operations manual

REBREATHER LAB

PELAGIAN DCCR

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Pelagian DCCCR – Operations Manual

www.rebreatherlab.com
info@rebreatherlab.com
53/10 Moo 3 Bophut Koh Samui • 84320 Surat Thani Thailand
Phone +66 1 9326149 • Fax +66 (0)77 231389

Using This Manual

The manual is written from a practical perspective and follows the intended chronological order of first receiving the Pelagian kit, assembling the Pelagian DCCCR for the first time, preparing for diving on the unit, skills and post dive maintenance.

▲WARNING! There are a number of critical safety warnings in the manual which appear in the same format as the text contained within this box. These instructions MUST be followed. FAILURE TO ADHERE TO THEM MAY CAUSE YOUR INJURY OR DEATH.

Guidance Notes: These notes will appear in italics and bold text.

Disclaimer

The Pelagian DCCCR has NOT been tested for CE approval and has NOT been evaluated by any other third party testing facility. The Pelagian DCCCR has been tested by Rebreather Lab during 18 months prior to its public release and found highly capable, but as any data presented herein is highly subjective, users should use caution and set their own personal limits for duration, depth and operation.

Using a rebreather is a potentially life threatening activity and a full understanding of its working principle and operation is absolutely necessary prior to use. Even with proper training there is no such thing as guaranteed safety. It must be understood that any mechanical or electronic device will fail at one point or another and typically when least desired or expected. A large part of your mandatory training course will be devoted to proper failure detection and appropriate response. In order to gain access to a Pelagian DCCCR you will be required to sign numerous documents containing a lot of legal print. The bottom line is that you are required to assume full responsibility of any outcome diving the Pelagian DCCCR.

The Pelagian DCCCR is sold as a kit of parts that can only function for life support after additional equipment has been added. Before each dive it will be assembled, tested and deemed functional, or not, by YOU, the diver. Out of the additional components not included with the kit the most crucial is your brain. Without your brain the Pelagian is simply a pile of parts that are guaranteed NOT to function at all. Using the Pelagian DCCCR kit can result in anything between a pleasant dive, all the way to YOUR injury or death, The only one responsible for the outcome is YOU, the diver. If you are not willing to accept these terms you should stop right now. Cancel your course and return the Pelagian DCCCR kit, regardless of financial consequence. This will come across very harsh and certainly not encouraging, but the fact is that rebreathers have claimed the lives of many divers regardless of experience level. Your life is worth a lot more than money. Your life is in your own hands. You have been warned!

Warnings

All diving is associated with the risk of injury or death.

Rebreather diving carries inherent risks which may result in a number of different physiological problems. These include but are not limited to, gaseous conditions which may not become obvious to the diver and can result in confusion, panic, loss of consciousness and death.

Rebreather specific physiological hazards include and are not limited to the following:

Hypoxia
Hyperoxia
Oxygen Toxicity
Hypercapnia
Respiratory (airway and lung) damage from inhalation of absorbent
Drowning

▲WARNING! It is imperative that all pre-dive checks are conducted before diving.

During normal diving operations, further checks and monitoring should be made on every dive, in addition to those made pre-dive. Displays should be monitored regularly and sensor integrity verified with instant cell validation.

▲WARNING! This manual is a work in progress and this version may contain information that has not yet been proof read for correctness or accuracy. Make sure to check crucial information with your instructor before any in-water activites!!!

PELAGIAN DIVER CONTROLLED CLOSED CIRCUIT REBREATHER SYSTEMS MANUAL

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Preface

Thanks for choosing the Pelagian DCCCR as your preferred vehicle for exploring the underwater world! The objective for writing this text is to provide a comprehensive user manual bundled with all unit specific information needed to compliment a generic CCR course manual provided by your instructor. As often as possible we have used practical examples to explain principles and functions. It is our hope that this will make concepts come to life and serve to shorten the learning curve so that you will perceive your training and introduction to rebreather diving as being as enjoyable as possible, and not solely as a necessary obstacle to pass before the fun begins.

No matter how comprehensive any manual may be, learning to dive happens in the water. Therefore you must use this manual in conjunction with a training course taught by a qualified instructor that leads to a certification by an authorized training agency.

As the basic principles of various Closed Circuit Rebreathers are similar the first section only addresses general rebreather concepts. If you have previous rebreather experience and qualification you may skip this section and proceed directly to the subsequent chapters. If you are unfamiliar with rebreathers and have not yet been given your course manual, reading it will provide a platform to better comprehend the rest of the text.

The material is presented in a chronological way starting with assembly and ending with dive skills. The appendix contains check lists, constant Po2 tables and other charts you might want to copy, laminate and bring on the boat.

Your Pelagian DCCCR kit is the result of years of development and hard work. The reason for bringing this rebreather to the market is our belief that a small and lightweight unit that still offers long duration, simple operation and easy field service is needed. Whether these goals have been achieved or not is open for individual perception. We are therefore grateful for your feedback and suggestions for improvements and will do our best to meet your expectations with future developments. Good luck with your training and future rebreather dives!

Andy Fritz
CEO
Rebreather Lab

Section 1 - A Primer on Rebreathers

Your body is only metabolizing a small part of the oxygen contained in the air you breathe. As you inhale the air contains around 21% oxygen and the exhaled breath typically contains 16 –17% oxygen. While scuba diving exhaling your breath into the water is rather wasteful and thus requires a relatively large cylinder of breathing gas if any dive duration beyond a few minutes is required. Long before the popular open circuit system emerged, the first underwater breathing systems looked more like a rebreather than the classic regulator and cylinder, popularized by Jacques Yves Cousteau.

Looking at a gas relief, several hundred years old, one can clearly see a diver breathing in and out of a bag, (a cow stomach?), thus recycling the breathing gas. If you were to breathe in and out of a plastic bag you would have a rebreather in its most simplified form. The problem would be that the exhaled breath would contain a proportion of Carbon dioxide, as this is our bodies “waste” product, produced through our bodies metabolic process. This CO2 would accumulate to dangerously high levels in the same time as the O2 content would gradually drop to the point where it would not be sufficient to keep you conscious.

These two problems have to be addressed in order to create a rebreather capable of keeping you alive for more than sixty seconds. By installing a cartridge containing an absorbent chemical, like calcium hydroxide, the CO2 can be trapped. By feeding fresh O2 into the bag it is possible to replace the consumed oxygen portion. With a few simple check valves it is possible to ensure that the exhaled breath has to pass through the CO2 cartridge before returning to your lungs. Hang on; is this what I just paid thousands of dollars for?!?

