Loop Heat Pipe

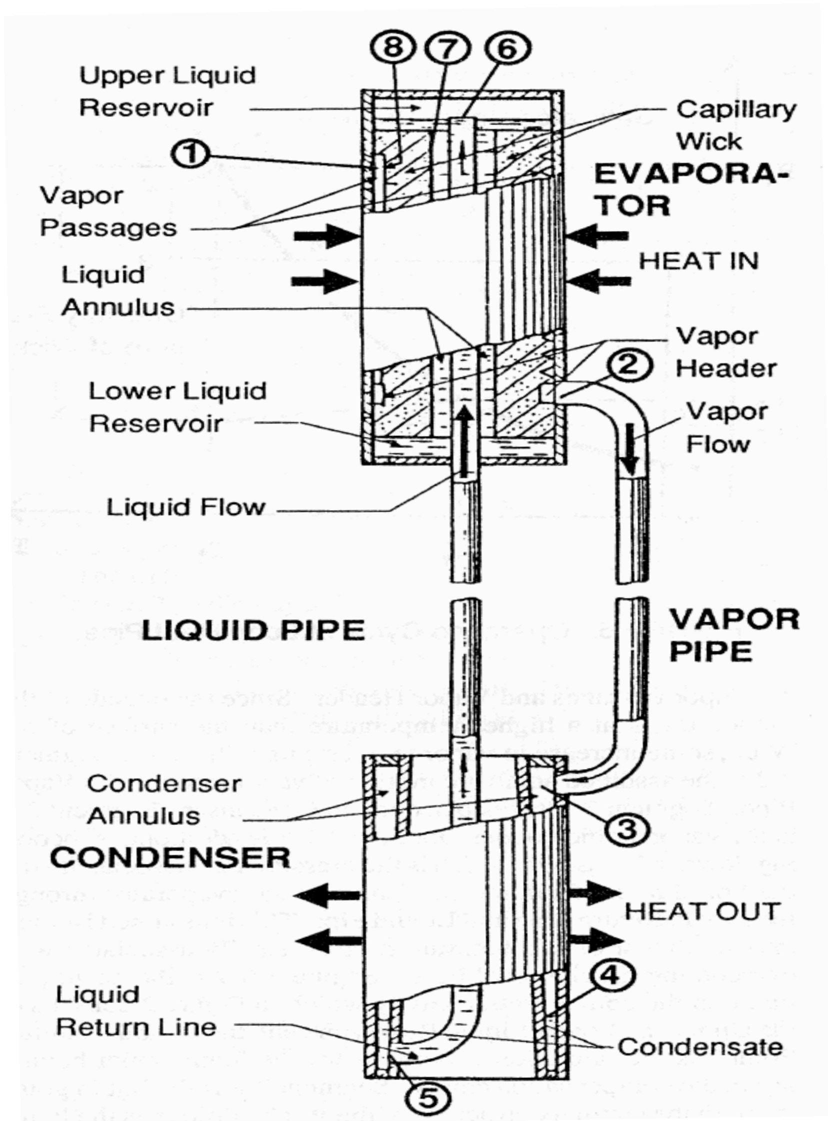

Figure 1. Self Priming Loop Heat Pipe

Loop Heat Pipes (LHP) combine the advantages of both conventional heat pipe and Capillary Pumped Loops, while overcoming the limitations of each (Wolf et al. 1994). It was developed by the former Soviets in the early 1980s and patented in the U.S. (# 4, 515, 209) in 1985. The DTX corporation became the exclusive North American licensee of this technology in 1993.

Referring to a representative LHP in Fig. 1, the upper portion is the evaporator; heat enters as shown and vaporizes working fluid at the surface of the wick. The vapor is collected by a system of grooves and headers and flows down the right hand pipe to the condenser. The condensate collects at the bottom of the condenser (which could be circular or, as shown, annular in cross-section) by gravity and/or capillary action (if the condenser is tapered to enhance collection by additional capillary pumping for operations in a microgravity environment). The vapor pressure of the working fluid forces the condensate up the central pipe where it replenishes reservoirs at both ends of the evaporator. A small annulus connects the upper and lower reservoirs in the evaporator and feeds liquid to the wick. The device is made self-priming by carefully controlling the volumes of the reservoirs, condenser, vapor pipe and liquid return pipe so that if all the liquid were drained from the reservoirs, the resulting liquid level in the vapor pipe would be high enough to saturate the wick. If the reservoirs were not completely drained, the wick would be directly saturated from the liquid remaining in the reservoirs.

Figure 2 is the operating cycle of a representative Loop Heat Pipe. The heavy line in Fig. 2 is the saturation curve for the operating fluid. The reader might refer to Fig. 2 to help visualize the LHP structures which correspond to the points on the diagram.

Although LHP has been successfully used in space-crafts (Maidanik *et al.* 1991), de-icing applications, avionics cooling, etc.; it is well known (see Douglas *et al.* 1999) that many LHP require long start-up times, and, furthermore, they often fail to achieve certain steady or quasi-steady states. This long start-up time is, in all likelihood, due to the vapor-compressibility induced flow oscillations in the condenser-section whenever the typically small pressure differences across an LHP's condenser section (e. g. see lines 3 - 4, 3' - 4', etc. in Fig. 2) does not lie within a certain range of allowed values for a given heat load and geometry. This allowable range for an LHP is further limited by the maximum pressure difference allowed by the capillary/wicking action in the wick.

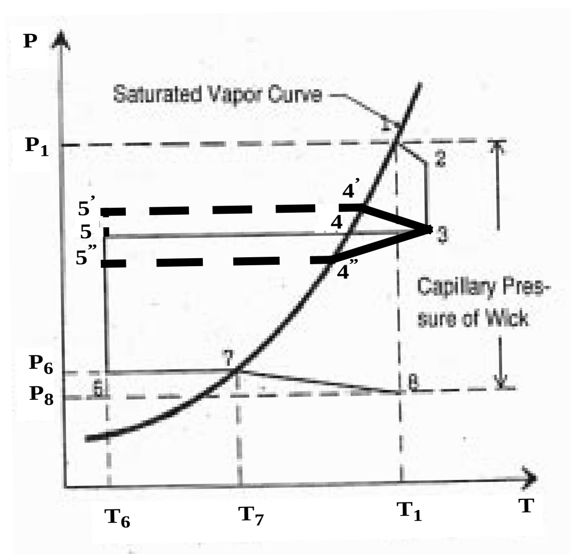

Figure 2. Operating Cycle of LHP (Courtesy: Wolf *et al.* 1994)

Wolf, D. A. Ernst, D. H. and Phillips, A. L., "Loop Heat Pipes - Their Performance and Potential", 24th ICES, SAE Trans. 4, pp. 1612 - 1618, Paper # 941575, 1994.

Maidanik, Y.F., Fershtater, Y.G., and Gorchnow, K. A., "Capillary-Pump Loop for the Systems of Thermal Regulation of Spacecraft", Proceedings for the 4th European Symposium on Space Environmental and Control Systems", Florence, Italy, ESA SP-324:88, 1991.

Douglas, D., Ku, J., and Kaya, T., "Testing of the Geoscience Laser Altimeter System (GLAS) Prototype Loop Heat Pipe", 37 the AIAA Aerospace Sciences Meeting and Exhibit, Paper # AIAA 99-0473, Reno, NV, Jan. 11-14, 1999.