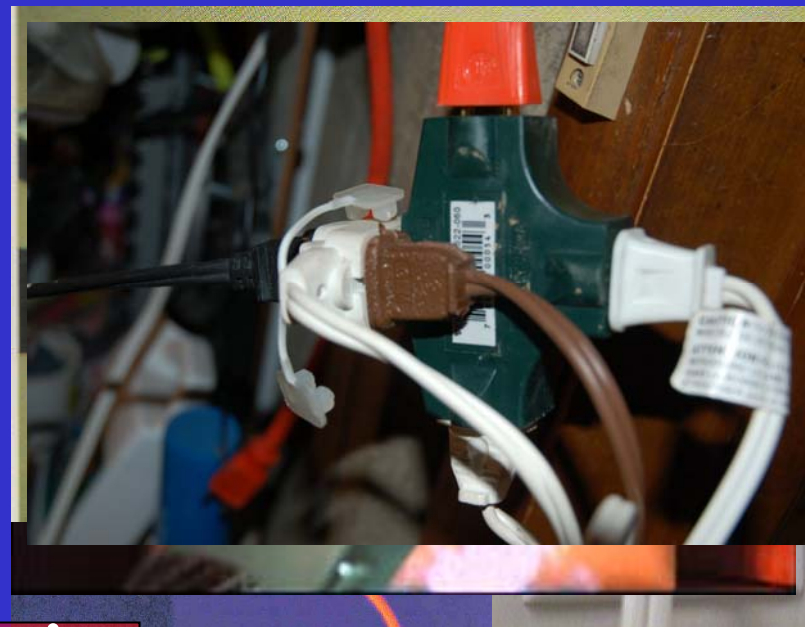


Identifying Causes for Certain Types of Electrically Initiated Fires in Residential Circuits

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Some Sources of Potential Electrical Fire Sources

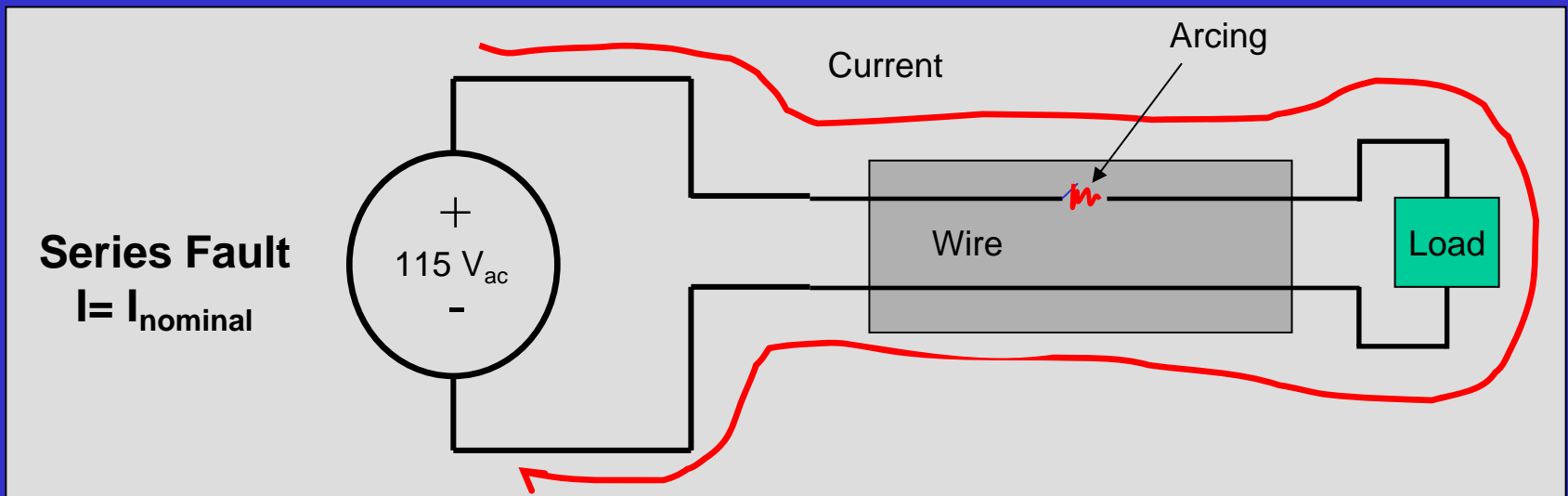
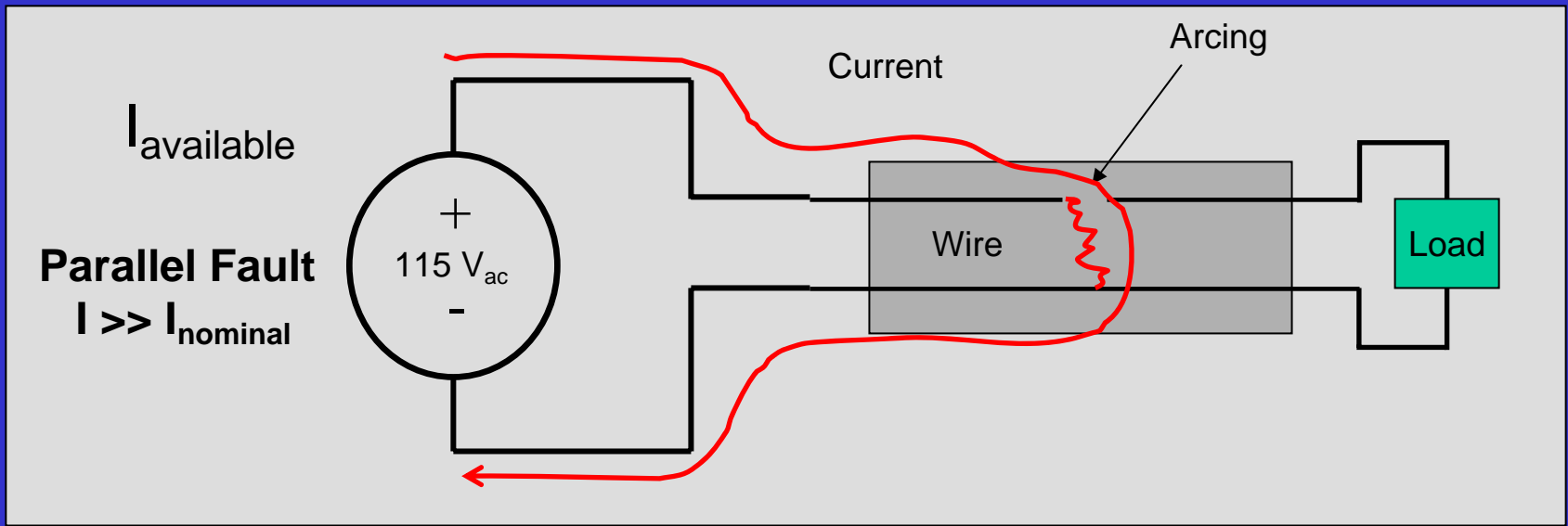
- overloaded wires
- series arcing faults
- parallel arcing faults
- last strand
- glowing connection
- loose plug/outlet connection
- loose wire nut
- staple in NM-B
- insulated overloaded extension cord



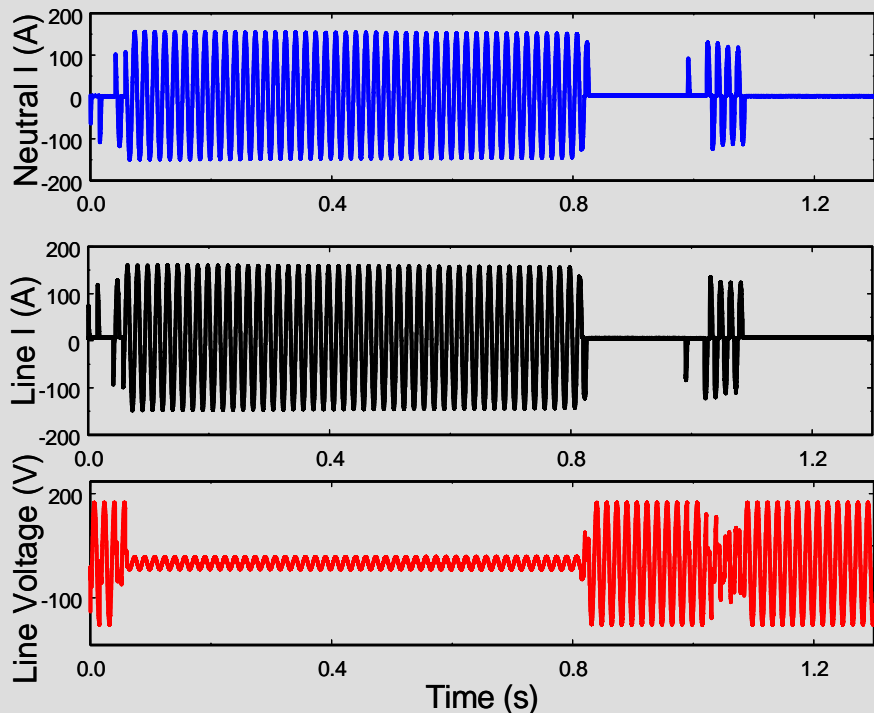
Outline

- Parallel and Series Arcing
- Circuit breaker response
- Extension cord abuse causing thermal overheating
- NM-B thermal overheating
- Glowing connections and PVC decomposition
- Series Arcing – char and glow initiated
- Accelerated thermal aging of wire insulation
- Conclusions

