HammerHead CCR Owner's Manual

Version 1, Rev 1

a product of Juergensen Marine

HammerHead CCR
Owner's Manual

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Juergensen Marine HammerHead Rebreather

Juergensen Marine

Table of Contents

Introduction

The ***Hammerhead CCR*** is a fully closed mixed gas capable closed circuit rebreather. Unlike other products both past and present, this design represents the collaboration of several manufacturers within the diving and safety industries. Each company was able to bring their strengths to this product, increasing safety and reliability. While many designs have needed to evolve over the years, the Hammerhead, at its release represented some of the best technology available.

Juergensen Marine has been supplying the rebreather industry with service and products for nearly a decade. The company's products have been used on a wide variety of equipment and have an installed worldwide user base. The company is dedicated in continual development of new products and upgrades of existing offerings.

MicroPore was founded in 1997, and specializes in reactive plastics. Using patented technology various powders are molded into a plastic matrix. Micropore's products are used for life support in the fire-fighting, medical, dive, submarine and military markets.

Golem Gear, although a relatively new company has been supplying cutting edge, quality gear to the cave and rebreather communities. Golem Gears products are responsible for increasing safety and creating specialty products that fit many needs.

Warning!!

*The **HammerHead** is a fully closed-circuit diving apparatus which functions in a manner distinctly different from traditional open-circuit scuba. Do not attempt to use the **HammerHead** without proper professional instruction from an authorized **HammerHead** Instructor and without a thorough and complete working knowledge of the material contained in this manual.*

Chapter 1
Common Terms and Diving Systems

Objective

The purpose of this chapter is to briefly outline the various diving systems in use, to discuss the advantages and disadvantages of each, and to define common diving terms and acronyms.

Glossary

The following is a list of terms that are frequently used by divers and may be used throughout this manual.

Automatic Diluent Addition Valve — **This valve is normally used to automatically maintain loop volume by adding diluent to the breathing loop. The addition is accomplished through either a demand valve or plunger arrangement that activated on decreased volume. Increasing pressure during descent reduces the loop volume by compression.**

Breathing Bag — **A flexible container that is used to receive and supply gas during respiration while using a rebreather system. Also referred to as a "counter-lung".**

Closed-Circuit Rebreather CCR — **A type of rebreather where the breathing loop is isolated from the environment. During normal operation at a constant depth, no gas is vented and only oxygen is added.**

Counter-Lung — **A flexible container that is used to receive and supply gas during respiration while using a rebreather system. Also referred to as a "Breathing Bag".**

Diluent Addition Valve — **This valve is normally used to manually add diluent to a CCR in order to increase volume due to compression on decent or to flush the loop with a known gas.**

Left Hand Valve — **This is the valve that would be operated by the diver using his/her left hand based on a set twin cylinders with**

a manifold. The knob is on the opposite side when compared to a "normal" valve. This designation is NOT universal with all valve manufacturers, consult the appropriate product catalog when ordering valves.

Over Pressure Valve — **This valve is used to automatically vent excess gas from the loop during ascent. This helps prevent excess buoyancy changes and potentially dangerous loop over pressure .**

Oxygen Addition Valve — **This valve is used to MANUALLY add oxygen on a CCR. This is used to manually raise the PO_2 due to a drop caused by metabolism or to raise the PO_2 above the selected set-point.**

Mouthpiece — **The mouthpiece on a rebreather always incorporates some type of valve to isolate the breathing loop from the environment. The mouthpiece is frequently called a DSV. And depending on who you ask it means either dive select valve or dive surface valve. A variation of the DSV sometimes called a BOV incorporates an integrated demand valve as an alternate gas source while the loop closed.**

Rebreather — **This is a generic term referring to breathing system that re-uses exhaled gas.**

Redundant Breathing System — **A totally independent breathing system of sufficient volume for the working depth. Sometimes called a "Pony System", carried for emergency / bailout situations.**

Right Hand Valve — **This is the valve that would be operated by the diver using his/her right hand based on a set twin cylinders with a manifold. This is the traditional valve arrangement. This designation is NOT universal with all valve manufacturers, consult the appropriate product catalog when ordering valves.**

Scrubber (Canister) — **A chamber filled with a CO_2 absorbent chemical through which the exhaled gas is channeled to remove the expired Carbon Dioxide. This can be in the form of either user packed loose granules or a disposable cartridge. There are two main types, Radial and Axial.**

Semi-Closed Rebreather
SCR — **A type of rebreather where the breathing loop is isolated from the environment. During normal operation some percentage of the gas is periodically or continually vented and replaced with fresh gas (usually Nitrox). The most common SCR is one with a constant preset gas flow but SCRs keyed to the diver's respiratory rate do exist.**

Work Of Breathing — **The amount of effort required by the diaphragm to move breathing gases in and out of the lungs.**

Common Acronyms

ADV	Automatic Diluent addition Valve
BOB	Bail Out (re-)Breather
BOV	Bail-Out Valve, a Dive/Surface Valve with an OC integrated second stage, aka OC/DSV
CC	Closed Circuit
DSV	Dive/Surface Valve
DV	Demand Valve (usually refers to a second stage)
EAD	Equivalent Air Depth
EAN (EANx)	Enriched Air Nitrox
eCCR	Electronically controlled CCR
END	Equivalent Narcotic Depth
FFM	Full Face Mask
FSW	Feet of Salt Water
HP	High Pressure
LP	Low Pressure, in Europe Frequently referred to as MP
MAV	Manual Addition Valve (Oxygen / Diluent)
mCCR	Manually (or mechanical) controlled CCR
MOD	Maximum Operating Depth
MP	Medium Pressure, Term used in Europe, Equivalent to LP in the USA
MSW	Meters of Salt Water
OC	Open Circuit
OC/DSV	a Dive/Surface Valve with an OC integrated second stage, aka BOV
OPV	Over Pressure Relieve Valve
OTU	Oxygen Toxicity Unit
PP	Partial Pressure
PSI	Pounds per Square Inch
RMV	Respiratory Minute Volume
SC	Semi-Closed
SCR	Semi Closed Rebreather
WOB	Work of Breathing

Scuba System Overview

The Open-Circuit Scuba system is the configuration that is usually associated with scuba diving and the configuration used by the average recreational diver. This chapter will introduce the semi-closed and closed-circuit rebreather designs or more simply, SCR and CCR.

In the past, the use of rebreathers were primarily the domain of the military with some limited use by the scientific and commercial diving communities. The recreational and scientific diving communities have traditionally used open-circuit scuba systems due to its simplicity, low operating cost, low initial investment and ease of training. The commercial diving community has primarily used a surface-supplied configuration that allows for two-way communication, and unlimited gas supply through an umbilical connection to the surface. The use of rebreathers by commercial diving operations has been increasing due to rising costs associated with continuous gas production.

Over the last decade the use of rebreathers by the recreational diving community has increased significantly due to the advent of user friendly systems, increased reliability, increased availability of support materials, broader choice of rebreathers and reduced cost. Continuing growth is expected in the coming years as additional manufacturers enter the market and the technology is exposed to a greater diversity of divers. Over the last several years many outspoken opponents to rebreathers have become advocates as they realize that rebreathers are ideal tools and increase safety in many situations. Rebreathers are often thought of as new and unproven technology even though rebreathers predate traditional scuba by over 50 years.

Rebreathers have gained the greatest acceptance in the deep diving/exploration communities and those involved with underwater video and photography. The reduction of bubbles allow a more natural interaction with marine life and a reduced environmental impact. The depth independent duration allows longer and deeper dives without compromising safety.

Open-Circuit Systems

This is the traditional SCUBA configuration. A high pressure gas stored in a cylinder and is reduced in two steps to deliver a breathing gas at ambient pressure. The first step reduces the cylinder pressure to a fixed intermediate pressure with respect to ambient pressure and the second step reduces this intermediate pressure to ambient pressure. Gas is inspired by means of a demand valve and is expelled into the surrounding environment. None of the exhaled gas is reused, so the breathing circuit is said to be "open", hence the term "Open-Circuit Scuba".

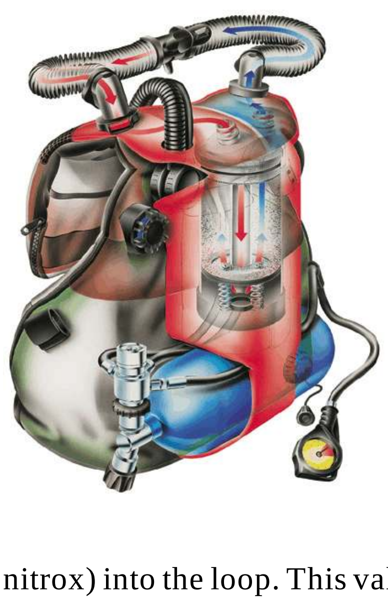
The original open-circuit scuba regulator was a two-hose style regulator and was based on previous designs of closed-circuit Oxygen systems. Inhaled gas comes over the right shoulder entering the first of two flexible breathing hoses, past a non-return or "one-way" valve and into the mouthpiece. The exhaled gas travels out the mouthpiece past another non-return valve, through the other flexible breathing hose and vented to the surrounding water through a final non-return valve. Eventually this system evolved into a single hose gas supply with a single non-return located in the mouthpiece. This design change significantly increased regulator performance. Today even budget regulator systems outperform the best early regulator designs.

Open circuit systems have many limitations, the most notable are:

- Gas selection must be chosen prior to the dive, and with one gas mix per open-circuit system, additional gases require additional open-circuit systems.
- Gas supply is limited, with low efficiency and poor weight to duration ratios.
- Breathing gas is inspired at ambient temperature reducing the diver's body temperature and is dry leading towards dehydration.

However, due to low cost, simplicity and ease of use, the Open-Circuit breathing systems is the most widespread breathing system in the world.

Semi-closed Circuit Rebreathers

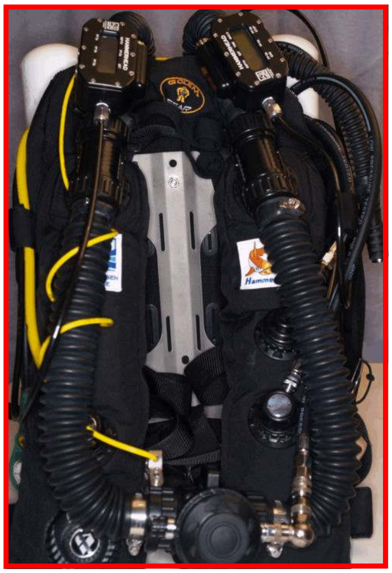


The breathing circuit is similar to the previously described two hose open-circuit types, except exhaled gas is retained in the system by means of a ***counter-lung or breathing bag***. The exhaled gas contains less Oxygen and increase Carbon Dioxide (CO_2). The gas need to pass through a chamber containing a chemical compound to remove the CO_2 before being inspired once again. This chamber is commonly called a **scrubber,** and may be made up of packed granules or a manufactured cartridge. Since this is a continual process, oxygen is being slowly depleted along with a decreasing breathing volume.

