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Transient heat transfer to He II due to a sudden loss of insulating vacuum

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We report on a quantitative study of the heat flux deposited into a He II bath consequent to a failure of its insulating vacuum jacket. Failure of this vacuum is often referred to as THE worst-case scenario seriously endangering the low temperature equipment and its surroundings. In the case of a vacuum break, air floods into the vacuum jacket and carries with it a significant amount of energy (~500 J/g for air) that must impinge on the inner vacuum wall and ultimately be absorbed by the He II coolant. For the present study, an experimental rig was designed, built, and successfully operated to simulate such a sudden loss of insulating vacuum incident confined to a one-dimension space. The rig consists of an evacuated tube that dead-ends to a He II-cooled disk, beneath which is a column of He II near 1.8 K, open to its bath. A wide range of mass flow rates are studied for warm gas flooding into the evacuated tube, causing the gas to cryodeposit and transfer its internal energy through the disk to the He II. Thermometry in the disk and axially through the He II column is used to quantify the heat transport generated by the cryodeposition process. In general, it is found that the heat flux to the He II is indeed limited by the peak heat flux theory. It is further confirmed that noisy film boiling, though mechanically violent, reduces the heat transfer to the He II. The cryodeposition behavior of warm gas onto a He II-cooled surface is also shown to be somewhat stochastic. In summary, an accurate conceptual model is developed to fundamentally describe and predict the coupled mass and heat transport phenomena that result after such a vacuum failure.

Primary author: BOSQUE, Ernesto (Florida State University)

Co-author: VAN SCIVER, Steven (Florida State University)

Presenter: VAN SCIVER, Steven (Florida State University)

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