An Evaluation of the U.S. Consumer Product Safety Commission's Electrocution Reduction Program

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Executive Summary

The Government Performance and Results Act (GPRA) requires federal agencies to perform evaluations of their programs to determine their effectiveness. In conformance with this requirement, staff in the U.S. Consumer Product Safety Commission's (CPSC's) Office of Planning and Evaluation conducted an evaluation of CPSC's Electrocution Reduction Program. The intent of the program was to reduce the rate of electrocutions associated with consumer products.

Available agency information was evaluated, including

- mandatory and voluntary standards addressing electrocution hazards,
- data on the numbers and circumstances of electrocution deaths,
- records of recommendations made by CPSC staff regarding National Electrical Code requirements and Underwriters Laboratories voluntary standards provisions,
- records of recalls and corrective actions conducted for products presenting electrocution hazards,
- information on the activities of the agency's Office of Information and Public Affairs, and
- data from budgets and operating plans.

A market and use study of ground fault circuit interrupters was conducted for this evaluation.

Consumer product-associated electrocutions decreased from approximately 600 per year in the mid-1970s to approximately 200 in 1998 (the latest year for which data were available at the time the evaluation was conducted). CPSC published two mandatory standards for antennas (including CB base station and TV antennas), one in 1978 and one in 1982. Electrocutions associated with antennas dropped from an estimated annual average of 186 in the mid-1970s to an estimated annual average of 30 in the mid-1980s and to an estimated annual average of 17 in the mid-1990s. A voluntary standard requiring double insulation on power tools became effective in 1978. Electrocutions associated with power tools and farm/garden equipment covered by the voluntary standard dropped from an annual average of 142 in the mid-1970s to 102 in the mid-1980s and to 51 in the mid-1990s.

In addition, beginning in 1973, CPSC staff made a series of recommendations for, and the National Electrical Code adopted, requirements for ground fault circuit interrupters to be installed in numerous locations throughout the home. Annual electrocutions associated with home wiring were estimated to be 76 in the mid-1970s, 68 in the mid-1980s and 29 in the mid-1990s.

Agency spending on the electrocution reduction program was almost $2.6 million in 2001. If spending at this level is assumed over the entire 21-year period 1978-1998, total agency expenditure was approximately $54 million. In the same time period, 6,250 lives were saved, based on comparing the number of deaths each year with the average number of deaths during the baseline period of 1975-1977 (620 average annual deaths).

It was concluded that the CPSC's Electrocution Reduction Program contributed to a very successful reduction in deaths with a relatively low expenditure by the agency.

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Introduction

In August 1993 Congress enacted and President Clinton signed into law the Government Performance and Results Act (GPRA). The intent of the law is to improve the effectiveness and accountability of federal agencies. Among the law's requirements are that each agency develop a strategic plan, setting forth quantifiable performance goals, and that agencies perform evaluations of their programs to determine their effectiveness.

In accordance with GPRA, the U.S. Consumer Product Safety Commission (CPSC) published its first strategic plan, "Saving Lives and Keeping Families Safe," in September 1997. The plan established five strategic goals:

- reduce the rate of head injuries associated with consumer products that occur to children
- prevent an increase in the low death rate from unintentional poisonings to children
- reduce the death rate from fires
- reduce the death rate from carbon monoxide poisonings
- reduce the death rate from electrocutions associated with consumer products

This report evaluates the performance of the CPSC in reducing the death rate from electrocutions associated with consumer products.

The Strategic Goal

When CPSC published its 1997 Strategic Plan, the most current data (1994) showed that there were 230 deaths from electrocution that year, a decline of about 30 percent from the 1984 level of 330 deaths. The average risk of death had decreased from 15.1 per 10 million persons in the 1980s to about 8.8 in 1994. CPSC set as its strategic goal a further reduction in the electrocution death rate by 20 percent within ten years, from the 1994 rate of 8.8 deaths per 10 million persons to 7.0 per 10 million persons in 2004.[1] This goal was retained unchanged when the Strategic Plan was updated in September 2000.[2]

The Strategic Plan identified four strategies to reduce electrocutions[2]. Staff activity would focus on

- working with the National Fire Protection Association's (NFPA's) National Electrical Code (NEC) Panels to propose improvements in requirements for appliances and electrical equipment,
- working with voluntary standards groups such as Underwriters Laboratories Inc. (UL) to continue to improve the design of ground fault circuit interrupters (GFCIs), facilitate their installation, increase their reliability, and enhance their safety features,
- increasing consumer awareness through continued educational efforts in electrical safety and publicizing "Electrical Safety Month" every May, and
- continuing recalls of or corrective actions for products that do not comply with safety regulations and products that are defective and present a substantial safety hazard.

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[1] CPSC Strategic Plan, "Saving Lives and Keeping Families Safe," September 1997, pages 25-26.
[2] CPSC Strategic Plan, "Saving Lives and Keeping Families Safe," Revised September 2000, page 32.

Evaluation Methods

To evaluate agency activities to reduce electrocutions involving consumer products (the Electrocution Reduction Program), available agency information was compiled. This included

- data on the numbers and circumstances of electrocution deaths from the Directorate for Epidemiology,
- information on engineering activities involving National Electrical Code provisions and Underwriters Laboratories standards related to electrocution prevention,
- information from the Office of Compliance on activities related to recalls and corrective actions for products presenting electrocution hazards,
- data from the Office of Information and Public Affairs on media activities alerting the public to the risk of electrocution and ways to reduce that risk,
- data from agency budgets and operating plans on the costs of activities undertaken.

In addition, the Directorate for Economic Analysis conducted a study of the market for and use of ground fault circuit interrupters for this evaluation.

Evaluation Results

Definition of Electrocution

Electrical shock results when electric current passes through the human body. The intensity of the sensation--a slight tingling, mild to severe pain, uncontrolled muscle contractions--depends in part on the magnitude of the current and its duration. Electrocution results when so much electric current flows through a major organ (or organs) of the body, such as the heart, lungs, or brain, for a long enough period of time that the organ becomes unable to function, and death results.

TAB A provides a discussion of the mechanism of electric shock and electrocution and presents some threshold levels for the amount of electric current required to produce damage to human tissue. Of particular concern for consumer-related electrocution is that the amount of current which flows through the body can be greatly increased when the skin is damp, such as with perspiration and/or in damp or wet environments, thus increasing the risk of severe injury or death.

Numbers of Electrocutions Associated with Consumer Products

TAB B presents information on the number of consumer product-associated electrocutions from the mid-1970s through 1998, the latest year for which data are available. In the mid-1970s there were approximately 600 electrocutions associated with consumer products each year. In 1998, there were an estimated 200. The estimated rate of electrocutions was 7.2, 7.1 and 7.4 per 10 million persons for 1996, 1997, and 1998, respectively. These rates are very close to the strategic goal of 7.0 per 10 million.

The product category showing the greatest decrease in associated electrocutions from the 1970s to 1998 was antennas. This category includes radio, TV, and CB antennas. Published CPSC documents indicate that these electrocutions generally involved CB antennas and resulted from contact between the antenna and an overhead power line during installation or removal of the antenna. The decrease in antenna-associated incidents was attributed primarily to a decrease in the number of incidents associated with Citizens Band (CB) radio antennas. Most of this decrease occurred between the mid-1970s and the mid-1980s. (See Table 1, TAB B.)

The second largest product category decrease occurred in "installed household wiring". Most of this decrease occurred between the mid-1980s and the mid-1990s. Decreases similar to those seen with household wiring were also observed with power tools and garden/farm equipment. However, most of these decreases occurred during the 1970s-1980s time frame.

In recent years (1996, 1997 and 1998) the number of electrocutions was relatively stable at about 200 electrocutions annually. Inspection of data from 1992 through 1998 revealed no readily apparent downward trends in any of the product categories.

Current Hazards and Possible Interventions

In-depth investigation reports (IDIs) were examined to identify the types of hazards associated with recent electrocutions and determine possible intervention measures to prevent them (TAB C).

In general, many products involved in electrocutions were described as old, worn, modified, or homemade. Such products may lack protective features such as grounding, polarized plugs, or double insulation. The lack may be due to the product's being old enough to have been manufactured before the protective features came into use, or the product may have been worn, causing deterioration of the protective features. Alternatively, the product may have been modified by the user to bypass protective features (such as three-prong grounding plugs and polarized plugs) which require compatible home wiring that may not be available in older housing. In many of the cases, the electrocution could have been prevented by the use of a ground fault circuit interrupter (GFCI), even in cases where product protective features had been bypassed. GFCIs were, by far, the single product intervention most likely to have prevented the observed electrocutions.

Standards Activities

TAB D provides a summary of CPSC's standards activities addressing electrocution hazards.

<u>Mandatory Standards</u>. CPSC enforces three mandatory standards intended to reduce the risk of electrocution.

- 16 CFR Ch. II Part 1505 – Requirements for electrically operated toys or other electrically operated articles intended for use by children. This standard went into effect in 1973.
- 16 CFR Ch. II Part 1402 – CB Base Station Antennas, TV Antennas, and Supporting Structures requires labeling to "provide notification of ways to avoid the hazard of electrocution which exists when these products are allowed to come near powerlines while the antennas are being put up or taken down." This requirement was published in 1978.

- 16 CFR Ch. II Part 1204 – Safety Standard for Omnidirectional Citizens Band Base Station Antennas requires that antennas be electrically insulated or that there be an insulating barrier between the antenna and the mast supporting it. This standard became effective in 1982.

Voluntary Standards. CPSC has worked extensively with two groups to develop and strengthen voluntary standards intended to reduce the risk of electrocution: Underwriters Laboratories Inc. (UL), and the National Fire Protection Association (NFPA). UL develops product standards for electrical appliances. NFPA develops the National Electrical Code (NEC) which covers the installation of electrical products, including electrical circuits in residences. The NEC is reportedly used in whole or in part in every state in the country (TAB E).

Major UL standards addressing electrocution hazards that CPSC was involved in developing include a standard requiring that power tools have double insulation (1978), a hair dryer standard requiring labeling warning of electrocution hazards (1978), and a hair dryer standard requiring immersion protection (1987, 1991). TAB D lists numerous other UL standards activities in which CPSC has been active.

TAB D also details extensive past and current CPSC involvement with developing NEC provisions concerning ground fault circuit interrupters (GFCIs). GFCIs measure the current flowing to and returning from a circuit. If the GFCI senses that the return current differs from the delivered current by more than a very small portion (i.e., a "ground fault" has occurred), it operates an internal switch and shuts off the flow of electricity almost instantaneously. Ground faults can occur when moisture causes current to flow in a path from an electrically energized conductor to a grounded conductor (or the earth itself), such as when a hair dryer is dropped into a bathtub of water, or when a person inadvertently provides a path to ground for electricity. By shutting off the flow of current, the GFCI helps minimize the possibility of electrocution.

CPSC has worked with the NEC to incorporate requirements for the installation of GFCIs in a number of different locations throughout residences. Articles in the current NEC require GFCIs on receptacles located outdoors, in bathrooms, on garage walls, and in basements and kitchens – areas of the home where many appliances and tools are likely to be used and where proximity to wet or damp conditions increases the potential for electrocution.

Ground Fault Circuit Interrupters: Market and Use Characteristics

Because a large part of the Electrocution Reduction Program involved working with the NEC to expand the locations where GFCIs are required, the Directorate for Economics provided a market sketch of GFCI use (TAB E). Included as Table 1 in TAB E is a timeline showing the years in which requirements for GFCI installation in various locations were adopted as part of the NEC.

The NEC is not retroactive; it applies to new construction only unless the local code enforcement mandates that specific locations be upgraded under well-defined conditions. Some local codes require that repairs of an existing residence bring the structure up to the current code, but this usually only applies if the cost of repairs exceeds a certain dollar amount or a certain percentage of the value of the building. Because of this, and because housing is so durable, it may take many years for changes in the NEC to affect housing characteristics.

This has proven to be the case with NEC's requirements for installing GFCIs. The Directorate for Economics estimates that 58 percent of American homes still may not have any installed GFCI protection because they were built before the first NEC requirement for installing GFCIs in residential locations went into effect in 1973.

In addition, the Directorate for Economics notes that housing that lacks GFCI protection tends to be older, and the occupants of older homes tend to be at-risk groups such as older consumers, minority populations, and families with lower income levels. These vulnerable populations may, therefore, be at increased risk of electrocution.

Office of Compliance

CPSC's Office of Compliance activities related to electrocution hazards are summarized in TAB F. From 1998-2001, there was an average of 37 Corrective Action Plans each year related to electrocution hazards, resulting in the correction or holding out of distribution of an average of more than 3 million product units each year. In addition, special enforcement was instituted in 1992 to identify hair dryers on the market not meeting the 1991 UL immersion protection requirements, and to require corrective action from the manufacturers and importers of non-complying products. Similar compliance monitoring programs have been conducted for holiday lights since 1999 to stop importation of or to recall lights not meeting UL requirements, effective in 1997, that tightened quality control over electrocution and fire hazards.

Office of Information and Public Affairs

A summary of the activities of CPSC's Office of Information and Public Affairs (OIPA) in support of reducing electrocutions is provided at TAB G. This summary covers the time period of the strategic plan (1994 to the most recent available data) as well as earlier work in the 1970s and 1980s on electrocution hazards associated with antennas.

OIPA work on electrocution hazards for the period covered by the strategic plan included the following:

- 16 publications (combined distribution in 2001 totaled over 245,000 copies)
- 6 safety alerts covering major hazards or urging the use of GFCIs
- 9 video news releases that CPSC produced or helped to produce
- 9 press releases covering seasonal or special events related to electrical safety
- 1 safety videotape and companion booklet
- Numerous press releases announcing recalls of products that presented electrocution hazards such as hair dryers lacking immersion protection, power washers with counterfeit GFCIs, Christmas lights and extension cords with poor wiring, and lighting timers and extension cords with reverse polarity, and
- Numerous wire and print stories from 1994-2002 mentioning CPSC and electrical safety.

Earlier work in the 1970s and 1980s included 12 announcements and press releases warning of the hazards posed by antennas, announcing CPSC's regulations, and announcing recalls of violative products after the standards became effective.

Generally, OIPA's efforts centered around publicizing known electrocution hazards and recommending precautions; promoting and explaining new product safety standards, both mandatory and voluntary; and announcing recalls of hazardous products.

Other Consumer Information

Other CPSC activities that provide information to consumers on electrocution hazards and prevention are documented in TAB H.

Through CPSC's toll-free hotline, consumers ordered over 200,000 copies of CPSC electrical safety publications in 2001 (these publications are included in the numbers cited above by OIPA). The hotline also provides audio scripts that callers can select using a telephone keypad. A review of current scripts found about 60 that referred to electrocution or shock hazards (out of a total of approximately 500 active recordings). All but seven of these scripts provide recall-specific information to the consumer. The remainder include information about seasonal or recurring special events such as National Electrical Safety Month, holiday light safety and Recall Round-up.

The Electrical Safety Publications page on CPSC's worldwide Web site (www.cpsc.gov) lists 14 downloadable publications related to electrocution hazards and how to prevent them. In 2001 there were approximately 3600 "hits" on these publications each month, (out of 6.2 million total hits on the Web site that year). In addition, an informal survey of the Web revealed approximately 3000 other electrical safety-related Web sites linking to CPSC and providing other "portals" for accessing CPSC electrical safety information.

Budget

TAB I provides information on the Commission resources expended on the Electrocution Reduction Program. For 1998-2001 (years for which separate accounting information is available by strategic goal), spending on the Program averaged $2.237 million, approximately 5% of the agency budget.

Discussion

Effectiveness of CPSC Actions

Electrocution deaths associated with consumer products have decreased, both in absolute numbers and in rate of death, over the period from the mid-1970s through the late 1990s. The total number of lives saved over this time period was calculated in the following manner. The annual average number of deaths for the three years 1975-1977 was 620 (from information in TAB B). This was considered to be the baseline number of electrocution deaths. The number of lives saved for any given year was the difference between the baseline number of deaths and the number of electrocution deaths occurring in that year. For example, in 1992 there were 200 deaths, so there were 420 lives saved (620-200). For the 21-year period 1978-1998 there were a total of 6250 lives saved.

In order to determine whether CPSC Electrocution Reduction Program activities might reasonably be considered to have contributed to these savings, a timeline was developed which combines information on CPSC standards development activities and electrocution deaths (Figure 1, following page).

Mandatory Standards. As was noted in TAB B, the major decrease in deaths over the time period covered by the graph was due to a decrease in the number of deaths associated with antennas. As shown in the "Deaths for Selected Consumer Product Categories" of Figure 1, most of this decrease occurred between the mid-1970s and the mid-1980s when the average annual number of deaths associated with antennas decreased from 186 to 30. During this time period, two regulations dealing with antennas went into effect, the first requiring labeling of antennas and the second requiring that the antenna be electrically insulated.

A study of the impact of the antenna labeling rule, conducted in December 1979 and January 1980, found that 60% of those who had "been exposed to warning labels or hazard avoidance instructions reported feeling at least somewhat concerned by them", that 69% of CB owners reported that "the warnings had caused them to consider the proximity of nearby power lines when selecting an installation site" and the study data "strongly suggested" that "pre-rule CB base station antennas were mounted closer to nearby electric power lines than post-rule base station antennas."[3] This suggests that the labeling rule had the intended effect. No similar evaluation was conducted for the insulation rule.

