Mechanical Design of a 4-Stage ADR for the PIPER mission
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XARM/RESOLVE

NASA Goddard Space Flight Center
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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.
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.
Design Overview

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

Stage 1

Stage 2

Stage 3

Stage 4

Passive Gas Gap Switch

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

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

Salt Pill

Bellows

Kevlar

GGG Salt
Stage 2 and Stage 3

Magnet Shield

Magnet Shield
Stage 2 and Stage 3 cont.

Kevlar

Salt Pill

Superconducting Magnet
Stage 1

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

Kevlar

Salt Pill
Passive Gas Gap Heat Switches

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

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>
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<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>
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<td>Aluminum 6061-T651</td>
<td>10000</td>
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<td>0.098</td>
<td>Rockwell A 40</td>
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<tr>
<td>Vespel SP1</td>
<td>475</td>
<td>12.5</td>
<td>12.5</td>
<td>0.41</td>
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<td>Unfilled Rockwell E45</td>
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<tr>
<td>GGG Salt</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.256</td>
<td>Gadolinium Gallium Garnet</td>
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<td>304 Stainless Steel</td>
<td>29000</td>
<td>31.2</td>
<td>73.2</td>
<td>0.29</td>
<td>0.289</td>
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<td>70-30 Copper-Nickel Niobium-Titanium Wire</td>
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<td>45.0</td>
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<tr>
<td>Niobium-Titanium Wire</td>
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<td>Silicon Iron C</td>
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<td>95</td>
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<td>Kevlar 49 195 Denier</td>
<td>13900</td>
<td>348.4</td>
<td>348.4</td>
<td>.35</td>
<td>.052</td>
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Results cont.

- Mode Frequency (Hz)
- Convergence

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<th>Mode</th>
<th>Frequency (Hz)</th>
<th>Convergence</th>
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<tbody>
<tr>
<td>1</td>
<td>9.123538e+01</td>
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<tr>
<td>2</td>
<td>9.149595e+01</td>
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<tr>
<td>3</td>
<td>1.644186e+02</td>
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<tr>
<td>4</td>
<td>1.646613e+02</td>
<td>3.5%</td>
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</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%