HEAT PIPE FLIGHT EXPERIMENTS

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The discussion that follows will be on heat pipe flight experiments as part of a Goddard evaluation program. The heat pipe is a general, all-purpose thermodynamic heat transfer device. It is rather simple in its theory.

The pipe, as seen in Figure 1, consists of a working fluid, usually ammonia methanol or acetone, with a wicking system. At the evaporator section where the heat enters, the working fluid is evaporated. The vapor travels down the tube to the condensor region, where it is condensed out and brought back by a wicking system. This device is generally used to transport large quantities of heat around the spacecraft. It is also used for isothermalizing optical instruments as in the Princeton Experiment on OAO, which I will discuss later.

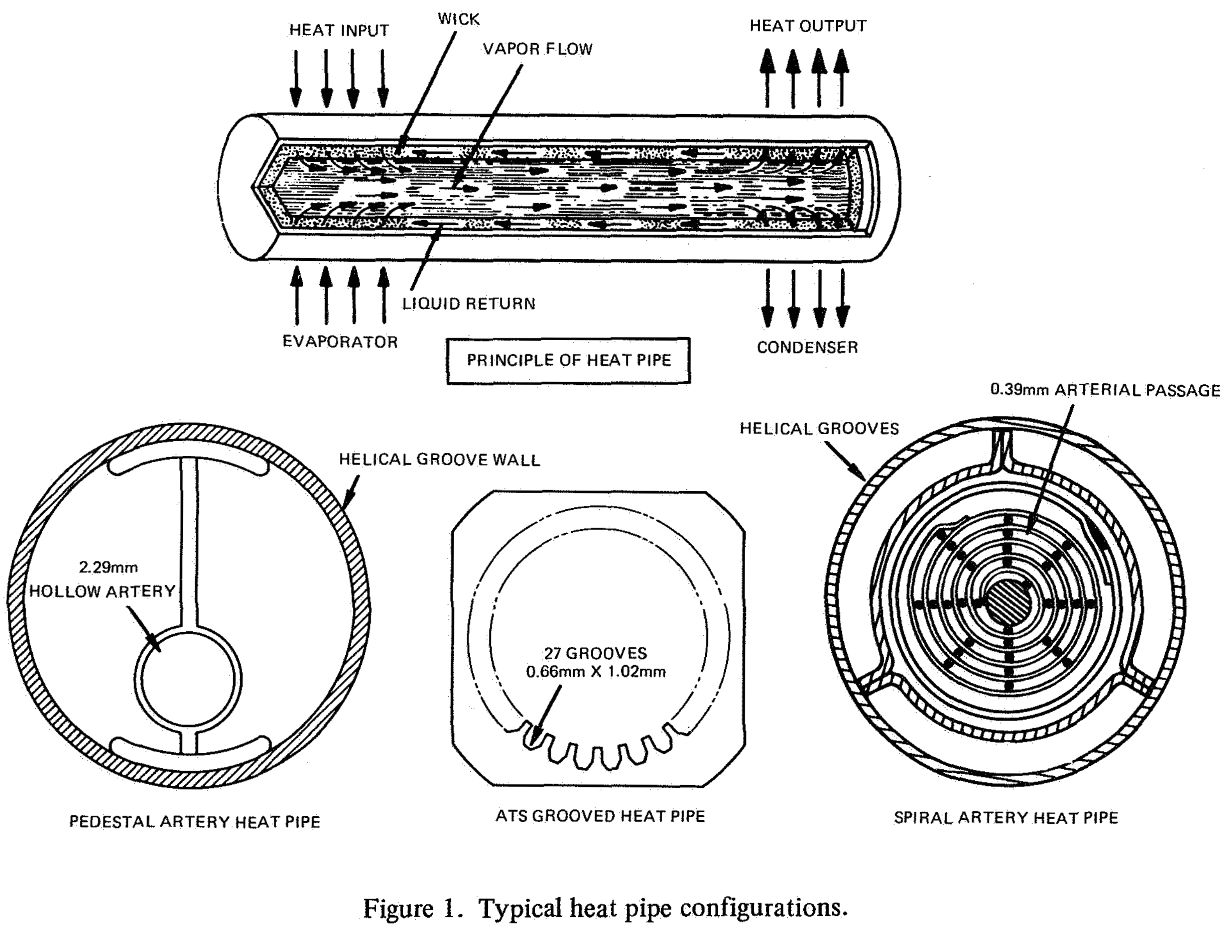

Figure 1. Typical heat pipe configurations.

