Electrical Arc Ignition Testing of Spacesuit Materials

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Background

- Testing in response to frayed cable discovered during spacewalk testing
- Reliance on Apollo-era arc testing
  - Limited applicability to current materials
  - Significant changes in voltage and circuitry
  - Poor understanding of test configuration
Test Objectives

• Gain better understanding of Apollo-era data
• Investigate new test methods
• Characterize minimum current levels necessary for combustion of EMU materials (at a given voltage)
Test Sample Materials

LCVG liner (tricot)
LCVG outer layer (nylon/spandex)
LCVG water transport tubing
Pressure garment bladder (urethane coated nylon)
Pressure garment cover-restraint (dacron)
TMG liner (neoprene coated nylon ripstop)
TMG insulation layers (aluminized mylar)
TMG cover (ortho-fabric)
Test Methods

- Multiple location intermittent arcing (scratch) test
- Single location intermittent arcing (poke) test
- Single location wire-break arcing test
Scratch Test Objectives

• Simulate Apollo-era testing
• Determine configurational effects
• Test materials currently used in the EMU
Cotton Scratch Test Video

Slit in Test Sample

Stylus
Scratch Test Results

- Testing yielded results similar to Apollo-era testing
- Frayed materials more reactive
- No distinguishable difference between horizontal samples and vertical samples
- Tests performed at 23.5 psia 100% O2, 22.5 V
  - 7 materials tested
  - Current required for ignition ranged from 0.8 A to 1.4 A
Scratch Test Problems

- Not possible to determine which arc ignited material
- Arc energies vary widely from test to test and arc to arc
- Difficult to ensure that test sample material is in intimate contact with arcing event
- Configuration not realistic for inside spacesuit because of size of stylus
Poke Test Objectives

• Determine whether more severe to arc with wires or stylus
• Determine whether more severe to arc in single location (poke test) or multiple locations (scratch test)
**Poke Test Results**

- Poke test results consistent with scratch test results.
  - No detectable difference between arcing in one location or multiple locations.
- Tests showed that it is more severe to arc with a wire than a stylus.
  - Wires are flammable and can burn in oxygen.
  - Burning wires easily ignite test materials.
Poke Test Problems

• Not possible to determine which arc ignited material
• Arc energies vary widely from test to test and arc to arc
• Difficult to ensure that test sample material is in intimate contact with arcing event
Wire-break Test Objectives

- Reduce variability in tests
- Test all materials
- Determine whether ignition is dependent on voltage or current
Wire Clamping Mechanism
Slide Cover Glass
Wire
Fabric Sample
Sample Mounting Plate
<table>
<thead>
<tr>
<th>AWG Size</th>
<th>% of Flight Wire Cross Sectional Area</th>
<th>Approximate Current Required to Break Wire (A)</th>
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</thead>
<tbody>
<tr>
<td>34</td>
<td>0.0063</td>
<td>1550</td>
</tr>
<tr>
<td>38</td>
<td>0.004</td>
<td>625</td>
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<tr>
<td>39</td>
<td>0.0035</td>
<td>479</td>
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<tr>
<td>40</td>
<td>0.0031</td>
<td>375</td>
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<tr>
<td>41</td>
<td>0.0028</td>
<td>306</td>
</tr>
<tr>
<td>42</td>
<td>0.0025</td>
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<tr>
<td>43</td>
<td>0.0022</td>
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<td>44</td>
<td>0.002</td>
<td>156</td>
</tr>
<tr>
<td>45</td>
<td>0.0018</td>
<td>127</td>
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<tr>
<td>46</td>
<td>0.0016</td>
<td>100</td>
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<tr>
<td>47</td>
<td>0.0014</td>
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<td>0.0011</td>
<td>47</td>
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<tr>
<td>51</td>
<td>0.00088</td>
<td>30</td>
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<tr>
<td>52</td>
<td>0.00078</td>
<td>24</td>
</tr>
<tr>
<td>54</td>
<td>0.000062</td>
<td>15</td>
</tr>
</tbody>
</table>
Cotton Wire-Break Test Video
High Speed Cotton Wire-break Test Video
Typical Data Plot

cc3.dat: Voltage/0 - Current/1 (25)
Closeup Data Plot

cc3.dat: Voltage/0 - Current/1

Time (milliseconds)

