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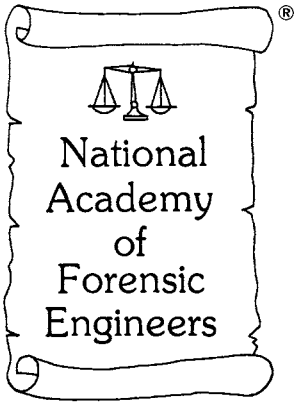

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Forensic Engineering Experience with Purported Electric Shocks

By Roger L. Boyell, P.E. (NAFE 696F)

Abstract

This paper summarizes the author's investigations into 12 different complaints of electrical contact causing bodily injury or death. Numerous photographs are provided for clarification. The 12 scenarios range from **obvious** to **unforeseeable**, and from **expected** to **impossible**.

Keywords

Electric Shock, Electrical Injury, Electrical Contact, Electrocution, Electric Circuit, Electrical Damage, Electrical Hazard.

Electrified Outside Sign

An experienced electrician was called to repair an illuminated free-standing sign. The complaint was intermittent operation. The following scenario was reconstructed from witness statements and after-incident examinations.

Figure 1

As illustrated by Figure 1 the electrician removed the translucent letter board and diagnosed the failure as due to a defective fluorescent lamp ballast, shown in Figure 2. Being familiar with the facility from previous visits, he turned off the circuit breaker for the building's "Outside Lights" and began to change out the ballast.

Figure 2

The detailed wiring diagram printed on the ballast can be seen in Figure 3. The primary winding accepts 120 V ac (volts, alternating current). Multiple taps on the secondary are used to feed individual fluorescent lamps with high voltage to strike, then limited current to remain illuminated. With no load the secondary winding develops 1,500 V center-tapped to ground.

Roger L. Boyell, 416 Parry Drive, Moorestown NJ 08057-2877

Kneeling on the grass and leaning against the sign, the electrician connected the primary wires using twist connectors, while experiencing no problem. When he picked up the secondary wires he apparently received a shock, as he exclaimed loudly, stood up, threw down his electrician's pliers, and fell back on the grass, face up. He expired in a few minutes, before emergency help could arrive. The medical examiner said death was due to heart failure from electric shock.

Figure 3

We do not know whether the electrician read the warning of Figure 4, also printed on the ballast. If he had used a meter or voltage probe he would have recognized that he was working, unintentionally, on a hot circuit. Later it was found that the circuit breaker he should have turned off was the one labeled "Outside Sign".

Figure 4

In addition, his procedure of connecting the primary wires before connecting the high-voltage secondary was logically flawed. The flaw was fatal in every sense of the word.

Steam Table

A restaurant worker complained of receiving a disabling electric shock from wires he said were exposed under a steam table. As shown in Figure 5 the steam table had a heavy cord and plug, and it drew 20 A (amperes) from a 240 V circuit, making it a good candidate for an accusation of shock.

Figure 5

Figure 6

And so it was that a legal claim was filed. The steam table was placed in storage until an engineer could investigate the complaint. Then the underside of the steam table shown in Figure 6 was found to be all metal with nothing exposed except a drain cock which itself was metal. No wires were present.

All surfaces were electrically connected and solidly grounded through the cord and plug. No leakage current flowed from steam table frame to earth ground. The receptacle in use at the time of the incident exhibited a solid ground.

Shock to the client from the steam table as described was thus impossible. When the lawyers were confronted with these findings, the claim was abandoned.

Baggage Scanner

Sometimes the initial focus of an investigation of electric shock is misplaced. While inserting the attachment plug for a baggage-scanning X-ray machine, an operator received a shock/flash/burn to her hand. The machine's manufacturer was placed on notice, and a formal examination of the machine was conducted – which revealed nothing.