The above is essentially the core of any rebreather, but depending on exactly HOW the O2 is replenished takes us to some different designs:

Closed Circuit Oxygen Rebreather

The closed circuit O2 rebreather was already in use during WW1, primarily by Italian Navy divers, who managed to blow up several British ships anchored near Gibraltar by swimming right up to the ships hull and placing ordnance without being detected due to their absent telltale bubble trail. The Brit’s later copied this very simple and reliable design after capturing a few Italian frogmen. Providing the diver sufficiently purged his lungs from nitrogen before starting to breathe from a Closed Circuit Oxygen Rebreather, or CCORB, the system is very reliable as the gas content is known without the need for any electronic monitoring system. As the volume of oxygen is gradually depleted in the breathing bag, fresh gas from a cylinder is added, usually with a simple manual valve or an Automatic Demand Valve, which is essentially the same as a standard second stage scuba regulator but without the mouth piece. The main disadvantage with an O2 rebreather is its limited depth range of max 4-6 m as pure O2 gets toxic at greater depths.

Semi Closed Rebreather

In order to allow deeper dives the O2 has to be diluted with another gas, typically nitrogen. A mixture of O2 and N2, (Nitrox) is fed into the breathing loop at a continuous flow, but only the O2 is metabolized by the diver. This presents a problem as the fresh

N2 will gradually increase the volume of the breathing loop to the point the breathing bag bursts, or more likely the diver looses his mouth piece. To cater for this an over pressure relief valve is installed allowing a constant venting of the loop volume. If it would be possible to separate the N2 from the O2 and only dump the N2 overboard this would be a nice little system. As this is not possible, what gets dumped is a mixture of both O2 and N2. Is short: A semi closed rebreather let's you go deeper than an O2 rebreather, but it is not as effective as a fully closed rebreather.

Closed circuit mixed gas rebreathers

This type of rebreather carries minimum two separate cylinders; one filled with oxygen and the other filled with air, trimix, heliox or any other suitable gas mixture with lower oxygen content. This gas is usually referred to as the "diluent" gas as it is used to dilute the oxygen in order to allow deeper excursions. Again, determined by the way O2 is injected, closed circuit mixed gas rebreathers have two variants: the Electronically Controlled Closed Circuit Rebreather, (ECCR) or the Mechanically Controlled Closed Circuit Rebreather (MCCR):

Electronically Controlled Closed Circuit Rebreather

In an ECCR the oxygen level in the breathing mix is controlled by a computer and an electromagnetic solenoid valve, set up to maintain a constant partial pressure of oxygen in the breathing mixture, regardless of the diving depth. This makes it possible to always have the optimum breathing mix, similar to an open circuit diver carrying several cylinders with various gas mixtures. The desired partial pressure of O2, or "set point", is programmed by the diver before the dive and typically three oxygen sensors placed inside the breathing circuit inform the computer of what the current PO2 is. If the PO2 is less than the set point, the solenoid valve opens to let more O2 in to the breathing loop. The reason three oxygen sensors are used is to allow "voting logic" determine your fate.

For example if two sensors read 1.3 BAR PO2 and the third sensor reads 0.16 BAR PO2, there is a 2:1 chance the third sensor is wrong. Therefore you will not get any more oxygen. Of course, if the third sensor is in fact correct and the other cells are wrong you are in for a long sleep.

The main advantage is that the computer usually does maintain the PO2, leaving the diver to explore and have fun during the dive. The disadvantage is that the diver easily gets complacent, enjoying the ride while the computer "drives the car". Should a noticeable technical failure occur, there are usually manual over ride valves available, but the question is if the diver will respond fast enough. With sufficient training and experience proper failure response can be achieved but still it lies within human nature to trust what usually works. After 200 successful dives, would you detect an emerging problem fast enough on dive 201 or much like a lobster in a saucepan, think the warm water around you simply means its bath time!

Mechanically Controlled Closed Circuit Rebreather

An MCCR is the same as an ECCR with the difference of taking the computer out of the equation and instead leaving the diver to manually feed oxygen or diluent into the breathing loop. The only electronic device is the oxygen PO2 monitoring system informing the diver of the current pressure of O2 in the breathing loop. If the PO2 is lower than desired, the diver presses a button to feed O2 into the loop. Many systems also have an orifice allowing a slow continuous flow of oxygen trickle in to the loop, usually at a slightly lower rate than the metabolic need of the diver, thus maintaining a more even PO2 with fewer manual button feeds. This type of system requires a bit more attention from the diver, but this is also the inherent advantage. It drives the diver to monitor the PO2 and take action accordingly. His brain is essentially replacing the computer. An interesting comparison is crossing a busy street. If you cross at a zebra crossing with traffic lights every morning for several years you may eventually just wait for green light and go, only to get hit by a colour blind motorist! If you try to cross the same street without the reassuring traffic lights you would be more likely to check both left and right before attempting to cross, right? A disadvantage is that in a task loaded situation, manually controlling the PO2 can be tricky for the inexperienced rebreather diver.

The main components of a closed circuit rebreather

To give you a basic understanding on how a closed circuit rebreather works it is essential that you can identify the common components, get familiar with abbreviations and understand what their functions are.

- **Breathing Loop**
  The loop is referring to all components your re-circulated breath travels through, this meaning the DSV, breathing hose, counter lung(s) and absorbent canister.

- **Dive Surface Valve, (DSV)**
  The DSV is the mouthpiece and it also contains flow directional valves, (also called "flapper" or "mushroom" valves), to ensure that your inspired breath only comes from one side of the breathing hose and that your exhaled breath only goes out on the other side of the hose toward the absorbent cartridge, or "Scrubber". There is usually some kind of lever or quarter turn grip so that you can close the loop to prevent water intrusion while surface swimming. Some models are called Bail Out Valve, (BOV), or Open Circuit / Closed Circuit, (OC/CC) Valve, with the additional function to let you switch from the CCR loop to Open Circuit with out removing the mouth piece, thus bypassing the whole rebreather in the event of a problem.

- **Breathing Hose**
  The breathing hose connects the DSV to the breathing bag or counter lungs and the exhale side of the hose is also feeding to the absorbent canister.

- **Counter lung(s)**
  A rebreather usually has either back mounted or front mounted counter lungs. If a diver is in a horizontal swimming position, back mounted counter lungs tend to give an easy exhalation but a restricted inhalation due to the hydrostatic pressure difference in relation to the divers own lungs. Front mounted counter lungs give a slight resistance exhaling and low resistance inhaling as they are placed below the divers own lungs. The Pelagian DCCCR

is currently the only rebreather with side mounted counter lungs keeping the breathing bags at the same depth as the diver's lungs, thus giving equally low resistance on inhalation and exhalation.