Metabolized Oxygen, and lost volume in the most common SCR design is replaced by means of a **flow control valve** that continually bleeds a constant flow of replacement gas (usually nitrox) into the loop. This valve is set and matched to a specific oxygen concentration, maximum depth of the dive, and to the oxygen requirements of the user. Most systems require this to be determined before the dive, however there are designs that allow adjustments on-the-fly. The second type of SCR dumps a fixed percentage of gas on each exhale and refills the loop from a demand valve with fresh oxygen rich gas. Since there is venting of used or excess gas while at a constant depth, the descriptive name of "semi-closed-circuit" is appropriate. The amount and quantity of exhaled gas will depend on the flow rate of the replacement gas source, whether its fixed or tied to the diver's respiration rate.

The main limitation of SCRs is that the system usually has to be setup for a specific target depth, using a specific gas and predefined flow rate prior to the dive. The current configuration limits the dive to the gas's physiological limits. Current designs have become more user friendly, but the basic breathing loop remains unchanged from the earliest units.

Closed-Circuit Systems



The closed-circuit system operates on the same concept as a "semi", but does not inject gas at a fixed rate nor does it lose any gas to ambient except during ascents. There are many variations of closed-circuit design that have evolved over the years. There are rebreathers that are being sold as "closed" systems that continually inject a very small amount of oxygen. These systems in reality are a hybrid system because while the diver is breathing off the loop they *normally* act the same as what is traditionally called a closed circuit system but when the diver is off the loop they will continually vent gas.

The first CCR systems used a single gas supply that was usually 100% Oxygen and were generally called Oxygen Rebreathers. These are the simplest form of all rebreathers and have a very limited maximum working depth due to the inability to vary the breathing mix. The limited depth and dangers associated with the use of oxygen underwater have restricted the use of oxygen rebreathers to military and scientific applications.

The oxygen rebreather is special in that it is the only rebreather type that can be truly bubble-less. As the diver ascends, the gas in the breathing loop expands and normally requires excess gas to be vented, but on an Oxygen rebreather, gas addition can be prevented and the loop can be reduced by metabolizing the oxygen prior to ascent. Oxygen rebreathers are still used by most militaries and find considerable use in non diving life support systems (fire, mine rescue, space ect.).

With the advent of electronic control and monitoring of the breathing loop, two types of electronic CCRs developed: *constant percentage of Oxygen* (fO_2) and *constant dosage of Oxygen* (PO_2). Current designs have standardized on constant PO_2 loop.

The earliest designs required the diver to chose the target PO_2 or FO_2 during setup but current systems allow the diver to vary the gas mixture being breathed ***during the dive.*** These CCR systems employ an electronically-controlled gas mixing system that blends the gas from two separate cylinders. The first cylinder (diluent) is usually used to make up the volume of the breathing loop while the second cylinder (usually 100% oxygen) is used to achieve the desired target PO_2. The original mixed gas CCRs were generally configured with the left-side cylinder containing Oxygen and the right-side cylinder contains a diluent gas such as Air or a mixture of Helium and Oxygen (Heli-Ox), or Tri-Mix (Helium-Nitrogen-Oxygen). Most CCR systems today reverse the cylinder placement an go with the adage "Rich Right".

There are also mCCR (mechanical) rebreathers that are a hybrid design, in that they inject a fix flow of gas like many SCR designs but usually do not vent any gas while at a constant depth like a true closed circuit system. These systems replace the constant flow of Nitrox with Oxygen. When properly configured, mCCR Rebreathers behave like an electronically controlled CCR in that no gas is vented except on ascent. The **DIVER** is the "controller" for this design and is responsible for maintaining the target PO_2 by manually injecting additional oxygen when needed.

The *HammerHead* is an electronically controlled CCR that can operate using, Air, Heliox or Tri-Mix as a diluent. Helium based diluents are the easiest for divers to breathe, especially at depths greater than 130fsw/40 meters. Although the HammerHead has been designed to use gases with Helium, the programming of these gases needs to be enabled by a entering a special PIN. Additional training is required to receive this PIN to allow the use of the *HammerHead* with Helium based diluents.

Chapter 2
Component Description

HammerHead Specifications

- Duration for the standard radial scrubber is 6 hours using 8 – 12 mesh Sofnolime in a cold water environment.
- Recommended maximum operating depth is 100m / 326 fsw.
- Multiple user selectable set-points.
- Integrated Decompression Computer.
- DIVA Heads-Up display.
- Dual independent handsets.
- Manual and automatic gas addition of Diluent and Oxygen.
- Multiple scrubber, canister, counter-lung options available.
- Tri-Mix Capable.

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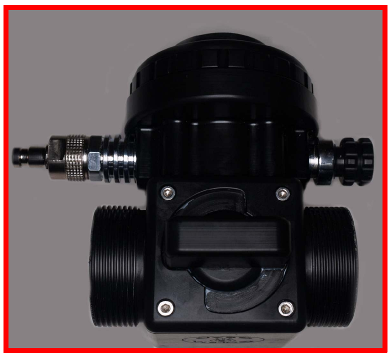
MAJOR COMPONENTS of the HammerHead

Breathing Hoses and Connectors

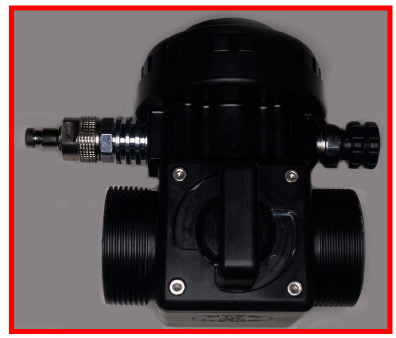
The breathing hoses, connectors and DSV can be broken down individually for easy cleaning and maintenance. The two hoses and the connected DSV should normally be handled as a single assembly. The components should not be separated unnecessarily. The hoses used on the HammerHead are heavy duty and are stiffer than those used on many other rebreathers. This means the DSV must be orientated correctly to avoid jaw fatigue and negative pressure tests must be performed without relying on the ability to crush the hoses.

Mouthpiece Valve



Loop Open

Anytime the DSV is not in the diver's mouth, it should be in the closed position. **ALWAYS** close the DSV **prior** to removing. Failure to close the loop while in the water, either underneath or at the surface, will allow water entry and loss of buoyancy. The ***HammerHead*** rebreather is fairly tolerant to moderate quantities of water entering the loop.



Loop Closed / Open Circuit

A common source for small quantities of water entering the loop is from loose lips. Closer attention may be necessary for new rebreather divers. When re-inserting into the mouth, exhale to remove the water through the OC exhaust and rotate the lever to loop position. Opening and closing the valve is accomplished by rotating the lever 90 degrees, the mouthpiece to loop is open when the lever is horizontal, and the loop is closed with lever in vertical position..

Inhale Side - 1 Way Valve

Located at both ends of the inner tube of the DSV are non-return valves. The non-return valves can be installed on either side permitting left to right or right to left flow, but due to the positioning of the sensors, the valves should be installed to force left side to right side flow (clockwise) on the *HammerHead* rebreather. This means that the "spider" should be visible on the left side (as if DSV was in diver's mouth) when no hoses are installed, and the flapper should be visible on the right side.

Part of the pre-dive equipment check is checking the direction of gas flow and the proper operation of the non-return valves prior to using the rebreather. Check for proper operation by alternately covering the inhale and exhale hoses as you inhale and exhale. Gas must come from the Left and go out to the Right. You must not be able to inhale gas from the exhale side and exhale gas into the inhale side.

Exhale Side - 1 Way Valve

Routine maintenance needs to be performed on the DSV to insure proper functionality. Lubrication of the body and center (inner) tube is necessary to maintain loop integrity and should be performed at least every SIX months. Should operation between the OC and CC positions become difficult immediate service is recommended. The replacement of the "flapper" on each non-return valve body should be performed yearly or whenever directional integrity is compromised.

The following service procedures are courtesy of Golem Gear. These procedures assume the standard Golem BOV, but can be used as a guide for servicing the Golem Vario BOV. The major difference is the BOV body that reverses the ball valve securing plate and the mouthpiece interface.

Tools needed:

2.5mm hex key

Needle-nose pliers or C-Clip tool

Brass or plastic hook

Remove one-way valves

INHALE SIDE

Using a brass hook, gently remove the one-way valve holder by sequentially pulling on each spoke. Pay careful attention to the hook placement to avoid damaging the soft valve.

EXHALE SIDE

Lift the flapper valve to reach the holder spokes and remove using the same procedure as on the inhale side.

Remove retaining washers

Preferred Method:

Insert needle-nose pliers or C-Clip tool into the two retaining washer holes. Gently squeeze pliers while pulling the washer out of the groove.

Repeat on other side.

Alternative Method:

The retaining washer can also be removed by using a hook to pull on one of the holes and twisting it out of the groove.

Repeat on other side.

Remove the ball valve

Unscrew the four hex screws (M3-16) from the ball valve cover.

Pull the ball cover (and the ball valve) out of the BOV body. Make sure that BOTH retaining washers from the inhalation and exhalation ports are removed, otherwise you will not be able to remove the ball valve, and might damage the BOV.

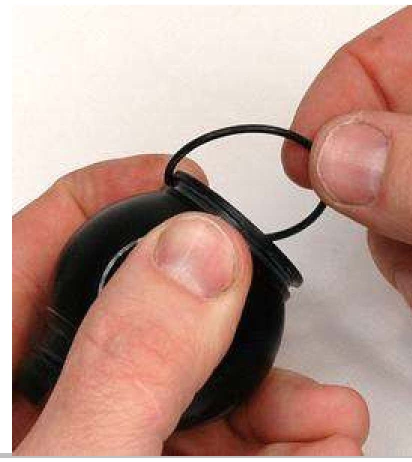
Remove the ball valve handle

Unscrew the two hex screws (M4-20) on the valve handle.

Separate the ball valve from the valve cover.

Inspect o-ring on the valve cover.

Inspect the o-rings on the ball valve.



Remove 2nd stage

Unscrew the diaphragm cover.

Locate four hex screws (M3-14) inside the 2nd stage case.

Unscrew all four screws.

Remove the 2nd stage case

After removing the 2nd stage body, take care not to damage or lose the o-ring between the BOV and 2nd stage.

Remove ball valve seats

The BOV body uses two removeable convex valve seats. One is located on each of the rebreather loop ports. **Carefully** push each seat towards the center of the BOV body (through each port) using your thumb.

Inspect/replace all o-rings

All O-rings should be carefully inspected for wear and debris.

1x – ball valve handle

1x – ball valve to mouthpiece

1x – ball valve cover

4x – ball valve seat (two each)

1x – BOV box to 2nd stage body

2x – one-way valves (one each)

Lightly lubricate with O_2 compatible grease.

Assemble the BOV in reverse order

Insert a valve seat on each side of hose ports. Do not pinch the o-rings!

Take extreme care when inserting the ball valve seats into the BOV body. Close attention must be paid to insure the proper O-ring placement. A pinched o-ring will render the BOV inoperative!!

Attach ball valve to valve cover and to valve handle with two hex screws (M4-20).

Insert ball valve into the BOV body. Make sure that the o-rings in the valve seats are in proper place.

Insert the retaining washers.

Screw in the four hex screws (M3-16) into the ball valve cover.

Attach OC Pod to BOV Body

Make sure that the o-ring around the 2nd stage port on the BOV body is properly positioned and lubricated.

Seat the body of the OC Pod and insure that the captured o-ring is properly seated between the OC Pod and the BOV body.

Secure the 2nd stage body to the BOV using the four hex screws (M3-14).

