THE LEWIS HEAT PIPE CODE WITH APPLICATION TO SP-100 GES HEAT PIPES

Karl W. Baker and Leonard K. Tower
Sverdrup Technology, Incorporated
Lewis Research Center Group
NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-6160

INTRODUCTION

The Lewis Research Center of NASA has a thermal management program, supporting SP-100 goals, which includes heat pipe radiator development. As a part of this program Lewis has elected to prepare an in-house heat pipe code tailored to the needs of its SP-100 staff to supplement codes from other sources (Woloshun and Merrigan 1988, Cunningham et al. 1986, McLennan 1983). These codes, which were designed to meet the needs of the originating organizations, were deemed not entirely appropriate for use at Lewis. However, a review of their features proved most beneficial in the design of the Lewis code.

FEATURES OF THE LEWIS CODE

Guidelines established for the Lewis code were, among others, a simple, logical, modular structure, and extensive documentation. Also, the capability of using the code as a design tool on a personal computer, or as a subroutine in a radiator code on a mainframe, was sought. Most of the required physical parameters, wick resistance for example, are computed from input specifications using accepted formulae, as in other codes. However, provision for user input of physical parameters enables wick configurations of the user's choice to be considered. The code at present incorporates the alkali liquid metals as working fluids, and the equilibrium between monomers and dimers in the vapor phase is considered.

A convenient iteration structure enables the computer to conduct an efficient search for the lowest applicable heat pipe limit by varying one input parameter chosen by the operator from several that are available. The aim has been to avoid the need for continuing operator interaction during a single solution. Alternatively, the program can be run using fixed inputs to determine the heat transfer, with warnings being provided when limits are encountered.

Because of the space power orientation of the program, some otherwise useful features have been omitted. These include the effect of hydrostatic head in a "g" field, which will be inserted when the need arises. Also, provision is not made for multiple heat addition and removal sections.

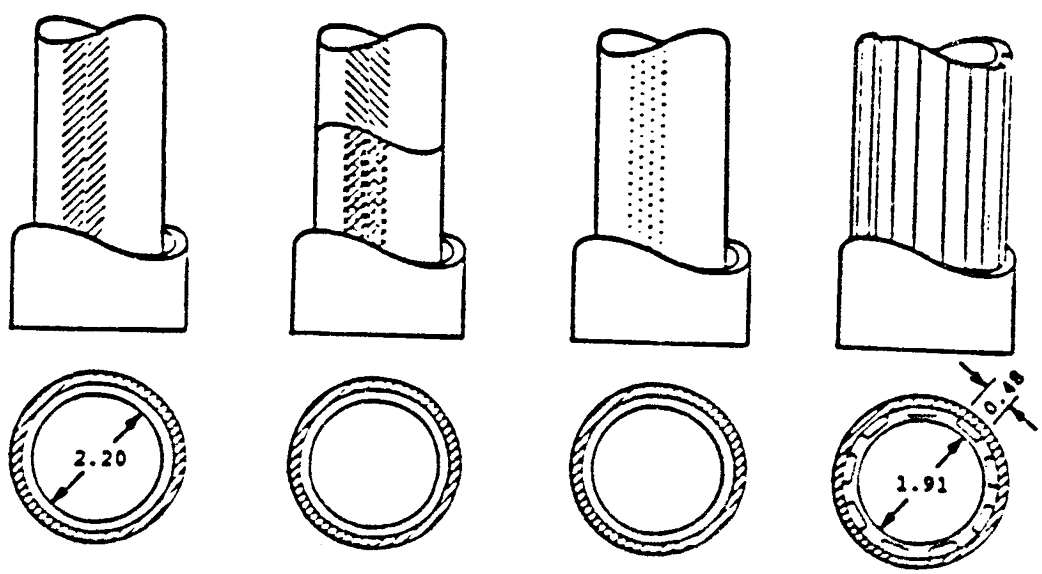
The source code was written and compiled with Microsoft FORTRAN Optimizing Compiler Version 4.01 to fully meet the FORTRAN 77 standard. Problems in compiling the code on a mainframe are not expected to be serious.

APPLICATION OF THE CODE

As a part of its SP-100 responsibilities Lewis was asked to participate in the periodic design review of the SP-100 GES (Ground Engineering System) program. Lewis elected to provide an ongoing independent evaluation of the heat pipe configurations being considered for the radiator. This gives an impetus for the development of the code while at the same time furnishing a useful service to GES. A computation for one of the GES prototype heat pipe configurations will serve to illustrate the use of the Lewis Heat Pipe Code.

Figure 1 shows some of the wicking systems that have been considered for the GES heat pipes. Singly, or in combination, these wicks constitute the liquid transport system for the heat pipe. The foil wicks provide an annulus between the pipe and the inner wall and are supported either by longitudinal spacers or at the ends. Foil thickness is about 50 um. Slots in the foil are about 50 um wide and 250 um long. Square orifices are formed in wick (b) by double wrapping of wick (a).The orifices of wick (c) are intended to be 75 um in diameter. The sintered wick has a

(a) Slotted foil One wrap 25% open (b) Slotted foil Two wrap 8% open (c) Orifice foil One wrap 10% open (d) Sintered with arteries



All dimensions in centimeters.

FIGURE 1. Some Wick Configurations in the GES heat pipe program.

porosity of about 0.24 to 0.28, a permeability of 2.2×10^{-12} m^2 to 3.0×10^{-12} m^2 without arteries, and an effective pore radius of 37 um. Some of the wick designs may be considered as interim stages on the path to a more desirable technology.

