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M1Or2C-03: Cryogenic Thermal Performance of the Vacuum Insulation System for LH2 Storage Tanks

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Due to the strict emission restriction standards for fossil fuels, hydrogen has great promise as a future ecofriendly fuel. It is the most abundant chemical element in the universe, and hydrogen energy production emits no greenhouse emissions. However, since hydrogen is the lightest element, large-volume storage tanks are required to realize the same fuel efficiency as fossil fuels. Hydrogen can be stored in gaseous, liquid, and solid forms (metal hydrides). However, in terms of the storage efficiency, liquid hydrogen is the most suitable. Moreover, since the risk of explosion of liquid hydrogen is significantly lower than that of high-pressure tanks, it can be employed for storage and transportation applications. Liquid hydrogen storage tanks require an effective insulation system to prevent heat ingress from the outside. Therefore, unlike conventional LNG, all heat transfer mechanisms, i.e., conduction, convection, and radiation, need to be blocked in liquid hydrogen storage tanks. Particularly, since liquid hydrogen has a lower boiling point and a lower density and latent heat of vaporization than LNG, even a small heat ingress may cause significant loss. For liquid hydrogen storage tanks, the design of its insulation system is an important influencing factor, and their performance depends on the filler and protective materials employed for the vacuum insulation system. The performance of existing insulation materials is evaluated in terms of thermal conductivity, but the performance of vacuum insulation systems is difficult to similarly evaluate. Therefore, effective thermal conductivity, which reflects both convection and radiation, is used as a performance index. Effective thermal conductivity is a material property that is calculated based on the heat flux and financial resources of the measuring equipment when no dominant heat transfer mechanism is present. The cryogenic thermal property data of the liquid hydrogen fuel tank insulation system have been measured by NASA for rocket propulsion. The apparatus used in the cryogenic insulation test has been reported in two technical standards of ASTM International: C1774 and C740. However, the standards recommend using 77 K liquid nitrogen as the test fluid. In this study, the advanced cryogenic insulation test apparatus and methods with 4 K liquid helium are investigated. The facility comprises two helium chambers (test and guard chambers), and the heat ingress is blocked using MLI vacuum insulation and liquid nitrogen shield to minimize the helium loss. For verification, the obtained results are compared with the data reported by NASA, and the insulation performance of powder materials (such as glass bubble and perlite) suitable for the insulation system of the current large-capacity liquid hydrogen storage vessel is evaluated. Furthermore, to evaluate the powder material insulation system, a sample container is separately manufactured and a special material filter is used.

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