding grid in mitigating water-to-deck voltages around a swimming pool during normal as well as abnormal conditions of the power supply system.

APPROACH

A field project was designed to measure water-to-deck voltages at an existing swimming pool in Buford, Georgia. The design included measuring voltages under two scenarios, first by installing a ground ring and then replacing it by an equipotential copper bonding grid.

POOL DESCRIPTION

Figure 1 shows the pool used for this investigation. The 14' x 31' pool consists of fiberglass material with a fibercrete lip around it. The fibercrete lip also secured the coping stones. The deck is made up of stone pavers that are sitting on fine sand and crusher run. There are no rebars in the entire pool shell. With the exception of an underwater light, there is no other metallic part in contact with the pool water.

The alternate means (ground ring) consisting of #8 AWG solid copper was buried around the pool first. The conductor was buried approximately 6" deep and 24" from the edge of the water as shown in Figure 2. After burying the ring, the soil was covered up and properly compacted. Pavers were installed prior to making measurements. Following the ground ring measurements, the conductor was removed and a 3' wide equipotential copper bonding grid was installed as shown in Figure 3. The equipotential copper bonding grid completely encircled the perimeter of the pool. The bond wire from the light niche, as well as the wire from the pump and the wire from the electrical panel, were all bonded to single wire via UL listed split bolts as shown in Figure 4. Figure 4 also shows two electrical panels. A four wire 240 volt power supply is received in the left side panel with a disconnecting switch. The wires from this panel go to the right hand side panel with a breaker. The wires from the output side of the breaker then go to the pool equipment.

The house and the pool are served from an overhead transformer which also serves one other house.

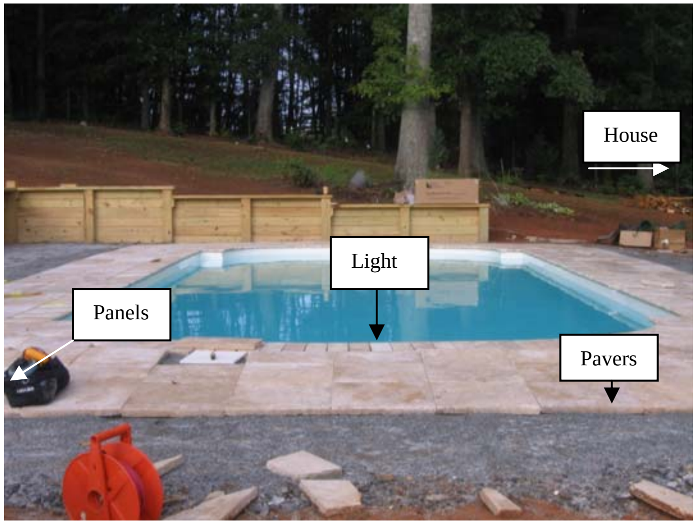


Figure 1: General Layout of the Pool


Figure 2: Installation of Ground Ring


Figure 3: Installation of Equipotential Ground Mat

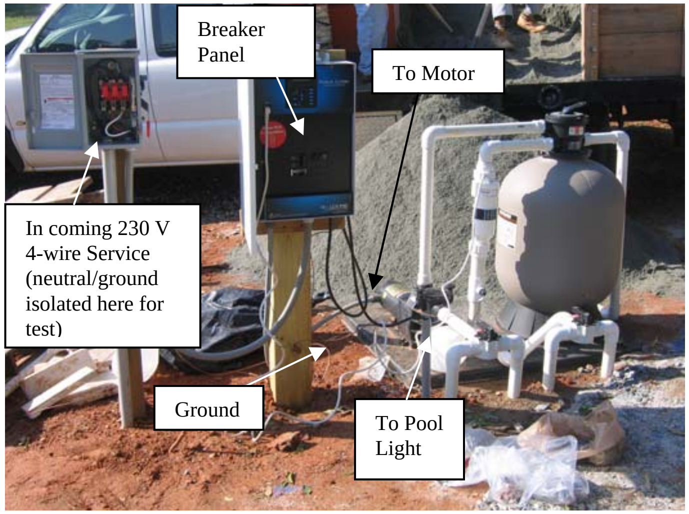


Figure 4: Electrical Panels Serving Pool Equipment

TEST PROCEDURE

The tests were performed on 6/30/2008. During the tests, the weather was partly cloudy and mild. The soil was wet due to previous rain.

