A SURVEY OF ELECTRICAL FIRES

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Contrary to popular opinion, the use of circuit breakers and fuses does not guarantee that short-circuit fires will be prevented. Even when these circuit protectors are properly sized and installed, a short circuit[1] can draw enough current to cause a fire, but not enough current to open a 15-ampere circuit breaker.[2]

Two other types of common electrical fires are overheating — from heating elements that stay on too long, for example — and high resistance, with normal current, that may occur at a poor aluminum-wiring connection, for example.

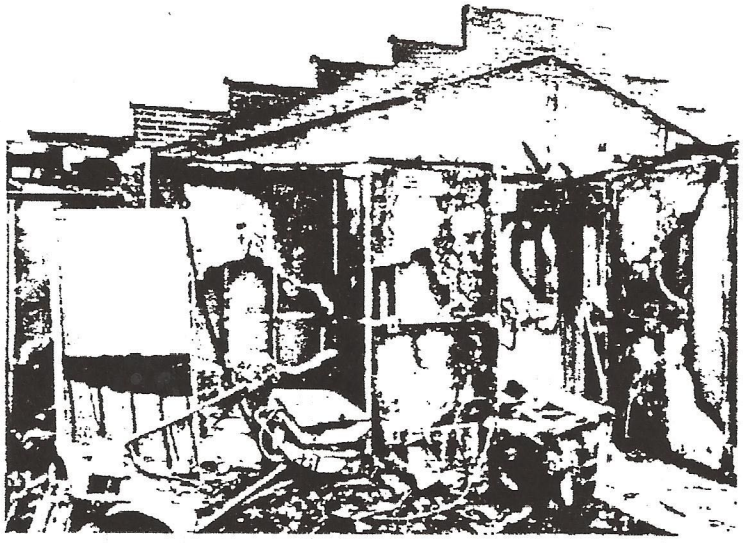
During investigations of 595 fires conducted over a period of seven years, fires involving short circuits, overheating, and high resistance/normal current were among the 115 fires determined to be of electrical origin.

As an example of an indisputable electrical fire, Figure 1 shows one of four apartments destroyed by a short-circuit fire. Just as the fire began, two members of a maintenance crew observed a red glow inside the dining-room wall adjacent to an electrical receptacle. This red glow began just after the crew had recycled the circuit breaker that controlled the receptacle three times. (Tripped circuit breakers should be left in the "off" position until the problem is corrected.) This short circuit caused $150,000 in damage to the apartment building.

This apartment fire demonstrates that a short circuit in a cable insulated with plastic, fiber, or rubber (nonmetallic sheathed cable) can cause a devastating fire. Two similar fires occurred when circuit breakers were recycled repeatedly.

The timing of the origin of these fires — just after a circuit breaker was reset — makes them indisputable examples of electrical fires. Some may argue that more electrical heating power was generated at these short circuits by the repetition of the fault currents. However, if the heating power delivered during three cycles of a circuit breaker can definitely cause a fire, the heating

Figure 1. One of four apartments devastated by a short circuit fire.



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[1] A short circuit is defined here as any unintended path of current flow.

[2] Resistance (the electrical quantity that impedes current flow) in the short circuit itself often keeps the current to such low values.

