Boiling Visualization, Enhancement through Porosity Modification and Anodization

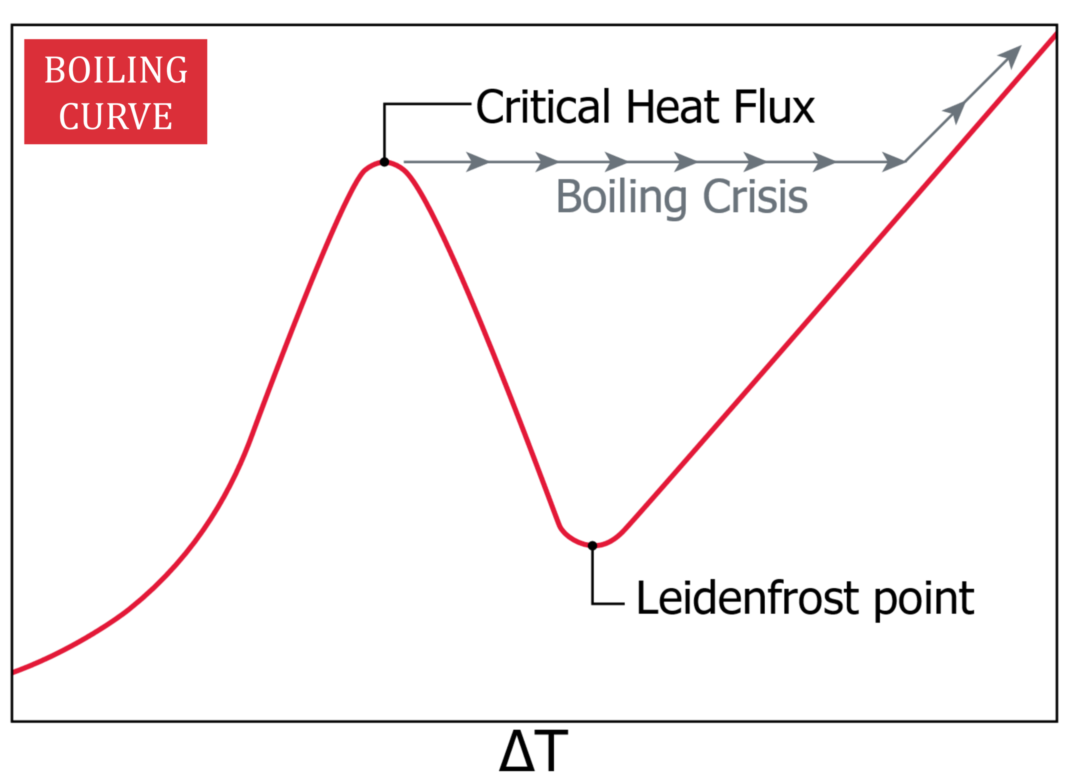
BLAKE NACCARATO and KWANG J. KIM
Active Materials and Smart Living (AMSL) Laboratory
Department of Mechanical Engineering, University of Nevada – Las Vegas

OVERVIEW

Boiling heat transfer is used in the cooling of power plants, rocket engines, server farms, and even the cell phones in our pockets. A fluid can absorb a lot of energy while it is boiling. For example, boiling water into steam requires the same amount of energy as heating steam to 1200°C. And yet, most space missions do not leverage boiling heat transfer because of the design complexity of two-phase systems.

The purpose of this study is to advance the material knowledge of boiling on porous and anodized surfaces, partly through visualization of bubble shapes and comparison to hydrodynamic models. This will facilitate the study of porous evaporators for cooling on space missions, such as the work being carried out today at NASA Jet Propulsion Lab.

A pool boiler has been built for measurement of heat flux and bubble visualization. The apparatus has been tested with untreated copper up to a boiling heat flux of 60 W/cm² thus far.