The neutral to earth and resulting water-deck voltages at the swimming pool were expected to be small and therefore, a customized test procedure to raise the voltage gradients around the pool was designed and carried out.

Figure 5 shows the test set up. The pool equipment including the light were isolated at the switch panel by opening the disconnect switch and physically isolating the ground wire from the ground bus. A 120 volt, 10 amperes variac was then connected between the equipment ground by the panels and a current return ground rod located approximately 160 feet from the pool. A Fluke ammeter was connected in the circuit to measure the test current. Another reference rod was driven to measure the ground potential rise (GPR) of the pool and connected ground approximately 125 feet from the pool in perpendicular direction to the current return rod.

The test consisted of passing a current between the pool ground and the current return rod and measuring water-deck voltages along eight radial directions (AA through HH) as shown in Figure 5. With the exception of directions AA and EE, the voltages were measured at 0.5’, 1’, 2’, 3’ and 4’ distances from the edge of the water. The location of the last measurement was at 3.5’ distance from the water along directions AA and EE. Figure 6 shows an example of water-deck voltage measuring procedure.

With approximately 95 volts applied, the water to deck voltages around the pool were measured for two different bonding scenarios. The test data for these bonding scenarios are presented and discussed in this report. These scenarios are as shown below:

Scenario 1: Pool light, pool equipment, pool water and ground ring are bonded together.
Scenario 2: Pool light, pool equipment, pool water and equipotential copper bonding grid are bonded together.

