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C1Po1B-02 [13]: Integrated Refrigeration and Storage of LNG for Compositional Stability

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Growing interest in liquefied natural gas (LNG) as a rocket fuel necessitates a greater technical understanding of the compositional changes due to preferential boil-off (or weathering) that occurs during long duration storage. The purity of methane in LNG can range from 90 to 98%, and is subject to preferential boil-off due to its low boiling point compared to other constituents despite the use of high-performance thermal insulation systems. Active heat extraction (i.e. refrigeration) is required to completely eliminate weathering. For future operational safety and reliability, and to better understand the quality and efficiency of the LNG as a cryofuel, a 400-liter Cryostat vessel was designed and constructed to measure the composition and temperatures of the LNG at a number of different liquid levels over long durations. The vessel is the centerpiece of a custom-designed lab-scale integrated refrigeration and storage (IRaS) system employing a G-M cryocooler capable of roughly 300 W of lift at 100 K. Instrumentation includes ten temperature sensors mounted on a vertical rake and five liquid sample tubes corresponding to five liquid levels. Two modes of operation are studied. The first is without refrigeration in order to determine a baseline in the change in composition, and to study stratification of the LNG. The second is performed with the cryocooler active to determine the operational parameters of the IRaS system for eliminating the weathering as well as stratification effects in the bulk liquid. The apparatus design and test method, as well as preliminary test results are presented in this paper. As a bonus in cost-saving and operational efficiency, the capability of the IRaS system to provide zero-loss capabilities such as zero boil-off (ZBO) keeping of the LNG and zero-loss filling/transfer operations are also discussed.

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