INTRODUCTION

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Agenda

• Introduction
• Hardware Provider Wire Systems
• Current Wire Insulation Issues
  ◦ Silicone Wire Contamination
  ◦ Tefzel Cold Temperature Flexibility
  ◦ Russian Polyimide Wire Insulation
• Conclusion

Hardware Provider Wire Systems

<table>
<thead>
<tr>
<th>Hardware Provider</th>
<th>TFE (Teflon)</th>
<th>ETFE (Tefzel)</th>
<th>Silicone</th>
<th>Polyimide (Kapton)</th>
<th>Teflon/Kapton/Teflon (TKT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>McDonnell Douglas</td>
<td>I</td>
<td>E</td>
<td>E</td>
<td></td>
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<tr>
<td>Rocketdyne</td>
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<tr>
<td>Boeing Defense &amp; Space Group</td>
<td>I, E</td>
<td>E</td>
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<td>Italian Space Agency (ASI)</td>
<td>I, E</td>
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<td>European Space Agency (ESA)</td>
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<td>Japanese Space Agency (NASDA)</td>
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<td>Canadian Space Agency (CSA)</td>
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<td>Russian Space Agency (RSA)</td>
<td>I, E</td>
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<td>I, E</td>
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</tbody>
</table>

I=Internal, E=External
ISS Wire Insulation Issues

- Silicone wire contamination
  - McDonnell Douglas baselined silicone wire for truss power applications because of its flexibility
  - Wire passes JSC-SP-R-0022 (ASTM E 595) thermal vacuum stability testing requirements
    - At elevated cure (24 hr. @400F)
    - TML = .123
    - CVCM = .018
  - Due to large usage (1X10^6 cm^2) material significantly fails integrated outgassing deposition rate requirements (MOLFLUX)
    - Required Rate <= 1X10^-14 g/cm^2/s
    - Calculated Rate = 2X10^-11 g/cm^2/s
  - PG-1 has developed Project Directive #130 to limit use of silicone wire for ISS applications
  - Current plan is to use Tefzel wire with spliced silicone pigtails
    - Splicing design under evaluation
    - ISS Program requirements for splicing being established

SSQ 21652 Silicone Wire Outgassing Results

[Graph showing outgassing results for CVCM and TML over 25 hours at 400F]

Data Source: WSTF Report # W27323, W27324
ISS Wire Insulation Issues (cont.)

<table>
<thead>
<tr>
<th></th>
<th>Silicone</th>
<th>Silicone (baked)</th>
<th>Tefzel</th>
<th>Silicone (wrapped)</th>
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</thead>
<tbody>
<tr>
<td>Measured 25C dep. rate (g/cm²/sec)</td>
<td>6.0E-10</td>
<td>8.0E-11</td>
<td>8.0E-12</td>
<td>3.0E-13</td>
</tr>
<tr>
<td>@ measurement time (hr.)</td>
<td>10</td>
<td>77</td>
<td>110</td>
<td>87</td>
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<tr>
<td>View factor to QCM</td>
<td>.6</td>
<td>.6</td>
<td>.6</td>
<td>.6</td>
</tr>
<tr>
<td>Outgassing rate (g/cm²/sec)</td>
<td>1.0E-9</td>
<td>1.3E-10</td>
<td>1.3E-11</td>
<td>5.0E-13</td>
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<tr>
<td>Total cable area assumed (cm²)</td>
<td>1.1E6</td>
<td>1.1E6</td>
<td>1.1E6</td>
<td>1.1E6</td>
</tr>
<tr>
<td>Avg. dep. on ATCS radiator (g/cm²/sec)</td>
<td>9.0E-12</td>
<td>1.2E-12</td>
<td>1.2E-13</td>
<td>4.5E-15</td>
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<tr>
<td>Dep. on attached payload (g/cm²/sec)</td>
<td>2.0E-11</td>
<td>2.6E-12</td>
<td>2.6E-13</td>
<td>1E-14</td>
</tr>
</tbody>
</table>

Source: JSC/ESS/M. Pedley

- **Tefzel cold temperature flexibility**
  - Tefzel known to have less flexibility than silicone wire at room temperature, however silicone has Tg at approx -110°C
  - Recent thermal vacuum tests revealed that at very cold temperatures (-100°F), astronauts could not manipulate test wire harnesses
    - “Freezes” in cooling/conditioning position
    - No “memory” when heated back to room temperature
  - McDonnell Douglas parametric studies
  - More parametric studies planned (function of temperature)
  - STS 72 flight experiment planned
    - 9 configurations of silicone and Tefzel wire
    - -60°F to -80°F
ISS Wire Insulation Issues (cont.)

