Evaluation of Aluminum Cable
Presentation for IEEE OCS
September 14, 2011
Breck Booker, Southwire
Today’s Topics

- Brief Overview of Southwire
- In-depth Discussion on Aluminum Characteristics
- Discussion of Southwire Aluminum 600 volt and MV Products.
History of Southwire

- Founded in 1950 by Roy Richards Sr.
- We manufacture all types of wire and cable that deliver power from the generation plant to the residential home.
Southwire Today

- Employ over 4,000 Worldwide
- Annual Sales Approx. $5.5 billion
- 9 distribution centers in North America
- Leaders in Research & Development
  - First to commercialize a superconductivity circuit that feeds one of our plants
  - Southwire holds more than 240 patents in 40 countries
Monthly Average Copper Price

COPPER PRICE
Jan 4, 2002 - Jun 24, 2011

ALUMINUM PRICE
Jan 4, 2002 - Jun 24, 2011
Why Market Aluminum?

- **COST SAVINGS**: 70% of the cable cost is in the metals.
  - With a differential of $2.00 between copper and aluminum there is a potential for 35% - 50% savings

- Aluminum is code compliant, safe and reliable
  - Honda Indiana Plant –15kv AIA and 600 volt AIA
  - Bloomingburg Ethanol Plant, Bloomingburg, Ohio
  - Met-Life Stadium (GO JETS)
  - Charlotte Bobcat Arena
  - GM 5E Spec

- Lead time 7 weeks
Aluminum Product Offering

- Medium voltage single conductor cable – 2kv-46kv
- Multi-conductor non-armored cable – CT3-13ET and CT3-09ET
- Interlocked armor – AL-13ET and AL-09ET
- Single conductor Tray Rated – XHHW-2
- Multi-conductor Tray Rated – XHHW-2/PVC
- Interlocked armor – AL-01XXH
- Sizes 250kcmil Aluminum and above; 3/0 copper equal ampacity and above
May 28th 1977, Beverly Hills Supper Club, Southgate KY Catches on fire, 165 fatalities. Aluminum wiring was cited as the most probable cause. It was used on branch circuits; receptacles, switches, cans ext.

What Caused the Fire??
Examples of Undesirable Materials Combination in an Electrical Connection

RESULT OF DIFFERENCES IN THERMAL EXPANSION AND CREEP OF MATERIALS:

- Rapid conductor deformation due to creep
- Loss of mechanical load and connector degradation
Definition of Thermal Expansion and Creep

CTE: The coefficient of thermal expansion is defined as the fractional increase in length per unit rise in temperature. Micro inches/inch °F

Creep is the measurement of the rate of change of a material’s dimension over a period of time when subject to a force at a particular temperature. Copper and AA8000 series aluminum have similar creep rates unlike EC 1350 which has a much higher creep rate than copper. Micro inches per inch per hour at temperature T and force F.
Conditions for a Reliable Aluminum Electrical Connection

The aluminum conductor and connector alloys must have similar “creep-properties” to avoid loss of contact load and electrical degradation over a long service life.
NEC and UL Requirements on Aluminum Conductors

- NEC 310-14 (1987)
  - Aluminum conductors rated 600 volt used inside buildings shall be made of AA-8000 series.
  - No aluminum grade specification on Medium voltage Cable.

- Connectors:
  - UL 486B
  - Dual rated lugs for copper or aluminum
  - mechanical or compression.
Aluminum Association
AA8000 Series

- Alloy:
  - Traces of copper gives better thermal stability
  - Traces of iron makes it more flexible

- Anneal:
  - Aluminum is treated with heat to removes internal stresses in the aluminum. Less brittle

- Southwire AA8176
  - six other series are registered with Aluminum Association AA
Conditions for a Reliable Aluminum Electrical Connection

Typical example of a UL Dual-Rated connection Al-Cu, Al7-Cu or Al9-Cu.
The creep properties of AA 8176 are comparable to annealed copper.
Connection Preparation For Aluminum Conductors