Basically there are three types of pipes which we have developed over the years at Goddard. The first is the so-called pedestal artery, a hollow-channel screen system which provides a low-resistance path for fluid to return to the evaporator. It contains helical grooves on the wall for putting the fluid in good contact with the wall.

The second pipe is the grooved heat pipe which is a similar multichanneled heat pipe with a wicking system consisting of horizontal grooves.

The third pipe is a spiral artery pipe similar to the pedestal artery, except it contains many more channels for fluid to return to the evaporator.

Figure 2 shows the sounding rocket experiment which we have developed at Goddard as a quick-turnaround, low-cost item to check out heat pipes in zero-g.

In testing heat pipes on the ground, the one-g effects tend to produce incipient dryout, to cause puddling effects due to fluid falling to the bottom of the pipe, and to retard the arteries from priming. The sounding rocket provides a good vehicle for zero-g performance testing by eliminating these problems. Many parameters can be studied on the sounding rocket experiment since we have up to a kilowatt of power provided by a battery, which is not available on spacecraft. We have multiple heat pipe capability, up to 90 channels of signal conditioning, and can study many parameters such as overfill and underfill.

We have a new mission coming up that has a photographic capability: a camera and glass-heat pipes to study artery priming. We can also vary the power over the length to give us a checkout of heat transport capability.

Some of the typical data taken during a heat pipe flight experiment on a sounding rocket last October are given in Figure 3. We had five heat pipes on board, with one control heat pipe. It had the same geometry as the others, except that it contained no wicking system to bring the fluid back to the evaporator. At the point of zero-g, during free fall, the control pipe dried out as we had predicted, and the evaporator temperature rose to a high level. In the other heat pipes on-board, the evaporator and condensor maintained a constant delta T, showing that the experiment did work.

Figure 4 shows the OAO-3 with three of the heat pipes we have flown on board. They are typical of the ones flown on the sounding rocket for checkout prior to this launch, and are wrapped around the structural tube of the OAO at three levels. The Princeton Experiment Package gradients were maintained within two degrees Centigrade. Predictions without the heat pipes due to internal and external environmental changes were ten degrees Centigrade. This helped maintain the Princeton alignment in orbit.

We have one more heat pipe that is not shown here in one of the bays, mounted on the on-board processor. A variable conductance heat pipe maintained this on-board processor at between 20 and 30 degrees Centigrade during all portions of its power modes.

