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## Pool Boiling in Microgravity with a Single Specie System

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Pool boiling experiments in microgravity on the small copper plate of  $1\text{cm}^2$  have been performed in the SOURCE 2 experiment aboard the sounding Rocket Maser 12 launched on February 13<sup>th</sup>, 2012. The SOURCE 2 experiment is a small-scale tank devoted to the study of heat and mass transfers with a liquid refrigerant HFE7000 pressurised with its vapour. SOURCE 2 (SOUNDing Rocket Compere Experiment) was developed in the frame of a French German space programme COMPERE (on the behaviour of propellant in launcher tanks) managed by CNES and DLR and a MAP ESA Project "Multiscale Analysis of boiling". During the 6 minutes of the flight different physical phenomena were studied by our partners: ZARM, University of Bremen, Air Liquide and Astrium.

The boiling experiment was performed in a 6 cm diameter and 28 cm long cylindrical tank partly filled with a refrigerant Novec HFE7000 with a low boiling point ( $34^\circ\text{C}$  at 1 bar) and pressurized by its own vapour. The heating element used for the boiling investigation consisted of an electrical resistance heated by Joule effect in contact with a flux-meter and a copper plate with a thickness of 40 micrometres. The flux-meter was equipped with two thermocouples. It was then possible to measure at the same time the heat flux transmitted to the liquid and the wall temperature. The liquid temperature above the heater was measured by 5 micro-thermocouples located in the vicinity of the wall. Images of the boiling phenomenon were recorded by a video camera through the transparent cylindrical wall of the tank.

SOURCE 2 is in the continuity of the SOURCE 1 experiment, which flew successfully on Maser 11 on 15 May 2008 (Kannengieser et al. 2010). The experiment scenario was similar to the present case. However, in SOURCE 1, liquid HFE-7000 was pressurized by gaseous nitrogen. The lateral glass wall was preheated and a strong evaporation took place at the free surface in the vicinity of the wall. Due to the presence of nitrogen a strong Marangoni convection occurred at the free surface enhancing nitrogen dissolution in the liquid phase. Then during the boiling experiment, the bubble growth was due to liquid vaporization and nitrogen desorption. Marangoni convection also occurred at the bubble interface leading to a capillary force pushing the bubble to the heated wall. In the SOURCE 2 experiment, a single specie configuration is studied (liquid/vapour HFE7000). This changes the thermo-hydraulic behaviour of the system. Since no Marangoni convection kept the bubble in contact with the heated wall, a primary bubble detached and grew by feeding itself with the smaller bubbles formed over the heated surface. The change in the bubble size is only due to vaporization. Then the measurements of the heat flux transferred to the fluid by the heater could be directly correlated to the amount of vapour production (balance of

evaporation and re-condensation) that could be evaluated from visualization and image processing.

When the rocket was launched, the test cell was empty. The top part and the lateral glass wall of the test cell were preheated before launch. Just before the microgravity period, the tank filling began, liquid HFE7000 at  $25^\circ\text{C}$  was injected in the tank by the pump and pressurized by hot vapour HFE7000. At the beginning of the boiling experiment, the tank pressure was reduced to 1.5 bars and the heating of the heater element was switch on and boiling started.

During this period, it was planed to study boiling with high sub-cooled liquid then to decrease the pressure to 1 bar to study saturated boiling. However while pressurization with hot vapour HFE7000, strong condensation occurred that rapidly warmed up HFE7000 up to  $40^\circ\text{C}$  during boiling study. As a consequence, at 1.5 bars, the sub-cooling was limited to 5 degrees. Then the tank pressured was reduced to 1.3 bars to investigated boiling in saturated conditions.

On the other hand, before launch, tests were performed on ground and boiling curves were plotted. In this paper we will attend to compare the results obtained in micro-gravity and in 1G.



**Figure 1:** Visualization of pool boiling of HFE7000 in the single species system of SOURCE 2.

### References

Olivier Kannengieser, Catherine Colin, Wladimir Bergez, Pool Boiling with Non-condensable Gas in Microgravity: Results of a Sounding Rocket Experiment, *Microgravity sci. technol.*, Vol. 22 pp. 447-454 (2010).