Intermediate Temperature Water Heat Pipe Tests

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Abstract. Heat pipes are among the most promising technologies for space radiator systems. Water heat pipes are explored in the intermediate temperature range of 400 to above 500 K. The thermodynamic and thermo-physical properties of water are reviewed in this temperature range. Test data are reported for a copper-water heat pipe. The heat pipe was tested under different orientations. Water heat pipes show promise in this temperature range. Fabrication and testing issues are being addressed.

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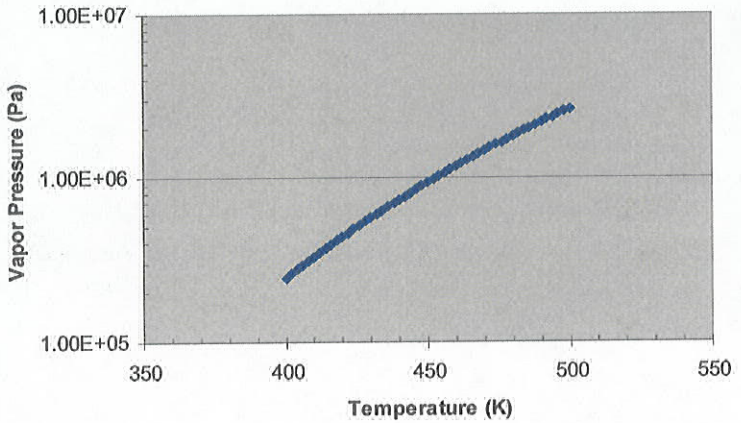
Intermediate Temperature Heat Pipes

- Temperature range: 400 to 700 K
- Heat pipe technologies in this range were not developed well
- Motivation for intermediate temperature heat pipe technology development - Higher temperature heat rejection systems for space power, tolerance to micrometeoroid impact and damage

Water for Intermediate Temperature Heat Pipes

- Water critical temperature: 647 K
- It is desirable to keep the maximum operational temperature of the heat pipe about 100 K below the critical temperature of the fluid
- Hence water is thermodynamically suitable as heat pipe fluid approximately up to 550 K

Vapor Pressure



Vapor Pressure Considerations

- In the temperature range of 400 K to 550 K, Vapor Pressure rises steeply.
- Technical Considerations:

1. The envelope material - stronger/thicker
2. Braze/weld strength

Figure of Merit

- Figure of Merit defined as

$$M = \frac{\rho_L \cdot \sigma \cdot \lambda}{\mu_L}$$

Higher Merit Number indicates better heat pipe performance from the fluid

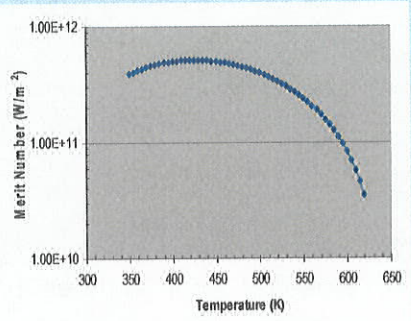


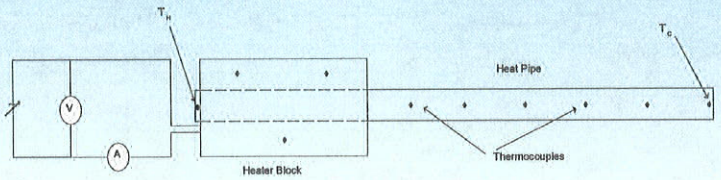
Figure of Merit Considerations

- The water merit number drops steeply above 450 Kelvin.
- Indicates that water heat pipe performance MAY decrease at higher temperature

Heat Pipe Testing

- Heat pipe thermal performance strongly depends on the ambient conditions.
- It means that the way the condenser is cooled significantly determines the ***heat transfer*** rate.
- The aim of the present testing is to investigate the higher operational ***temperature*** limit for water heat pipes.
- Testing under natural convection conditions is sufficient for this purpose.

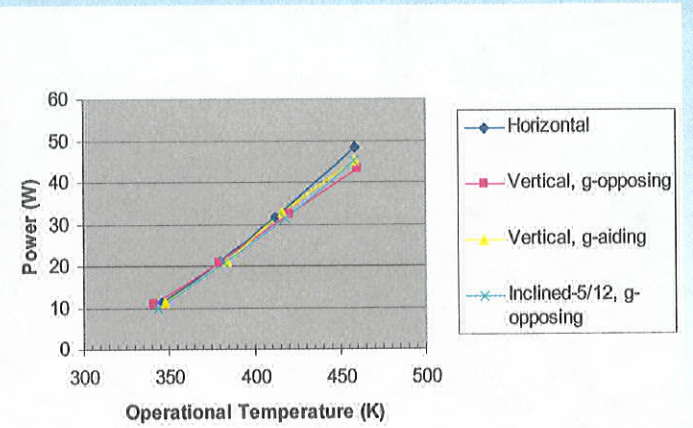
Experimental Setup



Heat Pipe Specifications

- 1 in O.D. and 6 in long
- Copper-water heat pipe
- Sintered copper powder wick

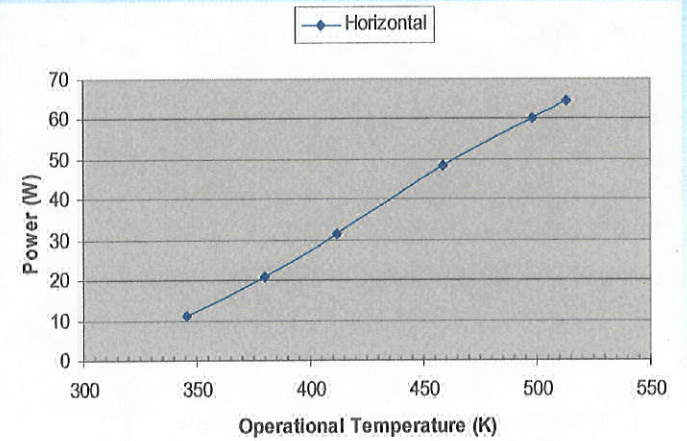
Heat Transfer



Observations from the Heat Transfer Data

- For the heat pipe tested, gravity did not have significant effect on heat transfer
- While the merit number of water falls steeply in the higher temperature range, the measured thermal performance continues to increase with increasing temperature
- The important suggestion from this is that merit number is a reasonable index to begin with, but it does not accurately predict the trend for the actual thermal performance

Higher Temperature Testing



High Temperature Testing

- Water heat pipe thermal performance continues to increase beyond 500 Kelvin

Summary

- It was experimentally demonstrated that the thermal performance of copper-water heat pipes continues to improve above 500 Kelvin.
- For water heat pipes, the figure of merit in the higher temperature range does not reflect the actual thermal performance of the heat pipes.