A Cabin Air Separator for Extravehicular Activity Oxygen

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Presently, the extravehicular activities (EVAs) conducted from the Quest Joint Airlock on the International Space Station (ISS) use high-pressure, high-purity oxygen that was delivered to the ISS by the space shuttle. With the retirement of the shuttle, a new method of delivering high-pressure, high-purity oxygen to the high-pressure gas tanks will be needed. One method is to use a cabin air separator to sweep oxygen from the cabin air, generate a low-pressure/high-purity oxygen stream, and compress the oxygen with a multistage mechanical compressor. This capability is being developed under the direction of the ISS Program Office with the project name Cabin Air Separator for EVA Oxygen (CASEO). This type of system can use the existing low-pressure oxygen supply infrastructure that is the source of cabin oxygen. The ISS has two water electrolysis systems that deliver low-pressure oxygen to the cabin, as well as chlorate candles and compressed gas tanks on cargo vehicles. Each of these systems can feed low-pressure oxygen into the cabin, and any low-pressure oxygen source can be used as an on-board source of oxygen. CASEO enables EVA-grade oxygen to be delivered to the ISS in the form of water—a dense, stable liquid that is safe to transport.

Physical Layout

CASEO will be delivered to the ISS in three modules: an oxygen separator module, an electronics module, and a boost compressor module. The modules will be connected and mounted along the same wall in the airlock where the Oxygen Recharge Compressor Assembly is presently located. A photo of a CASEO mock-up in the ISS airlock mock-up is shown in figure 1. As it appears in this figure, the compressor module is on the left, the electronics module is in the middle, and the separator module is on the right. Dimensions of the modules are also shown. The weight allocation at the time of the Preliminary Design Review is as follows: booster module—54.5 kg (120 lbs); electronics module—36.3 kg (80 lbs); separator module—68.1 kg (150 lbs); total system—159 kg (350 lbs).

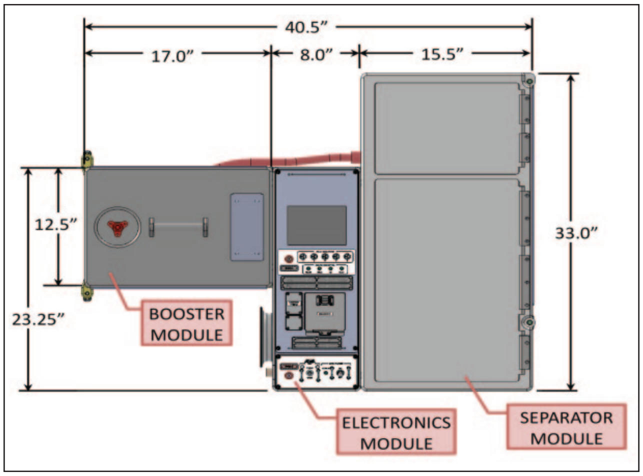


Fig. 1. *Physical layout and dimensions of modules (modules are 56 cm [22 in.] deep).*

Boost Compressor Module

The boost compressor module is a modified form of a three-stage mechanical piston compressor supplied by Cobham Life Support and Mission Equipment (Davenport, Iowa) and is shown in figure 2. It was originally designed for military medical oxygen applications. The major modifications are to use a direct-current-powered, flight-compatible motor, and to add a return spring on the first-stage inlet so the pump can receive oxygen product at low pressures, and a spring to the second and third stages to ensure electrical grounding. Without the first-stage spring modification, the inlet oxygen needs to have pressure of 15 psig or greater, or the first stage piston will not fully extend. Supplying oxygen at greater than 15 psig causes separator performance to suffer. The layout of the compressor module and balance of plant components is shown in figure 3, along with a detail of the first-stage inlet spring modifications.

Electronics Module

The electronics module consists of four sub-modules, as well as a cooling, data, power, and oxygen pass-through. The components are selected with a radiation hardness pedigree when possible. The Central Processing Unit is modified to include an external circuit to make it fault tolerant for single event upsets. The circuit protection is done at low voltages to allow for smaller gauge wires to be safely used. The circuit protection is done with fast-reacting devices. The CASEO circuit protection has a faster response time than the ISS vehicle power supply interface. All circuits are designed to withstand power spikes for a duration of 10 times longer than the response time of the circuit breaking devices.

