Design Models for Development of Helium-Carbon Sorption Coolers

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Designs for continuous cooling to 4--6 K

- Heat In: gas desorbed
- Gas storage: charcoal, metal hydride
- Heat Rejected: gas adsorbed
- Joule-Thomson expander (bi-directional)
- Heat Lift at low temperature
Implementation of continuous cooling

Single J-T with check-valves

Multiple bi-directional J-Ts

cold plate
Helium-Carbon cooler design model

**model inputs**
No. of compressor elements  
cycle time  
precooling temperature(s)  
maximum compressor temperature  
desorption and adsorption pressures  
required cold plate temperature  
required power lift  
heat exchanger efficiency  
materials properties of charcoal and container  
allowable pressure drops in tubing  
safety margins in pressure and temperature  
heater electrical properties  
length of J-T constriction

**model outputs**
charcoal mass required  
optimized dimensions of compressor elements  
container mass  
required heat rejection at precooler  
efficiency of system  
total mass of compressor elements  
required C-F mechanical configuration  
diameter of J-T constriction  
heat switch parameters (for Helium gas-gap)

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Basis of design model:

- employs GasPak code from NIST, coupled to Excel spreadsheet to find enthalpy of Helium gas
- charcoal properties from Duband, fits to Dubinin sorption model
- either set of properties can be replaced by data in tabular or functional form
Proposed Design for NGST 2-stage sorption cooler

Metal Hydride/Hydrogen Compressors (Mounted on 270 K radiator)

Counterflow Heat Exchanger (CFHX)

CFHX ISIM Radiator (35 K)

Hydrogen Cold Plate (18 K)

Gas-Gap Heat Switch

Helium Compressors

CFHX

J-T J-T J-T

Helium Cold Plate (6 K)
Model predictions for NGST 2-stage system performance

He-Carbon performance from design models

H2–metal hydride performance from similar models and scaling of Planck coolers

A) The heat lift required at 6 K as a function of the number of detector arrays.
B) The total system mass and power as a function of the number of detector arrays.

Table 2. Cooler System Properties for Various 6 K Cooling Loads

<table>
<thead>
<tr>
<th>Heat Lift At 6 K (W)</th>
<th>Charcoal Power (W) (at 18 K)</th>
<th>Charcoal Sys Mass (kg)</th>
<th>Hydride Input Power (W) (at 270 K)</th>
<th>Hydride System Mass (kg)</th>
<th>Total System Power (W)</th>
<th>Total System Mass (kg)</th>
<th>Passive Cooling requirements (W) At 35 K</th>
<th>At 270 K</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.005</td>
<td>0.43</td>
<td>0.56</td>
<td>66.4</td>
<td>12</td>
<td>66.8</td>
<td>12.6</td>
<td>0.44</td>
<td>66.4</td>
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<td>0.007</td>
<td>0.58</td>
<td>0.71</td>
<td>72.9</td>
<td>12.7</td>
<td>73.5</td>
<td>13.4</td>
<td>0.59</td>
<td>72.9</td>
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<td>0.010</td>
<td>0.81</td>
<td>0.95</td>
<td>82.6</td>
<td>13.7</td>
<td>83.4</td>
<td>14.6</td>
<td>0.82</td>
<td>82.6</td>
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<tr>
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<td>1.27</td>
<td>95.6</td>
<td>15.1</td>
<td>96.7</td>
<td>16.4</td>
<td>1.13</td>
<td>95.6</td>
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<td>100.1</td>
<td>16.7</td>
<td>1.21</td>
<td>98.9</td>
</tr>
</tbody>
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