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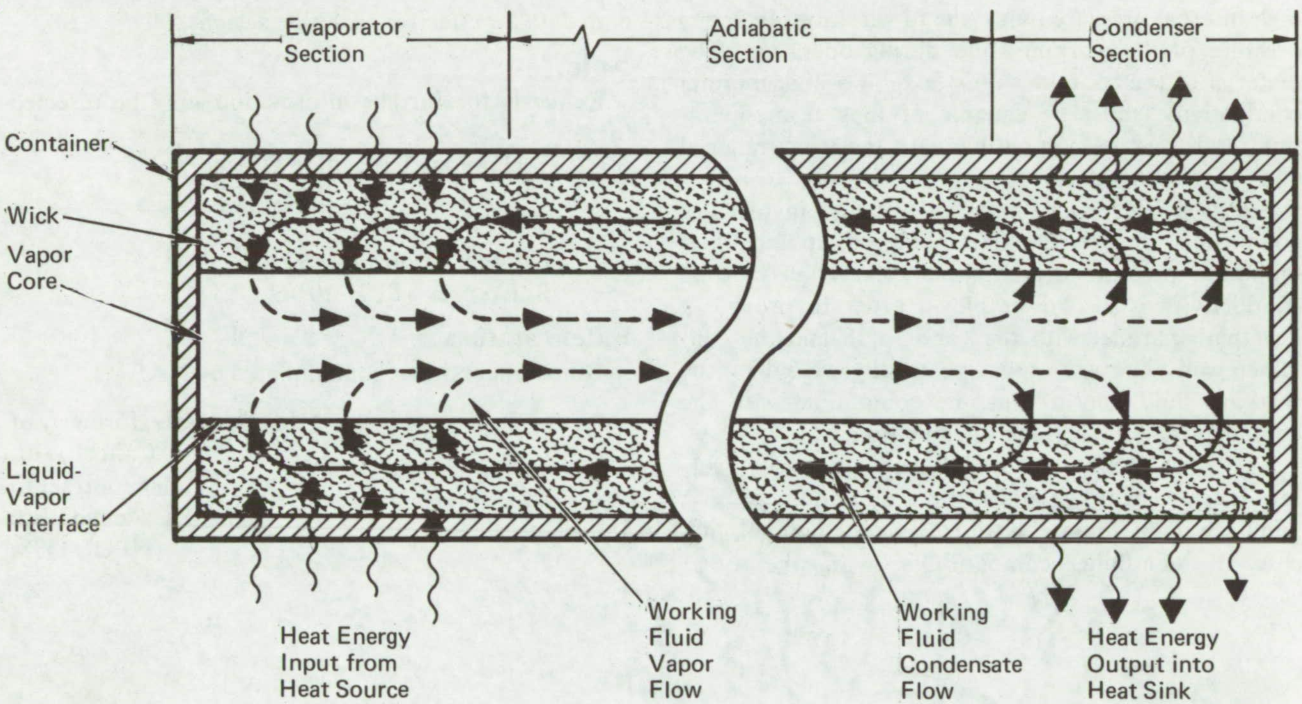
The Heat Pipe: A Simple, Versatile, Efficient Heat Transfer Tool

The heat pipe is a self-contained, closed system capable of transporting large quantities of heat from a source to a sink with only a small temperature drop. Thermal energy may be transferred to and from



the heat pipe by any combination of conduction, convection, or radiation heat transfer. Open flames, nuclear sources, and electronic equipment are among the heat energy sources whose energy has been transported by heat pipes. Thermal energy may be added at a high flux over a relatively small area and removed over a large area at a low flux, and conversely.

The heat pipe has no moving parts, requires no energy input other than the heat which it transfers, and does not rely on gravity for its operation. It consists simply of a sealed container lined with a wick and charged with a working fluid which is the primary heat transfer medium.

The container is usually a tube made of a metal which is compatible with the wick material and the working fluid. The wick may be metal, such as wire screens, sintered metal powder or fiber, or perforated metal sheets; or it may be a nonmetallic material, such as felt, cloth, or fiberglass. Water,

(continued overleaf)

ammonia, acetone, freons, alcohols, and various liquid metals have been used as the working fluid. Only enough fluid to saturate the wick is introduced into the heat pipe. The choice of a particular combination of container, wick material, and working fluid is based on the operation and design criteria of the heat pipe.

In the evaporator section, heat energy from the source is transferred by conduction through the container wall and the saturated wick to the liquid-vapor interface, where the working fluid vaporizes. The vapor flows through the vapor core to the condenser section, where it condenses at the vapor-liquid interface. Heat is transferred by conduction from this interface through the saturated wick and the container wall, and is dissipated into the heat sink in the condenser section. The working fluid condensate moves through the wick by means of capillary action to the evaporator section, where the cycle is repeated.

The container should be capable of withstanding high internal pressure loads due to variations in vapor pressure of the working fluid during operation. The material of the container must exhibit a high thermal conductivity, must be capable of long term operation, and must be compatible with the wick material and the working fluid.

Selecting the wick material usually involves a compromise between capillary pumping capability and minimum pressure drop in the wick. High thermal conductivity is also desirable in order to provide a heat path parallel with the vapor path and the container wall. The wick must be readily wetted by the working fluid and it must be compatible with the container material and the working fluid.

The working fluid should have high purity, surface tension, heat of vaporization, and liquid density, and have small liquid viscosity. Toxicity, flammability, ease of handling, compatibility with the other materials, and ability to wet the wick must also be considered.

Although the theory of heat pipes has been formulated, correlation of empirical data with theory is essentially nonexistent. For all practical purposes, therefore, one must resort to trial-and-error techniques in designing a heat pipe for a given set of operating conditions.

The performance map is an important design tool presenting a collective set of heat pipe data, such as heat transfer capabilities, lower and upper performance limits, and temperature distributions essentially over its entire operational range. The usefulness of the performance map is especially appreciated when a number of heat pipe designs are compared for the same set of conditions. This extends to heat pipes having the same working fluid but with dimensional variations, as well as those with a variety of working fluids. Data from wick permeability and rise test studies may eventually be instrumental in correlating theoretical results with the performance map data for effective heat pipe designs.

Note:

Requests for further information may be directed to:

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No patent action is contemplated by NASA.

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