Passive Gas-Gap Heat Switches for use in low-temperature cryogenic systems

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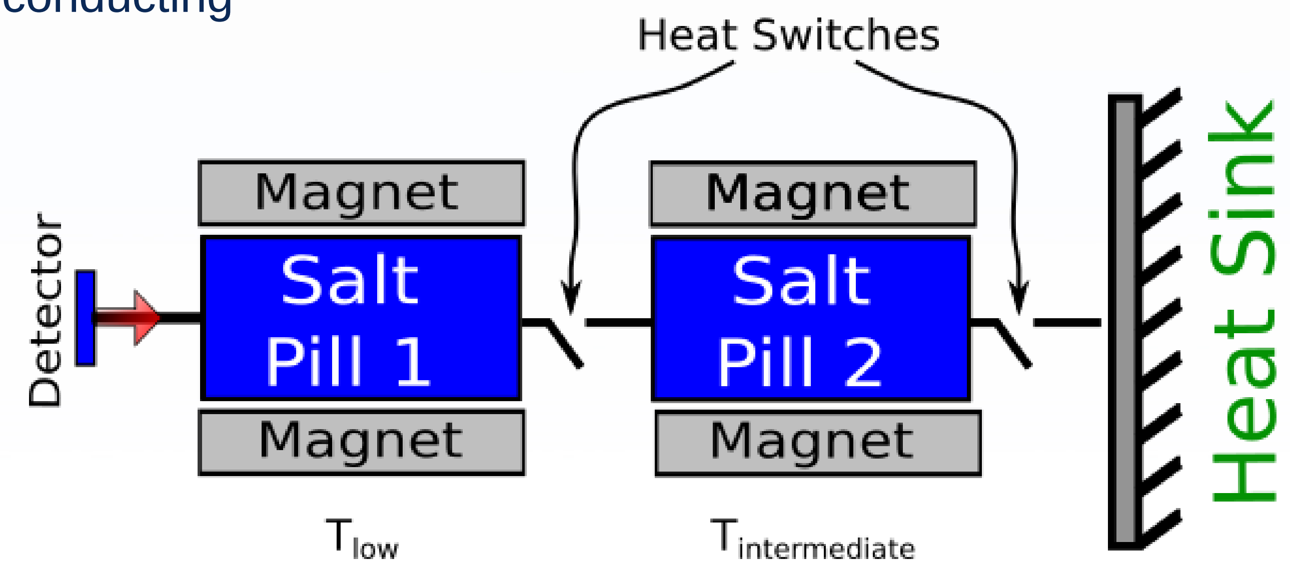
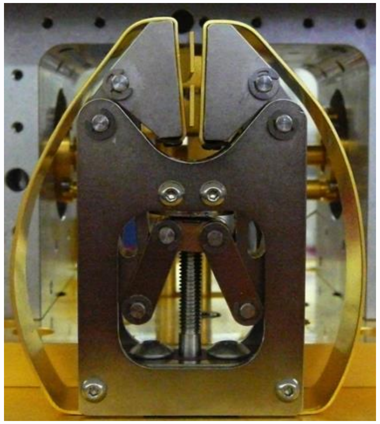
Why Heat Switches

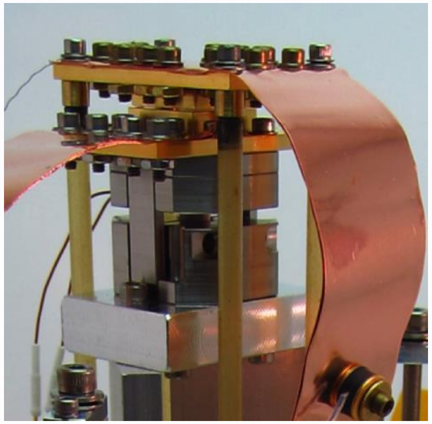
- Any cryogenic system that needs to have a predictable controlled flow of heat requires a form of a heat switch
- Come in many forms
  - Mechanical
  - Gas Gap
  - Superconducting