ACKNOWLEDGEMENTS

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INTRODUCTION

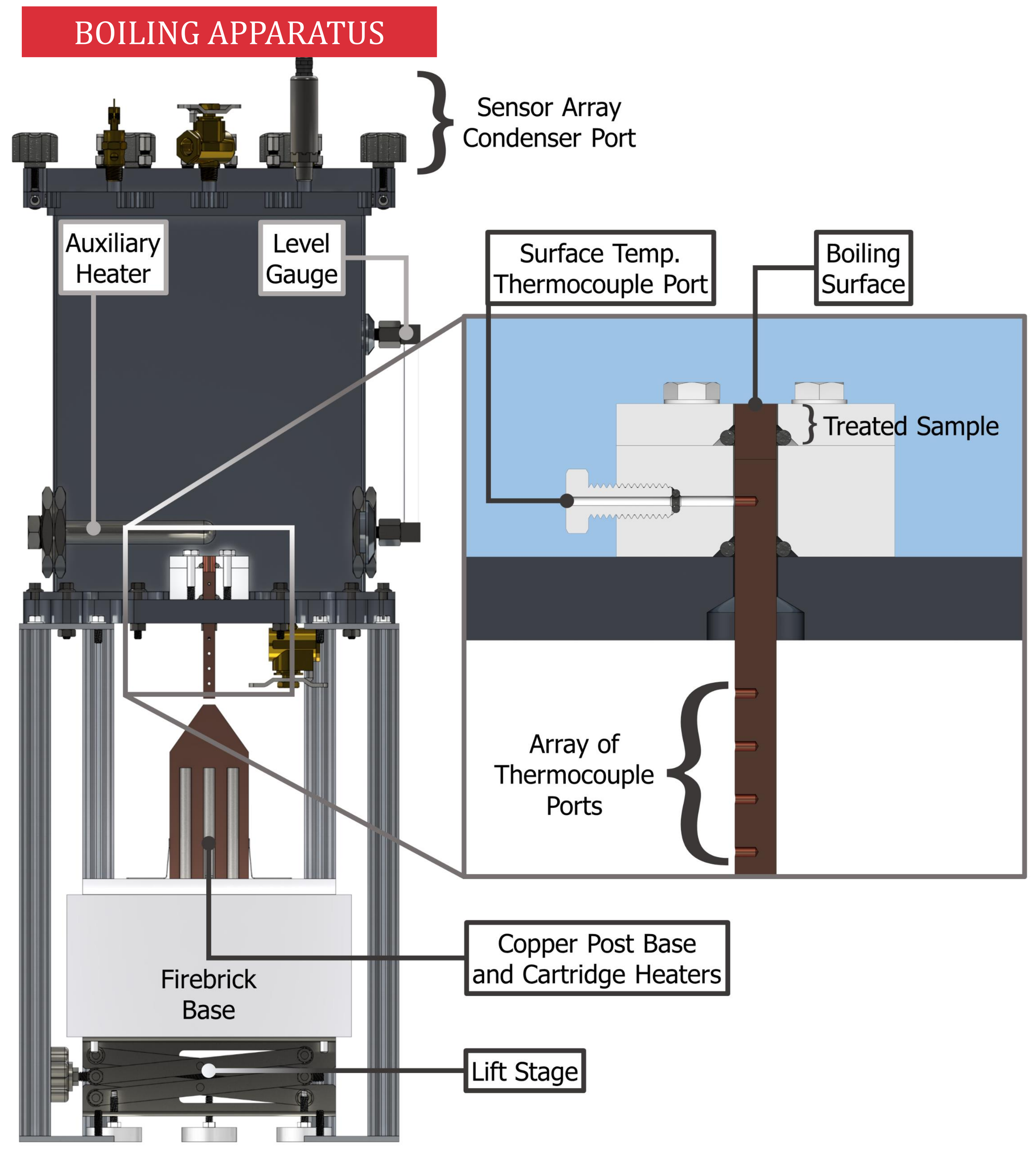
For a given boiling surface, the boiling curve *(left)* shows the relationship between heat flux, q'', and surface superheat temperature, ΔT. If heat flux is controlled, then raising heat input above the critical heat flux leads to boiling crisis, a rapid increase in temperature at the surface as a vapor bubble blankets the surface.