- **Absorbent canister**
  Your exhaled breath travels from one side of the breathing hose, either via one of the counter lungs, or directly to the absorbent canister if the rebreather only has one counter lung. The absorbent canister is filled with absorbent media, or "Sorb" or "Lime" in CCR lingo. The exact chemical content of the Sorb varies slightly between manufacturers, but contains normally a good portion of calcium hydroxide and sometimes also alkali phosphate or sodium hydroxide. Shapes and design varies but are commonly classified after the way the gas flows through, i.e. radial or axial. Lithium hydroxide offers superior duration, but as it reacts violently with water it is rarely used in recreational diving. The Pelagian standard scrubber canister will hold approximately 3.4kgs of sofnolime 797 grade (2.5mm) material

- **Automatic Diluent Valve (ADV)**
  Essentially a second stage regulator or similar type of valve that automatically injects fresh gas once a set pressure difference is achieved. Just as your standard second stage regulator opens its valve when you start inhaling and stops when you start exhaling, the ADV will trigger once the rebreather loop volume gets lower than usual. Just as the volume of your BCD compresses when you dive deeper, the flexible part of your rebreather will do the same. Therefore you will need to ad gas to make up for the compressed volume. Some rebreathers don't have an ADV, but then they should have a manual ad valve. The ADV just means you don't have to press a button to add gas, which is very useful while descending.

- **Oxygen addition system**
  In its most basic form this is an oxygen cylinder with valve, a 1st stage regulator and a basic on / off valve similar to a dry suit inflator valve allowing the diver to add oxygen manually when needed. Some systems incorporate an orifice that slowly allows oxygen to trickle in to the loop thereby prolonging the intervals between manual injections. The Pelagian DCCCR uses a fine metering needle valve and a manual add valve. ECCR's use a set-point controller and a solenoid valve to automatically add oxygen.

- **Oxygen sensors**
  Disregarding if a CCR is manually or electronically controlled, the diver has to know his loop PO2. Oxygen sensors work like batteries in that they output a voltage that can be read by a display. Common models output between 7 – 13 mV when exposed to air at sea level, or 0.21 BAR PO2. A higher pressure of oxygen, generates a higher milli-volt reading. The life span of an O2 sensor is limited and should generally be changed every year despite the fact that they may be rated longer by the manufacturer.

- **PPO2 display**
  A PO2 display is usually an LCD screen that gives the diver his read out or PO2 for each individual O2 sensor. As it would take some mathematics to work out what mV means what PO2 this is done by the display. As the output

from the O2 sensor slowly decays over its life span the display has to be calibrated to ensure correct reading. You will learn more about this procedure in a later section.

- **Cylinders**

  All CCRs need compressed oxygen and diluent to be added to the loop in intervals. The typical configuration is a pair of 2 – 3L cylinders and appropriate first stage regulators carried either valves up, or down. At first you may think that this modest volume must be insufficient, but dependent on dive depth it typically represents 6 – 8 regular 11L cylinders worth of duration for an open circuit diver!

Two Pelagian divers ready to dive

Section 2 - CCR Physiology

Closed Circuit Divers have extra issues to consider with regard to their physical well-being while immersed in a hyperbaric environment compared to their open circuit ilk. Even pre and post dive (while swimming in the shallows or on the surface) can be a life threatening event. Hyperoxia or Oxygen Toxicity are major concerns for CCR users as the equipment provides the user with the ability to maintain a constant partial pressure of oxygen (Po2) throughout the dive.

Maintaining high Po2's for lengthy periods can lead to CNS toxicity (see table below) but also, if the unit suffers a mechanical or electronic failure the user may be supplied with devastatingly high or low po2 causing immediate unconsciousness either way usually going unnoticed until too late – constant vigilance and attention to the CCR units control systems is mandatory.

Failure to monitor Po2's may lead to Hyperoxia / Hypoxia very quickly – both potentially leading to unconsciousness and death.

P02	Single Exposure Limit		24 Hour Exposure limit	
ATA	Minutes	Hours	Minutes	Hours
0.6	720	12:00	720	12:00
0.7	570	9:30	570	9:30
0.8	450	7:30	450	7:30
0.9	360	6:00	360	6:00
1.0	300	5:00	300	5:00
1.1	240	4:00	270	4:30
1.2	210	3:30	240	4:00
1.3	180	3:00	210	3:30
1.4	150	2:30	180	3:00
1.5	120	2:00	180	3:00
1.6	45	0:45	150	2:30

Use the above chart to find dive time limits for each P02 used.
When a single exposure limit is reached you must extend you surface interval to 2 hours. If a daily exposure limit is reached a full 12 hours must elapse to allow sufficient time for your CNS levels to normalise.
CNS (Central Nervous System) toxicity can be approximately measured throughout multiple dives using a CNS percentage exposure chart.

The CCR user must take on a mindset of close attention to detail and build experience driven responses that prioritize and thereby minimize risk.
The adage of 'Always know your Po2' cannot be stated heavily enough.

Breathing constant Po2's may offer substantial reduction in decompression obligations but with every Ladder comes a Snake. The Pelagian is a manual CCR in the sense that oxygen addition is user controlled and maintained – there are no safety systems inbuilt to ensure life supporting oxygen concentrations.

Maintaining a constant po2 at a constant depth is fairly straightforward using either the Bypass button or Needle valve as required but as ever with increasing or decreasing depth (ascending or descending) the partial pressure of oxygen can change very quickly. A user currently at 30metres depth having built a po2 of 1.3 bars maybe be at increased risk of Hyperoxia / CNS toxicity if a sudden drop to 40metres or deeper is performed.

Whenever the user makes a descent then close attention to the electronic po2 display must be maintained with an aim of maintaining / lowering loop po2 as it rises or 'spikes' during the descent – careful use of the ADV will achieve this. Boyles Law applies during the ascent also of course. In practice the breathing Loop will compress during any descent and the next breath will simply trigger the ADV causing an influx of diluent lowering the Po2 – this should not be relied upon to maintain breathability – proper observation and dynamic loop optimization by the user should take precedence. Hyperoxia can still occur if the Needle Valve is set to deliver excess oxygen or indeed the oxygen supply 1st stage regulator may malfunction causing the loop to increase po2 either quickly or insidiously slowly.

Guidance note: The Pelagian Po2 display will show 1--- when the loop Po2 goes above 2.0 bar. If this figure is observed the user must not take their next breath from the loop. All loop volume should be dumped via the Nose and the ADV used to supply a fresh breath. Another equally viable option is simply Bail-out to open circuit or switching to the BOV (Bailout valve) if installed.

Never breath a gas with an unknown po2 – immediate unconsciousness may occur.

