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C2Or2C-02: Parametric Analysis of the Charge-Hold-Vent Method for Cryogenic Propellant Tank Chill Down

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In the absence of external heat exchangers, the on-orbit transfer of cryogenic propellants requires the receiver tank to first be quenched to a sufficiently low energy state to allow for a continuous no-vent fill to avoid unnecessary venting of liquid. One proposed method for tank chilldown that minimizes the potential for venting liquid is the charge hold vent (CHV) method. CHV follows a cyclic process that gradually removes thermal energy from the receiver tank by injecting liquid with the vent valve closed and allowing the fluid and wall to reach near-thermal equilibrium before venting the superheated vapor. However, the CHV method must be optimized to minimize complexity, mass, and time. This paper presents a modular CHV analytical model used to quantify the number of cycles and propellant mass consumed based on first principles. The model is used to examine the effect of eight parameters: receiver tank material, volume, mass, maximum expected operating pressure, and initial pressure, liquid injection pressure and temperature, and the target temperature. The model is validated against the only two available CHV datasets. Based on results, the tank mass-to-volume ratio is the most important factor in determining the number of CHV cycles and thus degree of difficulty in tank chilldown. The model can easily be used for early-stage design, sizing, and analysis of cryogenic propellant transfer systems.

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