Parallel and Series Circuits

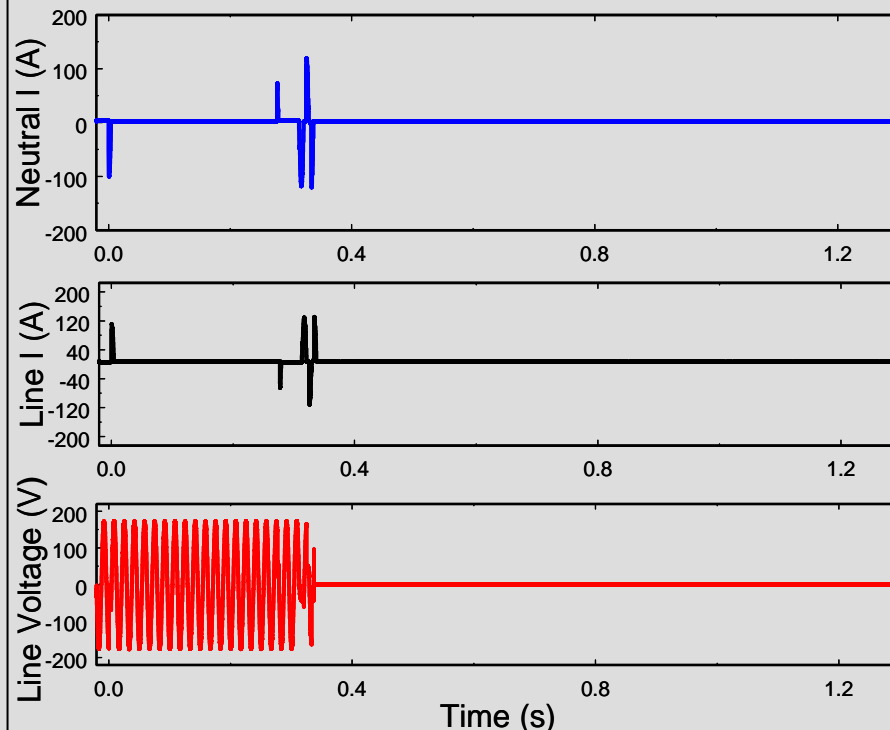


Breaker Response to Low Available Parallel Arcing Fault Currents



Thermal-magnetic Breaker

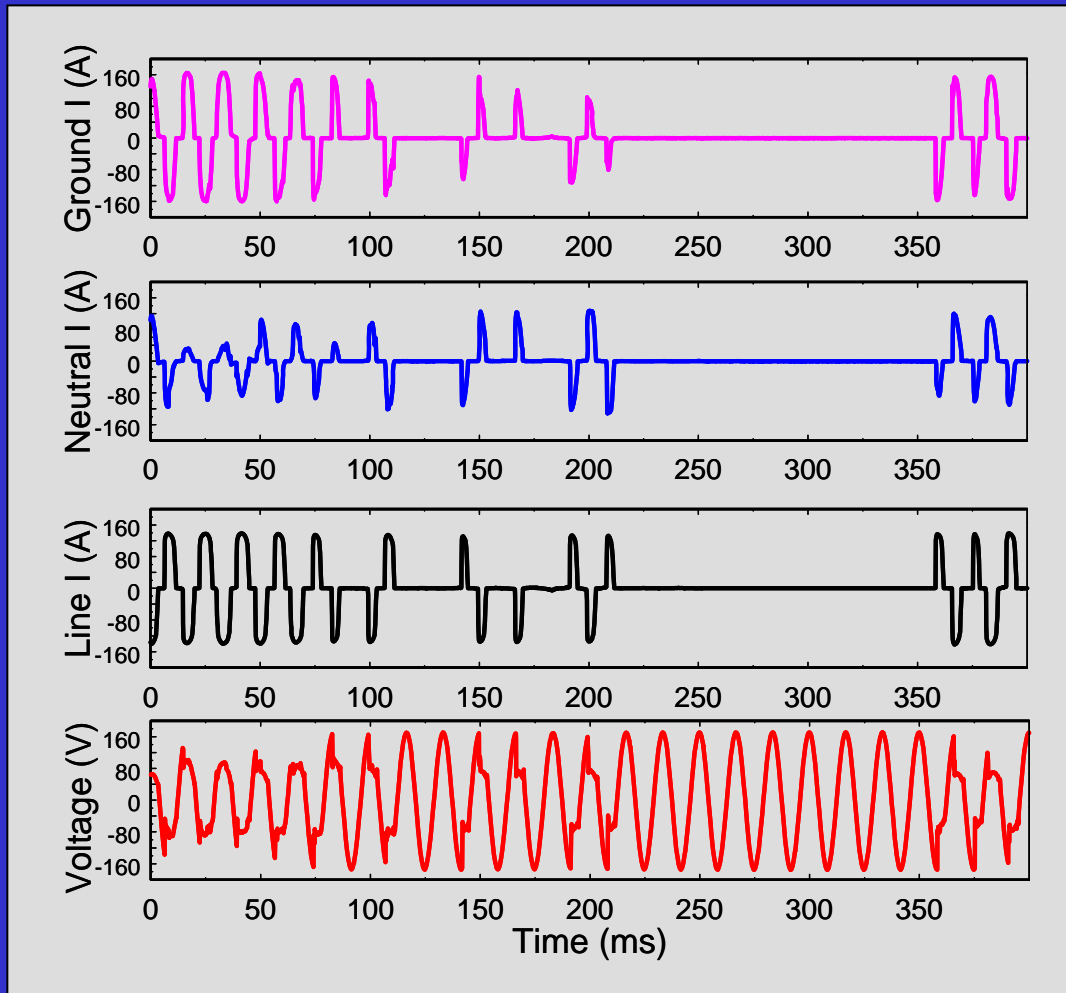
125 A_{rms} available



AFCI Breaker

125 A_{rms} available

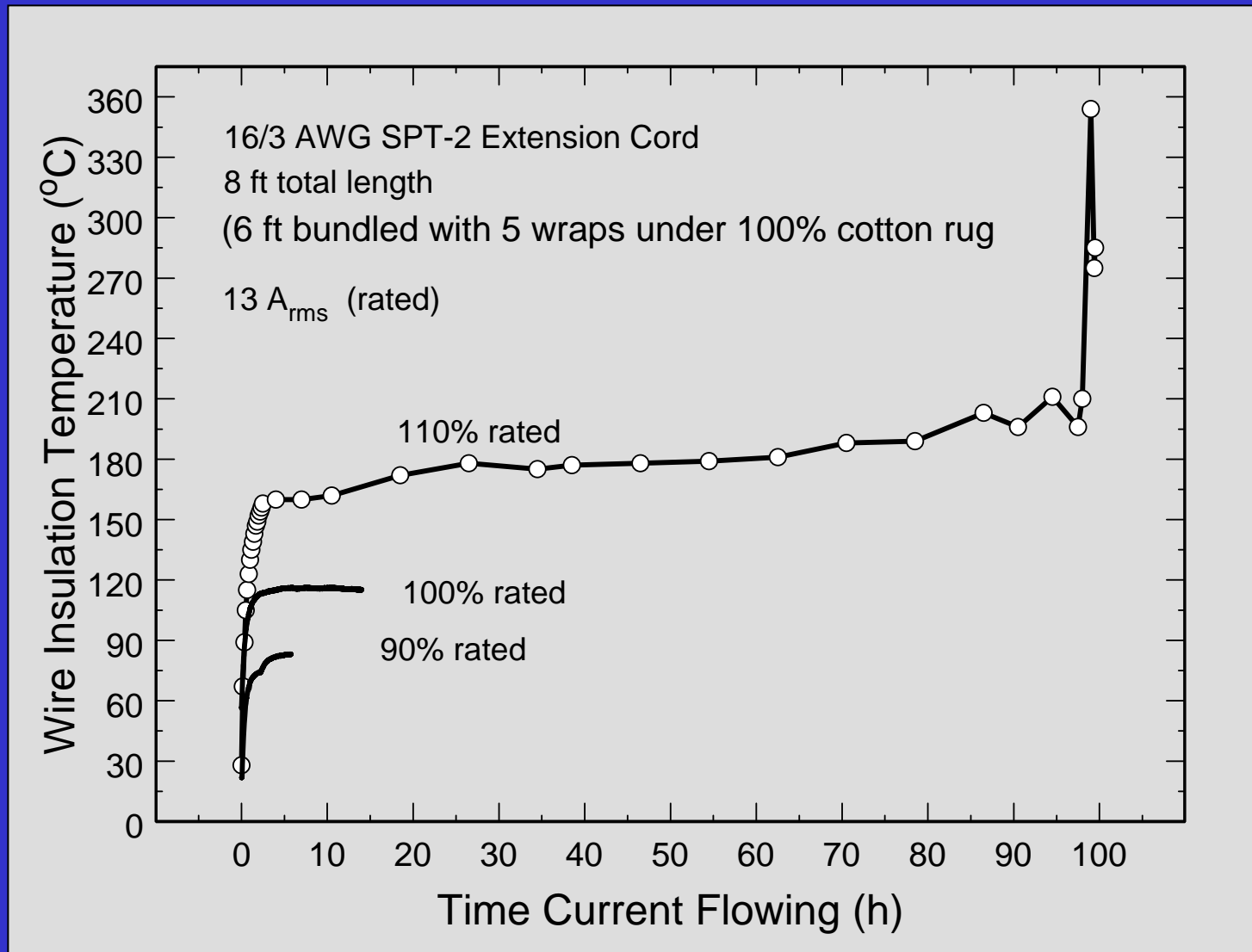
Extension Cord Under Rug – Conductor Self-Heating



125 A_{rms} available



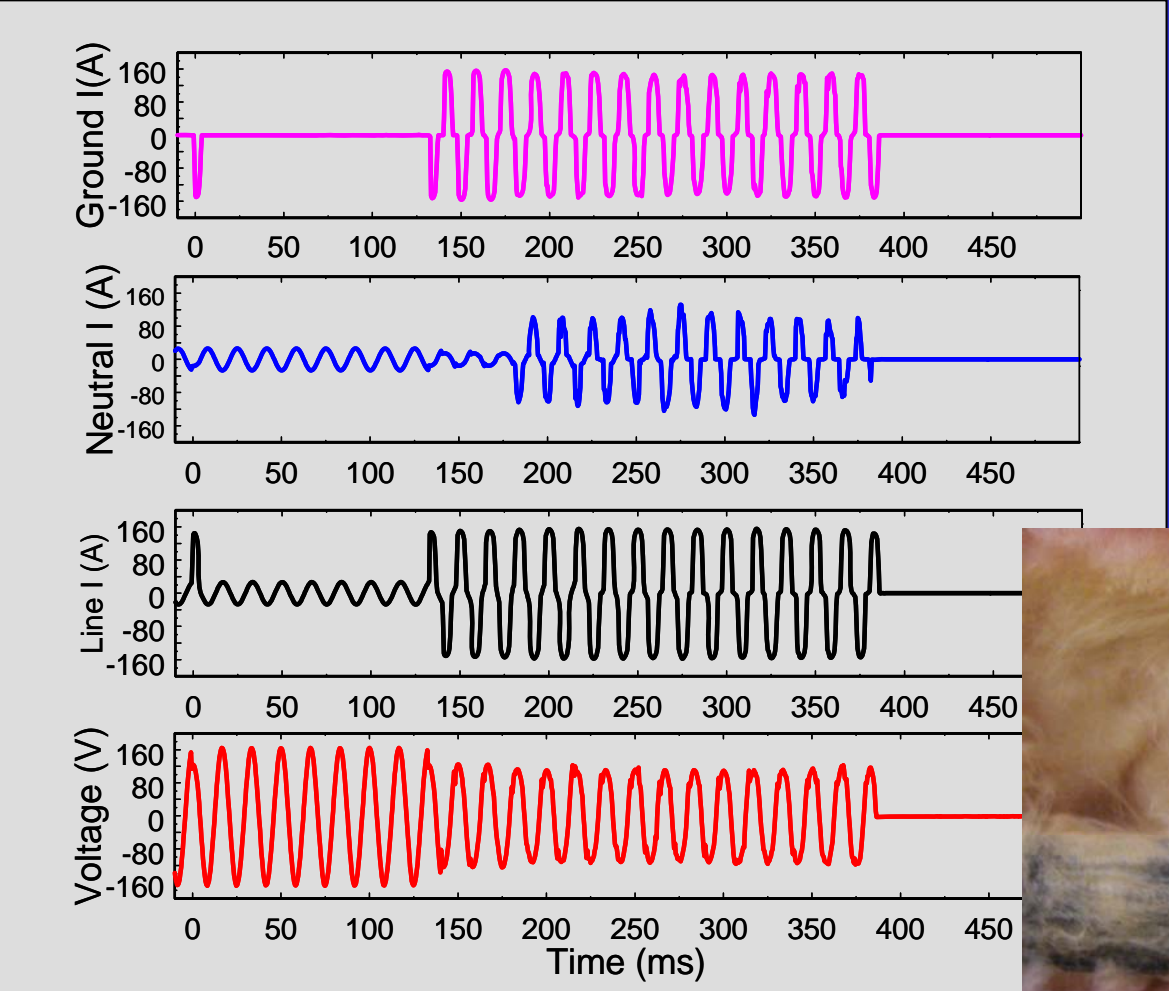
Extension Cord Under Rug – Temperature Results