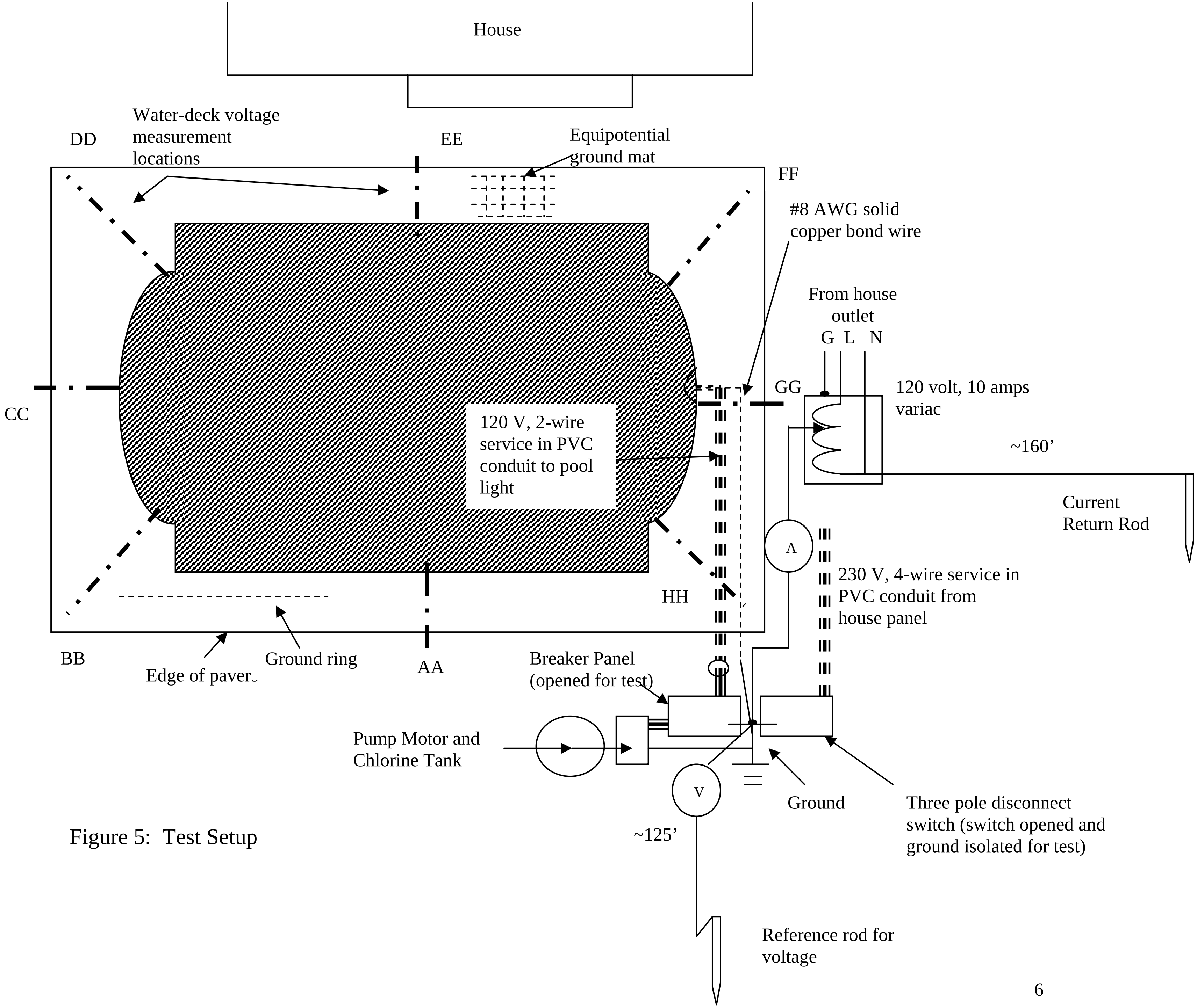


Figure 5: Test Setup

Figure 6: Typical Water-Deck Voltage Measurement

TEST DATA AND ANALYSIS

The Tables 1 and 2 show water-deck voltages for alternate means (ground ring) and equipotential copper bonding grid scenarios respectively. The last column in each table shows the step voltages. These voltages are calculated by taking a difference between water-deck voltages measured at 4’ and 1’ distance.

Each of Figures 7 through 14 shows a comparison between water-deck voltages measured with the ground ring and those measured with the equipotential copper bonding grid. Figure 15 provides a quantitative measure of the equipotential copper bonding grid’s effectiveness in reducing the water-deck voltages. The graph in Figure 15 shows % reduction in voltages due to the equipotential copper bonding grid compared to those due to the ground ring.

Referring to Figure 15, the equipotential copper bonding grid reduced the water-deck voltages in the range of 70% to 93% compared to voltages measured with the ground ring surrounding the pool. This investigation also compared the step voltages around the swimming pool as shown in Figures 16 and 17. The equipotential copper bonding grid reduced step voltages in the range of 57% to 97% compared to those measured with the ground ring.

Table 1
Water-Deck Voltage Data with #8AWG Ground Ring Circling the Swimming Pool

Scenario	Measurement Location (Figure 5)	Water-Deck Voltages (Volts)					*Step Voltage (Volts)
		Distance from the Edge of the Water Feet)					
		0.5	1	2	3	4	
<u>Scenario -1</u> - #8 AWG, bare, solid copper ring installed approximately 24” from the water and 6” deep. - Pool water, pool equipment and the ground ring bonded together. - Ground Potential Rise = 95.4 volts, Ground current= 0.98 amperes	AA	4.88	4.98	5.14	9.42	13.90 (@ 3.5’)	8.92
	BB	6.03	5.98	6.90	12.12	18.60	12.62
	CC	7.43	7.46	7.83	12.70	18.30	10.84
	DD	7.30	7.30	10.50	15.00	21.90	14.60
	EE	6.10	6.20	6.40	10.10	11.50 (@ 3.5’)	5.30
	FF	10.50	10.60	12.50	19.00	24.70	14.10
	GG	8.70	8.50	9.50	13.70	21.70	13.20
	HH	5.90	5.85	6.70	9.60	14.40	8.55
	AA (Repeat)	5.00	5.00	5.00	10.40	11.70 (@ 3.5’)	6.70

* Calculated by taking a difference between water-deck voltages measured at 4’ and 1’ distances.

