A Reactive Heat Pipe for Cooling Applications

Stefen Fuqua, William Kwochka, Namhee Kim and Scott Rowe

Western Carolina University – Department of Chemistry, Department of Engineering and Technology

**W**estern **Carolina** UNIVERSITY

ABSTRACT

To manage hot equipment, roughly 32 million heatpipes are sold annually, devices that maintain temperatures in spacecraft, electronics, and solar heaters.[1,2] This work seeks to double heatpipe performance through chemical reaction as described below. Putatively, this enhancement could halve the number of heatpipes needed globally and disrupt the current market. Potential heat pipe improvements at Western Carolina University are technology-enabling and invite further funds from NC Innovation, NC IDEA, or Venturewell towards a university spinoff company that commercializes this technology.

INTRODUCTION

Although heatpipes have myriad applications, their use in computers is likely most ubiquitous. The heat pipes mobilize energy from computer processors to fins and fans that dissipate heat. As shown below, heatpipes operate when hot fluid within a pipe boils.[3] Vapor from the tube's hot sump rises to the pipe's cool apex where condensation dissipates energy. The heat's destination is often air (as shown). This effect conveys heat from hot equipment to cooler areas. The fluid recirculates indefinitely to discard heat.

discarded heat
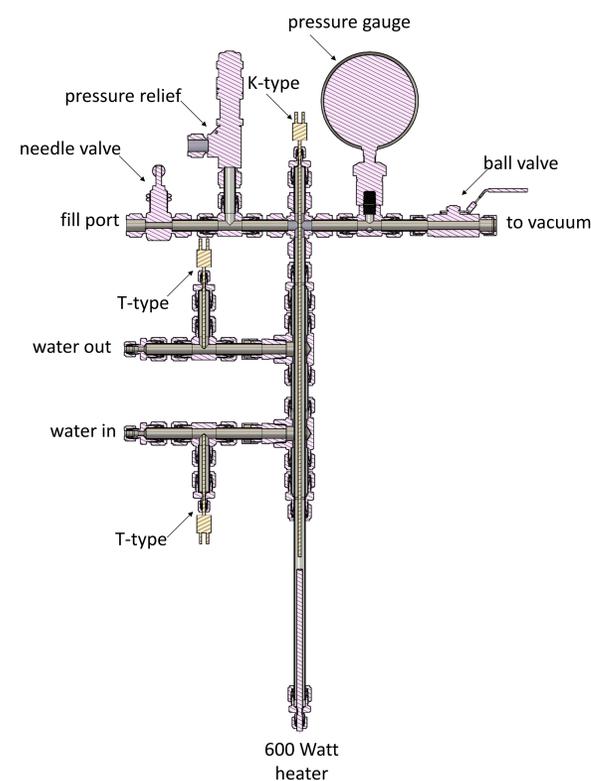
"heat pipe" thermosiphon

hot CPU
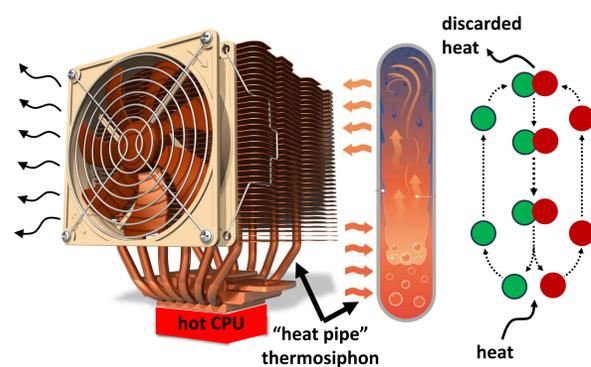
heat

Heat management is essential to computer operation and currently limits processor speed. "Moore's Law," which predicted exponential computer speed improvements, have plateaued because transistor density readily overheats processors.[4] Potentially, improved heat pipes can ameliorate this bottleneck. As shown above, to enhance heat pipe performance, we propose a reactive fluid (green & red dots above) that mobilizes additional heat through chemical conversions.
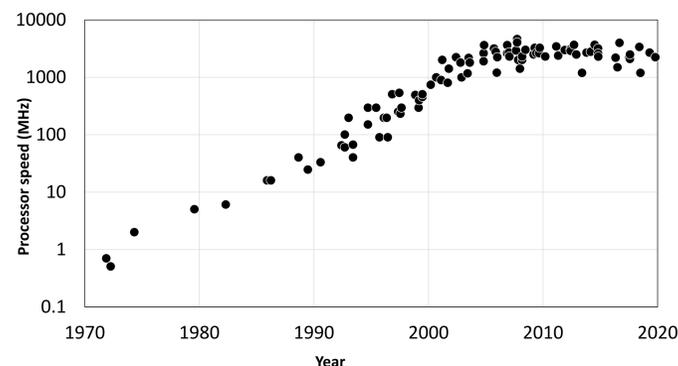

Experimental Apparatus

An experimental heat pipe was designed that consists of compression fittings rated to 350 barg, tubing rated to 179 barg and a 40 barg pressure gauge (MAWP):

pressure gauge

pressure relief — K-type

needle valve

fill port

ball valve

to vacuum

T-type

water out

water in

T-type

600 Watt heater

A 600 W insertion heater provides energy for dissipation. Chemical reaction and phase change mobilize heat to water coolant in an annular jacket (above). Heat sunk to the water coolant at a given operating point (temperature) reveals chemistry effects on heat pipe performance. Before experiments, the device is subjected to hydrostatic pressure testing for leaks and safety up to the maximum allowable working pressure (MAWP) of 40 barg.

