A Demonstration of Vacuum Pyrolysis. E. H. Cardiff[1], B. R. Pomeroy[1], and J. P. Matchett[2], [1]NASA Goddard Space Flight Center, [2]United States Air Force.

Introduction: The in-situ production of oxygen on the lunar surface is a key part of our future in-space propulsion infrastructure. Over 20 separate technologies have been identified as being capable of producing oxygen on the lunar surface. Taylor et al. concluded from a review of available technologies that the optimal technique to produce lunar oxygen is the vacuum pyrolysis technique[1]. However, very little research has been performed to develop this technique, with most research and development efforts focusing on reduction techniques.

Experiment: Preliminary work has been performed at NASA Goddard Space Flight Center (GSFC) to advance the readiness level of the vacuum pyrolysis technique. The technique is theoretically very simple. Lunar regolith is placed into a reactor that is heated to ~2500 Celsius by the native solar flux. The material vaporizes, and as part of this vaporization process, the highly oxidized lunar regolith is reduced and oxygen is formed. The reduced oxides are condensed out and discarded, and the gaseous oxygen is pulled out of the chamber. A picture of the prototype system developed to test vacuum pyrolysis is shown in Figure 1. The initial prototype was very similar to the work by Senior [2]. Two different solar concentrator concepts have been developed to heat the regolith: a large parabolic reflector, and a large Fresnel lens.

Figure 1. The prototype setup with the Fresnel lens.

Results: Several different lunar “simulant” materials have been vaporized and condensed, including ilmenite, enstatite, and MLS 1a. Masses of approximately one net gram of material have been vaporized with the small prototype system. Preliminary testing of the condensation system shows that the condensation will occur within a few centimeters of the crucible. Scanning Electron Microscope (SEM) tests of the slag have shown reduced oxygen at the surface of the remaining sample, indicating that there is a net oxygen production. An example of a SEM image from early testing is shown in Figure 2. Modeling of the process predicts oxygen yields of between 11 and 20%, depending on the feedstock.

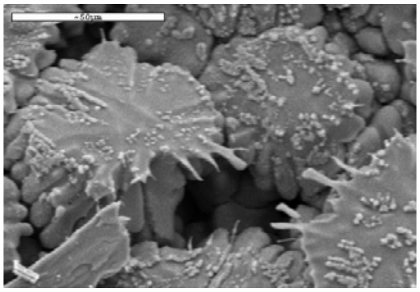

Figure 2. Scanning Electron Microscope (SEM) picture of ilmenite from the chamber. The surface of the crystals has been melted and vaporized.

Several problems were encountered as part of operations. The prototype system has been operated at pressure down to 10^{-3} Torr. The addition of a turbopump to lower this pressure will allow a mass spectrometer to be operated directly in the flow to measure the presence of oxygen. It will also reduce the vaporization temperature, and will more closely mimic lunar conditions. The windows for the chamber were also sensitive to thermal shock, vapor deposition, and thermal expansion. Window failures limited the durations of the tests to less than one hour. A combination of techniques have been tried and will be used to solve the problem of window failures, including a secondary window between the crucible and the vacuum window, increased distance between the sample and the window, and thicker replaceable vacuum windows.

Conclusion: The vacuum pyrolysis technique has been demonstrated with relevant lunar simulants, and shown to produce oxygen. The completion of a larger flux system, a lower gas pressure in the system, and more rugged windows will allow larger samples to be vaporized and to prepare for a flight experiment.

References: [1] L. A. Taylor & W. D. Carrier, III., Oxygen Production on the Moon: An Overview and Evaluation, Resources of Near Earth Space, (1993). [2] C. L. Senior. (1991) *JBIS.*, *44*, pp.579-588.