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Effects of Micro-gravity on Thin-Wire Subcooled Nucleate Boiling Dynamics

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Abstract
Nucleate boiling is a highly effective means of transferring heat, and as space exploration begins to reach farther from Earth, efficient heat management systems in microgravity are becoming increasingly important. In the summer of 2010, members of the USU Get Away Special (GAS) team flew aboard NASA’s Weightless Wonder in order to study the effect of various system parameters on nucleate boiling heat transfer behavior in microgravity. This one dimensional study of boiling used a new geometry never tried before and concluded that heat transfer rates during boiling in microgravity do not significantly differ from those observed on Earth. These results will allow for a more in-depth study of the phenomenon and hopefully lead to the development of a two dimensional heater with important practical applications.

NASA’s Reduced Gravity Program
Every year, NASA provides an opportunity for 14 teams from various universities to test microgravity experiments on board Zero G Corporation’s microgravity simulating aircraft. This modified Boeing 727 flies over 30 parabolic arcs (Figure 3) in order to provide up to 30 seconds of ~0.1 g’s. Utah State’s selection for this program was awarded after a successful proposal submission and allowed the team to compete with schools like Yale and Purdue.

Background
Boiling is an important method of transferring heat. On Earth, it is used for a wide variety of applications – from cooking to power generation and electronics cooling. A more fundamental understanding of boiling can help to improve these applications on Earth and make them available for use during space flight.

Experiment Methodology/Results
The experiment consisted of 30 self-contained fluid chambers (Figures 6 and 7) containing all the instrumentation needed to measure wire temperatures, water temperatures, power dissipated by the wire, and a three dimensional view of bubble dynamics via two perpendicularly oriented cameras. The identical cells allowed the experimenters to compare the effects of varying power dissipation and wire geometries between all the chambers.

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Power levels were also found to effect the dynamics of boiling. As power dissipated increased, the bubbles formed by boiling decreased slowly in size (Figure 11). Eventually individual bubbles stopped being formed and jet of tiny bubbles formed. This behavior was quantified by an image processing program developed to track the change in bubble area for the entire system between frames of video (Figure 14).

FUNBOE 2.0
With the success of FUNBOE, the GAS team is in the process of building a follow-up experiment to further explore the effect of nucleate boiling’s fundamental parameters on heat transfer behavior in microgravity.

Of special interest in this follow-up study is an innovative design of using heaters to cool. An array of microheaters (Figure 16) that would take low amount of power to generate and allow heat to be rejected from the component of interest as the bubbles continue to grow. This concept could serve as an effective means to have lower surface temperatures and smaller, more efficient heat transfer systems.