Power Cable Cold Bend Tests

![Graph showing Torque vs Temperature for Tefzel and Silicone]

Maximum Torque to bend 180 degrees
(Single 1/0 wire, 11" moment)

Tefzel EVA Handling Tests

<table>
<thead>
<tr>
<th>Harness Contents:</th>
<th>Total dia.</th>
<th>-120°C</th>
<th>-100°C</th>
<th>-75°C</th>
<th>-50°C</th>
<th>-25°C</th>
<th>0°C</th>
<th>25°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>2ea. @ 4ga., 1ea. @ 8ga.</td>
<td>0.681</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<tr>
<td>7ea. @ 8ga.</td>
<td>0.907</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
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<tr>
<td>4ea. @ 4ga., 2ea. @ 8ga.</td>
<td>0.994</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2ea. @ 1/0ga., 1ea. @ 4ga.</td>
<td>1.090</td>
<td></td>
<td></td>
<td>*</td>
<td>*</td>
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<tr>
<td>4ea. @ 1/0ga.</td>
<td>1.374</td>
<td></td>
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Shaded: Unacceptable
Unshaded: Acceptable
* : Operation could be performed with one hand
Source: MDSSC Technical Report #9500837

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ISS Wire Insulation Issues (cont.)

- Russians revealed February 1995 that they intend extensive use of polyimide wire
- Russian polyimide wire testing at WSTF for arc-tracking
  - Standard NHB 8060.1 Test 18
    - 200V AC
  - Nonstandard testing (DC)
    - 5 to 120V, 9 to 300A
- Russian comments to NHB 8060.1 Test Methods
  - Why AC for DC systems?
  - Wire cutting technique
  - Arc initiation method (Induced failure)
- Russian circuit protection philosophy
  - Physical separation of +/- wires
  - Floating ground
  - Quick-blow fuses
- Russian wire characteristics
  - 48 Extruded layers (1.5 μm ea.)
  - Small gages only (< 20 gauge)

SSQ Status

<table>
<thead>
<tr>
<th>Spec. Number</th>
<th>Title</th>
<th>Insulation Materials</th>
<th>Remarks</th>
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<tbody>
<tr>
<td>SSQ 21652</td>
<td>Wire and Cable, Electric, Silicone-Insulated, Nickel Coated Cu or Cu Alloy, General Specification for</td>
<td>Silicone</td>
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<td>SSQ 21653</td>
<td>Cable, Coaxial, Twinaxial, and Triaxial, Flexible and Semirigid, General Specification for Teflon (TFE)</td>
<td>Teflon (FEP)</td>
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<td>SSQ 21654</td>
<td>Cable, Single Fiber, Multimode, Space Quality, General Specification for</td>
<td>Fiber Optic</td>
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<td>SSQ 21655</td>
<td>Cable, Electrical, MIL-STD-1553 Data Bus, Space Quality, General Specification for Teflon (TFE)</td>
<td>Teflon (FEP)</td>
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<tr>
<td>SSQ 21656</td>
<td>Wire and Cable, Electric, Fluoropolymer-Insulated, Nickel Coated Cu or Cu Alloy, General Specification for Teflon (TFE)</td>
<td>Teflon (FEP)</td>
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</tbody>
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Conclusion

- ISS is a complex program with hardware developed and managed by many countries and 100s of contractors

- Most of the obvious wire insulation issues are known by contractors and have been precluded by proper selection

- New issues will continue to arise as Program progresses

- We’ll keep charging the windmills until they are all defeated