Contribution ID: **81**

Type: **Poster**

C3Po1F-04: Study on Cryogenic Fluid Circulation Loops for Efficient Heat Transfer of Small Cooling Capacities in the 4-20 K Temperature Range

Wednesday 21 May 2025 09:15 (1h 45m)

In cryogenic refrigeration systems, such as those used in space exploration instruments, heat loads (e.g., detectors) are typically fastened directly to cold sources (e.g., cryocooler cold heads) to minimize thermal resistance. However, in certain scenarios where a considerable distance exists between the detector and the cold source, direct connection is not feasible. In such cases, transitional connections, such as copper plates or braided copper straps, are employed. The heat transfer capacity in these configurations is inherently limited by the thermal conductivity of the connecting materials. This study proposes a cryogenic fluid circulation loop utilizing helium as the working fluid, which replaces the conventional solid thermal conduction with convective heat transfer, thereby enhancing the heat transfer performance. Through simulation calculations and experimental testing, the effects of operational and structural parameters, including charging pressure, operating temperature range, and connection tube length, on heat transfer performance were investigated. The computational and experimental results provide practical insights for the design of efficient small-capacity heat transfer systems operating in the 4-20 K temperature range.

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Session Classification: C3Po1F - Aerospace Applications II