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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

- 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”

Results from model

\[
\begin{align*}
\text{Thermal Conductance (mW / K)} \\
4 & \quad 6 \quad 8 \quad 10 \quad 12 \quad 14 \quad 16 \\
10^{-1} & \quad 10^{0} \quad 10^{1} \quad 10^{2} \quad 10^{3}
\end{align*}
\]
Switch Developed for “10 K ADR”

Results from model
100 torr − Ti Shell

Thermal Conductance (mW / K)

Temperature (K)
Switch Developed for “10 K ADR”

Results from model
- 100 torr – Ti Shell
- 120 torr – Ti Shell
- 200 torr – Ti Shell
- 200 torr – Ti Shell, baked
- 250 torr – CRES Shell, baked

Temperature (K)
Thermal Conductance (mW / K)

4 6 8 10 12 14 16
10^{-1} 10^{-2} 10^{-3}
10^{0} 10^{1} 10^{2} 10^{3}
Isosteric Heat of Adsorption

![Graph showing isosteric heat of adsorption](image)

- Log(Gas Pressure) vs. 1/Temperature (1/K)
- Isosteric Heat of Adsorption / kB (K)

Room temperature pressure
- 200 torr
- 200 torr -- post bakeout
- 250 torr -- post bakeout
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