# Aging Residential Wiring Issues: Concerns for Fatalities, Personal Injuries, and Loss of Property

Joyce Rasdall, Ph.D., Associate Professor
Family and Consumer Sciences Department, Ball State University, Muncie, IN
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**Abstract**

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Aging residential wiring is a major issue as the number of housing units over age 40 increases, historic preservation and restoration increases, and old wiring falls further behind with regard to improvements in the National Electric Code. Corroded wiring and arcing at poor connections behind faceplates of outlets and switches and in light fixtures are a few of the causes of 40,000 fires annually from poor wiring, often in older homes. This annually results in 350 fatalities, 1,400 personal injuries, and upwards of $1 billion of property losses, not to mention inconveniences and frustrations (Larder, p. 1, 2004). The U.S. Consumer Product Safety Commission continues to study these issues and to report statistics regarding this growing issue. Residential technology and consumer specialists are increasingly challenged to participate in a national campaign to deal with this issue.

## A New National Problem: Aging Residential Wiring

Electrical safety issues are myriad, covering a variety of consumer products and consumer behavioral issues. In this paper the problem of aging house wiring is the electrical safety focus. Aging wiring is referred to by technical specialists as 20, 30, 40, 50, or 60 years old, depending on the respective wiring specialist.

"According to the National Science and Technology Council's Wire System Safety Interagency Working Group report issued in 2000, the aging of electrical wiring systems is a *national* safety issue" (Lardear, p. 1, 2004). Currently, half of residences in the United States are 50 years old or older. These wiring systems are likely not adequate for the increasing power demands that consumers place on the systems. "…As their quality and safety deteriorate over time, potential hazards posed by aging residential wiring systems can be unseen or just casually neglected by homeowners or renters." Approximately 41,500 residential fires involving electrical wiring systems annually result in 1,400 injuries and 350 deaths and damage estimates totaling $650 million to $1 billion annually in the United States (Lardear, p. 1, 2004).

## Unintentional Residential Structural Fire Statistics

Twelve percent of annual unintentional residential structural fires are "attributable to electrical distribution system components (e.g. wiring, lighting, etc.)." These fires result in "8% of the total deaths and 7% of the total injuries" (Miller, Smith, & Greene, p. 1, 2003). Residential structural fire sources and their annual consequences in the United States are listed below:

- Installed wiring: 14,100 fires, 30 civilian deaths, 210 civilian injuries, and $260.1 million property losses (Installed wiring is concealed hardwiring; not extension, portable, or visible electrical cords in a household.);
- Cord, plug: 6,700 fires, 80 civilian deaths, 350 civilian injuries, and $140.7 million property losses;
- Receptacle, switch: 3,300 fires, 10 civilian deaths, 50 civilian injuries, and $60.6 million property losses;
- Lighting: 8,500 fires, 20 civilian deaths, 310 civilian injuries, and $127.0 million property losses;

- Panel board, meter, transformer: 3,300 fires, <20 civilian deaths, <40 civilian injuries, $48.4 million in property losses;
- Other: 3,900 fires, 20 civilian deaths, 130 civilian injuries, and $97.1 million property losses; and
- Total electrical distribution system: 39,800 fires, 180 civilian deaths, 1,090 civilian injuries, and $733.9 million in property losses (Miller, Smith, & Greene, 2003).

Table 1
Annual unintended residential structural fires and their consequences in the United States

| Electrical item | No. of unintentional fires | Civilian deaths | Civilians injuries | Property loss (millions) |
|---|---|---|---|---|
| Installed wiring | 14,100 | 30 | 210 | 260.1 |
| Cord, plug | 6,700 | 80 | 350 | 140.7 |
| Receptacle, switch | 3,300 | 10 | 50 | 60.6 |
| Lighting | 8,500 | 20 | 310 | 127.0 |
| Panel board, meter, transformer | 3,300 | <20 | <40 | 48.4 |
| Other | 3,900 | 20 | 130 | 97.1 |
| Total elec. Distribution system | 39,800 | 180 | 1,090 | $733.9 |

These losses drive up insurances rates, and the costs of fire protection in communities, and endanger firemen's lives.

