Development of a Rapid Cycling Carbon Dioxide and Water Removal Sorbent

Heather L. Paul, *Johnson Space Center*
Gökhan Alptekin, *TDA Research, Inc.*
Matthew Cates, *TDA Research, Inc.*
Casey Bernal, *TDA Research, Inc.*
Margarita Dubovik, *TDA Research, Inc.*

The plans for NASA's future missions set stringent demands on the design of the Portable Life Support System (PLSS), requiring dramatic reductions in weight, decreased reliance on supplies, and greater flexibility on the types of missions. Use of regenerable systems that reduce the weight and volume of the extravehicular mobility unit is of critical importance to NASA, both for low-orbit operations and for long-duration crewed missions.

The carbon dioxide (CO_2) and humidity control unit in the existing PLSS design is relatively large since it has to remove and store 8 hours' worth of CO_2. The capacity of the existing CO_2 control unit limits the duration of the extravehicular activity (EVA). As NASA's missions become more demanding, there is a need to reduce the logistics burden and the weight and volume of the PLSS components. If the sorbent regeneration can be carried out during the EVA with a relatively high regeneration frequency, the EVA duration could be increased and the size of the sorbent canister and weight can be significantly reduced.

A next-generation spacesuit design that uses a regenerable CO_2/H_2O removal system is under consideration. It relies on two alternating beds of solid amine sorbent to remove CO_2 and H_2O from the ventilation loop and is regenerated cyclically during the EVA. Although the solid amine system is simple, durable, and dependable, the performance of a rapid-cycling CO_2 and H_2O control unit could be further improved with the use of a higher-capacity and faster-cycling sorbent.

TDA Research, Inc. (TDA) is developing a compact, regenerable, long-life sorbent to control CO_2 and humidity levels in the ventilation loop of an advanced spacesuit. The sorbent can be regenerated using space vacuum during the EVA, eliminating all CO_2 and humidity duration-limiting elements in the life support system. The system uses two alternating beds; one bed removes CO_2 and H_2O from the ventilation loop, while the other bed regenerates under space vacuum (without additional heating). This material also has applications in other areas of space exploration including long-duration exploration missions requiring regenerable technologies and possibly the Crew Exploration Vehicle spacecraft.

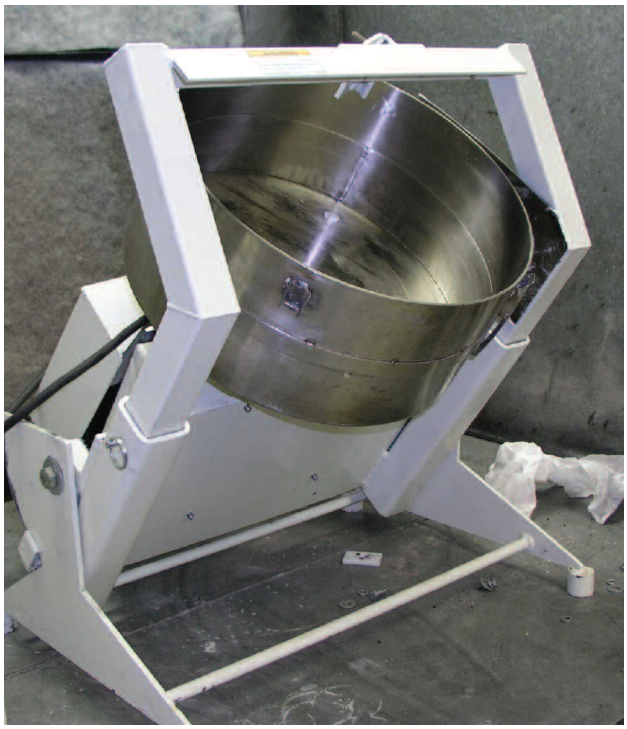

Fig. 1. Disc pelletizer.

Sorbent Development

The successful operation of the system requires a compact, regenerable, long-duration sorbent that can simultaneously adsorb CO_2 and H_2O vapors. The sorbent should be able to maintain its mechanical integrity through multiple adsorption/regeneration cycles and be regenerable by pressure swing only (with no heat provided to the system). The desirable sorbent for this application should have a relatively strong affinity for CO_2 for its effective removal; however, it should not bind the CO_2 too strongly so that regeneration can be performed without increasing the bed temperature and using space vacuum only. TDA uses a proprietary material to remove CO_2 from the gas mixture. The active material is prepared on commercially available high-surface-area (550-m^2/g) silica, which provides favorable support for the active phase and also serves as an excellent sorbent for H_2O vapor removal. The powder is then pelletized by using either TDA's proprietary geode

Fig. 2. Sorbent pellets made by the disc pelletizer compared to a sample made by the extrusion method.

technology or by disc-pelletizing operations. The former method produces 1/16 in. or 1/8 in. cylindrical pellets from an extrusion process while the latter can form spherical pellets in the range of 1/16 in. up to 1/2 in. The geode structure allows combining 80% or more of active material with an inert binder to provide the mechanical integrity and physical strength needed for the intended application. More recently, TDA developed formulations using the disc pelletizer, which allows much lower density and very high porosity to achieve better reactivity (although the mechanical strength of the latter pellets were much lower than those prepared with the geode technology). Many different silica substrates and binders were tested in multiple formulations. Figure 1 shows the disc pelletizer, which is used to process and pelletize sorbent samples with a high porosity and favorable pore structure. Figure 2 shows the sorbent pellets created by the disc pelletizer next to one made from pressure extrusion.

TDA's bench-scale test apparatus, which is capable of low-pressure (sub-ambient), closed-loop cycling, is shown in figure 3. The apparatus closely simulates actual EVA conditions and is capable of running a metabolic load profile to determine overall sorbent performance.

In addition to the development of the sorbent, TDA has selected the sorbent support structure, conducted trace gas analyzer tests, and developed and tested sorbent samples to characterize performance using a bench-scale test setup.

Fig. 3. Bench-scale test apparatus.

In this task, TDA developed a new, regenerable adsorbent for CO_2 and H_2O removal from the PLSS. The sorbent can be regenerated by pressure swing only without the need to increase the bed temperature. The sorbent maintains its activity over extended cycling under representative conditions.