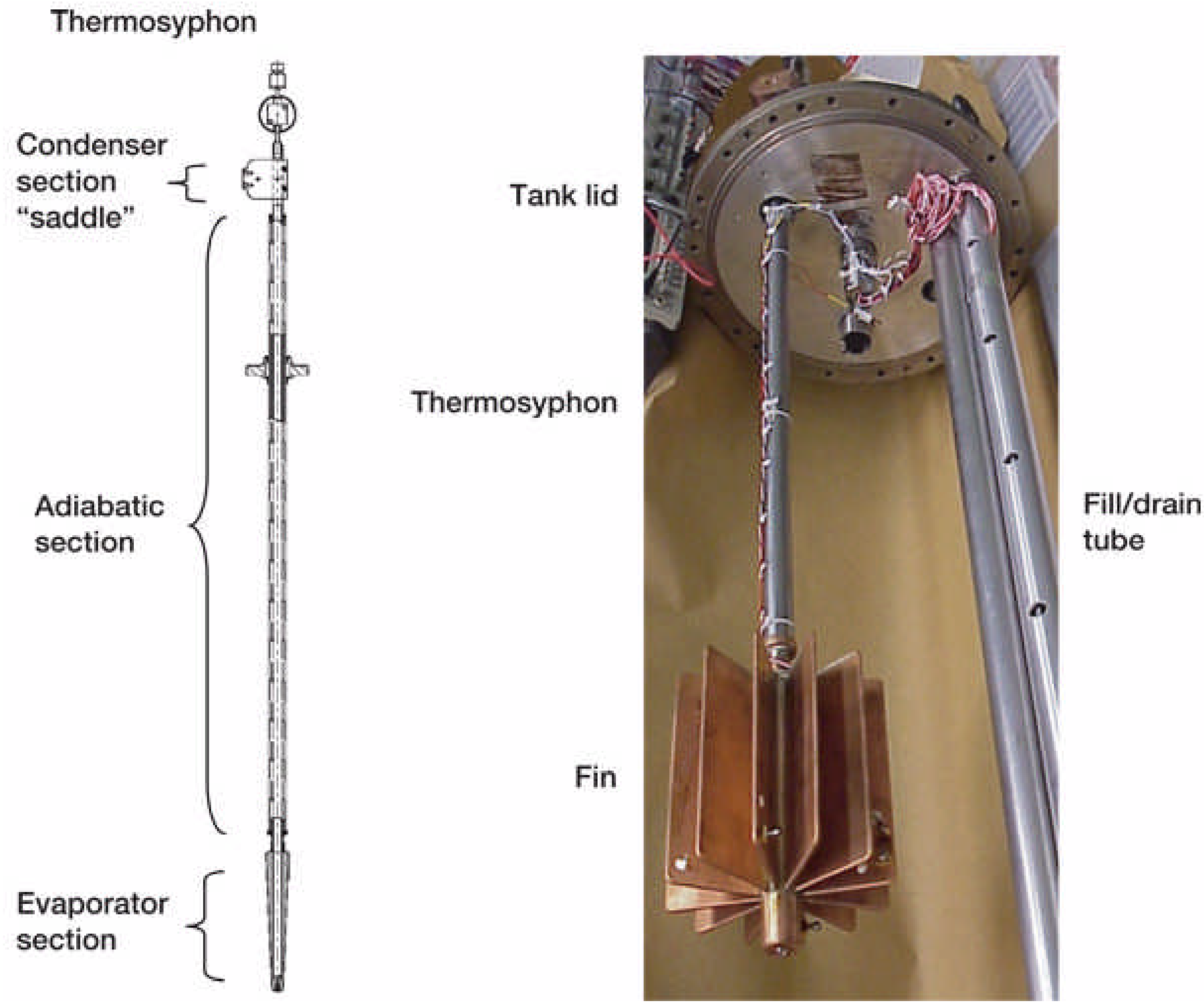
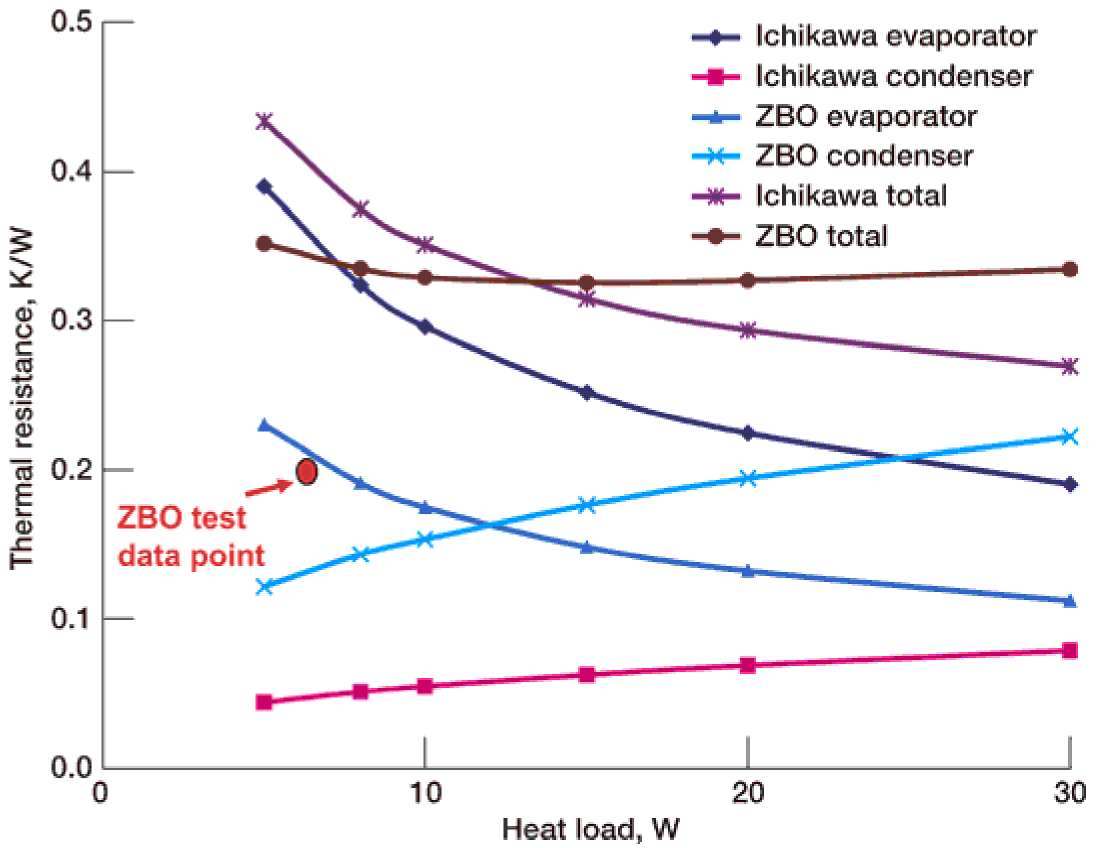
Cryogenic Nitrogen Thermosyphon Developed and Characterized



