Space-Resources Roundtable-PTMSS Abstract 2019

Dr. Stacy Carrera – Pioneer Astronautics

The objective of the Advanced Organic Waste Gasifier (AOWG) NASA Phase I project was to fabricate, test, and refine a reactor system capable of processing organic wastes to produce clean water for recycle during Mars transit to support human exploration missions. Wastes generated on Mars transit spacecraft are gasified in an oxygenated steam environment so that all organic matter in liquid and solid form (including feces and urine brine) is converted to vapor phase. The AOWG, which is designed for operation in microgravity, recovers water for recycle from the gasifier product gas while also producing a clean, dry gas suitable for venting. Only a small mass of sterile, solid inorganic waste remains from metallic packaging materials or other inorganic matter contained in the waste fed to the AOWG.

The AOWG incorporates significant novel enhancements to existing state-of-the-art Trash to Gas (TtG) steam reforming technology that include a feed preparation system, continuous feeder, a tar destruction reactor, downstream methanation to enhance water recovery, and condensate purification to meet electrolysis water specifications. The baseline AOWG Phase I crew operation requirements consist of packaging wastes in a manner similar to the 'football' preparation methods currently used in state-of-the art TtG systems but are not limited to this preparation method.

Key elements of the AOWG required for microgravity operation include feed preparation, a continuous feeder, a tar destruction reactor, and a microgravity condenser. The goal of the Phase I program was to establish that reforming reactions can be successfully achieved in a gas-tight system using components capable of operating in microgravity. The system design and operating parameters were selected to provide maximum recovery of water using a minimal amount of consumables and power. Automation features that limit crew commitment were also targeted by the AOWG effort.

The Phase I design lays the foundation for a baseline Phase II system to demonstrate continuous operation that can be carried out in microgravity. The AOWG system design effort was based on an evaluation of thermodynamic equilibrium modeling, the thermal and electrical input requirements, physical characteristics of the feed material and processed residue, and consideration of feeding and withdrawing materials in a microgravity environment. The Phase I program centered on a waste feeding system, an autothermal oxygenated steam reforming reactor to gasify organic matter, a tar destruction reactor to minimize condensate contaminant levels, and a condenser. Modeling was conducted to identify the best downstream process (methanation) to convert as much of the product gas to water as possible. Phase I hardware emphasis and experimentation was on the feed system and gasification system at a scale up to the target requirement for a crew of four during Mars transit. Other aspects were addressed during Phase I via modeling, engineering calculations, and laboratory experiments.

Phase I accomplishments include evaluation of feed methods, hardware design, feed system and reactor fabrication, AOWG system performance modeling, hardware operations using a variety of organic compositions to demonstrate continuous feeding, and condensate purification. A baseline Phase II AOWG design was developed on the basis of the Phase I results while leveraging NASA's microgravity technologies for materials handling and separations. The baseline Phase II design includes a shredder to allow for a compact gasifier, a feed dryer to minimize fluctuations in feed moisture content (and to prevent reactor quenching in the event of feeding a slug of high-moisture feed), actuated cylinders in combination with pneumatic assist to convey materials in microgravity through each unit operation, an oxygenated steam reformer, a tar destruction reactor, condenser, methanation reactor to enable maximum recovery of water while generating a clean vent gas, and instrumentation and controls. A condensate purification protocol was tailored to the AOWG to produce clean water using minimum consumables. Preliminary system mass and power estimates were prepared and show the AOWG to be highly effective given the benefit of the mass of water recovered for mission use and the mass of gas that can be vented during transit.