HYDROGEN EXTRACTION FROM LUNAR SOIL: METHODS APPLICABLE TO A LUNAR PROCESSING FACILITY.

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Hydrogen will be a critical resource for lunar activity, as a fuel for transportation to and from the moon and as a necessary component for water production (1). Recent research has found that hydrogen is present in the lunar soil in sufficient quantitites to make its extraction a viable alternative to transport from Earth (2). If a means of recovering hydrogen from the soil could be developed, which would be readily applicable to the lunar environment, the requirements for a lunar facility could be more easily met.

The hydrogen in lunar soil is derived from the solar wind and is readily removed by heating (3). We have recently examined two methods of hydrogen extraction which make use of energy supplies available to a lunar colony. Solar energy will be prevalent on the moon, and excess thermal heat will be available as a by-product of nuclear power production, the most likely sources of the initial power available for the lunar base.

Solar Heating. A solar furnace was constructed from a Fresnel lens (72 x 95 cm). The lens was mounted on a frame for ease in adjusting. A lunar soil sample was placed in an alumina tube and evacuated. After the lens was properly positioned, the sample tube was placed with its tip at the focal point of the lens and heated (at approximately $1000\pm50^{o}C$) for five minutes. After heating, the released hydrogen was measured using gas chromatographic (GC) procedures of Carr et al. (4).

Heating with Hot Gas. An apparatus was constructed so that different gases could be passed through a hot furnace and, immediately upon exiting the furnace, flowed around a sample tube which had previously been evacuated and attached to a GC for hydrogen analysis. Tests using He, Ar, CO_2, N_2 and steam were carried out to determine if they could be heated to elevated temperatures (i.e. $900^{o}C$) and used for heating the samples containers. It was found that helium could be used as the gas. Results showed that the temperatures inside the sample tube (location of the lunar soils) could reach $900^{o}C$ and easily maintained for five minutes. Results indicate that helium absorbed sufficient heat and retained it for a period of time adequate for heating the samples.

Results and Conclusions. A comparison of hydrogen concentrations measured for three lunar soils using the solar heating and hot gas extraction techniques with "normal" laboratory resistance furnace heating is given in Figure 1. Solar furnace and heated helium extraction methods produce comparable results with expected hydrogen values in the three soils. Results indicate the possible applicability of each method to actual resource management on the moon. The studies done, however, are merely prototypical, with the true merit of each method still requiring examination on a larger, mass production-type scale.

Before any of these methods can be used for mass hydrogen extraction, efficiency studies are necessary which show the percentage of a soil's total hydrogen released as a function of heating temperature and heating time. We believe that temperatures lower than the $900^{o}C$ used here will be adequate and the heating time required will decrease when the soil can be heated directly, as the alumina sample tube was found to slow sample heating.

To make the solar surface furnace adaptable to the moon, a larger heating zone is necessary. Although temperatures as high as $1600^{o}C$ could be achieved under proper conditions at the focal point of the Fresnel lens, the temperature zone providing sufficient energy to heat the soils properly was very small (1 cm in diameter). The temperatures were significantly influenced by atmospheric conditions, time of day, and decrease dramatically in the focal plane as one moved out radially from the focal point. A less dramatic, but significant drop was also observed as one moved out of the focal plane along the lens axis.

HYDROGEN EXTRACTION FROM LUNAR SOIL
Houdashelt, M.L. et al.

We believe that conditions on the moon will allow for a larger area to be sufficiently heated to make a solar furnace viable for hydrogen extraction. The lack of an atmosphere will allow consistent continual, direct heating of the soil with about 40% greater solar flux than the maximum flux experience on Earth (5). Additionally, a larger Fresnel lens could be used. The 14-day lunar sun cycle limits the productivity of this method for continuous hydrogen extraction operations.

Any scaling up of the heated helium extraction process will require considerable study of heat transport and heat retention of the gases used. We found helium to lose heat rapidly upon expansion after leaving the furnace's heating zone. With the proper heat management procedures, there is sufficient heat which could be used for extraction of hydrogen from lunar soils.

Our small scale laboratory studies have shown promising results which should be considered as methods for extracting hydrogen from lunar soils. The applicablility of each method to an actual lunar base depends upon the ability to properly control the heating of lunar soil on a much larger scale than that studied here. The preliminary investigations, however, indicate that further study of each method would be beneficial, since the economic ramifications are substantial.

References:

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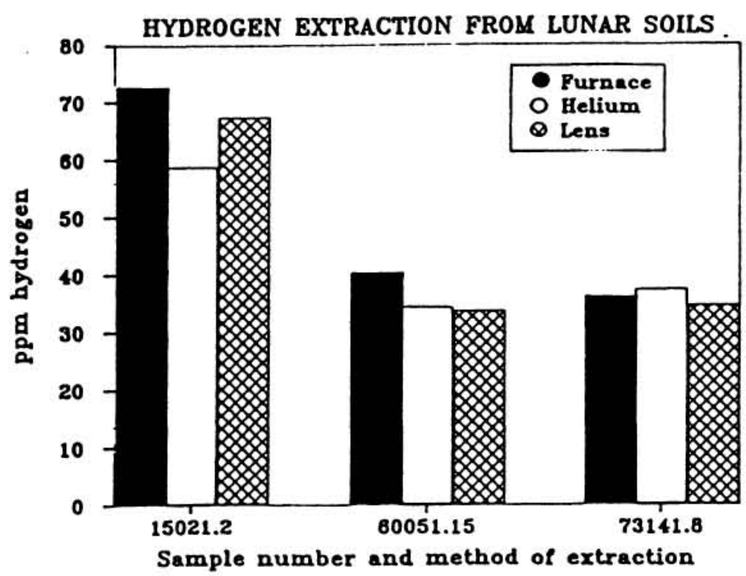

Figure 1. Comparison of Heating Methods