Residential Electrical System Aging Research Project

Dave Dini
Sr. Research Engineer
Underwriters Laboratories
Aging Residential Electrical Systems

Research Project Sponsors

- Fire Protection Research Foundation
- UL, CSA
- Consumer Product Safety Commission
- Insurance companies
- Wire and electrical device manufacturers
Gather detailed information at fire scenes regarding electrical components that were at the fire’s point of origin.
Part 1 Project Activities

- How does aging of electrical systems relate to fire incidence
- Review insurance company written case studies and the physical evidence
Aging Residential Electrical Systems

Project Plan - Part 2

Independent analysis of the condition of samples of various age groups (e.g. – 1930’s, 1940’s, etc.) of residential electrical system components
Aging Residential Electrical Systems

Part 2 Project Activities

- Identify older homes ready for demolition
- Recover electrical components (wiring, receptacles, luminaires, etc.)
- Send to UL for laboratory analysis
Local “Champions”
Local “Champions”

Andy Cartal - Pennsylvania
Tim Owens - California
Dave Hill - Oregon
Bob McCullough - New Jersey
Bob Meier - Wisconsin
Donny Cook - Alabama
Lanny McMahill - Phoenix
Nelson Mongomery - Florida
Identification of Older Homes Ready for Demolition
Volunteers Assisting in the Recovery
Residential Electrical System Aging Research Project

These instructions and data sheets are intended for use in conjunction with the FPRF’s Residential Electrical System Aging Research Project. The goal of this project is to improve residential electrical fire safety by more thoroughly understanding the effects that aging may have on the safety of electrical system components. One aspect of this project is to characterize the condition of various age groups of residential electrical components by surveying, recovering, and analyzing representative samples of actual installed wiring systems, wiring devices, and similar distribution and utilization equipment.

The following are procedures for selecting and surveying the residential building that will be used for the purposes of recovering and analyzing selected electrical components.
Data Collection and Recovery Process

Describe and Photograph Problems

- poor or unqualified workmanship
- damage to devices
- lack of Code compliance
- overlamping
- permanent use of extension cords
Room (or Area): _____________

Dimensions of room: ______________

Number of outlet receptacles: _______  Number of wall switches: _______

Describe number and type of luminaires:
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

Describe and photograph any problems in this room or area relating to poor or unqualified workmanship, damage to devices, lack of Code compliance, and/or other hazards such as overlampng, permanent use of extension cords, etc.:
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
____________________________________________________________________
Data Collection and Recovery Process

Poor or Unqualified Workmanship

110.12 Mechanical Execution of Work

“Electrical equipment shall be installed in a neat and workmanlike manner.”
Poor or Unqualified Workmanship

No Cable Clamp
Poor or Unqualified Workmanship

Duct Tape has Many Uses
Poor or Unqualified Workmanship

Don’t throw away your popsicle sticks
Poor or Unqualified Workmanship

Dining room fixture location
No box
Poor or Unqualified Workmanship

Nice splice
Poor or Unqualified Workmanship

Track Lighting Conductors Stapled to Wall
Poor or Unqualified Workmanship

Fluorescent Light Wiring Splice
Lack of Code Compliance

90.1 Purpose

(A) Practical Safeguarding The purpose of this Code is the practical safeguarding of persons and property from hazards arising from the use of electricity.
Code Compliance Issues

Few Receptacle Outlets Provided
Code Compliance Issues

Circuit Extension
Code Compliance Issues

No Grounding Type Receptacles
Code Compliance Issues

All branch circuits were required to be grounded in the 1962 NEC.
406.8 Receptacles in Damp or Wet Locations
C) Bathtub and Shower Space Receptacles shall not be installed within or directly over a bathtub or shower stall.
Damaged Equipment

1971 - Double T receptacles no longer permitted
Data Collection and Recovery Process