It is impossible to determine what part of the observed decrease in deaths associated with antennas was due to regulation and attendant information and enforcement activities, and what part may have been due to technological advances such as the increasing use of cellular phones and cable television. However, the study cited above and the finding in TAB C that recent cases involved mainly old or homemade antennas can be interpreted as supporting the effectiveness of both antenna standards and, thus, CPSC activities.

Voluntary Standards. Electrocutions associated with hair dryers have also shown a marked decrease from the 1970s to the present. In the early 1980s there was an average of 18 electrocutions each year associated with hand-held hair dryers.[4] Voluntary standards providing electrocution protection for hair dryers became effective in 1978, 1987, and 1991. The average number of hair-dryer associated electrocutions was four per year for 1990-1992. CPSC has reports of only two deaths in 1992.[4] In 1998, there were no reports of electrocutions associated with hair dryers. The ability to provide such effective protection was the direct result of CPSC-sponsored research into miniaturized GFCIs that demonstrated the feasibility of building electrocution protection into hair dryers.[5]

Similar to the case with antennas, power tool-associated electrocution deaths decreased in the time period in which a voluntary standard requiring double insulation became effective. The power tool double insulation voluntary standard went into effect in 1978. The annual average

[3] "Evaluation of the Impact of the Communications Antenna Labeling Rule", Contract No. CPSC-C-79-1165, Submitted by Public Sector Research Group, Market Facts, Washington, D.C. 20006, November 21, 1980.
[4] "CPSC Saves Lives Through Voluntary Efforts and Oversight: Making Hair Dryers Safer" in *Success Stories*, U.S. Consumer Product Safety Commission, Washington, D.C., February 1997.
[5] "Final Report on Miniaturized GFCI-Type Devices", Memorandum from Nicholas Mogan to Robert L. Northedge, Directorate for Engineering Sciences, U.S. Consumer Product Safety Commission, Washington, D.C., June 22, 1984.

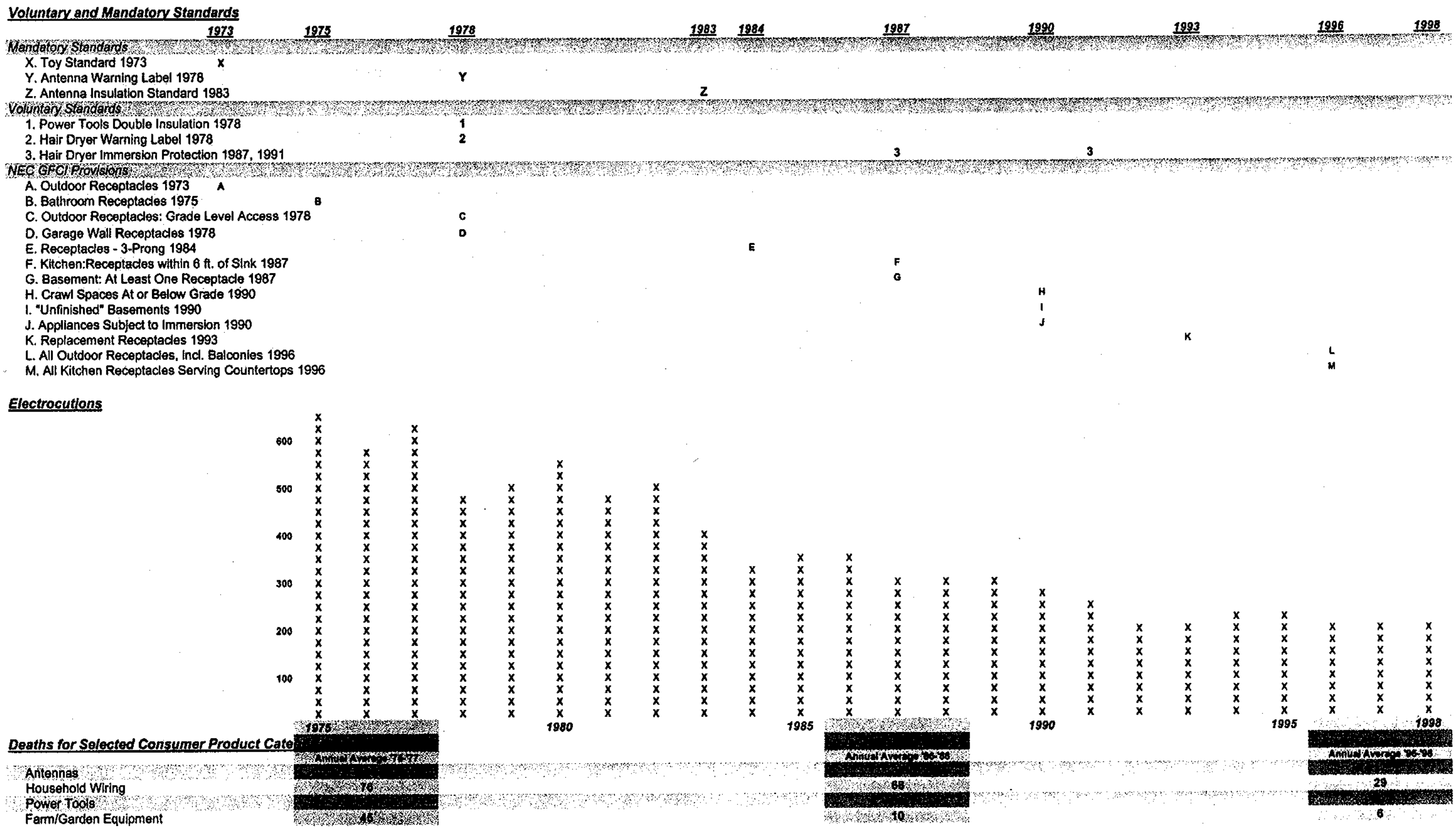


Figure 1. Timeline
Major CPSC Standards Activities and Electrocution Deaths

number of electrocutions associated with power tools decreased from 66 in the mid-1970s to 34 in the mid-1980s. This standard may also have contributed to the similar lowering of the number of electrocutions associated with farm and garden equipment from the mid-1970s to the mid-to-late 1980s.

NEC GFCI Provisions. The bulk of CPSC standards activities have involved GFCI provisions in the NEC. The earliest GFCI requirement to have significant impact on residential safety, that GFCIs be installed on outdoor receptacles, was included in the 1971 edition of the NEC and went into effect in 1973. Despite this and at least four other major GFCI requirements added during the 1970s and early 1980s, very little change was observed in the number of electrocution deaths associated with installed household wiring from the mid-1970s to the mid-1980s (76 deaths and 68 deaths, respectively). However, there was a drop in this type of electrocution between the mid-1980s and the mid-1990s, from 68 to 29 deaths. This may indicate that the interval necessary for the effects of NEC changes to appear in sufficient numbers in national housing stock to affect electrocution deaths is on the order of 25 years (1973-1998). This is reasonable, especially considering that more than half of currently existing housing stock was built before the first GFCI requirement went into effect. If the effectiveness of NEC changes takes this long to become evident, then it is possible that electrocutions associated with installed household wiring and with cord-connected tools and appliances will continue to decline as more residential GFCIs are installed in accordance with current NEC requirements.

No clear downward trends were observed in the recent, relatively short time during which reducing electrocutions has been a strategic goal at CPSC. However, the finding that many incidents involved old, worn, modified, or homemade products may indicate that current product standards, such as the power tool double insulation standard, and associated information and enforcement efforts are effective.

Agency Expenditures

Budget expenditures on the electrocution hazard program may be described as commensurate with the magnitude of the hazard addressed. Spending on the program has been approximately 5% of the agency budget from 1998-2001, the only years for which such program-specific reporting is available. The approximately 200 deaths associated with electrocutions each year represent about 6% of the deaths addressed by strategic goal programs. (In the 2002 Operating Plan, the total number of deaths addressed by strategic goal programs was 3410: 3000 for fire, 180 for carbon monoxide, 30 for child poisoning, and 200 for electrocutions.) Not all deaths addressed by agency activities are part of strategic goals. Therefore, more deaths are addressed by total agency activity than are addressed by strategic goal programs alone. So the percent of deaths addressed by the electrocution program (5% of strategic goals deaths) would be less than 5% of total agency activity.

If we assume that CPSC spending over the 21-year period 1978-1998 was at the 2001 level of $2.569 million per year, the total agency expenditure was $53.95 million. As noted above, the total number of lives saved over this time period was estimated as 6,250. The Electrocution Reduction Program has contributed to a very successful reduction in deaths with a relatively low expenditure by the agency.

Addressing current hazards

There are still approximately 200 consumer product-associated electrocution deaths each year. Inspection of recent in-depth investigations of electrocution incidents revealed that many of the incidents involved old, worn, modified, or homemade products. This may indicate that the product predated requirements for protective features, the protective features may have deteriorated, or the protective features may have been intentionally defeated.

A number of possible options could be considered if the agency chooses to address the electrocution hazard posed by old, worn, unprotected electrical products. One approach involves using GFCIs to compensate for safety inadequacies in the old products. Agency work could include advocating the use of portable GFCIs in unprotected locations, and continuing efforts with the NFPA to expand NEC requirements for installed GFCIs. This could include working to promote the use of GFCIs in all locations where they are currently required, expand the number of locations where they are required by the NEC, recommend the use of GFCIs with large appliances, and require that GFCIs have the ability to indicate when they cease to function.

Another approach is to reduce the use of older, worn products without safety devices. This could include activities such as continuing to alert consumers to the hazards posed by old, worn equipment and encouraging replacement of old equipment. Other innovative approaches could be developed.

Priority of Electrocution Reduction

In considering whether the Electrocution Reduction Program should continue to be a CPSC strategic goal, it may be useful to consider the criteria the agency is directed to apply in establishing and revising its priorities (16 CFR 1009.8). They are:

- frequency and severity of injuries,
- causality of injuries – includes the issue of addressability – the extent of product causality involvement and the extent of injuries that can reasonably be expected to be reduced or eliminated through commission action,
- chronic illness and future injuries – takes into account that, although there may not be current injuries, there may be reason to believe that a product will be associated with injuries in the future,
- cost and benefit of CPSC action,
- unforeseen nature of the risk,
- vulnerability of the population at risk,
- probability of exposure to hazard.

Concerning the issue of frequency and severity of injuries, this document and other agency documents provide a great deal of information about the number and types of injuries associated with electrocution hazards that can be considered in relation to deaths and injuries associated with hazards addressed by other agency projects to determine which projects should be agency priorities. As to causality and addressability, information presented in this document indicates that many electrocutions could be prevented by the use of GFCIs, so that electrocutions may be among the more clearly addressable injuries seen by the agency. The brief discussion of budget expenditures above indicates that the program has worked well with a relatively low expenditure of agency funds.

Considering the criterion "unforeseen nature of the risk" raises the issue of whether consumers truly understand the nature of the risk of using old, worn, or otherwise unprotected electrical equipment. Purposely defeating protective features such as three-prong plugs may indicate that consumers underestimate the risks posed by the use of electricity.

The fact that many recent incidents involved older, possibly second-hand, or homemade equipment may indicate that the population currently at risk for electrocution is economically disadvantaged (often including the elderly). This population may also have less access to information about hazards and how to prevent injury.

The probability of exposure to the hazard is extremely high. Given the ubiquity of electricity and electrically powered products in this country, very nearly all the population is exposed for large portions of time. This constant exposure may argue for continuing to consider this hazard a priority. Conversely, given the constant exposure to electricity, it could be argued that the current number of deaths per year (200) is extremely low.

Conclusions

The Electrocution Reduction Program has been effective. The annual number and rate of electrocutions decreased greatly from the mid-1970s through the late-1990s. The timing of the decreases in electrocutions associated with selected consumer product categories compared to CPSC standards activities may indicate that CPSC efforts contributed substantively to this decrease. In addition, the agency expenditures on the program are low in relation to the number of lives saved.

In determining whether the Electrocution Reduction Program should remain a strategic goal for the agency, several factors might be considered. Many recent electrocutions appeared to be preventable, the program addresses a ubiquitous risk, and the at-risk population appears to include vulnerable groups such as the elderly and/or economically disadvantaged. These observations, as well as the effectiveness of the program, support continuing the program. Continuing activity could include expanding required GFCI locations in the NEC and continuing current levels of enforcement and education. Additional efforts could involve new approaches to reducing the use of old, worn electrical products.

On the other hand, it could be argued that we may continue to see results from past efforts even if future agency efforts are minimal, as current NEC requirements result in more new homes with GFCIs in more locations throughout the home. However, if agency efforts were minimal, the time needed to achieve further reductions in deaths would probably be longer than if the agency were more active.

Whether reducing electrocutions should remain a strategic goal depends, at least in part, on how the numbers of electrocutions, the circumstances resulting in electrocutions, and the likely effectiveness of CPSC efforts to reduce electrocutions compare to those of other types of hazards whose reductions may merit consideration as strategic goals.

Tab A

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

DATE: June 12, 2002

TO: N.J. Scheers, Director, Office of Planning and Evaluation

FROM: Robert Garrett, Electrical Engineer, Office of Planning and Evaluation RG

SUBJECT: Electric Shock and its Physical Effects on the Human Body

Introduction

To meaningfully discuss how to prevent electrocution and its precursor, electrical shock, while using consumer products, we need to understand what is necessary for electrical injury to occur. To have fire there must be a combined presence of fuel, air and heat in the right amounts. Likewise, to experience electrical shock, there must be a combination of circumstances. A source of electrical energy must be present and there must be two points of contact with the body - one for energy to enter the body and one for it to leave - before a shock hazard can exist. Even what we think of as "static shock" - being shocked from walking across a carpet on a dry winter day and touching a metal doorknob - fits those requirements. Remarkably, although the static voltage generated and stored on the body may reach 5,000 volts, the duration of current is too short to be more than an unpleasant experience.

Shock vs. Electrocution

The difference between a painful but survivable shock and a possible electrocution is small. If the human body provides a path for current to flow from a source of voltage to ground or any other return element, the person who is in that path will suffer an electrical shock. If the voltage is high enough, the resistance is low enough, the duration is long enough, and the flow is through the head, chest or heart, the current will be sufficient to cause serious injury or death - electrocution.

Environmental conditions can play a big role in elevating a mild shock to a lethal one. Large surface area contact with a conductor - bare wire, metal pipe or sheet metal panel - or immersion in water - a pond, a swimming pool, a bath tub with metal plumbing - and even damp, sweat-covered skin - all serve to reduce the resistance to the flow of current.

Progressing from mild shock and the associated discomfort to severe, painful shock, and, ultimately, to death from electrocution means increasing the amount of current through the body, especially through the chest and heart, and lengthening its duration. A high voltage is not required to cause a potentially dangerous shock. And current less than that drawn by a 15-watt light bulb lasting only a few seconds can cause serious reactions in the nervous system and the muscles of the body. The result can be paralysis, cessation of breathing, and fibrillation of the heart, ending in death.

Industrial safety experts generally regard 30 volts AC as a conservative limit for dangerous voltage, but it is possible to come into contact with lower voltages and experience unpleasant sensations and consequential reactions. CPSC's National Electronic Injury Surveillance System (NEISS) reports an occasional shock incident involving contact with a car battery or even smaller storage cells. Though a shock may be slight, the startled reaction of the victim could cause more serious injury if the sudden movement causes loss of balance and falling, or jerks some portion of the body or an extremity into moving belts, turning blades or rotating shafts.

Physiological Effects of Electrical Current

The following discussion briefly outlines the physiological experience of a person who receives a shock from increasing levels of current. Omitted from the discussion are electrical burns that are typically found in victims who experience shock at dangerous levels and secondary neurological effects that can result from nerve tissue damage.

Alternating Current is the current found in the receptacles and electrical equipment in our homes. The "direction" of current flow changes 60 times every second (60Hz) as electrical energy is supplied to appliances and lighting. The rapidly changing current flow produces sensations and effects in the body that differ from those resulting from "direct current," such as from a battery[1].

First Sensation

- Occurs at microampere (1/1,000,000 Ampere = 1uA) levels with 60 Hz AC (household) current.
- Lowest levels range from as low as 3 - 5uA up to 300 - 400uA.
- Experienced as tingling, prickling, and stinging when electrified conductor is lightly touched.
- Generally not harmful, but may cause apprehension.

Perception

- Recognizable sensations in affected body parts start at 0.7 - 1.1mA (about 1/1000 Ampere = 1mA, or 1000uA), but as little as 500uA in some persons.
- May not be perceived as painful, but as uncomfortable.
- Level is generally not considered harmful, but startle reaction may cause fall or other sudden muscle reaction.

Pain

- Nerve cells begin to transmit signals perceived as painful at 6 - 9 mA.
- Victim usually retains muscle control to move away from contact.
- In rare cases, muscle may contract uncontrollably (tetanization).

[1] The effects of electric current are highly variable; the values cited are nominal and are adopted from "The Effects of Electric Shock on Man," Charles F. Dalziel, Industrial Radio Engineers Transactions on Medical Electronics, May 1956.

Tetanus

- Victim may become immobilized by continuous muscle contractions at 10 - 25mA and be unable to move away from contact or let go of a grasped electrical conductor; pain is severe.
- Sustained contact may be fatal if current affects the abdominal diaphragm controlling the lungs and heart. If the diaphragm becomes constricted, the victim is unable to breathe and the heart may no longer pump blood.
- Tetanization effects may continue for some time after current is interrupted.

Ventricular Fibrillation

- When current through the heart muscle reaches 100mA and is sustained for several seconds, nerve signals to the muscle are sufficiently disrupted so that the heart begins to "flutter," contracting rapidly and becoming too weak to pump blood through the body.
- Brain death can occur within minutes.