Table 2
Water-Deck Voltage Data with #8 AWG Equipotential Ground Mat Circling the Swimming Pool

Scenario	Measurement Location (Figure 5)	Water-Deck Voltages (Volts) Distance from the Edge of the Water Feet) 0.5	1	2	3	4	*Step Voltage (Volts)
Scenario -1 - #8 AWG, bare, solid copper equipotential ground grid installed approximately 1'-3.5' from the water and below the pavers. - Pool water, pool equipment and the ground mat bonded together. - Ground Potential Rise = 95.6 volts, Ground current= 1.13 amperes	AA	1.56	1.25	1.31	1.87	3.62 (@3.5')	2.37
	BB	0.92	0.85	0.95	0.86	1.52	0.67
	CC	1.23	1.24	1.50	1.46	2.87	1.63
	DD	0.93	0.89	0.95	0.95	1.37	0.48
	EE	1.23	1.27	1.53	2.30	3.60 (@3.5')	2.34
	FF	0.97	0.87	0.95	1.50	4.40	3.53
	GG	0.90	0.78	0.96	1.13	3.60	2.82
	HH	0.89	0.80	0.84	0.89	1.34	0.54
	AA (Repeat)	1.50	1.30	1.40	1.50	3.40 (@3.5')	2.10

* Calculated by taking a difference between water-deck voltages measured at 4' and 1' distances.