Bubble detachment is facilitated by sample surface roughness and porosity, which may enhance boiling heat transfer. Higher critical heat fluxes at higher superheating indicate better performance, as does the onset of nucleate boiling at lower superheating.

EXPERIMENTAL SETUP

Water-tight, insulated sample installation is possible with the boiling apparatus *(below)*. The sample is heated through an insulated copper block, and temperatures are monitored along the length of a rod to find heat flux and superheating. Viewports allow for high-speed recording of boiling phenomena.

BOILING APPARATUS

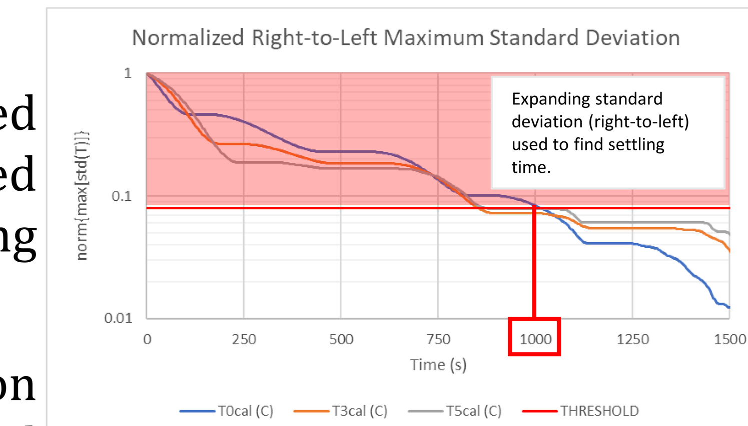


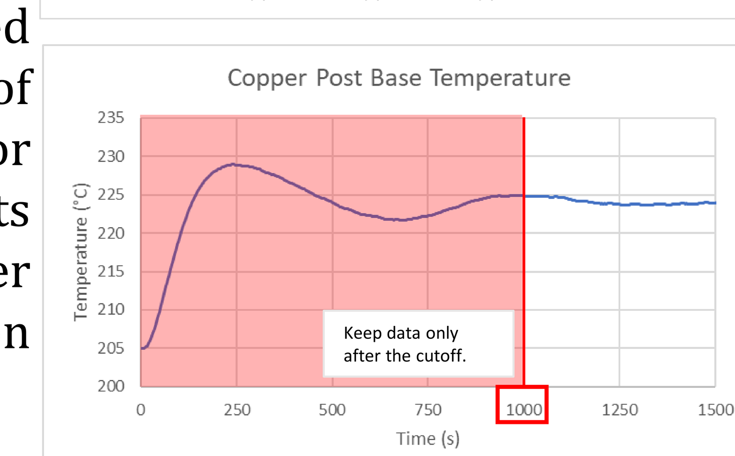
METHODS

The measured temperature profile *(right)* in the copper post is used to predict heat flux and surface superheating. Flux is obtained from the slope of the temperature-distance relationship, while superheat is obtained through extrapolation to the boiling surface.

PID control is used to achieve desired set points during experimentation.

Standard deviation over time is used as a measure of signal settling for each trial. Results are averaged over the settled portion of each trial.