Direct Current, from a battery or a "DC" power supply, more readily causes muscle contractions (tetanus) than AC because the electrical stimulation and current flow is continuous in one "polarity," or direction. The physical sensations tend to be less with DC than with AC, but the stimulation felt at the moment direct current flow starts or ends is typically strong and abrupt. The sensation from sustained high levels of direct current is more likely to be one of heating and warmth. Thresholds of sensation and effect, like those described for alternating current, are shown here for comparison:

	Direct	*Alternating*
First Sensation:	0.6 to 1.0 mA	0.003 to 0.4 mA
Perception:	3.5 to 5 mA	0.5 to 1.1 mA
Pain:	40 to 60 mA	6 to 9 mA
Tetanus:	50 to 75 mA	10 to 25 mA
Ventricular Fibrillation:	>500* mA	>100* mA

*if sustained for more than 3 seconds

The Effect of Body Contact Resistance

An online document from the Lawrence Livermore National Laboratory[2] provides additional, detailed descriptions of the electrical resistance provided by the human body -- what scientists call "body impedance."

> "Three components constitute body impedance: internal body resistance and the two skin resistances at the contact points with two surfaces of different voltage potential. One-hand (or single-point) body contact with electrical circuits or equipment will prevent a person from completing a circuit between two surfaces of different voltage potential. Table B-2 provides a listing of skin-contact resistances encountered under

[2] "Environment, Safety & Health Manual, Volume 2, Part 16, Electrical Safety," http://www.llnl.gov/es_and_h/hsm/doc_16.01/doc16-01.html.

various conditions. .... This table can be used to determine how electrical hazards could affect a worker in varying situations."

Table B-2. Human resistance (Q) for various skin-contact conditions

Body contact condition	Dry (ohms)	Wet (ohms)
Finger touch	40,000-1,000,000	4,000-15,000
Hand holding wire	15,000- 50,000	3,000- 5,000
Finger-thumb grasp	10,000- 30,000	2,000- 5,000
Hand holding a pliers	5,000- 10,000	1,000- 3,000
Palm touch	3,000- 8,000	1,000- 2,000
Hand around 1.5-in. pipe	1,000- 3,000	500- 1,500
Two hands around 1.5-in. pipe	500- 1,500	250- 750
Hand immersed	--	200- 500
Foot immersed	--	100- 300

How is this information significant in our considerations of electric shock and electrocution from consumer products? Let us consider the threshold levels for current that prevent "let-go" (10-25mA) and that may cause ventricular fibrillation (more than 100mA). At a "normal" residential receptacle, the voltage is 120 VAC. The amount of current the receptacle can provide before the circuit breaker interrupts the circuit is roughly 15 to 20 Amperes, greater than 150 times the current that causes fibrillation. If a person is grasping a piece of metal connected to the live side of the receptacle (the other side is "grounded,") and another body part is touching a good, low resistance path to ground, less than 10 mA will flow if the body resistance is more than 12,000 ohms. (That is, R = V / I = 120V/ 0.010A = 12,000 ohms.) When that happens the person will experience pain but may be able to release her grasp on the metal and save herself.

If the body contact resistance is less than 4,800 ohms, perhaps because of perspiration or working in a wet location, more than 25 mA will flow. Now, the victim may not be able to free herself from grasping the live metal and may be badly hurt if not rescued.

To reach currents that can produce ventricular fibrillation, a body contact resistance of less than 1,200 ohms is needed. If a victim were standing in water and holding a faulty, metal housed electric drill in his bare hands, those conditions would produce potentially fatal current flow through his body.

The values in the table show that, in day-to-day living, the greatest risk of serious or fatal electrical shock occurs in environments where electrical appliances and tools are used with wet hands and feet and when good contact, such as a firm grip, is made with a metal-enclosed tool or appliance. Those conditions exist in bathrooms or kitchens and almost anywhere outdoors when the ground is damp or wet or the body is immersed in water. Likewise, someone working with powered hand tools in a hot, humid environment and having damp skin may be at greater risk if the tool becomes energized. These are the types of circumstances reported in in-depth investigations of electrocution incidents that involved consumer products. Similarly, our investigations of shock incidents show the moderating, life-saving effects of a light or glancing contact with an energized product and the protection of wearing shoes and gloves and keeping dry while working outdoors with electrical tools.

The Current Path through the Body

Another significant factor in determining the severity of an electric shock is the current path through the body. The main reason many shock victims don't receive lethal shocks is that their body contact is localized. The current passes from finger to finger in the same hand or across the wet surface of the tongue, as when a child sticks an object into an electrical receptacle or chews an electric cord. The important factor is that the path is away from a major organ such as the brain or heart. Flow of current through the head, chest or heart, can quickly become fatal.

The Duration of Current Flow

Another reason that an electrical shock may not be fatal is that its duration is short. At 100mA alternating current, the approximate current at which ventricular fibrillation is likely, only a few seconds exposure can be fatal. At lower currents, such as 10mA when muscles may clench, death might not occur for several minutes. Limiting duration of exposure is the most effective benefit of having a working ground fault circuit interrupter (GFCI) in circuits where exposure to electrical energy and a ready ground path are most likely--outdoors, bathrooms, kitchens and many other locations around the home. The GFCI is designed to stop a faulty flow of as little as 5/1000 of an ampere of current into a ground path in less than 1/60 of a second after it starts.

Summary

The major factors influencing the severity of electric shock in the human body are the voltage, the duration of the current, the resistance the current encounters in the body, and the path of the current through the body. Of particular importance for users of consumer products is that environmental factors, particularly dampness, can decrease the body's resistance to current flow, thereby increasing the potential for a more severe shock. The major consumer protection device, the ground fault circuit interrupter, works by decreasing the duration of current, thereby decreasing the risk of severe shock.

Tab B

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date:	May 17, 2002
To:	Robert T. Garrett, Project Manager Electrocution Program Evaluation
Through:	N.J. Scheers, Ph.D. NJS Director, Office of Planning and Evaluation
From:	Susan B. Kyle, Ph.D. SBK Management & Program Analyst Office of Planning and Evaluation
Subject:	Electrocution Data Summary

This memorandum provides data on consumer product-associated electrocution deaths as part of a program evaluation of CPSC's Electrocution Hazard Program. The Electrocution Hazard Program is defined as the activities undertaken by CPSC staff to meet its stated Strategic Goal of reducing the rate of death from electrocutions by 20 percent from 1994 to 2004 with a target electrocution rate of 7.0 deaths per 10 million population.

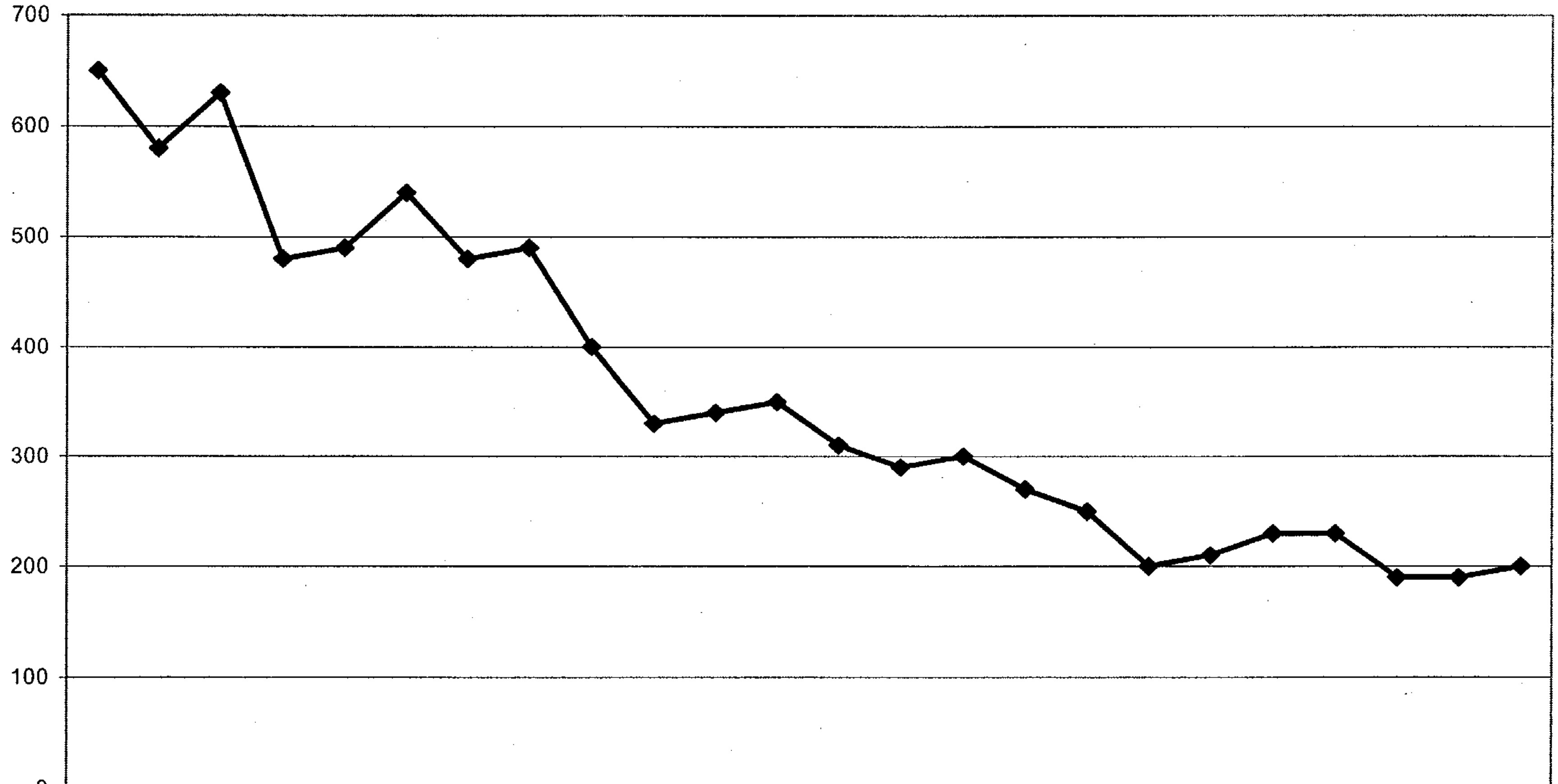
Data presented in this memorandum are extracted from previously published reports on electrocution deaths associated with consumer products. The documents used are listed in Appendix 1 "Memoranda Referenced".

This memorandum will present an overview of available historical information on the overall numbers of electrocution deaths and information on the numbers of deaths associated with specific types of consumer products. In addition, more recent trends will be presented.

Overall Numbers of Deaths and Rates of Death

As shown in Figure 1 on the following page, the annual estimated number of consumer product-associated electrocutions has declined markedly over the period covered by the available reports. In the mid-1970s, the estimated number was around 600. In 1998, the latest year for which data are available, the estimated number was 200.

Figure 1. Electrocutions Associated with Consumer Products



	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Deaths	650	580	630	480	490	540	480	490	400	330	340	350	310	290	300	270	250	200	210	230	230	190	190	200

Age adjusted rates, expressed as deaths per million population, are shown below for the most recent 11 years of available data. The decline in rates over this time period was statistically significant ($p<0.05$, ref 14, page 2).

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Rate	1.18	1.21	1.09	0.99	0.78	0.82	0.89	0.88	0.72	0.71	0.74

For the three most recent years, the age-adjusted rate has been very close to the target rate of 7.0 deaths per 10 million population (equivalent to 0.70 deaths per million).

Numbers of Electrocutions Associated with Specific Types of Consumer Products

A compilation of all available data on estimated numbers of electrocutions associated with specific types of consumer products is provided in Appendix 2. Various portions of these data are discussed below.

To determine what products were associated with the greatest decrease in electrocutions over the 1975-1998 time period, annual averages were compared for three different three-year time periods: 1975-1977, 1986-1988, and 1996-1998. The 1975-1977 and 1986-1988 annual averages were provided in the historical data. The 1996-1998 annual average was calculated from the yearly data in Appendix 2. Differences between the three time periods were also calculated. The results are presented in Table 1 on the following page, ranked by the difference between the 1975-1977 annual average and the 1996-1998 annual average.

The product category associated with the greatest decrease in electrocutions was Antennas. This category includes radio, television and CB antennas. "The majority of deaths in the earlier period involved citizens band base station antennas which were at their peak of popularity in the mid-70's" (ref 1, page 2) and generally involved contact with an overhead power line (ref 4, table 3, footnote 2).

Most of the decrease in electrocutions associated with antennas occurred between the mid-70s and the mid-80s with the annual average decreasing from 186 to 30. The decrease from the mid-80s to the mid-90s was much smaller.

The second greatest decrease in electrocutions was seen in the category "Other (undefined)". There was not enough information given in the memoranda from the early time periods to be able to determine what products were included in this category.

The Installed Household Wiring, Power Tools, and Garden and Farm Equipment categories were associated with decreases of approximately 40-45 in average annual deaths across the two time periods. The average annual electrocutions associated with Ladders decreased by almost 20 over the two time periods.

Table 1.
Electrocution Deaths Associated with
Specific Types of Consumer Products
Annual Averages for Three Time Periods
Ranked by Difference between 1970s and 1990s

	Annual Avg 1975-1977	Diff 70-80	***Annual Avg 1986-1988***	Diff 80-90	***Annual Avg 1996-1998***	Diff* 70-90
Antennas	***186***	156	***30***	13	***17***	169
Installed household wiring	***76***	8	***68***	39	***29***	47
Power Tools	***66***	32	***34***	12	***22***	44
Power Drills					***6***	
Power Saws					***6***	
Welding Equipment					***3***	
Battery Chargers					***4***	
Other power tools					***3***	
Garden/Farm Equipment	***45***	35	***10***	4	***6***	*39*
Garden Equipment	***21***	17	***4***			
Farm Equipment	***24***	18	***6***			
Ladders	***30***	-4	***34***	23	***11***	*19*
Radios,TVs,Stereos	***13***	7	***6***	0	***6***	7
Hair/Hygiene Equipment	***11***	-3	***14***	10	***4***	7
Small Appliances	***13***	0	***13***	1	***12***	1
Vacuum cleaners					***0***	
Portable Heaters					***0***	
Fans					***4***	
Other Small Appliances					***8***	
Pumps/Generators	***9***	5	***4***	-5	***9***	0
Swimming pools					***0***	
Lamps/Light Fixtures	***11***	-2	***13***	1	***12***	-1
Electric Cords, Work Lights	***11***	0	***11***	-1	***12***	-1
Extension Cords					***8***	
Work Lights					***4***	
Pressure washers					***2***	
Boat Hoist/Amusement Rides					***2***	
Large Appliances	***19***	-6	***25***	3	***22***	-3
Washer/Dryers					***2***	
Refrigerators/Freezers					***3***	
Ranges/Ovens					***1***	
Electric Furnace/Water Heater					***4***	
Air Conditioners					***12***	
Pipes, Poles, Fences	***11***	-7	***18***	1	***17***	-6
Microwaves					***9***	
Other (Undefined)	***120***		***37***		***0***	
*Total***	***620***		***317***		***200***	

*Positve numbers indicate a **decrease** in electrocutions.
**Detail may not add to total due to rounding.

In contrast to the pattern seen with Antennas, most of the decrease in electrocutions associated with Installed Household Wiring occurred between the mid-80s and the mid-90s, with a much smaller decrease occurring between the mid-70s and the mid-80s. Power Tools and Garden/Farm Equipment showed a pattern similar to antennas, with the larger decrease occurring between the mid-70s and mid-80s and a smaller decrease between the mid-80s and mid-90s.

With the exception of Ladders, all other product categories showed differences of less than 10 deaths over the 1970-1990 time period. Some showed decreases of less than ten deaths, some showed increases of less than 10 deaths.

Recent Data and Trends

Inspection of Figure 1 reveals that the overall downward trend in electrocution deaths may have leveled off starting in 1992 at approximately 200 deaths per year. To determine whether there were any product categories where the downward trend might be continuing, data from 1992-1998 were inspected. Table 2 on the following page presents estimated electrocutions by different types of consumer products for the years 1992-1998, ranked by the total number of deaths associated with the category over the time period.

The Household Wiring category is associated with the most deaths in the recent time period, with an average of 34 deaths per year in this time period, despite having shown the second largest decrease in electrocutions historically (see Table 1).

The Large Appliances, Power Tools, and Antennas categories were each associated with an annual average of approximately 20 to 25 deaths. Most of the antenna-associated deaths continue to involve CB antennas. This may indicate a particularly high risk associated with CB antennas since their numbers in use are probably lower than the products involved in the large appliance and power tool categories.

The Lamps/Light Fixtures, Ladders, Electric Cords/Work Lights, Small Appliances and Pipes/Poles/Fences categories were each associated with an annual average of 12-15 deaths. Within this group, both the Ladders and Pipes/Poles/Fences categories frequently involved contact with overhead power lines, as did the antenna category. The remaining categories were associated with an average number of deaths fewer than 10.

