Manufacturing & Prototyping

Development of a Centrifugal Technique for the Microbial Bioburden Analysis of Freon (CFC-11)

Commercial applications include pharmaceutical development and quality assurance, and chemical manufacturing.

NASA's Jet Propulsion Laboratory, Pasadena, California

NASA Procedural Requirement 8020.12C entitled "Planetary Protection Provisions for Robotic Extraterrestrial Missions" states that the source-specific encapsulated microbial density for encapsulated organisms (div(0)) in nonmetallic materials ranges from 1-30 spores/cm^3. The standard laboratory procedure, NASA Standard Procedures for the Microbial Examination of Space Hardware, NHB 5340.1B, does not provide any direction into the methodologies to understand the bioburden within such a fluid as CFC-11 (Freon). This general specification value for the Freon would be applicable to the Freon charged within the Mars Science Laboratory's (MSL's) Heat Rejection System. Due to the large volume required to fill this system, MSL could not afford to conservatively allocate 55.8% of the total spore budget of the entire laboratory system (rover, descent stage, cruise stage, and aeroshell) of 5.00×10^5 spores at launch.

A novel filtration approach was developed to analyze the Freon employing a 50 kDa molecular weight cutoff (MCO) filter, followed by 0.22-µm pore-size filter to establish a calculated microbial bioburden.

Filtration of microorganisms from liquid matrices is a standard laboratory approach. Due to the volatility of Freon, a standard vacuum filtration unit would not suffice because of the lack of a cold trap on the vacuum unit. A more economical approach had to be devised. The two-pronged concentration approach is advantageous due to the fact that it initially concentrates the Freon from liters to milliliters where it can then be feasibility filtered and microbes extracted from the filter. This is a technology improvement over prior art as it defines the specific parameters to concentrate microbial organisms from a low-boiling-point fluid such as Freon.

This work relates to the current MSL mission but also has implications for future NASA missions that will utilize the same or similar heat rejection fluids. If the same lot of material is utilized on a future mission, then the experimentally derived value can be directly used based on this study (MSL-heritage). If a new lot or similar material composition is used in a future mission, then this technology can be employed or modified accordingly to accommodate such a fluid. This technology development will allow for a heritage-based starting point for fluids on other missions in which a calculated microbial bioburden is necessary.

This work was done by James N. Benardini, Robert C. Koukol, Gayane A. Kazarians, and Fabian Morales of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48303

Microwave Sinterator Freeform Additive Construction System (MS-FACS)

This system can create hard surfaces for walkways, roadways, or landing pads.

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The harmful properties of lunar dust, such as small size, glass composition, abnormal surface area, and coatings of imbedded nanophase iron, lead to a unique coupling of the dust with microwave radiation. This coupling can be exploited for rapid sintering of lunar soil for use as a construction material that can be formed to take on an infinite number of shapes and sizes.

This work describes a system concept for building structures on the lunar surface using lunar regolith (soil). This system uses the ATHLETE (All-Terrain Hex-Limbed Extra-Terrestrial Explorer) mobility system as a positioning system with a microwave print head (similar to that of a smaller-scale 3D printer). A processing system delivers the lunar regolith to the microwave print head, where the microwave print head/chamber lays down a layer of melted regolith. An arm on the ATHLETE system positions the layer depending on the desired structure.

In support of long-duration human missions to the lunar surface, a variety of *in situ* derived structures have been proposed that would enhance the utility of a permanent outpost, provide safety for the outpost elements, and mitigate the generation of dust. Using regolith in a variety of ways, it has been proposed that berms, paving, walls, roads, and other structures could be constructed to serve as permanent outpost. However, the means of creating the *in situ* structures with hardened surfaces remains a challenge.

A lunar regolith processing system mounted on the underside of ATHLETE will deliver correctly sized regolith particles to a microwave print head via a material handling system. The microwave print head with tunable microwave chamber then lays down a layer of melted regolith as the ATHLETE arm traces a pre-defined path forming a layer of printed structure in any desired shape. The process is repeated for subsequent layers, allowing the system to construct hard walls, vaults, domes, paving, and other *in situ* structures. Since any solid structure can be printed in this way, the construction mechanism is named Freeform Additive Construction System (FACS), using a Microwave Sinterator (MS) as a print head. Structures can be modeled in advance using CAD systems, and then sent to the lunar system to "make a FACS (FAX)" of the structure on the lunar surface.

The key to the microwave heating of lunar soil is the coupling of certain microwave frequencies to specific materials. This will improve the efficiency of the device and expedite heating of the soil. Since lunar soil is composed of a variety of materials, a broadband microwave emitter must be used such as a magnetron or a traveling wave tube amplifier. The microwave energy must be aimed into a resonant chamber containing the regolith. The frequency, the chamber, or both will need to be autonomously tuned to excite frequencies that couple the microwave energy with the regolith. This will create a more efficient heating of the regolith.

The novelty of the FACS concept lies in the unique capability of the ATHLETE system as a positioning system, coupled with an efficient material handling system and the ability of the adjustable microwave chamber MS print head to produce hard structures in the vacuum environment of space, and result in a digitally printed *in situ* structure using *in situ* raw materials.

The **Microwave Sinterator Freeform Additive Construction System (MS-FACS)** uses the ATHLETE mobility system as a positioning system.

The simplest application of this technology is a microwave road-paver. This device will be able to create hard surfaces in the immediate area of astronauts for walkways, roadways, or landing pads. These hard surfaces will mitigate the effects of dust by limiting the exposure in the immediate area of habitats and minimizing the amount of dust kicked up by the descent engines of landing spacecraft.

This work was done by Alan S. Howe, Brian H. Wilcox, Martin B. Barmatz, Michael B. Mercury, Michael A. Seibert, and Richard R. Rieber of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48291