In contrast to the descent as the CCR user gets closer to the surface the loop volume increases and must be dumped overboard for the unit to remain comfortable to breathe from (dump excess through Nose or Mouth). An over-pressured breathing loop will give the feeling and look of a 'Hamsters Cheeks' with cheeks looking and feeling bloated – dumping the excess gas will fix this.
As the loop loses volume it loses Po2 of course as well. All CCR users strive to maintain a loop Po2 of 0.70bar to 1.0bar during an ascent – experience makes this easier to achieve and a slow ascent (circa 9-10 metres per minute) is very helpful also. Oxygen can be added as necessary via the manual Add Button. A series of short controlled bursts is best with a few moments between each burst to observe changes as loop po2 stabilises.

Failure to maintain a suitable po2 during an ascent may lead to Hypoxia and unconsciousness much the same as Free Divers suffer Shallow Water Black-out during a return to the surface.

It is recommended that users strive to maintain a po2 around 1.1 – 1.2 bars of oxygen throughout their dives – New users should avoid entering formal decompression obligations. Open Circuit 'Bail-Out' cylinders must be taken on all dives. The volume of these tanks must be sufficient to allow the user to reach the surface in comfort while performing any safety or decompression stops.

The oxygen cells in the head of the rebreather are integral part of the po2 measurement system. They should be replaced yearly or even sooner if their outputs start to degrade as in time they are sure too. Ideally, replacement oxygen cells should be obtained from different batches as the manufacturing process seems to be an in-exact science and even multiple brand new cells can be supplied faulty. The surface calibration protocol of measuring 0.21 po2 at the surface in air and 1.00 bar po2 (in a timely fashion) at the surface using 100% oxygen prior to every dive is mandatory as is the check to see if the oxygen cells have become 'current limited'. To check for current limitation the unit should be flushed with 100% oxygen and at the beginning of a dive taken to 6metres, ideally while holding onto an anchor line. This oxygen and depth combination will yield a display value of approximately 1.6 bars on both read-outs - this shows that the cells are not limited in output. If the displays fail to show 1.6 bars or thereabouts then either the cells are near expiration or maybe the ADV has triggered during the descent. Discuss with your instructor to ensure correct techniques are used to test for current limited oxygen cells.

Using a general diving set point of 1.2 bars and testing the cells prior to each dive to at least 0.4 bar above this will allow for a buffer that may reveal cell limitations within safety during your dive.

Guidance note: Ensure that the last digit of the display is constantly moving up or down. This will confirm that displays are not frozen. During your Pelagian user training course you will perform Instant Cell Validation checks throughout the course dives. Validating cells is as simple as exhaling the loop volume though the Nose and inhaling slowly via the ADV while noting the Po2 display. Using air as a diluent you would expect to see the figures in the chart below corresponding to the depths the validation was performed at.

Surface Readout with 21% o2 Diluent	**Displays Read 0.210**
10 Metres Depth	**Displays Read 0.420**
20 Metres Depth	**Displays Read 0.630**
30 Metres Depth	**Displays Read 0.840**
40 Metres Depth	**Displays Read 1.050**

Guidance note: Before performing a cell validation or if you observe one cell's output lagging behind another you should consider flushing moisture from cell faces by performing a rapid diluent flush.

The positioning of the ADV above the cells ensures each cell will have moisture removed during a fast diluent flush. Moisture on cell faces has been linked to erroneous po2 measurement.

Carbon Dioxide Build-Up

Carbon dioxide (CO_2) is a contributory factor to various forms of gas toxicity for instance Oxygen Toxicity and Nitrogen Narcosis. More importantly to the CCR diver is Carbon Dioxide's ability to build up and strike seemingly without warning in a term known as a 'Co2 Hit'. Co2 hits are relatively easy to avoid but virtually impossible to survive alone much like oxygen toxicity.
Being re-circulating equipment CCR relies heavily on the carbon dioxide scrubber to remove the divers exhaled carbon dioxide – anything that affects the efficiency of the absorbent material must be minimized or avoided.

Things that can have dire effects on scrubber effectiveness are as follows:

Workload
Deep water
Cold Water
Exhausted Scrubber
Improper Breathing Gases
Improper Unit Assembly

It is imperative that CCR divers maintain an 'at rest' breathing rate. In deep water (below 50metres) it is prudent to use a breathing gas containing Helium to help lower the Work of Breathing (WOB). Other CCR units state that they have CE accreditation for use as deep as 100m – users should be aware that this must be in conjunction with breathing gases with sufficient helium to allow a relative END of just 24metres! At 100metres this might Trimix 10/70 or even Heliox.

Before each dive users should pre-breathe their CCR units for at least 3minutes to start the exothermic reaction within the scrubber. If the air or water temperatures are less than 10' centigrade then consider extending the pre-breathe surface time to 10minutes. Failure to pre-breathe the unit before diving may render the carbon dioxide inactive leading to Hypercapnia and or Unconsciousness.

Hypercapnia

An excess of Co2 (% or partial pressure of 0.05 bar) is called *hypercapnia or hypercarbia*. Do not underestimate the significance of this. It can be a major contributory factor to many other gas toxicity problems and can cause unconsciousness In CCR diving, hypercapnia can be caused by the following.

- **Working too hard**
- **Packing Lime too tightly**
- **Breathing denser gases**
- **Exhausted Scrubber**
- **Excessive Moisture**
- **Inactive absorbent**

Major symptoms of carbon dioxide poisoning, which appear in many, but not all, cases of over-exposure, include:

Breathlessness (which can be obscured by hard work)
Headache (which is frequently confused with cold water headache or sub-clinical DCI headache)
Dazed / Confused / Lethargy
Unconsciousness / Inability to self rescue

Guidance note: DO NOT second guess ANY unusual symptoms while breathing from CCR. Carbon Dioxide poisoning can render the user beyond Self Help in just a few breaths

IF IN DOUBT – BAIL OUT

Vasodilation

Carbon dioxide is termed a vasodilator. Excess CO2 dilates the blood vessels, which in turn allows more dissolved gases to be carried throughout our system, and to the brain. An excess of CO2 can therefore increase the chance of O2 toxicity, nitrogen narcosis, decompression sickness and hypothermia, unless steps are taken to avoid it.

Co2 Poisoning Treatment

As with all gas poisoning, the first step is to remove the toxic source. Because excess CO2 is usually a result of poor breathing in some way or another, this is best done by taking deep, flushing breaths from an open circuit bail-out regulator and relaxing. Reducing the depth may help, though buoyancy should be controlled, and all work should be ceased.
If the diver is actually unconscious, he or she must be removed from the water and resuscitated if necessary. While underwater and if possible switch the DSV to the BOV setting. Carbon Dioxide poisoning may take a long time to recover from. Give 100% oxygen if available, though it may not immediately reduce all the symptoms, especially the headache. Carbon Dioxide build up can take many hours to subside even breathing Oxygen
As with all victims of unconsciousness or gas toxicity, continue to monitor breathing and circulation, and seek formal medical aid as soon as possible.