Trends were sought by inspection of the data for the time period 1992-1998. Graphs for the four categories associated with the largest average numbers of electrocutions are provided in Figures 2-5 following Table 2. Neither the graphs nor the data for the other product categories indicate any readily apparent downward trend during the 1992-1998 time period. Based on this, there are no particular product categories where additional future decreases would be anticipated

Table 2.
Electrocution Deaths Associated with
Specific Types of Consumer Products
Annual Estimates, Total, and Annual Average for 1992-1998
Ranked by Total Number of Deaths, 1992-1998

	Annual Estimates							Total	Average
	1992	1993	1994	1995	1996	1997	1998	1992-1998	1992-1998
Household Wiring	26	27	42	53	41	22	25	236	34
Large Appliances	22	22	25	25	21	18	29	162	23
Washer/Dryers	3	1	7		1	4			
Refrigerators/Freezers	3	4	3	3	1	6	2		
Ranges/Ovens		3	1				4		
Electric Furnace/Water Heater	6	3	3	6	5	4	4		
Air Conditioners	10	11	10	16	14	4	19		
Dishwashers			1						
Power Tools	23	25	29	13	15	21	28	154	22
Power Drills	*11*	*10*	*14*	*3*	*7*	*2*	*8*		
Power Saws	5	8	7	5	1	7	10		
Welding Equipment	5	7	3	4	5	4			
Battery Chargers						6	6		
Other power tools	2		5	1	2	2	4		
Antennas	21	36	16	24	19	20	12	148	21
Lamps/Light Fixtures	18	11	22	14	10	15	12	102	15
Ladders	*25*	*16*	*9*	*15*	*11*	*13*	*10*	99	14
Electric Cords, Work Lights	13	10	16	15	5	15	18	92	13
Extension Cords	6	3	14	9	4	9	12		
Work Lights	*7*	*7*	*2*	*6*	*1*	*6*	*6*		
Small Appliances	10	14	13	15	9	15	12	88	13
Portable Heaters		3							
Fans	6	6	6	10	4	4	4		
Other Small Appliances	4	5	7	5	5	11	8		
Pipes, Poles, Fences	8	4	11	11	19	13	19	85	12
Pumps/Generators	8	10	11	8	7	13	8	65	9
Garden/Farm Equipment	*15*	*10*	*7*	*14*	*7*	*6*	*4*	63	9
Microwaves		4	6	10	12	4	12	48	7
Radios, TVs, Stereos	4	8	5	3	4	9	4	37	5
Hair/Hygiene Equipment	2	3	1	4	5	4	2	21	3
Swimming pools	4	2	10					16	2
Boat Hoist/Amusement Rides		4	3	1	1	2	2	13	2
Pressure washers							6	6	1
Other (Undefined)			3	5	5	4		17	2
*Annual Published Estimate**	200	210	230	230	190	190	200	1450	207

*Annual published estimates are rounded to the nearest ten.

Figure 2. Household Wiring Electrocutions

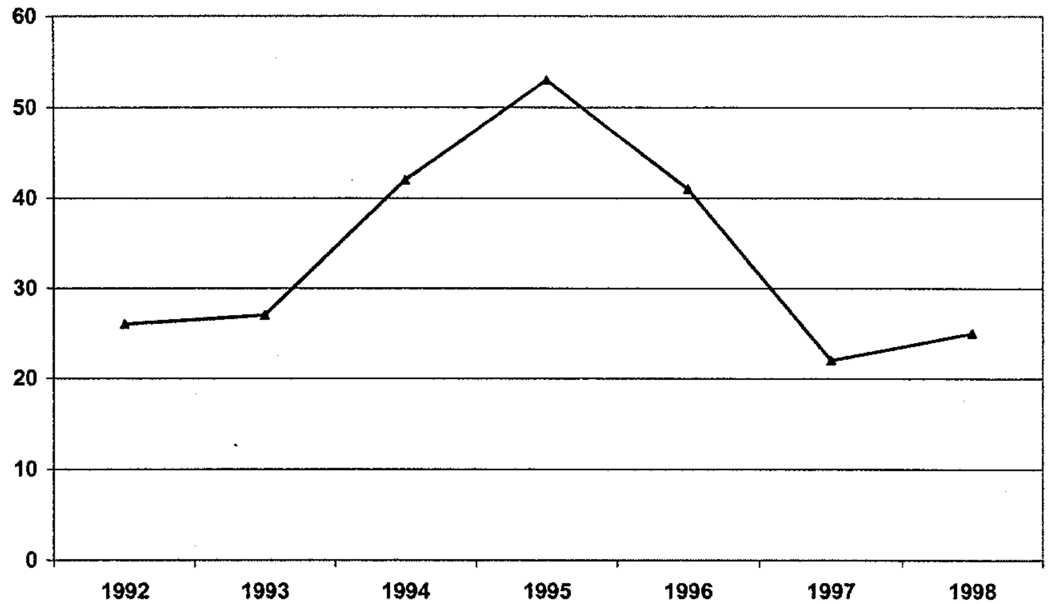


Figure 3. Large Appliances Electrocutions

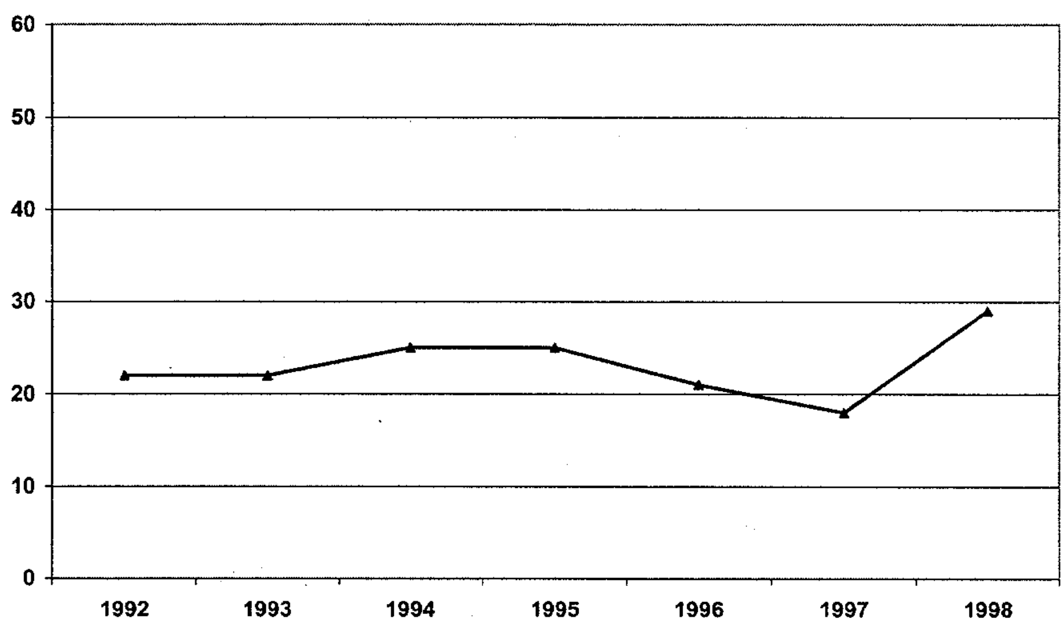


Figure 4. Power Tool Electrocutions

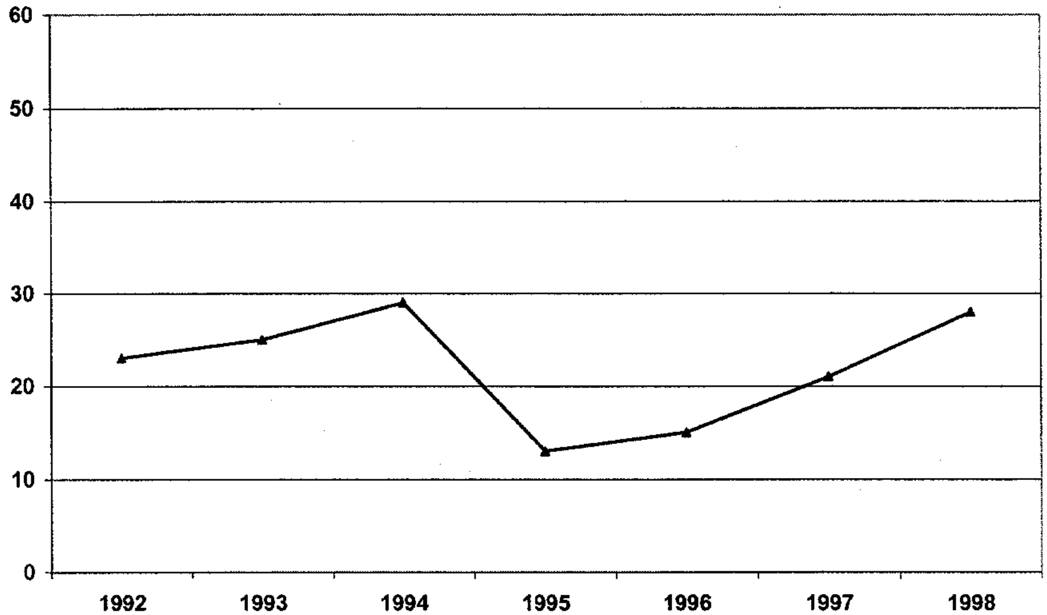
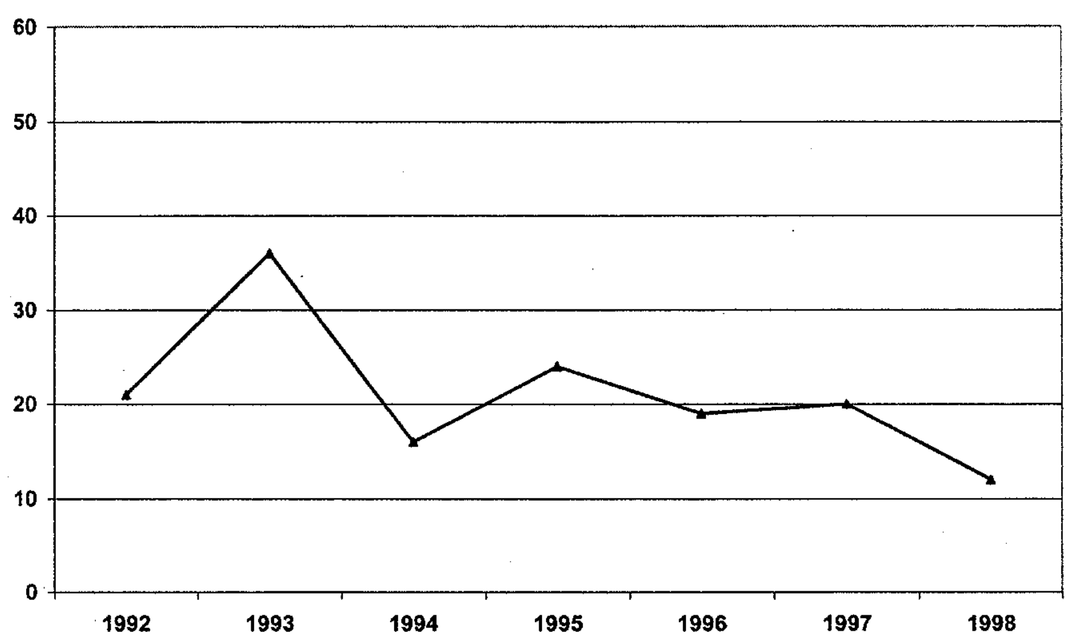


Figure 5. Antenna Electrocutions



without some type of intervention. However, this does not preclude continued minor reductions in any or all categories which might constitute a further drop in the overall number of electrocutions.

Summary and Conclusions

The number of consumer product-associated electrocution deaths has decreased markedly from the mid-1970s through 1998, the latest year for which data are available. The rate of death for the three most recently reported years was close to the strategic goal of 7.0 deaths per 10 million population. The product category showing the greatest decrease in deaths over this time period was Antennas. The Installed Household Wiring, Power Tools, and Garden and Farm Equipment categories also showed large decreases in deaths over this time period.

The downward trend in the number of consumer product-associated electrocutions may have leveled off beginning in 1992. Inspection of data from 1992 through 1998 revealed no readily apparent downward trends in any of the product categories. However, continued small reductions in any or all of the product categories may contribute to a continued decrease in the overall number of electrocutions associated with consumer products.

Appendix 1.
Memoranda Referenced

1. Memorandum from Linda Smith, EPHA, to Carl Blechschmidt, "Electrocutions Associated with Consumer Products", May 19, 1987 – contains data for 1984 and earlier.
2. Memorandum from Linda Smith, EPHA, to Carl Blechschmidt, "Electrocutions Involving Consumer Products", Feb 10, 1988 – contains data for 1985 and earlier.
3. Memorandum from Linda Smith, EPHA, to Carl Blechschmidt, "Electrocutions Involving Consumer Products", Mar 30, 1990 – contains data for 1987 and earlier.
4. Memorandum from Audrey E.J. Corley to A. Albert Biss, "Electrocutions Associated With Consumer Products", Jun 3, 1991 – contains data for 1988 and earlier.
5. Memorandum for the Record, Kimberley E. Long, EPHA, "Methodology for Estimating Product-Related Electrocutions for 1990", Sep 8, 1993.
6. Memorandum from Kimberly E. Long, EPHA, to A. Albert Biss, "Electrocutions Associated With Consumer Products", Sep 8, 1993 – contains data for 1990 and earlier.
7. Memorandum from Kimberly E. Long, EPHA, to Linda Edwards, "National Estimates of Electrocutions Associated With Consumer Products", Aug 19, 1994 – contains data from 1991 and earlier.
8. Memorandum from Kimberley E. Long, EPHA, to Linda Edwards, "1992 National Estimates of Electrocutions Associated With Consumer Products", Jul 27, 1995 – contains data from 1992 and earlier.
9. Memorandum from Kimberly E. Long, EPHA, to William King, "1993 National Estimates of Electrocutions Associated With Consumer Products", Sep 10, 1996 – contains data from 1993 and earlier.
10. Memorandum from Kimberly L. Ault, EPHA, to William King, "1994 National Estimates of Electrocutions Associated With Consumer Products", Mar 10, 1998 – contains data from 1994 and earlier.
11. Memorandum from Kimberly L. Ault, EPHA, to William King, "1995 National Estimates of Electrocutions Associated With Consumer Products", Sep 30, 1998 – contains data from 1995 and earlier.
12. Memorandum from Kimberly Ault, Ph.D., to Bill King, "1996 Electrocutions Associated with the Use of Consumer Products", Mar 29, 1999 – contains data from 1996 and earlier.
13. Memorandum from Signe Hiser, M.S., to Richard Stern, "1997 Electrocutions Associated with the Use of Consumer Products", April 5, 2000 – contains data from 1997 and earlier.
14. Memorandum from Signe Hiser, M.S., to Linda Edwards, "1998 Electrocutions Associated with the Use of Consumer Products", July 25, 2001 – contains data from 1998 and earlier.

Appendix 2.
Estimated Numbers of
Electrocution Deaths Associated with
Specific Types of Consumer Products

Available data on numbers of electrocutions associated with specific types of consumer products are summarized in the following table. Data prior to 1990 were available only as summary data for three time periods, the mid 1970's, the mid 1980's and the late 1980's. The data presented are the annual average for each of those three time periods. Yearly data were available for each year beginning in 1990 and continuing through 1998, the most recent year for which data are available.

	Annual Average			Annual Estimate								
	1975-1977	1984-1985	1986-1988	1990	1991	1992	1993	1994	1995	1996	1997	1998
Antennas	186	37	30	19	16	21	36	16	24	19	20	12
Household Wiring	76	38	68	42	42	26	27	42	53	41	22	25
Power Tools	66	31	34	34	38							
Power Drills						*11*	*10*	*14*	*3*	*7*	*2*	*8*
Power Saws						5	8	7	5	1	7	10
Welding Equipment						5	7	3	4	5	4	
Battery Chargers											6	6
Other power tools						2		5	1	2	2	4
Garden/Farm Equipment						*15*	*10*	*7*	*14*	*7*	*6*	*4*
Garden Equipment	*21*	*4*	*4*	*6*	*10*							
Farm Equipment	*24*	*23*	*6*	*10*	*3*							
Ladders	*30*	*27*	*34*	*30*	*15*	*25*	*16*	*9*	*15*	*11*	*13*	*10*
Radios, TVs, Stereos	13	7	6	6	6	4	8	5	3	4	9	4
Hair/Hygiene Equipment	11	21	14	7	5	2	3	1	4	5	4	2
Small Appliances	13	14	13	22	17							
Vacuum cleaners												
Portable Heaters							3					
Fans						6	6	6	10	4	4	4
Other Small Appliances						4	5	7	5	5	11	8
Pumps/Generators	9	11	4	6	6	8	10	11	8	7	13	8
Swimming pools						4	2	10				
Lamps/Light Fixtures	11	10	13	14	16	18	11	22	14	10	15	12
Electric Cords, Work Lights	11	21	11	19	16							
Extension Cords						6	3	14	9	4	9	12
Work Lights						*7*	*7*	*2*	*6*	*1*	*6*	*6*
Pressure washers												6
Boat Hoist/Amusement Rides							4	3	1	1	2	2
Large Appliances	19	28	25	30	24							
Washer/Dryers						3	1	7		1	4	
Refrigerators/Freezers						3	4	3	3	1	6	2
Ranges/Ovens							3	1				4
Electric Furnace/Water Heater						6	3	3	6	5	4	4
Air Conditioners						10	11	10	16	14	4	19
Dishwashers								1				
Pipes, Poles, Fences	11	28	18	16	25	8	4	11	11	19	13	19
Microwaves							4	6	10	12	4	12
Other (Undefined)	120	40	37	25	10			3	5	5	4	
*Total**	620	335	317	270	250	200	210	230	230	190	190	200

*Annual estimates are rounded to the nearest ten. Annual averages are not.

