Mechanical Design of a 4-Stage ADR for the PIPER mission
July 13, 2017
Bryan L. James, Mark O. Kimball, Peter J. Shirron, Michael A. Sampson, Richard V. Letmate, Michael L. Jackson/NASA GSFC

XARM/RESOLVE
www.nasa.gov
Agenda

• PIPER Mission Introduction
• Purpose of 4-Stage ADR
• Design Overview
  – Stage 4
  – Stage 3
  – Stage 2
  – Stage 1
  – Passive Gas Gap Heat Switches
  – Superconducting Heat Switch
• Mechanical Analysis Summary
  – Materials
  – Fundamental Frequency
The Primordial Inflation Polarization Explorer (PIPER) mission is a balloon borne mission that will fly 4 1280 bolometer detector arrays to measure the polarization of the cosmic microwave background.
Purpose of 4-Stage ADR

• The 4-stage adiabatic demagnetization refrigerator (ADR) is needed to cool the detector arrays to prevent instrument-generated heat from overwhelming the signal PIPER seeks during the mission.
Stage 4

Magnet Shield

Superconducting Magnet

Copper Base Plate
Stage 4 cont.

Mechanical Design of a 4-Stage ADR for the Piper mission

- Salt Pill
- Bellows
- Kevlar
- GGG Salt

XARM/RESOLVE

NASA Goddard Space Flight Center
Stage 4 cont.

Sintered Stainless Steel
Stage 2 and Stage 3

Magnet Shield

Magnet Shield

Mechanical Design of a 4-Stage ADR for the Piper mission
Stage 2 and Stage 3 cont.
Stage 1

Mechanical Design of a 4-Stage ADR for the Piper mission
Stage 1 cont.

Mechanical Design of a 4-Stage ADR for the Piper mission
Passive Gas Gap Heat Switches

Mechanical Design of a 4-Stage ADR for the Piper mission
Superconducting Switch

XARM/RESOLVE

Mechanical Design of a 4-Stage ADR for the Piper mission
### Materials

<table>
<thead>
<tr>
<th>Material (-/-)</th>
<th>Tensile Modulus (ksi)</th>
<th>Yield Strength (ksi)</th>
<th>Ultimate Tensile Strength (ksi)</th>
<th>Poisson’s Ratio (-/-)</th>
<th>Density (lbm/in^3)</th>
<th>Notes: (-/-)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper 10100</td>
<td>17000</td>
<td>45.0</td>
<td>50.0</td>
<td>0.31</td>
<td>0.323</td>
<td>H04 Full Hard ASTM B187 Rockwell F65 99.99% pure</td>
</tr>
<tr>
<td>Aluminum 6061-T651</td>
<td>10000</td>
<td>40.0</td>
<td>45.0</td>
<td>0.33</td>
<td>0.098</td>
<td>Rockwell A 40</td>
</tr>
<tr>
<td>Vespel SP1</td>
<td>475</td>
<td>12.5</td>
<td>12.5</td>
<td>0.41</td>
<td>0.052</td>
<td>Unfilled Rockwell E45</td>
</tr>
<tr>
<td>GGG Salt</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.256</td>
<td>Gadolinium Gallium Garnet</td>
</tr>
<tr>
<td>304 Stainless Steel</td>
<td>29000</td>
<td>31.2</td>
<td>73.2</td>
<td>0.29</td>
<td>0.289</td>
<td>Rockwell B 70</td>
</tr>
<tr>
<td>70-30 Copper-Nickel</td>
<td>22000</td>
<td>18.0</td>
<td>45.0</td>
<td>0.34</td>
<td>0.323</td>
<td></td>
</tr>
<tr>
<td>Niobium-Titanium Wire</td>
<td>13488</td>
<td>54.7</td>
<td>105.6</td>
<td>0.40</td>
<td>0.276</td>
<td></td>
</tr>
<tr>
<td>Silicon Iron C</td>
<td>28500</td>
<td>75</td>
<td>95</td>
<td>0.26*</td>
<td>0.274</td>
<td>Rockwell B 95</td>
</tr>
<tr>
<td>Kevlar 49 195 Denier</td>
<td>13900</td>
<td>348.4</td>
<td>348.4</td>
<td>.35</td>
<td>.052</td>
<td></td>
</tr>
</tbody>
</table>
Results cont.

- Mode Frequency (Hz)
  Convergence

<table>
<thead>
<tr>
<th></th>
<th>Mode</th>
<th>Frequency (Hz)</th>
<th>Convergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9.123538e+01</td>
<td>4.5%</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>9.149595e+01</td>
<td>4.9%</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1.644186e+02</td>
<td>3.6%</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.646613e+02</td>
<td>3.5%</td>
<td></td>
</tr>
</tbody>
</table>
Results cont.

- **Mode**  | **Frequency (Hz)** | **Convergence**
- 1  | 8.388150e+01 | 4.4%
- 2  | 8.407365e+01 | 4.8%
- 3  | 1.003635e+02 | 3.8%
- 4  | 1.005206e+02 | 3.9%
Results cont.

- Mode Frequency (Hz) Convergence
  - 1 7.887332e+01  4.4%
  - 2 8.707665e+01  4.8%
  - 3 1.103195e+02  3.8%
  - 4 1.105206e+02  3.9%