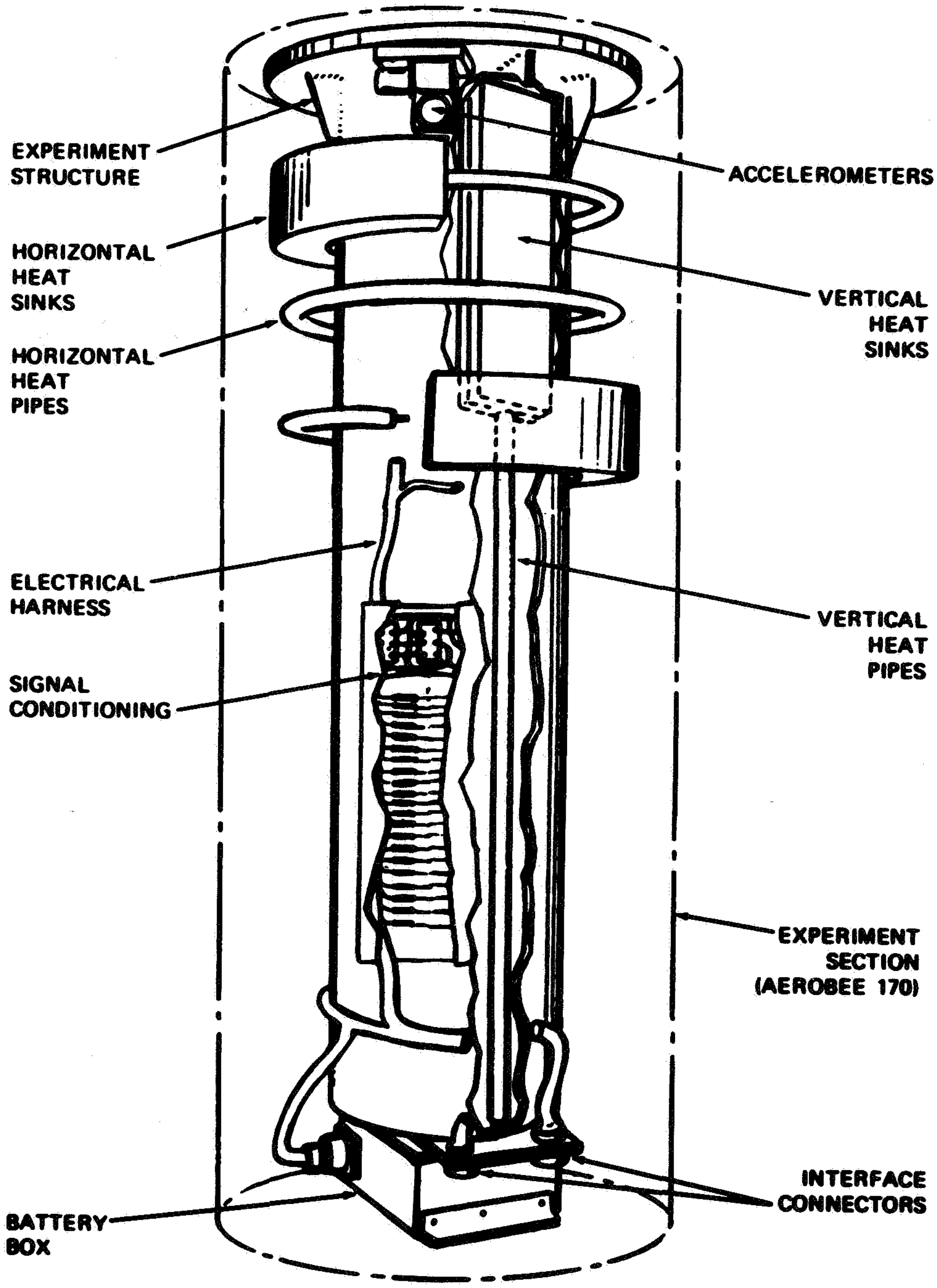

Figure 2. Experiment layout.

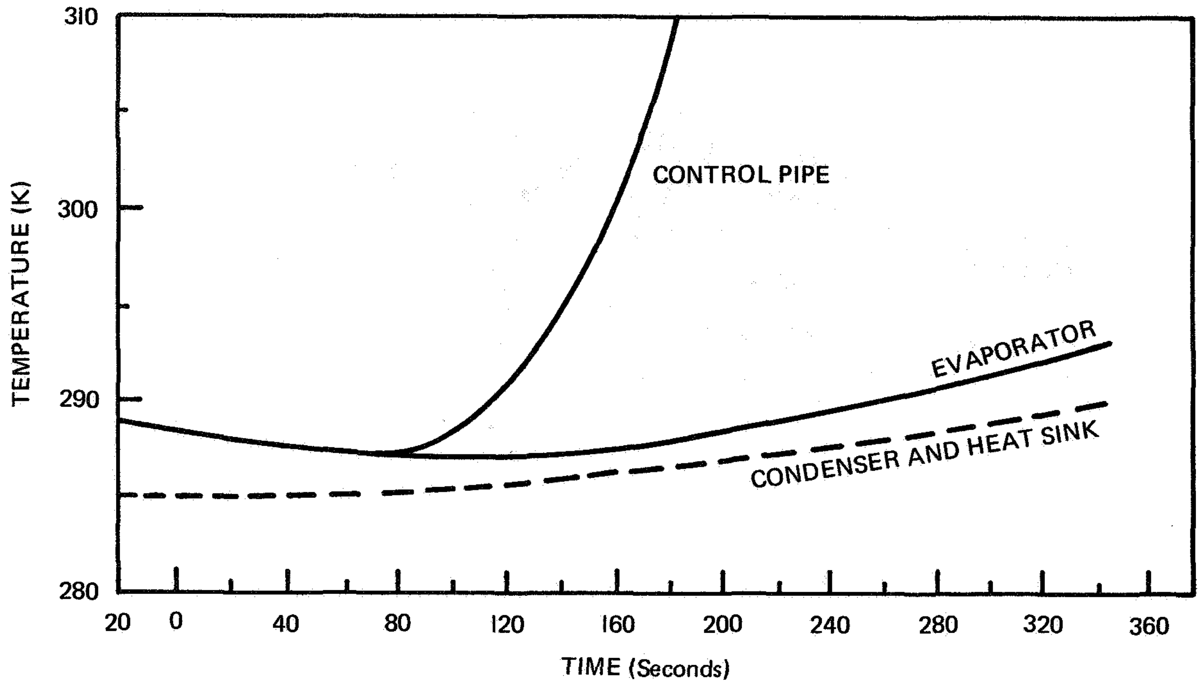

Figure 3. Thermal performance of spiral artery heat pipe.

