Engineering a Test Chamber to Replicate the Descent Environment of a Probe Through Europa

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Background

The process of descending through the icy crust of ocean worlds, like Europa, can be broken into three phases: entry, main descent, and ice-ocean interface. Each of these phases corresponds to a different temperature environment. Our chamber is designed to simulate the environment of the main descent phase.

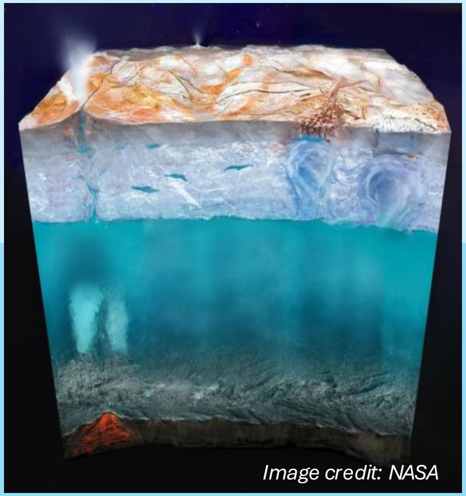

Image credit: NASA

Chamber Overview

To do this, the ice temperature in the chamber will range from 193 to 233 [K]. A small copper probe will be placed into a starter hole and use an internal heater to melt deeper into the ice. A rotary encoder will measure the descent of the probe while an array of thermocouples will measure the temperature of the ice throughout the duration of the experiment.

How Chamber Will Match Europa

The chamber will have an ice diameter of 80 [cm] with a layer of vacuum insulation over 4 [cm] thick. An 80 [cm] diameter allowed for minimal temperature error while keeping manufacturing costs at a minimum. To lessen the effects of Earth’s environment on the experiment, we want the chamber to be as well insulated as possible. 4 [cm] of vacuum insulation will further aid in thermally isolating the chamber from the outside environment.

Far-field temperature gradient

D =	10 cm	20 cm	30 cm	40 cm	50 cm	60 cm	70 cm	80 cm
0 s	193 K	193 K	193 K	193 K	193 K	193 K	193 K	193 K
3600 s	552 K	309 K	238 K	210 K	199 K	195 K	194 K	193 K
7200 s	588 K	341 K	263 K	228 K	212 K	203 K	199 K	198 K
10800 s	606 K	358 K	278 K	241 K	222 K	211 K	206 K	205 K
14400 s	618 K	370 K	290 K	252 K	232 K	221 K	215 K	214 K
18000 s	629 K	381 K	300 K	262 K	241 K	230 K	224 K	223 K

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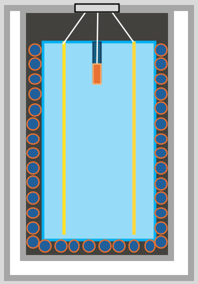
7200 s	588 K	341 K	263 K	228 K	211 K	202 K	197 K	195 K
10800 s	605 K	357 K	277 K	240 K	220 K	208 K	202 K	198 K
14400 s	616 K	367 K	287 K	248 K	226 K	213 K	206 K	201 K
18000 s	623 K	374 K	293 K	254 K	232 K	218 K	209 K	203 K

80 [cm] diameter chamber temperature gradient

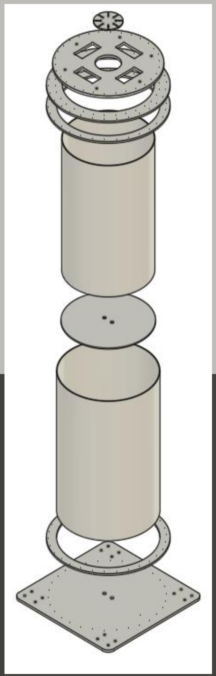
To find the temperature error between our chamber and Europa, we created two types of 2-dimentional models. The first was a far-field temperature gradient. The second type were a few different chamber diameters that we could compare to the far-field. The two tables to the right show the far-field gradient (up to a diameter of 80 [cm]) and the theoretical gradient of an 80 [cm] diameter ice block. 3600 seconds is the longest amount of time we expect for our probe to take to pass through a 2-dimentional plane of ice



Chamber Cross-Section Diagram

Experiment Procedure

The probe heater will be powered by an external source. The distance the probe has travelled will be measured by the rotary encoder at the top of the chamber. The thermocouples (seen in yellow) will be spaced radially and vertically throughout the chamber. The information from the encoder and thermocouples will be fed into our data acquisition system and used to validate our thermal. This will confirm that our chamber is matching the ice conditions of Europa.



Primary Chamber Assembly

Ice Making Procedure

The ice will be made as three separate cylinders with a diameter of 80 [cm] and a height of 40 [cm] instead of one cylinder with a height of 120 [cm]. These blocks will be made in ultra-low temperature freezers and then stacked into the chamber one at a time. Once all the blocks have been stacked into the chamber, a small amount of water will be added to the chamber. Then, using an external cascade refrigeration chiller, coolant will flow through a copper coil running along the interior of the chamber, freezing the blocks together.

Chamber Specifications

the primary structure of the chamber will be made entirely out of 304 stainless steel. Stainless steel provides both a high yield strength and a relatively low thermal conductivity. The chamber can be broken into four sub-assemblies: inner chamber, outer chamber, lid, and base. The chamber will ride on four large caster wheels. The wheels allow for the chamber to be installed and moved more easily as well as provide clearance for the vacuum and chiller ports in the baseplate.