Overheating Abuse of Extension Cord Under Rug – Conductor Self-Heating

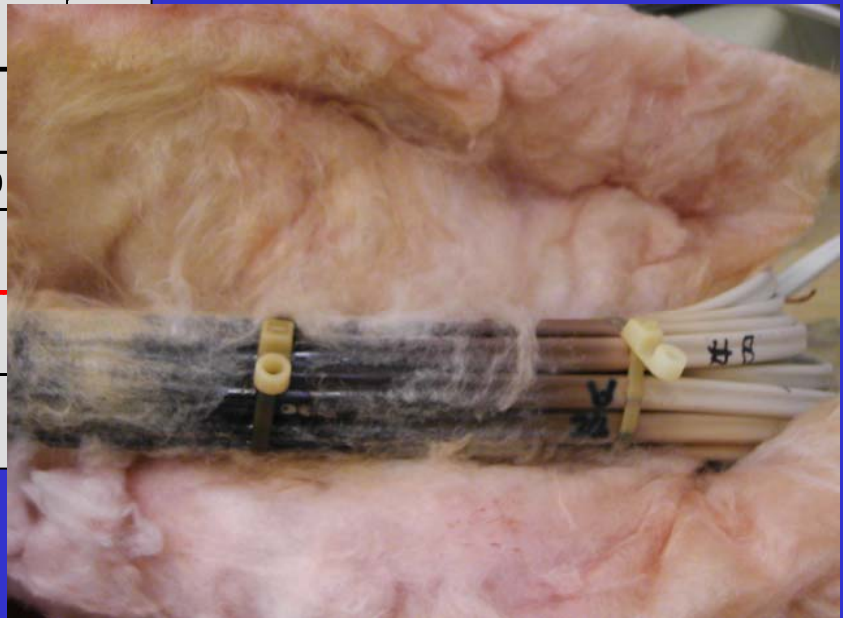


Overheating Abuse of NM-B Conductor Self-Heating

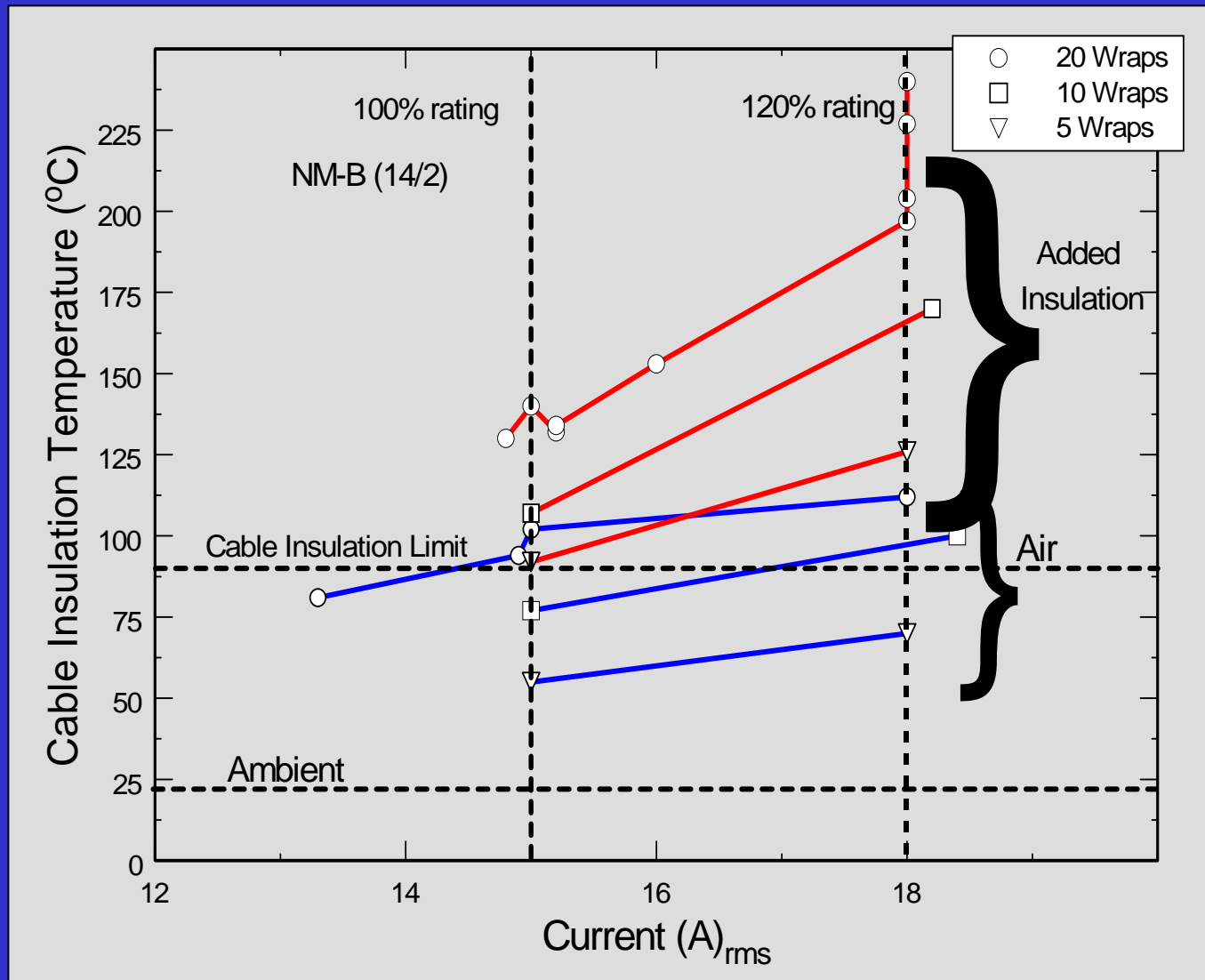


125 A_{rms} available

18 A_{rms} steady-state

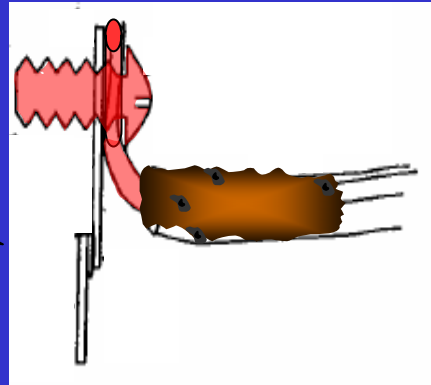
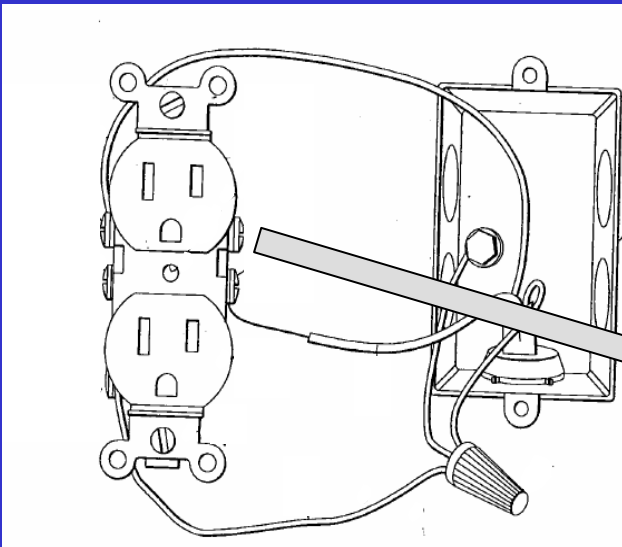


NM-B Insulator Temperature Results



Outlet Example of Glowing Contact Causing Overheating

Glowing Contact Loose Connection



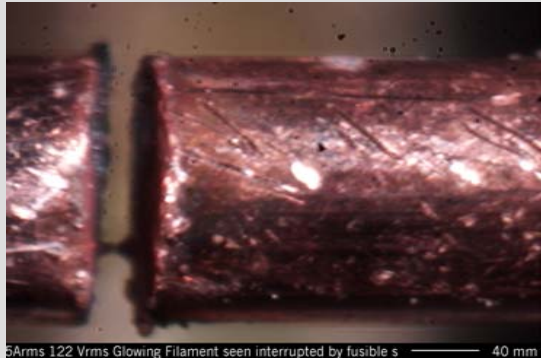
Insulation melts/burns

Glow

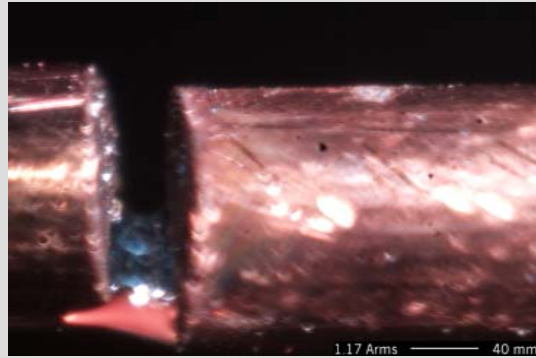


Connection overheats

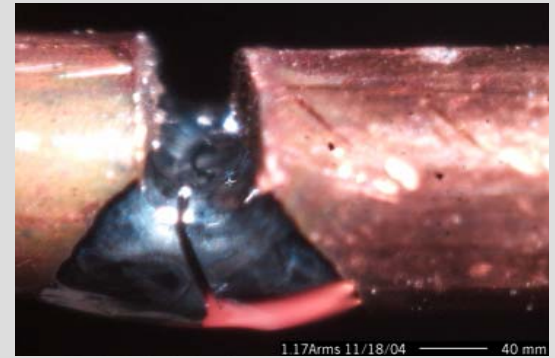
Glowing Can Form at Virtually Any Arcing Connection