The Pelagian Scrubber takes approximately 2.8kg of Sodasorb (large granule) up to 3.4kg of Sofnolime (small granule 797 grade) – The larger the granule size equals a lower work of breathing but at the expense of absorbent usage time. Larger granules are better suited to less than 50metre diving with Air diluent. Smaller granules are better suited to deeper diving with Helium based diluents.

Guidance note: Do not tightly over-pack scrubber material. Increased Work Of Breathing may result leading to carbon dioxide build-up. Review packing the scrubber with your instructor.

Section 3 - Initial Assembly of the Pelagian DCCCR

When you receive your Pelagian DCCCR kit, please start by inspecting the package for outside impact or damage. Should there be any damage, take a picture and notify the shipping company as it will help when claiming the insurance if parts are missing or broken. If everything seems ok, proceed by unpacking and make sure you have the following list of components.

1 pcs. X-plate with 4 cam locks and 2 pcs. 2” webbing
1 pcs. Scrubber canister
1 pcs. Scrubber head section with ADV
1 pcs. Scrubber bottom plug
1 pcs. Scrubber CO2 tube
2 pcs. Scrubber absorbent screens (top and bottom)
4 pcs. Scrubber lock pins
2 pcs. Counter lungs
2 pcs. 2” Keepers, (three bar slides)
1 pcs. Breathing hose with two T-pieces, two P-plugs and one DSV.
1 pcs. Balanced first stage regulator with short LP hose and swivel connection
1 pcs. Balanced first stage regulator with over pressure relief valve
1 pcs. Oxygen addition unit
1 pcs. PO2 Display with cable for continuous monitoring of two cell read outs.
1 pcs. O-ring kit

1 pcs. Operations manual, (CD or printed)
To prepare the Pelagian fully, ready for diving, the following equipment has to be added:

- **Oxygen sensors**
  Two Teledyne R22D oxygen sensors, or three if you want to use a VR3 / HS Explorer dive computer for independent PO2 monitoring.

- **Cylinders**
  One for diluent and one for oxygen. Any size from 2 – 11 liters can be used. The Catalina 19 cu.ft. (2.7L), cylinders are of perfect length. Ask your instructor for recommendations for your area and type of diving. The O2 cylinder and valve have to be for oxygen service. The diluent cylinder and valve are recommended to be for oxygen service.

- **Pressure gauges**
  Two submersible pressure gauges and HP hoses, (20" recommended), suitable for oxygen service.

- **Wing**
  Minimum 40 Ib with low top profile and short length to avoid abrasion when standing the unit. Avoid low lift single tank style wings as the X-plate will prevent full inflation.

- **Harness and back plate**
  Continuous webbing with 4 D-rings recommended. Crotch strap is usually not needed. The back plate needs bolt holes 11" apart, (industry standard).

- **Battery**
  One standard 9V battery drives both display read outs. Any battery will work, but a high quality alkaline will last longer!

- **Bail out**
  CCR diving requires OC bail out for emergency. The regulator should be good enough to breathe from at maximum depth during high work load. The cylinder should have sufficient capacity to bring you and your buddy to the surface. It is recommended to use the bail out for wing inflation for reasons discussed in a later section.

▲WARNING! The initial set-up of the Pelagian DCCR unit should only be performed under the close supervision of a Pelagian Instructor. Failure to do so may expose the user to increased risk of Hypoxia / Hyperoxia / Drowning / Death. The Pelagian user guide is supplied as a reference guide only with the aim of reinforcing principles covered during a formal Pelagian unit training course.

Component preparation

One of the goals with designing the Pelagian DCCCR was to make it compact and light weight without impacting on dive duration. The inherent disadvantage is that space is very limited and you will have to prepare and even modify some components before you can assemble your rebreather.

Sensors

The fuel cells will come in vacuum sealed bags with serial number and a date code labeled. Before you open the bags, take a look at the date code where the letter is a month and the number is the year. For example A5 means it was manufactured in January 2005. Teledyne rate their cells for 24 months shelf life, but you will want to have fresh cells. If the date is older than two years you should return them before you open the bag. Providing the date is ok, you can open the bag. Now you will need a volt meter to measure the output across the positive and negative pins. They are the outermost pins and it does not matter if you reverse the polarity of the probes. You should get 7 – 13 mV. If lower than 7 mV, return the cell for replacement. Exhale close to the cells membrane and check that the mV drops. Wave your hand in front of the membrane and check that the fresh air brings the mV back to where it was. The output might rise a tiny bit over the next few days. After a week they are stabilized and then slowly decay during their lifespan. They are rated for 36 months, but the higher the Po2 the faster they get consumed. Prudent CCR divers change their cells every year and stagger the replacement as to avoid all cells giving up on the same dive. Occasionally a bad batch of cells sneak through quality control and if you buy all cells on the same date you will at least statistically run a higher chance of getting all bad cells. It has happened a cell is DOA and some times they might seem ok for a few days only to go belly up after some dives. The moral of the story is to use caution and the provided Instant Cell Validation frequently. Providing the output is within range you should let the cell acclimatize over night before diving. Record the serial number of the cell and the mV for future reference. Mark cells with number 1 and 2.

If you take a look at the interiors of the scrubber head you will see the sensor mounting slots. The space is tight and the sensors need some trimming before they can be installed. If you take a closer look you will also find a hole ending up in front of each cell socket. This is where the diluent gas will be injected. In order for the Instant Cell Validation to work you will have to remove the o-ring and cut the threaded section of each cell as it would otherwise block the injected flow of diluent. Use a fine toothed hack saw or similar to saw off the threads. Do not use a knife as it can result in a cracked cell body. Make sure to put the saw blade flush to the cell body to make sure you remove all threads. The rear end of cell #1 has to be partially cut due to space limitations. Make a cut from the top placed parallel to the three Molex pins. End this cut where the tapered part of the cell body begins. Now lay the cell down on its side and cut from where the tapered part of the cell body begins toward the end of your previous cut.

Fig. 1 Cut the threads on all cells rear cut

Fig. 2 Cell one 1st rear cut

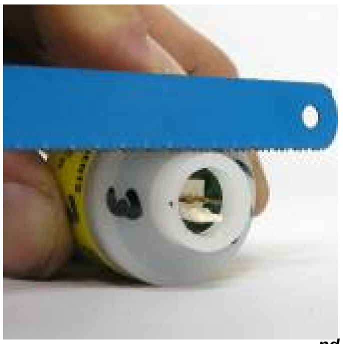


Fig. 3 Cell one 2nd

Fig. 4 Front on all cells

Fig. 5 Cell one after rear cut

Fig. 6 Cell one in socket

When done you will have removed a bit less than half of the 1st cell rear ring that surrounds the Molex connection. Study the pictures before cutting and ask your instructor if unsure! You are now ready to install the cells in the Head. Connect the Molex plug and carefully lower the cells into their respective sockets without bending the wires more than necessary. Avoid removing the cells if not needed. When it is time to replace the cells make sure to always bend the wires the same way to avoid breaking the copper strands. Remove the cell by inserting a pen or similar under the cell body and lift. The third cell connected to a computer need not be trimmed for the sake of using the Instant Sensor Validation as the computers response time would anyway be too slow. However, the secondary advantage with DILUENT injection over the cell membrane is to remove water from it and this is a valid enough reason to cut the threads anyway.