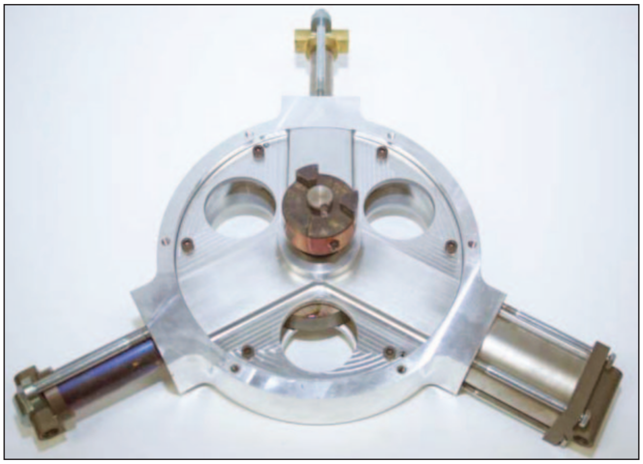
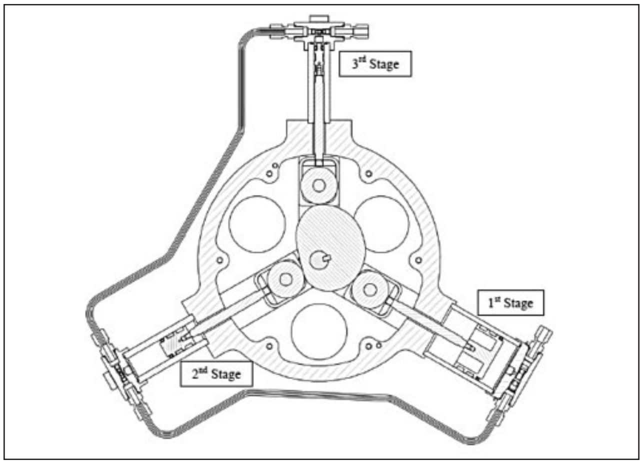
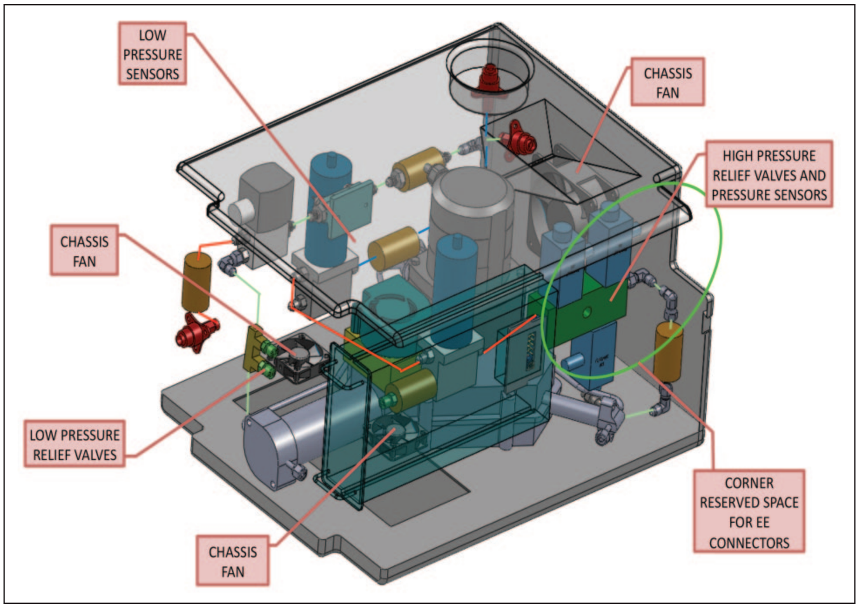



