

## ENHANCING HEAT PIPE PERFORMANCES USING SELF-REWETTING FLUIDS IN SELENE GROUND EXPERIMENT

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**FULL ABSTRACT** A cooling system device, designated Heat Pipe (HP), is commonly used to transfer heat more efficiently than simply connecting cold and warm zones with high conductive metallic connections. These devices can reach an effective thermal conductance several hundred times more than the copper (401 W/(m<sup>2</sup> K) at 25°C) [Reay, D. 2006]. HPs are passive heat exchangers using liquid-gases phase changes in a closed loop to remove a considerable quantity of heat from evaporator region to condenser one, with capillary driven return flow (Figure 1b). The interest in the development of more efficient HP is constantly increasing. It is possible to adapt HP to specific application using different working fluids, materials and shapes. For instance titanium-alloy/nitrogen HP are used for cryogenic ranges (< 30 K); tungsten/silver HP can work at high temperature range (> 2300 K); in electronic cooling applications where the temperature must be maintain below 400 K, copper/water HPs are typically used [Gamer, S.D. 1996]. There are also different designs to control capillary flow as wick structures, porous media and micro-channels [Wang, C. Y. 1994]. More advanced studies have been made on the use of particular mixtures called Self-Rewetting [Savino, R. 2007] that increase the pumping effect of the wick capillarity thanks to the inverse Marangoni effect [Savino, R. 2006]. This effect can be modelled when using

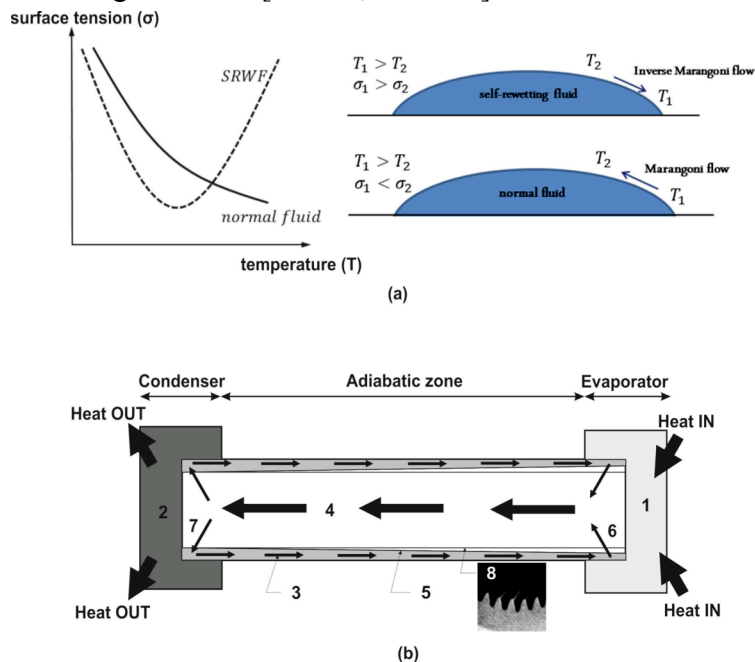


Figure 1. (a) SRWF special characteristic and difference respect normal fluid. (b) Scheme of HP: Heat IN comes from an external heat source; the liquid at the evaporator side (1) evaporates (6) and the vapor (4) flows through the adiabatic zone of the HP, it condenses (7) at the condenser (2) and is forced by capillarity (3) in the groove (8) to reach the evaporator again. In the case of the SRWF, an additional force applies at the free interface (5) of the liquid contained in the groove of the HP.