Residential technology educators understand the differences between conductors and insulators, however typical homeowners and students do not typically grasp the principles and consequences involved. Most homeowners and students flip a light switch on or off, casually plug in new electrical appliances they purchase, and if there is no open outlet, they add an extension cord or power strip. Furthermore, "electrical wiring systems that power the conveniences of modern life are hidden in walls and in panel boxes in basements. They are out of sight and out of mind. But that does not mean they are not overloaded and under severe stress" (Lardear, p. 1, 2004).

**Residences Wired in the 1960s or Earlier**

According to the United States Consumer Product Safety Commission, homes over 40 years of age are the greater risk, "but newer ones can have dangers of unacceptable wiring practices and environmental stresses on their wiring" (CPSC, 2005). Residential wiring systems installed in new or existing houses during the 1960s and earlier are almost surely at the end of their functional design life. "These products are showing some kind of deficiency after 50 or 60 years of service" (Lardear, p. 1, 2004). The housewiring poses hidden but real dangers. "According to the United States Census Bureau's 1999 Annual Housing Survey, there are 70 million homes (or 71% of all housing units) that are at least 20 years old…and they aren't getting any younger. In some respects, just by making a casual observation of older houses, you can understand why these fires are continuing to occur" (Lardear, p. 1, 2004).

In general, annual residential fires are going down because of better electrical codes, smoke alarms, and fire suppression systems. Thus, homes constructed today do not "face the same problems as the majority of the 100 million existing homes in the United States" (Lardear, p.1, 2004). Unfortunately, however, electrical wiring fires sustained by older residences that are especially vulnerable to the issues of aging wiring and overloaded electrical circuits, are not parallel to this downward trend.

Bill King, engineer at the U.S. Consumer Product Safety Commission (CPSC, 2004), indicates that if safety proponents do not deal with the issue of older residences and the inherent aging wiring systems, then the fire, fatality, injuries, and property losses have great potential for catastrophe. Homeowners generally upgrade construction components including roofs, windows, furnaces, and even electrical circuit breaker boxes or fuse panels. However, the remainder of the electrical wiring system is out of sight and unfortunately out of mind all too often. Wiring concealed in walls and their branch circuits are typically neglected and hardly ever are replaced (Lardear, p. 1, 2004).

**Primary Residential Wiring Safety Issues**

The growing problems related to aging residential wiring systems are due to the following parameters:

1. Cumulative effects of a variety of environmental stresses and the wear and tear of daily electrical uses impact life expectancy of residential wiring. The severity of aging of wiring depends on a variety of factors.

   A. **Degradation of conductors** increases with age.

      a) **Oxidation/corrosion** films can cover conductors, especially at connections.
      b) **Excess heat from overlamped light fixtures** causes brittle conductors.
      c) Conductor technology had little or no innovation during the last 30 years. The most recent major innovation in residential wiring occurred in 1985 when "the required maximum temperature rating of nonmetallic cable was increased to 90 degrees C while keeping the ampacity to 60 degrees C," resulting in an effective practice (Lardear, p. 1, 2004).
      d) **Conductor connections can loosen or even disconnect** with time, thus setting up a situation for sparking/arcing if electrical current is to flow when the consumer turns on a switch. "Sometimes switches can come loose from the wall, and the movement of the wiring back and forth can break connections, damage insulation, or make bare wires touch metal. Any one of these can cause a fire" (USCPSC, 2004).
      e) Connections in electrical outlets, switches, light fixtures, and the like can loosen due to a variety of reasons.
         i. Expansion and contraction due to temperature changes seasonally and daily;
         ii. Vibrations from trains, sonic booms from jet aircraft, other noisy vehicles, high decibel level music/radio equipment, and thunder;
         iii. Wind and air pressure changes are also causes; and/or
         iv. The frequency and or unnecessary use of the switch.