- **Disrupt surface contaminant films with steel brush**

Connection Preparation For Aluminum Conductors

• Apply a recommended inhibitor to the conductor

• Torque the bolt or screw to levels recommended by the manufacturer; excessive torque will deform the conductor excessively and may lead to loss of strands (this applies to aluminum and copper conductor)
# Copper and Aluminum Comparison

<table>
<thead>
<tr>
<th>COPPER</th>
<th>ALUMINUM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Heavier</strong></td>
<td><strong>Lighter – 54% lighter</strong></td>
</tr>
<tr>
<td>500kcmil strd: 1,544lb/1,000’</td>
<td>750kcmil strd: 704lb/1,000’</td>
</tr>
<tr>
<td><strong>Better Conductivity per size at 5 &amp; 15kv – dc Ohms</strong></td>
<td><strong>Aluminum – 61% Conductivity of Cu – dc Ohms</strong></td>
</tr>
<tr>
<td>500kcmil = .0216 ohms/1,000’</td>
<td>500kcmil = .0354 ohms/1,000’</td>
</tr>
<tr>
<td></td>
<td>750kcmil = .0236 ohms/1,000’</td>
</tr>
<tr>
<td><strong>Impedance at 75C 60 Hz in Magnetic duct 5 &amp; 15kv ohms/1,000’</strong></td>
<td><strong>Impedance at 75C 60 Hz in Magnetic duct 5 &amp; 15kv ohms/1,000’</strong></td>
</tr>
<tr>
<td>4/0 : 0.0650 + j 0.0583 ; z = 0.0873</td>
<td>350kcmil: 0.0614 + j 0.0468 ; z = 0.0773</td>
</tr>
<tr>
<td>250kcmil: 0.0557 + j 0.0570 ; z = 0.0797</td>
<td>500kcmil: 0.0435 + j 0.0444 ; z = 0.0624</td>
</tr>
<tr>
<td>350kcmil: 0.0386 + j 0.0562 ; z = 0.0681</td>
<td>600kcmil: 0.0366 + j 0.0431 ; z = 0.0566</td>
</tr>
<tr>
<td>500kcmil: 0.0300 + j 0.0526 ; z = 0.0605</td>
<td>750kcmil: 0.0298 + j 0.0419 ; z = 0.0514</td>
</tr>
<tr>
<td>750kcmil: 0.0223 + j 0.0497 ; z = 0.0545</td>
<td>1000kcmil: 0.0233 + j 0.0414 ; z = 0.0475</td>
</tr>
</tbody>
</table>

Source: IEEE 141 - 1993
Types of Strand Construction

Approximate size comparison:

<table>
<thead>
<tr>
<th></th>
<th>3%</th>
<th>9%</th>
<th>15%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentric</td>
<td><img src="image" alt="Concentric" /></td>
<td><img src="image" alt="Compressed" /></td>
<td><img src="image" alt="Compact" /></td>
</tr>
</tbody>
</table>

Concentric, Compressed, Compact, Solid
Aluminum Cable Construction

Aluminum cable is similar to copper with the exception the conductor will be aluminum. Tape shield will remain copper.
Comparison of Copper and Aluminum Conduit Fill, 600 Volt

