Before using the mask, you should be completely familiar with it. In particular, you should know how to don and remove the mask by yourself, and how to clear the mask should it flood. Obviously, it is impossible to breathe from a full face mask if it is full of water!

In an out-of-gas emergency, gas sharing with a full face mask is very awkward. The moment you remove the mask, you are essentially blind. Each time the mask is passed from user to user, it must be cleared of water, a procedure that requires far more air than clearing an ordinary scuba regulator. This is not a satisfactory arrangement. Under these circumstances, it is preferable to have a separate scuba regulator integrated with your system and to carry an ordinary face mask. This equipment can also serve as a back-up in the event that the full face mask fails for any reason.

If you are diving deep, in an overhead environment, or doing decompression diving, you should carry a back-up gas supply when using a full face mask. The back-up supply should be connected to a manifold block, also known as a "bail-out block". This block is usually positioned on the diver's harness, on the right side, at chest level. Diving Systems International manufactures a bail-out block that can be used for technical scuba diving but is more suited to surface supplied diving.

Figure 1 illustrates a possible arrangement for a bail-out block that might be better suited to technical diving. The block contains three non-return valves, so that should any one of the low pressure supply hoses fail, the breathing gas would not be lost in the ruptured hose between the first and second stage. There are three on-and-off valves in this block, and all are shape and color coded. The valves should have some sort of positive "locking" system to ensure that they won't be accidentally opened. The first valve is for the main supply, the second valve is for a second gas mix, and the third valve is for the bail out. There are enough ports to accommodate a dry suit, a full face mask, and a back-up regulator. Of course, some divers may prefer to use an independent suit inflation or argon system with their dry suit.

As an additional back-up, you can also install a quick-disconnect fitting

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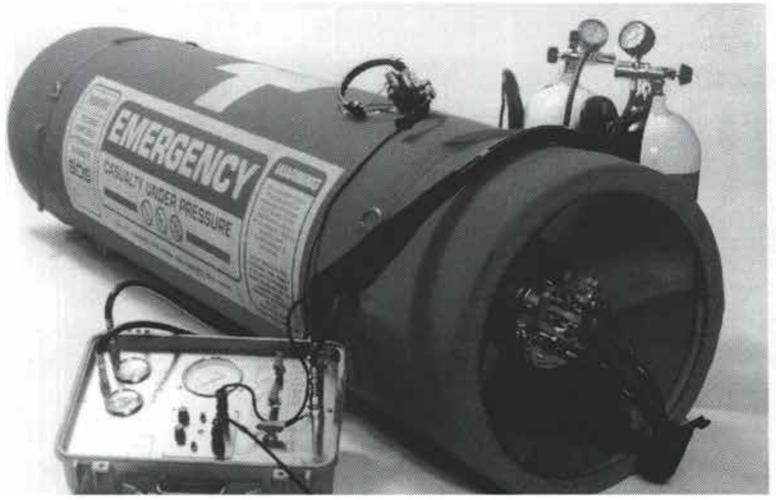
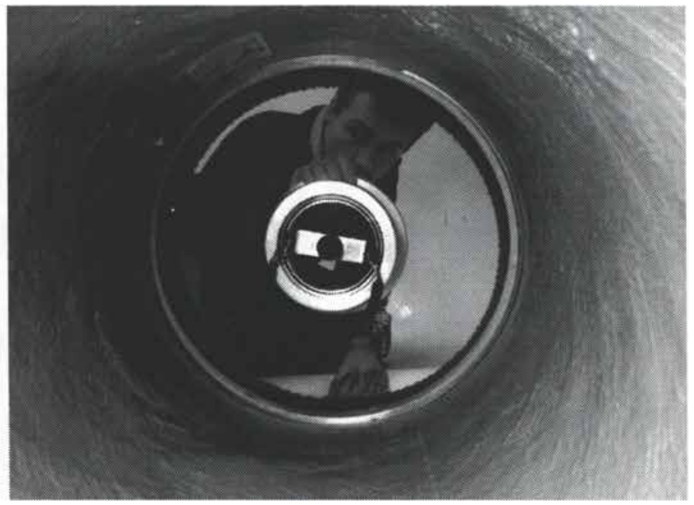




SOS Ltd.'s Hyperlite Portable Chamber

Portable Chamber TECHNOLOGY

by John Selby

Having a chamber on site has simply not been feasible in most cases, though its value would be hard to dispute given the kind of demanding diving that is often conducted by these groups.

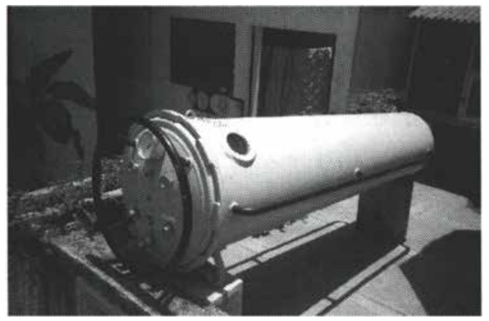
Five years ago, SOS Limited of London, set about to develop a radically new type of recompression chamber designed to address the problem of emergency field treatment for divers suffering from acute decompression illness. Today it is well known that if the diver can be put back under pressure immediately without delay, then the chances of residual injury are negligible. Failing that, the chances of permanent brain or spinal cord damage escalate with the time to treatment. Though in-water oxygen therapy has been used with success, in the absence of a accessible chamber, putting a stricken diver back in the water is rarely desirable if there are other alternatives.