Tab C

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

DATE:	June 3, 2002
TO:	N.J. Scheers, Director Office of Planning and Evaluation (EXPE)
FROM:	Robert Garrett, Electrical Engineer, EXPE RG Susan B. Kyle, Ph.D., Management & Program Analyst, EXPE SBK
SUBJECT:	Electrocution In-Depth Investigations 1994-2000 Hazard Patterns and Potential Interventions

Introduction

As part of the evaluation of the Electrocution Hazard Program, recent in-depth investigation reports (IDIs) involving electrocutions were examined to determine what types of electrocution hazards are currently being experienced by consumers and what interventions might be effective in reducing the risk from those hazards.

CPSC staff reviewed IDIs for the seven-year period 1994-2000 for electrocutions that occurred in locations which would have been considered in-scope for developing national estimates of the numbers of consumer-product-associated electrocutions. These locations were "residential", "farm", or "sports/recreation areas"[1].

There were 209 IDIs involving electrocution incidents associated with consumer products that occurred in in-scope locations for the seven-year interval ending December 31, 2000. They are presented in Table 1 by product category.

Table 1 - Investigated Electrocutions 1994-2000
By Product Category

Antennas	47	22%
Installed wiring	46	22%
Outdoor & power tools	36	17%
Large appliances	25	12%
Small appliances	21	10%
Lighting	21	10%
Other	13	6%
Total	**209**	

[1] Memorandum from Signe Hiser, M.S., to Linda Edwards, "1998 Electrocutions Associated with the Use of Consumer Products", July 25, 2001.

Table 2 below presents the sum of the national estimates for each product category for the time period 1990-1998, the latest year for which national estimates are available.

Table 2 – National Estimates of Electrocutions 1990-1998 By Product Category

Outdoor & power tools[2]	398	21%
Installed wiring [3]	377	20%
Antennas, pipes, poles	312	17%
Large Appliances[4]	253	14%
Lighting[5]	202	11%
Small Appliances[6]	182	10%
Ladders	143	8%
Total	**1867**	

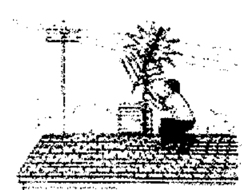
Although the IDIs were not chosen to be a statistical sample of the electrocutions, they were distributed across the product categories in approximately the same way as the estimated deaths. The major exception to this was ladders. There was only one IDI which involved a ladder (in the miscellaneous other category), whereas ladders were associated with 8% of the estimated deaths. The low proportion of investigated ladder incidents may indicate that the hazard pattern of ladder-associated electrocutions was well known to involve contact with overhead power lines and that staff felt that assigning cases for investigation was no longer necessary.

Hazards Observed and Potential Interventions

The major purpose of this analysis of the IDIs was to determine the hazard patterns currently involved with electrocutions in order to identify interventions. Therefore, for each product category, electrical hazard patterns will be described. The types of interventions normally used to protect against the identified hazards will also be discussed. A description of basic electrical terms, hazards and interventions is provided in Appendix I as background for those unfamiliar with home wiring hazards or types of electrical interventions.

<u>Antennas</u>

Forty-seven electrocution IDIs were reviewed.



Major Hazard Patterns

All 47 incidents involved contact with high voltage overhead power lines

[2] Outdoor & Power Tools include farm and garden tools, power drills and saws, pumps, generators, chargers, welders, pressure washers, and other miscellaneous electric power tools.
[3] Installed Wiring includes fuse boxes, panel boards, in-wall and surface wiring, and receptacles.
[4] Large Appliances include air conditioners, microwave ovens, electric water heaters and furnaces, freezers, refrigerators, dish and clothes washers, clothes dryers, ovens, ranges and stovetops.
[5] Lighting includes installed indoor and outdoor lighting, portable table and floor lamp fixtures and work lights.
[6] Small Appliances include radios, televisions, stereos, fans, hair dryers, personal hygiene appliances, vacuum cleaners, fans, portable heaters, extension cords, and other miscellaneous small appliances.

28 involved CB antennas and masts (including one being installed on a TV antenna tower); 12 of these incidents occurred in 1994 and 8 occurred in 1996; more recent IDIs involved far fewer CB antennas
10 involved TV antennas
2 involved other types of antennas (e.g., amateur radio) and
7 involved unspecified antennas

Other Characteristics Observed

20 involved installations
11 were removals
16 were described only as "moving antenna" or not described sufficiently to characterize
17 involved products described as old or very old (but not necessarily predating regulations)
Many incidents were in rural locations or mobile home parks

The IDI narratives frequently suggested that the antennas were acquired second-hand, were old, or were homemade. The age of the antenna was not often stated. Where the ages were described, they generally ranged from 10 to 30 years.

Several of the IDIs indicated that antenna work was being done in near or complete darkness, or when the power line was directly overhead and in close proximity to the workspace.

Labeling

A 1978 CPSC regulation requires antenna labeling that warns of the risk from overhead power lines. A 1982 regulation requires that antennas resist conducting current from high voltage sources. Determining whether the particular antenna assemblies involved in the investigated incidents were manufactured before or after these regulations was generally not possible.

The presence of warning labels was reported in very few cases. It is not possible to tell if this was because the assemblies were homemade or too old to have had labels, or because the labels wore away, faded, or fell off after exposure to weather. Only one antenna, in 1996, was described as being 3 or 4 years old but without labels or warnings.

Distance from power lines

Where mast, antenna, and power line heights and their separation distances were described, most antenna assemblies failed to clear the power line by a distance less than 5 percent of the assembly height, some only by inches. Reports suggested that those working with a tall antenna assembly for the first time may not have anticipated the effects of the lengthy, extended weight or the strength required to manage it.

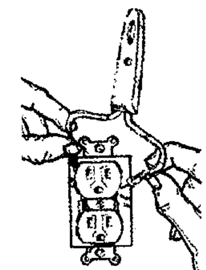
Interventions

Generally, protection from electrocution involving overhead power lines is based on isolation. Lines are installed at heights intended to prevent accidental contact. Coverings on high-voltage power lines do not provide electrical insulation, they merely provide protection for the lines from the weather. The CPSC labeling regulation for CB antennas was designed to warn about the hazard from overhead wires, alerting the consumer to keep the antenna away from the wires.

The 1982 performance regulation required that the uppermost portion of CB antennas be insulated, providing protection in case actual contact was made, which was the major hazard pattern observed.

<u>Installed Wiring</u>

Forty-six electrocution IDIs were reviewed.



21 resulted from direct contact with an energized conductor
18 resulted from an electrical fault (short circuit) to normally non-energized, grounded surfaces, including 3 when pool water became electrified
6 resulted from reversal of hot and neutral or ground conductors
1 resulted from contact with an unidentified energy source

30 occurred outdoors (including 5 in crawlspaces)
15 were indoors
1 was not described

20 resulted because a grounding conductor was missing, including several from hot-ground reversal

14 involved locations where the current edition of the National Electrical Code (NEC) specifies use of ground fault circuit interrupters (GFCIs) but a GFCI was not present
3 resulted from failure of an installed GFCI to operate correctly

In almost half the incidents (22 incidents) the victim was in contact with damp or wet ground (15 incidents), or actually immersed in water (7 incidents). In 3 of the 7 immersion cases, the water itself had become energized by failure of some electrical apparatus. Three cases of multiple deaths and injuries involved electrical system failures in underwater swimming pool lights that created an electrical field in the water. An incident in which two children died resulted from electrical cables being installed in the water at a residential dock. In all cases, moisture increased electrical conductivity, the insulation and grounding systems failed, and GFCIs had not been installed.

In many of the investigated incidents there was an error in the wiring of an electrical circuit such as omitting a ground connection on a receptacle, junction box, or appliance; reversing the connections to the energized supply conductor with those of the neutral or ground conductor; or failing to install a ground fault circuit interrupter (GFCI) in an appropriate location.

In other cases there was a procedural error: failing to bury an underground cable deep enough, failing to enclose or cover energized conductors from casual contact, failing to maintain degraded or damaged circuits.

Sometimes, the error involved more basic electrical safety issues: failing to turn off the power before going into a circuit box, picking up an unidentified cable lying on the ground, or not staying clear of bare electrical wires. On some occasions, investigating officials found evidence of alcohol or drug use.

Interventions

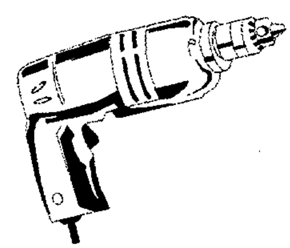
In almost every incident investigated, the presence of a correctly installed and operable GFCI might have prevented death. However, in many of these cases, the NEC does not currently require GFCI installation in the involved locations, such as living rooms and bedrooms.

Alternatively, in many of the examined cases, properly installed grounds (in conjunction with fuses or circuit breakers) might have provided protection. Absence of grounding usually occurred because it was not initially installed, sometimes in violation of the NEC but often because the code did not apply or was not enforced at the time or place of installation. In some cases, the grounding circuit failed or was removed after installation and not discovered until the incident.

<u>Outdoor and Power Tools</u>

Thirty-six electrocution IDIs were reviewed.

24 involved tools that must be hand-held to use (drills, circular or saber saws, weed trimmers, mowers, etc.)
12 involved stationary use tools (table or band saws, battery chargers, sump pumps, etc.)



16 were caused by a discovered electrical fault (short circuit) to metal housings or handles
15 were caused by an undetermined electrical fault
3 were caused by the tool and victim being simultaneously immersed in water
2 were caused by possible direct contact with cord having damaged insulation

26 occurred in locations where the NEC currently requires a GFCI, but no GFCI was installed
7 were in locations not specifically described but likely covered by the NEC
2 resulted because an installed GFCI failed to operate correctly
1 occurred in an indoor location not covered by the NEC for GFCI use

17 also involved wet or damp locations, including 7 with a barefoot victim and 3 immersions

5 involved the victim standing on a ladder (usually described as aluminum)

12 occurred after a ground connection (usually the ground blade of a three-wire plug) was removed
7 occurred after a two-wire power cord or plug was substituted for a three-wire cord and plug, removing the ground connection

2 occurred after the hot and neutral conductors of the power source were reversed (and a fault occurred)

13 involved tools described as old or very old (as much as 50 years old), some, therefore, predating current safety standards

UL standards have required power tool grounding since 1961. In over half these investigated cases (19 of 36) the grounding had been circumvented either by removing the ground blade in the plug, misusing an extension cord or adapter, or miswiring the ground conductor to the "hot" supply.

As an alternative to grounding the tool, UL made provisions in 1974 to allow double insulation (a supplemental level of insulation involving the housing in addition to the internal electrical circuit insulation, as described in Appendix I). Of the 36 investigated deaths, only two deaths could be attributed to double-insulated tools: both were walk-behind mowers on which the power cord insulation was mechanically compromised and shorted to the metal handle held by the user. There were no investigated deaths involving any other type of double-insulated hand-held tools.

Almost half (17 of 36) of the examined incidents occurred in damp or wet locations. In addition, 7 of these victims in damp or wet locations were barefooted while in contact with the tool. Three of these deaths happened when both the tool and victim were immersed in water.

Interventions

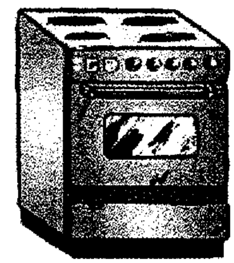
Double-insulation could have prevented the electrocutions involving a fault to metal housing or handles, even where the victim was standing barefoot on damp ground. Double insulation cannot prevent serious injury in situations where water enters the housing and provides an electrical path. However, GFCIs also could minimize the possibility of this type of electrocution.

In many of these cases involving power tools, including those without grounding or double insulation, the presence of a GFCI in the supplying circuit would have served to minimize the likelihood of a fatal injury. Except for two cases, all of the reviewed incidents lacked any report of a GFCI being installed in the electrical circuits involved in the lethal shock. In the two electrocution cases where a GFCI was installed, the device was defective and did not disconnect power from the faulted tool.

In over half of the cases studied, the tool had been altered. The ground blade had been removed from the power cord plug in 12 incidents. The three-wire, grounded power cord had been replaced with a two-wire ungrounded one in 7 incidents. This may indicate that the user who modified the tool was unaware of the function of the ground conductor and did not understand the protection it provided.

<u>Large Appliances</u>

Twenty-five electrocution IDIs were reviewed.



14 resulted from an electrical fault (short circuit) to normally non-energized, ungrounded metal surfaces
7 resulted from contact with energized high voltage circuits of microwave ovens during repair attempts
3 resulted from victim's contact with an energized conductor inside a non-microwave appliance
1 resulted from an undetermined contact

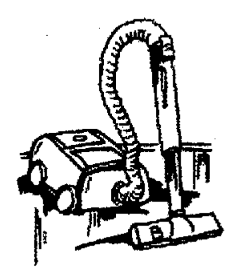
7 occurred after a ground connection was removed or not connected (and a circuit faulted)

2 occurred after the appliance was flooded; one when the victim apparently entered the water at the time of the incident and one after attempts to dry the appliance
6 occurred when the victim was on wet ground or a wet finished surface

3 involved faulted vending machines in public areas (one at a swimming pool, two at motels) that lacked proper grounding

<u>Small Appliances</u>

Twenty-one electrocution IDIs were reviewed.



7 resulted from an electrical fault (short circuit) to normally non-energized, ungrounded metal surfaces
4 resulted from victim's contact with an energized conductor inside the appliance because of a damaged housing
3 resulted from contact with energized internal circuitry during repair or alteration
2 resulted from incorrect supply wiring (hot-neutral or hot-ground reversal) and an apparent fault
3 resulted from hairdryers that lacked immersion or leakage protection circuitry being immersed in water with the victim
2 resulted from two-wire ungrounded appliances becoming immersed in water with the victim

9 occurred while a GFCI was not installed in an area as required by the NEC
4 occurred after a ground connection was removed or not connected (often in conjunction with a fault)

About half (21 out of 46) of the electrocutions involving large and small appliances resulted from an internal short circuit to the ungrounded metal of an appliance housing or frame.

Seventeen deaths occurred from contact with internal circuits, ten while the victim was repairing the appliance, which included contact with the high-voltage power supply of seven microwave ovens.

Six fatal incidents (including three older hair dryers) resulted when both the appliance and the victim were immersed together in water, one happening during a flood.

Interventions

UL has required grounding for most large appliances for decades (for refrigerators, for example, since the mid-1960's). In many of the reported incidents the grounding was damaged (corroded, etc.) or defeated (ground blade cut off, or not connected). In some cases the household wiring itself was not grounded. GFCI protection could protect against these electrocutions.

While major appliances are generally required to have grounding, few small appliances have the same protection, often relying instead on polarized plugs on power cords and/or housings made of insulating material (double insulation). However, damp, wet conditions or immersion in water can defeat both types of protection. GFCIs are needed to prevent electrocution in such instances. GFCIs can be effective even in situations involving water immersion, such as in bathtubs.

Lighting

Twenty-one electrocution IDIs were reviewed.

12 resulted from an electrical fault (short circuit) to normally non-energized, ungrounded metal surfaces (usually some part of the fixture assembly)
6 resulted from direct contact with an exposed energized electrical element (wiring, socket, filament support, etc.)
3 resulted from unknown causes, but plausibly a fault

10 were portable residential lamp fixtures, most described as metal
8 were clamp, work or drop lights (including 2 halogen work lights)
2 were outdoor fluorescent fixtures
1 was a permanently installed outdoor light fixture

13 occurred while a GFCI was not installed in a location where the NEC requires one
3 resulted when a grounding conductor was missing

8 described contact with water, wet skin or wet ground

Every fatal lighting incident reviewed resulted from a scenario (high leakage current in a fault path to a ground outside the return circuit) where GFCI use could prevent electrocution. More than half the examined incidents (12 out of 21) occurred in locations where the NEC mandates use of GFCIs, but they were not present. The current sources involved in the remaining fatalities (general lighting circuits and household receptacles) are not required by the code to have GFCIs.

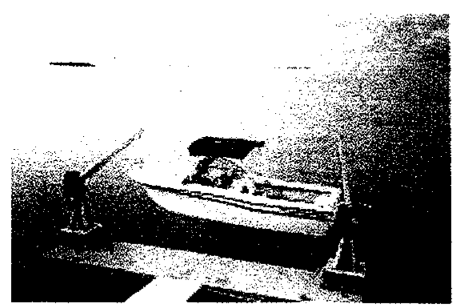
Even without a GFCI present, proper grounding might have provided protection in at least 11 incidents which involved work lights and outdoor fixtures. These lights and locations are required by UL standards or the NEC to be grounded. However, investigators did not report the use of grounding in most incidents, and it may be that the products were so old that they predated the requirements.

In other instances, grounding is not required by the NEC or UL, but it would have provided protection had it been present. Most portable lamps for residential use are not required to have a three-wire power cord and rely instead on a polarized two-wire cord and plug to reduce risk. In incidents where electrocution resulted from contact with the metal exterior of a lamp energized by a fault from internal wiring, the death might have been avoided with grounding techniques.

Miscellaneous

Thirteen electrocution IDIs were reviewed.

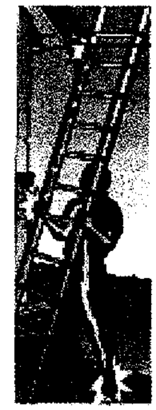
- *Boat Hoist* - In 1994 an apparently home-built boat hoist, powered by a buried electrical line whose bare hot and neutral (but not ground) conductors were simply stuck into the empty slots of an outdoor, unprotected, non-GFCI receptacle, electrocuted its victim while he was standing in water. A survivor/witness said the hoist had been shocking people for ten years, but never enough to hurt anyone.