Inspect the 2nd stage diaphragm

Carefully inspect the diaphragm body for punctures and inspect the 2nd stage cover for damage.

Verify the proper operation of the one-way exhaust valve in the center of the diaphram body.

Seat 2nd Stage diaphram/Exhaust valve

Carefully seat the diaphram assembly.

Insure that the o-ring on the circumference or the diaphram is properly seated.

Check the positioning of the assembly, insuring that the purge button on the 2nd stage cover is centered on the diaphram.

Screw in the 2nd stage cover.

Insert the one-way valves.

Make sure that the o-rings on the circumference of the one-way valve body are lightly lubricated and seated properly.

Always verify that the one-way valves are in the correct positions. The gas circulation on the HammerHead is LEFT to RIGHT!!! Failure to do so can result in serious injury or death!!!

The gas travels into the flapper valve where the spokes are visible, and out of the valve where flapper hides the spokes.

Make sure that each valve has the correct orientation.

DIVA

The DIVA ships from the factory as an assembled unit. The DIVA needs to be mounted to the DSV using the supplied DIVA bracket. The DIVA can be positioned so that it can be viewed by either the diver's right or left eye. To install line up the screw hole on the DIVA and use the supplied screws to secure to the mount. The proper locking ring for the desired side needs to be properly positioned. The DSV locking ring for the DIVA has a channel that the DIVA ring will rotate within.

A hood can be installed to improve the visibility in bright conditions. The hood is a cap that fits over the LED end of the DIVA. And can be made out of a hose protector or similar material. For optimum results it should have an opening on one side only which should face the diver. This hood shields the DIVA from ambient light allowing the diver to see the LED even in very bright conditions. The hood is only recommended for use in bright conditions because it also prevents the diver's buddy from seeing the LED in the DIVA. The visual indicator in the DIVA under low light conditions is easily visible to all the diver's around and may alert a buddy to a trouble even before the diver realizes there may be a problem.

Once the DIVA is mounted and the hoses are all connected, the diva cable should be wrapped around the breathing hose and routed up to the DIVA connector on the head. **The HammerHead must NEVER be used with the DIVA connector on the head exposed!** The cable must be fully plugged into the socket and securely tightened (do not use any tools) in order for a water tight connection. Alternate between tightening the locking ring and trying to seat the plug further into the socket. Continue until no further tightening is possible. The connector on the head and the cable end should be periodically cleaned with a suitable contact cleaner.

"T" Fitting

Inhale C-L T-Piece

The "T" fittings on the HammerHead are not fixed to the counter-lungs, instead they are removable. This permits easy cleaning and inspection of the counter-lungs.

Exhale C-L T-Piece

The hoses are secured to the T-Piece using threaded connectors. Each T-Piece has unique threading for the connecting hose and is engraved INH/EXH to help prevent the loop from being assembled backwards. The inhale side T-Piece should be installed on the diver's LEFT side and the exhale T-Piece should be installed on diver's RIGHT side. The T-Piece to counter-lung connection does not have a unique thread, pay attention to the proper orientation. It is recommended that the engraving on the T-Pieces face outward for quick visual confirmation. The O-rings on the T-Piece should be lubricated using Christo-lube® before use. Poorly lubricated O-rings can make it difficult to remove the fitting from the counter-lung.

Hose Ends

The securing ring on the hose fittings all have unique threads. This arrangement insures that only the correct hose can be connected to a specific "T" fitting, DSV side and port on top of the lid. This is to prevent incorrect connection of the breathing hoses and insuring the proper gas flow through the scrubber. The hoses are secured to the fittings using stainless steel hose clamps. Even with all these measures it is still important to verify proper operation before each dive. The O-rings should be lubricated using Christo-lube® before use.

Counter-lungs

The standard counter-lungs are a chest mounted over-the-shoulder (OTS) design. This orientation allows the best work-of-breathing in all possible positions . The counter-lungs must be properly secured and flush with the diver's body. The ***HammerHead*** can be ordered with optional rear mounted counter-lungs. These optional counter-lungs allow freeing up of the diver's chest at the cost of an increased Work of Breathing.

The OTS counter-lungs feature two pockets on the rear of each to facilitate easy attachment of trim weights.

Oxygen and Diluent Addition Valves

The manual gas addition valves are similar in design to Dry-suit style valves and use standard LP inflator hose connectors. These valves allow the manual addition of diluent or Oxygen and permit the use of off-board gas supplies. Unlike the valves used on many other rebreathers, the addition valves are specifically designed for use in a rebreather.

These valves are removable to aid in the cleaning of the counter-lungs, efficient pre-dive leak checks and service. The male QD nipple should be removed using a #8 spanner bit rather than pliers or the like as they can damage the sealing surface. The sealing nipple o-ring is size 6mm x 2mm.

The face button and stem can be removed by securing the stem from the underside and using a pin spanner to loosen the button. The stem o-ring is a size 3mm x 2mm. The main body o-ring is a size 22mm x 2.5mm. The threaded locking ring is secured in plcae by a plastic c clip.

Important note: It is essential not to confuse the Oxygen components with their diluent counterparts. The entire Oxygen delivery system should be maintained in an Oxygen clean state. It is the manufacturer's opinion that the entire system should be maintained in an oxygen clean state to prevent potential cross contamination.

Over-Pressure Exhaust Valve

The ***HammerHead*** rebreathers use a dry-suit type valve as a loop over-pressure relief. This valve will normally be operated in the open position (turned fully counter-clockwise). If the diver is frequently head down in orientation, it may be required to close the OPV ***slightly*** to maintain the proper loop volume. During the ascent, the gas in the loop will expand, increasing buoyancy and increasing the breathing effort slightly. Properly sized and adjusted counter-lungs will keep buoyancy shifts to a minimum.

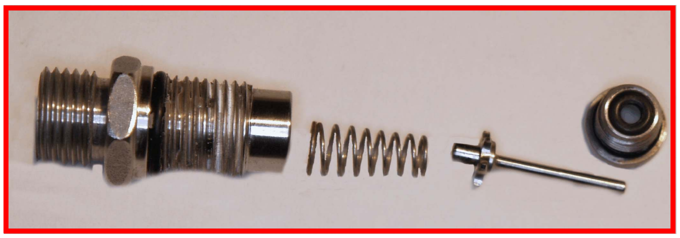
Excess gas can be vented by exhaling around the outside of the mouthpiece, through the nose, by positioning the body with the right side down and the exhale counter-lung slightly elevated, or exhaling more deeply into the loop forcing the OPV to operate. Exhaling around the outside of the mouthpiece is the preferred method of manually dumping the loop as this dumps gas from the diver's lungs and the counter-lungs simultaneously and is easily controlled.

The positioning of the exhaust valve on the ***HammerHead*** permits the removal of water from the exhale counter-lung. This requires that the diver assume a position head-up, allowing the water to collect at the bottom of the counter-lung and flushing the loop with diluent. The diver must be aware of potential buoyancy issues and take the necessary steps to prevent an unwanted ascent. This skill will be practiced at the end of confined water training.

Automatic Diluent Addition Valve

The automatic diluent addition valve is a simple plunger arrangement. The valve is operated when the counter-lung is collapsed on an inhalation forcing the plunger to press an upstream valve. The flow through the valve is quite high compared to the manual gas addition valves which have a restricted gas flow. The ADV can be manually operated by simply pressing down on the valve. The location and high gas flow make it the first choice when having to perform a loop flush. This valve should never be used without the addition of a "trombone" style gas shutoff valve.

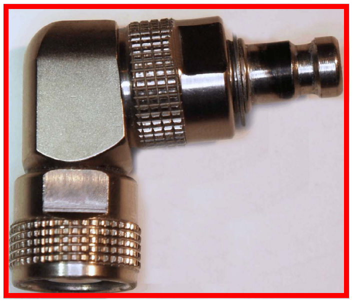
Most divers will start the dive with the gas shut-off valve in the open position which allows the ADV to function normally during descent. Once at depth the ADV may be disabled by sliding the gas shut-off valve to the closed position. In the event a diluent flush is needed, the sliding action of the shut-off valve allows it to be opened and the ADV operated in one quick motion.



The ADV requires very little maintenance other than rinsing with fresh water and lubricating the O-rings. The main ADV body o-rings are a size 26mm x 2.5mm. The ADV should be checked periodically for leaks by pressurizing the valve and submerging it in a container of water. The normal pre-dive checks will catch any significant leaks, but very small leaks may not be detected. A defective o-ring between the gas inlet fitting and the ADV body (size 10mm x 2mm) is a possible leak location. The fitting can be removed with a wrench and the o-ring replaced. **Do Not over-tighten** the fitting when re-installing as this may strip the threads in the ADV body. Another possible leak location is the Tilt valve, the condition of the valve will determine if a simple o-ring replacement or valve replacement is necessary. There are two o-ring internal to the tilt valve. The primary valve sealing surface is a 3mm x 1.8mm Shore 90 o-ring and a size 7mm x 1.5mm o-ring to seal the valve body to valve cap.

Should operation of the plunger become problematic inspection and possible replacement of the internal spring is necessary. The adv plunger body is held in place by a securing pin located in the bottom most (closest to plunger) o-ring groove. The pin can be removed by pushing it through the body using a dental pic.

Oxygen Quick Disconnect



The Oxygen delivery system to the solenoid consists of three parts: A quick disconnect plug (nipple), a quick disconnect socket and a right angle fitting. The *HammerHead* has a filter installed between this fitting and the Oxygen connector on the lid. The nipple does not have a built in gas cut-off or any other mechanism to prevent water entry. The socket will only deliver gas when connected to the nipple. The outer ring on the socket rotates and acts as the positive lock mechanism. The fittings should be rinsed with fresh water after each use and should **NEVER** be disconnected underwater as water will enter the solenoid. The Oxygen Quick Disconnect (QD) system is a possible source of corrosion to the solenoid.

It is important that both fittings are checked and cleared of any residual water before connecting. This can be accomplished on the QD receiver by direct directing dry gas towards the opening, while the QD socket can be cleared by depressing the tip while the oxygen supply is pressurized.

Cannister "Lid"

The cannister "Lid" is the heart of the ***HammerHead***. It is composed of the wiring for the handset displays (Primary and Secondary), the wiring and bulkhead connector for the ***DIVA (Heads-up Display)***, a blank port for connecting an independent computer or constant flow oxygen addition, solenoid and four Oxygen sensors.

The hose connections to the counter-lungs are on the top of the "Lid". The gas inlet port is located next to the solenoid output (on diver's right side) which maximizes mixing of exhaled gas with injected Oxygen. The center of the lid contains the sensor pod and the port at the base of the sensor pod to connect to the scrubber. The gas outlet port is on the diver's left side.

Sensor Pod

3 cells plus "dummy" plug

The sensor pod is composed of the permanently mounted pod body and a removable locking cap. The body houses the four Oxygen Cells, three for the HammerHead electronics and an optional cell for a 3rd party computer. The oxygen cells **must** be installed with the supplied O-ring. A gas tight seal between the cells and the pod body is necessary on the ***HammerHead*** because the cell housing side is exposed to the inlet gas, while the cell membrane is exposed to the outlet gas. Gas tight integrity of these seal should be periodically checked by blocking the gas outlet port on the lid and gently blowing into the port on the sensor cap. If gas escapes, isolate and correct leak.