Picture showing all 3 oxygen cells trimmed and installed correctly into lid. In this picture an optional 90' elbow has been fitted to allow a 'cleaner' hose routing.

Note: At this stage the oxygen cells should be marked with an indelible pen with the date of installation.

Loop o-rings

With the exception of the internal o-rings in the DSV, all loop o-rings will need to be installed. The Pelagian DCCCR uses double o-rings on most dynamic seals, meaning the seals that rotate with movement. Static seals use single o-rings but are not subject to much wear or movement. Open the provided o-ring kit and put the o-rings on a clean surface. You should have 8 small o-rings for the T-pieces and P-plugs, 4 o-rings for the scrubber Head and bottom plug and 1 o-ring for the Co2 tube socket, located next to the cell #1 socket. Inspect all o-rings for damage, apply a small amount of lubricant, clean the o-ring groove with a lint free cloth and install the o-rings. The Head and bottom plug o-rings needs generous lubrication to make disassembly easier. All o-rings should be inspected for wear at regular intervals and replaced if necessary. Annual replacement is recommended even if the o-rings may appear to be ok.

▲WARNING! Failure to install all o-rings will flood the rebreather which can result in your injury or death!

Display battery

Invert the scrubber Head and place it on a table while allowing the display cable to clear the edge of the table to avoid over bending it. Using a small Philips head screw driver, unscrew the four stainless steel screws securing the battery lid. Remove the lid and rubber gasket. Connect the strap to a fresh high quality alkaline 9V battery. Lower the battery into the slot while avoiding the cables to get pinched between the battery and compartment walls. The cable will need some bending. When replacing the battery, avoid straightening the cable. The battery strap is very short on early units and there is only 0.5 mm clearance between battery and lid. On early units the positive pole is up, (see fig. 7). Later units have longer cables, negative pole up and there is approx 2 mm clearance between the battery and lid, (see fig 8). This clearance should be used to loop the battery cables with out allowing them to cross. Do NOT loop the cable under the battery as it is not possible to visually confirm that cables don't cross. If you feel resistance and the battery does not seat all the way to the bottom, DO NOT force the battery as you will risk peeling the insulating jackets and create a short circuit! The reason for the longer cable is to allow easier replacement of the battery strap if needed.

Fig. 7 Short strap, means positive up

Fig. 8 Long strap, means negative up

Battery life

The battery life will vary primarily with use of display backlight, and to a lesser degree with water temperature. During tests batteries has lasted up to 20 days of continuous use with out back light. Once the “B” letter is lit on the display screen the battery should be replaced. When a battery runs low the Po2 will read higher than actual. Always validate the read out when you see the “B” letter and end the dive on Bail out OC if necessary! Re-chargeable batteries should not be used. Remove the battery if you will not dive for a longer period of time.

Lid and gasket

Make sure the battery gasket is flat and NOT piling up between lid and the sockets sealing area. When tightening the screws, avoid excessive torque. You only need to put a little pressure on the gasket so that the lid is level with the head rim.

▲WARNING! Forcing the battery can result in a short circuit, rendering the display useless! Failure to end a dive when the low battery warning is lit will render the display inaccurate! Both can result in your injury or death!

Section 4 - Preparing To Dive the Pelagian DCCCR

Filling the Scrubber Canister

Both screens and the inside of the scrubber tube are marked with dots (alignment marks) for easy alignment when filling the scrubber with co2 absorbent material. The top screen comes with a cable tie to aid pulling upwards. The bottom screen does not have a cable tie. The stainless steel mesh sides should face the absorbent material (sorb). The scrubber tube also has a line indicating how deep the Head will seat once installed. When properly filled, the sorb and both screens will occupy the space between the bottom ledge and this line, meaning the top screen should be level with the line.

Install the bottom screen flush to the scrubber bottom ledge and turn the scrubber up side down while holding the bottom screen in place. Make sure the dot on the bottom of the screen and the dot on the bottom of the ledge are aligned. Turn the scrubber upside up while keeping he bottom screen aligned. Install the exhale tube in the bottom screen hole. Pour a 3rd of the scrubber. Now install the top screen aligned it with the dot located just on top of the line. Pinch the exhale tube towards the side of the scrubber tube while tapping the scrubber. This will keep the exhale tube positioned while settling the sorb. Make sure to avoid too much sideway motion on the scrubber. The idea is to “chock” the sorb so it settles downwards. Remove the top screen, fill another third and repeat. For the last third, pour until the sorb is a few mm below the line. Once the last third is packed and level install the top screen. The top of the top screen should be exactly level with the alignment line in the scrubber tube. You may have to add / remove some sorb to get it right. This Pelagian DCCCR canister does not use any spring system to take up any play so the sorb needs to be packed tight to avoid channeling. Clean the top and bottom sealing area of the scrubber tube and inspect the orings on the Head and the bottom plug. Align the head with the locking holes, push it down and install the locking pins. Tap the scrubber some more to get any dust out. Align the bottom plug inserts with the two side holes in the scrubber tube, push the scrubber down and install the two lock pins.

Guidance Note: Sofnolime grade 797, (8-12), has less inter granular space than Draeger divesorb or Sofnolime of larger grade. Absorbent needs to be properly packed to avoid channeling. If you feel WOB is too high, you should use another grade such as Draeger Dive Sorb, or Sofnolime with larger pellets rather than experimenting with loose fills. Ask your instructor for advice on packing the scrubber.

Do not add sponges / tampons or other absorbent material in the bottom plug water trap area. Foreign bodies such as these may move and block the gas path with dire consequences.

Picture shows correctly filled scrubber with CO2 tube and
top screen correctly orientated.

Another option of filling the scrubber is detailed as follows. Insert bottom screen into scrubber tube and push down to support ledge (mesh side should face top of scrubber). Insert Co2 tube into bottom screen.

Rotate as necessary to line up bottom screen and CO2 tube with exhaust port of the Head. Insert top lid into scrubber and re-check that assembly is straight and true by inserting the Scrubber lock screws (remove bottom lid to aid fine adjustment if necessary).