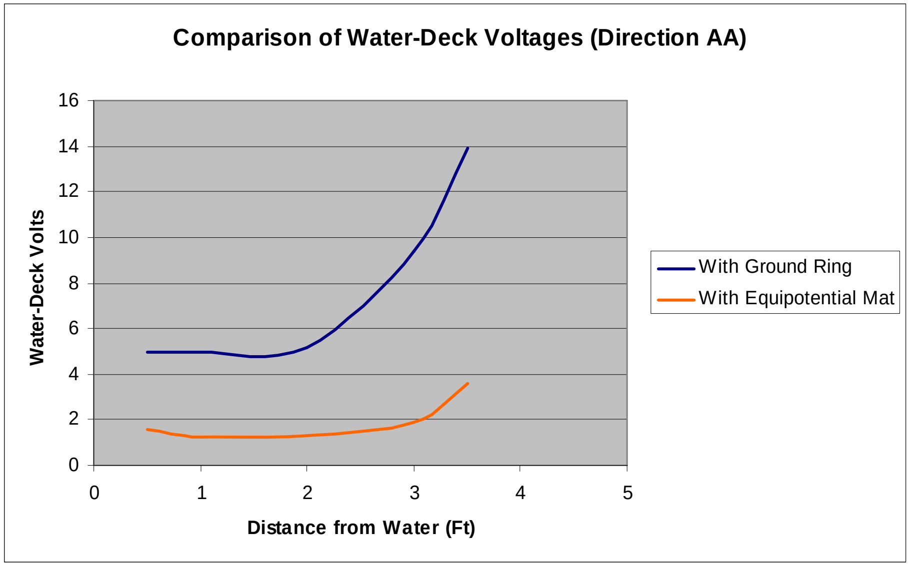


Figure 7

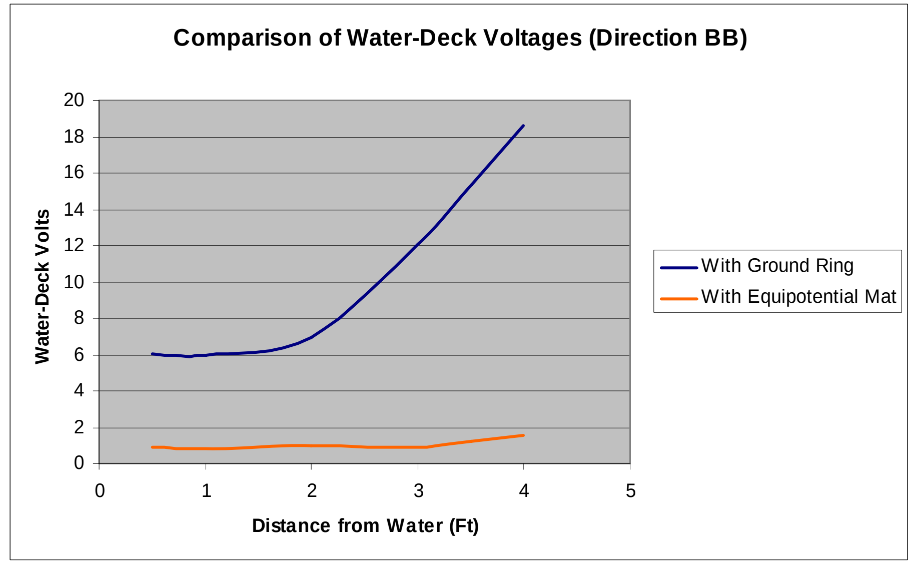


Figure 8

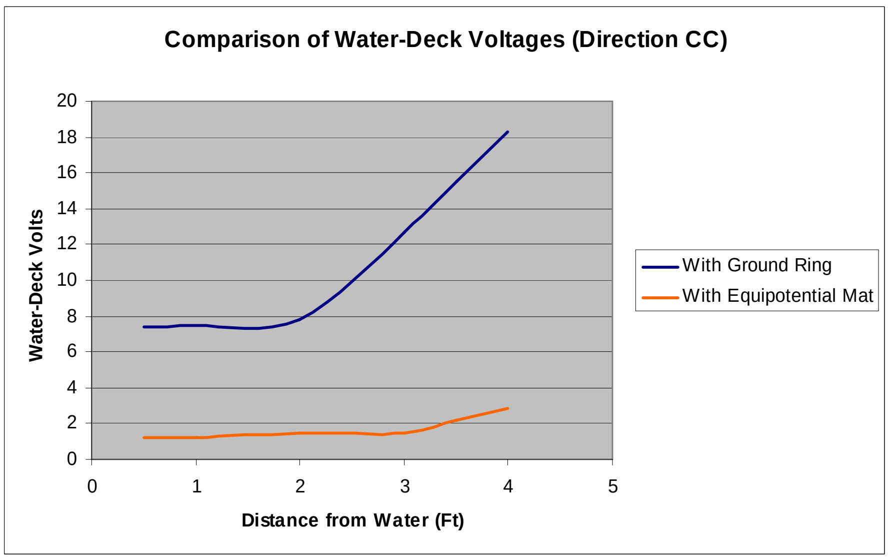


Figure 9