Though an on site chamber is a requirement for most commercial and military diving operations, this is not the case in sport and scientific diving. Having a chamber on site has simply not been feasible in most cases, though its value would be hard to dispute given the kind of demanding diving that is often conducted by these groups.

What SOS has tried to do with the development of the Hyperlite chamber is to produce a low cost, very lightweight "transport" chamber, that is easy to use and can be set up in less than five minutes. In the event of a DCI incident, the diver in question can be immediately pressurized up to 60 fsw (2.8 atm) and oxygen therapy begun, while transportation to a hyperbaric facility is arranged. The entire chamber along with an attendant can then be transported by helicopter, boat or car to the appropriate treatment center.

Note that the Hyperlite should not be considered a treatment chamber. Therapies can of course be conducted in it, especially when it is used in remote places, where transfer to a therapy chamber is logistically or geographically impossible. However, it is designed primarily as a transport chamber, or hyperbaric stretcher if you will, a first aid device for divers at a time when every minute counts.

Figure 1



Traditional Steel Monoplace Chamber
Photo: Bret Gilliam

Comparison to traditional mono-place chambers

To appreciate some of the unique features of the Hyperlite it is useful to review some of the background and characteristics of traditional mono-place (one person) chambers, which it was designed to replace.

Mono-place chambers, sometimes referred to as "iron coffins," are manufactured by rolling and welding aluminum or steel sheet which produces a good leakproof pressure retaining shell. The problem is that such chambers are bulky, heavy, expensive and cannot be easily transported, or stored when not in use. Most are very dark inside having a very small six inch window (hence the name "iron coffin") for the patient to see out, which often results in claustrophobia and sometimes panic in the patient. See Figure 1.

Typically these chambers are equipped with some form of lock-on device so that they can be coupled to a therapy chamber with a compatible flange. The problem is that there are so many different types and sizes of flanges that mating to a therapy chamber is often more a matter of luck than of design. Ugly problems can occur if this transfer, for whatever reason, can not take place.

When using a monoplace chamber, the patient breathes the chamber gas, usually air for treatments to 165 fsw (6 atm), or oxygen (2.8 atm) which results in a build-up of carbon dioxide (and/or oxygen). This means that the chamber has to be regularly flushed which consumes considerable amounts of gas. Alternatively, if there is a CO2 scrubber, heavy batteries are needed in the absence of main power. Though a Built-In-Breathing System (BIBS) is available for mono-place chambers, they are not the norm.

The Hyperlite chamber differs from metal mono-place chambers in several important ways. First of all, the Hyperlite uses modern Kevlar-based composites to replace heavy steel or aluminum. Like a car tire, the chamber tube is totally rigid under pressure, but when it is deflated it can be folded into a box one quarter of its length long. Each end of the chamber is enclosed by a full diameter acrylic window, which gives the patient a wide outside view and the medical attendent a clear view of the patient.
In addition, the Hyperlite utilizes a BIBS system to overcome the problems of CO2 and O2 build-up.

As a result of its construction, the Hyperlite can be folded and stored in two small carrying cases and transported out to the dive site. Once pressurized, with a patient inside, the chamber can easily be carried by a maximum of four people to suitable transportation, and the entire unit with the operator can be evacuated to the nearest therapeutic multi-place chamber. At the facility, immediate transfer under pressure is essential so that the patient can be treated without delay by qualified personnel. For that reason, the Hyperlite is designed to pass directly through the door of most chambers without the need for a flange. Therapy chambers usually have a minimum door size of 24 in., while the Hyperlite has an outside diameter of 23.5 in. Once inside, the therapy chamber can be pressurized and the patient can be transferred out of the unit.

Treatment depth

As an emergency transport chamber, the Hyperlite is designed to provide oxygen therapy at working pressure of up to 60 fsw (2.8 atm), suitable for a USN Table 5 or 6. Though air treatments to 6 atm (165 fsw), for example the USN Table 6a, are still used in the case of barotrauma and what used to be referred to as "Type II" decompression sickness, increasingly, the primary treatment for most cases of DCI is pressurization to 2.8 atm (60 fsw). This is a considerable advantage with respect to the Hyperlite, in the case that the patient loses consciousness, stops breathing, or becomes incapacitated in some other way as discussed below.

Removal of a patient under pressure

At pressures greater than about 2.8 atm (60 fsw), the immediate removal of a patient from a mono-place chamber is very much a last resort situation. At these pressures the patient will have been on air or nitrox. To reduce pressure to atmospheric quickly will almost certainly result in further decompression problems. In extreme cases this has resulted in a fatality. That is another reason why the 6 atm (165 fsw) one-man chambers were called coffins.