Left: A thermosyphon schematic is shown. Near the top is the condenser saddle, which is where the cryocooler was coupled. Right: Picture of the as-built hardware. The tank lid shown is toward the top of the adiabatic section of the thermosyphon. The fin is the heat exchanger coupled to the evaporator. It was where the heat entering the cryogenic test tank was removed.

A two-phase nitrogen thermosyphon was developed at the NASA Glenn Research Center to efficiently integrate a cryocooler into an insulated liquid-nitrogen-filled tank as part of an advanced development zero-boiloff (ZBO) ground test. NASA Marshall Space Flight Center's (MSFC) Advanced Space Transportation Program supported this test to improve the performance of in-space propulsion system concepts. Recent studies (ref. 1) have shown significant mass reductions and other advantages when incorporating active cooling in a ZBO configuration, enabling consideration of high-performing cryogenic propellants for long-duration applications in space. Active cooling was integrated via a thermosyphon, made of copper, 42 in. (1070 mm) long with an inner diameter of 0.436 in. (11 mm). It was charged with nitrogen to 225 psia at 300 K, which provided a fill ratio of 15 percent. The temperatures and heat flows through the thermosyphon were monitored during the startup phase of the ZBO test, and steady-state tests were conducted over a range of increasing and decreasing heat flows. The results also were compared with the initial design calculations and with results for a similar thermosyphon. They show that the thermal resistance of the thermosyphon was one-half of that expected--0.2 K/W at a heat flow of 8.0 W. The design calculations also showed that this resistance can be made relatively constant over a wider range of heat flows by making the ratio of evaporator area to condenser area 3:1. The better-than-expected results will translate into reduced integration loss for the ZBO concept. Analysis and test details are described in reference 2.



This figure shows that the Ichikawa (best reference available) total resistance was strongly influenced by the evaporator; the large condenser did not add much to the total resistance. The ZBO thermosyphon thermal total resistance is relatively constant, caused by a decreasing evaporator resistance counteracted by an increasing condenser resistance. The ZBO test data point shows that the built thermosyphon had much less resistance than predicted.

References

1. Plachta, David; and Kittel, Peter: An Updated Zero Boil-Off Cryogenic Propellant Storage Analysis Applied to Upper Stages or Depots in an LEO Environment.

NASA/TM--2003-211691, (AIAA Paper 2002-3589), 2003.
http://gltrs.grc.nasa.gov/cgi-bin/GLTRS/browse.pl?2003/TM-2003-211691.html

2. Christie, R.; Robinson, D.; and Plachta, D.W.: Design and Operating Characteristics of a Cryogenic Nitrogen Thermosyphon. Paper presented at the Cryogenic Engineering Conference, C3-C-07, 2003.

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