Recovery of Selected Devices

- service drop and entrance cable
- fuses and circuit breakers
- wire and cable systems
- outlet receptacles
- luminaires
- junction boxes and wire splices
Recovering Service Drop
Recovering Service Panel
Recovering Interior Wiring
Wire and Cable Systems

Knob & Tube
Outlet Receptacles
Luminaires
Junction boxes and splices
Recovered items sent to laboratory
Recovered Devices Sent to UL Labs

• visual inspection for damage
• temperature and dielectric testing of devices
• test of wire and cable insulation
• calibration of fuses and circuit breakers
Laboratory Analysis and Inspection

Missing Cable Clamp and Unused Opening
Laboratory Analysis and Inspection

White Insulation Used for Ungrounded Conductor
Laboratory Analysis and Inspection

Evidence of Arcing
Laboratory Analysis and Inspection

Improper Splice Glowing Red-Hot
# Circuit Breaker and Fuse Calibration

## Circuit Breakers

<table>
<thead>
<tr>
<th>Rating (Amps)</th>
<th>300% Calibration Test Amps</th>
<th>Allowable Min:Sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>45</td>
<td>0:50</td>
</tr>
<tr>
<td>20</td>
<td>60</td>
<td>0:50</td>
</tr>
<tr>
<td>30</td>
<td>90</td>
<td>0:50</td>
</tr>
<tr>
<td>40</td>
<td>120</td>
<td>1:20</td>
</tr>
<tr>
<td>50</td>
<td>150</td>
<td>1:20</td>
</tr>
<tr>
<td>60</td>
<td>180</td>
<td>2:20</td>
</tr>
<tr>
<td>70</td>
<td>210</td>
<td>2:20</td>
</tr>
<tr>
<td>100</td>
<td>300</td>
<td>2:20</td>
</tr>
<tr>
<td>125</td>
<td>375</td>
<td>3:20</td>
</tr>
<tr>
<td>150</td>
<td>450</td>
<td>3:20</td>
</tr>
<tr>
<td>200</td>
<td>600</td>
<td>3:50</td>
</tr>
<tr>
<td>225</td>
<td>675</td>
<td>3:50</td>
</tr>
</tbody>
</table>

## Fuses

<table>
<thead>
<tr>
<th>Rating (Amps)</th>
<th>200% Calibration Test Amps</th>
<th>Allowable Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>20</td>
<td>40</td>
<td>4</td>
</tr>
<tr>
<td>30</td>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>40</td>
<td>80</td>
<td>6</td>
</tr>
<tr>
<td>50</td>
<td>100</td>
<td>6</td>
</tr>
<tr>
<td>60</td>
<td>120</td>
<td>6</td>
</tr>
<tr>
<td>70</td>
<td>140</td>
<td>8</td>
</tr>
<tr>
<td>100</td>
<td>200</td>
<td>8</td>
</tr>
</tbody>
</table>
Fuse Inspection

Looking for pennies
Fuse Inspection

30 Amp Fuses?
Fuse Inspection

Corrosion?
Testing a Recovered Receptacle
Testing a Recovered Receptacle
# Testing a Recovered Receptacle

<table>
<thead>
<tr>
<th>ID</th>
<th>Amp Rating</th>
<th>Polarized</th>
<th>Grounding</th>
<th>Wire Size (Awg)</th>
<th>Min Torque (in-lb)</th>
<th>Min Retention (oz)</th>
<th>Max Temp Rise (C) - As Received</th>
<th>Max Temp Rise (C) - After Clean Blade Insertions</th>
<th>Max Temp Rise (C) - After Tightened Terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>BATH-R1</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>5</td>
<td>+24</td>
<td>41</td>
<td>108</td>
<td>32</td>
</tr>
<tr>
<td>BATH-R2</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>4</td>
<td>&lt;4</td>
<td>14</td>
<td>115</td>
<td>38</td>
</tr>
<tr>
<td>KIT-R1</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>4</td>
<td>16</td>
<td>41</td>
<td>40</td>
<td>47</td>
</tr>
<tr>
<td>KIT-R3</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>14</td>
<td>10</td>
<td>24</td>
<td>91</td>
<td>43</td>
<td>52</td>
</tr>
<tr>
<td>OUT-R1</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>2</td>
<td>4</td>
<td>51</td>
<td>41</td>
<td>33</td>
</tr>
<tr>
<td>UNK-R1</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>1</td>
<td>+24</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Luminaires