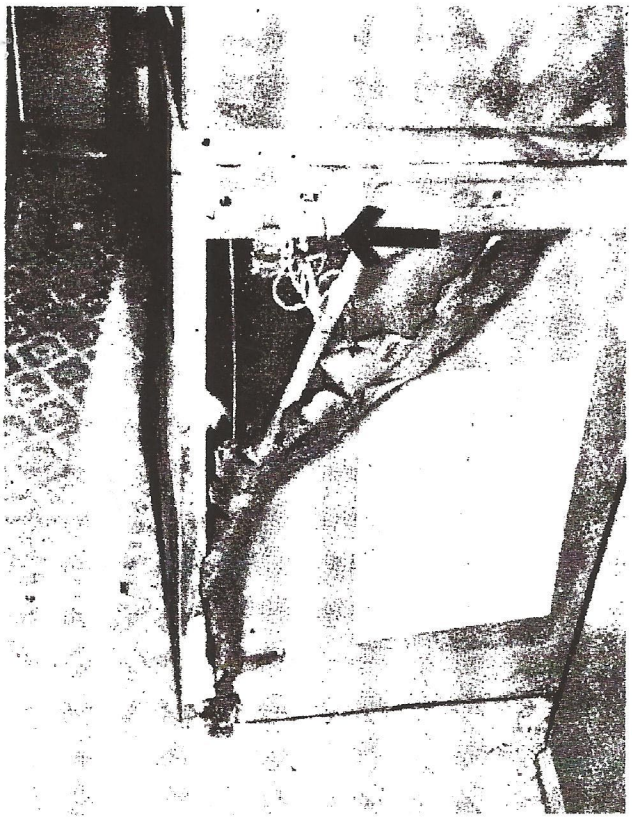


Figure 2. Short circuit occurred in this washing machine's power cord, which was pinched against the wall.

power delivered during one cycle, or during short-circuit conditions that do not quite trip the circuit breaker, may also cause a fire. This had been the case in more than 80 of the 115 electrical fires investigated in this survey. That is, short circuits often cause fires in plastic-, fiber-, and rubber-insulated cables and other electrical devices without ever tripping the circuit breaker or blowing the fuse after the fire has begun.

Plastic-, fiber-, and rubber-insulated cables that cause fire may short circuit months or years after they were either improperly manufactured (e.g., air bubbles in the insulation or conductors placed too close to each other) or were damaged during installation. Twenty-three of the investigated fires were caused by short circuits in branch circuit plastic-, rubber-, and fiber-insulated cables. Four more short circuits occurred in service entrance and feeder cables.[3]

The only way to determine that a short circuit in a cable (or other electrical device) caused a fire is to study the burn patterns and determine whether the short circuit is located at the point of fire origin. It is also necessary to eliminate all other possible causes, including arson, at that point of origin. Another, less-effective method is to have a reliable witness who can place the short circuit at the point of origin.

Power cords are also a source of electrical fires. For example, a short circuit occurred in a washing machine power cord because the cord had been pinched between the rear of the washer and a wall (Figure 2).

Other fires in this survey occurred in dryers (Figure 3). Of the 595 investigated fires, five were caused when the control thermostat in dryers of various manufacturers failed. This thermostat failure allowed the heating element to remain energized and to ignite clothing in the dryer. The location and high threshold temperatures of the other high temperature limit thermostats in these dryers prevented those thermostats from operating in time to prevent the fires. This situation is typical of the appliances that overheat and cause fires.

The Consumer Product Safety Commission (CPSC) has estimated that television sets cause approximately 0.3 percent of all residential fires each year. Half of those fires are contained inside the sets.[4] Eight of the fires investigated in this survey were caused by television sets. One was contained inside the set, four were confined to nearby areas, and three caused extensive damage.

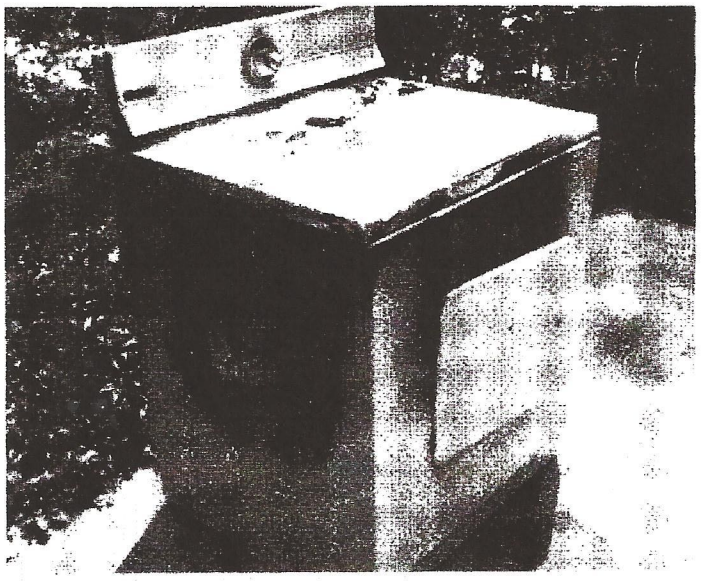
It should be pointed out that many fires that appear to have been caused by a television set or other appliance were actually caused by the use of an accelerant to make it appear that the appliance caused the fire. An investigator must always be careful not to assume that an appliance caused a fire merely because it is located at the origin of the burn patterns. For this reason, since 1976, the author has taken samples for chemical analysis at most of the fire scenes included in this survey, regardless of whether arson was suspected.