  CPSC worked with manufacturers to include GFCIs on boat hoists via Section 15 (Substantial Hazard) activities in early 1990s, determining that such electrical products without GFCIs were defective and represented unacceptable risks of personal injury. Numerous corrective actions resulted in raising safety awareness and increasing the use of GFCIs by commercial hoist builders.

- *Electrical cords* - Six deaths involving electrical cords were investigated. Three involved children aged under 24 months: a 2-month-old who became entangled in the damaged and poorly taped power cord of a heating pad; a 12-month-old who reportedly pulled the electrical tape off a power cord; and a 22-month-old, barefoot on muddy ground, who played with a poorly constructed, homemade outlet box on a power cord. Two extension cord cases involved a victim who was barefoot on wet ground with possibly submerged extension cords. The sixth incident involved a victim in a damp crawl space using a power tool with a reported faulty extension cord.

- *Fences* - One incident involved a victim who had attached an energized extension cord to a chain-link fence to protect his chickens from predators and then slipped as he climbed his aluminum stepladder while it leaned against a fence post. The other incident involving a fence was a child, alone, who slipped and grabbed a 7,000-volt charged fence used to corral horses.



- *Metal ladders* - In one incident in 1995, two died while lowering a 40-foot extension ladder when it struck a 7,200 volt power line at a public recreation center and park.

  Ladders, usually metal ones, are among the top non-electrically powered consumer product groupings (antennas, poles, and pipes being the largest) that are involved in electrical fatalities. Although electrical contractors and other professionals who work with electrical equipment above the ground often use insulated fiberglass ladders designed for protection, no UL standards or electrical codes specify non-conductive ladders for consumer use.

- *Worm Probes* - As recently as 1999 and 2000, three deaths, including a 12 year old and a 15 year old, were reported as a result of trying to use old homemade worm probes. Essentially, worm probes are two metal rods connected to a power cord. They are stuck into moist soil to drive earthworms to the surface so the user can collect the worms as fishing bait. In each investigated incident, the victim was working alone, barefoot on wet soil, and using a product described as homemade, with a frayed or spliced power cord.

Discussion

Electrocution hazards currently being experienced by consumers were identified from recent IDIs and can be summarized as follows.

For antennas, the hazard continues to be contact with overhead power lines. From the available IDIs, it could not be determined whether the CB antennas involved in recent incidents conformed to CPSC regulations intended to reduce the risk associated with overhead power lines, or whether the antennas may have predated regulations.

The number of incidents that involved CB antennas, as opposed to other types of antennas, was higher in the earlier years studied (1994 and 1996). In more recent years, fewer investigated antenna-related incidents involved CB antennas. Whether this is simply a result of analysts' decisions to assign fewer CB antenna-related incidents for investigation, or whether it indicates that fewer CB antennas are involved in more recent incidents cannot be determined from the available data. However, if most antenna-related electrocutions no longer involve CB antennas, then means of addressing the hazard must be found other than regulations relating to CB antennas.

Information in the IDIs indicated that many of the involved antennas were old or were homemade. In addition, conditions cited, such as working in near or complete darkness, or with the power line directly overhead, may indicate that consumers are unaware of the risks involved, or underestimate the risk to themselves.

Among the investigated incidents which involved installed wiring, many indicated unsafe practices, such as contact with damp or wet ground while working with electricity, failing to turn off power before working on a circuit box, or miswiring an electrical circuit. Properly installed grounds might have provided protection in a number of these cases. GFCIs could also have prevented many of these fatalities. Information and education might help to reduce the types of unsafe practices seen. These installed wiring investigations also identified three cases where an installed GFCI failed to operate properly.

In over half of the incidents involving power tools, grounding had been circumvented. In addition, almost half of the incidents occurred in damp or wet locations. This may indicate a lack of understanding of the protection afforded by grounding, an underestimation of the risk involved to the user, or an inability to afford better tools. Double insulation might have prevented some of these electrocutions. (There were no reported incidents involving double-insulated hand tools.) GFCIs could have afforded protection in cases where double insulation could not. In two cases, GFCIs were present but were defective.

Many of the incidents involving both large and small appliances involved damaged, worn, or otherwise modified appliances lacking grounding. GFCI protection would be effective even in these circumstances and is available for many small appliances. GFCI protection for large appliances is problematic but may be possible.

Providing grounding would also have prevented a number of the incidents involving lighting. But even without grounding, many of the incidents could have been prevented by GFCIs. This would include extending the number of locations where GFCIs are currently required to be installed, as well as ensuring that GFCIs are present in areas where they are currently required. As with many of the other products involved in electrocutions, the lighting products involved in incidents frequently were old.

The miscellaneous product category investigations involved many homemade items. Homemade items may lack the protection features incorporated into manufactured products. Even in these instances, GFCIs might offer protection.

Conclusions and Recommendations

Many of the products involved in the investigated electrocution incidents were described as old, worn, or modified. These attributes may indicate a number of causes why the product lacked protective features. An old product may have predated protection requirements. Worn products may have had protective features at one time, but the features are now deteriorated. In modified products, the protective features may have been intentionally defeated. The use of old and worn products may also indicate lower socioeconomic status and inability to afford newer, safer equipment. Or it may indicate the consumer is unaware of the dangers of using unprotected equipment. Likewise, the use of modified products may mean that the user is unaware of the purpose of protective devices or considers the risk associated with defeating protective devices to be minor.

There are two general approaches to overcoming these obstacles to the use of safe, protected electrical products. One is education to make consumers aware of the hazards of unsafe products and practices and how to remedy or prevent them. The other is to expand the use of GFCIs by ensuring that GFCIs are installed in all locations where they are currently required, to expand the number of locations where they are required, and to expand their capabilities to include the ability to indicate when they cease to function.

Both of these approaches involve long term efforts. If reducing the rate of electrocution deaths remains a strategic goal, or if it remains a regular project goal, the long-term nature of the effort must be kept in mind when setting time frames for these goals.

Appendix I
Basic Electrical Terms, Hazards, and Interventions

Basic Electrical Terms

Ground, strictly speaking, is the body of the earth. It is an infinite electrical sink and can absorb a huge amount of electrical current.

Current is the flow of electrical charge (electrons) through a wire or other conductor. The measure of current flow is **amperage**. Think of electric current through a wire as equivalent to water current flowing through a pipe.

Voltage is a measure of potential (stored) electrical energy. Voltage must always be measured relative to a reference point, usually "ground." Think of a battery storing charge as analogous to a tank storing water mounted on a tower. The higher the tower, the more energy the tank stores. Likewise, the higher the voltage, the more electrical charge is stored in the battery and the more energy is available. If you open a pipe in the dam, water flows downhill to a lower level. Likewise, if you connect the battery through wire to a ground, electric current flows to the ground.

Circuits are the paths through which current flows to move from a voltage source to a ground (or a lower voltage). There are hundreds of circuits in a home. The wiring from the power lines supplying the home, the wires in the walls to the outlets, the cords to the appliances, and even the motors, lights, heating elements and other electrical parts inside the appliances and tools are circuits.

Faults are abnormal paths through which current flows, outside the normal circuits. A fault may be to another circuit, to an ungrounded conductor, or to a grounded conductor. Any abnormal path that leads to earth or to a grounded conductor is called a **ground fault.**

Resistance is a measure of how easily current flows through a material or a circuit. A long, small diameter pipe "resists" water flowing through it more than a short pipe or a big diameter pipe. Similarly, a high resistance material (such as plastic or glass) "conducts" very little electric current to ground. **Conductance** is the inverse of resistance. Copper wire and metal tool housings are good conductors and allow the flow of large (high amperage) currents.

Water, moisture of many forms, can be a good conductor, but not as good as most metals. The dry skin of the human hand is a fairly high resistance material until perspiration dampens the skin. The extra moisture lowers the **resistance of a contact** between the hand and a conductor with voltage on it. Standing in water or on damp soil (or pavement) with bare feet also lowers the resistance of a person's contact with the ground.

Ohm's Law is a mathematical expression that shows the relationship among the measured elements of a circuit - Voltage, Amperage, and Resistance: **Voltage = Amperage x Resistance.** Basically, it shows that increasing the voltage connected in a circuit to a resistance will increase the amperage of the current flowing through the resistance. It also says that decreasing the resistance in the current path supplied by a voltage will also increase the amperage. These observations have important consequences when a human being becomes part of a current path.

Electrical Shock and Electrocution

Electrical shock results when the body becomes part of an electrical circuit and current passes through it in a sufficient amount to be experienced. The passage of current may be felt as a slight tingling, mild to severe pain, uncontrolled muscle contractions, etc., depending on the amount of current. *Electrocution* is fatal electric shock and results when so much current flows through the heart that it goes into ventricular fibrillation, unable to pump oxygen-bearing blood to the brain. *Preventing shock and electrocution* requires keeping the body from becoming a path between two points of differing voltage, such as an energized electrical appliance and the ground.

Electrical Circuits In and Around the Home

Power lines that run along the street or road outside the home are high voltage, carrying thousands of volts. (Industrial safety experts generally consider 30 volts to be dangerous to people.) These lines are not electrically insulated. They have a covering to protect the lines from the weather, but these coverings provide no resistance to the flow of electricity. If something, such as a tree limb or a ladder, provides a conductive path (completes the circuit) from the power line to the ground, large amounts of current will flow. If the path to ground includes a person, the current flow is likely to be great enough to be fatal.

Residential wiring circuits providing electricity for use in the home include the power line on the street, which carries voltage from the electric company's generating plant, transmission lines and transformers. A "power line drop" runs from the neighborhood power lines on the street, through the electric meter, which measures how much energy is used in the house. The meter connects to the panel board (actually a metal box containing circuit breakers or, sometimes, fuses) inside the house. The panel board then connects to numerous "branch circuits" - sets of wires that provide paths to the many outlets, light fixtures, and some of the large appliances installed in the home.

In every branch circuit, one wire, the energized, voltage-carrying, or "hot" wire, provides a current path to the outlet in the wall. (In U.S. homes, this wire carries 120 volts.) A second, non-energized or "neutral" wire provides the return current path from the outlet back to the panel board. The neutral wire is attached to a block of metal inside the panel board, called a "ground bus," which connects all the neutral wires to a metal rod or water supply pipe buried in the earth. The hot and neutral wires are wrapped in colored insulation--usually black for the hot wire and white for neutral. Some large appliances, notably stoves, clothes dryers and air conditioners, operate with 240 volts. They require a slightly different circuit, but the principle is still the same; the circuit is a continuous path from the voltage source through the appliance and back.

A third wire, usually bare copper, less frequently aluminum, provides a path for the ground connection at the outlet. It is not actually part of the circuit and should never carry current unless a fault occurs in one of the electrical products connected to the circuit. It, too, is connected to a separate ground bus in the electric panel with all the other ground wires. In most homes, the three wires are bundled together inside an insulated sleeve so that the whole assembly looks like one big wire.

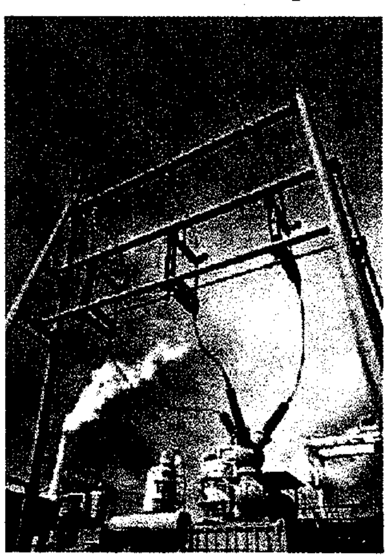
Very old homes may not have a ground wire in the set of wires and some may have separate hot and neutral wires supported on insulated posts. These old circuits can be extremely dangerous because they lack the protection of a ground.

Simply plugging an appliance into an outlet will not always complete the circuit. Current starts to flow only when the appliance is turned on, although some appliances are designed to turn on at least partly whenever they are plugged in. (Most electronic entertainment systems, for example, draw current immediately, but a desk lamp does only when the light is switched on.) When the appliance is turned on, current flows in the path from the power line's voltage source through the hot wire to the appliance and back through the neutral wire to the ground bus and ultimately back to the power line return.

The ground bus assures that the electrical circuit has a connection to earth. This grounding path provides a path of very low resistance, so that any stray current leakage or any inadvertent circuit that is formed (a fault) will take this path. This feature is an essential part of maintaining the electrical safety of the residential wiring circuit.

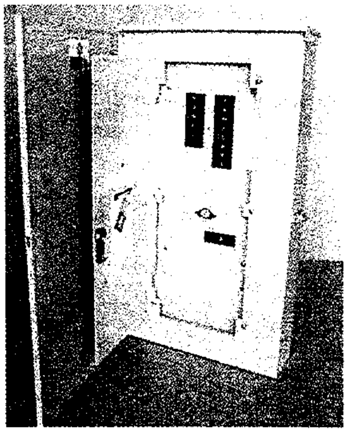
Types of Protection and Interventions

Personal protection from electrical injury generally involves one or more of three modes of intervention -- isolation, insulation, and interruption. "Isolation" is the physical separation of electrically energized ("live") conductors from casual contact by people and equipment. "Insulation" is the placement of non-conducting material around electrically energized conductors. "Interruption" is the active process of detecting abnormal current flow from energized conductors and breaking the flow. A brief explanation of each of these methods follows, as well as examples of devices and techniques that use the method.

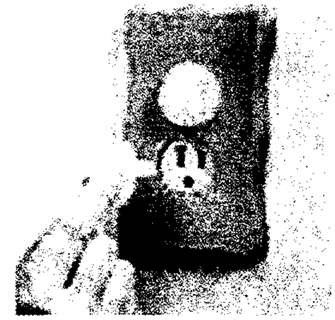


Isolation

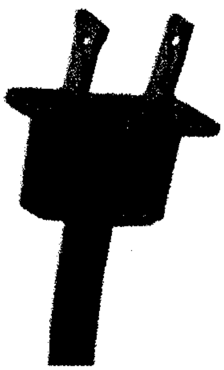
Electrical shock usually results from physical contact with an energized conductor that passes electric current through the body to the ground. One method of preventing such shock is to isolate, i.e., physically separate, energized conductors from accidental, casual, or even intentional contact. Power lines are mounted on overhead poles or buried in the ground to prevent contact. Transmission line substations are surrounded by fencing and marked with warnings to keep people away from dangerously high voltage. Electrical equipment for distribution of electricity throughout homes schools or other public facilities is locked behind doors or enclosed within panels to protect from casual contact. The energized contacts of electrical outlets are recessed behind wall surfaces.



Electrical safety devices available to consumers that utilize the isolation method of protection are outlet covers, tamper-resistant receptacles, and extension cords that have covers to conceal the unused outlets. Unplugging appliances when they are not in use is another example of isolation.



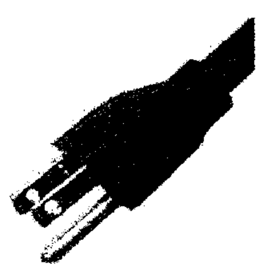
Polarized plugs in products such as lamps and appliances could be thought of as a form of isolation. In conjunction with polarized outlets, polarized plugs in appliances provide protection by aligning the appliance switch in the electrical circuit in a way that assures that there can be no current flow through the appliance until it is turned on. This prevents unintended current paths from occurring.



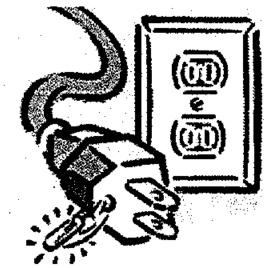
Polarized plugs place the appliance switch on the "hot" side of the circuit to the appliance. Inside the home, the circuit sequence with a polarized plug is: electrical panel, branch circuit wire to the appliance, appliance switch, any electrical working parts of the appliance, such as motors, heaters, etc., the neutral wire to the panel box, the wire to ground. When the switch is open (turned off), the appliance, even though plugged in, remains separated from the voltage source. Polarization assures that portions of the appliance that are accessible for maintenance, such as replacing a light bulb, or portions that are exposed, such as the heating elements of a hair dryer, are not energized when the switch is off.

Another form of protection is "grounding." Grounding an appliance housing essentially provides a more conductive path for electrical current to flow than the path provided by a person's body. If a person touches the housing of an appliance or tool that became unintentionally energized - such as from a stray wire or short circuit inside the device - the fault current will flow more readily through the ground path than through the person. Usually the current lasts only a moment until the protective circuit breaker or fuse opens, because a low resistance path will carry much more current than the protective device is designed to carry. By providing this better path for fault current, grounding provides a sort of electrical shield, isolating the person from the electrical source.

One common method of grounding an electrical appliance or tool is to use a three-conductor power cord and a three-blade plug. The two flat blades and their associated wires carry the current. The third wire in the cord is the ground wire and the third, round pin in the plug is the grounding pin. The grounding wire and pin are usually made of a highly conductive, low resistance metal. The grounding pin is longer than the other two blades so that it makes contact with the ground circuit in the outlet or receptacle before the other two blades contact the current supply to power the appliance. The appliance or tool is therefore grounded before the current begins to flow. Then, if the tool develops a "fault", the grounding wire and pin will provide a low-resistance



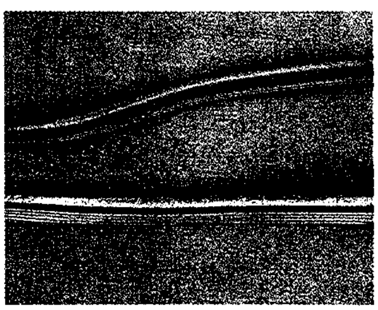
path for the erroneous current to leave the tool. This fault current will quickly cause a circuit breaker or fuse to open and turn off the circuit.



