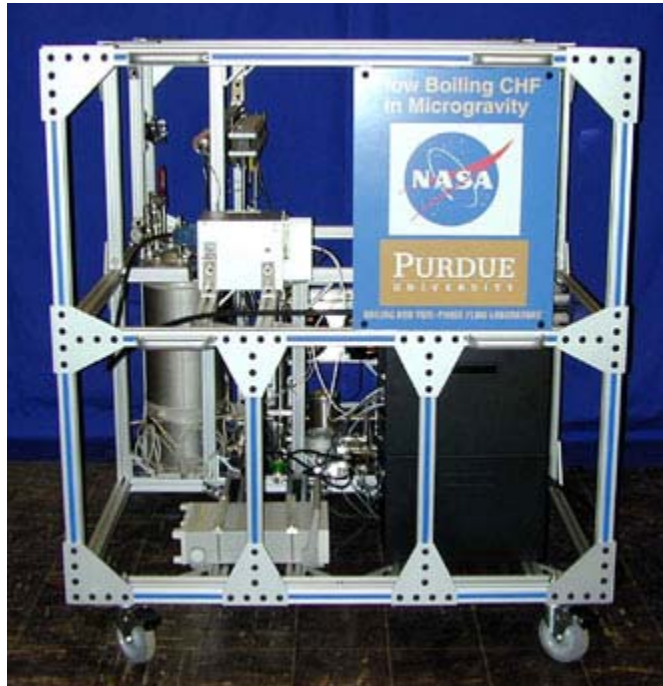


Flow-Boiling Critical Heat Flux Experiments Performed in Reduced Gravity

Poor understanding of flow boiling in microgravity has recently emerged as a key obstacle to the development of many types of power generation and advanced life-support systems intended for space exploration. The critical heat flux (CHF) is perhaps the most important thermal design parameter for boiling systems involving both heat-flux-controlled devices and intense heat removal. Exceeding the CHF limit can lead to permanent damage, including physical burnout of the heat-dissipating device. The importance of the CHF limit creates an urgent need to develop predictive design tools to ensure both the safe and reliable operation of a two-phase thermal management system under the reduced-gravity (like that on the Moon and Mars) and microgravity environments of space. At present, very limited information is available on flow-boiling heat transfer and the CHF under these conditions.

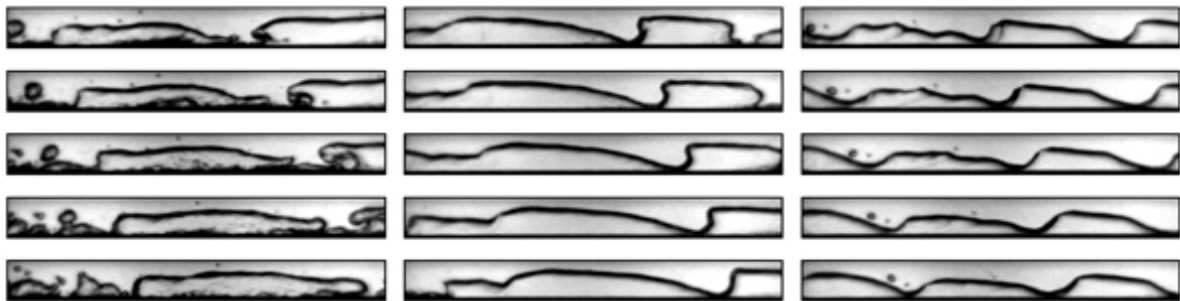


Flow-boiling apparatus flown onboard NASA's KC-135.