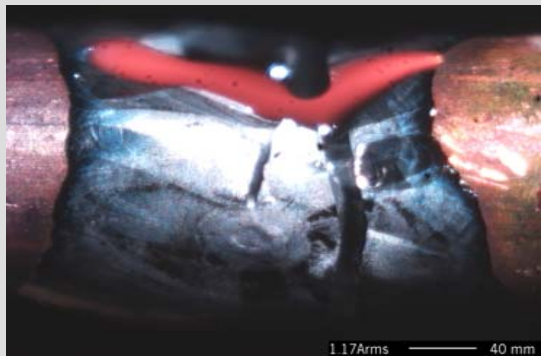
a). Initial Filament $t= 0$ min



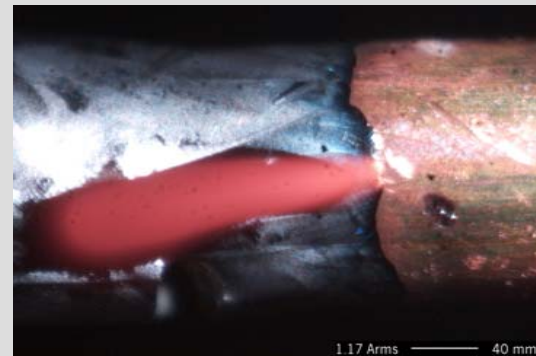
b). Oxide Growth $t= 2$ min



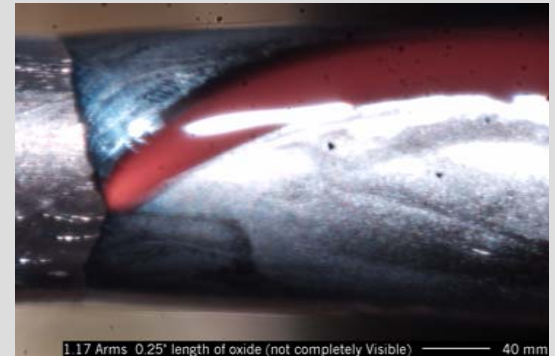
c). $t= 8$ min



d). $t= 28$ min



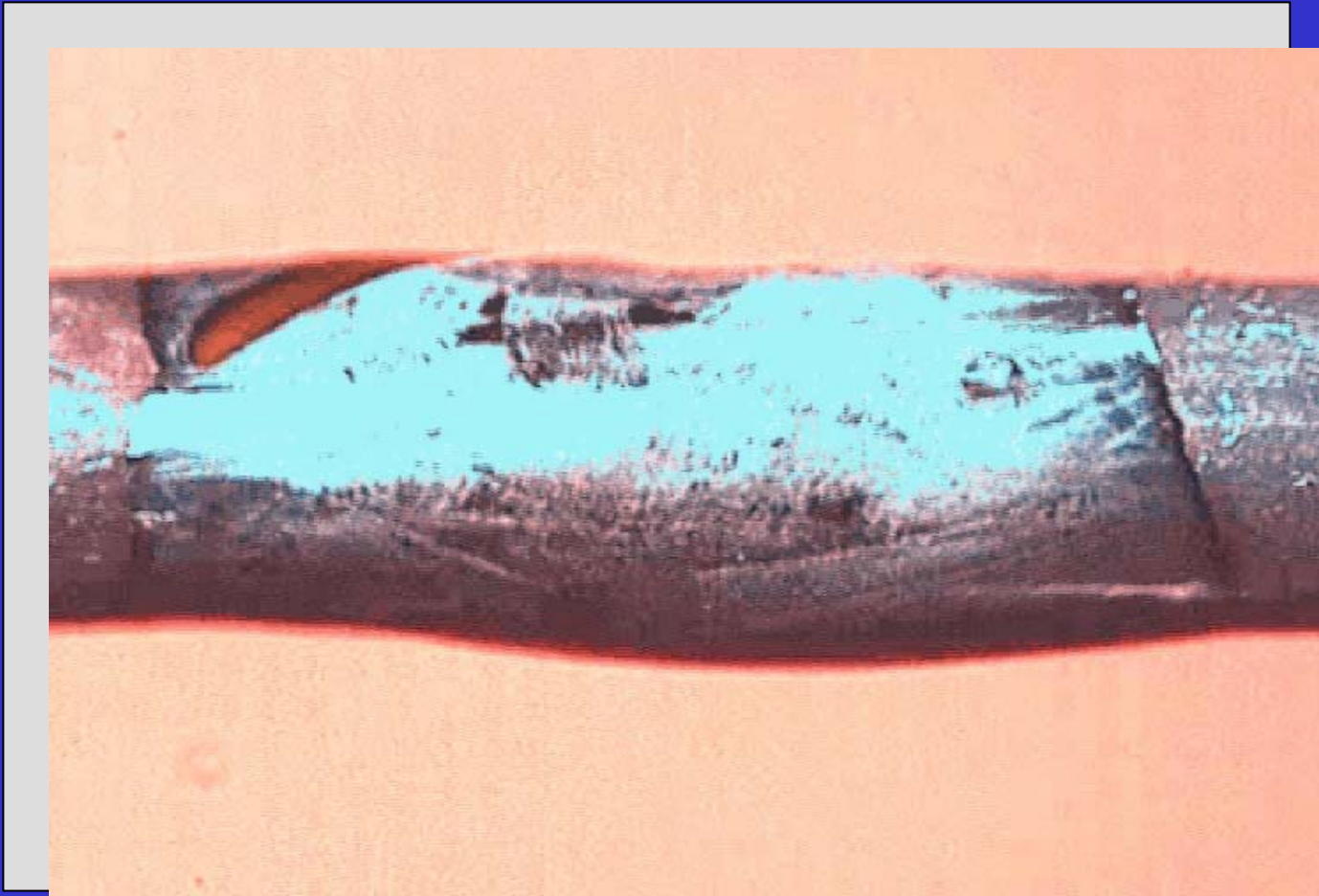
e). $t= 31$ min



f). $t= 64$ min

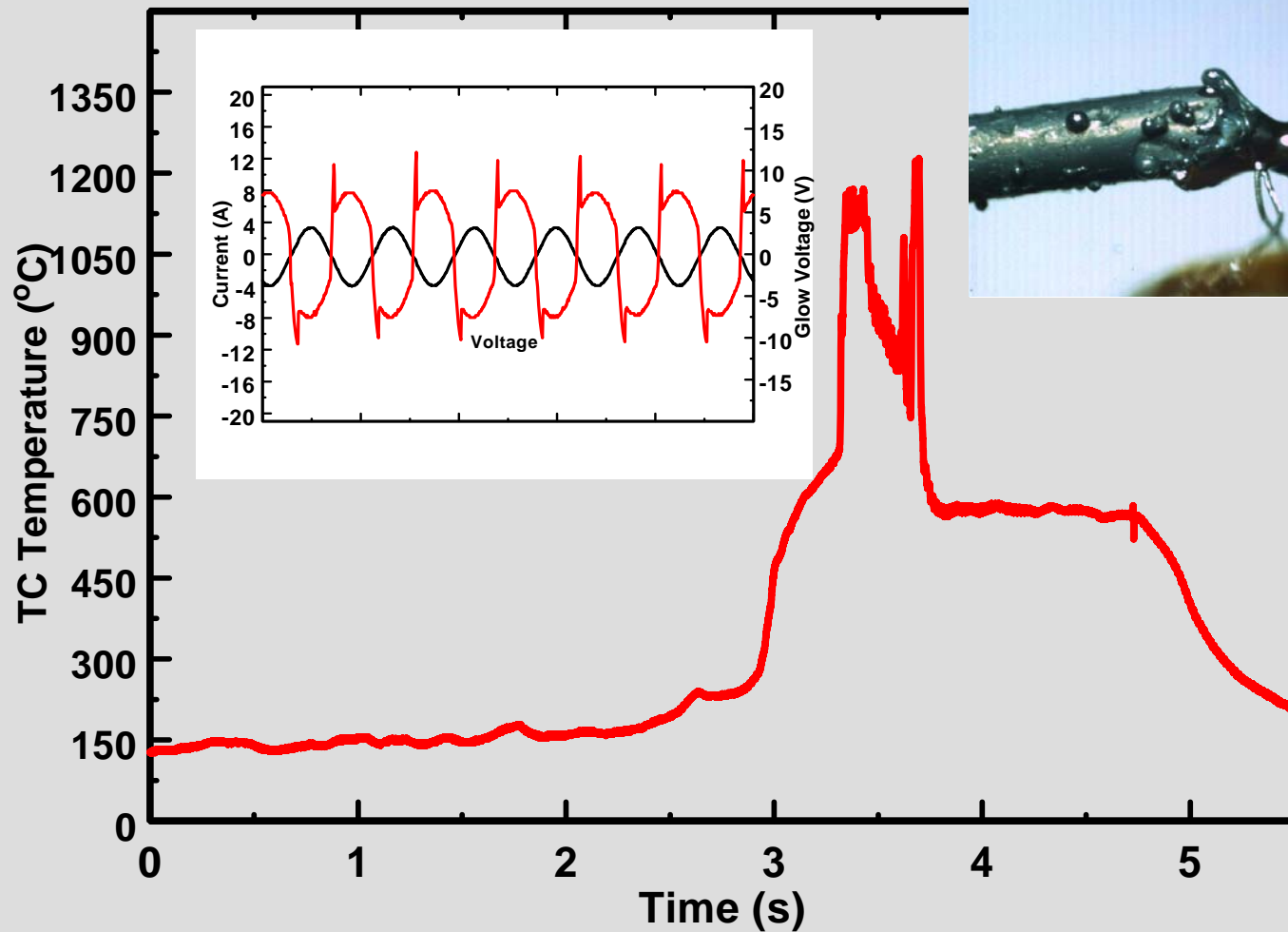
Glowing Contact ($1.2 A_{rms}$ Copper Wire)

