The Fathom CCR

By Charles Roberson

Charles Roberson (foreground) diving Fathom CCR in upstream Diepolder II cave system in Florida.

The Fathom CCR is designed to be the simplest and most intuitive closed-circuit rebreather for long-range cave exploration. Several years ago, as our dives became increasingly deeper and longer, my fellow Karst Underwater Research (KUR) divers and I recognized the need for a new closed-circuit rebreather (CCR) with excellent work-of-breathing and long scrubber duration that would stand up to the rigors of cave exploration. Semi-closed units, such as the Halcyon RB80, were considered, but we ultimately concluded that the improved work-of-breathing and greater efficiency of a CCR outweighed its added complexity for many of the dives being conducted. While there were a number of capable CCRs on the market, all had one or more features that either eliminated it from consideration or would require costly modifications to fit our purposes. The last thing we wanted was to spend thousands of dollars on new units only to strip them down and spend thousands more retrofitting them with different parts. The short list of desired features included:

1. a radial scrubber for the best possible work-of-breathing and scrubber efficiency,
2. at least an 8 lb/3.6 kg scrubber capacity for long duration dives,
3. back-mounted counter-lungs to maintain streamlining and easy stage-bottle handling,

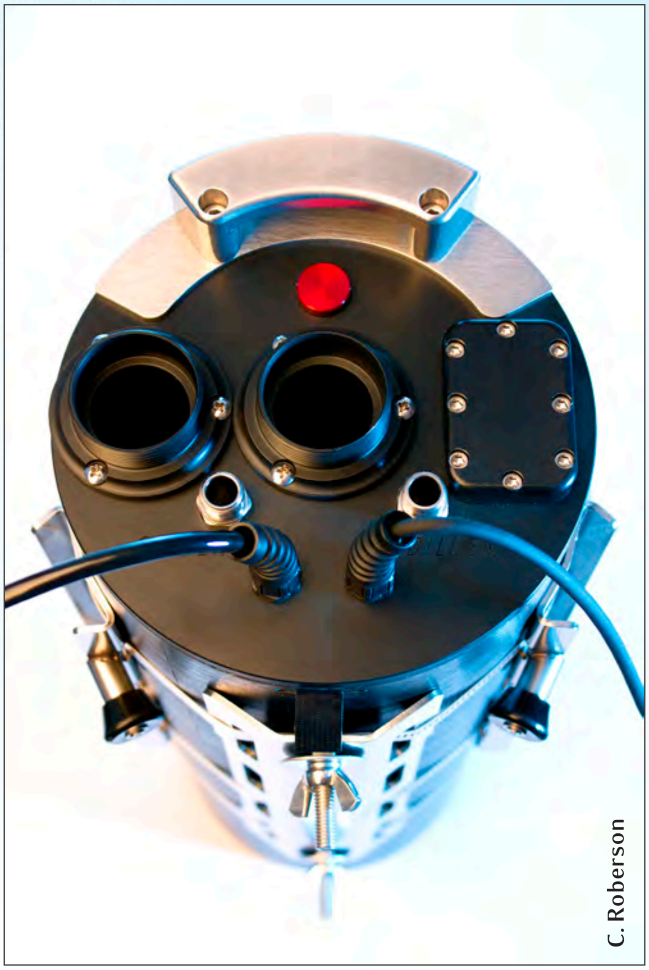
4. off-board gas addition for side-mounted diluent/bailout, and

5. mechanical oxygen addition for reliability.

Unable to find an existing unit that met these requirements, I started to design what would eventually become the Fathom CCR. There are no easy decisions when it comes to rebreather design and every choice, every dimension, every O-ring, was debated endlessly with fellow KUR divers. Andy Pitkin, Brett Hemphill, Ted McCoy, Kevin Leonhardt, and Jon Bernot were all heavily relied upon during the design process. I am grateful to them for tolerating the endless phone calls and hours of discussing minute details. Ultimately, the final decisions were mine and my background as a Hogarthian/DIR cave diver guided me towards simplicity and functionality.

OXYGEN ADDITION

The heart of any rebreather is its oxygen addition system. CCRs are broadly categorized as either electronic (eCCR) or mechanical (mCCR), which refers to how they add oxygen. While I had done demanding dives on an eCCR, there were several aspects that troubled me, not to mention the fact that I had seen a lot of divers missing dives due to faulty electronics. Arguably, the safest way to dive an eCCR is manually with the solenoid set at a low set-point. In this mode, the diver manually adds oxygen to maintain a desired setpoint and the solenoid only fires if the diver fails to do so. The problem with this method is that it's a lot of work and can add task-loading to an already complex dive. The other option is to allow the solenoid to do the work while the diver simply monitors the system. The problem with this is diver complacency that can creep in as the diver comes to rely on the reliability of the electronics. I believed that there had to be a better way.



