Creation and Management of Test Articles to Aid in the Development of an Icy World Sampling System

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***Abstract*—The Europa Lander aims to find evidence of life beyond Earth. The strong evidence for a salt water ocean that extends to the surface of the planet and geological activity show promise for finding life on Europa. The creation of a sampling system requires testing to be done on test articles that are like Europa's surface and composition. Standardization and testing of test articles, tagging and tracking, and database management have been key areas of focus for improving test infrastructure.**

***Index Terms*—Europa, sampling, sampling system, cryogenics, Europa Lander, magnesium sulfate ice**

I. INTRODUCTION

The Europa Lander aims to find life beyond our planet, Earth. Water has always been the focus to find life because of its importance to Earth and the survival of its inhabitants. Europa has become the best candidate due to evidence for its unique conditions: a sub-surface salt water ocean that spans down to the surface of the moon, geological activity, and hydrothermal vents.

A sampling system is in development to search for biological activity. Currently, the system is being designed as two parts: the blade to cut into the ice, and a sampling tool/collection system.

The development of this system required standardization and documentation of the creation of test articles, infrastructure to handle the life-time of test materials, tracking test article data, as well as further research on the material properties of test articles.

II. IMPORTANCE OF SURFACE COMPOSITION AND TERRAIN

Due to Jupiter's radiation, the lander would be required to cut 10 cm into the surface and collect samples below that depth. It is difficult to draw conclusions from the current images available of Europa's surface, shown in fig. 1, each pixel containing 6m of information. This meant that there were no real bounds as to the terrain requirements when creating test articles.

The surface composition of Europa also poses some difficulties. NIMS (Near-Infrared Mapping Spectrometer) testing has shown that the surface of Europa is likely a mixed composition of water ice with sulfuric acid hydrate and hydrated salts [1]. There has been research on the kinds of possible hydrated salts present on Europa and some have proposed magnesium sulfate salts [1]. The future sampling system must be designed to handle different types of surface structures as well as ice compositions.

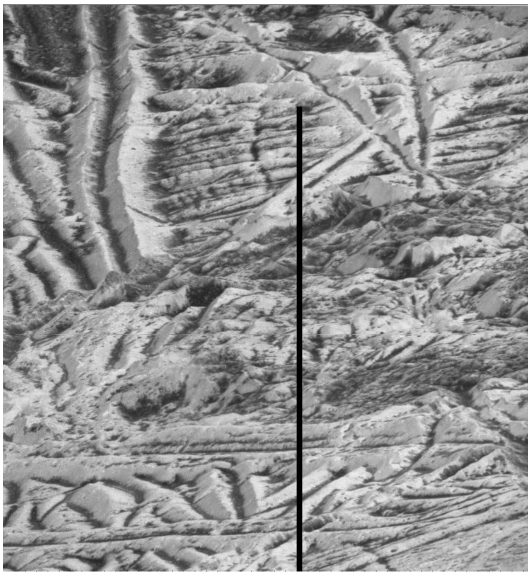

Figure 1. Highest resolution photograph of Europa's surface (Photo courtesy of NASA/JPL-Caltech)

III. TEST ARTICLES

The main test articles that were consistently created and tested were regular commercial ice, custom commercial ice, and aqueous magnesium sulfate ice of differing concentrations. Aside from the main test articles, there have been more test articles created to challenge the sampling system to deal with possibility of physical obstacles of cutting into cryogenic ice on Europa.

A. Regular Commercial Blocks and Custom Blocks

Previous attempts and studies in creating clear flat ice proved the process was too involved and was not a path the team wanted to continue to investigate for the time being. This was because the cost and time associated with this process posed very little benefits with inconsistent results. It was decided it best to purchase clear ice blocks off-site to be the standard for test articles.

Regular commercial blocks were originally purchased to place into test article trays, but later moved to purchasing custom ice blocks to reduce the risk of creating unusable test articles post-freeze due to the difference in size between the block and test article tray.

Regular commercial blocks were susceptible to shifting during the freezing process, leaving very little area to work with. Maximizing the area was not as important as it is currently. The test area was previously limited to the range in which the StORM (Stiff Operationally-flexible Robotic Manipulator) arm could operate. New test articles were being created in which thermocouple(s) were placed into blocks, thus reducing the area in which the arm could cut. It was pertinent to decrease the risk of data and time lost from cutting into a thermocouple — this problem along with inconsistent freezes were rectified with the use of custom blocks.

