Investigation Guideline

Product: **Electrocution / Electric Shock**
Appendix # : **34**
Date amended: **November 4, 2003**

I. Introduction

A. Background Information

In 2000, out of the estimated 400 electrocutions that occurred nationwide, about 150 (38%) involved consumer products. In-depth incident investigations will provide up-to-date information on the impact of current technological interventions that may prevent shock, help to identify whether and how safety features are being circumvented or omitted, as well as identify products that do not meet current voluntary standards.

Electric shock or electrocution can only occur when a person simultaneously touches two conductive surfaces that are at different voltage levels. One of the surfaces could be near zero volts or ground voltage such as water pipes, wet/damp soil or concrete floor, electrical conduits or boxes, the metal cabinet of a major appliance or metal-housed tool. If the voltage difference is high enough (generally exceeding 30 volts AC) and the resistance is low enough, an electrical current flows and the victim experiences a range of sensations or physiological responses.

Most people feel a slight tingling at about 1/1000 Ampere (1 milliampere)[*]. At ten times higher currents (1/100 Ampere or 10 milliamperes), the shock becomes painful and a victim's muscles begin to contract uncontrollably. A man holding onto an electrically charged power drill may not be able to let go of the tool. When the shock current reaches 100 milliamperes (1/10 Ampere)[**] and lasts for several seconds, the human heart may go into "ventricular fibrillation." The victim's heart, beating weakly and erratically, is unable to circulate oxygenated blood to the brain, and death can occur within minutes unless circulation resumes with rescue CPR (cardiopulmonary resuscitation) or the heart is restarted using an electronic defibrillator.

Modern household wiring systems incorporate 3-wire grounded branch circuits employing a separate grounding wire that attaches to the receptacle's yoke (frame) and to the outlet box. If it is equipped with a 3-wire cord and a plug having a

[*] One milliampere results if 30 volts are applied across a resistance of 30,000 ohms, which is the resistance of a dry finger tip touching a heavy copper wire.
[**] One-tenth ampere results from 120 volts applied across a 1200 ohm resistance, which is equivalent to a sweaty hand grasping an electric drill's metal handle.

round ground pin, an electrical appliance's metal housing will be connected to ground when the cord is plugged into a properly installed 3-wire receptacle. The ground wire supplies a path for fault current in case an internal short-circuit in an appliance connects the ungrounded, normally energized portion of the product wiring to its housing. Typically this fault current will be enough to activate a circuit protection device (fuse or circuit breaker) and disconnect power from the appliance. If the ground wire is missing or the ground pin is broken off the plug or the receptacle is miswired, that protection disappears. Not only is fire from short-circuit overheating a possibility, but severe electrical shock or electrocution is likely when someone touches the appliance.

Older homes may have only 2-wire circuits or receptacles and lack the protection provided by appliance grounding. Residents of older homes sometimes try to use appliances with 3-wire cords and plugs in two wire receptacles by installing "3-wire adapters." These adapters have a pigtail wire or terminal that must be connected to a ground screw, usually assumed to be the center screw on a receptacle cover plate. Sometimes the "Hot" and "Neutral" connections are reversed when an adapter is utilized, or the pigtail or terminal is left unconnected, or the center screw does not connect to a grounding circuit. Any of these instances increases the risk of dangerous, potentially fatal electrical shock.

Better protection from electrocution is provided by a Ground Fault Circuit Interrupter, or GFCI. A correctly installed, working GFCI can detect minute (6 milliampere) imbalances in current flow into and out of an appliance circuit and disconnect the voltage to protect against serious injury. GFCIs can even be installed when a ground wire is not available, but the *NEC (National Electrical Code)* requires that the receptacle be specially marked to show that the ground is missing. GFCIs provide the best protection against injury from electrical shock.

Some people buy "double insulated" tools to have increased protection from electrical shock. The tools are specially marked to show that they have an extra amount of protective insulation beyond the usual coating on wires and electrical components. While the extra insulation can be effective against internal wiring insulation faults, it can be compromised if the tool gets wet or when rough use damages even the extra insulation.

CPSC's data and analyses of electrical shock incidents[1] show that electrical products and systems have become better over the years. Still, we find incidents where a manufacturer did not understand or apply safety technology properly or where some person(s) created a situation by working improperly on a product or system that ultimately caused the injury or death. CPSC's continued investigation of shock incidents will help to identify root causes of increased risks of injury or death and, perhaps, to develop and propose workable solutions.

[1] See section V, item A, on page 7.

In addition to filling out the Data Record Sheet (DRS) attached to the end of this document, please provide any relevant information that is discovered in the investigation process that may not have been specifically requested in this guideline or the DRS.