100 W - Overlamping?
Luminaires

Splices don’t fit in box

Unused openings

What about fill?
Luminaires

90 C Supply Wire?
Fluorescent Luminaires

Conductor Damage
Wire and Cable Dielectric Testing

5000 Volts Withstand L-L & L-G for 1 Minute
Maximum Voltage to Breakdown L-L & L-G
<table>
<thead>
<tr>
<th>Sample</th>
<th>AWG</th>
<th>Bonding</th>
<th>Measured Ohms/100 ft</th>
<th>Max Permitted Ohms/100 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>yes</td>
<td>0.790</td>
<td>0.75</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>no</td>
<td>2.068</td>
<td>1.50</td>
</tr>
</tbody>
</table>

Resistance of Cable Armor
(B) Splices. Conductors shall be spliced or joined with splicing devices identified for the use or by brazing, welding, or soldering with a fusible metal or alloy. Soldered splices shall first be spliced or joined so as to be mechanically and electrically secure without solder and then be soldered. All splices and joints and the free ends of conductors shall be covered with an insulation equivalent to that of the conductors or with an insulating device identified for the purpose.
Analyzing Wire Splices

No Solder, Friction Tape?
Reporting the Findings

Residential Electrical System Aging Research Project

Project House AL-1

The following report describes Project House AL-1, an older residential occupancy that was secured for use as part of the Fire Protection Research Foundation's (FPRF) Residential Electrical System Aging Research Project. Access to the building was obtained and permission granted for removal of selected electrical system devices and wiring system components. The recovered items were then sent to the UL laboratories for further testing and analysis. This field recovery project was conducted in August of 2004.

Initial Description and Survey of Project House AL-1

Project House AL-1 was located at 4844 S. Shades Crest Rd., Helena, AL. The house was built in 1960. It was a single-family ranch style wood house, with a an accessible crawl space and a non-accessible attic. The house had three bedrooms, one bathroom, kitchen, living room, and laundry area with approximately 1100 square feet of living space. The electrical service consisted of a 100 Amp main fuse pull-out switch located in the bathroom, provided with 60 Amp main fuses. It had eight branch circuits protected by Edison base plug fuses, and a range circuit, however the range pull-out and fuses were missing. NM cable was the predominant wiring method for the house.

Electrical Survey of the Building

Although the power to the house had been disconnected, power was temporarily restored by the local utility in order to make some electrical measurements. The house had a mixture of grounding and non-grounding type receptacles. Some grounding type receptacles were found that did not have an equipment ground installed in the outlet, a temperature test was conducted for 10 minutes at 15 amps. The test was also repeated on the other outlet position. The temperature rise at each blade was measured. The maximum temperature rise is indicated in the table. If a temperature rise exceeded 20°C, the test was repeated after inserting and withdrawing a clean blade 10 times. If a temperature rise still exceeded 20°C, the test was repeated with the wiring terminals tightened to 9 in-

