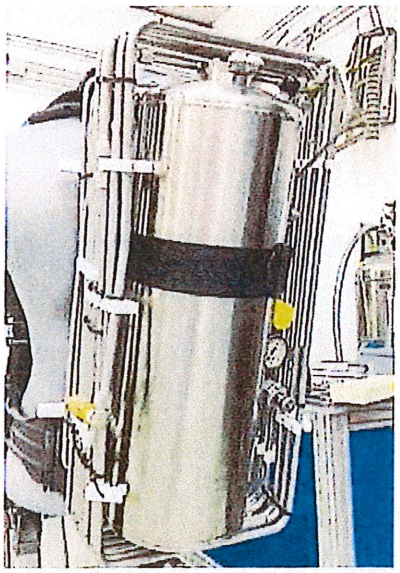
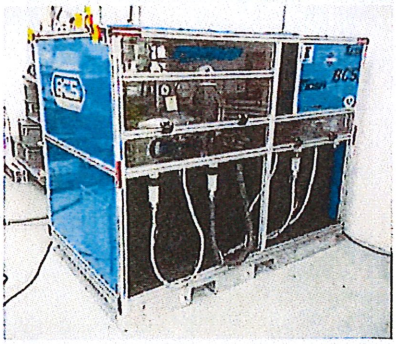
BCS Reimagines Life Support with Liquid Air

Former music teacher turned NASA propellants and pneumatics mechanic Ed Blalock understands cryogenic gases, and has positioned his new company, BCS Life Support, LLC, to revolutionize first responder and mine safety with cryogenic systems. The key is liquid air. BCS partnered with NASA's Biomedical Lab and the National Institute for Occupational Safety and Health (NIOSH) to develop zero-loss liquid air storage and a cryogenic breathing apparatus that works 90 degrees from vertical in any direction.

Current Self Contained Breathing Apparatus (SCBA) systems rely on compressed air. Liquid air systems were used in limited capacities for mine safety during the 1960s and 1970s, but abandoned because of logistical problems with handling and storage. Liquid nitrogen boils off faster than liquid oxygen and in time the liquid air mixture goes oxygen rich.





Cryofab, Inc., designed the dewar systems used by BCS in both the CryoBA and ACryoBA (top), while Cryomech, Inc., designed the cryocooler for the CryoRASS unit (bottom). Images: BCS

"In the commercial world you don't know when you're going to have a catastrophic event where you will need your liquid air. And so because it wasn't considered storable there weren't many serious efforts to commercialize," says Blalock.

The federal government, on the other hand, has used liquid air with regularity, most often to support military or space programs. NASA, for example, has used cryogenic life support systems since the Mercury program in the 1960s, incorporating it into astronaut cooling and ventilation devices, RED CREW rescue SCBAs and worker protection suits. During the Space Shuttle program, NASA would mix thousands of gallons of liquid air at the beginning of the week and simply dump what they didn't use at week's end, according to Blalock. "That won't work in the commercial world," he says.

In order to make liquid air commercially viable Blalock had to first address the storage problem. He developed a zero-loss solution while still working as a propellants mechanic. When he approached NASA about his findings he recalls being worried that he might face termination for infringing on intellectual property, but NASA representatives welcomed the findings and over time entered several Space Act Agreements with Blalock to continue development.

The BCS SCBA system that emerged from these agreements is an extension of ideas developed by NASA more than 50 years ago with its Self Contained Atmospheric Protective Ensemble, or SCAPE, suit. Inside a SCAPE is an environmental control unit that uses seven liters of liquid air to provide both breathable air and cooling when vaporized. Blalock's idea to incorporate SCAPE technology into safety equipment came to him under a hot August sun during a first responder certification course. He was inside a Level A vinyl protective suit with a Scott air pack. "It was about 100 degrees outside and it was about 120 degrees in the suit or more," Blalock remembers, "and I said, 'Boy, I wish I was in SCAPE with a liquid air pack,' because it's much cooler because you are vaporizing the liquid."

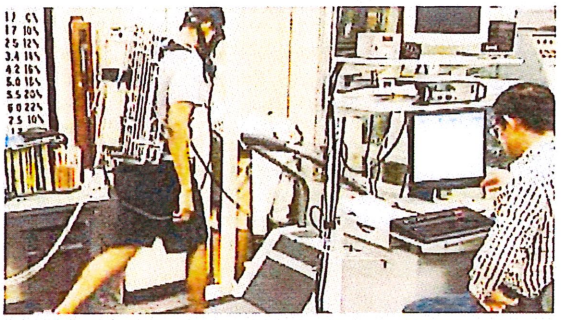
SCAPE suits are still used by NASA at Kennedy Space Center (KSC) but have never been adopted commercially anywhere outside the center because the suit and the liquid air unit aren't certified by NIOSH. Blalock says NASA wasn't trying to avoid NIOSH certification, only that NIOSH personnel had seen little success in attempts to commercialize liquid air devices. Contemporary experts at NIOSH's Office of Mine Safety and Health Research (OMSHR), however, are now funding the BCS research through a contract with NASA. The agreement calls for BCS to deliver five cryogenic systems, four related to breathing apparatuses and one designed to work with built-in-place mine refuges.