B. Product Class Description

We are interested in any consumer product involved in an electrocution or electric shock. If a product-specific guideline exists, please follow the instructions in that guideline in conjunction with this electric shock guidance.

For incidents involving contact with power line, use the guideline on "Outdoor Communications Antennas and Other Products", Appendix # 1.

C. Specific Items of Interest

Whenever possible, please include diagrams. We are particularly interested in obtaining information to assist in evaluating the effectiveness of:

a. Grounding circuits
b. Double insulation
c. Over-current protective devices (fuses or circuit breakers)
d. Ground fault circuit interrupters (GFCIs)

D. Headquarters Contacts

1. Doug Lee, ESEE, 301-504-7569, dlee@cpsc.gov
2. Richard Stern, CRC, 301 504-7620, rstern@cpsc.gov
3. Risana Chowdhury, EPHA, 301-504-7334, rchowdhury@cpsc.gov

II. Instructions for Collecting Specific Information

A. Synopsis

In the synopsis of the report, please use the keywords ***electrocution***, ***electric shock***, or ***GFCI*** as appropriate, to ease the computer-based data retrieval process. Also use the appropriate product code for the product primarily responsible for the shock.

• Try to include in the narrative a description of the circumstances that led up to the incident. Was an appliance or power cord damaged to expose electrically live conductors? Did an electrical product come into contact with or become immersed in water? Did someone assemble or rewire an electrical cord or appliance or perform work on a household wiring circuit?

• Describe in the narrative how the incident happened with supporting facts. What was the victim doing? How was contact with electricity made? Was the victim using protective equipment or clothing (gloves, boots, etc.--provide descriptions)? What else was being used? Who discovered the incident? How? What did they do?

• Describe in the narrative the deaths, injuries, type of treatment administered, and extent of any property damage. Describe the current condition of the product in question.

B. Description of Incident Environment

Describe the accident scenario with as much detail as available. In particular, try to identify **grounding paths** and **possible source(s) of stray current**. Describe whether water, moisture, or dampness might have been involved in aggravating the severity of the incident.

Definition: "Grounding Path"

A grounding path is the route that electric current takes to return to the lower voltage side of its source. Current always takes a path from the higher voltage component of a source of electrical energy through conductive material, like copper wire, or resistive material, like damp ground, to the lower voltage component of the source.

The low voltage side of all residential and commercial AC electrical systems is required to be connected to "Earth Ground", usually through a metal rod or copper pipe buried in the ground. So the return path for AC current is often called the "grounding path."

Definition: "Stray Current"

In a "normal" electrical circuit, the current flows only in the conductors, i.e., the wires, motor windings, lamp filaments, and other electronic components of the appliance, power cord and household wiring that supply the appliance.

If a person or some object that can conduct electrical current comes into contact with an energized (voltage-carrying) conductor, some of the current may "stray" from its normal path and flow through the person or object. Current will flow if the person or object is simultaneously in contact with a grounding path to a lower voltage. The amount of stray current that flows depends on the total resistance of the new path.

Sometimes the source of stray current is not obvious, such as when a faulty underwater light or a fallen extension cord in a pool energizes the water. Someone standing, barefooted, at the side of the pool who reaches into the water may be severely shocked.

C. Description of Victim's Contact with Product

- Describe victim's posture/condition (moist skin, fully clothed vs. bare arms, legs, or feet, sitting or standing on ground, etc.) at the onset of the incident.

- Determine, as well as possible, victim's experience with, or knowledge of product (e.g., whether victim had read and understood instructions or operator's manual, was aware of the safety devices or features, or was aware of potential hazards).

- Specify victim's point of contact with the product and grounding surface and the body part(s) involved (e.g., hand touching a knob on the product while a bare knee was in contact with a metal pipe, etc.). Describe the clothing and its condition if it was directly involved in the incident (e.g., work gloves, hat, or boots that touched the voltage source or ground path).

State the source of the above information (such as victim, witness, investigative report, etc.).

D. Description of Product

- Specify product characteristics and labeled ratings, such as BTU rating, size/capacity, volts/amps/watts, testing laboratory certifications (UL, ETL, or CSA, for example), CE markings, or indications of conformance with specific standards, and any other descriptive information or symbols on rating plate, etc.

- Whenever available, list manufacturer's name, brand name, model/serial number, date of manufacture and lot number, age of product (date of purchase or acquisition, if possible) and any markings or date-codes from which product information might be gained. Record a description of the condition of the product at the time of acquisition (new, used, reconditioned, other, specify).

- Provide wording of any warning/safety instruction labels affixed, and describe the shape and color of any symbols shown on them.

