Design Models for Development of Helium-Carbon Sorption Coolers


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Designs for continuous cooling to 4--6 K

- **Q**
  - Heat In: gas desorbed
  - gas storage: charcoal, metal hydride
  - Heat Lift at low temperature
  - Joule-Thomson expander (bi-directional)

- **Q**
  - Heat Rejected: gas adsorbed

Diagram showing the process of continuous cooling with heat in and out, storage of gas, and expansion through a Joule-Thomson expander.
Implementation of continuous cooling

Single J-T with check-valves

Multiple bi-directional J-Ts
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
(left) Scale drawing of a possible hydrogen/metal hydride 20 K compressor assembly for NGST, based on designs for the Planck cryocoolers.

(right) Concept drawing of an integrated 18 K cold-head and charcoal cooler compressor assembly based on our design model. (partially transparent for visibility of the compressor elements)
How the proposed charcoal/helium sorption cryocooler might fit into an NGST Mid-IR camera

Next Generation Space Telescope Integrated Science Instrument Module (ISIM)
Proposed Design for NGST 2-stage sorption cooler

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

Counterflow Heat Exchanger (CFHX)

ISIM Radiator (35 K)

Hydrogen Cold Plate (18 K)

Gas-Gap Heat Switches

Helium Compressors

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

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