   B. **Deterioration of insulation** occurs over time.
      a) **Heat from overlamped light fixtures and other installations heavily loaded electrically** and light cause deterioration and accelerate loss of plasticizer in insulation (Lardear, 2005).
      b) **Dry locations** lead to loss of the plasticizer in PVC insulation. Drying is dependent on length of time and high temperature factors as well (Lardear, 2005).
      c) Water absorption into insulation in **wet locations** reduces its insulative strength (Lardear, 2005).
      d) Rodents and other creatures can damage insulation over the years.

2. If older wiring during **add-on wiring jobs** is disturbed then safety risks result from cracking brittle insulation. In fact, some electricians operate with a policy that 30-year-old wiring be replaced because assessing how badly aging has damaged the wiring is difficult at best.

3. **Increased kilowatt hour use** involves most residential consumers owning and using more appliances and lighting than consumers used 40, 50, and 60 years ago. They expect the electrical system to provide adequate electricity for their growing electrical demands. Consumers make this demand operational by adding more circuits (and circuit breakers in blank spots on the breaker panel, or even another circuit breaker box) and outlets to accommodate their purchases. If an outlet is added to an existing circuit, then the load can easily be more than the wiring was designed to conduct originally—perhaps decades ago.

4. **Peak consumer/residential energy use** occurs twice daily (reflected in household energy use patterns from 6 to 8 a.m. and 5 to 8 p.m.), in most U.S. utility systems and consumer households, thus leading to major stress and safety risks on aging wiring systems during these hours. If consumers could level out the peaks, then risks associated with high KWH use could be mediated somewhat.

5. **Small wiring [number 14 American Wire Gauge** (AWG)] began to be disallowed by selected local codes during the 1960s in favor of larger 12 AWG. By about 1970, the National Electric Code changed to 12 AWG, thus making the older standard out of date regarding increasing KWH use and peaks. Unless wiring has been upgraded since 1970, then homes are probably wired with small wiring for common branch circuits.

6. Too often **unskilled homeowners engage in additions to circuits** resulting in installations that do not meet the National Electrical Code (either then or currently) and/or are not inspected by a qualified electrical inspector when finished. Do-it-yourselfers can create serious violations of the code, causing accidents waiting to happen.

7. Too often consumers do not know or do not want to engage in **managing aging wiring systems**. Maintenance and inspection can be expensive and time-consuming and technically challenging. "As the first step to addressing this issue, the National Fire Protection Association developed NFPA 73, which differs from NFPA 70 by providing requirements for evaluating existing electrical systems" (Lardear, 2004). During the sale of a home, a prospective owner might make certain that the house conforms to NFPA 73 before completing the sale, thus overcoming the most common and risky hazards of an aging wiring system.

8. According to the CPSC (2004), "an estimated 2 million homes and mobile homes were wired with **aluminum wire**" between 1965 and 1974 in the United States. This wiring used 15 and 20 ampere circuits of size 10 AWG or smaller and aluminum wiring in wall outlets, switches, circuit breakers, fuse sockets, and lamp sockets connected to the wiring. "In 1974, the CPSC determined that hazards associated with aluminum wire systems" were "unreasonable risk(s) of injury or death" and filed suit charging two dozen aluminum wire manufacturers. The CPSC indicates that homes wired with aluminum wiring manufactured before 1972 (old technology aluminum wire) are 55 times more likely" to sustain connections that reach Fire Hazard Conditions in contrast to

homes with copper wiring. In 1972, manufacturers modified aluminum, including switches and outlets, to enhance performance at connections—where aluminum wiring problems are—since aluminum wiring is fine. "…Aluminum expands and contracts three times the rate of copper, likely eventually creating a gap at wiring connections, causing both sparks and oxidation of aluminum ends"(Lardear, 2004). Oxidation fosters electrical resistance and elevated heat levels in the circuit. Oxidized aluminum is a poor conductor and acts as an insulator in elevated heat environments, a precursor to hazardous arcs and glowing red connections (Electrical Safety Foundation International, 2003).