Sometimes, electrical equipment fails with explosive force. In one investigated incident, a circuit breaker

[3] The author has never observed a fire caused by a short circuit inside a Bx cable nor in small, rigid conduit.

[4] *The Fire and Arson Investigator*, July–September, 1979.

Figure 3. The timer motor in the dryer malfunctioned, allowing the heating element to remain on. The clothing ignited.



panel exploded when a worker tripped one of its circuit breakers (Figure 4). A flying piece of panel severely injured his head. Another incident involved circuit breaker support contacts that arced when one contact arm fell onto another. The arms were designed to be held in position with a single bolt, instead of two. An electrician was severely burned in this incident while working on the energized panel. Two additional electrical panel short circuits in the survey involved injuries to workers. (When cables short circuit to electrical enclosures, they usually create holes that appear to have been cut with an acetylene torch.) Although some injuries did occur, none of the electrical fires investigated resulted in a fatality, possibly because most bona fide electrical fires propagate slowly.

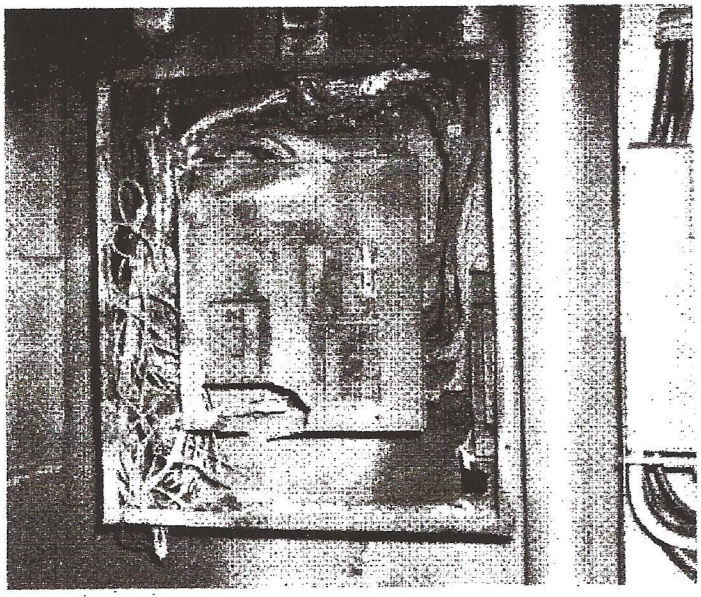


Figure 4. This circuit breaker panel exploded when a worker tripped a circuit breaker.

Although fires caused by the increase of electrical resistance at an aluminum wire connection have been well publicized, these fires are actually rare. One representative house fire was caused by an overheated connection between an aluminum service entrance conductor and its connector in the circuit breaker panel. Fires involving aluminum wire are rare because most aluminum connection points, especially those of the larger cables, are enclosed in a junction box or other steel enclosure that confines the overheated connection. As a result, fire does not occur outside the enclosure.

For a summary of the causes of the 595 fires investigated by P.A.C.E. between 1975 and 1981, see Table A.

A summary of the specific causes of the 115 electrical fires is presented in Table B.

Overcurrent caused only two of the fires because only two defective circuit breakers were found in the 115 electrical fires investigated. No defective fuse was ever found. Even when fuses and circuit breakers have a larger rating than required by code, they seldom cause fires because of the large safety factor built into the *National Electrical Code.*®

Throughout the investigations, short circuits that caused a fire left a melt on the metal conductor at the location of the short. Many investigators erroneously believe that short circuits can occur and cause fires without leaving a melt on the metal conductor because, theoretically at least, a short circuit could ignite the insulation without melting the metal conductor. However, experience disclaims this theory. If one does not find a melt on

Table A.
Fire Causes

Cause		*Incidence*
Definitely arson	163	27.4%
Probably arson	34	5.7%
Suspicious	30	5.0%
ELECTRICAL	115	19.3%
Fuel gas	23	3.9%
Accidental gasoline spill	16	2.7%
Smoking materials	13	2.2%
Wood appliances	7	1.2%
Cooking carelessness	6	1.0%
Other known causes	37	6.2%
Undetermined*	151	25.4%
TOTALS:	595	100.0%

* Damage repaired, no site visit possible (66); absolute totals (34); other (51).