This design is in contrast to most others where the entire cell is exposed to the "scrubbed" gas. A failure of seal integrity at this point may allow bypass of the CO_2 scrubber. The port at the base of the removable sensor pod cap has an o-ring that provides a gas-tight seal between the sensor pod and an installed scrubber. This is necessary to insure isolation between inlet and outlet gases. Installation of this cap must be verified during each assembly as it is possible to assemble unit without this cap in place. ***WARNING!*** **The absence of this cap will allow complete scrubber bypass!**

Sensor Cap Installed

The HammerHead is shipped without any oxygen sensors. The user needs to purchase R22d compatible oxygen sensors (Molex connector with a nominal 10mv in air at sea level) and install them into the sensor pod. Remove the oxygen cells from the sealed packaging and thoroughly inspect the o-rings. It is strongly suggested to inscribe the installation date and the associated cell location. The numbering of the cells insures that if during trouble shooting cell positions are swapped the cell can be returned to its original location. Tracking the mV measurements over time is useless unless the values always apply to the same cell. Carefully screw each cell into the associated location (the positions are marked on the sensor pod).

A common problem with many rebreathers is corrosion of the sensor wires. This usually requires the user to ship the unit back to the factory for repair. The HammerHead has taken a modular approach, and replacing the wiring only takes minutes. Carrying a spare harness in the save a dive kit is highly recommended.

Wiring Harness

Installed Oxygen Sensors

All sensor connections on the HammerHead are color coded, simply match up the colors. Be aware the certain colors look similar such as orange and red, and black and brown. The sensor block is numbered with Brown being the color code for sensor #1, Red for sensor #2, and Orange for sensor #3. Using this code as a guide, connect the proper molex connector for each cell and slide the black protective cap in place.

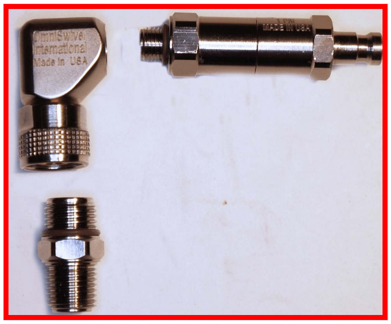
The sensor harness should now be connected to the banana block matching the colors as illustrated above. It is very important the black connection on each sensor is correctly installed into the proper jack otherwise the associated oxygen sensor will not work correctly.

Solenoid

The ***HammerHead*** uses a low voltage Snaptite solenoid that is prepped for Oxygen service. The exposed metal components are brass and are resistant to corrosion, while the less resistant metals are encapsulated for protection.. The blue tube directs the injected oxygen into the exhale inlet fitting to aid mixing. The solenoid and fittings connecting the solenoid into the "Lid" must be checked for leaks. Most leaks can be detected during the pre-dive checks by pressurizing the Oxygen regulator (with the set-point control in manual mode or with the electronics in sleep mode), recording the pressure and then shutting down the valve.

The pressure should be compared several minutes later to the pre-recorded value. Any pressure drop indicates a leak. The leak must be identified and corrected before diving the rebreather again. Oxygen leaks into the loop can cause a dangerous rise in PO_2 and must not be ignored. Normally a soapy water solution can be used to isolate leaks, but for slow leaks a commercial leak detecting solution may be necessary.

Constant Oxygen addition Valve



The Hammerhead can be optionally configured with a constant oxygen bleed. The fitting can be fitted in two possible locations. The first location is as a replacement for a failed Oxygen solenoid. The solenoid needs to be disconnected inside the lid and the right angle and QD nipple replaced with the "*leaky valve*", plus a filter, check valve and qd combo.

The second connection would be the 1/4 npt port used for an integrated dive computer. A 9/16 -18 female to 1/4 npt male adapter is required to use this port. The right angle "*leaky valve*" is secured to this adapter and a filter, check valve and qd combo is connected to the "*leaky valve*". If using this port stand alone the Solenoid connection must be sealed, connecting oxygen to both the solenoid and "*leaky valve*" allows the ***HammerHead*** to be used in a hybrid mode.

Before configuring and using the HammerHead with a constant oxygen bleed, additional training and modification of the 1st stage is required.

First Stages

Both the Oxygen and diluent cylinders use a first stage pressure regulator. Both are marked accordingly and must not become mixed-up. i.e do not use the Oxygen 1st stage on the Air cylinder and vice versa. The Oxygen 1st stage has been specially prepared using Oxygen compatible O rings and lubricants, the diluent 1st stage has not. It is only prepared for use with Norm-oxic gas (21% Oxygen).

Oxygen 1st Stage, Manifold and Hoses

The Inter-stage Pressure is normally 10 bar / 145 psi with a range of 9.0 to 10.4 bar. (130psi-150psi). Under special circumstances the inter-stage pressure may be increased above 10.5 bar. The normal arrangement is an oxygen feed with a M & J quick disconnect, an oxygen clean LP inflator hose for manual gas additions and a submersible pressure gauge.

Diluent 1st Stage, Manifold and Hoses

The Inter-stage Pressure is normally 10 bar / 145 psi with a range of 9.0 to 10.4 bar. (130psi-150psi). The inter-stage pressure of the diluent cylinder may be altered to suit an open-circuit 2nd stage if fitted with a maximum pressure of 12.5 bar (165psi). The normal configuration from the factory is a LP regulator feed connected to a gas cut-off valve for the ADV, a LP inflator that can be used for a BCD or for the manual diluent addition valve, a submersible pressure gauge, and a first stage Over-pressure Valve (OPV). Additional LP whips and a second stage can be fitted.

Gas Cylinders

The Oxygen cylinder is located on the right hand side of the diver and the diluent cylinder on the left. Both cylinders should be marked according to their contents following industry standards.

The Oxygen cylinder and Oxygen components, such as the first stage, hoses, contents gauge and addition valve, are Oxygen service rated when shipped from the factory. Proper maintenance is required.

The first task is to mount the valves to the cylinders. Inspect the valves and tank neck O-rings. Lubricate the tank neck O-ring and threads with Christolube MCG 129 or equivalent. The Oxygen cylinder uses a left hand DIN valve with the valve face towards the diver when mounted. The Diluent cylinder uses a right hand DIN valve (this is the traditional arrangement) with the valve face towards the diver when mounted.

Cylinders are mounted to the cannister using MetalSub brackets. This allows easy mounting and removal of the cylinders. The bracket locks/unlocks by a spring loaded pin. The receiving brackets come installed on the cannister, while the cylinder side mounts must be installed by the user. The cylinder side bracket is normally secured using stainless steel hose clamps, but can also be secured using cam bands. It is preferred to install either heat shring tubing or some other protective covering on the hose clamps to prevent damage to the cylinder surface.

The brackets should be loosely installed on each cylinder, then the cylinders mounted and regulators connected. The height of the cylinder should be adjusted so that the 1st stages will not be able to hit the surface when the rebreather is standing up and the lp hose between the 1st stage and the manifold is fully extended. The valve knobs should be turned slight in to allow easy manipulation. Once the positioning is correct the hose clamps should be tightened to prevent movement.

Warning!

It is the manufacturer's recommendation, that the condition of the Oxygen cylinder and valve be assessed at 6 month intervals.

Both cylinders should be internally inspected at least on an annual basis. Cylinders that are frequently de-pressurized for shipping, or exposed to the atmosphere without valves should be examined more frequently.

In particular, if the Oxygen cylinder is contaminated with salt water then it must be Oxygen cleaned without delay otherwise corrosion *may occur more rapidly* in an Oxygen-rich environment[1].

The diluent cylinder, first stage and components, however, are NOT Oxygen clean as the diluent used is normally compressed Air. If it is intended that this rebreather is to be used with a Tri-Mix or Heli-Ox diluent and the fill method is by partial pressure blending, then it will be mandatory to Oxygen clean both the cylinder and cylinder valve. It is *Juergensen Marine*'s very strong recommendation that all components are to be maintained as "Oxygen-Service equipment to prevent cross-contamination of the equipment.

BC Wing and Harness

The ***HammerHead*** rebreathers can be ordered with or without a back buoyancy wing system and harness. The bolt patterns uses the standard 11 inch spacing as used with most back-plates from other manufacturers.

[1] ***NOAA examined its EAN cylinders to determine if the increased Oxygen content accelerated the corrosion process. The results were negative or inconclusive.***

CO_2 Scrubber

Radial Scrubber

ALWAYS use oxygen compatible lubricants on any system where oxygen, or an oxygen enriched environment is in use. It is not a good practice to mix silicon and oxygen compatible lubricants in the same system even on surfaces not exposed to oxygen. This helps to prevent cross contamination.

A) Remove breathing hoses and Oxygen supply Quick disconnect hose. Rotate securing ring and remove head. Allow sensors to dry in ambient air.

B) Remove scrubber assembly, spacer and absorbent pads from bottom of canister. Inspect bottom of main housing and absorbent pads for water and dry if necessary.

C) Remove the canister cover by removing the retaining nut and pulling on the two handles located on the top of the lid.

D) Empty the used chemical into a suitable container for disposal following manufacturer recommended disposal guidelines.

E) Cover the top of the inner tube with an appropriately-sized piece of tape, or with some other sort of cover.

F) Fill canister about one-third full. While in an upright orientation, agitate and tap lightly on a solid (but not hard) surface until the absorbent material settles and is level.

G) Fill canister another third and repeat agitating and tapping.

H) Top off canister and fill to the top of the outside screen (fill line of center tube). Tap and agitate (adding additional sorb as necessary) until the sorb is level and no longer settles below the fill line.

I) Replace canister cover and loosely install locking ring. Hold the canister horizontally and lightly tap while rotating along its axis. Complete at least two rotations, then stand the canister upright and tap several times.

J) Gently tighten securing nut. Repeat above until securing ring is flush with center tube.

K) Shake canister and listen for rattling of Sorb.

L) In the event of rattling, remove cover, add a small amount of chemical and repeat steps I through K. Repeat procedure until no rattling is present.

M) Replace dry absorbent pads into main housing. Insert the spacer and scrubber assembly.

N) Inspect sensors and sensor wires. Inspect CO_2 canister mating O-rings on sensor carriage.

O) Inspect lid assembly for waterproof integrity (O-rings, and all fixed components).

P) Instal lid into canister/scrubber assembly and Secure head.

Q) Re-install all disconnected hoses.

Mini and Standard Radial Scrubbers

MicroPore Scrubber - Future Option

ALWAYS use oxygen compatible lubricants on any system where oxygen, or an oxygen enriched environment is in use. It is not a good practice to mix silicon and oxygen compatible lubricants in the same system even on surfaces not exposed to oxygen. This helps to prevent cross contamination.

A) Remove breathing hoses and Oxygen supply Quick disconnect hose. Rotate securing ring and remove head. Allow sensors to dry in ambient air.

B) Remove scrubber assembly, spacer and absorbent pads from bottom of canister. Inspect bottom of main housing and absorbent pads for water and dry if necessary.

C) Fold scrubber seals onto top and bottom adapters and remove adapters from cartridge.

E) Dispose of used chemical following manufacturer recommended guidelines.

F) Remove new cartridge from SEALED packaging, and inspect for any damage.

G) Install both cartridge adapters, and fold top and bottom seals onto new cartridge. Lightly lubricate inside of top ring on scrubber assembly with Cristo-lube.