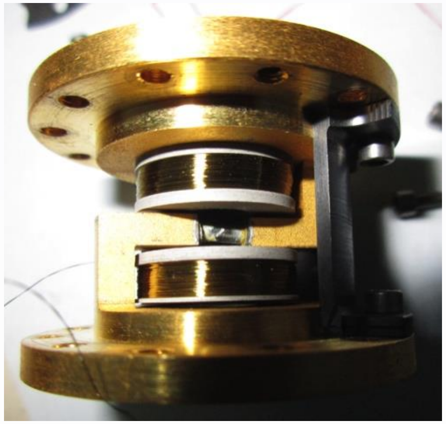
Heat Switches in Cryogenics Systems



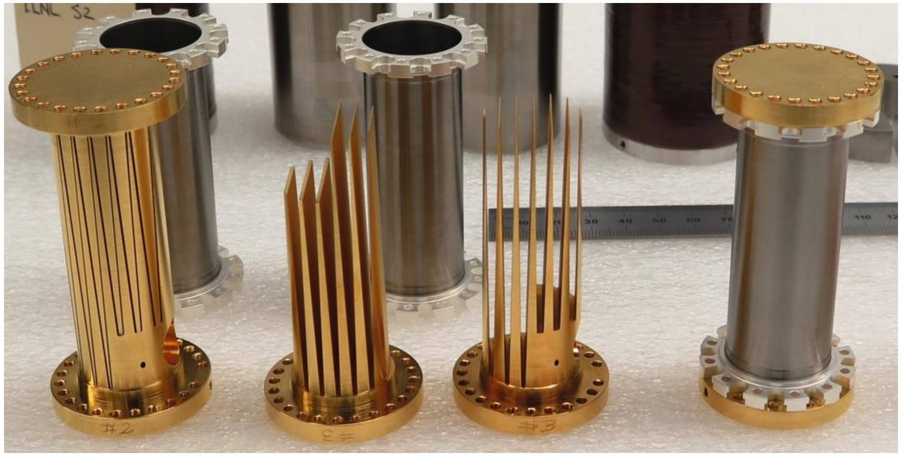
Mechanical



Electro-Mechanical

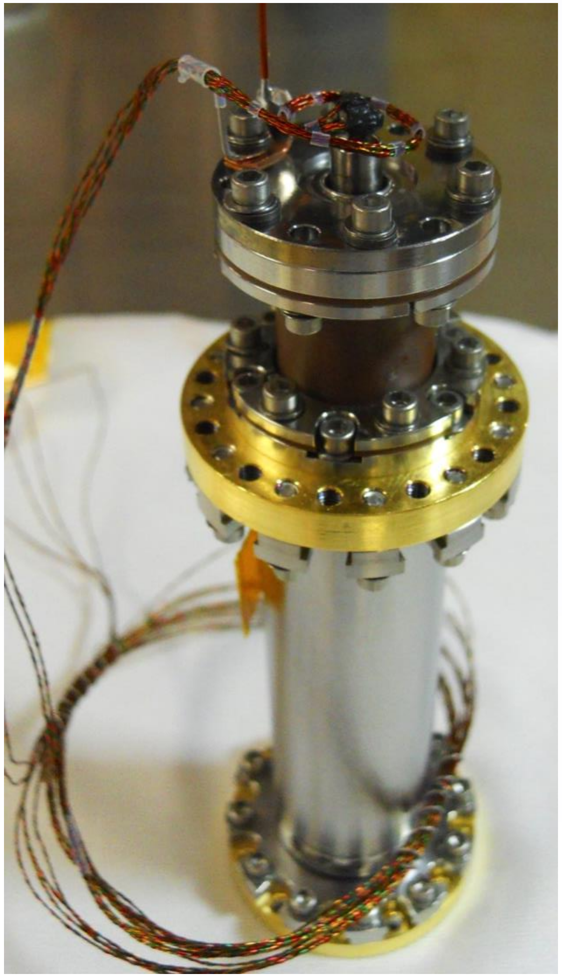


Superconducting

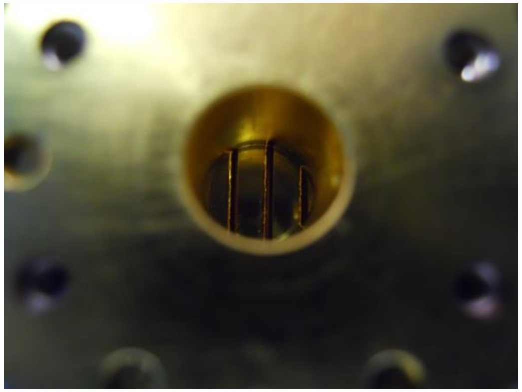


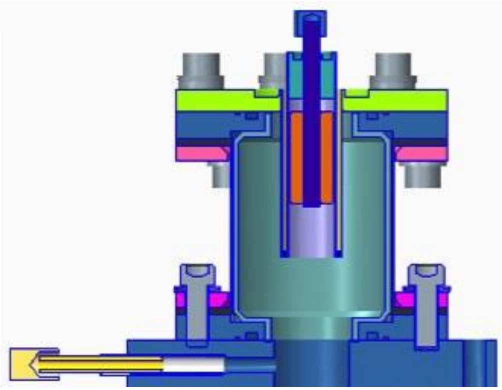
Gas Gap

Active GGHS



- A large-surface area getter absorbs gas below some temperature evacuating the region between the two sets of fins
- Getter temperature controlled by a heater in thermal contact with the getter
- Below 10 K, bituminous charcoal is a good choice— used on Astro-H

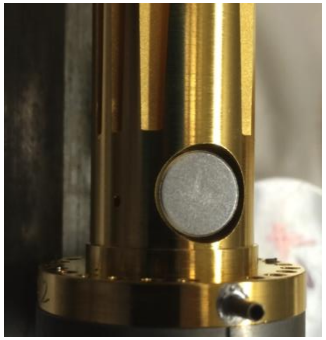


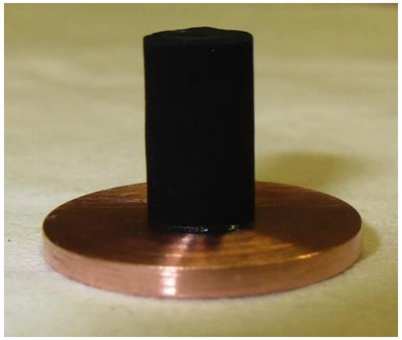


Passive GGHS

No separate input needed to activate switch

- Switch state controlled by temperature of a getter
    - For us, often controlled by an ADR stage temperature
- For our use, choice of getter material dictated by temperature range of intended use
    - Charcoal ("high" temperature)
    - Sintered stainless steel puck (~ 1 K)
    - Gold-plated copper fins provided by innards (~ 0.16 K)

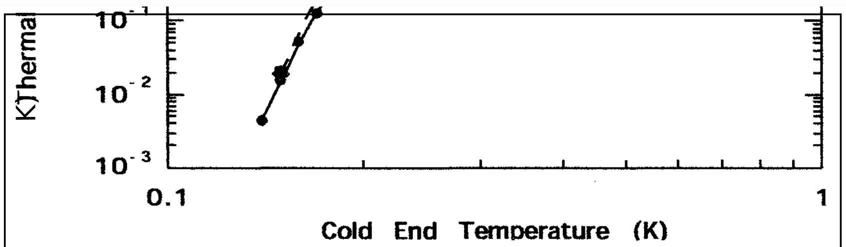




Benefit of a PGGHS

- More simple control system
  - No need to activate a getter heater
  - No need to measure a getter temperature
- Since no additional heat is added to the system to activate the switch, more thermodynamic efficiency
- Rapid on / off times
- More compact
  - no external getter housing