Glow Persists and Lengthens Especially at Currents $< 5 A_{rms}$

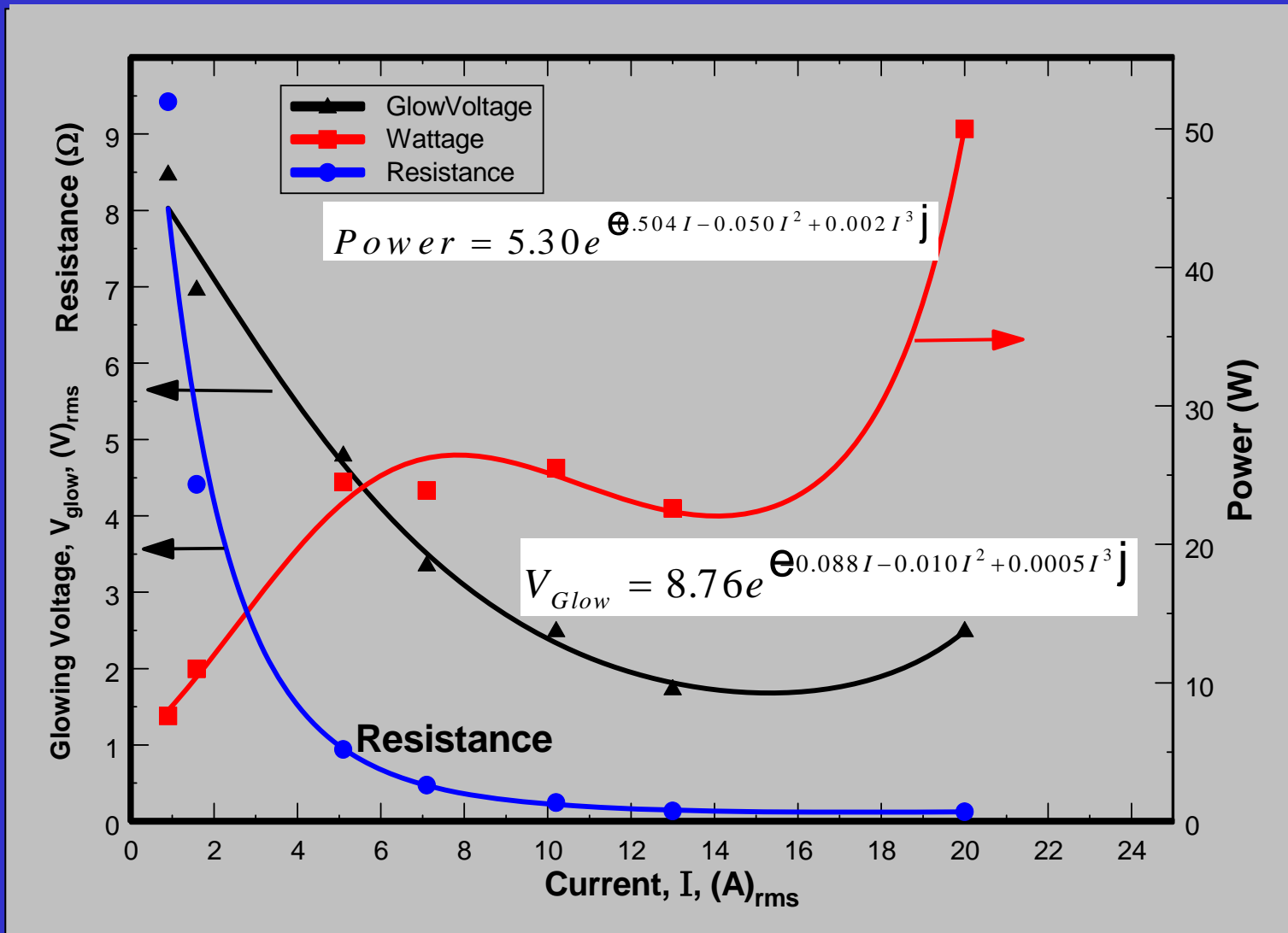


Glowing Contact at $1.2 A_{rms}$ Copper Wires

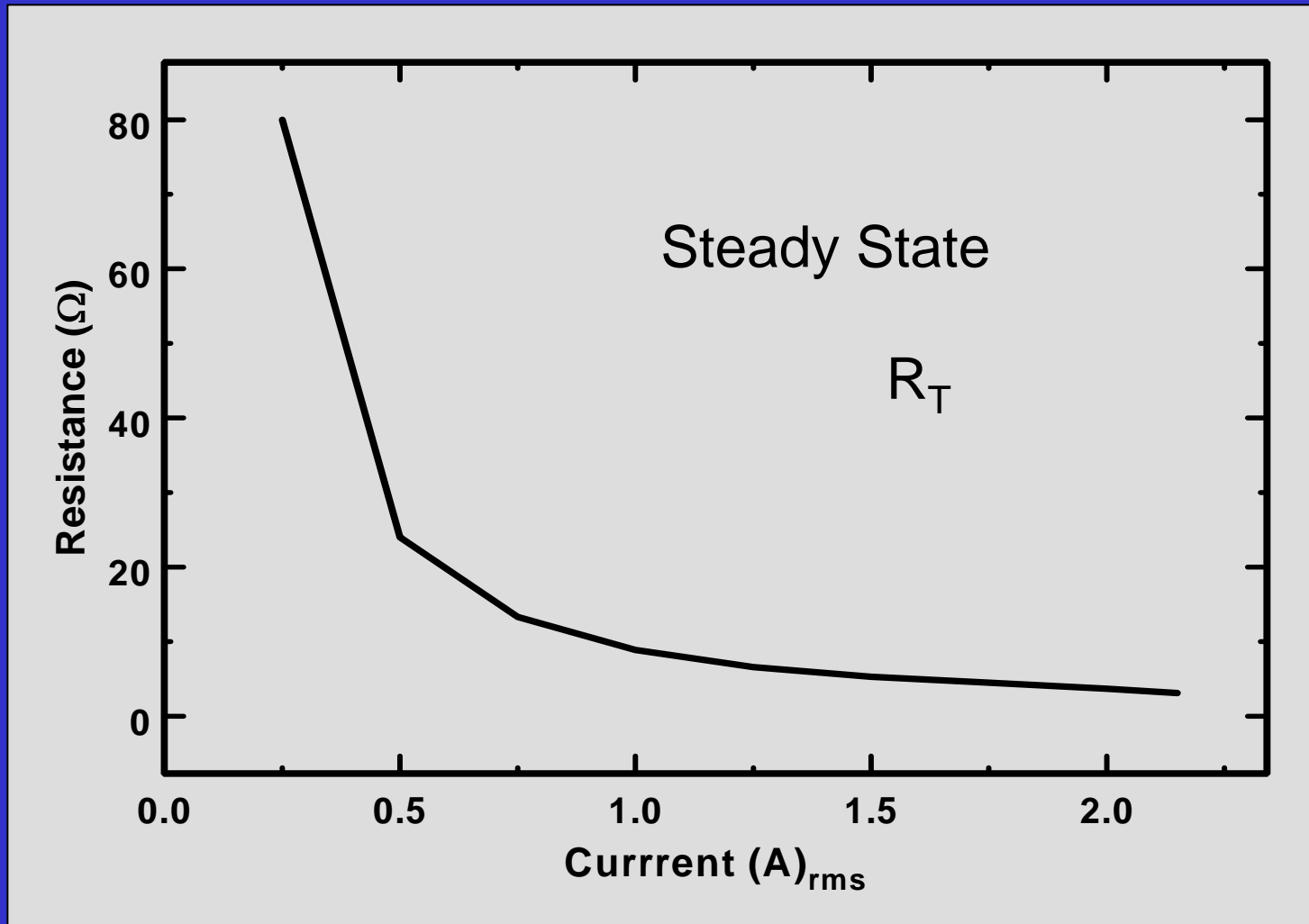
Glowing Filament Temperature



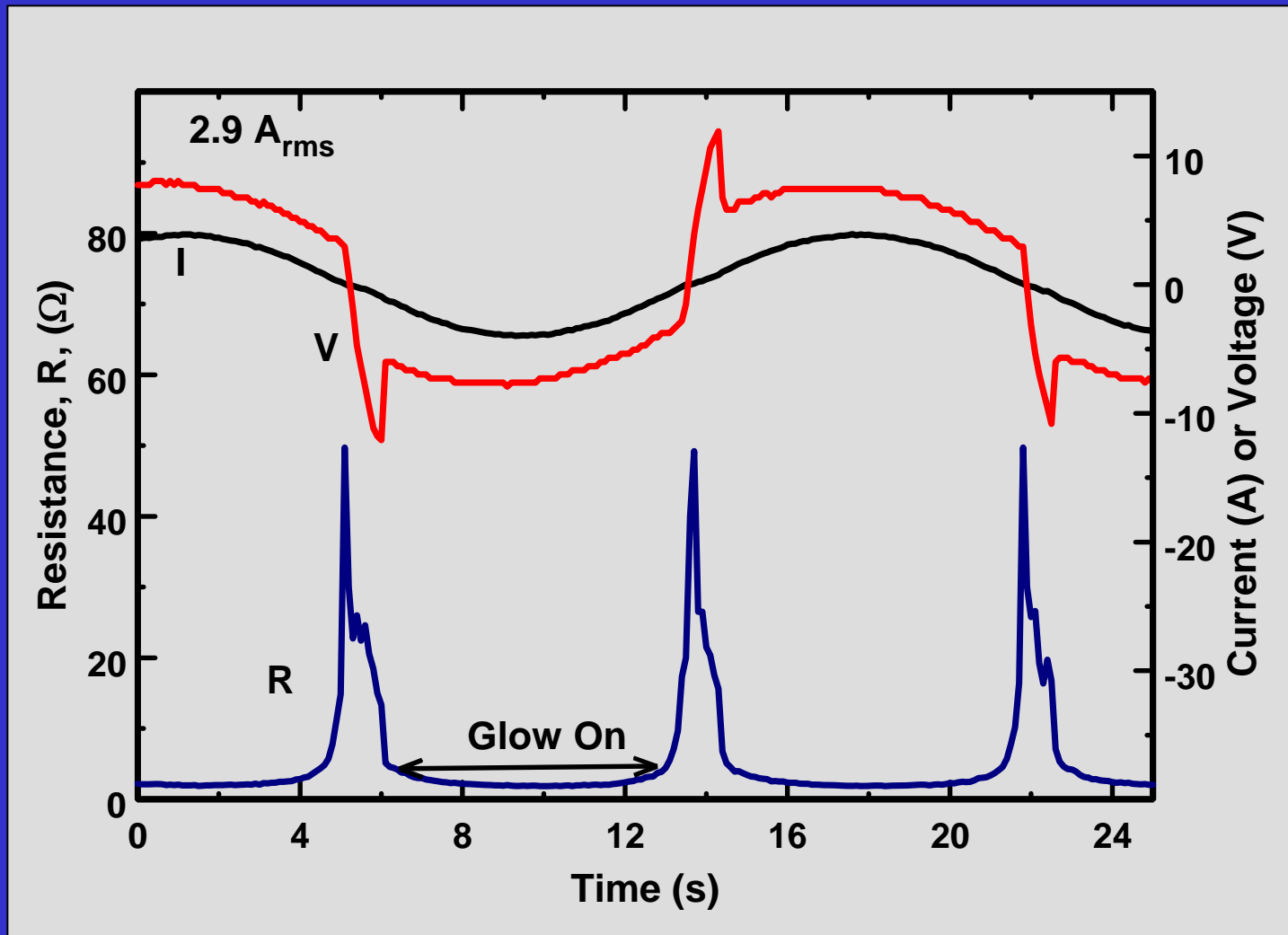
Wattage of Glowing Contact up to 20 A_{rms} (Cu – Cu)



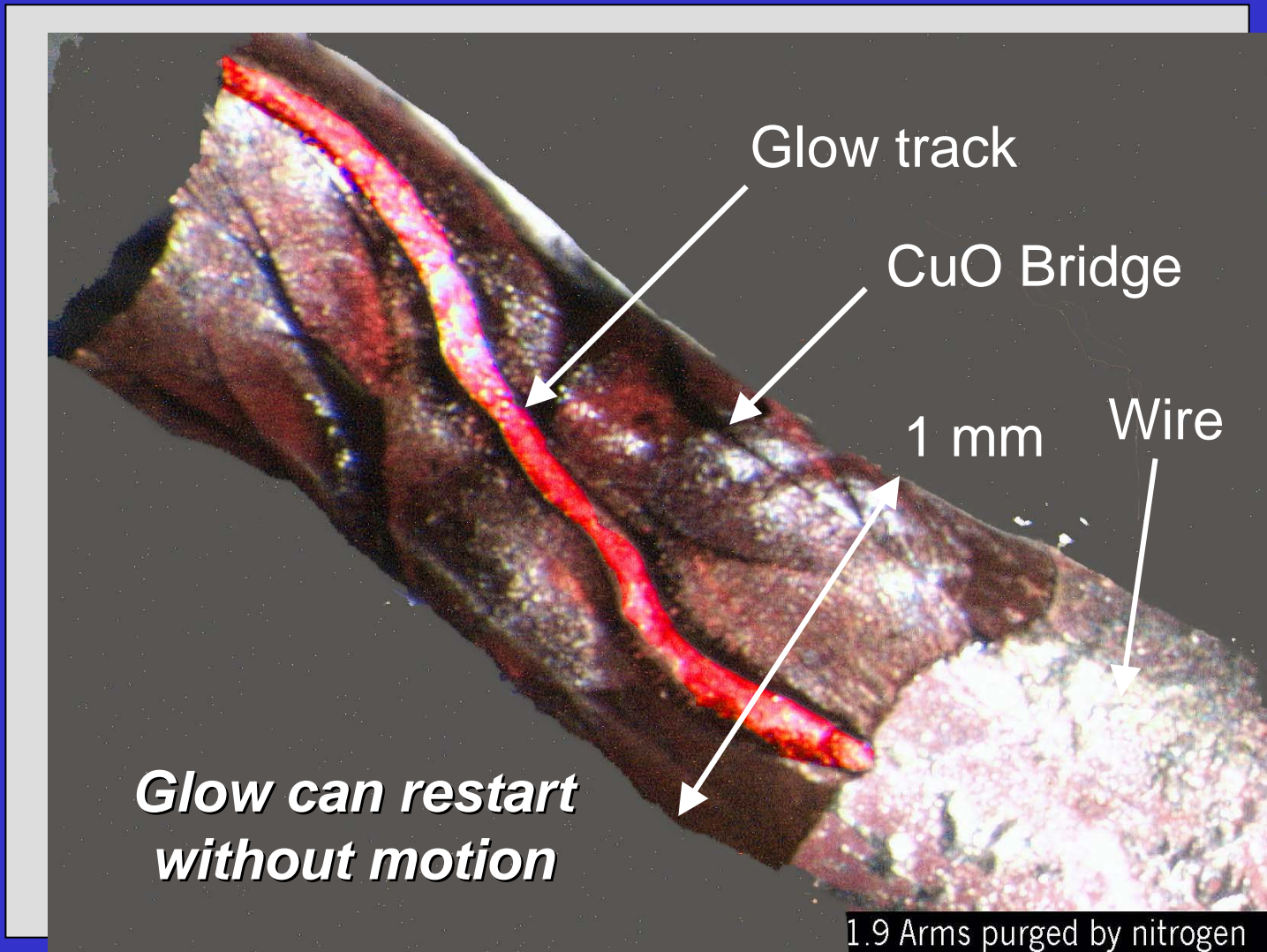
Low Current Glowing Contact Resistance



Glowing Contact Dynamic Resistance

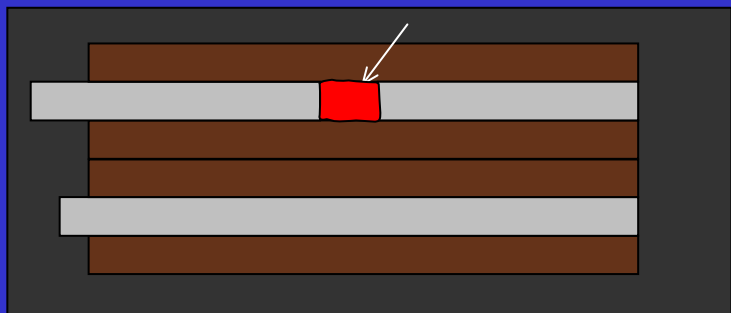


Unusual Remaining Glow Track

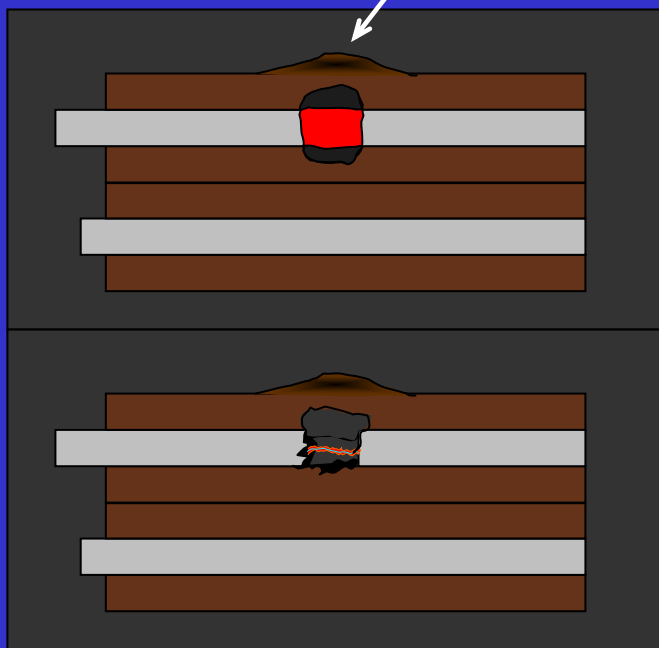


Series Arcing Can Lead to Glowing or Char Formation

Make/break action under load leads to oxide formation and Char if near insulation