H) Replace spacer and pads into canister insuring the proper orientation. (Bottom side is completely flat, while top has 2 notches to accept scrubber assembly.)

I) Replace dry absorbent pads into main housing. Insert the spacer and scrubber assembly.

J) Inspect sensors and sensor wires. Inspect CO_2 canister mating O-rings on sensor carriage.

K) Inspect lid assembly for waterproof integrity (O-rings, and all fixed components).

L) Instal lid into canister/scrubber assembly and Secure head.

M) Re-install all disconnected hoses.

Important information regarding Scrubber Duration

1) Never expect the Sodalime to last longer because the dives are conducted in warmer water. It is always best to assume a conservative approach towards scrubber duration. CO_2 effects can come on quickly and have potentially deadly consequences.

2) The design of the scrubber, not just the weight of Sodalime, is a major factor in the duration. Performance figures from one product cannot be used for determining the duration of another brand or scrubber design.

3) At the time of publication, the performance of the various ***HammerHead*** scrubbers have not been independently certified. All durations are based on manufacture recommendations. Do not assume that the reports from other users are more accurate than the manufacturer's.

4) Material that has been left exposed to the atmosphere can appear to be satisfactory but in reality may not be fully effective working for a much shorter period. Never leave your adsorbant chemical or scrubber cannister assembly exposed to atmosphere unnecessarily.

5) Replace the Sodalime if the material is soaked, do not attempt to dry it out.

6) The efficiency of the material may vary slightly from batch to batch.

Certain brands of Sodalime have an optional color indicator that changes color (usually violet / purple) as it is used. This is useful as a guide to see which portions of the scrubber were most active but should not be used to determine if the scrubber is still usable. The material returns to the natural color after a time and is also temperature dependent. In cold condition, there may be no color change at all. Considering these facts .....

Warning: DO NOT RELY ON COLOR CHANGE

Important Rules to Live By:

Avoid leaving the adsorbent open to the atmosphere. The material can become contaminated. If you intend to use the adsorbent again, be certain that the scrubber chemical is dry and the assembly dried. Seal up the scrubber using the assembled rebreather.

NEVER Remove the scrubber chemical from the cannister and attempt to re-pack it at a later date. Anytime the material has been removed it should be discarded and not reused. Once the packing order of the chemical has been disturbed, there is no way to predict how the used chemical will end up in a re-packed scrubber. It is possible that paths of used chemical will form allowing premature breakthrough of the scrubber.

Question: How do I know when the CO_2 adsorbent can no longer adsorb CO_2 ?

Answer: Record the time used and stay within manufacturer recommendations.

Warning !

Hypercapnia, an excess of CO_2 at cellular level, can become a problem in any form of closed circuit rebreather diving. Channeling of breathing gas through the adsorbent due to poor packing during refill or wet adsorbent can lead to reduced efficiency and increased CO_2 levels.

Always be vigilant and aware of the common signs and symptoms of hypercapnia, most notably, increased breathing rate, confusion and drowsiness. If the CO_2 exceeds 0.10 bar symptoms such as difficulty in breathing, rigidity and muscle spasms may become evident. Symptoms of Hypercapnia may be quickly reversed by flushing the breathing loop with diluent or switching the DSV to the Open Circuit position and breathing directly off the diluent cylinder.

After Every Scrubber Replacement

Inspect sensors and sensor harness for corrosion and damage.

Inspect O-rings on sensor Cap for debris and proper lubrication. Clean and lubricate if necessary.

Insure Sensor cap is installed and locked in place.

Inspect O-rings on Lid for debris and proper lubrication. Clean and lubricate if necessary.

Carefully inspect the lid assembly for waterproof integrity and physical damage.

Install lid into canister/scrubber assembly and secure.

Re-install all disconnected hoses.

System Integrity Checks

Leaks

It is extremely important to cure any leaks before diving. Any loop with an integrity problem should not be used until the problem is identified and corrected. Even a small leak is irritating and saps confidence.

Be aware that a loss of buoyancy or gas from the breathing loop while at constant depth is a sure indicator of something being amiss. If there is a constant need to inject diluent to breathe from the bag then it is very likely that there is a leak in the system. There is another problem with gas leakage that is often overlooked by inexperienced CCR divers. The constant injection of diluent lowers the PO_2 in the loop, making your decompression schedule invalid. In addition, the frequent and wasteful addition of Oxygen required to return the PO_2 to the set-point.

To check for leaks first insure that the OPV exhaust valve is in the highest resistance setting by rotating it fully clockwise, and then inflate. This can be done by mouth, the manual add valve or by pressing down on the ADV. The DSV should then be closed while gas is still being added to ensure the counter-lungs are inflated fully. Make sure the tank valve is then shut off and purged of all gas. Make sure gas is added until the OPV operates. The rebreather should then be allowed to sit for 30 minutes and checked to see if the counter-lungs have remained firm.

Test with negative pressure by sucking a vacuum on the apparatus, the convoluted hoses will contract, and close the mouthpiece while still pulling vacuum. Gently allow the DSV to hang supported by the hoses. If air leaks into the system the hoses will stretch and the DSV will sag lower. It is extremely important to find any small leaks and rectify them before diving. Water will ingress into the apparatus through the smallest of leaks. This test should be run with the Oxygen and diluent regulators pressurized. The ADV needs to be disabled with a gas cut-off valve to prevent gas addition. If no cut-off is fitted, make sure the diluent side is not pressurized, but in this case the manual add valve (if connected on the dil side) can't be tested for a leak.

An audible gurgling noise originating from the exhale side of the DSV indicates that there is a leak somewhere on/in the DSV. A likely source is where the mouthpiece attaches to the DSV. Check for proper tensioning of the "tie-wrap" and for tears in the mouthpiece itself. The hose connections are the next best check-point.

Indications

Know your PO_2 at all times! Learn how to evaluate the information provided by the Oxygen displays.

Compare the cell readings. While breathing, the cell readings should change. Bearing in mind that these Oxygen cell readings are shown in real time, the ability to see all three sensors simultaneously is a great diagnostic aid. If one is failing to react as quickly as the others, there may be water on the cell's sensor face. The modifications made to the sensors prevent large quantities of moisture reaching the face and affecting the internal circuitry.

General Pre-Dive Checklist

(for permanent record use *Juergensen Marine* detailed Checklist)

- ☐ Verify sufficient adsorbent time remaining, and pack new Scrubber if necessary.
- ☐ Analyze diluent and O_2 cylinder and record.
- ☐ Check the DSV for proper operation and verify the direction of the gas flow.
- ☐ Mount Diluent and Oxygen Cylinders onto unit .
- ☐ Switch on Primary and Secondary Handsets.
- ☐ Record cell *mV* readings on both handsets in Air.
- ☐ Install and Secure Lid
- ☐ If calibration was not completed, perform Oxygen calibration and record cell mV readings.
- ☐ Check over-pressure relief valve. Carry out positive and negative pressure tests.
- ☐ Check battery health by battery voltage display on each handset.
- ☐ Turn on gas supplies and check function of valves, bailout regulator systems and ADV.
- ☐ Check LP inflators for buoyancy system and dry-suit (if in use) are properly attached.
- ☐ Record diluent and Oxygen cylinder pressures, shut off valves. Verify that there is no pressure drop in either cylinder after TWO minutes.
- ☐ Verify proper computer function
- ☐ Turn on Oxygen supply and Diluent supply.
- ☐ Verify correct calibration of O_2 sensors
- ☐ Pre-breathe for 2 minutes to check proper scrubber function.
- ☐ Verify operation of ADV by dumping gas from the loop and taking a breathe deep enough to trigger gas addition, and observing a PO_2 reading decrease
- ☐ Verify operation of Manual Oxygen Addition valve by depressing the button and observing a PO_2 reading increase.


HAMMERHEAD
HAMMERHEAD
GOLEM GEAR
LOW PRESSURE TESTED

Chapter 3
HammerHead Electronics

Introduction

This chapter is a basic overview of the electronics used on the HammerHead CCR. This chapter is meant as a quick introduction rather than a detailed manual documenting all the features and their uses. A separate document "HammerHead Electronics User Manual" that is meant as a complete documention is available from Juergensen Marine and several sources on the internet. The electronics user manual is continually updated as features are added and improved.

The HammerHead electronic package consists of two handsets called the primary and secondary, and the DIVA Heads-Up display. The primary is responsible for maintaining the selected set-point, displaying the measured PO2 for the three main oxygen sensors, time, depth and decompression information. The secondary is a backup display for the main Oxygen sensors, secondary depth gauge, timer, DIVA Heads-Up display controller and OPTIONAL decompression information. The secondary DOES NOT CONTROL the solenoid, it is meant to allow the diver to manually maintain the breathing loop in the event of a primary failure. The only common point between the primary and secondary is the oxygen sensors. Each handset is fully independent and does not communicate with the other in any way. All set-point changes and calibration must be independently performed.

System Overview

Before being able to dive the unit, it is necessary to understand the conventions used by the handsets, calibrate the oxygen sensors and set diver preferences. Initially out of the factory, some common set-points are defined, all gas mixes are programmed to AIR, and the units are set to imperial. The handsets need activation before they will operate. This is done by the entry of a PIN which can only be obtained for a specific unit from the manufacturer through a certified instructor. The primary handset requires one PIN to enable the handset and another to enable helium based decompression. The secondary requires one PIN to activate the handset and has an optional PIN to enable deco functionality.

Activation PINS:

Primary: Serial Number: __________ User: _________ Helium: _________

Secondary: Serial Number: __________ User: _________ Deco: _________

The primary handset can operate using Imperial or Metric units of depth and temperature but the PO2 on both handsets is ALWAYS displayed in units of ATA not Bar. This should be of particular interest because several other CCRs and dive computers use Bar as base unit. The use ATA as the base unit conforms to NOAA exposure definitions. The European tradition of using NOAA exposure tables but treating the values, in units of Bar is slightly more conservative for oxygen exposures. Planning the dive with the set-point in Bar while set-point is actually in ATA will result in a slightly more conservative profile.

The HammerHead features automatic set-point switching and set-point maintenance, manual set-point switching with automatic set-point maintenance, and fully manual PO_2 control. The control mode is chosen by the diver and can be changed at anytime. Closed circuit rebreather divers typically use more than a one set-point during a dive, the Hammehead allows for 5 preprogrammed (and editable) set-points.

Set-Point Switching

The HammerHead determines manual or automatic set-point switching based on the selected Set-point. Manual mode is selected on the surface by choosing any set-point 1.0 ATA or less. If the diver chooses a set-point greater than 1.0 ATA, the electronics will start the dive with a set-point of 0.4 ATA, transition to 1.0 ATA at 1m (~3fsw), and finally the chosen set-point at 3m (10fsw). Automatic set-point switching is performed (in reverse) on ascent if the selected set-point is greater than 1.0 ATA and the depth is less than 3m (10fsw).