9. Other results from aging residential wiring systems beyond the safety hazards are the inconveniences, either potential or realized when fire disasters occur. Psychological costs, personal injuries, fatalities, and property losses are difficult to sustain and involve a variety of monetary and temporal costs with daily living patterns, employment during disasters, and other issues. Inconveniences of aging wiring can involve questionable practices of using extension cords, power strips, and even unplugging a device to plug in another. Aging wiring typically involves few or no exterior outlets and few outlets in kitchen and other task areas.

10. Covering wiring rated for open use is an issue. Covering wiring with attic insulation can cause a fire hazard in attics and other concealed spaces. If insulation is added to a house, then any wiring or fixtures covered with insulation must be certified/rated for such conditions (USCPSC, 2004).

11. Lack of safety improvements over the years that are now required in the National Electric Code include Ground Fault Circuit Interrupters (GFCIs) and Arc Fault Circuit Interrupter (AFCI). Having at least 5 feet between an outlet and a bathtub may be violated in older wiring.

**Arc faults: a Growing Safety issue**

An arc fault is commonly called a spark. An arc fault is "a discharge of electric current across a gap" between electrical conductors. "In a home, arc faults can be years or just seconds in the making. Arc faults can be caused by a variety of factors including loose or improper connections to outlets or switches; cracked wire insulation stemming from age, heat, or corrosion; and electrical wire insulation chewed by rodents or punctured by nails." Arcs are particularly dangerous in walls and ceilings since temperatures of 10,000 degrees F or above can ignite wood easily. The CPSC (2004) estimates, fires starting with electrical distribution systems amounts to more than 10 percent of all home fires, partially because of arc faults. "Since household fuses and circuit breakers do not respond to early arcing and sparking conditions, in January 2002, the National Electrical Code (1999 NFPA 70, Section 210-12), began requiring Arc Fault Circuit Interrupters (AFCIs) for all branch circuits supplying 125V, single phase, 15- and 20-ampere outlets for bedroom circuits in new residential construction" (Lardear, p. 1, 2004). Scorched areas around faceplates and circuit breaker or fuse panels can mean sparking or overloaded, inadequate wiring that could ignite paper, fabric fibers, and/or wood nearby (USCPSC, 2004).

Thus, AFCIs and their capacity to identify unique electrical current and voltage characteristics are probably more important for deteriorated aging wiring systems. AFCIs sense arcs and sparks in wiring at receptacles and switches. AFCIs have capabilities beyond that of fuses and circuit breakers, particularly for deactivating arc faults hidden in walls and ceilings. AFCIs are unique from Ground Fault Circuit Interrupters (GFCI) that protect against shock (dangerous overcurrent flow). Both GFCIs and AFCIs deactivate a circuit, but each protects a unique cause, dangerous power surges/shorts or arcs and sparks at wiring connections at receptacles and switches respectively.

The CPSC and the National Fire Protection Association have worked together to require arc fault detection devices in new and retrofit construction (USCPSC, September 2000). The 2002 edition of the National Electric Code specifies Arc Fault Circuit Interrupters in bedrooms in order to reduce risks among consumers while sleeping (National Fire Protection Association, 2005). The 2005 edition adds AFCIs to within a few feet of the circuit breaker panel in order to protect from sparks in that vicinity. More AFCI provisions are under consideration for future editions.

**Aging Residential Wiring Safety Educational Campaigns**

A partnership of the National Fire Protection Association's (NFPA) Fire Protection Research Foundation with several other groups is a major educational campaign (Lardear, 2004). In May 2003, the Electrical Safety Foundation International (ESFI) initiated its "Inspect and Protect!" program to spur homeowners to engage a qualified, licensed electrician to inspect wiring systems in homes 40 years and older, to learn about the potential hazards posed by aluminum wiring systems and to consider installing AFCI technology (Electrical Safety Foundation International, 2003).

**Implications for Consumer Educators and Residential Technology Specialists**

Encouraging consumers to maintain house wiring, just as a car, furnace, roof, or chimney needs maintenance is critical. Establishing priorities for first and then second maintenance/updates is a functional step (USCPSC, 2004). Asking consumers to check with the respective insurance agent to ascertain if wiring safety improvements qualify the policy holder for a premium reduction is a recommendation.

