DEVELOPMENT AND TESTING OF A MINIATURE ROBOTIC ELECTRODIALYSIS (MR ED) SYSTEM TO REMOVE SALTS FOR OCEAN WORLD SAMPLING. F. E. Bryson[1], E. D. Ingall[1], A. M. Hanna[1], M. Cardelino[1], T. Plattner[1], M. R. Meister[1], J. D. Lawrence[1], A. Mullen[1], D. Dichek[1] and B. E. Schmidt[1,2], [1]Georgia Institute of Technology (fbryson7@gatech.edu), [2]Cornell University

Introduction: Jupiter's moon Europa is believed to have a subsurface ocean beneath its ice shell, making it a compelling astrobiological target. In support of the search for life, the Vertical Entry Robot for Navigating Europa (VERNE) project recommended a system of instruments for characterization and life detection with sample processing for high salinity environments [1] [2]. A primary challenge this system would face on Europa is the unknown range of sample composition and salinity in the ocean, as well as the potential for encountering highly saline brines within the ice shell. Although these brines are biologically interesting as they could preferentially preserve organics [3] [4], the s alts can clog small fluidic systems and alter and inhibit measurement capabilities in instruments, e.g. mass spectrometers and DNA or other biomolecule sequencers, requiring samples to be desalted before analysis [2]. Therefore, a key technology development for liquid sampling on ocean worlds is a robust system to desalt highly saline fluids.

Electrodialysis (ED) systems remove salt from aqueous solutions by applying an electric potential across a series of ion-selective membranes that separate the sample solution from another solution that receives ionic species, called the concentrate. The electric potential causes ions to move from the sample into the concentrate, which creates a low salinity sample. ED is proven to retain a significant percentage of dissolved organic carbon (DOC) [5], and thus it is a promising technology to desalt samples to permit analysis of biomolecules on ocean worlds. However, current electrodialysis systems used for DOC recovery are too large for deployment on instruments sent to ocean worlds. Here we present results from the testing of a Miniature Robotic Electrodialysis (MR ED) system that is more suitable for deployment on spacecraft.

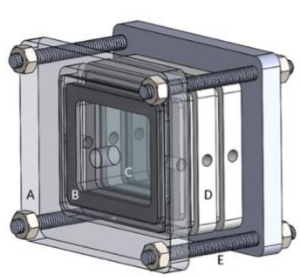

Figure 2 MR ED apparatus: Endcaps (A) seal the outer chambers, between which gasket material (B) seals the chambers and the ion-exchange membranes (C) between the three Delrin chambers (D). Nylon threaded rods and nuts (E) are used to connect the endcaps.

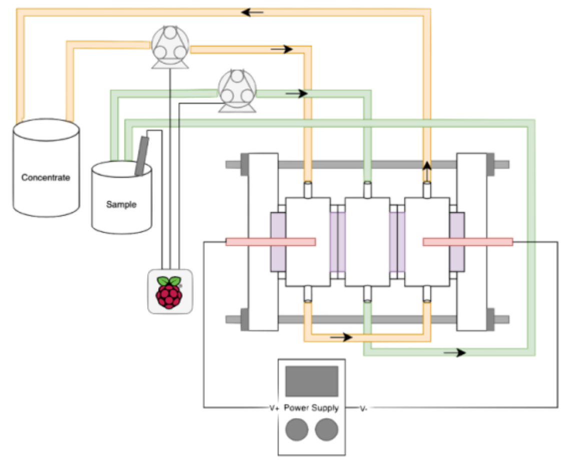

Figure 1 Schematic of the experimental setup: Raw sample is pumped through the central sample chamber, across which an electric potential supplied by the anode and cathode encourages ion transport across membranes. The sample is constantly evaluated for salt concentration via conductivity.

System Design: The MR ED system uses one pair of ion selective membranes with continuous specific conductivity monitoring to achieve a self-contained, autonomous system for desalting samples (**Figure 2**). The system currently supports as little as 50 mL of sample in circulation, which allows for additional downstream processing and analysis and requires less sample be collected than larger ED systems.

This sample is circulated through the center sample chamber as the electric potential is applied across two custom platinized titanium electrodes, while a separate solution is circulated through the outer chambers separated by the ion-selective membranes (**1**). To minimize system size and the need for electrode rinse solutions, the electrodes reside within the concentrate chambers. A solution of Na_3PO_4 is used for the concentrate in most desalting experiments to avoid unwanted reactions with the electrodes, although tests that use a separate volume of the initial sample solution for the concentrate have been completed in order to mimic *in situ* operations. An external power source that applies up to 30 V at up to 1.5 A is used to supply the electric potential; a low power comparative to other ED systems is useful to prove desalting for ocean world operations where power is limited.

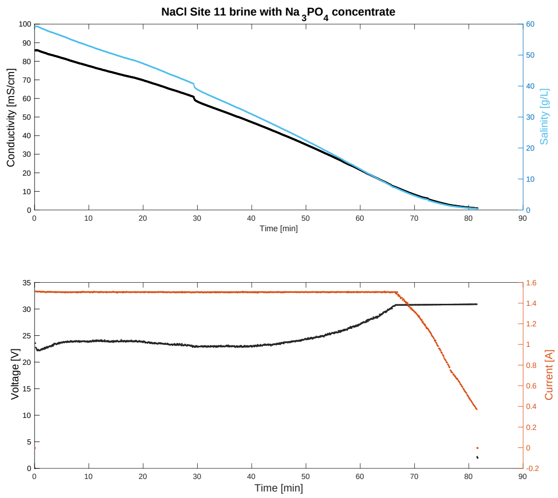

Figure 3 Conductivity, salinity and power results from NaCl brine desalting test: A NaCl brine taken from South Bay Saltworks in San Diego, CA was desalted to 7.7 mM salinity within 82 minutes, using a Na_3PO_4 concentrate. Salinity is calculated from the specific conductivity, which is continuously measured throughout the test using conductivity and temperature sensors.

Results: Initial results show an average 70% DOC recovery in tests of laboratory NaCl solutions with added glucose, as well as in field samples taken from

the Skidaway River (Savannah, GA), and NaCl brines from South Bay Saltworks (San Diego, CA). Furthermore, tests with field samples from the Skidaway River that mimic mission operations, in which a separate volume of the sample solution is used for the concentrate (at the same initial ionic strengths), have additionally achieved successful desalting and DOC recovery.

Future Work: We intend to further develop the benchtop system into an autonomous miniature ED system self-contained with its power and sensing systems. This contained, portable unit would allow for allows for easy transport to field testing locations and allow in situ processing on Earth.

Additionally, more work is needed to better characterize MR ED's effectiveness on brines, as well as on salts other than NaCl that might exist on Europa, such as $MgCl_2$.

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