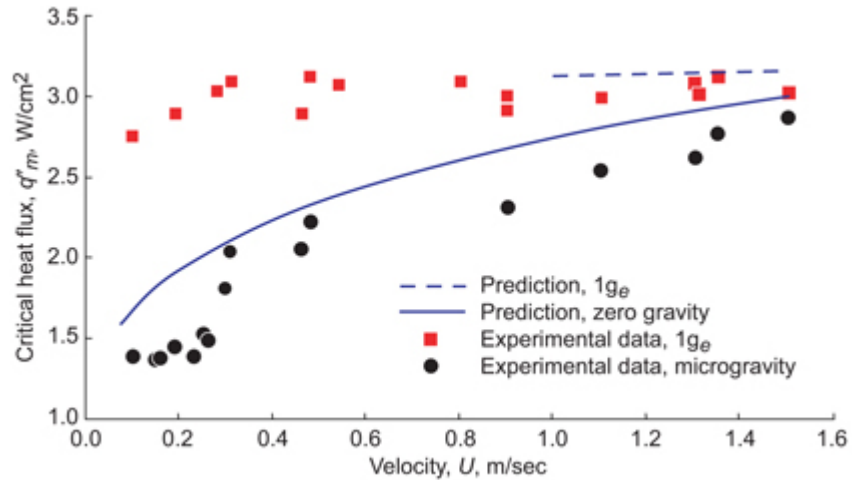
The goal of this project of the NASA Glenn Research Center and Purdue University is to develop a comprehensive understanding of and a predictive model for flow-boiling CHF in reduced gravity. This project is a continuation of a recently concluded NASA project at Purdue University to explore flow-boiling CHF at different angles of orientation with respect to Earth's gravity. The findings of this research work are reported in several publications by Zhang et al. (refs. 1 and 2). The flow-boiling apparatus for that project

was modified to perform experiments in parabolic flights. This apparatus is shown in the preceding figure.

A limited number of experiments to determine the flow-boiling CHF in reduced gravity, including lunar and Martian gravitational levels, were performed in parabolic flight with a fluorinert liquid onboard NASA's KC-135. At high heat fluxes, bubbles quickly coalesced into fairly large vapor patches along the heated wall. As the CHF was approached, these patches grew in length and formed a wavy vapor layer that propagated along the wall, permitting liquid access only in the wave troughs. These phenomena, captured during the flight experiment, is shown in the next figure. The CHF was triggered by separation of the liquid-vapor interface from the wall because of intense vapor effusion in the troughs. This behavior is consistent with, and accurately predicted by, the interfacial liftoff CHF model. The graph shows that at low velocities the CHFs are significantly smaller in reduced gravity than they are in horizontal flow on Earth. However, the CHF differences between the two environments decreased with increasing velocity, culminating in virtual convergence at about 1.5 m/sec. This proves that it is possible to design inertia-dominated systems by maintaining flow velocities above the convergence limit. Such systems allow data, correlations, or models developed on Earth to be safely implemented in space systems.



CHF transient in microgravity for flow velocity, $U = 0.15$ m/sec, and subcooling, $\Delta T_{sub,o} = 3.0$ °C. Left: Below CHF. Center: CHF transient. Right: Above CHF.



Comparison of CHF data and interfacial liftoff model predictions for microgravity and horizontal Earth gravity ($1g_e$) flow boiling. Subcooling, $\Delta T_{sub,o}$, 2 to 8 °C.

References

1. Zhang, Hui; Mudawar, Issam; and Hasan, Mohammad M.: Experimental and Theoretical Study of Orientation Effects on Flow Boiling CHF. *Int. J. Heat Mass Transfer*, vol. 45, no. 22, 2002, pp. 4463-4477.
2. Zhang, Hui; Mudawar, Issam; and Hasan, Mohammad M.: A Method for Assessing the Importance of Body Force on Flow Boiling CHE. *J. Heat Tran.*, vol. 126, no. 2, 2004, pp. 161-168.

Find out more about this research:

Glenn's Microgravity Fluid Physics Research at

<http://microgravity.grc.nasa.gov/6712/research.htm>

Professor Mudawar's Research at <http://btpfl.www.ecn.purdue.edu/BTPFL/>

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