Three-prong plugs require three-prong receptacles, wired properly, in order to provide grounding protection. If the available receptacles can accommodate only two-prong plugs, properly grounded adapters should be used, or receptacles should be rewired to include proper grounding. However, consumers sometimes "adapt" three-prong plugs by breaking off the grounding pin. This destroys the grounding circuit. The appliance or tool will still work, but the ground circuit no longer exists to protect against electrocution.

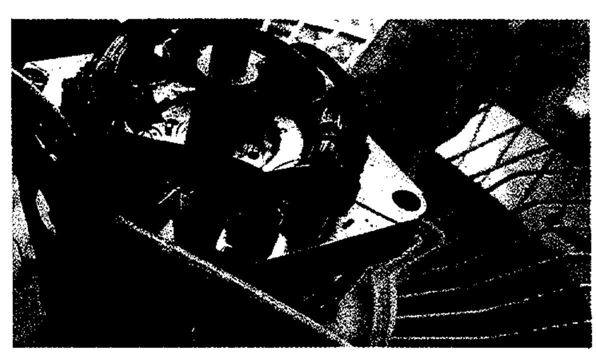
Insulation

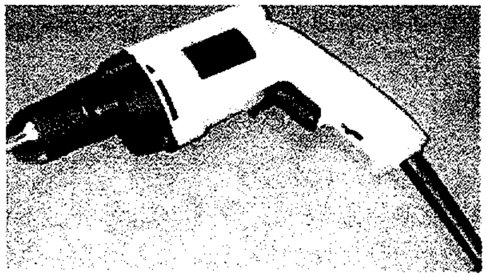
In the above examples, isolation is used to provide protection where electrical circuits can be kept far away from people. Frequently, however, to use electricity, a person has to be close to an electrically energized circuit, for example, in an appliance, a lamp, or power tool. In such cases "insulation" is used. Insulation is electrically non-conductive material that is used to surround electrical circuits to separate them from each other and from people. Power cords and extension cords are covered with insulation. Large and small appliances, light fixtures and electrical tools have internal components that are covered with insulation.



Over time, insulation may age, degrade and break down or become damaged or contaminated. When the quality of insulation is compromised it changes from being a non-conductor to become a poor conductor, allowing small amounts of current to leak through to an outside path. Electrical tape and sealing compounds are frequently used to repair damaged insulation and can be effective insulators when properly used. However because the bond between the old material and the new can weaken if the new material is improperly applied, or left exposed, or used in an inappropriate application, such repairs should be considered only temporary measures. Replacing the parts that have failing insulation is a preferable solution, or discarding the appliance or tool entirely.

An added form of protection is "double insulation". Generally, the internal wiring that connects electrical parts and makes appliances and tools work has insulation. This is the first layer of insulation. However, under conditions of overload or misuse, this insulation may break down, both electrically and mechanically. Because of this possibility, many tools now have "double insulation." When the handle and housing of the tool are made of an insulating material such as plastic rather than a conductor such as metal, the outside of the tool itself protects against shock, and the tool is considered to be double-insulated.





In the United States, tools that are double insulated usually carry a mark that looks like a "square-inside-a-square" or the words "double insulated." Sometimes these tools will have a three-conductor power cord, but they are usually required only to have a two-conductor cord because the extra insulation reduces or eliminates the need for grounding.

A double-insulated power drill, above, and the accepted "square-in-a-square" symbol for "Double Insulation"

Interruption

Receptacle-type GFCI

The third method of personal protection is to "interrupt", i.e., stop, the flow of current when a stray current begins to flow outside the usual circuit. Devices which do this are called "ground fault circuit interrupters" (GFCIs). The GFCI measures the current flowing to and returning from an appliance or a circuit connected to it. If the GFCI senses that the return current differs from the delivered current by more than a very small portion, it operates an internal switch and shuts off the flow of electricity almost instantaneously.

Often, the difference in current flowing in and out of the appliance is caused by moisture bridging across insulated wires, such as when a hair dryer or curling iron is dropped into the bathtub. Sometimes, a breakdown of insulation inside an appliance lets an energized wire touch the metal housing of the appliance. If a person touches the housing and a ground path at the same time, he or she may experience a brief electric shock before the GFCI interrupts the circuit. By quickly shutting off the circuit, the GFCI stops current from traveling through the person, thus minimizing the risk of electrocution.

The National Electrical Code requires GFCI protection on household receptacles in many, but not all, locations. Outdoor receptacles, bathroom and kitchen receptacles near sinks, kitchen countertops, basement and garage receptacles are some of the locations currently required to have GFCIs. However, laundry and utility rooms are not. General living areas such as living rooms and bedrooms are also not currently required to have GFCI protection.

GFCIs can fail. There is currently no requirement that GFCIs indicate when they have ceased being operational. A recent study[7] by the National Electrical Manufacturers Association (NEMA) of installed GFCIs showed that 8 percent of receptacle-type and 14 percent of circuit breaker-type GFCIs surveyed were not operational. The study found a variety of causes, including miswiring, environmental conditions (humidity, temperature, location, lightning strikes) and aging. It showed that humidity was the most important environmental condition affecting GFCIs. GFCIs

[7] *GFCI Field Test Survey Report,* National Electrical Manufacturers Association, January 2001.

that meet the existing UL standard can stop working without giving any indication that they have failed. This means that the consumer may be relying for protection on a device that is no longer functioning.

Tab D

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

DATE: July 18, 2002

TO: N.J. Scheers, Director, Office of Planning and Evaluation

FROM: Robert Garrett, Electrical Engineer, Office of Planning and Evaluation RG
William King, Electrical Engineer, Directorate for Engineering Sciences WHK

SUBJECT: Reducing Electrocutions with Mandatory and Voluntary Standards

Background

The majority of electrical safety requirements applicable to consumer products are contained in standards and codes developed within the private sector, with input in many instances from representatives of government at local, state and federal levels. These standards are consensus documents that represent a commitment by the affected industries to conform to the requirements. They are also the baseline for safety criteria used by the U.S. Consumer Product Safety Commission (CPSC) to judge the risk of injury and death from using a product. The Federal Government regards these as "voluntary standards" because they are not incorporated into the Code of Federal Regulations (CFR).

Mandatory Standards

On rare occasion one of these voluntary standards is converted into a Federal regulation for reasons unique to the particular circumstance at the time of conversion, and not necessarily because the regulated products are considered a higher risk for injury. The safety standards for electric toys and for garage door operators[1] are the only two instances during the history of the CPSC when voluntary standards for electrically operated products were later promulgated as Federal requirements. Only one other electrical product group, Citizens Band (CB) base station and television (TV) antennas and their support structures, is regulated to protect against the risk of electrocution.

Toys and products that operate electrically and are intended for use by children are banned by 16CFR Ch.II §1500.18 unless they meet the specific regulations of Part 1505. Part 1505 specifies requirements on the labeling, manufacture, design and performance of articles that operate on more than 30 volts AC[2]. To protect users from injury, many of the performance requirements limit the electrical and thermal energy that the covered articles can use and release. To reduce the risk of electrocution from contact with overhead power

[1] Garage door operators are not specifically regulated to reduce the risk of electrical shock but, rather, to reduce the risk of a person becoming entrapped and crushed by the door.
[2] Exempted from the requirements are video games and articles designed to be used by adults that might incidentally be used by children.

lines, Part 1500 also bans kites having any parts larger than 10 inches in any dimension that are made of aluminized polyester.

As for antenna regulations, 16CFR Ch.II § 1402, starting in 1978, required manufacturers of TV and CB antennas and their support structures (such as masts and towers) to provide warnings and safety-related instructions. These were meant to reduce the hazard of electrocution from proximity with overhead power lines. A study[3] two years afterward reported that half of TV antenna owners and two-thirds of CB antenna owners reported seeing installation instructions and those who installed antennas after the labeling requirements became effective were more likely to report seeing them. Likewise, one-third of TV antenna owners and half of CB antenna owners recalled seeing the warning labels during installation, more so if they made the installation after the effective date of the rule.

In 1982, Part 1204 added performance requirements that could reduce the risk of electrocution if a CB antenna touched a power line while it was being erected or taken down. The standard requires electrical insulation that can withstand contact with 14,500 volts AC under test conditions specified by the regulation. No subsequent studies were made to evaluate the effect of these rules, but electrocution incidents involving antennas have dropped to about 12 per year, according to our most recent estimate[4].

Voluntary Standards

Underwriters Laboratories Inc. (UL), an independent, not-for-profit company, is the developer of the product standards used by industry for electrical appliances and other products that connect to or form a part of the electrical circuits in residences and other buildings. The *National Electrical Code* (*NEC*), developed by the private National Fire Protection Association (NFPA), covers the installation of those products. UL and NFPA seek to have most of their standards recognized by the American National Standards Institute, Inc. (ANSI).[5] ANSI acts as a national clearinghouse to approve standards and codes prepared by private sector groups, such as UL and NFPA, that have agreed to write standards adhering to the ANSI consensus process. Once approved, the standards become American National Standards.

In developing requirements and standards, CPSC staff is required by the Consumer Product Safety Act to rely on voluntary standards rather than promulgate a mandatory standard whenever compliance with such voluntary standards would adequately reduce the risk of injury addressed by the standards and it is likely that there will be substantial compliance with such voluntary standards. Therefore, federal strategies to improve electrical safety that involve upgrading standards must pursue this goal by participating in non-Governmental, voluntary standards processes.

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[3] "Evaluation of the Impact of the Communications Antenna Labeling Rule." Contract No. CPSC-C-79-1165, November 21, 1980.

[4] "1998 Electrocutions Associated with Consumer Products," Signe Hiser, CSPC EPHA, July 2001.

[5] ANSI is a non-governmental, non-profit organization that coordinates and administers the voluntary standardization system in the United States. ANSI is the official U.S. representative to the major world standards bodies--the International Organization for Standardization (ISO) and, via the U.S. National Committee, the International Electrotechnical Commission (IEC).

In accordance with these requirements, CPSC has participated for over twenty years in private sector electrical safety codes and standards development activities, principally with the NFPA and UL. During that time CPSC promulgated only one mandatory safety standard to address electrocution--requirements for omni-directional citizens band base station antennas. On the other hand, the actions of CPSC staff in the voluntary standards processes have resulted in substantial improvements in electrical safety. Upgraded requirements include expanded applications of ground-fault circuit-interrupters (GFCI shock protectors), improved safety of appliances and equipment, and improved outlet devices and wiring products.

CPSC Staff Involvement in UL Standards Development

Beginning in 1995, UL established methods for CPSC's technical staff to participate more actively in discussions that led to developing new and upgraded safety standards, including many standards that addressed electrocution hazards. UL formed Technical Advisory Panels (TAPs) to collect knowledgeable input from a broad range of resources and interests. UL then invited CPSC to assign technical staff members to the TAPS that dealt with consumer products for which CPSC had an interest in improving safety requirements. Table 1 lists the TAPs for UL standards that addressed the risk of electrocution and to which CPSC assigned technical staff members.

In 1999, UL reorganized their standards development procedures, forming Standards Technical Panels (STPs) to develop standards through an accredited consensus process that conforms to ANSI development methods. The process generally assures that new and revised UL Standards will also be ANSI-approved. CPSC's technical staff serves on numerous STPs to improve the safety of products within the agency's jurisdiction.

During the period from 1994 to the present, CPSC staff advocated many upgrades to UL product standards to address the risk of electrocution. The products involved include microwave ovens, countertop cooking appliances, lamps, room heaters, extension cords, night lights, electric holiday decorations, and GFCIs. As a result, new and improved standards have been adopted. The agency's activities to collect, analyze, and disseminate information are detailed in the attached "Summary of Voluntary Standards Activities 1994 - 2001" at the end of this memorandum.

Table 1
CPSC Staff Membership on Technical Advisory Panels (TAPs)
For UL Standards that Address the Risk of Electrocution

69	Electric-Fence Controllers
73	Motor-Operated Appliances
153	Portable Electric Lamps
484	Room Air Conditioners
489	Molded-Case Circuit Breakers and C-B Enclosures
498	Attachment Plugs and Receptacles
499	Electric Heating Appliances
507	Electric Fans
588	Christmas-Tree & Dec-Lighting Outfits
696	Electric Toys
745	Portable Electric Tools
749	Household Dishwashers
817	Cord Sets and Power-Supply Cords
858	Household Electric Ranges
858A	Solid-State Controls for House Electric Ranges
859	Household Electric Personal Grooming Appliances
867	Electrostatic Air Cleaners
923	Microwave Cooking Appliances
943	Ground-Fault Circuit-Interrupters
964	Electrically Heated Bedding
982	Motor-Operated House Food Preparing Mach
987	Stationary and Fixed Electric Tools
1005	Electric Flatirons
1018	Electric Aquarium Equipment
1026	Electric House Cooking and Food Service Appliances
1042	Electric Baseboard Heating Equipment
1082	House Electric Coffee Makers & Brewing-Type Appliances
1083	House Electric Skillets & Frying-Type Appliances
1278	Moveable and Wall- or Ceiling-Hung Room Heaters
1363	Temporary Power Taps
1410	Television Receivers & High-Voltage Video
1492	Audio-Video Products and Accessories
1570	Fluorescent Lighting Fixtures
1571	Incandescent Lighting Fixtures
2158(&-A)	Electric Clothes Dryers (and Duct)

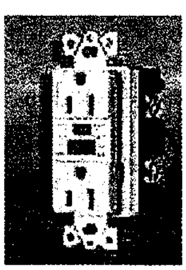
CPSC Staff Involvement in the *NEC*

The basic code for installation of electrical systems in most buildings is the *NEC*. During the period from 1982 to the present, CPSC staff has been an active member of NFPA's National Electrical Code Committee, serving on the code-making panel that included appliance safety requirements. In recent years, the CPSC staff's level of participation has increased, with three electrical engineering staff members now serving on code-making panels. Those panels convene to consider branch circuit requirements for wiring in buildings, including homes, as well as requirements for appliances, swimming pools, and other electrical equipment.

During the period 1994 to the present, the CPSC staff submitted in writing numerous proposals and comments to address electrocution. These included new and expanded requirements for ground-fault circuit-interrupter (GFCI) shock protectors for spa and hot tubs, backyard boat hoists, and other outdoor locations, and improved grounding. These submittals resulted in new provisions in the 1996, 1999 and 2002 editions of the *NEC*.

The Ground-Fault Circuit Interrupter - A CPSC Focal Point with UL and *NEC*

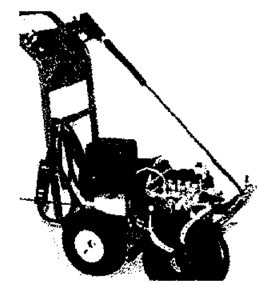
The Ground-Fault Circuit Interrupter (GFCI) is a device intended to prevent electrocutions. The GFCI operates by sensing the flow of current through an electrical circuit and detecting an imbalance caused by any stray current that may escape the intended path. The flow may be through a person on its way to earth ground or through a path caused by moisture, contamination or other damage to the circuit. The GFCI is sensitive and quick enough to detect as little as 0.005 amperes (5mA) of current and open the circuit in time to prevent sustained current levels that could cause an electrocution. In contrast, a regular circuit breaker or fuse in a household branch circuit is designed to open the circuit when the current exceeds 15 amperes--3000 times greater current than the GFCI trip level.



The GFCI comes in several basic designs. The most popular is the electrical receptacle device with an integral GFCI. It has "TEST" and "RESET" buttons on its face to permit user testing. GFCIs also are available as circuit breakers with GFCI technology built-in, and as portable devices with GFCI technology designed into extension cords, plug-in adapters, outlet strips, etc.

The GFCI was introduced into homes in the United States in the early 1970's, during the time when the CPSC was created. The *NEC* requirement that went into effect in 1973 called for electrical receptacle outlets installed outdoors at grade level to be protected by a GFCI. Over the years, *NEC* requirements expanded to include GFCI protection for other receptacle outlets in and around homes. The current edition of the *NEC* includes GFCI protection for receptacle outlets in bathrooms, above kitchen counters, in unfinished basements, in garages, and around swimming pools.

In addition, the *NEC* requires some specific appliances and equipment to be equipped with GFCI protection. These include bathtubs with water jets, electric power spray washers, and hot tubs. Further, the *NEC* specifies that handheld hair dryers and portable spa appliances cannot cause a deadly shock hazard when the products are immersed in water. Either a GFCI or another shock protection device that opens the circuit if the appliance becomes immersed can satisfy this requirement. CPSC staff has consistently advocated the *NEC*'s adoption of expanded GFCI requirements.



As powerful a preventive device as the GFCI is, it has some limitations. The GFCI cannot protect the consumer from the electrical hazard of line-to-line (hot-to-neutral or phase-to-phase) contact. In such cases the victim becomes part of the circuit path and may suffer serious injury or death. Moreover, once properly installed and in use, the GFCI may fail without warning. Regular testing by the consumer will minimize the risk of accidental injury. If the device fails to trip and disconnect the protected circuit from the electrical supply when the "TEST" button is pressed, the consumer should have the GFCI replaced. Nevertheless, a GFCI may fail between tests, perhaps immediately after the consumer actuates the "RESET" mechanism to reconnect the power. Several manufacturers have demonstrated various methods to enhance the GFCI protection system, and one or more show significant potential to reduce the risk of undetected failure. At CPSC's urging, UL enacted revisions to their requirements that become effective in 2003 and include some of these improvements. One brand of safety-enhanced GFCI with a "lock-out system" that prevents resetting a failed GFCI is already available for sale in the United States.