The first device developed by BCS is the Cryogenic Air Breathing Apparatus (CryoBA), a dual four-liter dewar system attached with delivery pneumatics and mask to a harness carried on a user's back. The CryoBA is designed to provide two hours of breathable air, an improvement over current SCBAs that only provide 35 to 40 minutes of real-time use, according to Blalock. The dewars are used in parallel and are thus filled and depleted at the same rate. "If there is a mining accident, [the miners] could be a mile deep and three miles in," Blalock says. "And it could be after a methane explosion. [The mine] could be full of smoke. It could be completely black. They could be crawling on their bellies and it might take 10 or 12 hours to get out." The device incorporates BCS's patented Attitude Independent Pickup (AIP), an apparatus designed to draw cryogenic liquids from a container 90 degrees from vertical. The AIP ensures that miners, or potentially first responders, can use the device while vertical, crawling or lying horizontally.

Development and testing for the CryoBA is complete and NIOSH-OMSHR is reviewing the final report. BCS is meanwhile moving ahead with the ACryoBA, an advanced, single seven-liter dewar system that weighs 20 lbs. when empty and only 35 lbs. full. "When we man-tested it we had the guy on the treadmill doing all the [NIOSH] protocols—lifting weights, climbing a ramp, running on a treadmill, crawling around on his hands and knees, on his side and back—and at the end of the two hours we weighed the device and it still had one third of its quantity left," says Blalock. "[It] would have gone three hours."

Miners using the breathing devices for mine escape would periodically refill either system at Cryogenic Air Storage and Filling Stations (CryoASFS) housed in protective steel enclosures and placed about one and

a half hours apart throughout the mine. Blalock says refilling is easy to accomplish. The breathing apparatus dewars are filled through a large-handled cryogenic disconnect that allows miners to breathe off the apparatus while filling it. The CryoASFS unit consists of a large dewar that stores the liquid air and a modified GM compressor that prevents boiloff. "As long as you keep the nitrogen from boiling off (below 77K), then you can maintain the mixture and the commodity (the volume) for as long as you have electricity to run the cryocooler," says Donald Doerr, retired chief biomedical engineer at KSC and current business partner in BSC.



Testing the ACryoBA. Image: BCS

BCS is also developing liquid oxygen Retrofit Kits (LOXK) for Closed-Circuit Breathing Apparatus (CCBA) and a Cryogenic Refuge Alternative Supply System (CryoRASS). The LOXK kit will be an alternative for the compressed oxygen gas cylinder typically used for CCBAs. Each kit is designed to replace a CCBA's high pressure gas system with a refillable low pressure oxygen dewar, switching regulator and new piping. The CryoRASS is a liquid air breathing and cooling system designed for built-in-place mine refuge alternatives (BIP RA). The refuges provide trapped miners an enclosed space for either a short-term stay immediately after a disaster or a long-term refuge (96 hours) if escape paths are blocked.

NIOSH in April 2015 published "Facilitating the Use of Built-in-place Refuge Alternatives in Mines," a report in which it determined that BIP RAs provided a practical but under-utilized resource for mine escape. There are currently only 30 BIP RAs in US underground coal mines. Deployment is hindered by high cost and the challenge of delivering a reliable supply of breathable air, both of which are addressed by the BCS research. "The state of the art right now is compressed oxygen," says Blalock. "So you've got high pressure oxygen in a mine environment being operated by miners who know little about high pressure gas. And they are covered in coal dust. That's why we got involved in this. It's a fire waiting to happen. And so liquid air, if it spilled, would probably put out a fire. It's no more volatile an oxidizer than the air we are breathing."

Once complete, final reports, technical data packages and prototypes for all the BCS breathing apparatuses will be reviewed by Rohan Fernando, senior research engineer at NIOSH-OMSHR. "All this research work is interesting for us," he says, "especially because we can get more duration from a similar-sized breathing apparatus." ▶

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Each prototype unit must meet provisional certification criteria under CFR 42 Part 84 Subpart H. Included here are rules covering everything from containers and breathing tubes to gas tightness and man tests. The rules adhere to guidelines established by the 2006 Miner Act, and include some important distinctions made between miner rescue and mine escape equipment. The Miner Act, for example, requires that SCBAs used for mine rescue have a minimum four-hour capacity, but NIOSH-NPPTL (National Personal Protective Technology Laboratory) only requires a device provide one hour of use to be certified for mine escape.

There are only two companies that manufacture approved four-hour devices and both of those are closed circuit units, according to Jeff Peterson, deputy branch chief for conformity, verification and standards development at NIOSH-NPPTL. Closed circuit SCBAs are often called rebreathers. Such devices recycle exhaled breath, first removing carbon dioxide and then restoring oxygen concentration before its wearer rebreathes the air. The BCS LOXK system, if produced, would retrofit these closed systems with liquid instead of compressed oxygen. BCS is also considering a semi-closedcircuit four-hour unit, according to Blalock.

NIOSH-NPPTL can't evaluate prototypes but will be responsible for certifying any production devices that emerge from the BCS research. Peterson says cryogenic systems have been evaluated before and at times require additional tests. "Typically, it's not much more that we do in terms of what we see in Subpart H, but it could be, depending upon their design. It's design dependent." Previous systems have been evaluated specifically for positive pressure and by-pass flow capability in addition to requirements in subpart H.

BCS expects to deliver all prototypes in 2016 and then begin ramping up for manufacture with industry partners Cryofab, Inc. (CSA CSM), and Cryomech, Inc. (CSA CSM). Blalock wants to expand the BCS system beyond mine safety. BCS is already working with NASA to retrofit and test existing environmental control units and to upgrade SCAPE devices with attitude independence. The big goal, however, is establishing BCS in the first responder and disaster response industry. Both Blalock and Doerr envision BCS systems providing hours of both breathable air and cooling to not only firefighters but also teams responding to everything from chemical or biological catastrophes to subway or tall building rescue. "We're really looking forward to the day lives are saved," says Blalock. ■