Regenerative Gas Dryer for In-Situ Propellant Production

Aaron Paz
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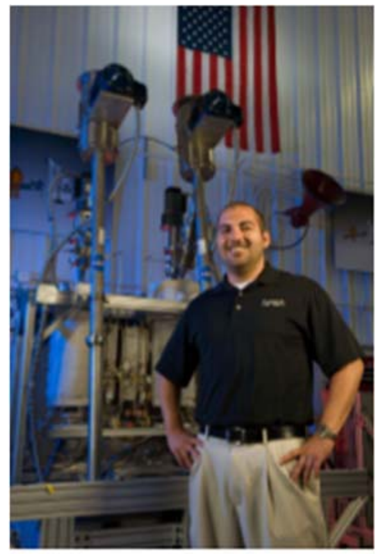
Start TRL	2
End TRL	4
Procurement	$50K
FTE	0.25
TABS	7.1

Goal / Gap



Pictured Above: Aaron Paz

Rocket propellant can be produced anywhere that water is found by splitting it into hydrogen and oxygen, potentially saving several tons of mass per mission and enabling the long term presence of humans in space beyond LEO. When water is split into hydrogen and oxygen, the gaseous products can be very humid (several thousand ppm). Propellant-grade gases need to be extremely dry before being converted into cryogenic liquids (less than 26 ppm water for grade B Oxygen). The primary objective of this project is to design, build and test a regenerative gas drying system that can take humid gas from a water electrolysis system and provide dry gas (<26ppm water) to the inlet of a liquefaction system for long durations. State of the art work in this area attempted to use vacuum as a means to regenerate desiccant, but it was observed that water would migrate to the dry zone without a sweep gas present to direct the desorbed vapor. Further work attempted to use CO_2 as a sweep gas, but this resulted in a corrosive carbonic acid. In order for in-situ propellant production to work, we need a way to continuously dry humid gas that addresses these issues.

Approach / Innovation

The primary objective of the project is to assess an alternative sweep gas, in combination with vacuum to regenerate desiccant. For ISRU applications, it is not necessary to retain 100% of the products, but it is a goal to minimize losses. A secondary objective of this project was to assess the potential utilization of this technology for a closed-loop air revitalization system. Three systems were built in FY16. One system can be integrated into existing systems at JSC as part of a LOX production demonstration. The second system can be used to demonstrate the production of liquid CH_4. The third system will be available for experimentation and will be used to find the ideal parameters for regeneration throughout FY17. The experimental system will also be available for investigating ECLSS applications.

Results / Knowledge Gained

Testing of the canister design verified that the product gas was below the dryness required (26 ppmv) after 4 hours of continuous use. The canister was designed to operate on a 4 hour regeneration cycle. Visual observation of the desiccant (indicating drierite) after 4 hours shows that approximately half of the desiccant became saturated. After four hours of operation, the water content at the outlet of the canister

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was 15 ppmv. This test validated the design of the canister, where the residence time of the gas is a function of the canister diameter. The picture below shows the relative content of saturated desiccant (non-blue) to remaining margin (blue) after four hours of continuous operation.

Picture shows the relative content of saturated desiccant (non-blue) to remaining margin (blue) after four hours of continuous operation.

Testing also revealed the importance of controlling the release of liquid water upstream of the gas dryer. This issue has been observed in water electrolysis systems, and proved to be problematic during the first canister checkout test. ISRU electrolysis systems rely on gravity to separate liquid water from gas, so a bubbler was used to imitate a water separator tank when performing a functional checkout of the desiccant canister. Visible amounts of liquid water were observed to flow from the bubbler into the canister, which saturated the desiccant much sooner than intended. This problem must be addressed at the water electrolysis separator tank in order for any gas drying system to be effective.

The PI has received funding from the JSC Propulsion and Power Division to continue testing in FY17.

This technology has been featured in a proposal (currently under review) to the SMD Solar System Exploration Research Virtual Institute (SSERVI) dealing with lunar polar water/ice. The math model developed for this project is also being used in the Solar Arrays With Storage (SAWS) study.

Product	Type	Status	Brief Description
JSC Engineering Directorate	Funding	Confirmed	To continue testing in FY17
SMD Proposal	Proposal element—under review	Submitted	This technology has been featured in a proposal (currently under review) to the SMD Solar System Exploration Research Virtual Institute (SSERVI) dealing with lunar polar water/ice.
New Technology Disclosures	New Technology Report	Submitted	Disclosure of Invention and New Technology to NASA's New Technology Reporting System (NTRS) - MSC-26231-1, MSC-26237-1

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Technology Maturation Opportunities

Recommended STMD Next Steps	Type	Description
Phase 2 proposal in FY18 as an ISS X-Project	ISS flight experiment	Long-term interaction with a crewed habitat will demonstrate the potential for ISRU hardware to be used as a backup to specific ECLSS functions as part of a surface system architecture. Further collaboration with ECLSS engineers could also result in a single system with multiple uses.
ISRU automated demonstration by Game Changing Development	Integrated Water Electrolysis/Regenerative Gas Dryer/Liquefaction Test	ISRU demonstrations have been limited to short durations in the laboratory and field tests. An automated end-to-end ISRU demonstration by Game Changing Development with this technology would expose any issues that occur from system fatigue.

Partnerships

Collaborator	Type	Benefits
NASA/JSC	Intra-Center	Dr. John Graf provides expertise on gas drying systems used in life support applications. Tanya Rogers has provided support with the development of a test stand used to evaluate the design
NASA/JSC	Intra-Center	Joe Riccio provided support for the manufacturing of this system and coordinated the various fabrication tasks
NASA/KSC	Intra-Agency	Dr. Anthony Muscatello has provided requirements for integration with a methane production system.
NASA/WSTF	Intra-Agency	Oxygen Hazards Analysis.