Each handset has two buttons, which are used for programming and control. Pressing either button will activate the backlight for the user chosen time, and will wake up a handset that is in sleep mode. The left button scrolls through menu selections and values while the right button selects the current value. The handsets will timeout after a 10 second period of inactivity, and return to the normal operation mode. Several options will require confirmation. Failure to confirm action cancels any changes. The handset Backlight and LEDs also serve as a CRITICAL ALARM. This alarm is disabled on the primary while operating in open circuit mode

HANDSET DISPLAY DETAILS

PRIMARY:

The Primary handset has several informational screens that vary depending on whether the unit is in surface or dive mode, and if decompression stops are required.

```
1:38 OC   008 000
0.73  0.73  0.71
```

This is the surface mode screen; the top line consists of the surface interval, selected set-point or open circuit indicator, maximum depth of previous dive, and finally dive time. The second line is the current PO_2 reading for each of the three oxygen sensors. The display is updated approximately every two seconds.

```
031 1.0 0:00 031
1.11  1.11  1.10
```

```
031 1.0 0:00 3.2
1.11  1.11  1.10
```

The next display is the first of three screens presented while in dive mode. The first line displays current depth, selected set-point, dive time and alternates between maximum depth and measured battery voltage or battery alarm. The second line displays the PO_2 readings of the three sensors. If any sensor reading is followed by a "*" that sensor has been voted out and is not used in the average PO2 calculation. This screen is displayed for approximately 2 seconds.

```
033 0.7 0:00 034
21%  NO STOP
```

The second screen depends on the status of the diver's decompression obligation. The top line is the same as on the previous screen with the change being on the second line. Instead of the PO_2 being displayed, the oxygen percentage of the selected diluent and "No Stop" is displayed until the diver enters a required decompression stop. This screen is displayed for approximately 2 seconds.

```
170 1.0 0:12 172
21%  2@ 20   12
```

If there are any required decompression stops, the second screen have the same first line as the previous two screens, but the second line now displays the oxygen percentage of the diluent, deepest stop depth and stop time followed by the total ascent time. The sample screen shows the deepest stop at 20fsw for two minutes and a TTS of 12 minutes. This screen is displayed for approximately 2 seconds.

```
032 0.7 0:00 034
Air     21%
```

The third screen may seem like an annoyance, but it serves as a reminder to the diver. The name of the diluent the diver has selected and the programmed oxygen percentage of the diluent are displayed on the second line. This should help insure that the diver doesn't accidentally use a nitrogen only mix with same oxygen percentage as a mix containing helium. This screen is displayed for approximately 2 seconds.

HANDSET DISPLAY DETAILS

SECONDARY:

The Secondary handset has three possible display options (“Classic” - Classic, “D/Timer” - Depth/Timer, and “D/TandS” - Depth/Timer/Stack Timer).

Classic Mode

This mode displays system status, warnings and PO_2 on a single screen. All warnings and alarms are based on the deviation from the target set-point. The secondary must be set to the desired set-point in the same manner as the primary.

```
<OK>  1.0   1.0
1.00  1.00  1.00
```

The top line of the display shows the system status or the battery status / voltage (<OK>, <WARN>, ALERT, PO2! ERROR!, or <BAT>). This is followed by the calculated average PO2, and the selected set-point. The second line displays the PO2 measurements for each sensor. If any sensor reading is followed by a “*” that sensor has been voted out and is not used in the average PO_2 calculation. All sensors that fail calibration (less than 40mV in 100% oxygen) will be disabled until successfully calibrating; the disabled cells will show FAIL and not be used in any calculation.

```
<WARN> 0.8   0.7
1.1*  0.86  0.81
```

```
ALERT 1.0    0.7
1.2*  0.96  0.99
```

```
PO2!  ERROR   0.0
0.1*  0.0*  FAIL
```

The voting logic used in both the primary and secondary handsets is identical. Any sensor that is 15% out of range from the average of the remaining two sensors will be voted out. The three screenshots above show sensor one voted out. The second screenshot shows system status of <WARN>, this is indicated if any sensor is voted out or the average PO_2 is at least 15% from selected set-point. The next screen shot shows an error of at least 25%, so ALERT is indicated. The last screen shows a status that no diver wishes to see, PO2 ERROR, this will be indicated if the average PO_2 reaches 1.8 or is 0.19 and below, the RED LED and the backlight are illuminated.

```
<BAT> 1.0   1.0
1.00  1.00  1.00
```

```
<3.0> 1.0   1.0
1.00  1.00  1.00
```

Depth/Timer Mode

This mode cycles between THREE different screens. The PO_2 for all cells is displayed on the second line of all screens. The first screen is identical to classic mode and is the main status screen. The second screen displays current depth, Temperature and maximum depth. The third screen displays the current depth and the total dive time in the format hours:minutes:seconds.

```
<WARN>0.8     0.7
1.1*  0.86  0.81
```

```
 25.6 68F > 28.6
1.00  1.00  1.00
```

```
 24.0 T    :22:40
1.00  1.00  1.00
```

Depth/Timer/Stack Mode

This mode cycles between FOUR different screens. The PO_2 for all cells is displayed on the second line of all screens. The first three screens are the same as in Depth/Timer mode. The fourth and final screen displays the remaining stack time. The stack time display is simply a countdown timer based on a user programmed limit. This timer counts once the diver submerges. An alarm will be generated once this time is exceeded and the remaining stack time will now show a negative time.

```
Stk Left  129 Min
1.00  1.00   1.00
```

```
Stk Left  -13 Min
1.00  1.00   1.00
```

Display of Deco Information

```
<OK>  1.0   1.0
21%  NO STOP
```

When the secondary deco is enabled and the deco display is enabled, the PO_2 information on the second line on the display will replaced with decompression information. Depth/Timer mode displays the deco information after the depth and time screens and in Depth/Timer/Stack mode; the information is displayed after the depth and time but before the stack time data.

The first "deco" screen depends on the status of the diver's decompression obligation. The top line is the standard status screen with the change being on the second line. Instead of the PO_2 being displayed, the oxygen percentage of the selected diluent and "No Stop" is displayed until the diver enters a required decompression stop. This screen is displayed for approximately 2 seconds.

```
<OK>  1.0   1.0
21%  2@ 20   12
```

If there are any required decompression stops, the next screen will have the standard status line, but the second line now displays the oxygen percentage of the diluent, deepest stop depth and stop time followed by the total ascent time. The sample screen shows the deepest stop at 20fsw for two minutes and a TTS of 12 minutes. This screen is displayed for approximately 2 seconds.

```
<OK>  1.0   1.0
Air     21%
```

The final screen may seem like an annoyance, but it serves as a reminder to the diver. The name of the diluent the diver has selected and the programmed oxygen percentage of the diluent are displayed on the second line. This should help insure that the diver doesn't accidentally use a nitrogen only mix with same oxygen percentage as a mix containing helium. This screen is displayed for approximately 2 seconds.

STACK OVERRUN ALARM – ALL MODES

Once the programmed max stack time is exceeded, the secondary will turn on the backlight for 5 seconds, indicate STACK OVERRUN on the display, flash the DIVA Red/Green, Red/Green, and operate the buzzer in the DIVA twice. This alarm will recycle every TWO MINUTES until it is cleared by reprogramming the max stack time to a greater value.

```
STACK    OVERRUN
1.02  1.00  1.01
```

Handset Operational Overview

The options available in the primary handset are grouped into two main "menus". The first grouping contains the functions most likely to be used during a dive, while the second grouping under the options menu "OPT" is used to gain access to additional functions including handset configuration. For safety reasons several functions in the second grouping are unavailable while in dive mode.

The secondary handset has a similar arrangement, where the first grouping scrolls through the user set-points, and the second grouping under the options menu "OPT" is the configuration functions. For safety reasons several functions in the second grouping are unavailable while in dive mode.

Common Functions:

Set-Point Operation

One of the main features of the HammerHead is the ability for the diver to select a new set-point based on a user programmed set of five choices. The HammerHead comes pre-programmed with set-points of 0.4, 0.7, 1.0, 1.2, and 1.4. Regardless of the current operating set-point pressing the left button will cycle through the set-point choices in sequence. Once the desired set-point is displayed it is selected by pressing the right button and confirming once prompted with the left button.

```
1:38 0.4 008 000
0.73  0.73  0.73
```

```
1:38 0.7 008 000
0.73  0.73  0.73
```

```
1:39 1.0 008 000
0.73  0.73  0.73
```

```
1:39 1.2 008 000
0.73  0.73  0.73
```

```
1:39 1.4 008 000
0.73  0.73  0.73
```

SELECTING DILUENT/ OC GAS

```
GAS
NEXT      SELECT
```

```
Air       21/ 0
NEXT      SELECT
```

On the primary, the first option available is the gas selection prompt. Pressing the right button will select this function. Each press of the left button scrolls to the next programmed gas mix until all 10 are displayed, eventually returning to first mix. Once the desired mix is displayed, pressing the right button will select it. The diver will then be prompted to confirm or cancel the mix change. Pressing the left button confirms the selection, while the right button or no action for 10 seconds cancels the switch.

SELECTING CC / OC

```
OC
NEXT      SELECT
```

```
OC
Open Circuit
```

```
OC
Closed Circuit
```

The next option allows the diver to put the handset in either open circuit or close circuit mode. In open circuit mode, solenoid control is disabled, unless the PO2 falls to 0.19Ata. This function allows the diver to bail onto open circuit and still have decompression obligations calculated. Switching to open circuit mode also prevents the display from flashing while the system is being worked on, or disconnected from the rest of the rebreather. The left button toggles between modes while the right button selects the displayed mode. The system has a short cut out of open circuit and into closed circuit. If the diver chooses a set-point while the handset is operating in open circuit, the handset immediately switches to closed circuit mode with the selected set-point.

CONSERVATISM

The next option is setting the level of conservatism for the decompression model. Upon selecting the Conservatism function the current Gradient Factors are displayed. The HammerHead is a true gradient factors implementation with separate limits determining where the stops begin and when to proceed to the next level. There are five preprogrammed gradient factor sets and one user programmable setting. The selected gradient factor can be changed during the dive allowing full control over the dive profile. The user programmable selection can even be reprogrammed while in dive mode.

Changing the conservatism requires entering the “OPT” menu by scrolling past the set-point changes and other miscellaneous functions until “OPT” is displayed. Enter this menu by pressing the RIGHT button. Press the left button until “Conservatism” is displayed, press the RIGHT button to select. The current conservatism will be displayed.

```
GF Now   [10/100]
NEXT      SELECT
```

The user can now scroll through the 6 programmed settings with the LEFT button. Each choice will display the associated GF-Low and GF-High settings.

```
GF [1]   [10/100]
NEXT      SELECT
```

```
GF [2]   [20/95 ]
NEXT      SELECT
```

```
GF [3]   [25/85 ]
NEXT      SELECT
```

```
GF [4]   [30/75 ]
NEXT      SELECT
```

```
GF [5]   [35/70 ]
NEXT      SELECT
```

```
GF User [95/100]
NEXT      SELECT
```

Once the desired setting is displayed, select it with the RIGHT button then confirm the choice when prompted with the LEFT button. All confirmations on the HammerHead are done using the LEFT button. This prevents accidental confirmations due to double button presses.

MILLIVOLT DISPLAY

```
MV Display
```

```
Sen1  Sen2  Sen3
```

This option displays the millivolt output for each of the three sensors. While in this mode the backlight remains illuminated and does not timeout. Pressing either button exits the test. This option should be used to record the output of each sensor while in AIR and 100% Oxygen. A log with this information can aid in tracking the cells decay over time. The mV display is also used to diagnose cell problems. Unlike the PO2 display which disables cells that fail calibration, the cells can always be measured.

