Heat Transfer In Helium Injected Liquid Nitrogen

Fenner Colson,1,2 Dogan Celic,2,3 Steven W. Van Sover,2,3
1Department of Physics and Astronomy, Minnesota State University College of Social and Natural Sciences, Moorhead, MN 56563 USA
2National High Magnetic Field Laboratory, Florida State University, Tallahassee, FL 32310, USA
3Mechanical Engineering Department, FAMU-FSU College of Engineering, Tallahassee, FL 32310, USA

ABSTRACT

Liquid nitrogen boiling suppression is a known phenomenon occurring when gaseous helium is injected directly into boiling nitrogen. The heat transfer coefficient, which determines how efficiently heat is transmitted from a heat source to a material, is not the same in boiling liquid nitrogen and helium injected liquid nitrogen. This change is not due to the temperature drop of the nitrogen, nor from the chemical interaction of helium gas and liquid nitrogen, but because of some other mechanism not covered by the scope of this project.

RESULTS AND CONCLUSIONS

The change in temperature due to heat flux through the aluminum disk was measured for a number of different power inputs. The ∆T is illustrated in the graph below.

The method of extracting ∆T, as demonstrated above, was replicated for all data runs with plain liquid nitrogen as well as helium injected. Power input per unit area is known since the disk was held at a measured voltage.

Our area of interest lies in the ∆T values, which define how the heat transfer coefficient is behaving. Evaluating the quotient of Q/A and ∆T at a point will be the means that the heat transfer coefficient is calculated. The accepted format to present the data is on a logarithmic scale graph.

Heat Transfer Coefficient (W/m²K)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Heat Transfer Coefficient (W/m²K)</th>
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</thead>
<tbody>
<tr>
<td>LN2</td>
<td>848.54</td>
</tr>
<tr>
<td>Boiling</td>
<td>9085.27</td>
</tr>
</tbody>
</table>

Figure 6: Summary of heat transfer coefficients. The helium and nitrogen values are calculated by direct division of data from Figure 4.

The heat transfer coefficient for helium injected liquid nitrogen agrees nicely with the equivalent super-cooled nitrogen at low ∆T, but as ∆T increases, the difference rises dramatically. Thus HT cannot be the only factor in changing the heat transfer coefficient.

Calculations from Figure 7 reveal that the gas itself has no effect on the heat transfer coefficient, since the results are the same if helium or hydrogen is used. Therefore the reason for the coefficient change cannot be related to molecular interactions with the gas, nor can the coefficient change be explained by ∆T. One possibility is that film boiling, which occurs at high ∆T, is affected by the helium injection. This interaction may reduce film boiling, which would normally increase the heat transfer coefficient.

Our measurement apparatus consisted of a bulb shaped glass dewar into which we suspended a rod to which we attached an aluminum disk. This aluminum disk is surrounded by G-10 insulation, with one face being open to the liquid nitrogen and the other face having a resistive heater and insulation. Two thermocouples were run down the rod to monitor the temperature of the nitrogen bath and the temperature of the disk.

EXPERIMENTAL METHODS

The heat transfer coefficient of liquid nitrogen was experimentally verified first. The aluminum disk was subject to a certain amount of heat, which allowed it to remain at a different temperature than the nitrogen bath. By observing the behavior of the temperature of the disk and nitrogen, the heat transfer coefficient can be calculated using Newton’s Law of Cooling. The coefficient for liquid nitrogen can be compared with known values to verify the quality of experiment. The same process was repeated to helium injected nitrogen, and the heat transfer coefficient for liquid nitrogen at the equivalent super-cooled temperature was used for comparison.