<table>
<thead>
<tr>
<th>Cu Size</th>
<th>Amps</th>
<th>Al Size</th>
<th>Amps</th>
<th>EMT Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4</td>
<td>85</td>
<td>#2</td>
<td>90</td>
<td>1 1/4</td>
</tr>
<tr>
<td>#2</td>
<td>115</td>
<td>1/0</td>
<td>120</td>
<td>1 1/2</td>
</tr>
<tr>
<td>1/0</td>
<td>150</td>
<td>3/0</td>
<td>155</td>
<td>2</td>
</tr>
<tr>
<td>2/0</td>
<td>175</td>
<td>4/0</td>
<td>180</td>
<td>2</td>
</tr>
<tr>
<td>3/0</td>
<td>200</td>
<td>250 kcmil</td>
<td>205</td>
<td>2 1/2</td>
</tr>
<tr>
<td>4/0</td>
<td>230</td>
<td>300 kcmil</td>
<td>230</td>
<td>2 1/2</td>
</tr>
<tr>
<td>250 kcmil</td>
<td>255</td>
<td>350 kcmil</td>
<td>250</td>
<td>2 1/2</td>
</tr>
<tr>
<td>350 kcmil</td>
<td>310</td>
<td>500 kcmil</td>
<td>310</td>
<td>3</td>
</tr>
<tr>
<td>400 kcmil</td>
<td>335</td>
<td>600 kcmil</td>
<td>340</td>
<td>3</td>
</tr>
<tr>
<td>500 kcmil</td>
<td>380</td>
<td>750 kcmil</td>
<td>385</td>
<td>4</td>
</tr>
<tr>
<td>600 kcmil</td>
<td>420</td>
<td>900 kcmil</td>
<td>430</td>
<td>4</td>
</tr>
</tbody>
</table>

Conduit Fill - Table C.1; C.1A, 2005 NEC Annex C, 4 wire plus ground
Ampacity – Table 310.16 @75C; 30C ambient.
### Comparison of Copper and Aluminum Conduit Fill, 5kv

<table>
<thead>
<tr>
<th>Cu Size</th>
<th>Cu OD</th>
<th>Amps</th>
<th>Rigid Size</th>
<th>Al Size</th>
<th>Al OD</th>
<th>Amps</th>
<th>Rigid Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>#2</td>
<td>0.76</td>
<td>130</td>
<td>3</td>
<td>1/0</td>
<td>0.84</td>
<td>140</td>
<td>3</td>
</tr>
<tr>
<td>1/0</td>
<td>0.87</td>
<td>180</td>
<td>3</td>
<td>4/0</td>
<td>0.98</td>
<td>215</td>
<td>3</td>
</tr>
<tr>
<td>2/0</td>
<td>0.91</td>
<td>205</td>
<td>3</td>
<td>4/0</td>
<td>0.98</td>
<td>215</td>
<td>3</td>
</tr>
<tr>
<td>4/0</td>
<td>1.02</td>
<td>280</td>
<td>3</td>
<td>350kcmil</td>
<td>1.13</td>
<td>305</td>
<td>3</td>
</tr>
<tr>
<td>250kcmil</td>
<td>1.07</td>
<td>315</td>
<td>3</td>
<td>500kcmil</td>
<td>1.26</td>
<td>380</td>
<td>4</td>
</tr>
<tr>
<td>350kcmil</td>
<td>1.18</td>
<td>385</td>
<td>4</td>
<td>600kcmil</td>
<td>1.35</td>
<td>385</td>
<td>4</td>
</tr>
<tr>
<td>500kcmil</td>
<td>1.30</td>
<td>475</td>
<td>4</td>
<td>750kcmil</td>
<td>1.45</td>
<td>490</td>
<td>4</td>
</tr>
<tr>
<td>750kcmil</td>
<td>1.49</td>
<td>600</td>
<td>5</td>
<td>1000kcmil</td>
<td>1.60</td>
<td>580</td>
<td>5</td>
</tr>
</tbody>
</table>

Conduit fill is based on 3 phase with equipment ground size per NEC. All Conduit Sizes are Rigid Metal. Ampacity based on Table 310.73 and 310.74 conduit in air. 1000kcmil Al DOES NOT meet the ampacity of 750kcmil Cu.
## Comparison of Copper and Aluminum Conduit Fill, 15kv

