LUNAR WATER PROSPECTING USING A THERMAL PROBE. C. A. Purrington,[1] C. Dreyer[1], and P. Abel[2] [1]Colorado School of Mines, Department of Space Resources, 1310 Maple Street GRL 140 Golden, CO 80401. Email: cpurrington@mines.edu, cdreyer@mines.edu, [2]NASA Glenn Research Center, NASA, 21000 Brookpark Rd, Cleveland, OH 44135; Email: phillip.abel@nasa.gov

Introduction: Lunar ice has been detected through various remote sensors and indirectly through the LCROSS impact study. This information doesn't provide the localized prospecting information required to define an ore reserve. Without this information funding cannot be secured for a mining operation. Localized prospecting data is required to build confidence in the ice ore reserve. Localized prospecting is possible with drilling and mass spectrometers. However, these tools are energy and time intensive.

The thermal properties of icy regolith change as function of Water Weight Percentage (Wt%) and as a function of ice structure. It's possible to leverage these thermal properties and detect them using a thermal probe. The primary advantage of a thermal probe is relatively low energy expense of ~10kJ and short sampling period of approximately 15 minutes.

Experimental Setup: This study uses a modified penetrometer probe that has been fitted with an aluminum tip. The tip is fitted with a 15W cartridge heater to input heat near the top of tip. Temperature measurements are taken with a Lakeshore DT-600 temperature sensor located near the bottom of the tip. This tip is effectively thermally isolated by using 36 AWG wire leads and a thin-walled shaft.

The icy regolith simulant container used contains a icy regolith bed with a 8.89 cm diameter and depth of 8.89 cm. This bed is cooled by a jacket container with LN flowing through it. A LN cooled lid that sits 0.5cm above the container provides a surface for the icy regolith simulant to radiate too. But still allows a path for vapor to escape while in the vacuum chamber. The lid contains a 1cm diameter pass through hole for the 0.635cm probe to pass through. This entire apparatus sits inside of a vacuum chamber and experiments are conducted at pressure between $1x10^{-5}$ and $1x10^{-6}$ Torr. The probe is then inserted into the icy regolith simulant at a rate 0.25mm/s using a z-motor that is controlled remotely outside of the vacuum chamber.

Once, the sample has cooled to less than 100K, the probe is inserted. When the temperature of the probe has reached a steady state with a temperature change less than 0.001K/s. A thermal event is started. Heat is applied ~11.5W for 60s to the tip. The temperature sensor captures the heating event and the subsequent cooling event as the tip returns to the ambient temperature. This study specifically focuses on the tips temperature rate of decay after the tip has reached the maximum temperature.

Icy Regolith Simulant: The structure of ice in lunar Permanently Shadowed Regions (PSR's) is not well understood, as to date there have been no soft landing lunar missions to PSR's. For this study, we have focused the experiments on two types of icy regolith simulants, Granular and Pressure Fused Granular (PFG). Both samples use lunar regolith simulant, Colorado School of Mines, Lunar Highlands Type (CSM-LHT). For a Granular sample, dry CSM-LHT is cooled to -20C in a freezer and mixed with ice grains smaller than 500 um at the desired Wt%. This is thoroughly mixed and then placed in the LN container and compressed using a 7.5kg surcharge. There is no ice fusion for Granular samples.

A PFG sample is initially constructed the same method as Granular with a follow on step of compression. Once, the sample is in the LN container, a press is used on the surface on the Granular sample at a force of 115kg for 5 minutes. This causes ice grains to slightly melt and adhere to local regolith simulant grains. After pressure is released, the sample is more dense and mechanically stronger than Granular.

Conclusions: By analyzing the rate of decay of each test , this data can be used to determine the approximate Wt% with an accuracy of ±1.5Wt% for either simulant of Granular and PFG. This is constrained by experimental data between 0-9 Wt%. The rate of decay for each simulant type is relatively similar with the corresponding Wt%. This implies that a thermal sensor could be used alone, to provide an approximate Wt% in any PSR regardless of ice structure.

A sensor this simple is also a great tool that does not provide a complex operation but still provides relative data to a Prospecting Campaign to be build confidence is a lunar Ice Reserve. With a relatively cheap energy (10kJ) and time expense (15 minutes) many samples can be taken in a PSR mission where time and energy are constrained.

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