Faulty installation also affects the protective capabilities of the receptacle GFCI. The "line side" hot and neutral pair of conductors (providing power to the device) and "load side" hot and neutral conductor pair (supplying other downstream receptacles or an attached appliance) are all attached to terminals on the receptacle-type GFCI. Because the conductors may be identical in appearance and difficult to distinguish, an installer may reverse them during a less careful installation. GFCIs designed for home use typically will continue to give protection even if the hot and neutral wires are reversed on either the line side or the load side of the GFCI. If the GFCI is connected backwards--the line wires connected to the load terminals and the load wires connected to the line terminals--the protection is compromised. When a stray current causes the GFCI to trip, only the downstream devices will be disconnected from power. The receptacle containing the GFCI will continue to receive power and present a shock hazard if the faulty appliance causing the leakage current is plugged into it.

CPSC Studied GFCI Reliability

For many years CPSC aimed its voluntary standards activities at expanding the application of GFCI products to provide additional protection for consumers from electrocution involving household branch circuits, appliances, and electrical equipment that previously did not require GFCI protection. After 1994, the voluntary standards activities related to GFCIs took a significant, additional direction. Besides seeking wider applications for GFCIs, the CPSC staff began to address the reliability of the GFCI as a safety device.

CPSC received information that brought into question the effectiveness of these shock protection devices. Concerns were raised as to whether they were being installed correctly, whether they were sufficiently able to withstand electrical voltage surges and corrosion, and whether the monthly testing recommendations were effective and being followed by users. To address these issues, staff initiated work in the mid-1990s.

Following reports that receptacle GFCIs were being installed incorrectly, thereby compromising the shock protection provided at the outlet containing the GFCI, CPSC's human factors experts conducted an in-depth study of the installation instructions. This study included having volunteers install a receptacle GFCI following the instructions provided with the devices. The results of the study led to improved standards that provide for uniform installation instructions to help installers identify the correct wiring terminals for connection to the branch circuit wires.

CPSC staff analyzed data supplied by private home inspectors that indicated significant numbers of installed GFCIs were inoperable. The staff worked with GFCI manufacturers who were part of the National Electrical Manufacturers Association (NEMA) and with UL to obtain accurate field statistics and laboratory evaluations of inoperable GFCIs collected from homes. This led to UL's adoption of new requirements in 2001 that address resistance to power surges and the effects of weather, and require removing power from receptacle GFCIs when internal electronic parts become defective. These changes and others expected in the near future will make GFCIs even more effective in reducing the risk of electrocution.

CPSC engineers continue to explore ways to improve the safety standards applicable to the GFCI. The CPSC staff is currently promoting the adoption of standards calling for a new level of GFCI protection that would reduce reliance on monthly testing by the user. A new concept in applied technology could result in the GFCI automatically "self-testing" its internal circuitry on a periodic basis and signaling the user when the device is not providing electrocution protection. This enhancement could be used to disconnect electric power from the supplied receptacle when the shock protection feature is not working.

During their April 10, 2002, annual meeting with UL, CPSC engineering staff reiterated its interests and concerns in improving the GFCI standards. In response, UL's vice president and chief technical officer acknowledged CPSC's role in proposing and promoting improvements in their standards. He also recognized CPSC's contributions in specific areas that addressed reversal of line and load wiring while installing receptacle GFCIs, and increased resistance of GFCIs to electrical surges and to the environmental effects of installation in wet locations.

CPSC Recommends Broader Use of GFCIs

CPSC staff continues to advocate the widespread use of GFCIs. Analysis of data from epidemiological studies and In-Depth Investigations shows that GFCI use has probably contributed to the reduction in the death rate from electrical shock in the United States. The data suggest that even greater effects will manifest as GFCI use increases beyond the currently estimated 40% of homes where at least one GFCI is installed. CPSC staff will continue strongly to encourage consumers to install GFCIs in their existing older homes to bring the level of protection up to the current code level. Since analyses also show that electrocution incidents occur within the home in areas presently not required to have GFCI protection, the staff has proposed expanding the *NEC* requirements to include GFCI protection for all general-purpose receptacles and lighting branch circuits in homes.

SUMMARY OF VOLUNTARY STANDARDS ACTIVITY 1994 - 2001

EXHR Voluntary Standards Activities - 1994

CPSC staff conducted testing and evaluation of electrical heat tapes used to keep water pipes from freezing in residential structures. The work resulted in a new UL Standard based on specific CPSC staff recommendations for reducing the risk of the electrical hazards of electrocution and fire. These included recommending the additional protection provided by GFCIs. In addition, the CPSC staff supported a new *NEC* code requirement that called for these products to be certified to the new UL standard.

In response to reported miswiring or improper installation, CPSC conducted behavioral studies of how consumers install GFCIs. Results from the study led to upgrading the UL Standard for GFCIs and to working with NEMA to develop improved installation instructions. UL proposed to add requirements for standardized terminal markings, visual indicators of miswiring, and new installation instructions to explain the function of the markings and indicators. NEMA offered to head a task force to develop the improved installation instructions.

CPSC staff submitted eight separate actions to revise the 1993 edition of *NEC,* covering GFCIs, as well as electrical heat tape, boat-hoists, spas and hot tubs. Effective July 4, 1995, the code became effective that required covering GFCI load terminals with a warning label that explained proper installation and giving improved instructions for differentiating "line" from "load" wiring and determining proper wiring.

<u>Meetings and Discussions of GFCIs and other issues related to electrocution</u>

Oct 19, 1993	*NEC* Committee Panel 20 on code revisions
Nov 12, 1993	NEMA on GFCIs
Dec 7, 1993	UL on safety standards issues
Jan 20-22, 1994	*NEC* on code revisions
Feb 16-17, 1994	UL on GFCIs, microwave ovens, and holiday decorative products
April 7-8, 1994	MHCSS (Manufactured Home Construction and Safety Standards)
May 8, 1994	NEMA on GFCI installation instructions
June 23, 1994	Pass & Seymour - design of GFCIs
Aug 10-11, 1994	UL

EXHR Voluntary Standards Activities - 1995

CPSC staff focused a study on wiring in older homes and identified promising technologies to rehabilitate existing residences and provide practical, cost-effective electrical protection against fire and shock.

CPSC recommended major improvements to UL Standard 588 on temporary holiday lighting to eliminate electrical shock and fire hazards. UL adopted new requirements that became effective January 1997.

CSPC staff requested greater input to UL's process for developing standards. UL initiated a program of Technical Advisory Panels (TAPs) to include CPSC at the earliest stage of a consumer product safety standard's development.

CPSC staff met regularly with the *NEC* Code Panel to propose and comment on revision to the 1996 *NEC*. The new code was approved in May 1995 and provided safety features involving GFCIs, heat tape, and spas and hot tubs.

CPSC reviewed and commented on improved GFCI installation instructions developed under contract to NEMA by the American Institutes of Research. NEMA later conducted tests using the new instructions. NEMA development effort was guided by results from CPSC's 1994 Human Factors study of behavior during GFCI installations.

CPSC became involved with the newly established National Electrical Safety Foundation (NESF, recently renamed the Electrical Safety Foundation International - ESFI) to provide electrical safety information to consumers. NESF/ESFI is a non-profit foundation sponsored by the electrical industries, retailers, contractors, testing labs, electricians, and inspectors.

<u>Meetings and Discussions of GFCIs and other issues related to electrocution</u>

Sept 28, 1994	NEMA on GFCI indicators
Nov 30, 1994	ANSI (American National Standards Institute) on electrical hazards
Dec 12-14, 1994	*NEC* Code Committee Panel 20 on revisions
Jan 11, 1995	UL on electrical standards
Feb 8, 1995	UL on Christmas and decorative lighting sets
Feb 17, 1995	UL on various issues related to electrical shock hazards
March 2, 1995	Erico (manufacturer) on repairing/renovating residential wiring
March 22-23, 1995	NFPA on revisions to NFPA 73 Maintenance Code for One- and Two-Family Dwellings
April 20, 1995	ANSI (American National Standards Institute) on electrical hazards
April 25-26, 1995	UL Council on consumer product safety activities and future plans
May 22-25, 1995	*NEC* on code revisions
July 6, 1995	UL teleconference on topics related to electrical shock hazards
Aug 15, 1995	CABO (Council of American Building Officials) on GFCIs for heat tape in manufactured homes
Aug 21, 1995	UL status report on various consumer product safety activities
Sept 28, 1995	UL on indicator lights for GFCIs

EXHR Voluntary Standards Activities - 1996

CPSC continued to promote major improvements to UL's Standard 588 on temporary holiday lighting. Central issues of concern were quality control requirements and specifications on minimum wiring and plastic materials. UL adopted new requirements that became effective in January 1997 to prevent use of wire size smaller than 22AWG, to address plastic flammability, and to tighten quality control concerning electric shock and fire hazards.

CPSC staff identified numerous electrocutions resulting from consumers repairing microwave ovens and recommended a series of upgrades to UL Standard 923. UL adopted changes based on CPSC staff input.

CSPC staff continued its focus on NFPA 73, the "Residential Electrical Maintenance Code for One- and Two Family Dwellings," which became effective in February 1994. Staff met with the second Technical Committee in December 1995 to consider proposed revisions and to expand the code to cover multi-family dwellings. The second edition of NFPA 73 was released September 1996.

CPSC staff continued work with the *NEC* Code Committee to develop the next edition. A key improvement in shock prevention strengthened the methods used for appliance grounding.

CPSC staff also continued efforts with NEMA to improve UL Standard 943 for GFCIs. A NEMA-sponsored study of proposed new installation instructions revealed that they needed improvement. CPSC staff provided comments on the new proposed instructions.

<u>Meetings and Discussions of GFCIs and other issues related to electrocution</u>

April 4, 1996	UL annual meeting on activities of mutual interest
May 1, 1996	Technical Research Corp on leakage current-protected electric cords
July 22, 1996	Technical Research Corp on electric cords safety

EXHR Voluntary Standards Activities - 1997

In January 1997 UL Standard 588 on Christmas lights and decorations became effective, and UL immediately lost most of its clients for electric lighted decorations. However, improved products meeting the new standards were available in stores for the December holiday market.

CPSC staff produced a 12-minute videotape, "Wired for Safety," initially intended for use by electrical safety inspectors and code officials. A thousand copies were made for nationwide distribution and NESF joined with the Commission to promote the videotape and its companion booklet, "Guide to Home Wiring Hazards." The tape contains information about old electrical wiring hazards in the home and how to fix them. The guidebook warned consumers of electrical dangers in the home that could cause fires or electrical shock. It also tells how to find the locations of problems within home electrical systems before calling for professional repair services.

CPSC staff was re-appointed to the NFPA Technical Committee for the NFPA 73 Residential Electrical Maintenance Code. NFPA set its schedule for proposals to revise the 2000 edition.

CPSC staff submitted several proposals for the 1999 *NEC* and made supporting comments on others, such as one calling for enhanced circuit breakers for residential circuits.

CPSC expanded its work with UL on Standard 943 for Ground-Fault Circuit-Interrupters to include UL 943A, "Standard for Leakage Current Protection Devices." Staff gave comments to NEMA on its continued studies of the proposed, improved standardized installation instructions. GFCI manufacturers now include the improved instructions to minimize the chance that key installation steps are omitted or overlooked.

<u>Meetings and Discussions of GFCIs and other issues related to electrocution</u>

Dec 4, 1996	ANSI on electrical hazards
Jan 12-15, 1997	*NEC* on proposals for new code
Feb 6, 1997	UL on various electrical and fire topics
May 5-7, 1997	UL annual meeting of consumer product safety activities and issues

EXHR Voluntary Standards Activities - 1998

CPSC staff developed proposals for submission in FY1999 to the 2000 edition of NFPA 73.

CPSC staff worked with UL to integrate the essential safety requirements for common household extension cords from several voluntary standards into a single unified document. The new guide was published by UL in September 1998 to be used as a reference by cord manufacturers, distributors, importers, and retailers. It provides assistance in applying the UL safety requirements for extension cords.

The 1999 *NEC* incorporated proposals for changes that were supported by CPSC staff to reduce risk of electrical shock and fire associated with electrical consumer products.

CPSC staff evaluated the effectiveness of a manufacturer's enhanced GFCI. The new GFCI was designed to provide an indication of specific installation errors, reducing the risk of miswiring and compromised safety.

<u>Meetings and Discussions of GFCIs and other issues related to electrocution</u>

Dec 1-5, 1997	NFPA on proposals to amend *NEC*
April 2, 1998	UL on various electrical and fire topics
May 5,6, 1998	UL on voluntary standards issues of mutual concern
May 14, 1998	NESF (National Electrical Safety Foundation) on safety programs
May 18-21,1998	NFPA on the proposed 1999 *NEC*
June 2, 1998	Eagle Manufacturing Company on GFCI design
June 11, 1998	Leviton Manufacturing Company on GFCI design

EXHR Voluntary Standards Activities - 1999

CPSC staff discussed and promoted enhancements to GFCIs such as automatic self-testing features that could alert the consumer to a GFCI malfunction and lock-out functions that could prevent the GFCI from being reset after it stopped working properly.

CPSC staff asked UL to add requirements to its safety standards for enhanced GFCI features to signal or lock out a failed protective device.

In January 1999 CPSC staff submitted five proposed changes to the 2000 edition of NFPA 73 Residential Electrical Maintenance Code, three of which were accepted in principal. In September 1999 staff drafted rebuttal comments on the rejected proposals for discussions during November 1999 with the NFPA 73 Committee.

CPSC staff developed three proposals to the 2002 edition of the *NEC* to include GFCIs with enhanced reliability (self-test and lockout) features for use in outside locations.

<u>Meetings and Discussions of GFCIs and other issues related to electrocution</u>

Oct 1-2, 1998	Intertek Testing Service on general electrical safety issues
Oct 14, 1998	Leviton Manufacturing Company on GFCIs
Feb 16, 1999	Technology Research Corp. on shock and fire protection devices
Feb 24, 1999	NESF on electrical safety programs
Feb 25-26, 1999	NFPA on Residential Electrical Maintenance Code revisions
April 15, 1999	UL annual meeting to review electrical and fire safety topics
May 27, 1999	Technology Research Corp. on shock and fire protection devices
June 17, 1999	Leviton Manufacturing Company on GFCIs

EXHR Voluntary Standards Activities - 2000

CPSC staff continued meetings and discussions with manufacturers of GFCIs to encourage and promote enhancements to safety performance. The focus included a lockout function that prevents a failed GFCI from being reset and automatic test capabilities that detect impending device failure and alert the consumer.

CPSC staff continued discussion with NEMA on GFCI reliability. NEMA funded a nationwide study of GFCI reliability, planning to report results in 2001. The study intends to estimate the numbers and causes of non-functioning installed GFCIs.

CPSC staff submitted three proposals for the 2002 *NEC*, including requirements for enhanced reliability functions on outside-located GFCIs, and met with the Code-Making Panel 20 to support and defend its proposals.

<u>Meetings and Discussions of GFCIs and other issues related to electrocution</u>

Nov 8-9, 1999	NFPA on Residential Electrical Maintenance Code revisions
Dec 2, 1999	Technical Research Corporation on safety device innovations
Dec 21, 1999	Pass & Seymour on electrical safety device innovations
Jan 17-20, 2000	*NEC* Code-Making Panel 20 on code revisions
April 19, 2000	UL to review electrical and fire topics
May 2, 2000	UL to discuss issues related to electrical product safety
May 25, 2000	NEMA and manufacturers on GFCIs

EXHR Voluntary Standards Activities - 2001

CPSC staff submitted comments on proposals to revise the 2002 *NEC* requirements for leakage current detection interrupters for air conditioning systems that gave remedy for both shock and fire hazards. Staff also requested reconsideration of an earlier proposal to require enhanced GFCIs for outdoor installations, which have the greatest risk of failure.

NEMA released the report of its field study[6] of non-operational installed GFCIs, showing that 8 percent of installed receptacle-type and 14 percent of installed circuit breaker-type GFCIs were not operational and that humidity was the most likely environmental factor in inoperability. A subsequent CPSC analysis of the data produced similar results and also showed a statistically valid relationship between GFCI age and operability.

CPSC staff reviewed a study of a receptacle-type GFCI design contracted by Pass & Seymour. The designs included enhancements such as a lockout mechanism or status indicator. The study concluded that a passive lockout was preferable and that two-color indicators were better understood by consumers

CSPC staff made proposals for GFCI enhancement to UL that included three GFCI classes: a class having automatic self- and manual-test modes that will not supply power if it fails the test; a class with automatic self-and manual-test modes that provides a visual indication if it fails the test; and a class having a manual-test mode that will not restore power if it fails the test.

CPSC staff prepared comments for ANSI (American National Standards Institute), which was balloting the UL GFCI standard for approval as an ANSI standard. Staff recommended that major upgrades to the UL Standard be accomplished before ANSI recognizes it.

<u>Meetings and Discussions of GFCIs and other issues related to electrocution</u>

Oct 17, 2000	UL, NEMA, Leviton on GFCIs
Oct 18, 2000	ACES (American Council on Electrical Safety) on safety issues
Nov 1, 2000	NEMA, NESF, UL and manufacturers on GFCIs
Nov 8, 2000	GFCI manufacturer on enhancements to electrical safety devices
Dec 4-6, 2000	*NEC* Code-Making Panel 20 on proposed changes to 2002 *NEC*
April 11, 2001	UL annual meeting on UL standards covering consumer products

[6] "GFCI Field Test Survey Report," NEMA, Washington, D.C., January 2001.