PVC Insulation Decomposition



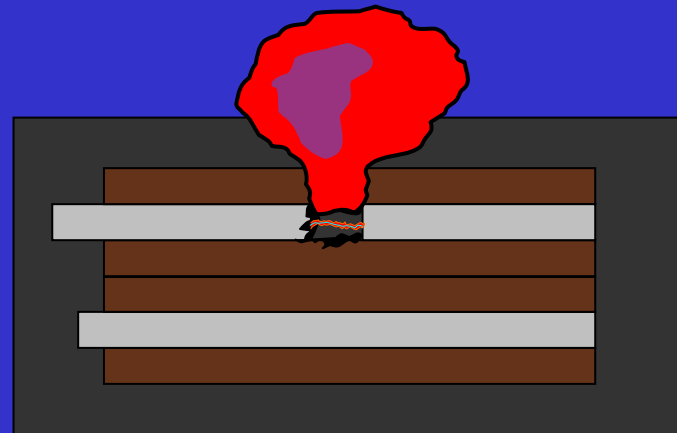
Glowing Contact

Arcing Over Char



2 wire SPT-2 cord

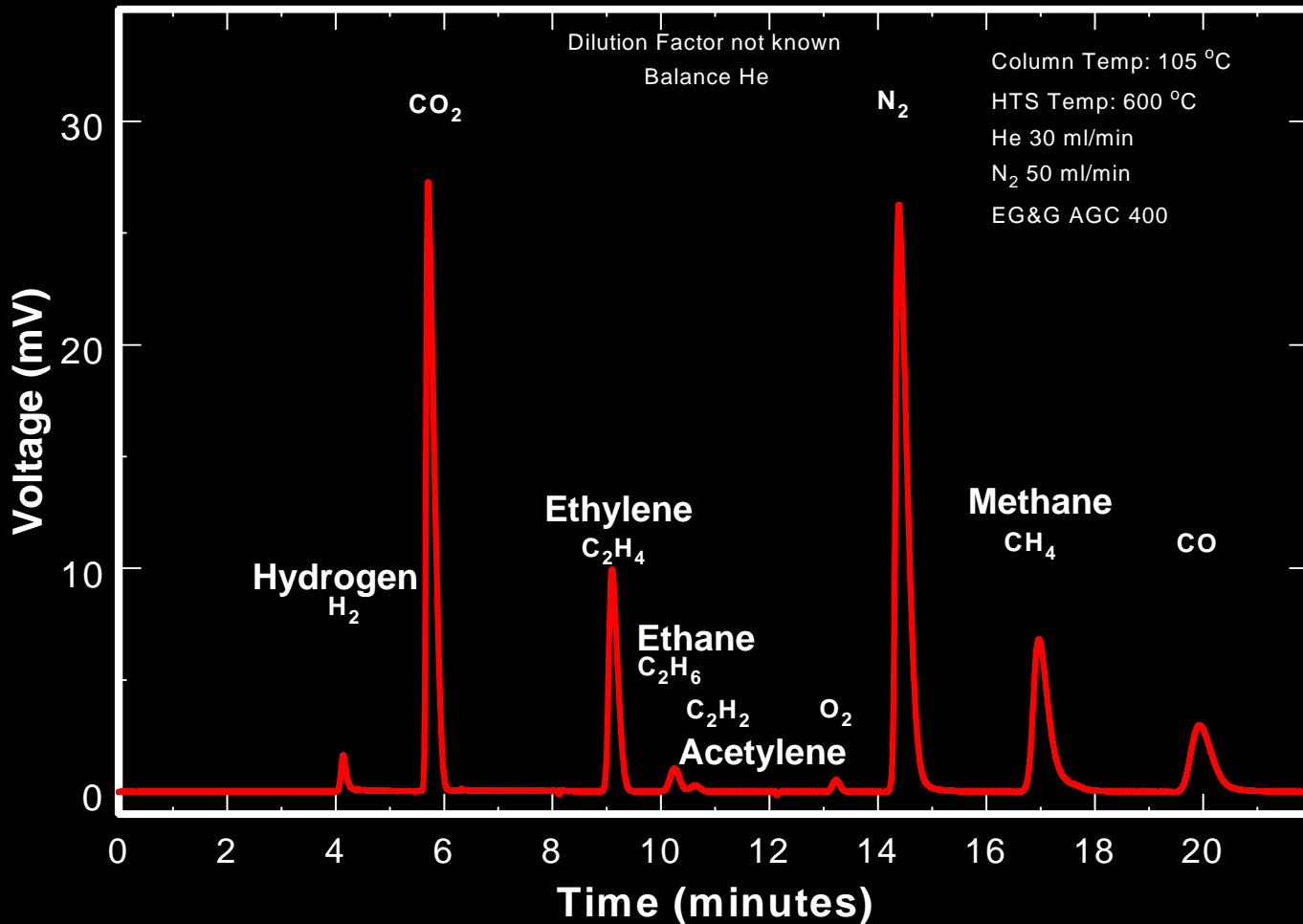
Arcing ignites gases



Ignitable Gases from Pyrolyzed PVC Insulation

SPT03white Oct. 17, 2002
J.J. Shea

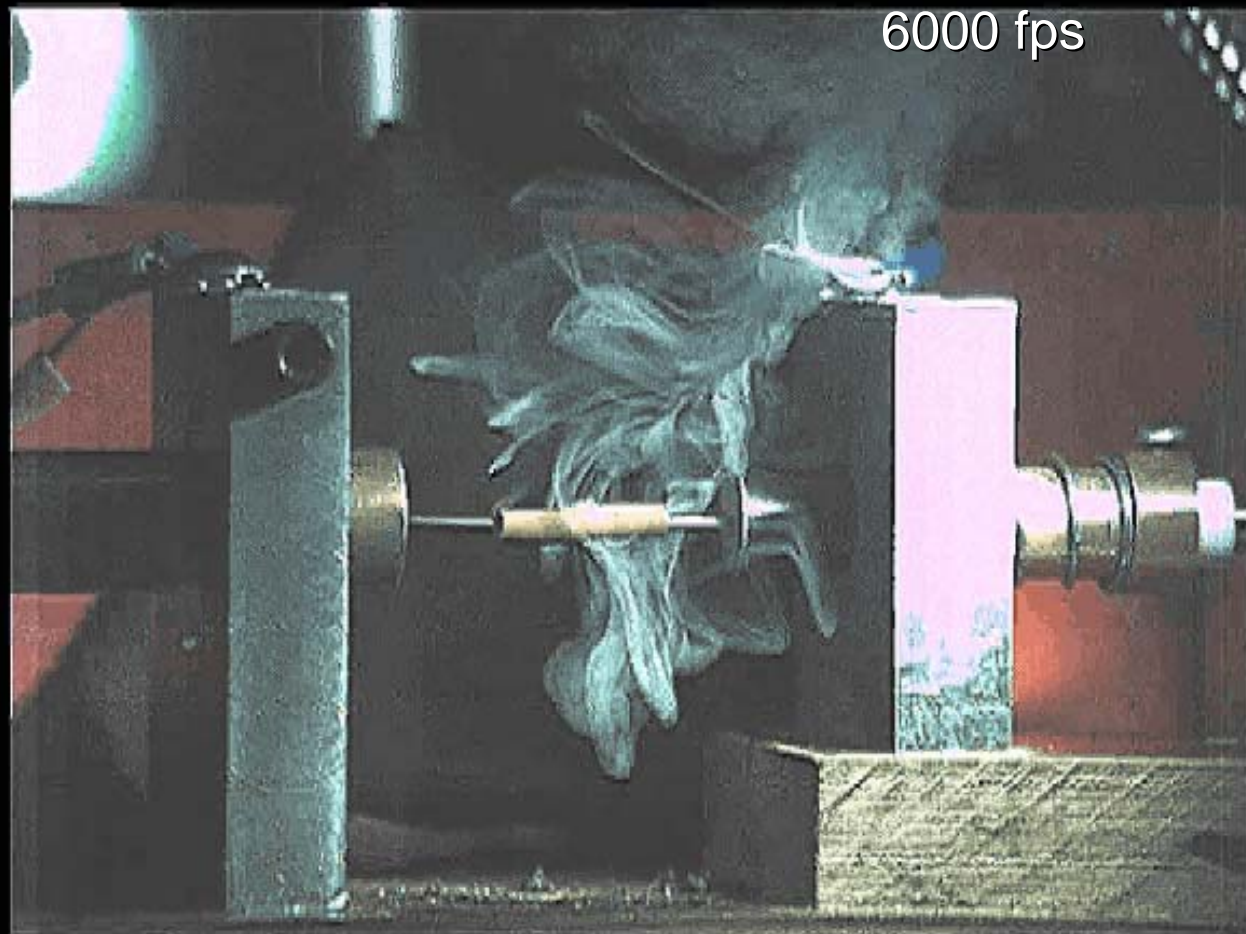
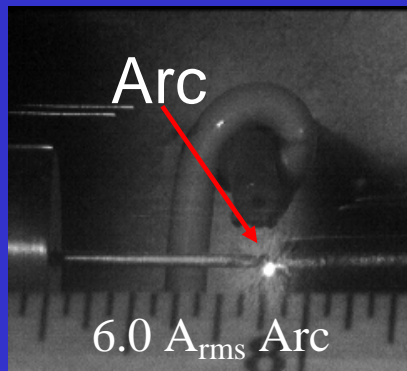
Gas Chromatograph of SPT-2 PVC Insulation Pyrolyzed in Air



High-Speed Video of Series Arc at 3 A_{rms}

Series Arc Energy
2 J/cycle at 6 A

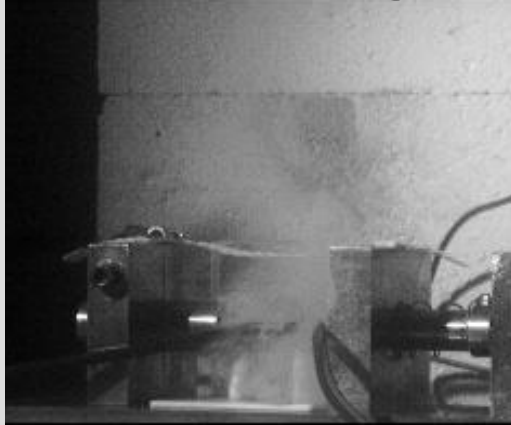
Chemical Energy
360 to 440 J
Heat of reaction from
gas (6 cm diameter)



**Overheated PVC insulation can produce flammable
gasses that can start fires**

Series Arcing Initiated by Glowing Contact at 5 A_{rms} (Cu – Cu)

