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FUNBOE



Follow-Up Nucleate Boiling On-orbit Experiment

Project Overview

This experiment will focus on the visual recording of bubble generation and departure during nucleate boiling in microgravity to better understand boiling dynamics in the absence of the dominant buoyant and convective forces. The experiment will use a braid of three nichrome wires and a single nichrome wire to boil water. The onset of bubble generation and bubble departure for the two different heating surfaces will be compared to understand the effectiveness of a braided wire configuration in the enhancement of bubble generation.

Payload Requirements

Mass: 250 g

Dimensions: 6.5 cm x 6.5 cm x 10 cm

Power: 3V and 2A for 5 min

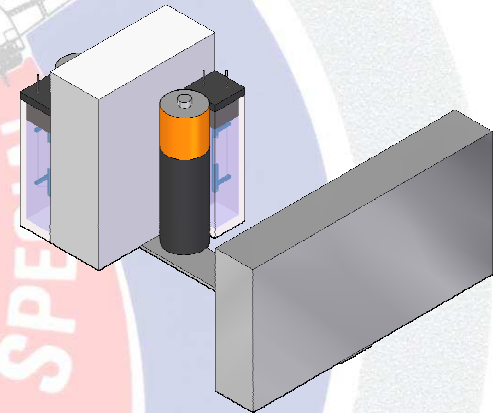
Data Acquisition: Volt and Amp Measurements (60 Hz)

10 min video at 30 fps

Experiment Objectives

Empirical data from the experiments will be compared with theoretical bubble growth and departure force models which are dominated by buoyancy on Earth. Key outputs from the experiment are:

- Bubble growth versus applied power
- Bubble density versus applied power
- Braided versus single wire bubble departure characteristics



Experimental Setup



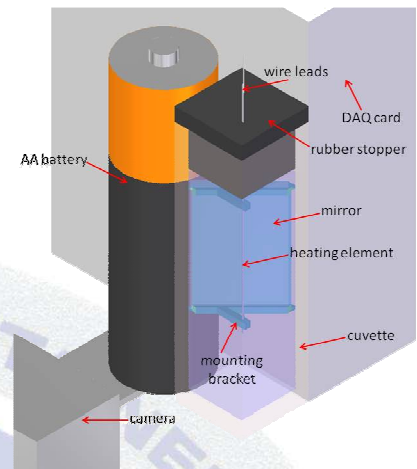
Picture of bubbles growing and departing radially from a braided wire heating element taken from the STS-108 GAS team boiling experiment

Scientific Justification

If a braid of wires is successful in enhancing the generation of bubbles, more efficient and effective heat transfer mechanisms can be designed with similar surface characteristics. Nucleate boiling is a well known, highly efficient mode of heat transfer; however, the absence of free convection due to lack of gravity reduces the convective heat transfer on orbit, resulting in more localized heating and larger thermal gradients. Microgravity experimentation is needed to provide a fundamental understanding of the behavior of boiling in space before thermal management, fluid handling and control, and power systems based on phase change can be designed for use on satellites and deep space probes.

Experiment Design

The experiment consists of two test sections, a data acquisition system, and a camera. Each test section consists of a 3.5 cm³ water-filled cuvette and two AA alkaline batteries. Within the cuvette is a 1 cm nichrome heating element and a mirror to allow the growth of bubbles to be measured in 3 dimensions. The batteries are attached to the outside of the cuvette supplying 3V and 2A to the heating element for 5 minutes. The two test sections study the difference between braided and straight wire boiling characteristics. The data acquisition system will measure the voltage and current at 60 Hz while a high definition camera records the boiling at 30 frames per second. By focusing on a 1.5 cm² area in the fluid chamber, the bubble radius and departure velocity can be measured with very high precision. Multiple experimental runs are possible by varying power input and cell orientation to residual gravity on the station.



Experiment Apparatus

Involvement of the Space Flight Participant

The SFP will be required to setup and initiate the experiment by deploying the camera and turning on the data acquisition system, camera, and heating element. After 5 minutes, the SFP will turn off all systems and rotate the camera to repeat the experiment using the second fluid cell. Detailed instructions and a training video will be provided and on-Earth training time should not exceed 1 hour. If desired, the SFP can monitor boiling action and take notes on observations.

SFP On-orbit Time Required: 15 min.

SFP Training Time Required: 1 hr.

Critical Safety Issues

Two low-risk potential safety hazards have been identified.

- *Container Breach:* A container breach could occur due to fluid solidification. Upon melting, a water leak could provide a threat to other electrical systems, but does not pose a threat to humans. The rubber stopper will provide room for fluid expansion and double containment will provide redundancy for hazard prevention.
- *Battery Overheating:* Faulty equipment may cause battery overheating, posing a potential burn threat. A current limiter, fuse, and safety switch will be included as safety measures.

Project Timeline

Current analysis of a previous boiling experiment has led to the improved design of this experiment; these results will be published as proceedings at the 39th AIAA Fluids Dynamics Conference and the 48th Aerospace Sciences Meeting. The full design of the current experiment is nearly complete and terrestrial experimentation will be used to determine the effects of certain design features and small adjustments can be made accordingly. Safety tests will be performed to prove space flight readiness. Currently this project is expected to be completed by early August; however, completion could be expedited if needed.

Date	Milestone
June 8	Prototype completed
June 15	Preliminary ground testing completed
June 22	Safety review submitted
July 6	Safety review completed
July 20	Final ground tests and videos completed
Aug 3	Apparatus and instructions delivered to SFP

Project Leads

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