Contributions to Switch Conductance



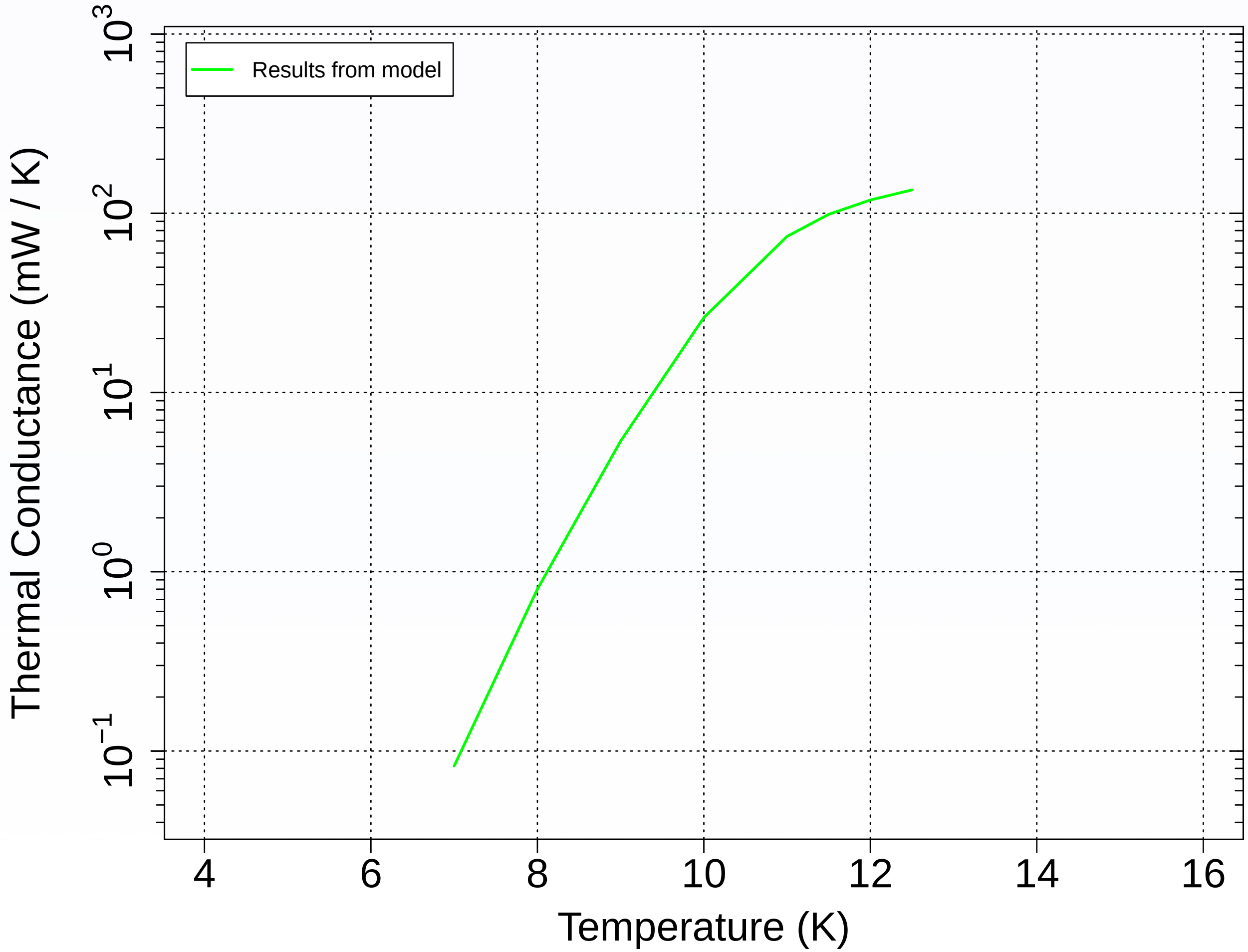
E 2. Measured (●) and calculated (◆) thermal conductance of the low temperature passive g
itch. The separate contributions to the calculated conductance are also shown: copper (△), 3l
]), and the Kapitza boundary resistance between 3He and copper (○).

e heater power. Low power was used to not overload the ADR. The
tance of the switch as a function of cold end temperature is shown in FIG
aken for different heater powers show the heat flow to be linear with temp
nt, and the conductance therefore dependent only on the cold end temp
the temperature of the cold end fell to 0.13 K and below the conductance
was indistinguishable from the background heat flow in the heat switch she
he hot end of the switch was heated to above 1.3 K.
hese data are compared to calculations of the Kapitza boundary resistance.