Overheating



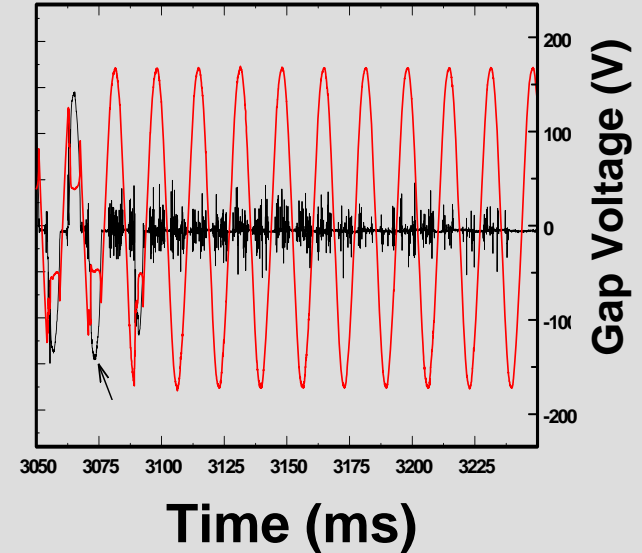
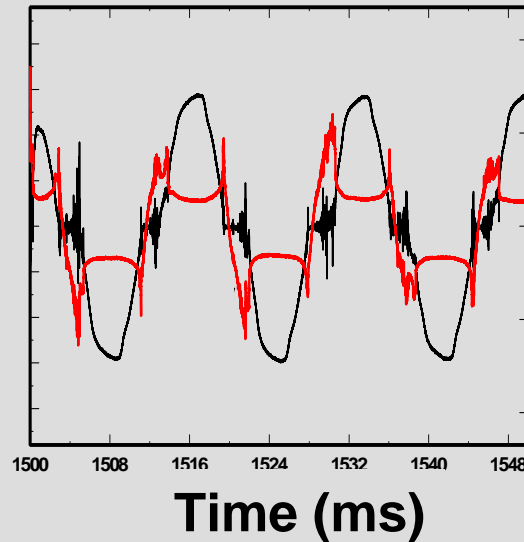
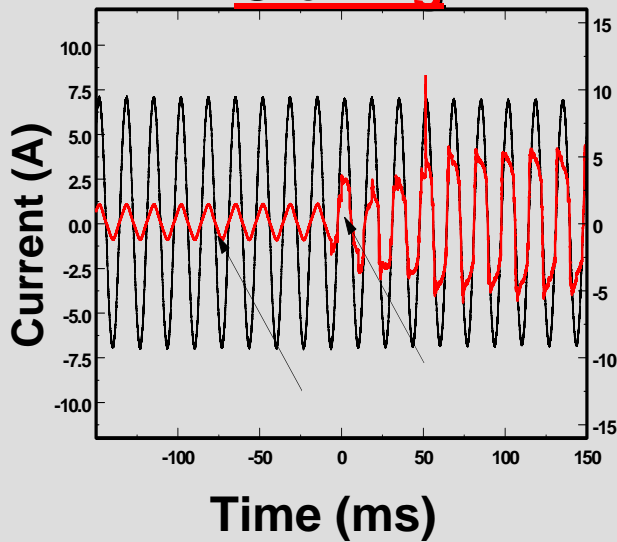
Gas Ignition



Burnout

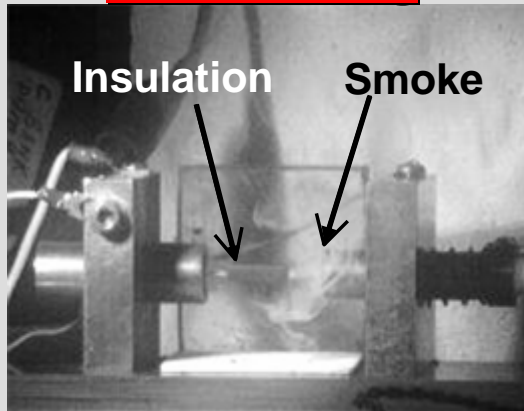


Glowing

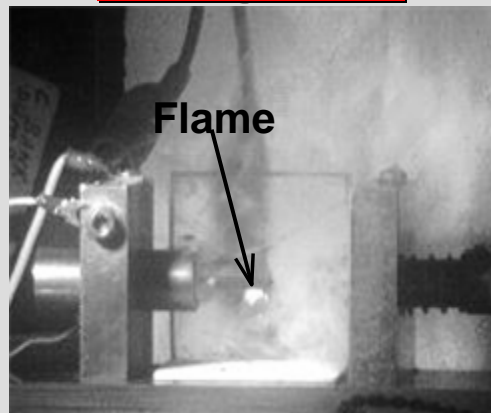


Series Arcing by Over-Surface Char at 1.67 A_{rms} (Cu – Cu)

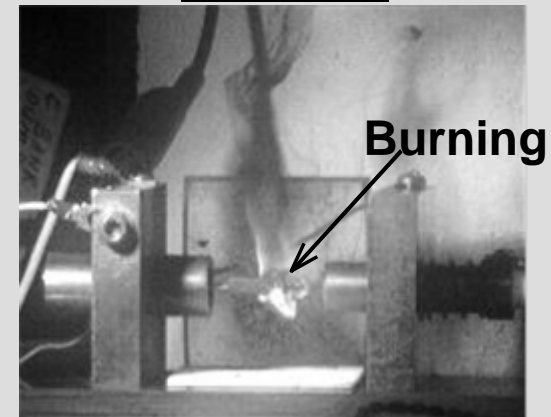
Overheating



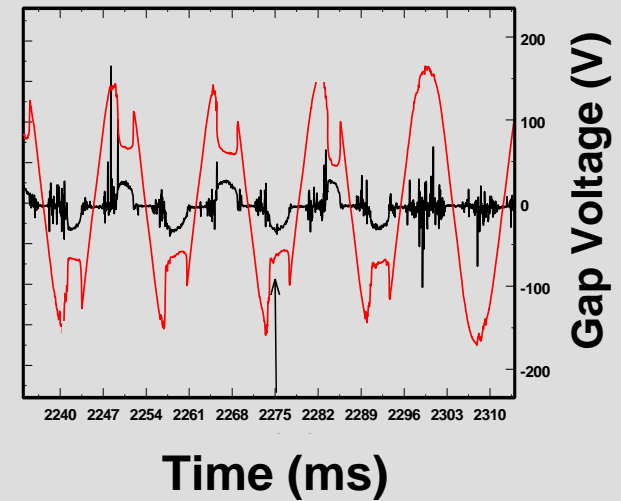
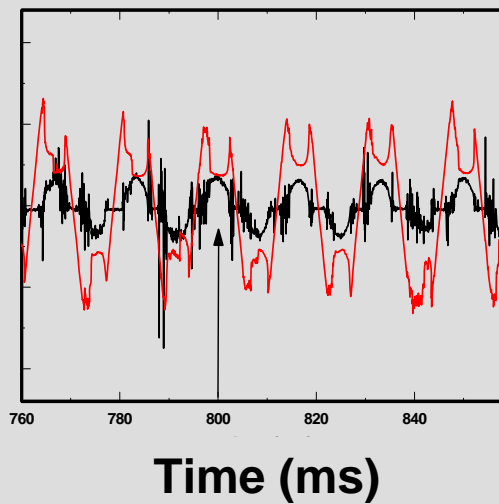
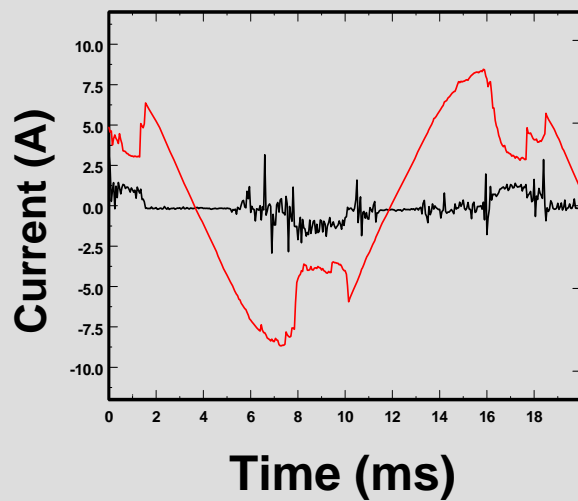
Gas Ignition