<table>
<thead>
<tr>
<th>Cu Size</th>
<th>Cu OD</th>
<th>Amps</th>
<th>Rigid Size</th>
<th>Al Size</th>
<th>Al OD</th>
<th>Amps</th>
<th>Rigid Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>#2</td>
<td>.99</td>
<td>150</td>
<td>3</td>
<td>1/0</td>
<td>1.04</td>
<td>150</td>
<td>3</td>
</tr>
<tr>
<td>1/0</td>
<td>1.08</td>
<td>195</td>
<td>3</td>
<td>4/0</td>
<td>1.19</td>
<td>230</td>
<td>3</td>
</tr>
<tr>
<td>2/0</td>
<td>1.12</td>
<td>225</td>
<td>3</td>
<td>4/0</td>
<td>1.19</td>
<td>230</td>
<td>3</td>
</tr>
<tr>
<td>4/0</td>
<td>1.22</td>
<td>295</td>
<td>4</td>
<td>350kcmil</td>
<td>1.35</td>
<td>310</td>
<td>4</td>
</tr>
<tr>
<td>250kcmil</td>
<td>1.28</td>
<td>330</td>
<td>4</td>
<td>500kcmil</td>
<td>1.47</td>
<td>385</td>
<td>4</td>
</tr>
<tr>
<td>350kcmil</td>
<td>1.38</td>
<td>395</td>
<td>4</td>
<td>600kcmil</td>
<td>1.56</td>
<td>395</td>
<td>5</td>
</tr>
<tr>
<td>500kcmil</td>
<td>1.50</td>
<td>480</td>
<td>5</td>
<td>750kcmil</td>
<td>1.66</td>
<td>485</td>
<td>5</td>
</tr>
<tr>
<td>750kcmil</td>
<td>1.76</td>
<td>585</td>
<td>5</td>
<td>1000kcmil</td>
<td>1.89</td>
<td>565</td>
<td>6</td>
</tr>
</tbody>
</table>

Conduit fill is based on 3 phase with equipment ground size per NEC. All Conduit Sizes are Metal Rigid. Ampacity based on Table 310.73 and 310.74 conduit in air. 1000kcmil Al DOES NOT meet the ampacity of 750kcmil Cu.
Flexibility

- Alloying and annealing processes make AA-8176 as flexible for equivalent Ampacity copper conductors.

- NEC 312.6(B) requires the same bending space in enclosures at terminals for equal ampacity copper and AA-8176 conductors.
AA 8176 aluminum has higher tensile strength to weight ratio than equivalent copper ampacity.

Max allowable tensile for copper is 0.008 lbs/cmil and for AA 8176 is 0.006 lbs/cmil.

Minimum bending radius for both aluminum and copper shielded cable is 12 times the OD and 8 times the OD for non-shielded cable.
## Pulling Tensions (Cont.)

<table>
<thead>
<tr>
<th>Conductor Size</th>
<th>Max Allowable Tension lbs</th>
<th>Weight lbs/1,000’</th>
<th>Max Pull Length (ft) 0.3 coef fric</th>
</tr>
</thead>
<tbody>
<tr>
<td>500kcmil Cu</td>
<td>4000 lbs</td>
<td>1544</td>
<td>8,639</td>
</tr>
<tr>
<td>750kcmil Al</td>
<td>4500 lbs</td>
<td>704</td>
<td>21,307</td>
</tr>
</tbody>
</table>
New Products

New No Lead EPR Polymer
New “Sim pull” Jacket for MV cable
Instrumentation Cable (600V)
Ingredients of our Current EPR Insulation ERI-3728-5

- Base Filler (EPDM)
- Silane
- Paraffin Wax
- Red Lead
- Clay Filler
- Zinc oxide
- Polyethylene
- Peroxide

Southwire buys its EPR from Electric Cable Compounds, Inc located in Seymour Connecticut. The present EPR compound we use is Superohm ERI-3728-5.
Ingredients of our New EPR Insulation ERI-3748

- Base Filler (EPDM)
- Silane
- Paraffin Wax
- Red Lead
- Clay Filler
- Zinc oxide
- Polyethylene
- Peroxide

Eco Friendly Cable EFC – Dovetails with green environments, Hospitals, schools, institutional.
Features of our New EPR Insulation ERI-3748

- No Lead
- Creamy in color – Lead is what gives EPR its reddish color
- UL listed
- AEIC qualified
- Has wet rating just like leaded EPR
- EXACT SAME Characteristics
Questions?

We want to earn your business !!!

[Image of a building with the Southwire logo]