B. Salt Solution Test Articles

Salt test articles were created using epsomite ($MgSO_4 \cdot 7H_2O$) at varying concentrations to create a baseline, but also to give some insight as to the difficulties in cutting salt solutions. The maximum magnesium sulfate that could be dissolved in 23.5 °C water was calculated to be 365 g/L. The bounds were taken at the extremes, 0 g/L and the maximum concentration previously stated. Different concentrations between the extremes were chosen to supply more data points: 35 g/L, which is about the salinity of Earth's ocean and an arbitrary 133 g/L. Figure 2 shows the average current needed to cut into each magnesium sulfate ice test article.

1) Epsomite vs. Anhydrous Magnesium Sulfate

Upon completion of tests, it was concluded that another data point was needed between 133 g/L and 365 g/L. An arbitrary concentration of 250 g/L was created and tested. The results are shown in fig. 3, where the red point is the newly tested 250 g/L.

The results for the final test did not follow the linear trend expected, and further research was done. This led to the discovery that the calculations for the maximum concentration was done for anhydrous magnesium sulfate ($MgSO_4$) as opposed to the epsomite ($MgSO_4 \cdot 7H_2O$). The newly calculated maximum concentration for epsomite was found to be 272 g/L at 23.5°C. Figure 4 illustrates the difference in solubility graphically. It is easy to see there is a very clear distinction in solubility when comparing anhydrous magnesium sulfate and epsomite. There is still an ongoing discussion as to whether solutions should be created using epsomite or anhydrous magnesium sulfate.

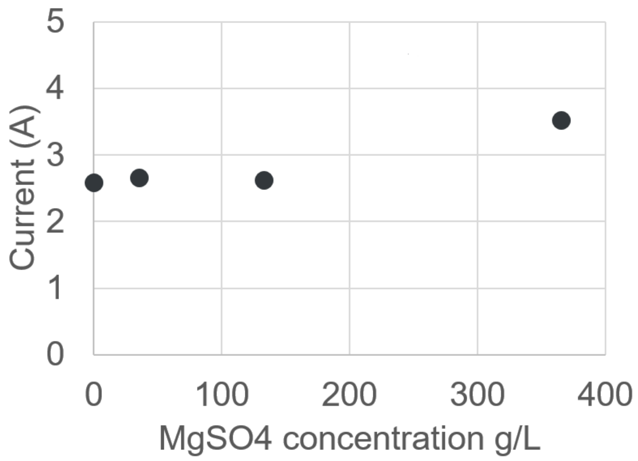

Figure 2. Graph of average current for each concentration

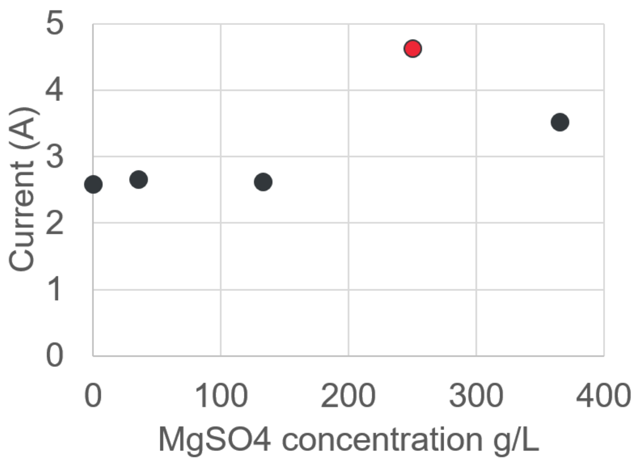

Figure 3. Graph of average current with new data point

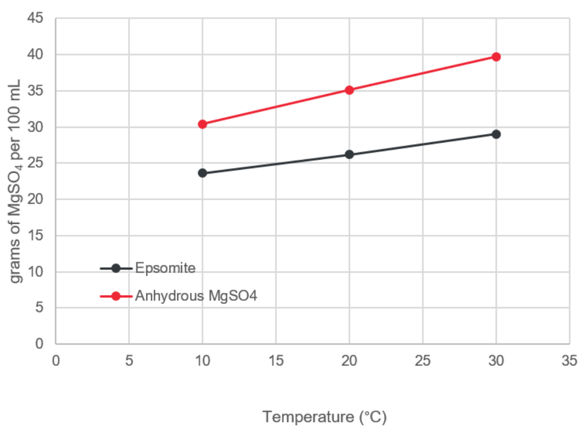

Figure 4. Solubility comparison of anhydrous magnesium sulfate vs. epsomite

C. Bi-weekly Challenge Test Articles

The bi-weekly challenge consisted of three teams: materials, excavation, and sampling. The materials team created a test article, the excavation team would test blades and its ability to cut as much of the test article as possible, and then the sampling team would retrieve as much sample as possible with their chosen method.