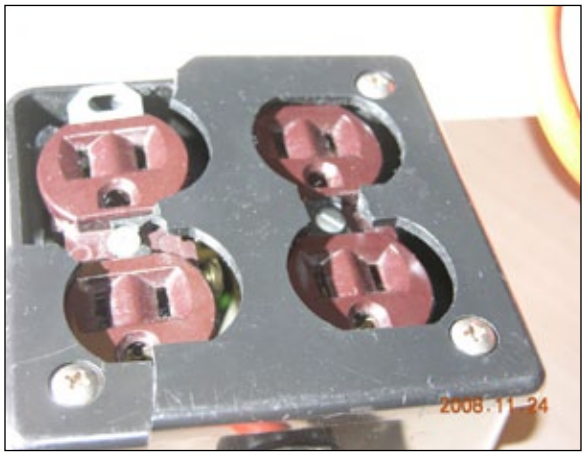

Figure 7

After lengthy legal process another party was compelled to produce the extension cord into which, it was learned, the machine was being plugged at the time of the incident. Figure 7 shows the portable outlet box whose plastic cover plate was fractured and whose receptacle yokes were unsecured. Its condition explains why the party was unwilling to provide it for examination.

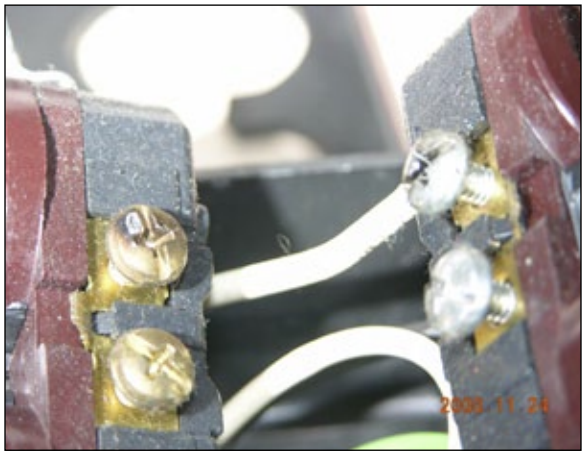

Figure 8

Reconstruction of the incident (but not under power) showed that plugging in any appliance cord set would dislocate the loose receptacles. When finally opened for examination the box showed electrical scars seen in Figure 8, where the hot side of one receptacle had contacted the neutral side of the other receptacle.

The electric arc which occurred in the damaged box could certainly have given rise to the claimed shock/flash/burn injury. The case against the manufacturer of the baggage-scanning X-ray machine was dismissed, and the party supplying the extension cord became the defendant. A confidential settlement was rapidly reached.

Hot Tin Roof

The electrical junction box shown in Figure 9 illustrates many National Electrical Code violations: stressed and overstuffed connector body, L-body should have been straight type, unapproved retaining clamp, PVC pipe instead of a listed fitting for the armored cable.

Figure 9

An air conditioning technician observed these violations while checking the rooftop air conditioning unit shown in Figure 10. He claimed that the shock and burn he received from an electrically energized surface of the unit disabled him such that he couldn't do any more air conditioning work.

Figure 10

Careful engineering examination of the entire unit shown in Figure 11 revealed no electrical hazard. Despite its appearance no conductors were accidentally exposed or shorted, and the junction box afforded no opportunity for insertion of even a child's finger.

However, the metal roof itself was indeed hot. The examination was conducted at around noon and on a date close to the Summer Solstice. The shadow of the pipe in the foreground of Figure 11 shows that the Sun was essentially overhead. The real danger to workers on that corrugated metal deck was found to be the baking temperature of the roofing material, which was hot enough to burn foot soles even through leather shoes.

Figure 11

Giving the worker the benefit of a doubt, perhaps he confused electrical burn with thermal burn from the rooftop unit. In any event, the original claim evaporated.

Abandoned Overhead Crane

The wires shown in Figure 12 ran across the 5-meter-high ceiling of a dingy warehouse, serving an overhead crane which had not been operational for many years. The old crane was simply abandoned, off in a corner of the bay, because its scrap value would not have covered the cost of removal.

Figure 12

Figure 13

A worker installing security cameras used a 3-meter-high forklift platform to boost himself up toward the ceiling. Losing his balance he grabbed the wires for support. His hand made contact with two of the wires, and an arc flash vaporized much of his hand before he fell to the floor.

The investigators, crawling through a crumbling and dusty section of the warehouse, found the cobweb-draped disconnect switch shown in Figure 13. Sure enough, it served the abandoned crane wires with 460-volt 3-phase power, and its rocker switch was still in the ON position. Liability of the warehouse owner to an employee of an outside contractor was the subject of the subsequent litigation.