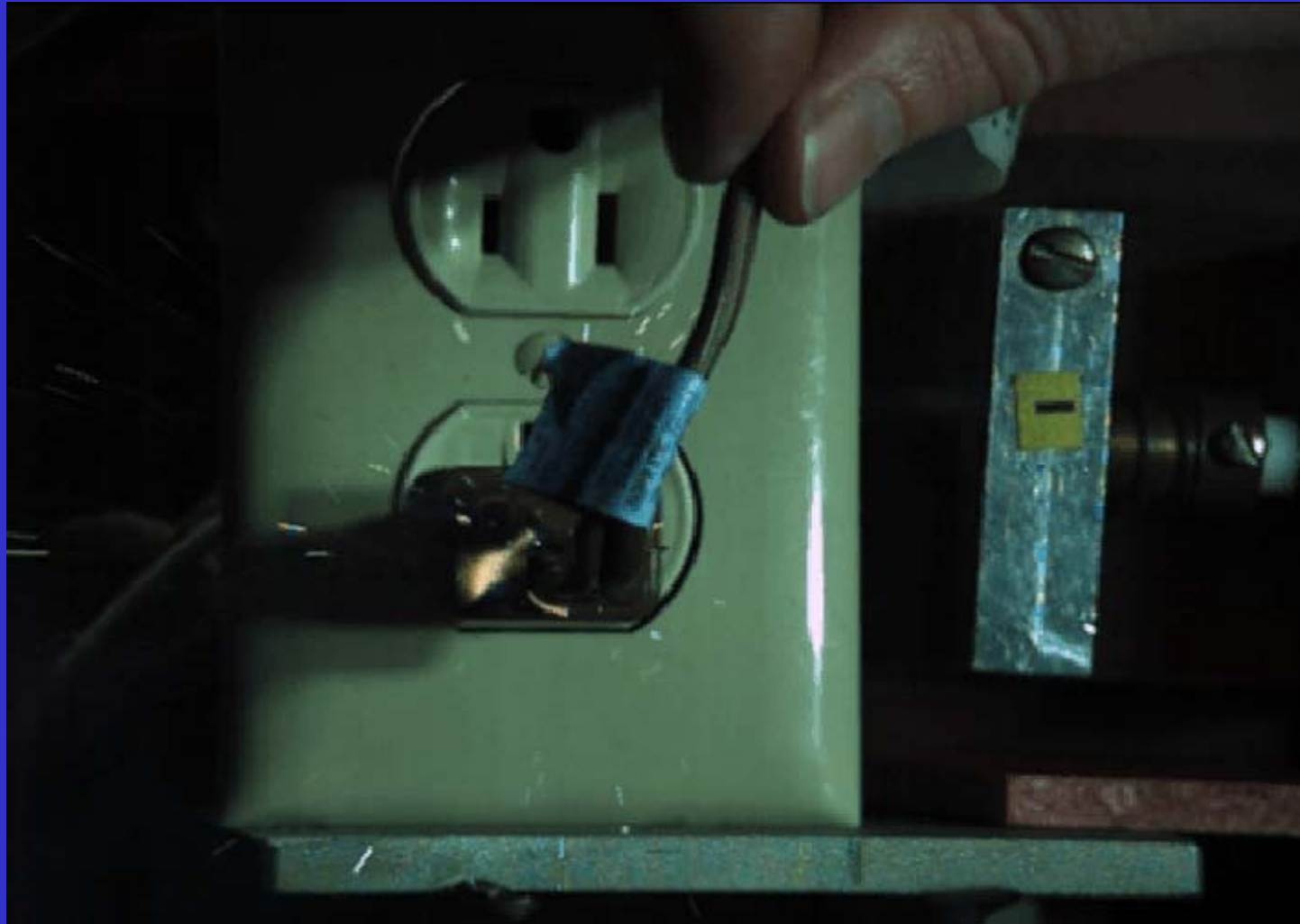
Burnout



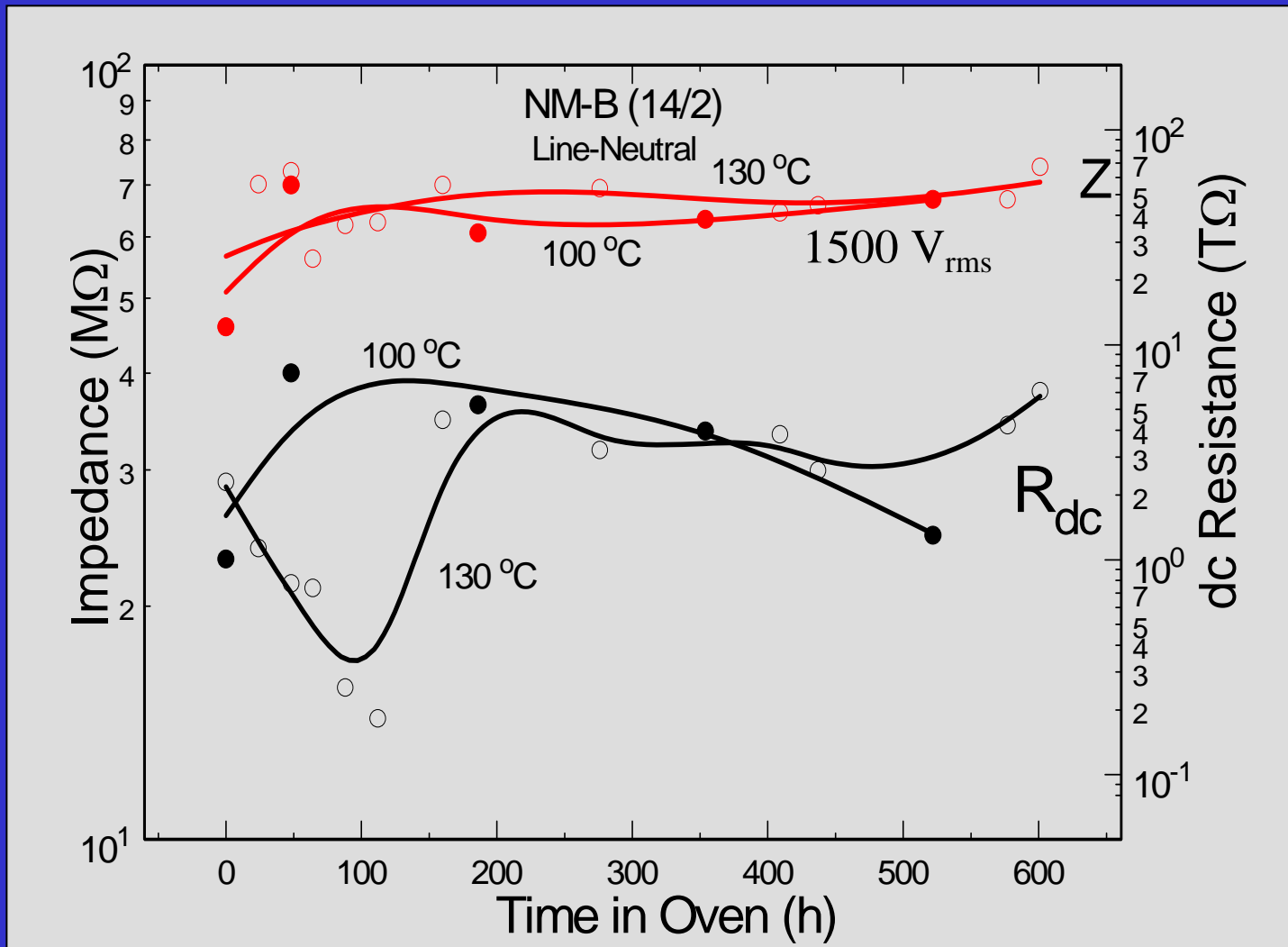
Arcing Over Char



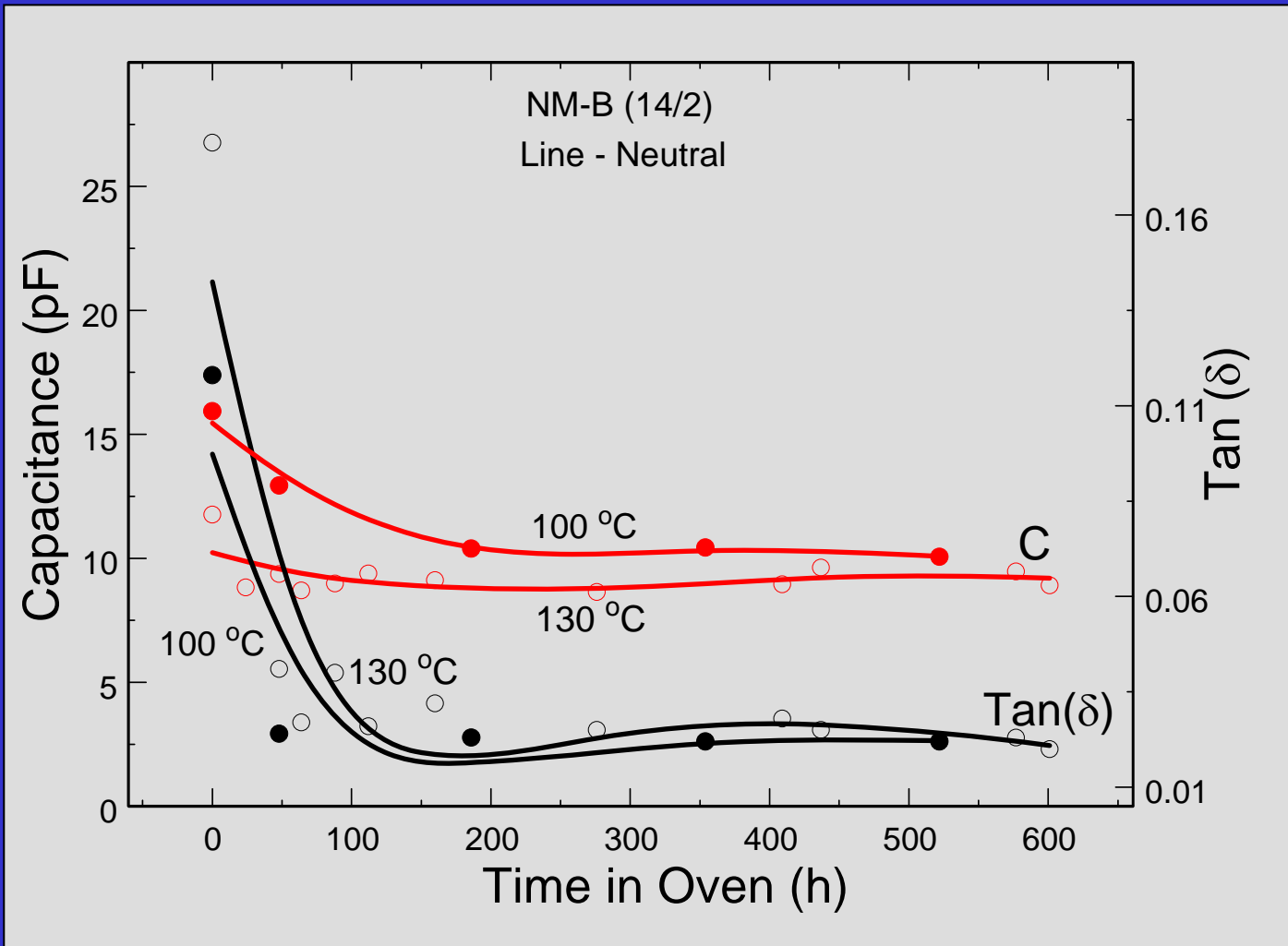
Gas Ignition at Outlet 15 A_{rms}



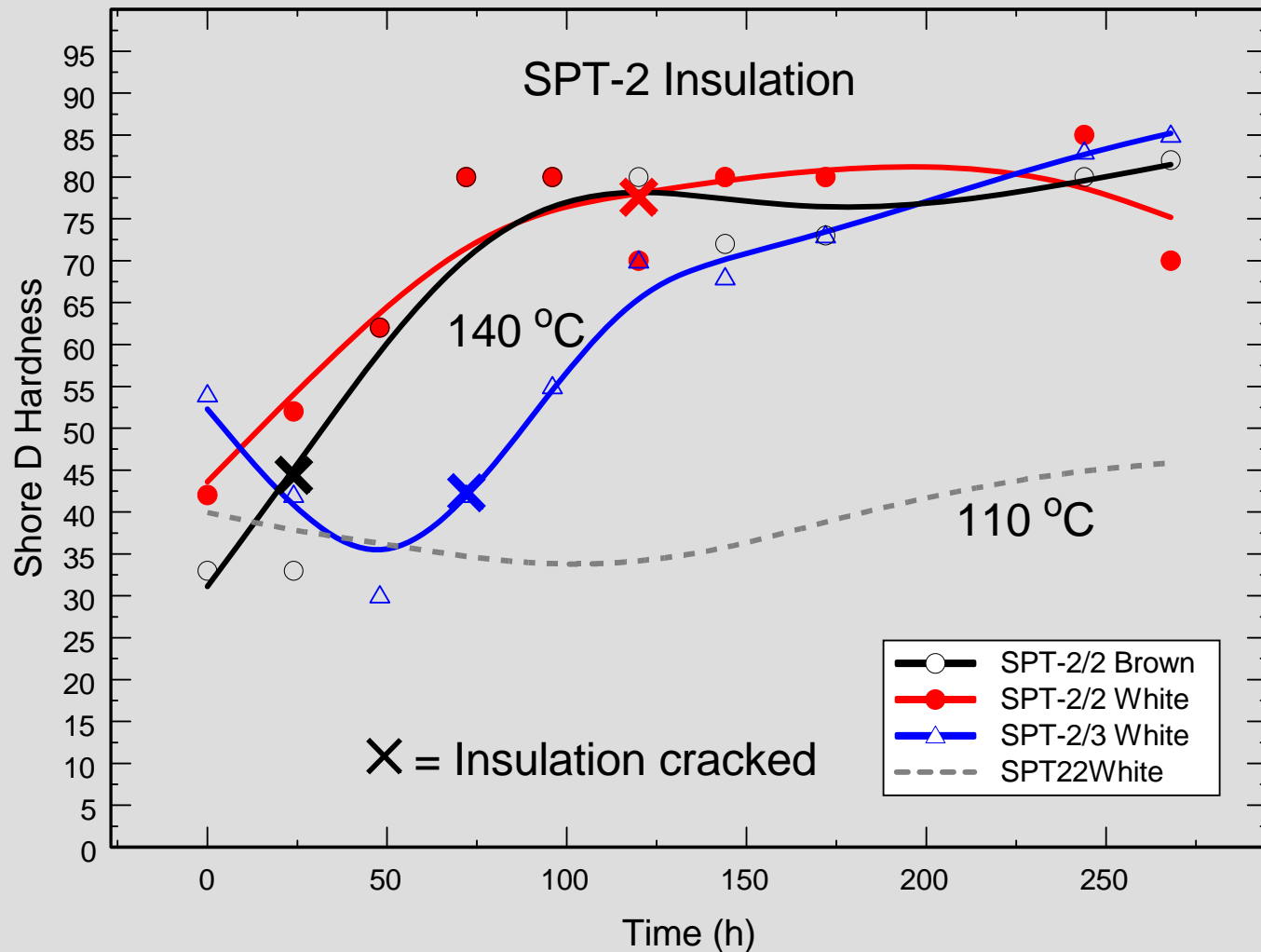
Dielectric and DC Resistance on Accelerated Aged Wires



Capacitance and Tan(δ) on Accelerated Age Testing



Hardness Indicates Insulator Life



Conclusions

- AFCI type breakers may reduce the likely-hood of starting a fire by reducing the effective “magnetic trip” level and recognizing sputtering arc patterns
- Bundled extension cords under rugs is not a good idea!
- Bundled NM-B wire at the load center has the potential for overheating, especially if added thermal insulation covers the wires.
- Glowing connections alone can cause overheating of electrical wire insulation at currents as low as $0.9 A_{\text{rms}}$.
- Glowing can initiate continuous arcing.
- Glowing can lead to series or parallel arcing

Conclusions (continued)

- Intermittent series arcing can produce char on electrical insulation that can lead to continuous series arcing and ignition of insulation
- Series arcing can initiate fires at currents of $1.7 A_{\text{rms}}$ and potentially lower.
- Both series or parallel arcing can cause PVC insulation to decompose and produce ignitable gases.
- Residential electrical wiring insulation becomes brittle with accelerated thermal aging. Arcing faults can result from cracking and breakage of the brittle wire insulation even though electrical properties, including withstanding $1500V_{\text{rms}}$ are maintained in aged wiring

Conclusions (continued)

- Hardness may be a useful measure of wire end-of-life. Data showed time to cracking for various wire types with brown SPT-2 cords having the shortest life.
- Unintentional series or parallel arcing or glowing has the potential to produce fires in aged as well as new residential wiring.
- Continuous improvements in connection methods, insulation materials, standards, and arc fault detection/protection and insulation monitoring systems can be used to reduce residential fires.