CALIBRATION

```
Calibrate O2
NEXT     SELECT
```

```
Standard Cal
NEXT     SELECT
```

```
Altitude Cal
NEXT     SELECT
```

```
Calibrating at
  1019 mBar
```

```
Fill  loop  w/O2
Cancel    Ready
```

Once the calibrate option is selected the next menu is presented that allows the selection of standard calibration (P02 set to 1.00 regardless of ambient pressure), or calibration for altitude which is based on measured ambient pressure. If altitude calibration is selected the measured pressure will be displayed and the PO2 will be set to this value (converted to ATA). The next screen for both modes will show "Fill Loop w/o2", with prompts for "Cancel" and "Ready". The calibration techniques used with the HammerHead electronics are the same as many other CCRs.

Recommended Calibration Sequence:

(1) Connect ALL regulators, leave DILUENT Valve off. On systems equipped with an ADV and cut-off valve, make sure the valve is in the off position.

(2) Turn on Oxygen and Activate handsets. Make sure that the solenoid fires for several seconds to flush Oxygen through the solenoid. This is easily accomplished by setting the set-point to 1.0 then setting it to a 0.4 once the purge is completed.

(3) Evacuate all the gas from the loop, flush with oxygen and repeat at least FOUR times. This is accomplished by inhaling off the loop and exhaling through the nose. The counter-lungs should be bottomed out before adding Oxygen. The hose on the exhale side of the DSV will not be flushed by inhaling only, make sure that you blow Oxygen rich gas around the loop, once or twice (best performed during the second and third flushes) before exhaling out the nose. On final flush add Oxygen until OPV vents gas.

(4) Go to the “MV display” screen and take note of the values, exit this screen to prevent the unit from remaining on.

(5) Let the unit sit for at least FIVE minutes. Top with oxygen if there is any loss of volume and go to the “MV display” screen again. If the sensor values have decreased, the flush was incomplete so flush again and repeat until readings are stable.

(6) Once mV readings are stable, vent excess gas until the loop is at ambient pressure (the BEST way is to force excess gas through the OPV, opening the DSV/BOV risks contamination).

(7) Record mV readings (any cell under 40mV will be rejected, the minimum mV will be adjusted for altitude when in altitude calibrate mode)), enter the “Calibrate O2” screen, select the calibration method and select ready. Any sensor that fails to meet minimum mV values will be rejected and the user alerted to the specific cell number.

(8) Immediately go to the “Calibrate O2” screen on the secondary, select the calibration method (Altitude or Standard) and select ready.

The typical mV reading for good sensor is between 8.4mV and 13mV in AIR at sea-level and between 40mV and 62mV in 100% Oxygen at sea-level.

The HammerHead was designed to be used with 100% oxygen for calibration, using oxygen percentages less than this will cause errors in calibration and depending on how long the loop is left to sit, the measured PO2 and mV readings will drop since Oxygen is being consumed and there is another gas present. The primary and secondary each require calibration. The two handsets are independent! The calibrate option is disabled while in dive mode to prevent a possible accident by the wet switches sensing water or depth sensor detecting a depth.

The HammerHead holds a very stable calibration; it is not necessary to constantly recalibrate the handsets. The sensors should be verified to be within a few percent of expected values by performing a quick loop flush with oxygen and/or exposing the sensors to AIR prior to each dive.

Although not endorsed by the manufacturer, alternate procedures for calibration can be found in an article published on WWW.REBREATHERWORLD.COM entitled "Accurate PO2 Calibration". This article discusses hardware, procedures and warnings necessary to calibrate various types of RB electronics using alternate oxygen concentrations and at altitude when not specifically supported by the electronics.

PASSWORD MANAGER

```
Passwrd Manager
NEXT      SELECT
```

```
Enter UsrEN PW
NEXT      SELECT
```

```
[1234]
NEXT      SELECT
```

```
Enter HeEN PW
NEXT      SELECT
```

```
[1234]
NEXT      SELECT
```

This option allows the user to enable/disable Helium gas usage and to erase all PINs to disable the unit entirely. PINs are supplied to certified users through a student's instructor.

```
Erase ALL Passwd
NEXT      SELECT
```

Upon the sale of the rebreather/electronics to another party, the handsets should be disabled by clearing all the PINs. The PINs can be reissued through the proper channels once the liability waivers / releases and training has been completed.

PRIMARY Handset Options and Programming

SOLENOID FIRING

```
Solenoid Firing
NEXT      SELECT
```

```
Solenoid Firing
Juergensen
```

```
Solenoid Firing
Standard
```

```
Solenoid Firing
Manual(OFF!)
```

The solenoid firing function chooses the set-point control algorithm. The modes are scrolled through by use of the LEFT button and selected by the RIGHT button. The HammerHead supports two automatic control methods: "Standard Mode" and "Juergensen Mode", plus the non-automatic "Manual Mode". Standard mode uses the error setting from "Standard Error", while "Juergensen Mode" is an adaptive algorithm that changes firing duration and rate based on error from selected set-point. "Manual Mode" requires the diver to maintain the loop PO2, automatic PO2 control is disabled. This function would be used to override the master when it is suspected that the controller is basing the PO2 control on bad data. An example of this would be two cells agreeing, while a third cell does not agree and the diver determined that the third cell is the correct one. The handset will override the manual setting and fire the solenoid if the loop PO2 drops to a 0.19.

SECONDARY Handset Options and Programming

The secondary handset has many of the same options as the primary handset. The notable differences are the lack of functions supporting the deco computer and set-point control options. The secondary has FOUR additional options, "Stack Time Opt" , "Decompress Mode", "Display Options" and "Set DIVA Mode".

STACK TIME OPT

```
Stack Time Opt
NEXT      SELECT
```

The stack timer is convenience reminder, and should not be counted on as a life support feature. How useful this option is to the diver is dependent on how faithfully the diver remembers to reset the counter after each scrubber change. The stack timer cannot be disabled, but the user has the freedom to set their own limits and can reset the timer at any time. Selecting "Stack Time Opt" under the "OPT" menu allows the user to scroll through several options relating to the stack timer function.

VIEW STACK TIME

```
View Stack Time
NEXT      SELECT
```

```
Max Stk Time 180
Used 53 Left 127
```

The "View Stack Time" option can be used at any time to view the timer limits and how much UNDERWATER time has been put on the scrubber. This is a VERY important concept to remember, time spent on the loop but not at depth is NOT counted towards stack time. Scrubber durations in excess of the limits (stack overrun) will be displayed as a negative time remaining.

SET STACK TIME

```
Set  Stack  Time
NEXT      SELECT
```

```
Set  Stack  Time
[_60]  Minutes
```

The "Set Stack Time" option allows the user to set the scrubber duration timer in 60 minute intervals ranging from 60 to 600 minutes. Upon entering this function the stack time is set to 60 minutes, the diver now must set the timer limit by using the left button to increment by 60 minutes at a time, with the right button programming the displayed time. WARNING Even if the right button is not pressed, once the programming screen times out, the scrubber limit will be set to whatever is currently displayed as the new limit. Time previously counted as "on the stack" is also reset. This function can be seen as setting the scrubber stack time limit and resetting the counter to the new limit.

RESET STACK TIME

```
Reset Stack Time
NEXT      SELECT
```

The “Reset Stack Time” option resets the current stack time to the limit as set in the “Set Stack Time” option. Choosing this option (with the RIGHT button) will prompt the diver to confirm with a LEFT button press.

TEST STACK TIME

```
Test  Stack  Time
NEXT      SELECT
```

The purpose of the “Test Stack Time” option is to allow the diver to become familiar with the alarms generated on the secondary display, the flash protocol on the DIVA coupled with the vibrating of the DIVA. This option sets the stack time to one minute, with one minute remaining. This allows the diver to periodically familiarize him/herself with the alarms without having to play with programming the stack time. Once the alarms are confirmed the diver just has to select “Reset Stack Time” and all the previous limits are restored. This option uses the actual stack timer, so this alarm can only be generated while in dive mode.

DECOMPRESS MODE

```
Decompress  Mode
NEXT      SELECT
```

The “Decompress mode” function turns the secondary dive computer options on or off. This option is only available when the proper secondary Deco PIN has been entered.

```
Decompress  Mode
OFF       SELECT
```

```
Decompress  Mode
ON        SELECT
```

DISPLAY OPTIONS

```
Display   Options
NEXT       SELECT
```

The "Display Options" explanation is detailed in the section on display details earlier in the manual. The Three supported display modes are "Classic" (Classic), "D/Timer" (Depth plus Bottom Timer), "D/TandS" (Depth, Bottom Timer plus Stack Timer).

```
Display   Options
Classic    SELECT
```

```
Display   Options
D/Timer    SELECT
```

```
Display   Options
D/TandS    SELECT
```

After selecting a display mode and if the "Decompress mode" is enabled, the handset will prompt whether or not the deco information should be displayed. The Left button toggles On/OFF and the right button selects the displayed mode.

```
Display   Deco
OFF        SELECT
```

```
Display   Deco
ON         SELECT
```

SET DIVA MODE

```
Set   DIVA   Mode
NEXT       SELECT
```

This option controls the function of the DIVA/HUD. The two selections are "User Set Point" and "PPO2 Mode". Once the function is selected the current mode is displayed, the LEFT button toggles the function while the RIGHT button selects the desired mode.

```
Set   DIVA   Mode
PPO2 Mode
```

```
Set   DIVA   Mode
User Setpoint
```

DIVA DISPLAY MODES

User Set Point:

The secondary uses the 3 available colors within the DIVA to signal alarm conditions. The flash rate and color is dependent on the error percentage from the user selected set-point.

(1) Set-point error is less than 15%; the secondary blinks the DIVA GREEN LED every 8 seconds.

(2) Set-point error is 15% to 24% or a sensor voted out; the secondary blinks the DIVA ORANGE LED every 5 seconds.

(3) Set-point error is 25% or more; the secondary blinks the DIVA RED LED every 2 seconds.

PPO2 mode Flash Protocol:

The DIVA uses the 3 available colors **RED**, **ORANGE**, and **GREEN**. The sensor values are rounded to the nearest integer for example 0.75 becomes 0.80, while a 0.74 is rounded to a 0.70. The values for all three sensors are presented in succession with a short pause between sensors. There is an extended Pause (about 3 flash periods) between displaying the sensor #3 and starting again with sensor #1. The duration of the **RED** and **GREEN** blinks are the same duration, while the duration of the blink for **ORANGE** is about 50% longer.

The PO_2 benchmark value is 1.0 and is indicated by a short in **ORANGE**. Each cell is displayed by one blink. Three blinks in **ORANGE** will indicate that each cell is reading 1.0 PO_2.

Each individual cell reading will be indicated by blinking once in **GREEN** for every 0.1 above the benchmark or by blinking **RED** for each 0.1 below the benchmark. There will be a short pause between each cell announcement and a long pause after the last cell.

When the PO_2 for a cell is <=0.25 or >=1.75, the DIVA will display several rapid flashes consisting of **GREEN** followed by a **RED** with a pause between the current sensor and the next.

Chapter 4
Dive Planning and Procedures

Oxygen

Oxygen is the gas that sustains life, but the oxygen *dosage* ***must*** fall within a *specific range* in order to sustain life. Too little leads to unconsciousness and eventually death, and too much causes respiratory and central nervous system issues. The term used to describe the amount of Oxygen present in the breathing mixture is "*partial pressure dosage*" or PO_2. **The PO_2 value is obtained by multiplying the O_2 % in the mixture by the total pressure.** The units of pressure quantifying the dosage are *ata* or *bar*. The percentage of oxygen in a breathing mix is not the critical factor, the critical factor is the *partial pressure* of oxygen that is being inspired.