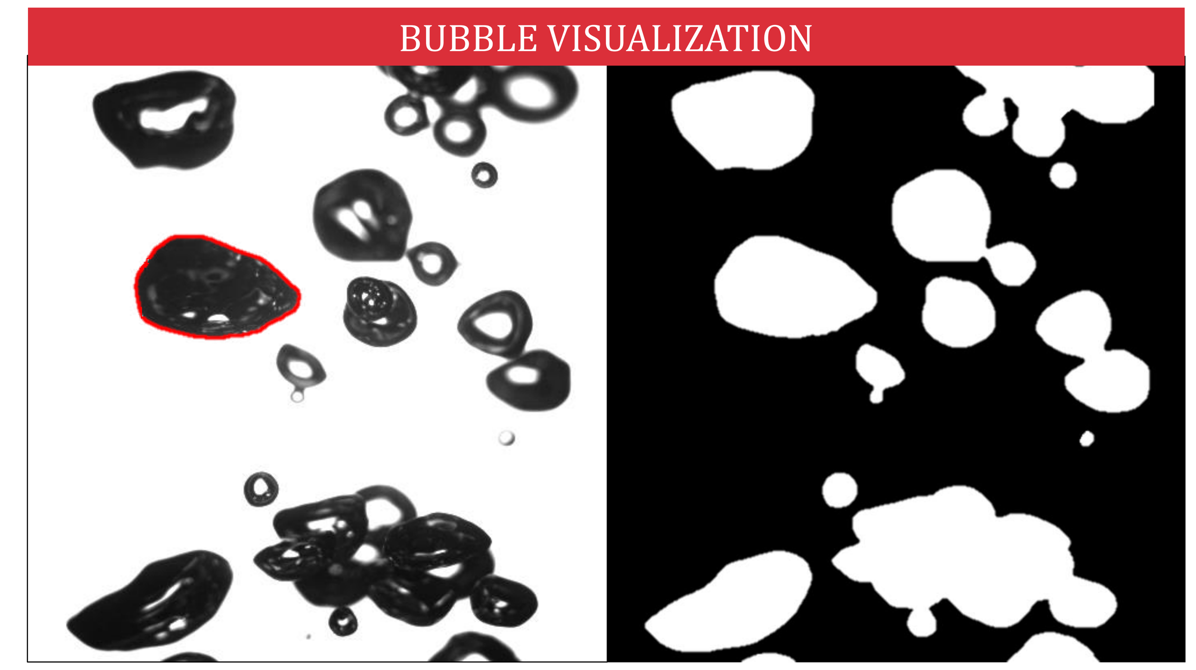




VISUALIZATION

High-speed video is captured through chamber viewports. Backlighting ensures good contrast of bubbles with the background. Contours are captured through image processing. Tracking the contour of a given bubble throughout its lifetime allows for direct comparison of experimental data to hydrodynamic models. Bubble visualization data *(below)* will be compared to physical models in this way.

