NASA Phase II Project Summary

Firm: Creare LLC
Contract Number: NNX13CJ44C
Project Title: Water Recovery for Regenerative Life Support Systems

Identification and Significance of Innovation:

Thermal and environmental control systems for future exploration spacecraft must meet challenging requirements for efficient operation and conservation of resources. Regenerative CO2 removal systems are attractive, but unfortunately they vent water to space along with the carbon dioxide. Use of conventional condensing heat exchangers to conserve water is also not feasible, since they would need to operate below 0°C and would add a significant load to a spacecraft's thermal control system. Our innovation is a water vapor exchanger (WVX) that minimizes water loss without additional demands on the thermal control system. The innovative design uses highly water-permeable membranes in a compact core design that enables high water recovery efficiency with no need for external cooling and very low pressure drop. The WVX conserves water in long-duration missions, reduces use of consumables by enabling use of state-of-the-art regenerative CO2 removal systems, and minimizes demands on the spacecraft thermal control system. The innovative core comprises a highly uniform array of Nafion tubes. The unique design enables higher water transfer effectiveness and lower pressure losses than conventional hollow fiber gas dryers. For a spacecraft with a crew of six, the WVX can save over 23 lbm of water per day.

Technical Objectives and Work Plan:

Objectives. The objective is to enable thermal and environmental control systems on future exploration spacecraft to operate with minimum consumables and without large water losses. The approach is to develop a membrane water vapor exchanger (WVX) that will enable use of state-of-the-art, amine-based CO2 removal systems without the associated penalties of water loss. Technical objectives are high water recovery, high flow capacity (crew of six), very low pressure drop, negligible CO2 leakage, compatibility with regenerable CO2 removal systems, long-term durability, and small size and mass.

Work Plan. We formulated analysis models to predict performance, and developed fabrication methods for producing a shell-and-tube type core that maintains uniform flow channels under all operating conditions to achieve high water recovery efficiency. We demonstrated the durability of key core components in long-duration, high-stress, separate effects tests under simulated ECLSS conditions. We measured the effects of ammonia absorption on membrane permeability.

We built a WVX sized for the ventilation flow corresponding to a single crew member. We measured/observed the response of the Nafion tube array to cyclic high humidity/dry conditions. We measured the water recovery efficiency in tests with and without an amine bed CO2 removal system.

Technical Accomplishments:

We successfully demonstrated the key water recovery and pressure loss objectives of Phase II. The WVX recovered 85 to 93% of the water vapor from the simulated cabin inlet stream with total pressure losses of only 0.5 in. H2O under conditions that simulate operation in an exploration spacecraft ECLSS. Water recovery was 88% under nominal operating conditions. The mass and volume of the WVX is much smaller than the potential water savings.

We found that the basic construction elements of the WVX core were highly durable, with zero failures after 60 weeks of testing at > 145% design stress. The WVX core design successfully maintains a highly uniform geometry across a wide range of humidity conditions (20 cycles from 4% to 70% RH) to promote uniform flow and high efficiency. Ammonia absorption had significant effects on water permeability, and

must be addressed in future system designs by sizing the WVX to account for permeability losses and/or including ammonia absorption beds to protect the water-permeable membranes.

Measurements showed that 0.75% of the inlet flow bypasses the WVX, which will have negligible effects on the cabin atmosphere

NASA Application(s):

The primary NASA application for the WVX will be in environmental control and life support systems for future, exploration spacecraft in which water conservation is a key requirement. Examples include lunar/planetary rovers or short duration habitats.

Non-NASA Commercial Application(s):

High-efficiency water vapor exchangers are needed to close the water loop in fuel cell power systems, in which product water must be recovered from exhaust streams and fed back into the system as a reactant in fuel reformers or to humidify electrolyte membranes.

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