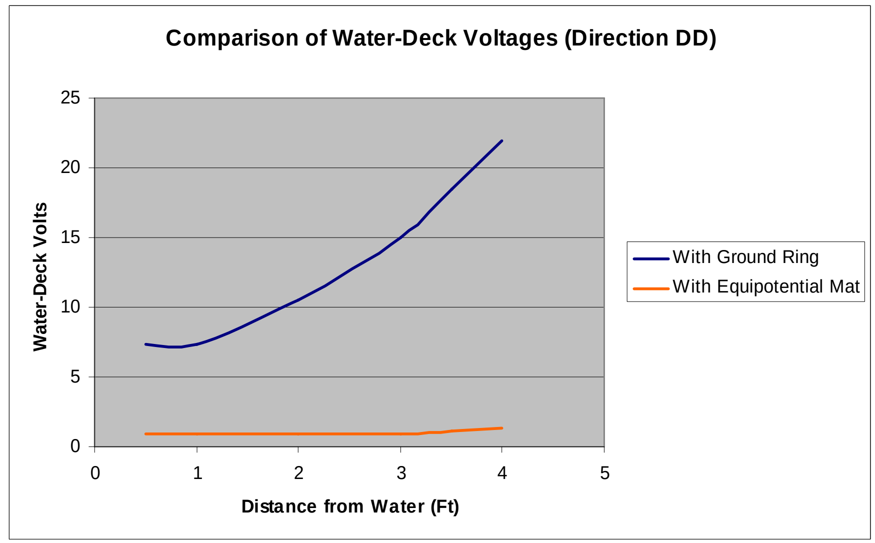


Figure 10

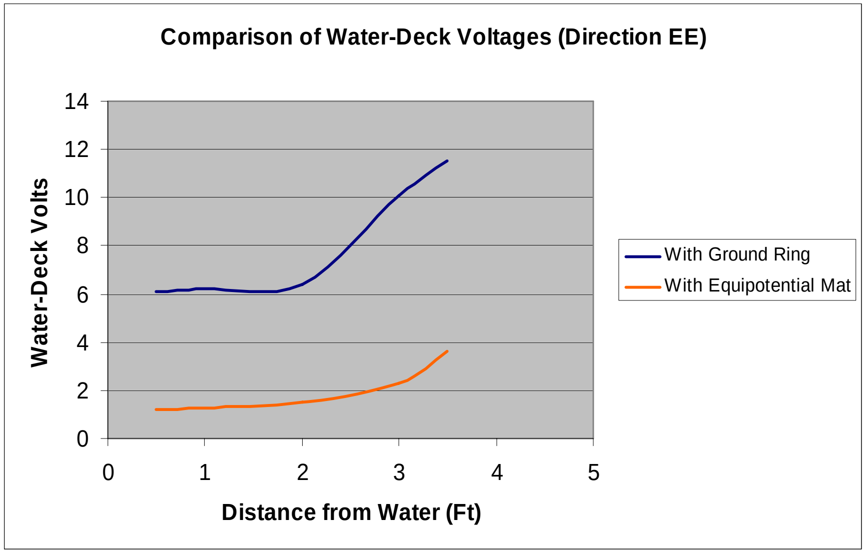


Figure 11

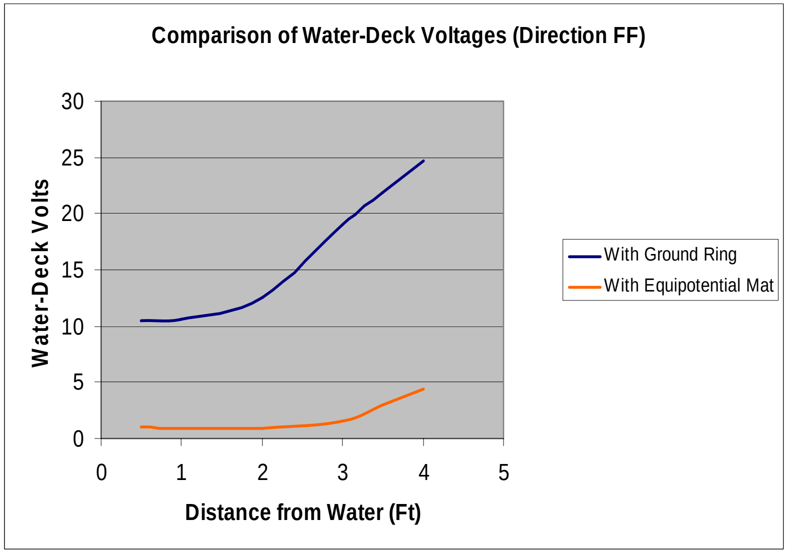
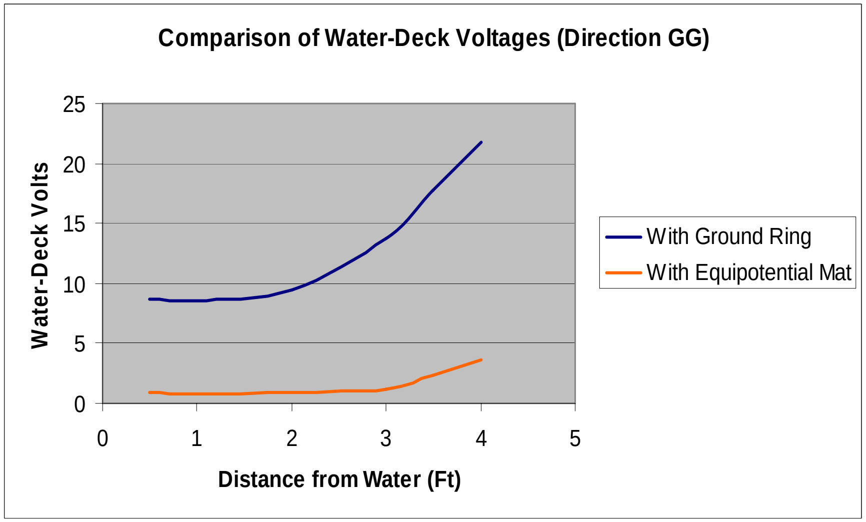


