TOP3–00155

Innovative Heat Pipe Systems Using New Working Fluids

Technology

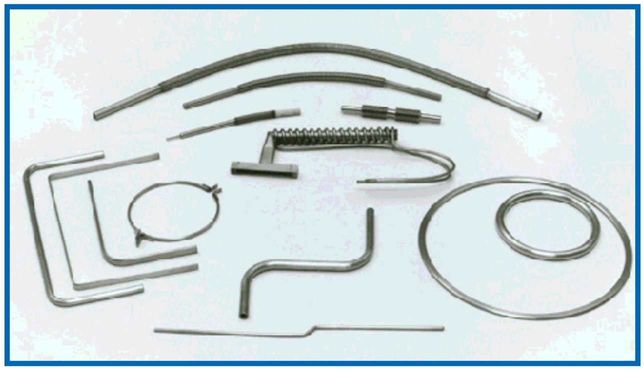
An innovative, patent pending, heat pipe design that incorporates a working fluid with a positive gradient of surface tension to temperature.

Benefits

Water is widely used as the working fluid in terrestrial and microgravity environment heat pipes by virtue of its availability, cost, safety, and its high surface tension. However, because the surface tension of water decreases as the temperature increases, the heat load and performance of water-filled heat pipes are limited. The innovative design presented here suggests the use of dilute aqueous solutions of long-chain alcohols to replace water as the working fluid. Experiments have revealed that the surface tension of aqueous solutions of alcohols with chain lengths longer than four carbon atoms, have positive gradients with temperature above certain temperatures.

In addition, this positive surface tension characteristic overcomes problems encountered in low-gravity heat pipe designs. Capillary-pumped loops (CPL) and loop heat pipes (LHP) have demonstrated instabilities in operational capacity and temperature hysteresis. Use of these new working fluids will

- Provide increased heat dissipation for heat pipes in such applications as electronics cooling, air conditioning, engine cooling, power generation, and energy recuperation
- Allow for increased operating temperatures and heat loads for all heat pipe systems
- Ultimately reduce costs and increase reliability and performance of finished products that utilize heat pipes for thermal management



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Various heat pipe configurations.

Commercial Applications

- Spacecraft temperature equalization, component cooling, and radiator design in satellites
- Commercial, residential, and vehicular air conditioning systems
- Microheat pipes for electronic devices such as cooling in laptop computers
- Refrigeration and heat exchangers
- Chemical engineering and cryogenics

Technology Description

Capillary pressure drives the circulation of the working fluid in heat pipes and sets an operational limit with respect to the total pressure drop. For the wick-structured heat pipe systems, including conventional heat pipes, CPL's, and LHP's, the capillary-pressure head, developed by the wick structure, is responsible for stable working fluid circulation. The available capillary-pressure-pumping head is a function of the surface tension of the working fluid. Surface tension is a key factor in determining the capillary limit of all heat pipe systems.

The effectiveness of a heat pipe can be measured by its maximum heat load value. To ensure a large heat load without reaching the boiling limit at the evaporator, the most important factor is the wetting of the heated wall by the working fluid. Experimental results and theoretical analysis have revealed that heating retards the spreading process by creating flows and increases the contact angle. These effects also stem from the surface tension characteristics—in this case a negative-gradient relation with temperature—and limit the heat load capacity of heat pipe systems.

NASA GRC has proposed to address these problems by utilizing a new working fluid—one that exhibits a positive surface-tension gradient with temperature in the operating temperature region.

It has been experimentally revealed that the surface tensions of aqueous solutions of alcohols, with chain lengths longer than four carbon atoms, have a positive gradient with temperature when the temperature exceeds a certain value. For example, for aqueous solutions of n-heptanol, the surface-tension gradient with temperature turns positive after the temperature reaches 40 °C, as long as the concentration of n-heptanol exceeds 1×10^{-3} mole per liter. Because of the very large positive surface-tension gradient with temperature, the working fluid tends to move towards the hot region in the heat pipe, reducing the liquid pressure drop, increasing the capillary limit and the boiling limit, and consequently, increasing the heat load.

Ammonia is another working fluid widely used in heat pipes. Adding an ionic surfactant into ammonia can create amino-group fluids with positive surface tension gradient with temperature. These new amino-group fluids should significantly increase the performance of the existing ammonia/metal heat pipe systems.

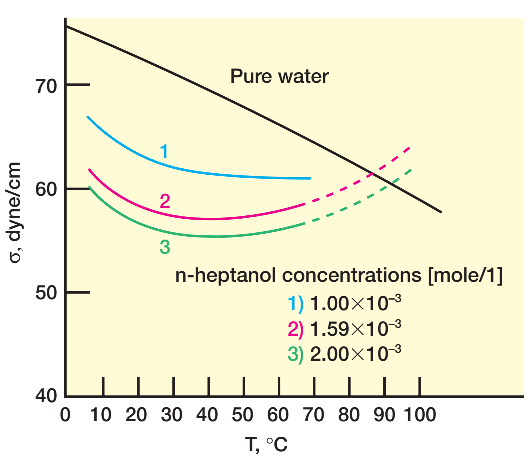

Fig. 1—Surface tension of water and aqueous solutions of n-heptanol.

Options for Commercialization

NASA Glenn Research Center is looking for industrial partners interested in collaborating on prototyping and verification studies for this new working fluid heat pipe design, and its subsequent integration into new and existing commercial products. A patent application has been filed for this technology innovation. Space Act Agreements and/or licensing agreements are sought to facilitate technology development.

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Key Words

Heat pipe

Thermal management

Heat dissipation

Capillary pressure

Electronics cooling