High Turndown Two-Phase Thermal Switch for Lunar Lander and Rover Thermal Management. N. Van Velson[1], D-P. Schulze[1], J. Diebold[1], C. Tarau[1], and W.G. Anderson1[1], [1]Advanced Cooling Technologies, Inc., 1046 New Holland Ave., Lancaster, PA 17601

The lunar night poses a significant challenge to the thermal management of lunar landers and rovers. In order for lunar landers and rovers to operate for long durations on the lunar surface, the on-board electronics must be maintained above their survival temperature during the long lunar night. This could be done with the use of survival electric heaters; however, it has been estimated that for every Watt of power supplied by batteries during the lunar night, an additional 5 kg of battery mass is required. Surviving the lunar night without the use of electric power for heating will require advanced passive thermal management technologies.

Thermal switches are among the passive thermal control devices that can be utilized in lunar lander and rover thermal management systems. Thermal switches are designed to minimize heat transport when in the “Off” condition, and to maximize heat transfer when in the “On” condition. The actuation of the thermal switch often happens at a specified set point temperature. To date, most passive thermal switches use the expansion/contraction of a volume to make/break a mechanical contact between two surfaces. These thermal switches typically have a capacity of only a few Watts.

As an alternative, a new passive thermal switch design has been developed and demonstrated, that can carry high powers with a high On/Off conductance ratio. This thermal switch design utilizes a sealed flexible bellows that contains a saturated two-phase working fluid. At low temperatures, the saturated vapor pressure within the bellows is low, and the bellows is not in contact with the heat sink. At higher temperatures, the vapor pressure increases, causing the bellows to expand until in comes into contact with the heat sink, allowing heat to be transferred by evaporation and condensation of the working fluid. The actuation temperature at which the bellows comes into contact with the heat sink is determined by the balance of forces between the vapor pressure of the working fluid and the spring force of the bellows, as well as the pressure of any external gas surrounding the bellows. An internal wick structure can be incorporated to enable gravity- and orientation-independent operation.

A coupled thermal-mechanical model of the bellows-based thermal switch was developed to understand the dynamic performance and estimate the thermal On/Off conductance ratio. Several thermal switch devices were fabricated for concept demonstration and model validation. These devices utilized bellows with different spring constants and were charged with different working fluids to fully characterize the thermal performance. Additionally, a thermal management system utilizing a high On/Off conductance ration thermal switch was developed for a small lunar rover. A prototype lunar rover thermal management system was fabricated and tested. Further development and optimization of the two-phase thermal switch technology is ongoing, including strategies for maximizing the On/Off conductance ration, and design of a thermal switch for high powers (~100 W).