Once aligned, add funnel through inhale P-connector port. Fill scrubber through funnel approximately 1/3rd full. Tap the scrubber body as appropriate. Add additional sorb until 2/3rds full and tap down once more. Remove scrubber Head and add additional sorb until just below the top screen alignment line. Insert the top screen (mesh down) and tap until the top of the top screen is aligned with the line. To help in the removal and replacement of the scrubber head complete the filling procedure with both the scrubber head o-rings removed. Additionally, lubricating the CO2 tube's sealing o-ring will make it easier to remove the Head.

The scrubber tube has an alignment line inside that should be level with the top of the top screen. Loose fills can cause channeling leading to CO2 bypass and hypercapnia.

Inspect the oxygen sensors and lid internal area, blowing away any visible signs of absorbent material dust.

Finally, add both scrubber head o-rings to the lid (a shine of grease on these o-rings will help with subsequent removal). Carefully push the scrubber head into the scrubber tube. Insert the two scrubber head retaining bolts and tighten. You are now ready to assemble rest of the unit.

▲WARNING! Failure to correctly fill the scrubber assembly may cause an increase of carbon dioxide in the breathing loop. Excess carbon dioxide causes Hypercapnia which can result in your injury or death!

Insert the scrubber assembly into the centre section of the X-plate together with the tanks each side. The Oxygen bottle will take the right side and Diluent tank the left, orientated as when you would be wearing the unit. Do not tighten the cam bands yet.

Section 5 - Pelagian Pre-Dive Check Sequence

The following set-up steps must be done under the direct supervision of your course instructor and repeated at least 6 times or until you demonstrate mastery.

Add the left and right lungs to your back-plate harness. You should use the tri-slide buckle to fix the lungs to the uppermost part of the harness webbing. The base of the lungs are anchored to the back-plate using bungee cord Allowing the lungs to move up or down will change the hydrostatic loading and to some extent affect the work of breathing (WOB). Once the lungs are anchored to the harness simply Velcro the loops on the wings to the harness. The buoyancy wing and then the back-plate complete with lungs may
then be added.

The X-plate assembly has two bolts welded in place 11 inches apart. This distance is used by virtually all back-plate manufacturers, so your own back-plate should fit straight on, but of course there may be some that won't. Advice from your instructor will help remediate any back-plate incompatibility issues.
The Pelagian is a low profile unit and is ideally suited to a moderately sized wing with 20kg's of lift. Bigger wings may of course be used. Single tank wings should not be used as they would become partially wedged between the back plate and X-Plate.

Next, check all o-rings to breathing loop hose ends and scrubber lids both bottom and top have been installed and lightly lubricated. Check mushroom valve integrity by exhaling in to the exhaust P-plug and inhaling from the inhalation P.plug while blocking the T-piece and the DSV barrel in the open (CCR) position. This should not work. If any gas creep is noticed, replace the mushroom valves. The flow of gas should be as such EXHALE to RIGHT and INHALE from LEFT. If incorrectly connected, the T-piece P-connectors will orientate upwards, away from the counter lung P-ports.

Picture shows differences between each side of breathing hose. To the right is the exhale side with moisture deflecting plate. Exhale lung is on right side of harness (as worn).

Once buoyancy wing and back-plate are installed, next add the breathing loop. The loop o-rings should be cleaned of dirt and hairs and lightly lubricated before installation.

Check the correct orientation of the loop by breathing through it and checking water trap deflector side attaches to exhale bag (right side as worn, exhale bag has no Pelagian logo)

▲WARNING! Failure to ensure cleanliness of o-rings and orientation of loop may cause flooding or hypercapnia leading to personal injury or death !

Next, Install first stages to tanks. The stage with the oxygen addition valve goes to the oxygen tank (right side as worn)

Ensure that Oxygen 1st stage has over pressure valve installed. Angle all hoses downwards to avoid damage.

Connect oxygen low pressure inflator hose (lpi) to the nipple on lid. Turn on oxygen supply tank and verify contents.

Check operation of addition button and needle valve.

Once you are happy with operation of oxygen addition system. It is time to set an initial flow rate of oxygen via the needle valve (in litres per minute) During training you will your 'at rest' oxygen metabolic rate. This figure may typically be somewhere in the region of 0.6lpm at the surface (rising during exertion of course but largely independent of depth). Using a floating ball gauge set the output of the oxygen addition needle valve to approximately 0.6lpm.

While breathing from the unit; if the figure is correct you should not notice your po2 falling for 2-3 minutes. The initial training dives will not use the needle valve to maintain po2. During these first few dives you should maintain po2 using the manual add button.

Next, add the diluent1st stage regulator. You may wish to add an LPI hose to allow wing inflation from the diluent tank. Ensure that your back up buoyancy system (2nd wing bladder or drysuit has its supply coming from a different tank)

You are now ready to check the integrity of the unit with both Positive and Negative Pressure testing.

Inflate the breathing loop using the diluent ADV valve. Lay unit down on back. Place a 1kg weight on breathing bag. Leave unit inflated for 10 minutes. Breathing bag should stay inflated. If it does not, suspect loop volume leak and check for cause. An easy way to do this is to spray the inflated unit with a water and liquid soap solution while looking and listening for bubbling and leaks. Remediate all leaks.

Left Photo shows Bubble trouble!

Right photo shows squeezed down loop for Negative Pressure test

Next, pull exhale lung overpressure dump valve to empty unit. Place DSV in your mouth and open valve. Breathe in through mouth and out through nose in an effort to drain all gas from the unit. This may take a minute...be patient. Once unit is empty, squeeze the breathing loop in several places before closing the DSV mouthpiece.

The purpose of Negative pressure test is to check if unit can maintain a vacuum. Breathing hoses should stay deflated for at least 5 minutes. If breathing hoses re-inflate prematurely, suspect a leak and inspect system fully to remedy.

▲WARNING! Failure to perform adequate leak tests may cause flooding leading to your drowning, injury and death!

Calibration

Once you have installed the Alkaline 9-volt battery in scrubber lid and installed a minimum of two matched oxygen cells to lid, trimmed appropriately you will need to calibrate these cells. The PO2 display handset will need calibrating to atmospheric air at sea level and then verified in 100% oxygen. Removing the 3/8 UNF port plug adjacent the handset cable gland will expose the trimming pots for each oxygen sensor. Ensure that the display shows 0.21 +/- 0.01 in atmospheric air and 100% +/- 0.03 in pure oxygen.

An easy way to ensure the cells are exposed to pure oxygen is to put the Head in a small plastic bag with the O2 feed hose connected to the O2 inlet nipple. Then slowly open the tank valve with the needle valve set to approx one half turn open. Seal the bag with your hand, but make sure it never inflates fully.