Figure 12



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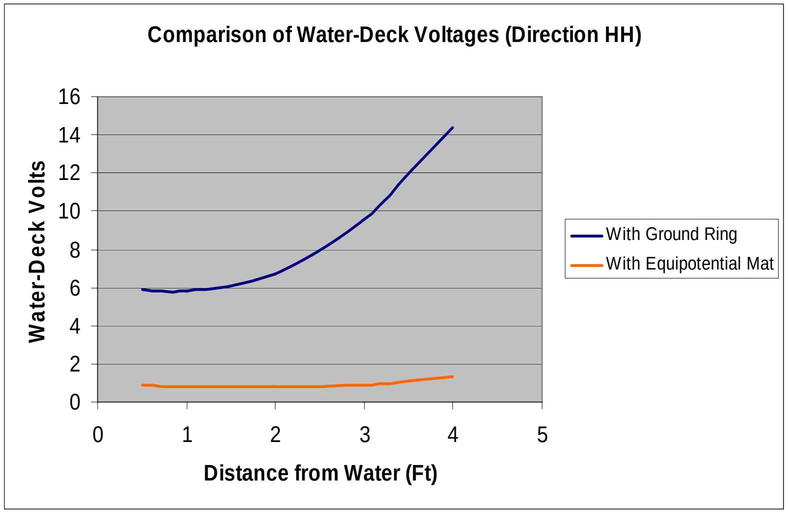