Unresolved Copy

A copy machine operator was stacking just-printed pages from a copying machine when she suffered a spark-like shock to one hand. No scene documentation or photographs were taken. Over the years her arm nerves degenerated all the way up to her shoulder.

During the same interval legal arguments were made about worksite conditions, preservation of the copying machine, responsibility for a contract employee using rented equipment, and so on. Eventually a similar copying machine configuration was provided for examination.

Figure 14

Figure 15

As shown in Figures 14 and 15 the basic machine was coupled with a 'buffer' and a 'sorter' as separate chasses. One theory of the incident was that the just-ejected paper carried a sufficient static electric voltage to spark across the operator's hand to the grounded machine, although the injuriousness of the minute current from a static discharge was questioned.

Another theory was that the separate chasses, being simply pushed in to position, were not electrically bonded. Somehow the potential of one chassis was raised 120 V ac with respect to another, across which the operator's hand was moved. Of course a third theory was that the incident didn't occur.

Figure 16

The engineering examination was compromised, as the actual machine configuration was not fully preserved after the incident. Burdened by mounting legal costs to explain and refute suppositions and conjectures, and to argue who was responsible for spoliation of evidence, the case settled before the actual trial.

Sometimes a reasoned scientific explanation of an incident cannot be offered.


Figure 17

Laser Power

Other times an electrical incident represents a known hazard waiting to happen.

A well-known manufacturer of high-voltage power supplies had a subsidiary whose specialty was serving the high-power laser industry. They produced a unit which held 15,000 V dc to tight tolerances for regulation and ripple even when subjected to loads up to 300 mA (milliamperes). To test such a laser-driving power supply they built fixtures of the type shown in Figure 16.

The fixture includes a switch which slams a 50,000-ohm, 5,000-watt heating element across the otherwise unloaded 15 kV supply, while instruments track its performance. Figure 17 shows some of the other components associated with the test fixture – obviously not a commercially sold device.

Figure 18

A worker for the company was performing the final test of a newly manufactured power supply. He turned the power off to make an adjustment of the test fixture; the power supply output was at zero voltage. When he reached into the test fixture several minutes later he was electrocuted. (Electrocution: death by electricity.)

No one in the company had informed the worker that the component at the upper right of Figure 17 was a capacitor. Its markings are in the close-up of Figure 18. (It is ironic that the capacitor is labeled to contain no harmful chemicals. It bears no warning about harmful electricity.) Although the worker had attended safety briefings, he had never been given a shorting bar. He didn't know the capacitor would retain any of the 15 kV charge.

Based on the time constant of a leaky circuit whose capacitance is 0.1 microfarad into the bleeder resistor of 1,000 megohms we estimate the worker contacted 5,000 volts. The company received a citation from the Occupational Health and Safety Administration and revised its practices accordingly. The estate of the worker was unsuccessful in their lawsuit against the company for gross negligence.

An Earful

Claims of electric shock to a subject may be difficult to verify. The user of the telephone set illustrated in Figure 19 suffered damage to her ear and head, allegedly an electric shock from the handset. Investigation of crossed power lines, lightning strikes, and dielectric withstand of the plastic all refuted the claim of electric shock.

Figure 19

Perseverance by the claimant's lawyer raised the possibility of acoustic shock. An intermittent connection was found to initiate the boot-up sequence of a microprocessor in the base of the telephone while the earpiece remained unmuted. The unexpected static may have been a blast in the ear of the unalerted user.

Experts differ about the cause and the severity of the possible acoustic – but not electric – shock to the ear. The legal case for damages was dismissed and appealed, then upheld and reheard, and is still pending at press time of this paper.

Sorry, My Error

Electric power networks incorporate network protectors to disconnect the power under fault conditions such as line-to-ground short circuits. Simulating faults in electric networks requires test equipment. One such device is an Automatic Network Protector Test Box shown in Figure 20.