Source: Shirron, Canavan, DiPirro et al., **Passive gas-gap heat switches for use in adiabatic demagnetization refrigerators** AIP Conference Proceedings **613**, 1175 (2002)

- On-state conductance has many contributions
  - Conductivity of the copper fins
  - Conductivity of the gas between the fins
  - Boundary resistance between the gas and copper fins
  - Boundary resistance between the switch and other components
- Off-state conductance dominated by the hermetic outer shell
  - Typical “Low-temperature” switches use titanium (superconduct below ~3.4 K)
  - Higher temperature switches may use stainless steel

Switch Developed for "10 K ADR"



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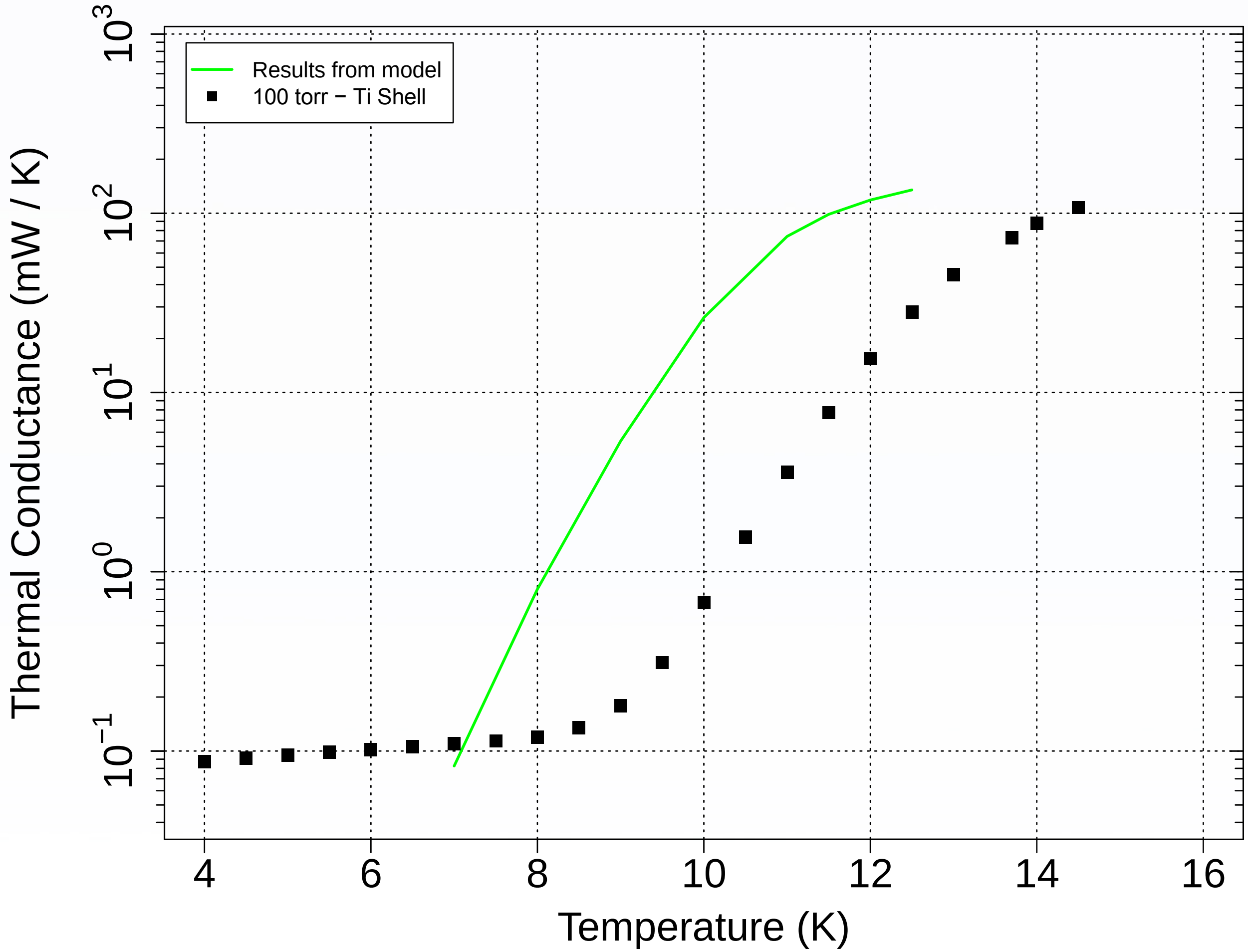

