WILLIAM E. BOEING DEPARTMENT OF
AERONAUTICS & ASTRONAUTICS
College of Engineering

Cryogenic Boiling Test Plan

Cryogenic Boiling Team 1 (aka Charlie)

Adam Delbow, Emi Peterson, Evelyn Madewell, Felicity Cundiff

Faculty Advisor: Professor Jim Hermanson

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William E. Boeing Department of Aeronautics
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I. Introduction

Cryogenic Boiling Team 1, aka Charlie, aims to understand heat transfer and cooling properties of liquid nitrogen by measuring the temperature gradients of individual spheres using thermocouples at various points on the same plane along the radius, and changing planar orientation for different tests. For long term space travel to be possible, storage and transfer of cryogenic propellants like hydrogen and oxygen are crucial for mission success. The propellants are prone to boiling off due to the extreme heat they are exposed to from rocket engine exhaust and air friction in the atmosphere, this can potentially lead to significant losses. To help prevent this, this experiment will demonstrate the behavior of immersing spheres initially at ambient conditions suddenly in liquid nitrogen, and then measuring the time-varying temperatures using thermocouples. The result will provide engineers insight on heat transfer, boiling rate, and cool down time, ultimately providing a greater understanding of cryogenic propellants and long-term space travel.

Our approach will consist of immersing two 25 millimeter (1 inch) aluminum spheres into a dewar full of liquid nitrogen. The first sphere will have one 1/16 inch diameter hole drilled from any edge into the center of the sphere and one mounting hook attached. With a Type T thermocouple adhered into the hole, the first aluminum sphere will be lowered into the liquid nitrogen and the heat transfer from room temperature (about 293 K) to the temperature of liquid nitrogen (77 K) will be recorded using the thermocouple connected to a sensor control box displaying values on LABVIEW. This sphere will have 2-3 tests conducted to check if our equipment is consistent and working correctly, as well as providing a baseline measurement to see any effects on heat transfer due to additional holes drilled in the second sphere. The second sphere will have holes drilled and thermocouples inserted into points 1/2, 3/4, and 7/8 of the way across the diameter of the sphere. This will test the heat transfer across radius of the sphere. This sphere will have 3 tests conducted using different mounting screws in order to see if the orientation of the testing plane affects our results.

II. Test Constraints

Constraint	Description	Value/Range
Liquid Nitrogen Temp	The temperature of the nitrogen in which the spheres are being submerged, should not change throughout the experiment.	77K
Size of Spheres	Radius of all spheres tested, all coming from same source company.	12.5mm
Length of Thermocouple Probe	All probes will be the same length , all coming from Omega.	152.4mm
Cryo Dewar Dimensions	Height and diameter of cryo dewar used to hold liquid nitrogen, this will not change.	OD 349.25mm ID 203mm Ext Ht 450.85mm Int Ht 381mm
Size of Hanging Hook	Length and diameter.	7.62mm x 4.91mm
Hook Eyelet Diamter	Diameter of hole for hanging sphere	7.94mm

Table 1 Test Constraints

III. Test Parameters

Parameter	Description	Value/Range
Room Temp	Ambient temperature will likely vary day to day. Need to know what temperature sphere starts at to analyze heat transfer.	290-300 K
Depth of Liquid Nitrogen	Level will decrease as it boils off and we need enough depth to conduct each test.	No less than 50mm

Table 2 Test Parameters

IV. Test Variables

Variable	Description	Value/Range
Sphere Tested (Var 1)	We are testing two different spheres: Sphere 1 and Sphere 2. Sphere 1 tests the temperature at the center of the sphere and Sphere 2 tests the temperature at 1/2, 3/4, and 7/8 of the way through the sphere.	1 or 2
Orientation (Var 2)	In order to test the uneven boiling around the sphere, Sphere 2 will be tested at 3 different orientations, with the testing plane level (orientation 1), at a 45 degree angle downwards (orientation 2), and straight down (orientation 3).	1, 2, or 3

Table 3 Test Variables

V. Measurements

Measurement	Description	Value/Range
1/2 Sphere Temperature (Meas 1)	Labview will record the voltage obtained from the thermocouple throughout the time of the experiment, with a 2 second delay time. This voltage can then be converted to temperature and the temperature at the center of the sphere throughout the experiment can be found.	Room Temp to Cryo Temp (293 to 77 K)
3/4 Sphere Temperature (Meas 2)	Labview will record the voltage obtained from the thermocouple throughout the time of the experiment, with a 2 second delay time. This voltage can then be converted to temperature and the temperature 3/4 of the way through the sphere can be found for the duration of the experiment.	Room Temp to Cryo Temp (293 to 77 K)
7/8 Sphere Temperature (Meas 3)	Labview will record the voltage obtained from the thermocouple throughout the time of the experiment, with a 2 second delay time. This voltage can then be converted to temperature and the temperature 7/8 (this is considered our "surface" reading) of the way through the sphere can be found for the duration of the experiment.	Room Temp to Cryo Temp (293 to 77 K)
Cool Down Time (Meas 4)	The time (in seconds) from when the sphere is submerged in liquid nitrogen til the time it reaches 77-80 K (approximately the temperature of liquid nitrogen).	5 seconds - 5 minutes (5-300 seconds)

Table 4 Measurements

VI. Test Matrix

Run	Var 1	Var 2	Meas 1	Meas 2	Meas 3	Meas 4
1	Sphere 1	any		XXX	XXX	
2	Sphere 1	any		XXX	XXX	
3	Sphere 3	Orient. 1				
4	Sphere 3	Orient. 2				
5	Sphere 3	Orient. 3				

Table 5 Test Matrix