Variable Conductance Heat Pipe with Non-Condensable Gas Flow for Lunar Night Survival Kuan-Lin Lee[1], Calin Tarau[1], William G. Anderson[1], Cho-Ning Huang[2], Chirag Kharangate[2] and Yasuhiro Kamotani[2], [1]Advanced Cooling Technologies, Inc. (1046 New Holland Ave. Lancaster 17601, kuan-lin.lee@1-act.com) [2]Case Western Reserve University (10900 Euclid Ave., Cleveland, OH 44106, crk91@case.edu).

Introduction: As NASA adventures back to the moon, spacecraft thermal designers are facing the unprecedented challenge of surviving extended excursions in the cold environment of the lunar night, potentially using only resistive heating. Thermal management for the Moon is challenging, due to the 14-day-long Lunar night. Since many Lunar Landers and Rovers are solar-powered, batteries are required to provide survival power. Survival power must be minimized since providing 1 Watt over the 14-day long Lunar Night requires about 5 kg of extra solar cells and batteries. This can be done with a passive variable thermal link between the battery box and the radiator, which can be a Hot Reservoir Variable Conductance Heat Pipe.

A hot reservoir variable conductance heat pipe has a Non-condensable Gas (NCG) reservoir located near the evaporator, which offers passive and tight thermal control capability compared to a regular VCHP with a cold-biased reservoir. It was found through the ISS test [1] that the reliability of hot reservoir VCHPs is a development bottleneck. Under an STTR program, Advanced Cooling Technologies, Inc (ACT) and Case Western Reserve University (CWRU) developed a new VCHP configuration that involves continuous internal NCG flow. This flow will prevent the working fluid from condensing in the non-wicked hot reservoir during normal operation as well as will effectively remove working fluid from the reservoir. As illustrated in Figure 1, this new configuration consists of a warm reservoir, a heat pipe section, and two NCG tubes. One is internal, coming out from the reservoir and going through the heat pipe section from the evaporator side. The second NCG tube is external, coming out from the reservoir and entering the end of the condenser. Because of the loop configuration, a flow can be induced by the momentum of the primary vapor flow through the annular region of the heat pipe. This flow will provide continuous NCG humidity control in the reservoir and, therefore, eliminate the otherwise needed additional electric heating.

A compact VCHP prototype (shown in Figure 2) was developed by ACT. The thermal control performance, purging capability, and startup behavior were experimentally characterized. The bulk NCG flow induced by the momentum of the vapor is in 1 cm/s range. Without the flow, purging is dominated by diffusion and it will take hours to complete. With the NCG flow, the purging rate is much faster and the heat pipe can get back to normal operation within 20 minutes. The presentation will summarize the development progress of the VCHP with NCG flow, including prototype development, thermal control testing, purging, and startup testing in different orientations and with different working fluids.

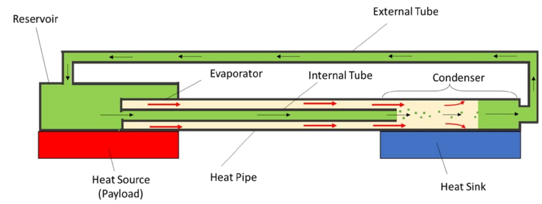

Figure 1. Hot Reservoir VCHP with NCG Flow for Reliability Enhancement

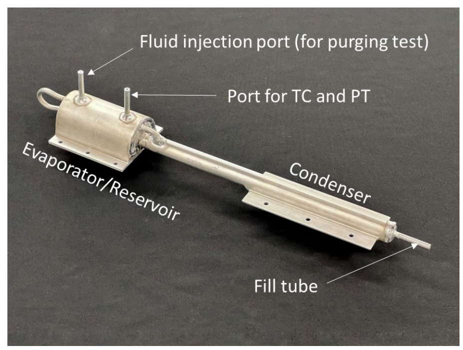

Figure 2. A compact hot reservoir VCHP with NCG flow Prototype

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