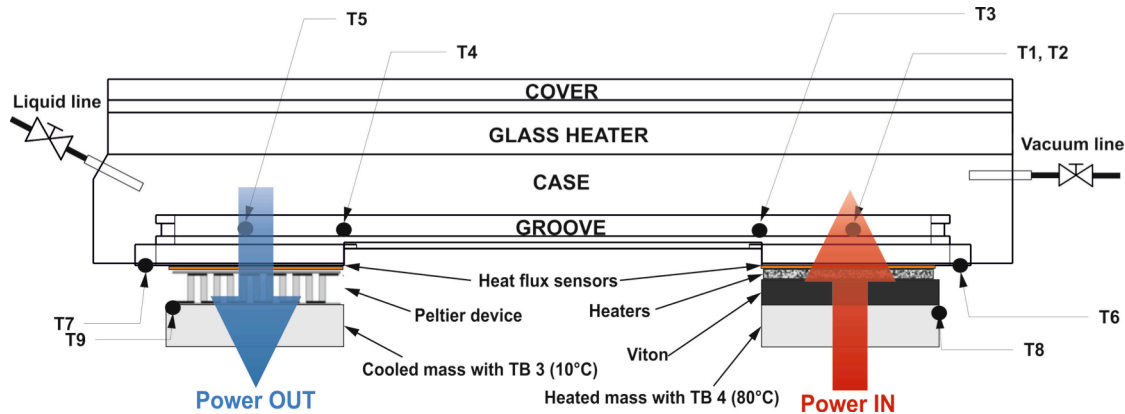


Figure 2. SELENE breadboard section drafting with the heating and cooling systems.

a groove instead of a porous media. In the scope of researching HPs with SRWFs (Self-Rewetting Fluids) was developed the project SELENE (SELf-rewetting fluids for ENERgy management): it is a space experiment to study SRWF transfer mechanisms under microgravity conditions [Savino, R. 2013] and it is part of an international cooperation with the European Space Agency (ESA) on a Space Program called Thermal Platform 1 (TP1). SRWFs are binary mixture of diluted aqueous solutions of fatty alcohols that show interesting properties [Savino, R. 2007, Abe, Y. 2004]; Figure 1a shows the difference in surface tension trend with temperature for SRWFs respect normal fluids and its different behaviour if we consider a drop on a heated surface; with a SRWF the inverse Marangoni applies at the free surface (under specific conditions in temperature and concentration) spreading the liquid. As sketched in Figure 1b, inside a HP, the liquid phase in the channel (number 8 in Figure 1b) is pushed from the cold end to the hot one by a decreasing radius of curvature, as results from the meniscus receding by evaporation at evaporator side. The difference of meniscus' curvature between the evaporator and the condenser provides the capillary pressure difference, according to the Young-Laplace relation. When a SRWF is used as working fluid inside a grooved HP, the surface tension variation along the groove of the HP triggers an additional component of flow towards the evaporator that is added to the capillary force (number 3 in Figure 1b).

The setup configuration (showed in Figure 2) is similar to HP and it allows investigation of thermal-solutal processes for binary mixture measuring thermal coefficient at different operating regimes. The study consists of heat transfer experiments with SRWF using a mono-grooved HP 180mm long made of Brass with isosceles trapezoidal section of dimensions 1mm, 5mm and 4.5mm respectively for the bottom side, top side and height of the section. The groove can be split into three main zones (Figure 2) as for HPs (Figure 1b): the evaporator, the condenser and the adiabatic zone; the adiabatic zone is the region between the evaporator and condenser and is half of the pipe groove length (Figure 2b). The groove is inserted in a "case" made of PEEK that isolates the working fluid from the external environment. The "case" presents an aperture on the top to allow direct visualization of the groove and lateral tube connectors for water thermal circulator. The "glass heater" part also presents connectors for tubes to control in temperature the visualization window but in the actual experiments neither this or the thermal loop for the "case" part was used. The part "glass support" fixes the window on the "case" and the "cover" keeps everything together. In Figure 2, heat is extracted from the evaporator by phase change; the vapour flows along the groove (always in contact with the liquid part) through the adiabatic zone and condensate at the condenser that is kept at lower temperature. The condensed liquid at the condenser side spreads in the groove to the evaporator by capillarity and the loop is closed.

Experiments were made keeping the condenser side at 30°C and varying the input power injected at the evaporator side. From experimental data it was observed a decreasing of the thermal resistance for the SRWF with respect to the experiments performed with distilled water. The reduction in terms of thermal resistance is increased when the injected heat power rises at the evaporator side

(figure 2). It was also notice a deformation in the temperature profile along the groove. The temperatures in the case of SRWF are lower than the distilled water case. This effect can be related to the inverse Marangoni force that supplies additional liquid to the evaporator side increasing the heat extracted by evaporation. Additional experiments with the same setup configuration are planned to investigate the effect of the changing of concentration of n-Butanol in water solution and the effect of the condenser temperature. Finally the dry out problem has to be visualized experimentally performing experiments reducing the amount of liquid injected into the HP and will be studied in on going works.

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