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C1Or2B-03: Exergy measurements between a 4 K pulse tube refrigerator and its compressor

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At only about 1% of Carnot, the overall efficiency of 4 K, Gifford-McMahon cryocoolers and Gifford-McMahon type pulse tube refrigerators is not impressive. These refrigerators are most often studied from the perspective of minimizing losses in their regenerators and/or thermal buffer tubes, which are important topics, especially in the real-fluid regime where regenerator losses are very large. However, there are also significant inefficiencies that occur between the compressor and the refrigerator during the generation and delivery of acoustic power. These losses have rarely been considered in detail. In this study, we highly instrumented the flow paths between a commercial 4 K, two-stage pulse tube refrigerator and its compressor with high-speed mass flow meters, pressure transducers, and thermometers. With these measurements, we calculate and track the evolution of exergy between the outlet of the compressor and the inlet to the refrigerator, so that the efficiency of each process can be determined. Measurements show that a large amount of exergy is destroyed at the rotary valve, as the work of compression is not recovered in these systems. We also measure the efficiency of the commercial scroll compressor, and the exergy destroyed in the helium hoses between compressor and refrigerator. Measurements are presented for a variety of operating frequencies and cold-end temperatures. These results demonstrate that state-of-the-art pulse tube refrigerators generate acoustic power with low efficiency.

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