The heat pipe worker program, a computer routine aboard the spacecraft, enabled us to activate up to 90 watts of heater power on each of these pipes, demonstrating an order of magnitude of greater capability than had ever been shown before in orbit. The heat transport capability, watts times centimeters, which is a measure of heat transport around the spacecraft, was approximately 15,240 watt-centimeters. This demonstrates that one can carry large amounts of heat over long distances and isothermalize within two degrees Centigrade.

The main function of the heat pipes on the OAO-C was to check out heat pipes over long-term life. Secondarily, of course, we have maintained gradients within the Princeton Experiment. We have had up to 1000 hours in orbit, and have checked the pipes three times. No degradation from gas generation or leakage of ammonia has been evident.

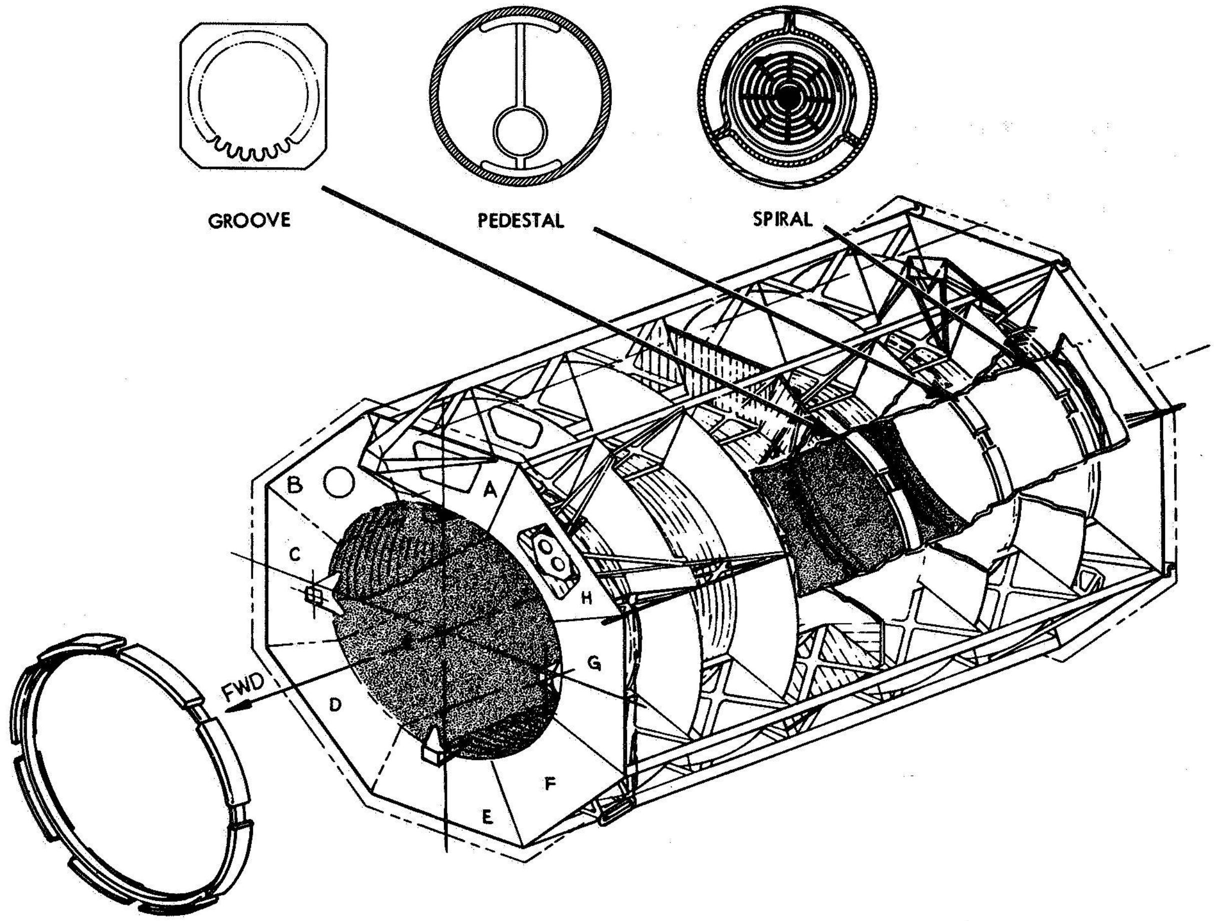

Figure 4. Positions of heat pipes in OAO-C.