Figure 20

Figure 21

The user is instructed to apply the safety ground clamp a to a reliable earth ground, before connecting any test cables to the multipin connectors. Do not assume a 'neutral' conductor is at ground potential. Maintain the "Safety Ground" wire, shown at the upper left of Figure 20, connected to a securely grounded conductor such as the unpainted frame of an electric switchboard. Use the clamp shown in Figure 21, all through any test procedure.

A worker operating of necessity in standing water down a manhole got shocked while holding the test box and manipulating its cables to effect a network protector test. His complaint was investigated with a view to determining how the ground wire and ground clamp could have allowed the test box to rise in potential.

Under questioning the worker admitted that he had not secured the clamp to a known earth ground but simply let it pinch a convenient nearby surface to hold the wire out of the way. Having disregarded formal instructions, his shocking claim was dismissed.

Not an Open and Shut Case

A completely disabling electric shock was reported by a victim who held the handle of the door shown in Figure 22, and a witness testified that the victim exclaimed he was hurt when he pulled on the handle.

It was a metal door with metal hinges hung on a metal frame inside a concrete building. Everything was solidly interconnected and grounded. Wires for the card reader, exit pushbar (The pushbar was on the opposite side of the door.), and door strike are all low voltage (12 V dc, 24 V ac), and all were in metal conduit as shown in Figure 23. Apparently the victim had been hauling something with his other hand at the time of the alleged shock from the door. Further, other people used the same door on the same occasion, and no else reported an injury from it.

No means of electrifying the door itself could be supported. Examinations were made by a host of experts for the victim, the facility, the builder, the security card reader supplier, the pushbar supplier,

Figure 22

Figure 23

the control system installer, and the manufacturer of the electric strike. Even if the door somehow became momentarily electrified with respect to ground, the victim's shoes were measured to have zero conductivity. Nevertheless he and his lawyers persisted in continuing the claim against the facility, while his medical condition degraded – allegedly all caused by the original shock.

After four years of accusations, complaints, court pleadings, and expert reports, the date finally came for the victim to testify as to exactly what happened. He was sworn in for his first deposition (In New York it is called an Oral Examination Under Oath.), and questioning began. Lawyers for the several involved parties sat breathless, finally expecting to hear the victim's story.

Before the preliminaries of the deposition could be completed, the deponent slumped in his chair, medically unable to proceed – because of the effects of the shock, so they said – whereupon the assemblage dissolved.

The unsatisfactory outcome is that this case has not been resolved. I understand that it has not gotten so far as a settlement offer or request for a nuisance settlement.

Pole Light Fixture

A worker for a condominium had erected a 4-meter A-frame ladder in order to service a 5-meter pole light fixture in the parking lot. Figure 24 shows the fixture, and Figure 25 is the view from beneath the fixture when two lens-holding fasteners are removed and the lens has swung out of the way. The 250-watt metal-halide lamp has been unscrewed from the mogul-size socket.

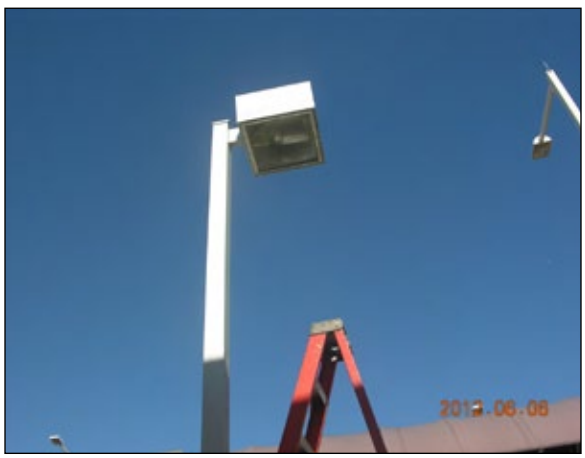

Figure 24

The worker was simply changing the lamp. While reaching up, and about to screw in the new lamp, he claimed to been shocked such that he recoiled and fell off the ladder. He was unable to recall what part of his body received the shock, nor could he explain the sensation of being shocked. However, having been seriously injured