Operating regime

A proprietary chemical blend was selected to mobilize heat at moderate temperatures and pressures. Reversible chemical reaction is expected at an overall reactant conversion of 50% for optimal heat pipe action:
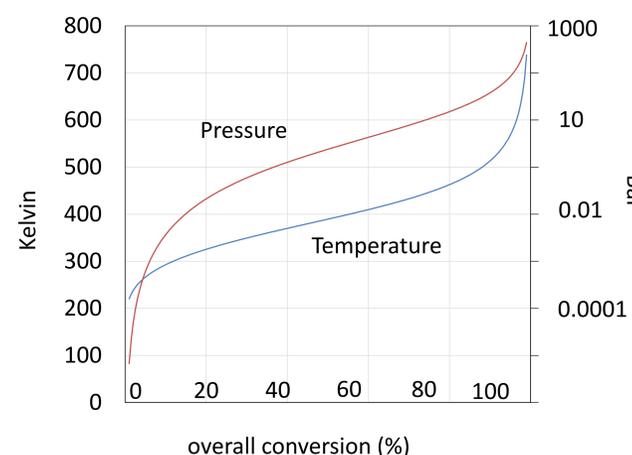

Relief Sizing

Based on an operating point of 50% overall conversion, pressures up to 10 barg are expected within the heat pipe. The pressure relief was sized based on a volatile (boiling) flow of the lightest chemical constituent under 600 watts of heating.

RL3 and RL4 Series

operating point, emergency relief
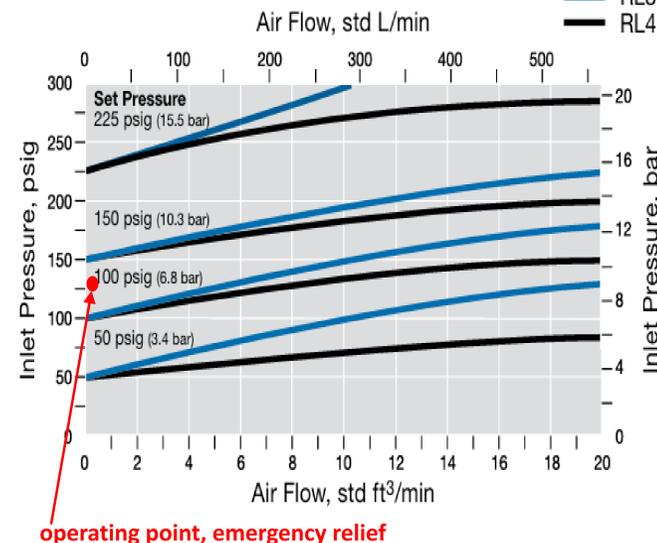
Chemical Analysis

A gas chromatograph was modified to monitor the heat pipe chemical reaction. This analytical equipment allows the quantification of species against an internal standard; an essential approach towards the accurate determination of chemical kinetics. Presumably, the heat pipe requires homogeneous and heterogeneous catalysts for substantive reaction and thermal performance boosts. Catalyst development is underway. Below are GC results that show peak shifts for changing chemical composition:

$$A + B \rightleftharpoons C + D$$
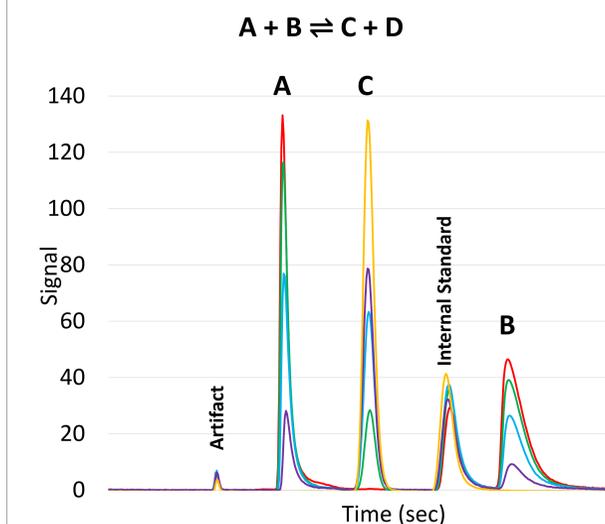
References

1) Bali V. *Heat Pipe Market*. Cognitive Market Research; 2024.
2) *Heat Pipe Market Share, Size, Growth Drivers & Opportunities Forecast*. Research Rockets; 2023.
3) Jouhara H, Chauhan A, Nannou T, Almahmoud S, Delpech B, Wrobel LC. *Heat pipe based systems-Advances and applications*. Energy. 2017;128:729-754.
4) Theis, Thomas N., and H-S. Philip Wong. *The end of moore's law: A new beginning for information technology*. Computing in science & engineering 19.2 (2017): 41-50.

Acknowledgements