Solid-State Compressor for Space Station Oxygen Recovery

John Finn

At present, the life support system on the International Space Station *Alpha* vents overboard the carbon dioxide (CO_2) produced by the crew members. Recovering the oxygen contained in the CO_2 has the potential to reduce resupply mass by 2000 pounds per year or more, a significant weight that could be used for experimental payloads and other valuable items. The technologies used to remove CO_2 from the air and to recover O_2 from CO_2 are flight-ready; however, the interface between the devices is a problem for the Space Station system. Ames Research Center has developed a new technology that solves the interface issue, possibly allowing closure of the oxygen loop in a spacecraft for the first time.

The relevant part of the air revitalization system is shown in figure 1. CO_2 produced by the crew is removed in the Carbon Dioxide Removal Assembly (CDRA). This device effectively produces a pure CO_2 stream, but at a very low pressure. Elsewhere, the oxygen generation system which makes O_2 by electrolyzing water produces a hydrogen stream. In principle the CO_2 and H_2 can react to form methane and water over a suitable catalyst. Water produced in this methane-formation reactor can be returned to the water electrolyzer, where the O_2 can be returned to the cabin; however, the methane-formation reactor requires CO_2 at a much higher pressure than that produced by the CDRA. Furthermore, the CO_2 and H_2 are often not available at the same time, due to power management and scheduling on the space station. In order to get the CO_2 to the reactor at the right pressure and at the right time, a device or assembly that functions as a vacuum pump, compressor, and storage tank is required.

One solution to this problem is to use a mechanical vacuum pump/compressor combined with a high-pressure buffer tank. However, this has implementation problems: (1) the rapidly moving parts of a mechanical compressor wear out relatively quickly, requiring frequent maintenance or replacement; (2) the mechanical compressor can add noise and vibration to the sensitive station environment, unless large amounts of insulating material are provided; (3) there is so little space available for the buffer tank that the compression ratio would have to be quite high; and (4) the power required to compress the CO_2 to high pressure is considered very high for the power-limited Space Station.

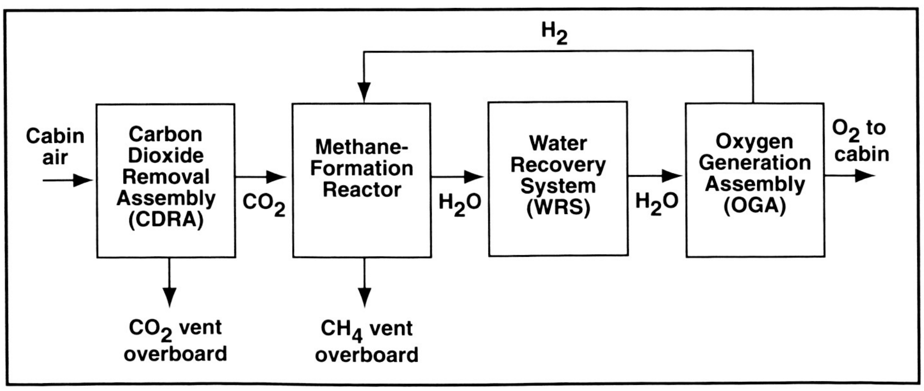

Fig. 1. Carbon dioxide removal, carbon dioxide reduction, and oxygen generation planned for the International Space Station (methane-formation is not yet implemented). The compressor would be placed between the carbon dioxide removal and methane-formation reactor assemblies.

The solution being developed by Ames engineers uses a technique that was originally developed for compressing the very low-pressure Mars atmosphere so that it could be used in an in situ propellant production plant. The compressor uses a temperature-swing adsorption cycle and has no rapidly moving parts. Low-pressure CO_2 from the CDRA is adsorbed in a cool cylinder containing a sorbent material that has a high capacity for CO_2. In this step, the device acts like a vacuum pump. Next, the cylinder stays in a standby mode until the CO_2 is required; that is, the device acts like a storage tank. Finally, the cylinder is heated and the CO_2 is driven off the sorbent, producing CO_2 at a high pressure. The compressed CO_2 flows into the methane-formation reactor. Coolant from the Space Station's thermal control system cools the cylinder back to its initial state, and the process is repeated. Several such cylinders are combined in the device. They operate out of phase from each other, so that there is always a "vacuum pump" and a "compressor" available whenever they are needed by the processors on either side.

A single-bed prototype solid-state compressor was built at Ames and successfully tested with a high-fidelity CDRA at Marshall Space Flight Center in FY00 (figure 2). The temperature-swing adsorption compressor uses less power than the mechanical compressor system and has fewer parts. Its lifetime is estimated at ten years. It is free of vibration and noise, and is also smaller and lighter than its counterpart.

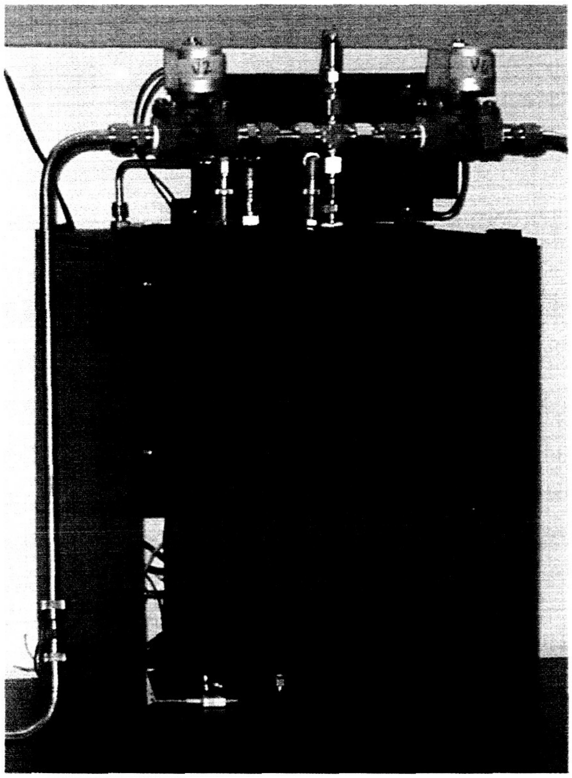

Fig. 2. Single-bed prototype of an Ames solid-state compressor.

Point of Contact: J. E. Finn
(650) 604-1028
jfinn@mail.arc.nasa.gov