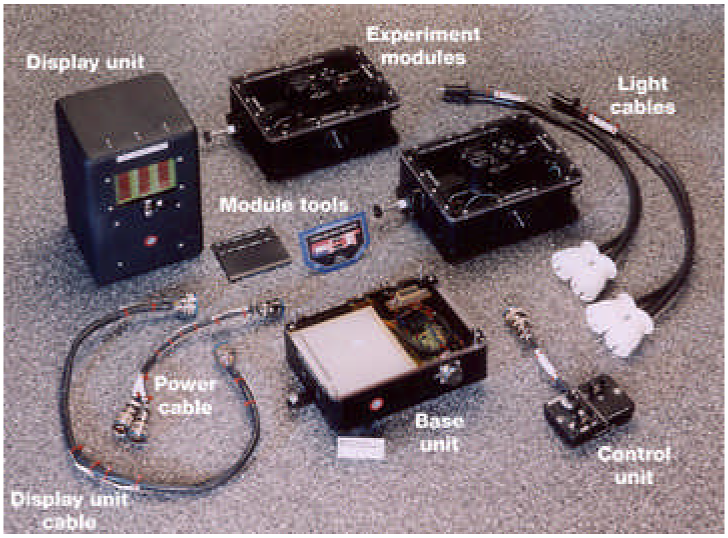
# Capillary-Driven Heat Transfer Experiment: Keeping It Cool in Space

Capillary-pumped loops (CPL's) are devices that are used to transport heat from one location to another--specifically to transfer heat away from something. In low-gravity applications, such as satellites (and possibly the International Space Station), CPL's are used to transfer heat from electrical devices to space radiators. This is accomplished by evaporating one liquid surface on the hot side of the CPL and condensing the vapor produced onto another liquid surface on the cold side. Capillary action, the phenomenon that causes paper towels to absorb spilled liquids, is used to "pump" the liquid back to the evaporating liquid surface (hot side) to complete the "loop."

CPL's require no power to operate and can transfer heat over distances as large as 30 ft or more. Their reliance upon evaporation and condensation to transfer heat makes them much more economical in terms of weight than conventional heat transfer systems. Unfortunately, they have proven to be unreliable in space operations, and the explanation for this unreliability has been elusive.

The Capillary-Driven Heat Transfer (CHT) experiment is investigating the fundamental fluid physics phenomena thought to be responsible for the failure of CPL's in low-gravity operations. If the failure mechanism can be identified, then appropriate design modifications can be developed to make capillary phase-change heat-transport devices a more viable option in space applications. CHT was conducted onboard the Space Shuttle Columbia during the first Microgravity Science Laboratory (MSL-1) mission, STS-94, which flew from July 1 to 17, 1997.

The CHT glovebox investigation, which was conceived by Dr. Kevin Hallinan and Jeffrey Allen of the University of Dayton, focused on studying the dynamics associated with the heating and cooling at the evaporating meniscus within a capillary phase-change device in a low-gravity environment. The CHT experimental hardware was designed by a small team of engineers from Aerospace Design & Fabrication (ADF), the NASA Lewis Research Center, and the University of Dayton. The hardware consisted of two experiment modules that each contained an instrumented test loop (idealized capillary-pumped loop), a base unit for power conversion and backlighting, a display unit with 15 LED's (light-emitting diodes) to display temperatures, pressure, heater power, and time, a control unit to select heaters and heater settings, a cooling fan, and associated cables.



*Flight hardware components of the Capillary-Driven Heat Transfer (CHT) experiment. The experiment modules contain the instrumented capillary-pumped loops.*

Several different CHT experiments were performed by the astronaut crew during the course of the MSL-1 mission. Although there is still a large volume of flight data to analyze, preliminary results indicate the following. First, instabilities of the evaporator meniscus can be violent enough to cause system failure. Also liquid slugs were found to develop in the vapor leg of the loop. These slugs blocked the vapor flow to the condenser, thus rendering another failure mode. This situation was not appreciated prior to on-orbit operations. Since all the CPL designs have a significant number of bends in the vapor leg, it is very probable that previous low-gravity capillary-pumped-loop experiments exhibited poor performance because liquid slugs were formed in the vapor line.

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