Materials that have been tested thus far have been layered ice and salt lick blocks glued with epoxy 2216.

1) Layered Ice

Layered ice was chosen because of the possibility of Europa's ice being layered like glaciers on Earth. If large pieces of ice were to be cut off where layers met, the sampling system would need the ability to collect these pieces.

The process for the creation of this ice was to pour 500 mL of de-ionized water into our sample trays. The tray was then placed in the 190K freezer and allowed to freeze. Water dyed with food coloring was cooled in the freezer and then painted on to the frozen layer. Cooled water was used to prevent cracking when the liquid came into contact with the ice. Food coloring was painted on to the tops of each layer to make it easier to differentiate between layers. Primary colors were chosen for the dyes for differentiation purposes as well. If non-primary colors were used and the colors from the layers began to mix, it would be difficult to tell if the colors observed were painted or mixed. This process was repeated until the test article tray was filled.

2) Salt Lick Block

Previous tests of salt saturated ice (not to be confused with magnesium sulfate solution ice) proved difficult to cut into, but the team was curious as to whether the sampling system would be able to handle a block of salt. This test was used as an opportunity to observe and collect data on the difference in cutting in a solid block as opposed to pieces of salt blocks with vacancies, shown in fig. 5.

There was difficulty with the blade when cutting through vacancies, especially where jagged pieces protruded due to the high probability the blade would get caught.

Figure 5. Salt lick test article post-test. Intact salt lick block (left) epoxied salt lick pieces (right)

Figure 6. Powdered tailings from salt lick block and epoxy test article

Figure 6 shows the powdered tailings from the result of cutting into the test article. During the excavation process, a fair amount of powdered tailings were airborne, prompting such questions such as: Is there the possibility of ice on Europa cutting off in powdered form? Could it get into parts of the lander and damage it, thus decreasing its lifetime?

IV. Test Article Management

Proper management of samples is crucial to operations. The tag used to label each test article holds information such as: unique serial number, test article type, and the date and time of creation. The tag was a sticky note and was partially submerged in water and placed on the outside of the test article tray. The water allowed the tag to adhere and freeze onto the side of the trays, reducing the risk of losing the tags. Test articles had a tag on the outside as well as the inner wall in case the outer tag was lost or vice versa, fig. 7.

All information on test article tags were also located on the database as well as additional information: location and the freezer test article was made in, temperature of the freezer, chemical recipe, physical recipe, and notes.

V. Future Of Test Article Management

The current system has been sufficient for the project's current needs, but a more robust system will be required in the future. Future test beds would require tags to be able to withstand being submerged in liquid nitrogen, placed in vacuum, and withstand contact with different materials. There has been ongoing research on implementing a new database to better complement new test articles and the future tagging system.

The new test bed requirements as well as the introduction of new materials required research to find a new tagging system that would not fail under these new conditions. Paper tags would not suffice in the new test bed environment, and the loss of these tags prior to proper disposal would affect the

Figure 7. Test article with outer and inner tags

project's ability to work efficiently and appropriately under JPL's hazardous waste guidelines.

The biomedical field was the area researched to find an appropriate tagging system. This was because biomedical companies store valuable biological samples that are, oftentimes, kept long-term in harsh environments.

There has been interest in an Australia-based tracking solutions company, bluechiip®, to help with a tagging solution. The chip their tracking devices include would enable the instantaneous temperature measurement of test articles. This would eliminate the guesswork when test articles are moved from one location to another because the temperature change in a test article can change its structure. Their device uses MEMs (microelectromechanical systems) technology to exclude the use of electronics, decreasing the risk of damaging and losing test article data held within these tags. The risk is high in using electronic products because of the types of test articles created, many of which require water as a solvent. The company's ability to customize their products to better fit the project's needs was also taken into consideration.

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References

[1] L. M. Prockter, J. H. Shirley, J. B. Dalton III, L. Kamp, "Surface composition of pull-apart bands in Argadnel Regio, Europa: Evidence of localized cryovolcanic resurfacing during basin formation," *Icarus,* vol. 285, 2017, pp. 27-42., in press.

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