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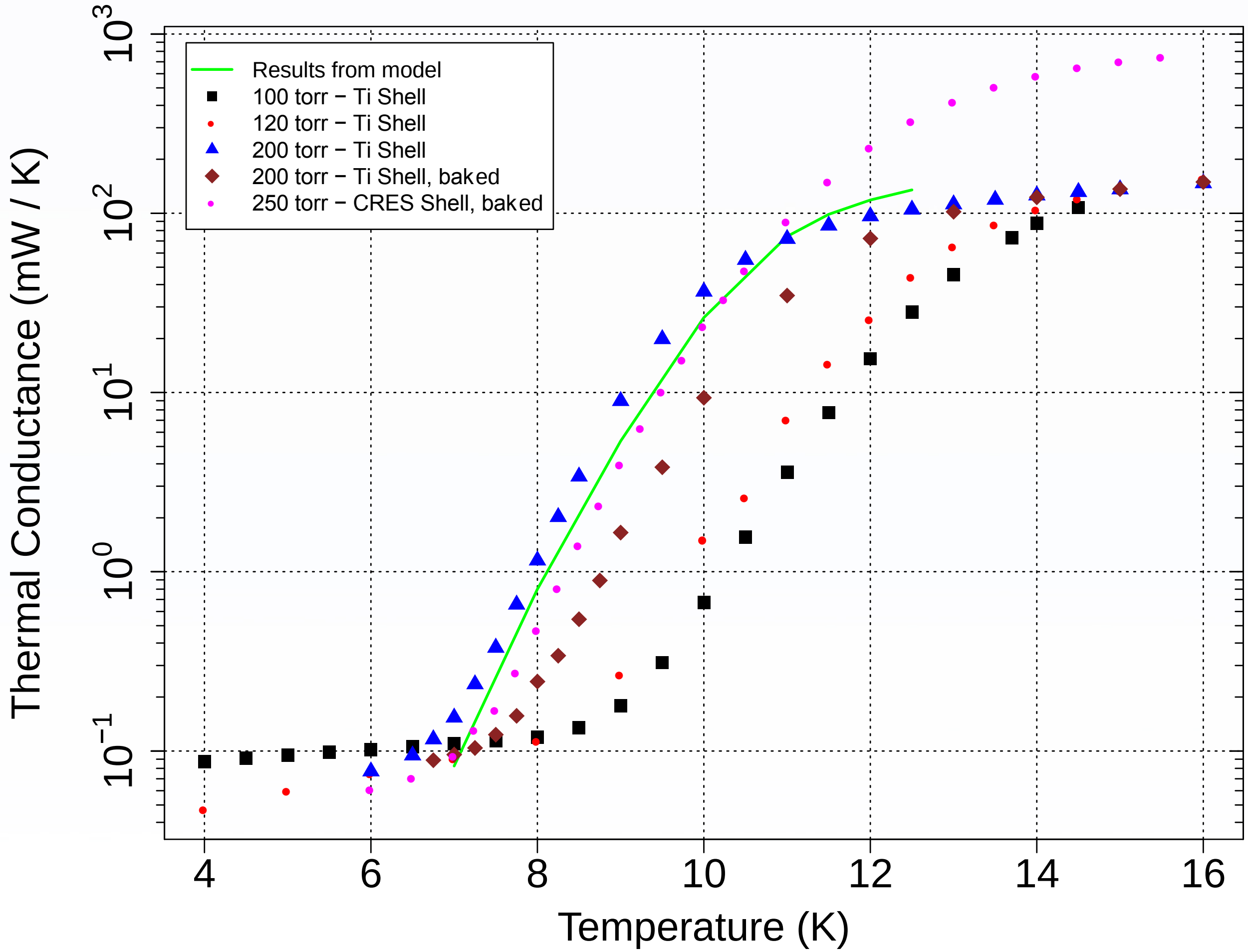
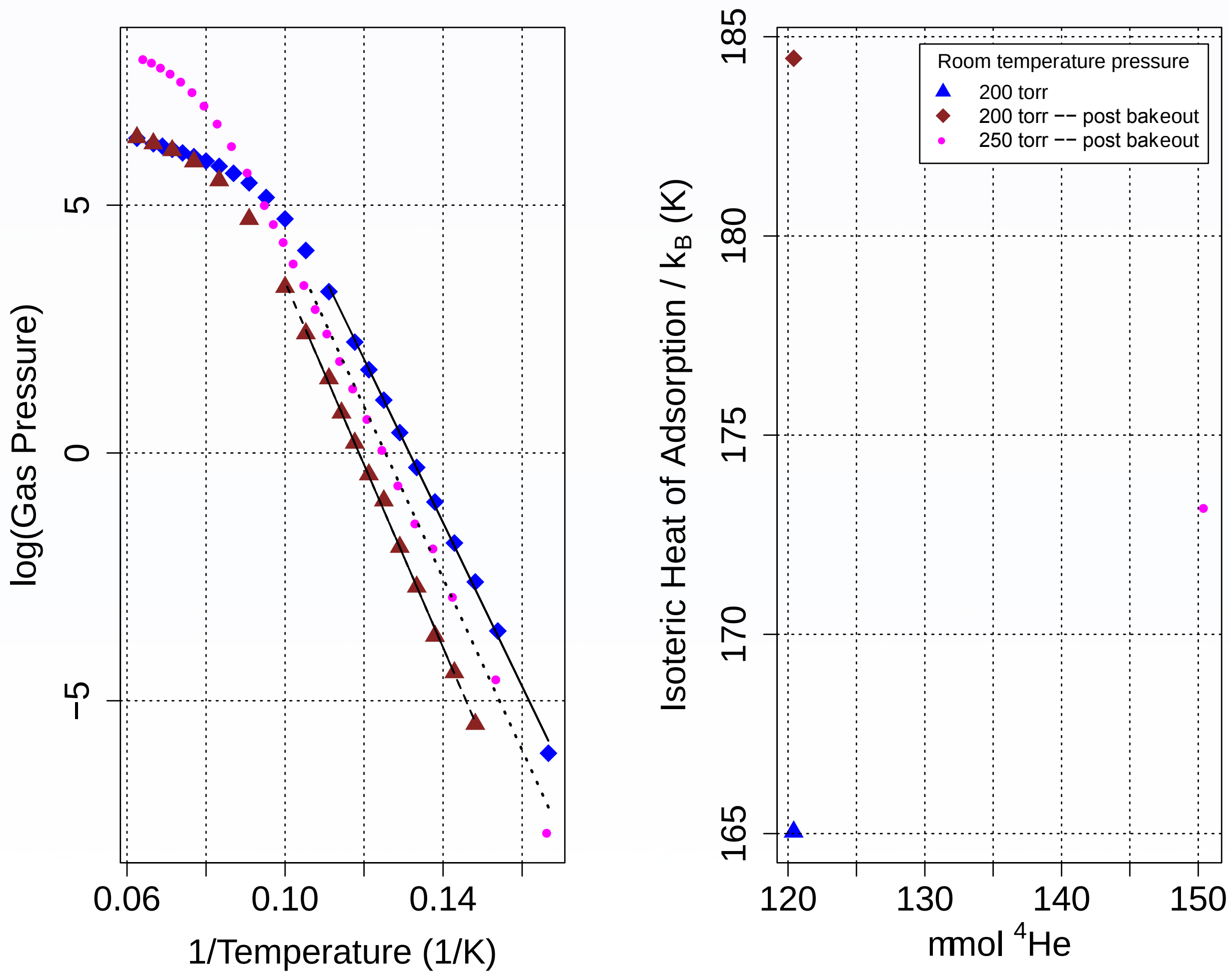


Isosteric Heat of Adsorption



Summary

- Presented passively-activated gas-gap heat switches with transition temperatures ranging from 0.16 to 10 K
- Wide temperature range provided by choice of gas and getter material
- Compact size, rugged, thermodynamically efficient
- Currently in use in multi-stage adiabatic demagnetization refrigerators at NASA/GSFC