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C3Or3B-04: Development of hydrogen-filled traveling-wave thermoacoustic engine for powering pulse-tube and traveling-wave refrigerators

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Current cryocooler technologies rely on compressors and displacers to generate pressure oscillations requiring high electrical power and regular maintenance intervals. These requirements limit the convenience of cryocoolers for renewable energy, specifically zero-boil-off applications. Thermoacoustic instabilities are spontaneously excited sound waves in resonators, which transport energy along a piping network. Utilizing these sound waves to remove heat from the cold space creates a robust paradigm for cryogenic refrigeration (cryocooling) with no moving parts. This study discusses the design and implementation of a thermoacoustic cryocooler using hydrogen as the working fluid. A toroidal acoustic resonator system is designed to excite traveling sound waves using an imposed temperature gradient on an engine regenerator between the ambient and hot heat exchangers. The generated acoustic waves then propagate into the pulse-tube or traveling-wave setup producing refrigeration in the cooler regenerator. Modeling techniques, results, and the optimal geometric configurations for the engine-refrigerator combinations are reported. The geometric configurations are selected to minimize the temperature gradient required in the engine core to reach a cryogenic temperature below 100 K for a single-stage pulse-tube or traveling-wave setup and produce acceptable cooling power and COP at 110 K. A goal of this initial study is to establish the feasibility of this new cooling paradigm which can be scaled up to intercept heat leak in liquid hydrogen storage vessels.

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