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Evaluating Fluid-Induced Vibrations in Sorption-Based JT Coolers

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The ETpathfinder (ETPF) is a scaled prototype of the Einstein Telescope Gravitational Wave Observatory (ET), aimed at testing and refining the necessary technologies for gravitational wave detection. The ETPF utilizes two Fabry-Perot Michelson Interferometer arms with mirrors that are cryogenically cooled using liquid nitrogen (LN2). One of these arms requires additional cooling of its mirrors to about 10 K, essential for achieving the desired sensitivity levels in the detectors. This extra cooling is crucial for the accurate measurements demanded by third-generation laser-interferometry detectors in the ETPF and later in the ET, necessitating a cooling system that emits minimal vibrations. To address this requirement, the University of Twente has already proposed a modular cryochain design, employing a combination of sorption-based compressors and Joule-Thomson (JT) cold stages. This design features a parallel cascade configuration with stages at 40 K (neon), 15 K (hydrogen), and 8 K (helium), providing cooling powers of 2.5 W, 0.5 W, and 0.05 W, respectively. The cooler chain is advantageous due to its minimal vibration levels, achieved by having no mechanical moving parts. This characteristic is critical to ensure that the vibration levels at the 8 K cold-tip do not exceed the seismic background vibrations at the ETPF site. Specifically, these vibrations must stay below the environmental vibration threshold of 30 nm peak-to-peak, with an amplitude spectral density of 4 nm/Hz within the vital 2 - 20 Hz bandwidth. Therefore, evaluating the low but present vibrations emitted by the sorption JT cooler is essential. The predominant vibrations arise from fluid flow in the various JT cold stage components, such as tubing, bends, JT restriction devices, and evaporators. Our initial approach involved evaluating these fluid-induced vibrations and forces through fluid-structure interaction (FSI) simulations and preliminary room temperature measurements. This foundational research lays the groundwork for more detailed future characterizations of relevant fluid-induced vibrations in sorption-based JT coolers.

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