Various combinations of these wick types have been tested or considered in the course of the GES heat pipe development program. Thus a sintered wick evaporator may be mated to an orifice foil condenser wick. For this example a configuration was considered that may represent the direction in which the wick is evolving. Wick (b), in which slots intersect to create a roughly rectangular open space, is intended to approximate the circular orifice wick of configuration (c) for which the fabrication technology is being developed.

Figure 2 shows the performance of a heat pipe containing a configuration (b) wick throughout its length. The assumed pipe dimensions, approximating those that have been under consideration, are a length of 89 cm, an outside diameter of 2.5 cm, a vapor space diameter of 2.2 cm and a wick groove width of 50 micrometers. A fin giving a total effective isothermal radiating area 1.25 times that of the pipe exterior was assumed.

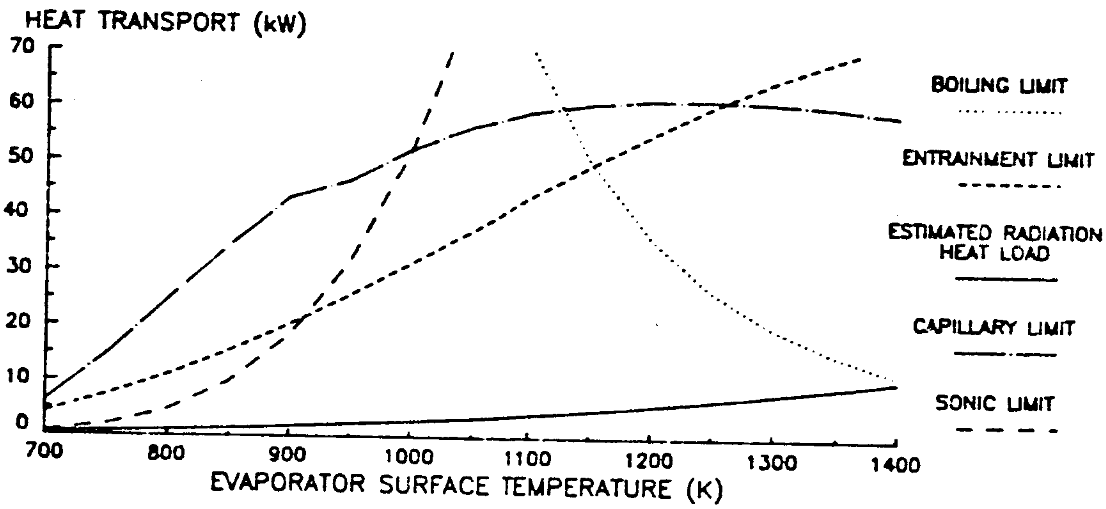


FIGURE 2. Performance of a Heat Pipe with Wick Configuration B, Two-Wrap Slotted Foil.

The perforated foil wick has a greatly diminished effective evaporation area compared to screen or sintered wicks. For this reason the vapor-liquid interface thermal resistance recommended by Dunn and Reay (1982) was compensated by multiplying by the ratio (total wick area)/(hole open area) . The approximate location of the recognized heat pipe limits are shown for this pipe. Also shown is the load placed on the heat pipe by the radiator at the specified conditions. The only limit near this transported heat flux is the sonic limit of Busse (1973).

The entrainment limit was computed from the theory of Feldman and Thupvongsa (1977). From Figure 2, it appears that the pipe should operate below its limits for the application intended. Data points for the limited experimental data available at this time could not be placed directly on the figure because too many parameters of the experiment are not specified.

Figure 3 illustrates the use of the program to search iteratively for the envelope of heat pipe limits. At fixed evaporator surface temperature, the condenser length of the heat pipe of Figure 1 was varied to change the radiative power until the lowest heat pipe limit was reached. The data for the figure were produced in one pass through the main heat pipe program. In a similar manner, parameters other than condenser length can be varied to search for the limit envelope.

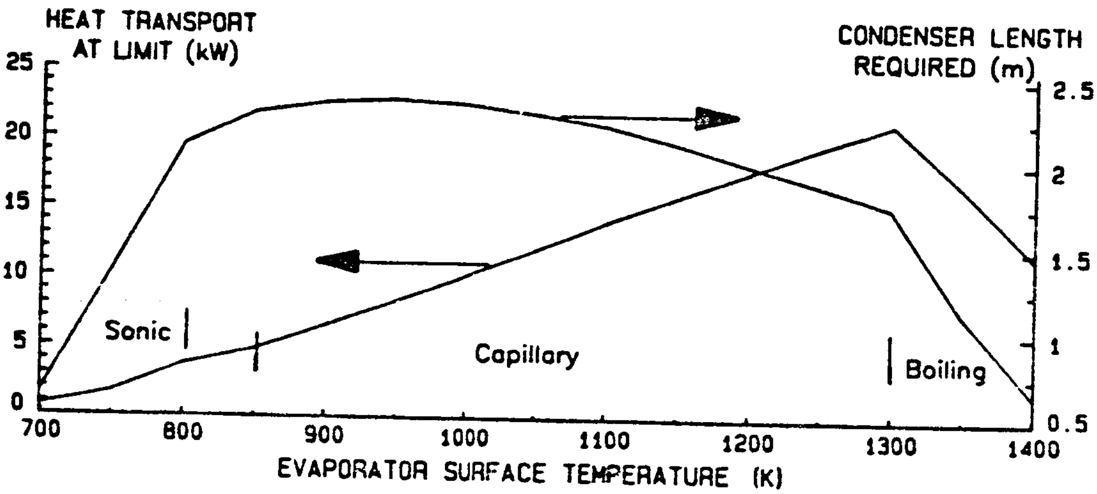


FIGURE 3. Envelope of Limiting Heat Transport for Variation of Condenser Length.

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