- Provide as much detailed information as available about:

a. Grounding circuits - Describe branch wiring that provided power (2-wire, 3-wire, type and gauge of wire, receptacles grounded or not, HOT and NEUTRAL connections properly polarized). Describe condition of extension cords or accessory cords and wiring that were used, including number of wires, presence or absence of ground pins on plugs, repairs, polarization of wires, etc. Describe condition of power cord(s) on product(s).

b. Double insulation - Describe materials used on product enclosure, housing or case. Identify any label references to insulation systems, including specific wording, such as "Double Insulated," or "square-inside-a-square" symbol.

c. Over-current protective devices (fuses or circuit breakers) - Describe location, type and condition of fuse-box or panel-board. Describe type and condition of fuses and circuit breakers. Attempt to determine whether they are in working condition or whether they have been bypassed in some way. Try to determine when they were most recently replaced, exercised (turned on and off several times) or tested. Identify any GFCIs or AFCIs (arc-fault circuit interrupters) by brand, model, type, ratings, etc.

d. Ground fault circuit interrupters (GFCIs) - Describe location, type (breaker, receptacle, portable, etc.), brand/model, ratings, and condition of any GFCIs found that may have been involved with incident. Attempt to determine when GFCI was installed, how often it was tested, and when it was most recently tested. DO NOT ATTEMPT TO TEST OR RESET the GFCI or otherwise alter its state. Attempt to determine if an installed receptacle-type GFCI is correctly wired into its circuit (LINE and LOAD or HOT and NEUTRAL not reversed). **Seek the services of a licensed electrician if necessary.**

III. Photographs/ Diagrams of Incident Scene

A diagram or photograph of installation is particularly useful. Good photographs of the product and/or the incident scene are always helpful.

IV. Obtaining samples and documents related to the investigation

- Collect sample(s) if available, keeping the sample(s) as undisturbed as possible. If no sample is present, describe similar products at the incident site. Record observation of their appearance compared to the failed unit.

- Collect any extension or accessory cords involved in the shock incident.

- The GFCI should be collected if it was in the circuit that supplied shock current. If there are competing interests for the GFCI or other product samples, contact the CPSC Compliance Officer for guidance. Attempt to negotiate for possession or to gain written assurance from an official having proper jurisdiction that a report of analysis will be delivered to you. Examination of possibly non-functioning GFCIs should be conducted by a competent forensic investigator who is an expert in failure analysis of electronic power-handling devices. **Refer to the CPSC Investigation Guideline on "15- and 20-ampere Electrical Receptacles" for recommendations on collection methods involving receptacles.**

- Obtain copies of reports and photographs from repair facility or insurance company.

- Include copies of any installation instructions, user manuals, or product safety information inserts.

V. Additional information on electrocution and electrical safety

A. *An Evaluation of the U.S. Consumer Product Safety Commission's Electrocution Reduction Program*, November 2002, Robert Garrett, Susan B. Kyle, Ph.D., Office of Planning and Evaluation. PDF document available in two parts at:
http://www.cpsc.gov/LIBRARY/FOIA/FOIA03/os/Electropt1.pdf and
http://www.cpsc.gov/LIBRARY/FOIA/FOIA03/os/Electropt2.pdf

B. *Lessons in Electrical Circuits, Vol. I, Ch. 3, "Electrical Safety,"* web-published 2000-2003, Tony R. Kuphaldt *at:*
http://www.ibiblio.org/obp/electricCircuits/DC/DC_3.html

C. *Electrical Safety--Safety and Health for Electrical Trades*, DHHS (NIOSH) Publication No. 2002-123 at http://www.cdc.gov/niosh/docs/2002-123/2002-123a.html

DATA RECORD SHEET

Investigation Guideline

PRODUCT: Electric Shock / Electrocution

TASK NUMBER s_____ INCIDENT DATE s_____

A. Product / Accessories

1. Product Code_____

2. Product Name _____

3. Label Ratings: _____Volts AC? or DC? (circle choices)

   _____ Amps

   _____Watts or volt-amperes (VA)

4. Describe and/or photograph any warning labels on the product.(Present?) (None?)

5. UL, CSA, or other agency mark _____

6. Manufacturer _____

7. Model Name/Number _____

8. Serial Number _____

9. Age of appliance _____

10. Purchased (NEW?) or (USED?) Date: _____

11. What was the appliance cord like?
    11.1. Permanently connected? _____ Or Removable? _____

    11.2. What markings are on the cord?_____
_____

    11.3. What markings are on the plug body or the prongs? _____
_____

12. What was appliance plug like (Use Table with NEMA configurations on page 13)?
    12.1. Two-pronged (NEMA 1-15P)? **YES NO** ☐
    - Polarized (different sizes for prongs) **YES NO** ☐