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Table B.
Causes of Electrical Fires

Cause	*No. of Fires*
SHORT CIRCUITS:	
Plastic, rubber, and fiber cables	27
Panels and switch gear	12
Vehicles of all types	11
Power cords	9
Television sets	8
Other home appliances	6
Commercial appliances	6
Kitchen ranges	2
OVERHEATING:	
Home clothes dryers	5
Coffeemakers	4
Deep fat fryers (commercial)	4
Other heating elements poorly protected	6
Insulation too close to recessed fixtures	4
Other overheating*	6
Poor electrical connection	3
Overcurrent in conductors	2
TOTAL:	115

* Motors, large transformers, etc.

the metal conductors at the point of origin, the investigator may be virtually certain that the fire was not caused by a short circuit.

Metal conductors are often melted by the heat of an ensuing fire. The fact that a melt was caused by a short circuit may be determined by examining the conductors. For example, the heat of an ensuing fire cannot melt copper in a small concentrated area, such as ¼ inch in diameter, without also melting the copper in the larger surrounding area. Thus, a melt at only one very small area almost always indicates that a short circuit occurred in that area. Conductors melted by the heat of the fire will generally melt over a length of a few inches or more. With some experience, one can easily discern the difference between a short circuit and melting due to the heat of a fire.

The difficult question often is to determine whether the short circuit caused a fire or was caused by the fire. Answering this question requires the investigator to examine the burn patterns and determine whether the short circuit is located at the single point of fire origin, and to eliminate all other causes at the point of origin. One helpful hint is that short circuits in power cords within approximately one inch of the cord's male plug in an outlet are almost always caused by the ensuing fire. The fire usually attacks that location first at the downward bend in the cord.

In most accidental fires, copper (which melts at 1,900°F) is not melted by the heat of the ensuing fire. Therefore, a short circuit in copper conductors is usually easier to determine or eliminate than in aluminum conductors, which melt at 1,100°F during most fires. Of the 27 short circuits in plastic-, rubber-, and fiber-insulated cables that caused fires, 21 occurred in copper conductors and 6 occurred in aluminum conductors.

The only types of electrical equipment found to have caused any of the fires investigated by P.A.C.E. (in addition to those already listed) were toasters, can openers, range hoods, large transformers, motors, and sauna bath heaters.

Of the 595 fires in this survey, not one was caused by electric furnaces, refrigerators, radios or stereos, clocks, lamps (except for attic insulation too close to recessed fixtures), refrigeration compressors, telephone systems, low-voltage or battery-powered circuits of any type (except those in vehicles), washing machines or electric hot water heaters, air conditioners, fluorescent ballasts, intercoms, an outlet itself, or a wall switch itself. Power cords and supply cables to those types of equipment did cause some of the investigated fires, however. In most cases in which short circuits caused fires in power cords, the power cord had been damaged in some manner.

That these items infrequently cause significant fires[5] is a tribute to their design. For example, electric furnaces have so many safety features — such as high temperature limit thermostats, fuses, and metal enclosures — that a fire during a furnace malfunction is almost impossible. The thermal capacity of the water in electric hot water heaters and the massive enclosures of refrigerators prevent those appliances from causing many fires. Hermetically sealed compressors are similarly protected. Low-voltage systems generally do not provide enough current to cause a fire.

Short circuit fires could be prevented by a new generation of circuit breakers. A microprocessor continually monitoring the alternating current waveforms in each of the circuits could detect any change or signature in the sine wave that would indicate a short circuit. Since 70 percent of all electrical fires are caused by short circuits, such a detector could prevent about 70 percent of electrical fires, or 14 percent of all fires.[6] This design concept is a partial solution to the significant existing problem of electrical fires. The problem is real and needs to be corrected. △

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[5] P.A.C.E. is rarely asked to investigate fires causing less than $5,000 damage.

[6] It has recently been learned that at least some of the circuit breaker manufacturers are developing a computer waveform analysis program. (The details are proprietary.) The May 1982 issue of *IEEE Spectrum* reported that a similar program has been completed in an award-winning development to disconnect high tension lines that fall to the ground, but do not draw enough current to open the large circuit breakers that feed them. The intent is to prevent electrocutions from fallen, energized lines, which occasionally sputter on the ground for an hour or more without this device. The program design principles are the same in both applications.