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# METHODS OF EXTRACTING HYDROGEN FROM LUNAR SOIL


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## INTRODUCTION

Increasing interest in establishing a lunar base has generated considerable study on utilization of lunar resources. Because of its importance in producing water, reducing oxides, and serving as a fuel for orbital transfer vehicles, hydrogen is of prime importance as a resource. Lowman (1985) states that hydrogen would greatly facilitate the establishment of an autonomous permanent colony, and he calls hydrogen "the most valuable lunar resource."

Through the centuries, hydrogen has been imbedded in lunar soil by the solar wind. The hydrogen can be extracted by heating the soil to 900$^{o}$C (Carr *et al.*, 1987). In order to obtain hydrogen on the lunar surface, an extraction method must be developed which will not only be reliable but also economically feasible. In this study, three heating methods have been examined for possible use in extracting hydrogen from lunar soil.

## EXPERIMENTAL

### SOLAR HEATING

A solar furnace was constructed from a Fresnel lens 72 cm by 95 cm. The lens was mounted on a frame for ease in adjusting. A soil sample was placed in an alumina tube which was then attached to a quartz adapter and evacuated. After the lens was properly positioned, the tube was placed with the tip at the focal point of the lens and heated for five minutes. The tube and adapter were then attached to the sampling line.

### FURNACE HEATING

A resistance wire furnace was constructed using Kanthal A wire. The sample was placed in an alumina tube which was attached to the sampling line and evacuated prior to heating in the furnace. The sample was heated for five minutes at 900°C.

### HEATING WITH HOT GAS

The apparatus was constructed so that a gas was passed through a hot furnace and, immediately upon exiting the furnace, hit the sample tube which had previously been evacuated and attached to the sampling line. The temperature of the hot gas was kept at least 900°C for the five minutes it was in contact with the sample tube.

### HYDROGEN DETERMINATION

After the hydrogen was extracted from the sample, it was injected directly into a gas chromatograph equipped with a 12 ft. Molecular Sieve 5A column and a helium ionization detector. In order to obtain a linear response for hydrogen, it was necessary to use a carrier gas containing an impurity. Helium containing 90 ppm nitrogen was used in this study. The sample volume was determined for each of the above systems. Calibration was accomplished by filling the system with standard gas of hydrogen in helium to a given pressure, as measured by a capacitance manometer.

## RESULTS AND DISCUSSION

### SOLAR HEATING

Solar heating would be a logical choice for use in the lunar environment. In this study, a Fresnel lens was used for converging the sun's rays. Temperatures as high as 1300°C could be achieved at the focal point with optimum conditions; however, the temperature was very dependent on external factors such as wind and atmospheric haze. Because of this, it was difficult to maintain a constant temperature. The highest temperature zone was very small, with a diameter of about 2 cm. Moving out from the focal point in the focal plane, the temperature decreased dramatically. There was also a temperature decrease, although not as pronounced, when moving up from the focal point toward the lens. It was much harder to achieve good reproducibility with this method than with either of the other two methods used in this study. Results improved near the end of the study because a thermocouple was placed on the outside of the sample tube, making it much easier to adjust the position of the tube in order to maintain a fairly constant temperature. Much better results would be obtained on the moon because of the absence of an atmosphere, eliminating a lot of the problems encountered in this study.

## FURNACE HEATING

Heating with a resistance wire furnace is excellent for laboratory use. Although the furnace temperature flucuates a little as line current changes, it is easy to achieve reproducible temperatures. The sample tube is heated evenly, and reproducible data are obtained. This same technique could be used on a large scale on the moon, but it would require a considerable expenditure of energy.

## HEATING WITH HOT GAS

On an operational lunar base, there will be places such as nuclear power plants which build up large amounts of heat. Using the excess heat will be highly desirable. One way to harness this heat would be to pass gas over the heated zone, transferring some of the heat to the gas. The hot gas could then be used as a heat source. In this study, five gases and a gas mixture were used to see which achieved the highest temperature and which held its temperature for the longest period of time. The gases studied were argon, carbon dioxide, helium, a mixture of argon and helium, nitrogen, and steam. Each gas was passed through a hot furnace (used in place of the lunar nuclear reactor), and the temperature of the gas coming out of the furnace was monitored. Results are shown in Table 1. Argon retained heat much longer than the other gases; however, it did not reach a very high temperature. The highest temperature was achieved with helium, and by adjusting the flow rate so that a temperature below the maximum was reached, the temperature could be maintained for an acceptable time period. When passing the helium through three resistance wire furnaces, an exit temperature of above 1000°C could be achieved, and the temperature would remain above 900°C for several minutes. This was the set-up used in heating lunar soil; a heating time of five minutes was chosen to correspond with the time required when using the solar furnace. A disadvantage of this technique was the rapid loss of heat experienced by the hot gas after leaving the heat source. If this technique is employed on the moon, pressure control will be important in order for the gas to retain its heat until it reaches the hydrogen extraction plant. Because it can be recycled, large amounts of gas will not be required.

## COMPARISON OF METHODS

Three different lunar soils were used with each extraction method. The results are shown in Figure 1. It is clear that all three methods could be used effectively for extracting hydrogen from the soil. In this study, the furnace was the easiest to use and gave the most reproducible results. The least reproducible results were obtained with the Fresnel lens because of the difficulty in maintaining uniform heating.

## CONCLUSION

All three of the heating methods shows promise for use on a lunar base. Larger, bench-top models with pumps, pressure controls, etc. need to be constructed in order to make accurate predictions concerning the relative usefulness of the three methods for hydrogen extraction on the moon.

## REFERENCES

CARR R. H., BUSTIN R., and GIBSON E. K. ( ) A Pyrolysis/Gas Chromatographic Method For The Determination of Hydrogen in Solid Samples. *Analytica Chimica Acta*, *202*, 251-256.

LOWMAN P. D. (1985) Lunar Bases: A Post-Apollo Evaluation. In *Lunar Bases and Space Activities of the 21st Century* (ed. W. W. Mendell). pp. 35-46. Lunar and Planetary Institute.

## TABLE I

| GAS | MAXIMUM TEMPERATURE (°C) | TIME INTERVAL FOR MAINTAINING TEMPERATURE WITHIN 10°C OF MAXIMUM |
|---|---|---|
| Helium | 723 | 2.9 minutes |
| Argon | 487 | > 2 hours |
| Helium/argon mixture | 621 | 5.5 minutes |
| Nitrogen | 542 | 5.9 minutes |
| Carbon dioxide | 610 | 4.0 minutes |
| Steam | 702 | 7 minutes |

Figure 1

HYDROGEN EXTRACTION FROM LUNAR SOILS