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C1Po3B-05: Simulation experiment of vacuum insulation deterioration in liquid hydrogen tank due to minute air leaks

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Liquid hydrogen tanks and transfer tubes have vacuum layer for thermal insulation which is usually enclosed by a sealing-off valve with rubber O-ring. The rubber O-ring must degrade with age and then air leak from the outside should be considered for long term operation over several years. However, most of the air content could be condensed by cryo-pumping effect and vacuum pressure may be maintained due to low temperature on the outside of liquid hydrogen vessel. Thus, the scenario can be predicted that vacuum loss suddenly could occur when cryo-pumping speed decline because of rather large leak or thick ice layer composition, and the condensed ice evaporate in a chain reaction. This study aimed to reveal the process of vacuum insulation degradation in liquid hydrogen tanks.

This kind of problem may be predicted by past experimental studies for the development of cryo-pump or the sudden vacuum loss of super conducting cavities. However, the condensation speed on minute air leak to vacuum layer due to aging degradation of rubber must be small so that the pressure growth may be slow since the cryo-surface is stainless steel. Thus, a compact experimental setup has been developed to perform accelerating tests. The time constant should be proportional to the ratio between vacuum volume and cryo-surface area. In this experiment, the vacuum vessel of 38 mm in diameter equipped with temperature-controlled tube of 6 mm inside 20 layers MLI to leak air was immersed in liquid hydrogen. The vacuum vessel is made of stainless steel. The buffer tank of air about 100 torr and two tiny valves in series have been used to realize minutes leak rate on the order of 10-4 m3Pa/s. The condensation speeds were much lower than that of knowledge of cryopumps. It is indicated that degradation process of vacuum insulation strongly was related to heat transfer through the rarefied gas in the region between free molecular flow and continuous flow.

Since the number of experiments using liquid hydrogen was limited, the present experimental results have been compared with the results using liquid nitrogen and carbon dioxide in our previous experimental study. Liquid hydrogen test had been carried out at Noshiro Rocket Testing Center in JAXA where provides support for safe experiments related to hydrogen. Understanding physics of condensation and predicting results with wide parameters were examined.

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