Fig. 2. *Photograph and schematic diagram of the boost compressor.*



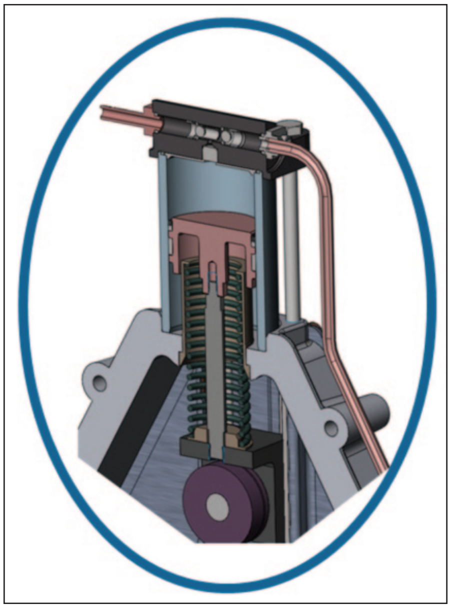


Fig. 3. *Layout of the boost compressor module with first-stage spring detail.*

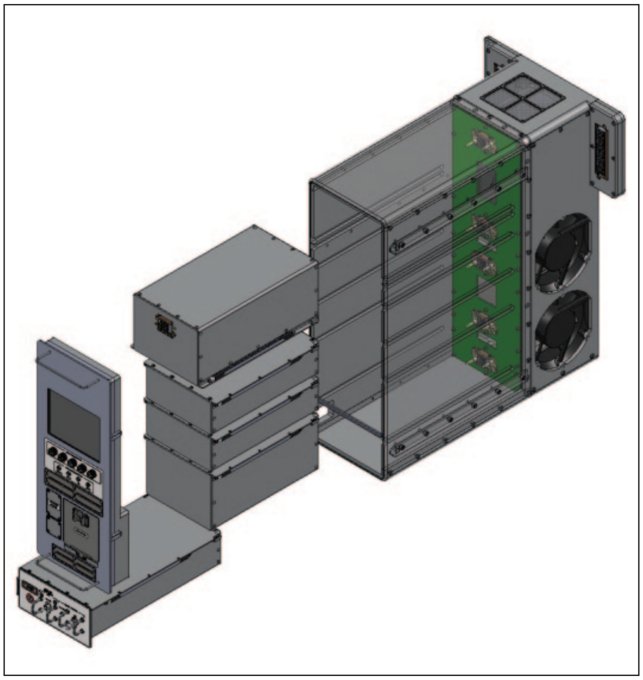


Fig. 4. *Electronics module configuration.*

CASEO can safely operate as a stand-alone device. It needs no command from the ISS, and it does not need any data from the vehicle. It has two methods of transferring data to the ground: one through a wired Ethernet, and one through a portable Universal Serial Bus device. The configuration of the electronics module is shown in figure 4.

Separator Module

The oxygen separator is a two-stage device that uses pressure swing adsorption as the method of oxygen separation. The separator module uses a compressor to compress cabin air to a pressure of 100 psig. When compressed, two different humidity control devices dry the air to -45°C (-50°F) dew point conditions. The first dryer is a membrane dryer; the second dryer is a pressure swing adsorption dryer that uses silica gel and type 13X zeolite. The first stage of the separator removes nitrogen from cabin air, and is designed to deliver a product that is nominally 95.5% oxygen, 4.3% argon, and 0.2% nitrogen. The second stage of the separator uses carbon molecular sieve material to remove the argon from the first-stage product. The calculated recovery efficiency projects a 1.5 liter per minute oxygen delivery rate. The nominal composition of the product gas is 99.6% oxygen, 0.3% argon, and 0.1% nitrogen.

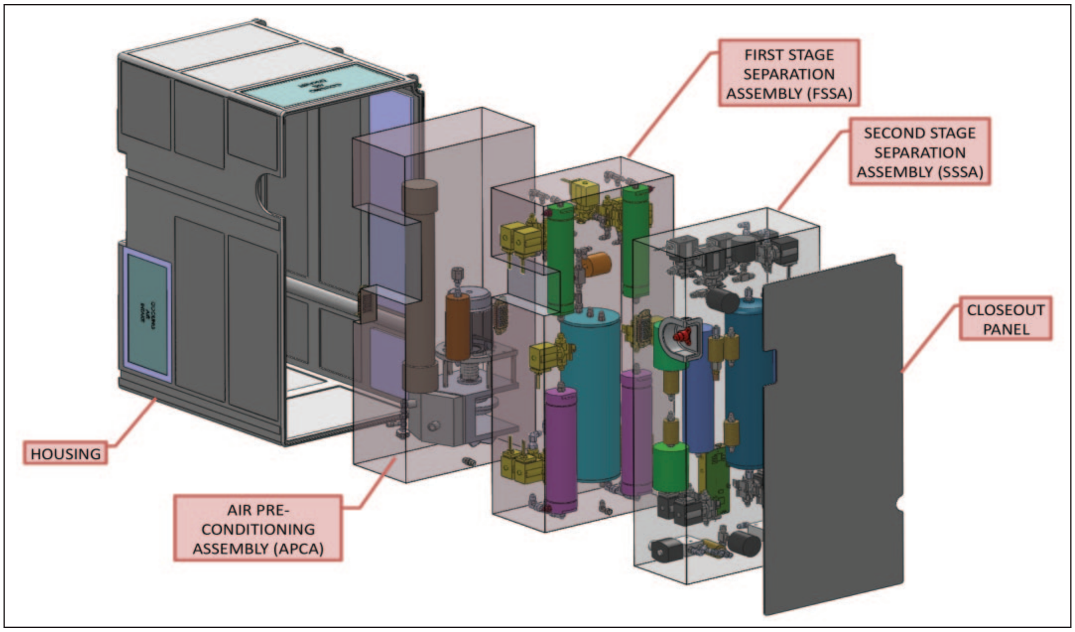


Fig. 5. *Packaging concept of the separator module.*