Aluminum-Ammonia Screen Wick Heat Pipes for Lunar Surface Missions

J. Diebold, N. Van Velson, D.P. Schulze, C. Tarau, and B. Anderson, Advanced Cooling Technologies, Inc.

Introduction: On the lunar surface, the design of a passive two-phase thermal management system requires careful consideration of gravity. Grooved-wick aluminum-ammonia heat pipes cannot operate in a gravitationally adverse orientation (heat source above the heat sink) due to the inability of the grooves to pump liquid against gravity. On the lunar surface this limits their orientation to vertical surfaces so that the heat pipe is always gravity aided. Space copper-water heat pipes with screen or sintered powder wicks can operate against gravity but present complications due to the freezing of water. Advanced Cooling Technologies (ACT) is currently developing aluminum-ammonia heat pipes with screen wicks. With properly designed wicks the heat pipes can carry a significant amount of power at slight adverse gravity orientations. This enables applications where the heat pipes will be on nominally horizontal surfaces of a lander or rover that may experience arbitrary and even dynamically changing tilt angles due to the lunar terrain.

In this presentation, ACT will discuss the design and performance of a heat collector plate with embedded aluminum-ammonia screen-wick heat pipes. The system is designed to collect heat from several electronics and direct it to a centrally located loop heat pipe evaporator for transport to a radiator. Theoretical analysis and experimental results for individual heat pipes and the entire heat collector plate at various orientations with respect to gravity will be discussed.

Key Results: The screen wick aluminum-ammonia heat pipe is capable of operating over a wide temperature range, -60°C to +60°C, and against gravity up to 30° on the lunar surface. Prototype performance agreed well with capillary limit predictions. In addition, the screen wick allows the pipe to startup in an arbitrary adverse orientation with respect to gravity.

An aluminum heat collector plate was fabricated with eight embedded aluminum-ammonia screen-wick heat pipes. The heat collector transports 213W from three separate heat sources to a loop heat pipe evaporator with a maximum temperature drop of 10-15°C. Operation of the system is demonstrated up to an equivalent of 30° with respect to gravity on the lunar surface with no impact on performance.

Advantages: The aluminum-ammonia heat pipe and heat collector/spreader with screen wick has several advantages for thermal management on the lunar surface. Aluminum provides a lightweight envelope. Ammonia is a strong working fluid with a wide operating temperature range (-60°C to +60°C). The freezing of ammonia, for example during the lunar night, does not present the same challenges associated with water freezing. The screen wick allows the heat pipe to operate against gravity relaxing geometric constraints on the thermal management system. This is especially valuable for rovers and landers where the precise orientation is unknown or even dynamic.

Acknowledgments: This work has been performed under NASA Small Business Innovation Research (SBIR) Sequential Phase II Contract: 80NSSC21C0614.