Comparative CFD Analysis of Insulation Thickness and Material Selection for Boil-Off Mitigation in a Type V Liquid Hydrogen Tank

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Abstract

Liquid hydrogen storage is highly sensitive to heat ingress, leading to boil-off and self pressurization. This study presents a two-dimensional axisymmetric CFD model of a 92 L composite Type V tank containing approximately 6.5 kg of LH_2. The model couples conjugate heat transfer, external convection, radiation, natural convection, Volume of Fluid, and Lee phase-change formulations.

Under the same imposed accelerated thermal boundary conditions, near-complete liquid disappearance occurred after approximately 11 min without insulation. Adding 10, 20, and 30 mm of polyurethane extended liquid retention to approximately 20, 22, and 30 min, respectively, demonstrating the beneficial effect of increasing insulation thickness.

At a fixed thickness of 30 mm, liquid retention reached approximately 30 min with polyurethane, 55 min with vacuum perlite, and 70 min with silica aerogel. These results highlight the strong influence of insulation material on heat ingress and boil-off mitigation, with silica aerogel providing the longest retention time under the simulated conditions.

Overall, silica aerogel delivered the best thermal performance among the materials investigated, followed by vacuum perlite and polyurethane at the same insulation thickness. These findings identify insulation thickness and material selection as key design parameters for reducing boil-off in Type V liquid hydrogen tanks.

Keywords

Liquid Hydrogen, Boil-Off, Type V Tank, CFD, Thermal Insulation, Silica Aerogel, Polyurethane.