A Self-regulating Freezable Heat Exchanger for Spacecraft

Final Project Summary

NASA Contract # NNX12CG21P

A spacecraft thermal control system must keep the cabin (both air and its structure if manned) and electronic equipment within a narrow temperature range even though the environment may vary from very cold to warmer than room temperature. Since water is safe to use and an excellent coolant (other than its high freeze point and volumetric expansion during freeze), a water coolant loop often is used to transport heat to or from the spacecraft via heat exchangers to the heat sink systems that reject heat to space. Some of the heat exchangers would freeze, particularly the ones transporting heat to a flash evaporator or cold radiators exposed to deep space, if not for system controls to prevent it. Yet, the principle of allowing a heat exchanger to freeze can be utilized to increase the turn-down of the heat rejection rate (e.g. to vary the heat rejection from radiators). Unfortunately, the expansion during the phase change of water to ice may damage and ultimately fail the heat exchanger if it is not designed to withstand this event. TDA Research, Inc. has been developing water/ice phase change heat exchangers for several years, since the thermal control system can be simpler (a secondary loop between the coolant water loop and the heat sink systems may no longer be needed) and smaller in size while reducing the use of consumables.

In this NASA STTR Phase I project TDA Research designed and built a lightweight and freeze tolerant water/ice heat exchanger to passively regulate the heat rejection rate from the water coolant loop to the heat sink systems. The heat exchanger has no actively moving parts and thus proved to be extremely reliable; it was undamaged and in excellent working condition after nearly two-hundred freeze/thaw cycles. In our experiments the steady-state heat transfer ranged from 50 W to 1000 W (Figure 1). Our collaborator, the University of Colorado, conducted a systems analyses of spacecraft active thermal control systems (ATCS) using our heat exchanger. They concluded that the self-regulating freezable heat exchanger could reject the anticipated range of heat loads. Further, architectures with our freezable water/ice heat exchanger can eliminate the ammonia loop to improve safety and reduce the size of the radiator to reduce the mass of a single-loop ATCS by up to 20%.

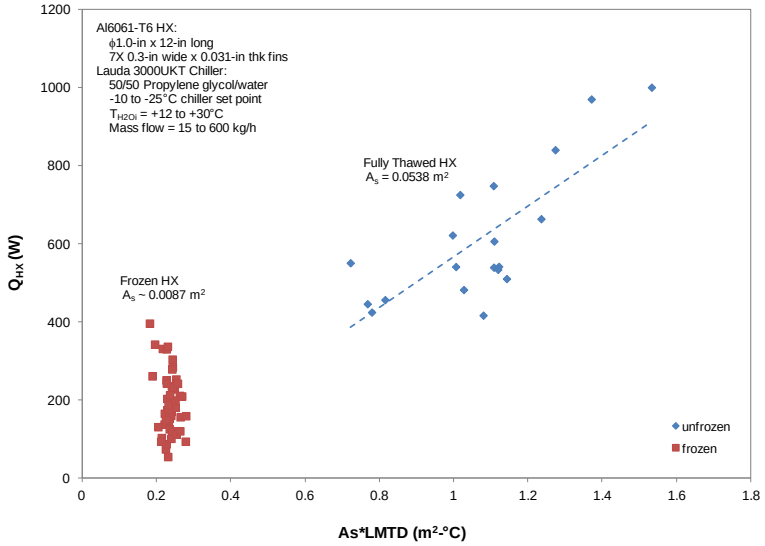

Figure 1. Heat transfer rates with the Al-6061-T6 SRHX when thawed (the blue diamonds) and frozen (the red squares). Photo: Most of the heat transport channels are frozen. A thermally insulated channel remains open.