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C3Or4A-07: Effect of sloshing conditions on the boil-off rate of cryogenic liquid in membrane tank

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Evaluating the boil-off rate (BOR) of liquefied natural gas (LNG) transported in cargo containment systems is crucial for assessing system performance. Research has focused not only on static cryogenic storage tanks but also on tanks under sloshing conditions. Numerical simulations have demonstrated that sloshing significantly affects the thermophysical processes and boil-off gas (BOG) generation in LNG tanks. However, experimental data to validate these numerical simulations remain limited. This study aims to address this gap by experimentally investigating the effect of sloshing on the BOR of a cryogenic liquid stored in a prismatic membrane tank. Liquid nitrogen was employed as a substitute for LNG to ensure safety. A custom-designed shaker was developed to generate oscillatory motions of the tank. Two lab-scale tanks with identical inner dimensions were used in the experiments: a transparent Plexiglas water tank to observe sloshing behavior and measure impact pressures, and a cryogenic membrane tank for BOR measurements. The effects of key parameters, including excitation frequency, amplitude, and tank filling level, on BOR were systematically analyzed. Additionally, the mechanisms driving BOG generation during sloshing were thoroughly analyzed. The findings of this study are expected to provide valuable insights into BOG generation mechanisms under sloshing conditions and offer an experimental dataset to validate numerical models, thereby contributing to the design of more efficient LNG transport systems.

Keywords: Liquefied Natural Gas; Cryogenic Membrane Tank; Sloshing Dynamics; Boil-Off Rate.

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