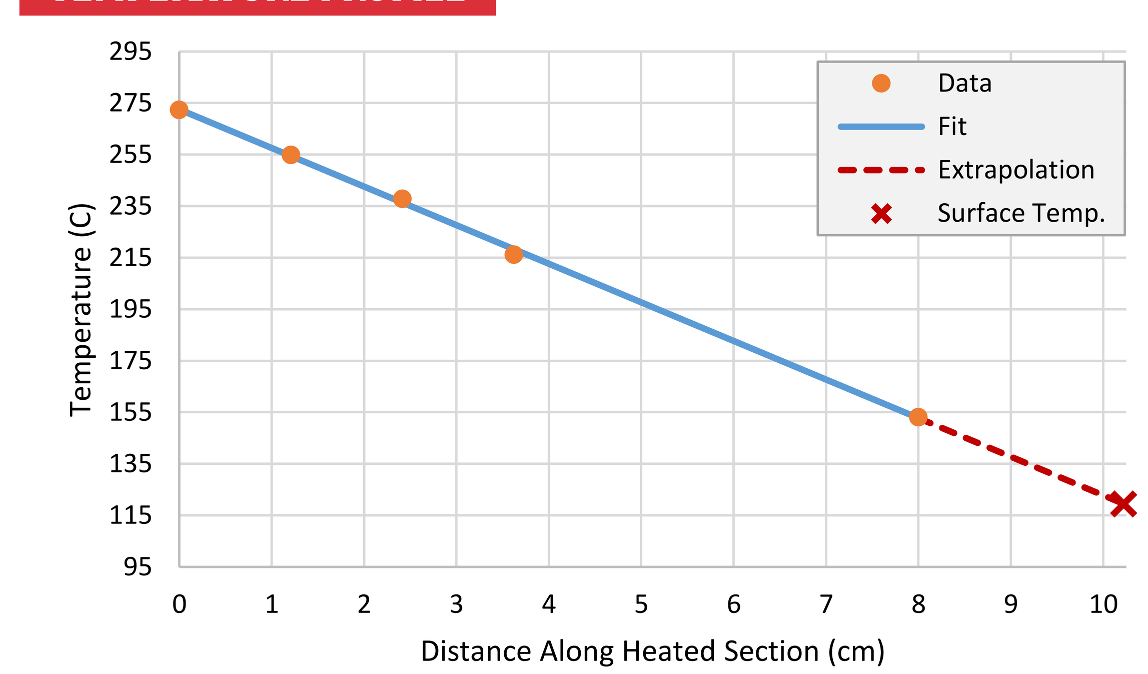
BUBBLE VISUALIZATION



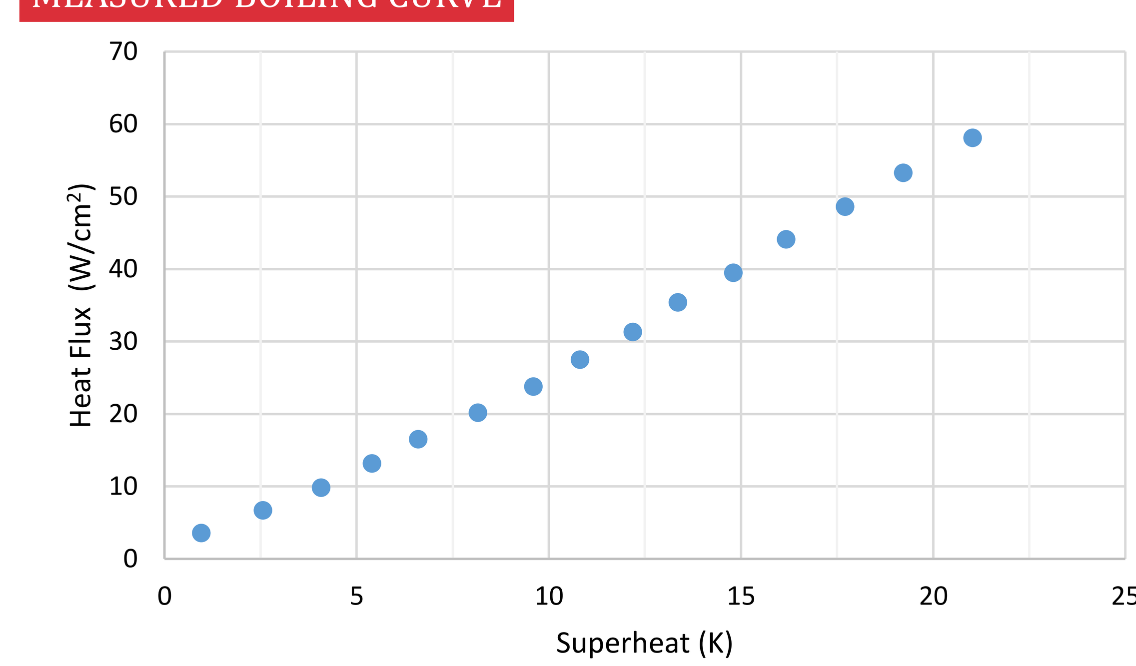
PRELIMINARY RESULTS

The temperature profile *(below)* yields a heat flux value and a superheat value for a given experimental set point. The measured boiling curve *(also below)* results from processing multiple set points for a given sample. This curve is for untreated copper, which will serve as the baseline for future datasets captured on anodized and porous samples.

TEMPERATURE PROFILE



MEASURED BOILING CURVE



CONCLUSION

This study of pool boiling on anodized and porous surfaces contributes to the development of porous evaporators for cooling of sensitive electronics in future space missions to hostile environments the likes of Venus or the Sun. The success of such missions is crucial to furthering space science.

Contour estimation through video processing will also enable direct comparison of experimental data to bubble dynamics models.

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