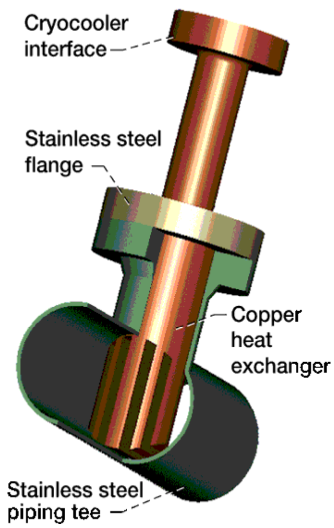
Zero-Boiloff Cryogenic Storage Cryocooler Integration Test

Developments in NASA Glenn Research Center's Centaur work have led to an exciting new cryogenic storage concept being considered for future NASA space missions. With long-duration cryogenic storage, propellants will boil off because of the environmental heating of the tank. To accommodate these losses, extra propellant is required along with larger propellant tanks. Analyses of space transportation concepts show that space-transfer cryogenic stages with the zero boiloff (ZBO) cryogenic storage concept reduce the stage mass for missions longer than approximately 45 days in low Earth orbit. The ZBO system consists of an active cryocooling system using a cryocooler in addition to traditional passive thermal insulation.

Engineers at Glenn analyzed, designed, built, and bench tested a heat exchanger and integration hardware for a large-scale ZBO demonstration for the NASA Marshall Space Flight Center. The heat exchanger, which transfers the heat that enters the tank from the fluid to the cryocooler, must limit the temperature difference across it to limit the cryocooler size and power requirements. With a low temperature difference, the system efficiency is improved.

For that temperature difference to be reduced, the thermal conductivity must be as high as possible at liquid hydrogen temperatures, around 25 K (-248 °C). In addition, it is important for the heat exchanger to be welded to a stainless steel flange and have enough strength to accommodate piping stress. High-conductivity copper was selected and fabricated, then integrated with the stainless steel piping tee as shown in the cutaway representation. Literature showed that this conductivity might range from 2 to 100 W/cm/K but that is was likely to be around 13 W/cm/K. Unexpectedly, this conductivity was measured to be 23 W/cm/K, which limited the temperature increase along the heat exchanger to just 2 K. This limited temperature increase, compared with the predicted difference of 3.5 K, improves the overall system efficiency by 7.4 percent and limits the expected integration losses to a projected 4 percent with a flight design for liquid hydrogen storage. These results improve the cryocooler integration concept by allowing the cryocooler to operate at a lower input power, or by potentially permitting a smaller cryocooler to be selected.



Zero-boiloff heat exchanger concept.

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