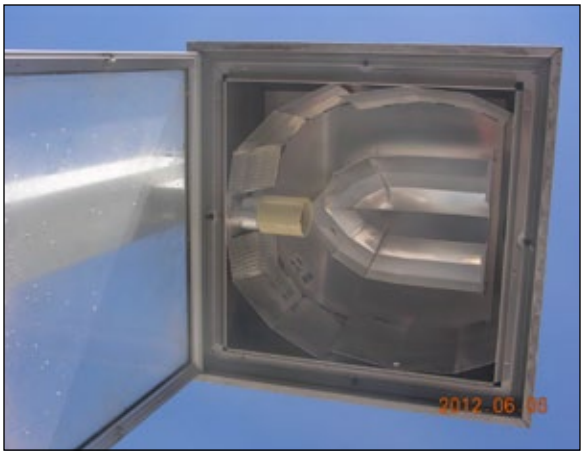

Figure 25

Figure 26

in the fall, he was bringing suit against the manufacturers of the lamp, of the pole, and of the fixture, in addition to a claim against his employer the condominium for the alleged electric shock.

Examination and testing of the fixture, the pole, and the wiring thereto showed that everything touchable was at neutral/ground potential and thus could not cause a shock. The electrically energized center pin was deep inside the lamp socket and could not be touched by a worker while he was holding the lamp.

Further, simply screwing the new lamp into the socket effected normal operation of the fixture, as shown in Figure 26. The examining engineer thus concluded that no physical evidence existed to support the shock part of the worker's claim.

Ungrounded Receptacle

A plumber attempting to clear a clogged bathroom drain was allegedly injured by electricity as he handled a "plumber's snake". One length of snake had been pushed into the drain, while another length was fastened in the jaws of the drain machine. The machine was plugged in to a 3-pin receptacle of the ground-fault circuit-interrupter (GFCI) type, but the motor of the drain machine (which rotates the snake to clear the drain) remained switched OFF

The plumber reported that just as he started to couple the two lengths of snake, he received a disabling shock across his entire body. The drain machine manufacturer was formally placed on notice of pending legal action.

Expert examination determined that the drain machine was properly wired, and its frame was properly grounded through the third pin of its attachment plug. An inspector's outlet tester had revealed no issue with the GFCI receptacle, which was of the type shown in Figure 27. The electrically hot (black) and neutral (white) conductors were found to be attached to their proper terminals.

There was no ground conductor. The house wiring was old and did not carry a ground to the location of this receptacle. In this event the proper installation would be to label the receptacle “No Equipment Ground” and let the GFCI capability protect the appliance user as it is designed to do.

Unfortunately the receptacle installer (obviously an amateur) was unhappy with leaving the ground terminal unconnected, so he ran a jumper from it to the neutral terminal, shown as the green wire in Figure 28 – wrong but still not hazardous to the plumber.

The presence of the jumper, however, exposed another defect in the house wiring. Somewhere upstream of the receptacle at issue the polarity had been reversed. The black wire was actually the neutral, and the white wire was the hot conductor. The unwarranted jumper therefore caused the third pin of the GFCI receptacle, intended as a safety ground, to carry full line voltage.

In turn any appliance whose third pin on its attachment plug was wired as a safety ground for its frame, would exhibit a potential of 120 V ac on any exposed surface when merely plugged in to that defectively wired receptacle. Accordingly the drain machine was cleared, as was the clogged drain itself. Legal action against the homeowner is contemplated.

Figure 27

Figure 28

Conclusion

These scenarios show that the forensic expert must be cautious when dealing with claims of electric shock. Information about a purported electrical injury may be incomplete, misleading, or misinterpreted.

In order to establish that an electric shock occurred to a human, it is necessary to show (a) that a sufficient electrical potential was present between two electrical conductors (one of which may be ground), and (b) that a person’s body (or some part of his body) was positioned so as to be in contact with both those conductors.

The National Electrical Code® (NFPA 70®, National Fire Protection Association®) treats potentials above 50 V as levels which require “safeguarding of persons and property from hazards arising from the use of electricity”.

No electric current flows through the bird sitting on a single wire whatever the voltage of the wire. The bird does not place itself **in** the electric circuit.

Electrical energy spurts out from a complicated apparatus, causing jagged streaks of light and flickering negative images, **only** in the comic strips and motion pictures.