<table>
<thead>
<tr>
<th>ID</th>
<th>Manufacturer</th>
<th>Amp Rating</th>
<th>Polarized</th>
<th>Grounding</th>
<th>Wire Size (Amp)</th>
<th>Min. Torque (in-lb)</th>
<th>Max Temp Rise (°C) As Received</th>
<th>Max Temp Rise (°C) After Clean Blade Insertions</th>
<th>Max Temp Rise (°C) After Tightened Terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>BATH-R1</td>
<td>Leviton</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>5</td>
<td>41</td>
<td>32</td>
<td>38</td>
</tr>
<tr>
<td>BATH-R2</td>
<td>Eagle</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>4</td>
<td>&lt;4</td>
<td>108</td>
<td>115</td>
</tr>
<tr>
<td>KIT-R1</td>
<td>GE</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>4</td>
<td>18</td>
<td>14</td>
<td>40</td>
</tr>
<tr>
<td>KIT-R3</td>
<td>unknown</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>4</td>
<td>10</td>
<td>24</td>
<td>41</td>
</tr>
<tr>
<td>OUT-R1</td>
<td>Leviton</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>2</td>
<td>4</td>
<td>91</td>
<td>43</td>
</tr>
<tr>
<td>UNK-R1</td>
<td>Leviton</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>1</td>
<td>+24</td>
<td>51</td>
<td>41</td>
</tr>
</tbody>
</table>
Project Goal

100 houses
(12 from each Champion’s area)

20’s and older
30’s
40’s
50’s
60’s
70’s and newer
Aging Residential Electrical Systems

What Have We Found So Far – and What Might be Recommended

(Top 5 List)
1. Install GFCIs as required per Code
Aging Residential Electrical Systems

1. Install GFCIs as required per Code
   - Bathrooms
   - Kitchens
   - Outdoors / Garage
   - Unfinished Basements / Crawl Spaces
   - Laundry and Utility Sinks
2. Replace Old Receptacles

- Especially before ~ 1965
- Especially if damaged or broken
- Especially of low retention force
- If no Ground – Install GFCI

<table>
<thead>
<tr>
<th>ID</th>
<th>Amp Rating</th>
<th>Polarity</th>
<th>Grounding</th>
<th>Wire Size ( Awg</th>
<th>Min Torque (in-lb)</th>
<th>Min Retention (oz)</th>
<th>Max Temp Rise (C) - As Received</th>
<th>Max Temp Rise (C) - After Clean Blade Insertions</th>
<th>Max Temp Rise (C) - After Tightened Terminals</th>
</tr>
</thead>
<tbody>
<tr>
<td>BATH-R1</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>5</td>
<td>+24</td>
<td>41</td>
<td>32</td>
<td>38</td>
</tr>
<tr>
<td>BATH-R2</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>4</td>
<td>&lt;4</td>
<td>108</td>
<td>115</td>
<td>110</td>
</tr>
<tr>
<td>KIT-R1</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>4</td>
<td>16</td>
<td>14</td>
<td>40</td>
<td>47</td>
</tr>
<tr>
<td>KIT-R3</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>14</td>
<td>10</td>
<td>24</td>
<td>41</td>
<td>43</td>
<td>52</td>
</tr>
<tr>
<td>OUT-R1</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>2</td>
<td>4</td>
<td>91</td>
<td>41</td>
<td>33</td>
</tr>
<tr>
<td>UNK-R1</td>
<td>15</td>
<td>yes</td>
<td>yes</td>
<td>12</td>
<td>1</td>
<td>+24</td>
<td>51</td>
<td>41</td>
<td>33</td>
</tr>
</tbody>
</table>
3. Install Plug Fuse Adaptors / Proper Size Fuses
Aging Residential Electrical Systems

4. Use Proper Wiring / Surface Raceway to Add Outlets & Receptacles

• Especially before 1960
5. Armored Cable (BX) Before ~1960

- Probably does not have bonding wire

<table>
<thead>
<tr>
<th>Sample</th>
<th>Awg</th>
<th>Bonding Strip</th>
<th>Measured Ohms/100 ft</th>
<th>Max Permitted Ohms/100 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>14</td>
<td>yes</td>
<td>0.790</td>
<td>0.75</td>
</tr>
<tr>
<td>2</td>
<td>14</td>
<td>no</td>
<td>2.068</td>
<td>1.50</td>
</tr>
</tbody>
</table>
5. Armored Cable (BX) Before ~1960

- Probably does not have bonding wire
- Consider protecting entire circuit with AFCI or GFCI (GFP)
Thank you!

Dave Dini
Underwriters Laboratories
David.A.Dini@us.ul.com