Volts

Amps
Wire-break Test Results

- Much more severe than scratch and poke tests
- Test conditions
  - 23.5 psia 100% O2, 22.5 V
  - 50 psia 50% O2 and 50% N2, 15 V
- Several materials failed testing at the lowest possible current, ~0.3 A
- Current required for ignition for most materials ranged from <0.3 A to 0.97 A
Wire-Break Test Results (cont.)

- Gore-Tex only ignited under much more severe conditions
  - 100% O2, 54 psia
  - Zigzag wire configuration
### Wire-break Tests vs. Scratch Tests

**23.5 psia 100% O2, 22.5 V**

<table>
<thead>
<tr>
<th>Material</th>
<th>Wire Test Available Current at Ignition (A)</th>
<th>Scratch Test Available Current at Ignition (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generic cotton</td>
<td>0.36</td>
<td>0.95</td>
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<tr>
<td>Moleskin</td>
<td>0.3</td>
<td>0.8</td>
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<tr>
<td>UCN (shiny side)</td>
<td>0.70</td>
<td>1.4</td>
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<tr>
<td>Nylon/Lycra Comm Cap</td>
<td>0.59</td>
<td>1.3</td>
</tr>
<tr>
<td>Astronaut undergarment</td>
<td>0.64</td>
<td>1.4</td>
</tr>
<tr>
<td>LCVG spandex</td>
<td>0.53</td>
<td>1.4</td>
</tr>
<tr>
<td>LCVG tricot</td>
<td>0.49</td>
<td>1.3</td>
</tr>
</tbody>
</table>
Urethane-coated Nylon

2.5 V, 4.99 A

No Ignition
Ignition
21.8 Watt Power Curve
Moleskin

6.8 Watt Power Curve

- ▲ Ignition
- ▼ No Ignition

- 1.3 V, 0.25 A

NASA White Sands Test Facility
<table>
<thead>
<tr>
<th>Surface Characteristics</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Interface cable Gore-Tex® sleeve</td>
</tr>
<tr>
<td></td>
<td>Urethane-coated nylon suit bladder (fabric side)</td>
</tr>
<tr>
<td></td>
<td>Interface cable polyurethane jacket</td>
</tr>
<tr>
<td></td>
<td>Urethane-coated nylon suit bladder (shiny side)</td>
</tr>
<tr>
<td></td>
<td>Astronaut longhandle undergarment</td>
</tr>
<tr>
<td></td>
<td>CCA cap spandex (nylon &amp; Lycra® knit fabric)</td>
</tr>
<tr>
<td></td>
<td>LCVG garment (multifilament nylon / spandex knit 1106 treated with 3% TCHDE solution)</td>
</tr>
<tr>
<td></td>
<td>LCVG garment inner liner (nylon tricot treated with 3% TCHDE solution)</td>
</tr>
<tr>
<td></td>
<td>Cotton flocked Rucothane® glove bladder</td>
</tr>
<tr>
<td></td>
<td>TCU assembly (Capilene® – hollow fiber polyester treated with 3% TCHDE solution)</td>
</tr>
<tr>
<td></td>
<td>Kerlix dressing</td>
</tr>
<tr>
<td></td>
<td>Generic cotton</td>
</tr>
<tr>
<td></td>
<td>Moleskin</td>
</tr>
</tbody>
</table>

Best

Worst
Conclusions

• Wire-break test is worst-case
• Fuzzy materials generally easier to ignite
• Current appears to have greater effect than voltage
• Controlling risk must include both
  – Physical isolation of easy to ignite materials
  – Limiting current and voltage