Extended Length Helium Pulsating Heat Pipes

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Pulsating heat pipes, also known as PHPs, are passive two-phase heat transfer devices capable of moving heat at cryogenic temperatures with high effective thermal conductivities around two orders of magnitude higher than copper. Depending on many parameters, such as the number of turns or orientation, helium PHPs can transfer heat with an effective thermal conductivity up to 150 kW/m-K. These unique heat transfer devices are inherently lightweight and easy to manufacture owing to their design, and do not require external flow devices since the fluid flow is entirely thermally driven. Their attractive performance, as well as the other additional benefits, have made pulsating heat pipes a technology of interest in cryogenics engineering research and potentially applicable to many aerospace systems, such as thermalizing large liquid fuel containers or cooling large space telescopes.

There are several fluid dynamic features unique to PHPs that set them apart from conventional heat pipes, such as the separation of the two-phase liquid and vapor, and the combination of unidirectional and oscillatory flow modes. These flow regimes have made PHPs notoriously challenging to model accurately, and as a result, much of the current understanding of PHP operation has been derived from experiments. A recent helium Pulsating heat pipe experiment conducted at UW-Madison demonstrated a surprising phenomenon, where helium PHPs of different lengths (300 mm and 1000 mm) displayed the same thermal conductance over a range of heat loads. Despite extending the length of the PHP by over three times, the temperature difference remained the same. The results of this experiment seem unintuitive since increasing the heat transfer difference typically results in a larger temperature gradient. The purpose of this research is to experimentally characterize this apparent length-independence and determine the expected length limit for such behavior in helium PHPs.

An experimental approach is developed where three additional helium PHP experiments will be conducted with the same operating parameters as the original experiment except with extended lengths – 1.25 m, 1.5 m, and 1.75 m. A range of initial fill ratios will be tested for each PHP length, and the conductance will be compared at each respective optimal fill ratio. All PHPs considered in this study are in the vertical orientation, bottom-heated, and have 14 parallel tubes. The experimentation described will give five complete sets of data from which the influence of length on helium pulsating heat pipes' performance may be analyzed. This paper serves as a work-in-progress report describing the experimental design and fabrication of these helium PHP experiments, the relevant design challenges, as well as an initial thermal modeling attempt.