12.2. Three-pronged (NEMA 5-15P, for example) **YES NO** ☐
- Type? _____
- Are all prongs present? **YES NO** ☐
- If not, which one is missing? (Make sketch if necessary)

12.3. GFCI or ALCI (Appliance Leakage Circuit Interrupter, 2-blade) on the plug? (Usually has "TEST" and "RESET" button on plug body.) **YES NO** ☐

12.4. Was a 2-blade-to-3-blade grounding adapter used? If so, describe or sketch adapter. _____
_____
_____
_____

13. What was the receptacle like? (Use Table with NEMA configurations on page 13)

13.1. 2 slots (like NEMA 1-15R)? **YES NO** ☐
- Polarized? **YES NO** ☐
- GFCI present in circuit breaker panel? **YES NO** ☐
- GFCI label on receptacle? **YES NO** (required if GFCI breaker) ☐

13.2 3 Slots (NEMA 5-15R or others, for example)
- Type? _____
- GFCI present in receptacle or in circuit breaker panel? ☐

14. What was the condition of the product before the incident?

14.1. Cord _____
_____
_____

14.2. Plug _____
_____
_____

14.3. Appliance _____
_____
_____

14.4. Any attachments or accessories _____
_____
_____

15. Was an extension cord used? Please describe the cord and any markings on it.
_____
_____
_____
_____

16. What, if any, repairs or maintenance were made to the appliance, cords, or accessories prior to the incident date? _____

_____

17. Were any evaluations performed by police, fire, medical examiners, independent investigators, etc. on the appliance, cords, or accessories following the incident? (Obtain copies of any evaluation reports.)_____

_____

_____

_____

18. Are the gripping surfaces of the product metal or insulated? _____

_____

_____

19. Did the product shock anyone before? If so, describe any differences between that incident and this incident (location, user, extension cords, weather, etc.). _____

_____

_____

_____

_____

B. Power Source

20. Did the incident cause any circuit breakers or other protective devices to activate? What are the voltage and current ratings of the protective devices? _____

_____

_____

21. Describe any visible changes to the appliance after the incident (smoked areas, blackened areas, melting, etc.)? _____

_____

_____

22. If you have an electrical tester (SureTest® or equivalent), what are the results of the receptacle test? _____

_____

C. Victim

23. Who was using the appliance? _____

_____

_____

24. How much experience did the victim have with this and similar appliances/tools?

_____

24.1. Did the intended task differ from previous tasks done by the victim?

_____

_____

24.2. How long did it normally take the victim to perform the task involved and how long did the task take when the victim suffered the shock?

_____

_____

25. Who else has used the appliance? _____
_____
_____

26. Did anyone notice any unusual operating characteristics of the appliance?
_____
_____

27. Describe what the victim was wearing. _____
_____
_____

28. Specify if the victim's body was wet or sweaty. _____
_____
_____

D. Circumstances

29. Weather conditions at time of incident
    29.1. Temperature _____

    29.2. Humidity _____

30. Was water involved? How and where? _____
_____
_____
_____

31. Were other live electrical circuits involved (e.g. saw cut through a power cord, tiller hit buried wire, drill cut into household wiring, etc.)? _____
_____
_____

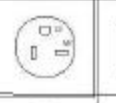
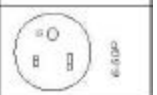
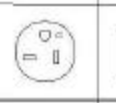
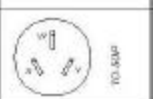
32. If possible, specify the victim's point of contact with the product where the shock occurred and with the surface that provided a path to ground (or to a different voltage level). _____
_____
_____

E. ADDITIONAL NOTES and INFORMATION

_____
_____
_____
_____
_____
_____
_____
_____
_____

F. SKETCHES

TABLE -- NEMA **(National Electrical Manufacturers Association)** Plug and Receptacle Configurations (*for use as reference to answer Q12 and Q13 on DRS)*

DESCRIPTION		NEMA NUMBER	15 AMPERE		20 AMPERE		30 AMPERE		50 AMPERE	
			RECEPTACLE	PLUG	RECEPTACLE	PLUG	RECEPTACLE	PLUG	RECEPTACLE	PLUG
2-POLE 2-WIRE	125V	1								
	250V	2								
2-POLE 3-WIRE GROUNDING	125V	5								
	125V	5ALT								
	250V	6								
	250V	6ALT								
3-POLE 3-WIRE	125 / 250V	10								
	3ø250V	11								
3-POLE 4-WIRE GROUNDING	125 / 250V	14								
	3ø 250V	15								

(NOTE: 3-pole (3-phase) plugs and receptacles are not likely to be in homes, but heavy stove, heater and air conditioner circuits may use 3-poles, 3 or 4 wires)