Figure 14

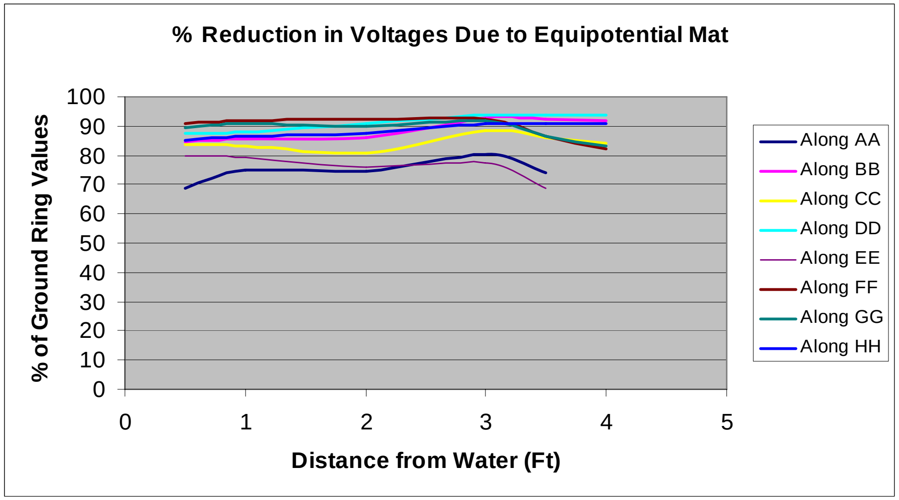

Figure 15

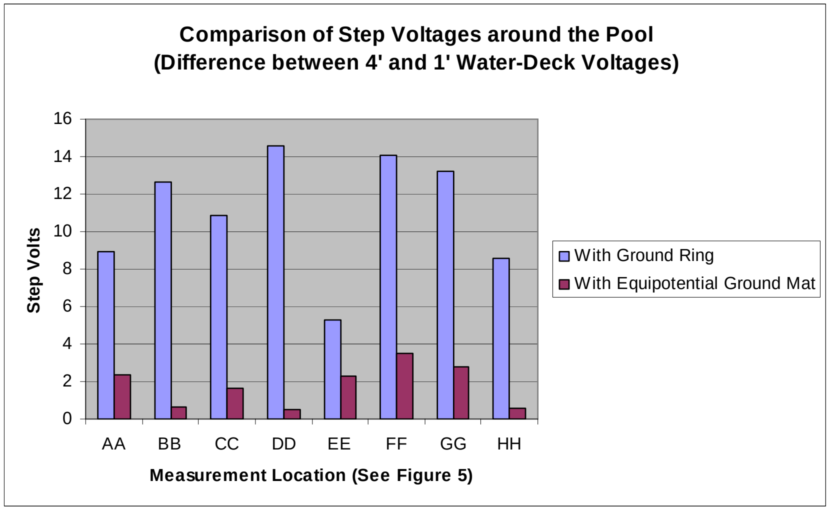

Figure 16

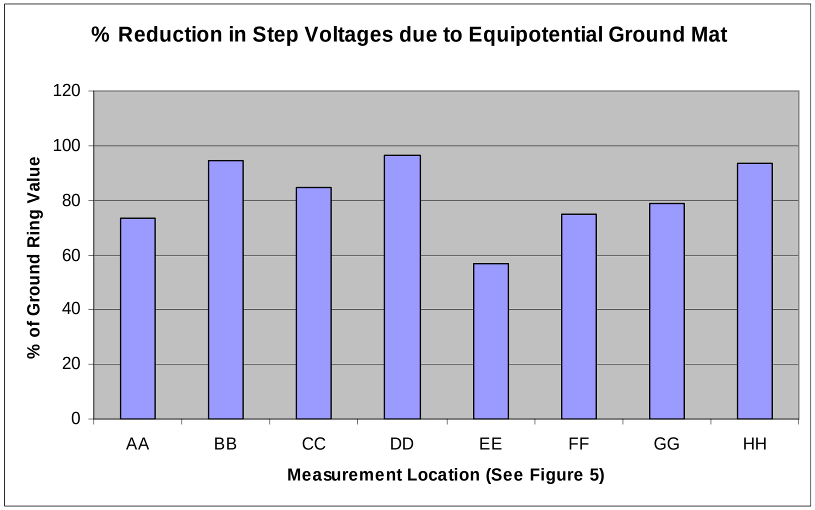

Figure 17

CONCLUSION

There are several sources of touch and step voltages that can exist around a swimming pool. Some of these sources such as neutral-to-earth voltages or stray voltages are due to normal operation of the power system. Typically less than 10 volts, these voltages result from the load current returning to its source through a multigrounded neutral system. Higher voltages may also exist if the secondary neutral is corroded or, in an extreme case, is open. Another source that can cause high voltages around the pool area is a high impedance fault in an underground cable circuit. This type of fault is characterized by lower current and higher voltage and can remain undetected for a long time. Although the probability is extremely small, a phase-ground fault on the primary cable can bring high voltages in the swimming pool areas. These voltages are significantly high but usually are of short duration.

The data of this investigation proves unequivocally that an equipotential copper bonding grid around a swimming pool can and will effectively mitigate the voltages described above and provide adequate protection to the swimmer and person walking on the deck. The alternate means (ground ring) described in 680.26(B)(2)(b) of the 2008 NEC may not provide adequate protection to the swimmer and person walking on the deck. The test data is supportive of the University of Wisconsin, Midwest Rural Energy Council, American Society of Agricultural and Biological Engineers, and the University of Minnesota’s test data for equipotential bonding grids in dairy barns and Article 547 of the NEC.

EQUIPMENT

Fluke 87 (CQ 4007) for voltage measurement
Fluke 87 (CQ 4028) for current measurement