



Abstract #836

English

Demonstration of an Energy Efficient Lunar Volatiles Extraction System Using a Heat Pipe Heat Exchanger

A prototype volatiles extraction system is being developed to demonstrate a process for acquiring helium-3 (^3He) from mare region lunar regolith. This helium-3 would be used to fuel future fusion power plants that would produce little to no radioactive waste. From another perspective, helium-3 is only a small portion of the volatiles released from the extraction process being investigated. Hydrogen, helium-4, carbon dioxide, carbon monoxide, methane, nitrogen, and water (from hydrogen reduction within the extraction system) are by-products of the process. These volatiles could be vital in supporting people in space (space stations, Lunar or Martian outposts) for extended periods of time. The prototype system being developed is called the Helium Extraction and Acquisition Test bed (HEAT) and it is based on past lunar volatiles miner designs that were developed at the University of Wisconsin Fusion Technology Institute (FTI). HEAT is being developed to process 157 g/s of JSC-1A lunar regolith simulant. This corresponds to a 1/1000th scale prototype relative to the previously mentioned miner designs. Handling of fine and abrasive granular material, like the JSC-1A lunar regolith simulant that will be used for HEAT, can be difficult and will certainly be a challenge during the prototype's development. Testing of HEAT will focus on obtaining information on the rate of ^3He extraction possible and to what extent thermal energy recovery can be employed in this kind of volatile extraction system. The goal is that the prototype scales down perfectly from the baseline miner design, and if it does, the ^3He extraction rate should be 16.7 mg/hr (assuming a 20 ppb ^3He concentration in the regolith processed) and the system should achieve 85% thermal energy recovery efficiency of the input thermal power. The heating system for HEAT is the most critical of the prototype, as it is where the ^3He is actually released from the regolith. The design of HEAT starts with the heating system and moves outward to the systems and components that enable a continuous stream of properly sized regolith to enter and exit the heating system. To date, the progress made on the heating aspect of the HEAT project has been in the form of an analytical heat pipe heat exchanger model. The heat pipe heat exchanger model determines the number, dimensions, and arrangement of heat pipes for a given regolith mass flow rate, heat exchanger energy recovery efficiency and set of restrictions on the physical size of the system. The determined system parameters minimize the heat exchanger's mass. The heat pipe configuration was then used in an ANSYS Fluent™ computational fluid dynamics (CFD) model that determined the temperature evolution of the regolith as it travels between the heat pipes in the heating system, confirming that the regolith would become hot enough to release the embedded ^3He . There are assumptions made in the aforementioned heat exchanger model that need to be evaluated. The model treats the granular regolith material like a continuum fluid with a bulk density, constant specific heat, and effective viscosity. Bulk granular material can support shear stress without continually deforming (a fluid will continually deform or flow) to varying levels depending on the specific material. This ability to support stress can inhibit the flow of granular media in a given device. An experimental granular flow test cell was designed and constructed to obtain more effective flow properties for JSC-1A regolith simulant as it flows through a matrix of cylindrical extrusions that are meant to represent heat pipes. The results from the experiments will allow for a more accurate heat exchanger model and ensure that the JSC-1A simulant will continuously flow through the device. The effective viscosity of JSC-1A through varying heat pipe arrangements will be presented along with the minimum pipe spacing for given mass flow rates. The HEAT system will be constructed and tested for its continuous release rate of ^3He and its thermal energy recovery efficiency. The instrumentation system for HEAT will record temperature measurements and trace gas measurements. Thermocouples (or possibly other temperature measurement devices) placed in the regolith flow stream between the heat pipes will give regolith temperature measurements at select locations in the heat exchanger. These measurements will be used to determine the thermal energy efficiency of the HEAT system. If the regolith reaches 700 °C in the center of the HEAT heating system and exits the heating system at 130 °C, then the system will have an 85% thermal energy recovery efficiency. Trace gas concentration can be measured with a residual gas analyzer (RGA). RGA measurements of the atmosphere inside of the HEAT system will give the concentration of ^3He as a function of time. The release rate of ^3He can be determined from these measurements.

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