Because the Hyperlite chamber only operates at pressures of up to 2.8 atm (60 fsw) using oxygen, treatment will have been initiated as soon as pressure is applied. In the event that the removal of the patient becomes necessary, this can be accomplished by returning the chamber to surface pressure at the normal ascent rate of 60 fpm. Thus the elapsed time until a patient can be removed from the chamber is less than 90 seconds. Provided that the patient has been under pressure on oxygen, nitrogen levels should be greatly reduced and the chances of reoccurrence of DCI should be lower.

Construction and operation

Having established the reasons for developing the Hyperlite chamber and some of its principal features, it may be useful to discuss its construction and how the unit is operated.

The tube shaped body of the chamber is made from a composite of Dupont Kevlar 49 fibers, filament wound in a matrix of silicone rubber. Kevlar, which is used in bullet proof vests, was chosen for its strength and the fact that it does not stretch under load. Silicone rubber is very flexible, inert, has low fire, smoke and toxicity properties, resists ultraviolet light and is easy to clean. Neither material suffers from degradation during storage over long periods of time.

The tube incorporates identical seals at each end. The two full diameter acrylic windows are inserted by deforming the flexible tube ends just enough to allow the windows to go in at right angles to their final position without touching the ends of the tube. One of the windows incorporates the necessary penetrations for the various supplies to the chamber, while a medical lock can be installed in the other, if required, so that food, drink and medication can be passed to the patient.

Sealing the chamber on initial pressurization is accomplished by turning on the air supply while pulling the two end windows away from each other. This is easily accomplished. Once the initial seal has been achieved, no further pulling is necessary as the higher the pressure, the tighter the seals become.

The only remaining piece of equipment is a control box that is very simple to operate. It has only three main control valves, a gauge to read chamber pressure, and incorporates a full intercom system to allow two way communication.

The unit has two connectors, one for oxygen and air supplies, and a set of connectors for the umbilical that connects the control box to the chamber. All connectors have built-in non-return valves so that if they are disconnected for any reason, no pressure losses occur. The patient inside the chamber breathes through a BIBS mask which supplies oxygen or air on demand. Note that most protocols require the patient to breathe oxygen for twenty minutes followed by a five minute air break.

Chamber pressure is supplied by a scuba cylinder and requires approximately one half of a standard cylinder (about 40-50 cf.) to achieve maximum operating pressure. Breathing air for the air cycles during therapy uses the same air source. An additional filtration system is available on the air supply line to protect the oxygen BIBS system from contamination.

To complete the package, the entire chamber folds away into a custom built lightweight sealed case. It is so small in fact that the chamber can be checked in as personal baggage at the airport, usually without excess fares being charged.

Testing and certification

The Hyperlite chamber has been subjected to very extensive testing and certification procedures. The initial prototypes were subjected to pressure and cycle testing. Although it is very unlikely that the chamber would be used daily, a unit was subjected to over 16,000 cycles from zero to a maximum pressure of 70 fsw (3.1 atm) over a ten day period. This is equivalent to four treatments a day for a period of ten years. No damage to the seals was detected. The chamber was also subjected to low temperature operation to insure that the flexibility of the composite did not restrict the setting up and pressurizing of the equipment.

More recently at the request of the ASME Pressure Vessels for Human Occupancy (PVHO) committee, a burst test was conducted on a production unit. The chamber started to break down and lose pressure at 426.5 fsw (13.9 atm), or 6.2 times the maximum working pressure of the chamber (70 fsw). Metal chambers simply do not have that safety margin. These tests were followed by drop tests with sand bags to simulate the weight of a patient. The chamber was dropped at a 45° angle through a distance of 3 feet on a rough concrete surface without damage.

Eventually, like its commercial diving counterpart, *"having a chamber on site"* may become a "consensus standard" in the technical community. Given the level of diving that is likely to be conducted in the future, the question will become," Can you afford not to have one?"

The Hyperlite is currently certified by Lloyd's register and has clearance for sale in the U.S. by the FDA. No additional approvals are required by law, even though the chamber is still undergoing ASME PVHO approval, a lengthy exercise, as the code relates to fixed hospital chambers made of weldable materials.

The future of portable chambers

Priced at around $30,000 U.S., the Hyperlite chamber represents a significant cost reduction over steel or aluminum mono-place chambers which run in the neighborhood of $125,000 U.S. plus. Nevertheless, this cost is still high in terms of widespread use among technical divers.

With acceptance by insurance carriers, entrepreneurial leasing and service providers, and with volume, the price of having a portable chamber on site is likely to fall putting it within the reach of dive operators, resorts and clubs. Eventually, like its commercial diving counterpart, *"having a chamber on site"* may become a "consensus standard" in the technical community. Given the level of diving that is likely to be conducted in the future, the question will become," Can you afford not to have one?"

A chartered engineer, John Selby is the founder and Managing Director of SOS Ltd. which manufactures and distributes equipment designed to improve diving safety. Selby can be contacted at: SOS Ltd., Po Box 328, London NW7 3JS, England. Fax: 44(81)959-7971.