Sensor array inside the Fathom CCR head

Brett Hemphill had done extended dives at Weeki Wachee on his modified KISS Classic using a needle valve and was a big proponent of the system. The needle valve has all the advantages of a fixed-orifice constant mass flow (CMF) system with few, if any, of the drawbacks. Unlike the Pelagian DCCCR, which uses a needle valve with a standard depth-compensated first-stage, the Fathom CCR follows Brett's lead and employs a needle valve with a blocked non-compensated Apeks DS4 first stage, creating an adjustable CMF system. This eliminates the need to constantly adjust the needle valve with depth changes. Once the needle valve is dialed in to the diver's metabolic needs, it only needs to be adjusted when those needs change, such as swimming versus scootering.

The only real drawback of a CMF system is a depth limitation that is reached when the first-stage intermediate pressure is equal to the ambient pressure. For example, a CMF system with a 145 psi/10 bar intermediate pressure (IP) has a practical depth limit of 260 fsw/81 msw.[1] The Fathom CCR addresses this by modifying an Apeks DS4 with a stronger spring that allows for much higher intermediate pressures. The first-stage intermediate pressure is set from the Fathom factory at 205 psi/14 bar for a practical depth limit of 395 fsw/120 msw. If a deeper maximum depth is needed, the intermediate pressure can easily be increased in the field to 290 psi/20 bar for a practical depth limit of 585 fsw/177 msw. Low pressure hoses rated for 400 psi/27.5 bar are used to safely handle the increased pressures.

Smaller fixed-orifices can also be used for deeper depths with higher intermediate pressures but the risk of a blockage is increased and the options are limited by orifice availability. A fixed-orifice requires that the first stage intermediate pressure be adjusted to achieve a flow rate that corresponds to the diver's metabolic needs, typically around 0.6 L/min to 0.8 L/min. Conversely, the needle valve allows the first-stage intermediate pressure to be set to any pressure since the needle valve handles the flow adjustments. Perhaps more importantly, the needle valve minimizes the risk of a blockage from debris since it can be opened up to allow small particles to pass.

SCRUBBER

If the oxygen addition system is the rebreather's heart, then the scrubber is its lungs. The Fathom CCR uses an 8 lb/3.6 kg radial scrubber, which has been used in 68-degree Fahrenheit/20-degree Celsius water for dives exceeding thirteen hours. A 5 lb/2.3 kg

[1] (145 psi/14.7 psi/ata - 2 ata) x 33 fsw/ata = 260 fsw (Note: always subtract 2 ata when calculating the maximum operational depth of a CMF system.)

Fathom CCR head

radial scrubber is also available, which is far more practical for most divers. The flow through the scrubber is inside to out, which was determined to be slightly more efficient than outside to in during extensive testing by Peter Ready, the designer of the Prism Topaz rebreather. The scrubber is housed in a Black Amalgon canister, which is nearly indestructible and insulates the scrubber four hundred times better than aluminum. Constructed of fiber-reinforced thermoset epoxy matrix, Black Amalgon features an ultra-smooth inner surface. It is a lightweight, high-strength, corrosion-resistant composite alternative to aluminum. Both the head and bottom are CNC machined Delrin and secured to the canister with a strong and simple latchless line-lock design that streamlines the profile and eliminates snags or broken latches. With both the head and bottom in place, the scrubber canister measures 16 in/406 mm tall and 7 in/178 mm diameter. The canister bottom has a recessed water trap that holds 6 to 8 chammies to absorb condensation and small amounts of water. The stock canister also accepts the 8 lb/3.6 kg Meg radial scrubber and the Cis-Lunar radial scrubber.

HEAD

The Fathom CCR's head is where everything comes together and was designed to minimize head space for the lowest possible static loop volume and overall unit footprint. The head is CNC machined from one piece of solid Delrin. Only the threaded cell holders and hose connectors are separate pieces, which allows for easy replacement if the threads get damaged during transport. A 1 lb/0.5 kg stainless steel handle and strike plate are attached to the back of the head to take the brunt of any accidental ceiling contact and assist with trim. It's also quite useful for lifting the unit and removing the head.

The oxygen sensors are located at nine, eleven, and one o'clock positions when the diver is prone in the water. These positions keep the sensors high and facing downward to avoid water collecting on the cell faces when the diver is in any position other than lying on their back. The unit uses JJ-CCR style sensors with an SMB connector on a hardwired lead. This eliminates unnecessary connections within the head and ensures a new female SMB connector every time a sensor is replaced. There are no batteries or electronics inside the head, only a fully potted splitter/isolation board that allows for two separate cell monitoring devices, such as a handset and a HUD. Only the gold-plated male SMB connectors protrude from the potting, so, once the sensors are removed, the head can be fully submerged in your dunk tank for cleaning. A hardwired HUD with Shearwater electronics is included as standard equipment. Handset options include a Shearwater Petrel 2 EXT or a Shearwater NERD 2 on the included Fischer cable.