Aging residential wiring issues pose serious implications to consumer educators and residential technology specialists. How will these professionals/educators deal with this growing problem? Residential technology educators are challenged to

1. Engage in curriculum upgrades that involve aging house wiring issues,
2. Develop resources and reference list with strategic data,
3. Develop class learning experiences with speakers and tours focusing on aged wiring issues, and
4. Incorporate student real world projects such as that described below.

Old wiring needs to be abandoned and replaced. The consequences of not upgrading old wiring are clear, can be formidable, and need to be addressed among students preparing for careers in Residential Technology and related Family and Consumer Sciences Programs.

**Residential Technology Student Project**

Experiential learning is enhanced by students in an Interior Design studio 2 course at the sophomore level completing a project with one to five owners or occupants of aging housing, depending on the percentage of the final grade the project represents. Students identify their contacts and use the implications section outlined above to structure their own interview outline. Each student uses the section following for questions and priority issues addressed in this project in order to identify consumers' real world experiences with this electrical safety issue.  A summary of each interview/site is reported separately in outline format by the student. Lastly, an overall summary and analysis is synthesized by each student.

Objectives for the project include

1. To investigate current aging residential wiring/electricity use and practices for safety concerns.
2. To discuss aging wiring issues and their consequences with occupants.
3. To examine occupant awareness and understanding of aging wiring recommendations.
4. To summarize findings from occupants in each residence and synthesize recommendations as for best practice and electrical safety of the occupants.

Students gain greater insights from on-site, in-person interviews than through only the lecture and class discussion prior to the field experience.  Many students are interested in do-it-yourself residential upgrades and restorations and thus through this project they gain increased human capital for decision-making personally and for professional consultations in their future careers.  Thus, this project enables students to gain ownership of their careers, rather than only learning on the sidelines.

**Questions and Priority Issues for Consumer and Student Consideration**

1. List the causes of hazards of aging residential wiring.
2. Cite the consequences of aging residential wiring issues.
3. What visible evidences are there in and outside the home of aging wiring practices?
4. What problems do the occupants report regarding dysfunctions of aging wiring?
5. What improvements have the occupants made with the aging wiring, if any?
6. What plans and timetable for improvements do the occupants report, if any?
7. What recommendations should we propose among Do-It-Yourselfers?
8. What implications are there for historic preservation, restoration, and retrofits of homes, offices or retail space or other adaptive reuse,
9. When a home constructed prior to 1960 is sold, will the buyer have it electrically inspected by a competent, licensed electrician or inspector?
10. Based on the consumer's experiences with wiring in an older home, what recommendations does he/she propose if she/he were to move/relocate?
11. Unless the residence is rewired, will it have an electrical inspection as a part of responsible electrical system management?  If no, cite reasons; if yes, cite reasons.
12. Will electrical inspection by a competent electrical inspector be completed during initial wiring of a new home or rewiring during home improvements and added on space both for interiors and exteriors?
13. What consequences can be incurred when rooms or homes are redesigned as in the current popularity of shows such as Designers' Challenge, Design for the Sexes, and Chic Design on the Home and Garden Channel?  What recommendations for re-wiring or wiring updates are needed during these television segments?

**Summary**

Because aging residential wiring is a national issue involving substantial property losses, fatalities, and personal injuries annually, this problem is becoming more critical among relevant professionals, including residential technology educators and consumer specialists.  A student learning project was designed to examine aging wiring issues in the field via on-site interviews.  This experience builds on the traditional lecture and discussion method and enables residential technology and other FCS students to gain insights in order to build human capital for personal decision making.  Thus, the learning experience is strategic for critical thinking processes and for building ownership of students' careers. When electrical safety decisions by other consumers are at stake residential technology students can benefit from the descriptive and analytical processes included in this real world project.

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Comment from Jim McCabe, ANSI (3 Nov 2005):

Joyce,

As a homeowner, I wanted to tell you that I really appreciated the information contained in your paper on aging residential wiring issues. We're now considering having a full electrical inspection and replacement done of the wiring in our home.

Jim McCabe
Director, Consumer Relations and Public Policy
American National Standards Institute