It is imperative that the concept of *partial pressure* be well understood in order to safely use rebreathers. If you are unsure about any aspects of this concept please review with your instructor before continuing.

At standard atmospheric pressure, it is possible to have partial pressures of Oxygen range between 0 and 1.0 ata because we could vary the % of O_2 between 0% and 100%. The percentage of oxygen in the atmosphere is approximately 21% and does not vary with altitude, but the PO_2 does change with altitude. At sea-level that means the normal exposure is 0.21ata, this is called *normoxic exposure*. Our bodies can still perform work with a PO_2 down to about 0 .16ata (this occurs at approximately 7500 feet/ 2300m above sea level), below this our bodies enter a hypoxic state.

Hypoxia is the condition where there is insufficient Oxygen to sustain normal activity. If asleep or at rest, life could continue. Around 0.1 ata, there is not enough Oxygen to sustain life - death is the eventual result from *anoxia*. **Anoxia is the condition where there is insufficient Oxygen at the cellular level to sustain life.**

The opposite of *hypoxia* is *hyperoxia* where there is a greater oxygen exposure than normal. Hyperoxia can result in a condition called Oxygen toxicity which results from breathing a hyperoxic gas for an excessive period of time. By exceeding the limits of Oxygen, the bodies compensating mechanisms have been exhausted. This results in several symptoms that may occur in any order and without progressively increasing severity.

These exposure limits have been determined over time. The greater the dosage the lower the allowable duration. Due to the length of the dives typically performed on rebreathers and the typical scrubber duration, most rebreather divers limit the working exposure to a max 1.3ata. The following chart lists the limits as established by NOAA.

NOAA O_2 EXPOSURE LIMITS				
Oxygen Partial Pressure (PO_2)	**Maximum Single Exposure**		**Maximum Daily Exposure**	
(ata)	**(min)**	**(hrs)**	**(min)**	**(hrs)**
1.6	**45**	**0.75**	**150**	**2.5**
1.5	**120**	**2.0**	**180**	**3.0**
1.4	**150**	**2.5**	**180**	**3.0**
1.3	**180**	**3.0**	**210**	**3.5**
1.2	**210**	**3.5**	**240**	**4.0**
1.1	**240**	**4.0**	**270**	**4.5**
1.0	**300**	**5.0**	**300**	**5.0**
0.9	**360**	**6.0**	**360**	**6.0**
0.8	**450**	**7.5**	**450**	**7.5**
0.7	**570**	**9.5**	**570**	**9.5**
0.6	**720**	**12.0**	**720**	**12.0**

Percentage of Oxygen Toxicity

The *Percentage of Oxygen Toxicity* concept was developed to permit a simple application of the Oxygen partial pressure limits chart. To calculate the percentage of Oxygen toxicity, look up the partial pressure of Oxygen on the Oxygen Partial Pressure Limits chart and divide 100 by the maximum number of minutes allowable at that dosage. This will give the percentage of the total limit each minute is worth. This procedure can be performed for either a fixed fO_2 or a fixed PO_2.

Open Circuit divers need to calculate their exposure at multiple depths and add up the individual exposures because the PO_2 varies with depth, but CCR divers generally use a single set-point for "bottom" portion of a dive so only total time needs to be considered.

Lets examine a dive for 20 minutes at 100fsw and 30 minutes at 60fsw using a setpoint of 1.3ata.

(20 minutes + 30 minutes) X 100 / 180 minutes = % CNS

50 minutes X 0.56 % / minute = 28% CNS

Residual Oxygen Toxicity **(CNS%)**

While on the surface, your *Percentage of Oxygen Toxicity* is reduced in a similar fashion to the way Nitrogen out-gases from the body. Essentially after 90 minutes the Oxygen loading is reduced by half and again by another half after the next 90 minutes. This is the definition of a half-time.

$$\text{Residual \% Toxicity} = \text{Starting \% Toxicity} \times (.5)^{\text{surface interval} / 90}$$

The above formula is implemented in the chart below, simple look up the starting %CNS and find the appropriate surface interval (for added conservatism use the closest **SHORTER** interval if exact interval is not on the chart) to determine the divers residual %CNS.

	Residual CNS%										
%CNS / SI	60 min	90 min	120 min	150 min	180 min	210 min	240 min	270 min	300 min	330 min	360 min
100	63.0	50.0	39.7	31.5	25.0	19.8	15.7	12.5	9.9	7.9	6.3
95	59.8	47.5	37.7	29.9	23.8	18.9	15.0	11.9	9.4	7.5	5.9
90	56.7	45.0	35.7	28.3	22.5	17.9	14.2	11.3	8.9	7.1	5.6
85	53.5	42.5	33.7	26.8	21.3	16.9	13.4	10.6	8.4	6.7	5.3
80	50.4	40.0	31.7	25.2	20.0	15.9	12.6	10.0	7.9	6.3	5.0
75	47.2	37.5	29.8	23.6	18.8	14.9	11.8	9.4	7.4	5.9	4.7
70	44.1	35.0	27.8	22.0	17.5	13.9	11.0	8.8	6.9	5.5	4.4
65	40.9	32.5	25.8	20.5	16.3	12.9	10.2	8.1	6.4	5.1	4.1
60	37.8	30.0	23.8	18.9	15.0	11.9	9.4	7.5	6.0	4.7	3.8
55	34.6	27.5	21.8	17.3	13.8	10.9	8.7	6.9	5.5	4.3	3.4
50	31.5	25.0	19.8	15.7	12.5	9.9	7.9	6.3	5.0	3.9	3.1
45	28.3	22.5	17.9	14.2	11.3	8.9	7.1	5.6	4.5	3.5	2.8
40	25.2	20.0	15.9	12.6	10.0	7.9	6.3	5.0	4.0	3.1	2.5
35	22.0	17.5	13.9	11.0	8.8	6.9	5.5	4.4	3.5	2.8	2.2
30	18.9	15.0	11.9	9.4	7.5	6.0	4.7	3.8	3.0	2.4	1.9
25	15.7	12.5	9.9	7.9	6.3	5.0	3.9	3.1	2.5	2.0	1.6
20	12.6	10.0	7.9	6.3	5.0	4.0	3.1	2.5	2.0	1.6	1.3
15	9.4	7.5	6.0	4.7	3.8	3.0	2.4	1.9	1.5	1.2	0.9
10	6.3	5.0	4.0	3.1	2.5	2.0	1.6	1.3	1.0	0.8	0.6
5	3.1	2.5	2.0	1.6	1.3	1.0	0.8	0.6	0.5	0.4	0.3

CO_2 Scrubber Duration

At this time, scrubber duration testing has not been completed. The recommend duration for a diver lightly working is 6 hours.

CO_2 production can be approximated y tracking oxygen usage. Depending on the source of energy (proteins, carbohydrates, fats) the ratio of CO_2 to oxygen will be between .7 to 1.0. This is called he *respiratory quotient*.

Defined as :

RQ = $CO_{2\ \text{produced}} / O_{2\ \text{consumed}}$

	RQ
Carbohydrates	1.0
Fats	0.7
Proteins	0.8 - 0.9
Anaerobic respiration	>>1.0

A diver with a normal diet and proper caloric intake will average approximately .9l of CO_2 for every liter of oxygen consumed.

Juergensen Marine's recommendation is based on the same procedures as the U.S. Navy. At depths beyond recreational limits or near freezing temperatures, scrubber duration is significantly shorter.

The U.S. Navy testing protocol calls for a CO_2 production rate of 1.35 lpm at 40F at a series of test depths. The fittest divers could not maintain the required level of activity to match the test parameters for more than a few minutes.

Decompression / No Decompression Dive Planning

The *Hammerhead* features a built in dive computer capable of tracking gas loading on a constant PO_2 profile. This does not negate the need to pre-plan the dive nor does it negate the recommendation that some form of backup planning/tracking being employed. Alternate planning/tracking is essential should the tissue loading in the HammerHead become lost or corrupted.

Rebreather dive planning can be realized without any special tables or computers by determining the Oxygen percentage in the breathing loop. This allows an Equivalent Air Depth to be calculated and used in exactly the same manner as in Nitrox diving.

The fO_2 is calculated by dividing the set point's PO_2 at the maximum depth (total pressure in ata's or bars). This value can be used on your favorite tables or standard nitrox dive computer.

By using the lowest oxygen percentage (achieved at the deepest part of the dive), a good margin of safety can be realized as there is more Oxygen and less inert gas in the breathing mix at all other depths when diving a constant PO_2.

There are constant PO_2 tables, various dive planning software and dive computers that allow planning of constant PO_2 profiles.

Important Cautionary Notes

DO: **Know your PO_2 at all times!**
DO: **Always open Oxygen and Decompression gas valves very slowly as a prevention against Oxygen fires!**
DO: Understand all topics presented in this manual
DO: Always dive within manufacturer and certification limits.
DO: The pre-dive checks prior to each dive.
DO: Use diving quality gasses.
DO: Always use a fresh scrubber for deep dives.
DO: Always dive with an independent Bailout System.
DO: Follow Post Dive Checklist after every dive.
DO: Annual service should be performed by a Juergensen Marine approved service center.
DO: Maintain a record or the Pre and Post Dive Checklists
DO: Dispose used Sorb responsibly.
DO: Use the recommended batteries and dispose of them in responsible manner.
DO: Take a complete spares kit when traveling. Spare oxygen cells and batteries should always be carried.

DO NOT: Allow non certified ***HammerHead*** divers to dive the rig.
DO NOT: Attempt to dive without supervision until certified.
DO NOT: Ascend too rapidly.
DO NOT: Descend too rapidly. The PO_2 may increase to dangerous levels.
DO NOT: Mix up the diluent and oxygen fittings.
DO NOT: Use silicone grease or oil on the system. Use **only** oxygen compatible grease.
DO NOT: Do not use chemicals to clean the handset lenses especially those containing alcohol. Use only water.
DO NOT: Try to extend the life of the oxygen cells by storing in a sealed bag or inert gas.
DO NOT: Recharge the batteries.
DO NOT: Fill the oxygen cylinder with Nitrox
DO NOT: Fill the diluent cylinder with pure gasses such as Helium, Nitrogen

METRIC - IMPERIAL CONVERSIONS

PRESSURE

1 msw = 1/10 bar
1 msw = 3.2568 fsw
1 ata = 1.01325 bar
1 ata = 1013.25 millibars
1 ata = 760 mm Hg
1 ata = 14.6959 psi
1 ata = 33 fsw
33fsw = 10.1326 msw
1 bar = 14.5037 psi
1 bar = 0.98692 ata
1 bar = 10 msw
1 kg/cm^2 = 14.223 psi

DISTANCE

1 meter = 3.28 feet
1 foot = .3048 meter

VOLUME

1,000 liters = 1 cubic meter
1 cu. ft. = 28.3168 liters
1 cubic inch = 0.016387064 liter
1 cubic inch = 16.387064 cubic centimeter
1 gallon [US, liquid] = 3.7854118 liter

Example Conversions

fsw ÷ 3.2568 = msw
msw × 3.2568 = fsw