PNEUMATICS

Offboard diluent gas is plumbed in through a female QC-6 connector on the bottom of the diluent manual add valve (MAV) and ported directly into the inhalation side of the head where it is directed over the cell faces of number one and two sensors. This allows for instant cell verification with a known gas source. The Shearwater Petrel 2 makes this a simple process by displaying the diluent pO_2 and the actual pO_2 side by side on screen number two. There is no need to perform a complete diluent flush to verify your cells; simply add a few short bursts of diluent via the MAV and you have instant verification. The diluent MAV also has a bypass port, which can be used to plumb gas to a Shrimp BOV or a backup regulator on a necklace. The oxygen MAV, which contains the needle-valve, is ported directly into the exhaust side of the head so oxygen must travel through the scrubber and mix with loop gas before reaching the diver.

BREATHING LOOP

Fathom CCR oxygen and diluent MAVs

The Fathom CCR breathing loop consists of back-mounted counter-lungs (BMCL), large bore T-pieces, loop hoses, and a Shrimp DSV or BOV. BMCLs provide excellent work of breathing in all positions while keeping the diver's frontal area free of clutter as well as minimizing their profile. I found out the hard way how much front-mounted counter-lungs can add to a diver's profile. I had discovered and partially explored a new section of cave passage in Madison Blue diving my typical open-circuit configuration of double 104s. When I went back a few weeks later for further exploration on a CCR, I was shocked that I could not get through the initial section of low bedding plane without dragging the front-mounted counter-lungs on the bottom. What had been easy in 104s was just not practical with the front-mounted counter-lungs. After that dive I switched to back-mounted counter-lungs and never looked back. Not only have they reduced my profile but they have made stage-bottle handling much easier. Since a large portion of the gas bubble is up around the shoulders, similar to front-mounted counter-lungs, they have excellent work-of-breathing in all positions.

The Fathom CCR utilizes flexible stretch hoses in front and more traditional stiff hoses in the rear. The front stretch hoses allow divers to turn their head more easily while the rear hoses offer greater durability in case they come in contact with the ceiling. A Shrimp DSV with bayonet-style hose fittings is standard, with the Shrimp BOV a strongly recommended option. The Shrimp BOV not only gives the diver immediate access to their bailout gas without removing the mouthpiece but also acts as a chin rest for reduced jaw fatigue while scootering. The standard T-pieces are large-bore machined Delrin without any low-pressure hoses or fittings since both the diluent and oxygen MAVs are ported directly into the head. A low-profile ADV T-piece is an available option. It's recommended that the unit be configured with either a BOV or ADV to give the diver a second means of adding diluent to the loop.

HARDWARE

The Fathom CCR uses low profile and extremely secure onboard cylinder mounts manufactured by Kent Tooling. The 220mm long mounts are made of 316 stainless steel and will hold anywhere from 3 to 8 L cylinders. A low-profile single tank adapter, also made of 316 stainless steel, allows divers to use a standard backplate and harness. The onboard cylinder mounts and single tank adapter are secured to the scrubber canister with 316 stainless steel hose clamps, which gives the diver incredible flexibility in configuring the unit. For example, the Fathom CCR can easily be configured with 50 cf/8 L manifolded diluent/bailout cylinders for ocean diving. In the cave environment, we prefer larger side mounted bailout cylinders, so our typical configuration is 3 L onboard cylinders, oxygen on the right and inflation gas on the left. For dives over 10 hours we replace the 3 L cylinders with 45 cf/7 L cylinders. Unlike most rebreathers, the Fathom CCR is designed to mount the onboard cylinders upright, which solves many of the trim issues common to rebreather divers. It also puts the valves in a protected and easily accessible position much like open-circuit doubles and greatly simplifies using a range of onboard cylinder sizes without having to change any hoses. After several years of diving with my onboard cylinders oriented upright, I have yet to hit the valves or regulators.

FIELD TESTING

The real-world testing on the Fathom CCR has been uniquely rigorous. Jon Bernot and I used Fathom CCRs on our 16.5-hour, 26,930 ft/8,208 m penetration dive at Cathedral Canyon as well as numerous 8 to 14-hour dives at Manatee, M2, and Lineater. One of my more memorable dives on the Fathom CCR, which really demonstrated its depth capability, was an exploration dive at 330 ffw/100 mfw in Weeki Wachee from the Twin Dees entrance. While it has certainly proven itself on big dives, the Fathom CCR is smaller and lighter than most units, which coupled with its simplicity makes it ideal for the traveling diver. Those who know me know that I'm particular about my gear and expect it to be dependable as well as functional. I set out to build a CCR that I wanted to dive and that would allow me to safely and confidently push the envelope of cave exploration. In this respect, I believe we have succeeded.