SESSION 11: Regenerator & Recuperator Investigations

Paper No. 11-1 Thursday Morning 9:30 AM

Role of Non-Temperature-Gradient Power Flow Terms in Low-Temperature Regenerators

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The total power flow in regenerators of pulse tube refrigerators is key to their performance because it reduces the gross cooling power available at the cold heat exchanger. At low temperatures (below approximately 10 K), the real-fluid properties of helium and the finite heat capacity of regenerator matrix solids create physical mechanisms for total power flow that depend only on the fluid's mean temperature, i.e., "non-gradient" mechanisms; these mechanisms add to those that depend on the gradient of mean temperature. The conservation of total power flow and the sensitivity of real-fluid properties to mean temperature leads to rapid variation of mean temperature along the regenerator axis. Using analytical calculations and experiments where we vary the regenerator warm-end and cold-end temperatures, we show that the relative magnitude of non-gradient power flow terms at the warm and cold ends of the regenerator determine the general shape of the mean temperature profile—whether a large temperature gradient appears at the warm or cold end of the regenerator while the opposite end shows nearly zero temperature gradient. We use the relatively abrupt boundary between these two types of profiles as a probe to better understand the non-gradient power flow mechanisms in regenerators and show its utility in determining where and how to improve materials and design in low-temperature regenerators.