The oxygen entering will be at approx 0.3 – 0.5 LPM and this also needs to leave the bag to prevent a overly high reading due to elevated ambient pressure. The reading should slowly climb and stop at 0.97 – 1.03 BAR. If lower, check for excessive leaks from the bag. If still low, analyze the O2 tank with a third party oxygen analyzer. If necessary replace the Oxygen sensor(s). If the reading seems too high, make sure the bag is not fully inflated. Oxygen sensors have to be verified functional and linear before each dive. If you are on a rocking boat it will be easier to flush the rebreather loop 4 – 5 times with oxygen, but you will likely use more gas. The third check point for linearity is easily made under water with the loop filled with pure O2. Your instructor will show you how this is done.

A healthy cell might need its calibration adjusted slightly every 3 – 4 weeks. If you have to adjust very often the cell has reached the end of its useful life. Oxygen sensors should be replaced every year or as soon as they seem unreliable. To avoid both sensors dying during the same dive it is wise to stagger their replacement.

▲WARNING! Failure to verify calibration and linearity of the oxygen sensors before each dive can lead to hypoxia and / or hyperoxia which can result in your injury or death!

The ADV (Auto Diluent Valve) is factory installed in the scrubber lid but needs to be adjusted for optimal performance by the end user with instructor supervision. The internals of the ADV are standard demand valve regulator components. In-Line adjustment tools designed for real time adjusting are highly recommended for this process – your instructor will loan this tool and advise on its usage. Some subsequent adjustment maybe be necessary to achieve the ideal setting. ADV should trigger easily when diver is in vertical position but become ‘stiffer’ with diver in horizontal position.

▲WARNING! Failure to correctly adjust the ADV may lead to hyperoxia and / or rapid change of buoyancy – either of which can result in your injury or death!

The oxygen addition valve allows two means of supplying O2 to the unit. A variable output needle valve allows a user-definable amount of oxygen. Take care not to over tighten the valve stem. Even at fully closed, the needle valve allows approximately 0.2lpm past to protect its sealing seat.

The manual addition button can be used to bypass the needle valve and will add a burst of oxygen with every depression. The O2 addition button should be used by adding one short burst combined with 3-4 breathes to allow the oxygen to mix. Then verify PPO2 before adding more oxygen. During your training course your instructor will advise how best to use the oxygen addition system. The oxygen addition block has a standard low pressure quick release connector that connects directly to the O2 inlet nipple of the Scrubber Head.

The PPO2 display has a magnetic slide switch on the left side. In the lowest position the handset is in standby mode (off). Moving the slide to the middle position will activate the display and show current PPO2 readings. Moving the slider to the uppermost position will turn the handset backlight on. A high quality alkaline battery should give approximately 30 hours of use. Carrying a spare battery and spare oxygen fuel cells will ensure that lost dives are minimised.

Just before entering the water and after all other checks it is now time to pre-breathe your unit. Pre-breathing is a very important step that kick-starts the exothermic reaction within the carbon-dioxide absorbent. In moderate or tropical temperatures it is sufficient to pre-breathe for 3 minutes or so. If entering very cold water then a longer pre-breathe session (up to 10 minutes) is necessary.

Guidance note: Cold temperatures are an enemy of the CCR diver and can cause failures in absorbent leading to carbon dioxide increases and even death. Always Pre-Breathe for 10 minutes directly prior to entering the water if surface temperatures are less than 6' centigrade.

During ALL rebreather dives, divers must use an off-board Bail-out cylinder of adequate size to return the user AND buddy to the surface!

▲WARNING! Failure to carry adequate bail-out breathing gas may result in personal injury and/or death!

Pelagian DCCCR dive planning and pre dive safety checks

Student name:
Dive buddy:

Course start date:
Instructors name:

Students metabolic rate lpm

Assembly and function	**Pool dive**	**Dive 1**	**Dive 2**	**Dive 3**	**Dive 4**	**Dive 5**	**Dive 6**
Date							
Tanks analyzed. O2 / DIL / BAIL	/ /	/ /	/ /	/ /	/ /	/ /	/ /
Scrubber filled properly / rem. time							
Battery test satisfactory							
Air calibration / check with head off							
Hose check valves / P-con. orings							
Tees & plugs “twist and tug”							
Assembly satisfactory							
Tank pressure O2 / DIL / BAIL	/ /	/ /	/ /	/ /	/ /	/ /	/ /
O2 feed / ADV / Bail reg tested							
Gauges tested O2 / DIL / BAIL							
Positive pressure test satisfactory							
Negative pressure test satisfactory							
Flow rate @ surface set to							
Pre-breathe 3-10 mins satisfactory							
Cells 0,97 - 1,03 PO2 after 4 purges							
Sensor readout at 6m in O2							

Dive plan	**Dive 1**	**Dive 2**	**Dive 3**	**Dive 4**	**Dive 5**	**Dive 6**	**Remedial**
P. G. after surface interval							
Max depth							
Set point							
EAD (set point - 0,1 bar)							
NDL on Buhlmann Air Table							
CNS % (set point+0,1 bar)							
Theoretical tank duration							
Scrubber duration							
Actual bottom time							
RNT							
Pressure group							
Surface interval							
Signature Student							
Signature Instructor							

Notes:

Reference

MOD = *1,3 / Tank FgO2 - 1 x 10*
Loop mix = Set point / depth (ATA)
EAD = *FgiN2 / 0,79 x (MOD + 10) - 10*
O2 duration = *Volume x BAR / Flow rate*
OC Bail Requirement = *TxPxSACx2*
Scrubber dur. = 360 min tropical water / 240 min cold water
MassFlow increase = *1% / m deeper than surface*

PO2	Single dive	% / min	24 hour
1,6	45	2,22	150
1,5	120	0,83	180
1,4	150	0,67	180
1,3	180	0,56	210
1,2	210	0,48	240
1,1	240	0,42	270
1	300	0,33	300

Note; For calculations for EAD, NDL / Deco assume set point is 0,1 BAR Po2 less than planned.
For CNS % assume set point is 0,1 BAR Po2 higher than planned.

Section 6 - Pelagian DCCCR Working Principle

The "DCCCR" in Pelagian stands for "Diver Controlled Closed Circuit Rebreather". This means that the diver is responsible for injecting Oxygen into the breathing loop and monitoring the levels of O2 at all times though out the dive. This is accomplished by adjusting a fine metering needle valve so that it is allowing a little bit less than the divers O2 consumption in to the loop at a continuous flow. The diver can also push a manual over ride button to quickly bring up the level of oxygen without re adjusting the needle valve. The O2 is fed to the exhaust side of the Scrubber to allow it to mix with the diver's exhaled breath. The gas is then carried through the absorbent material that bonds with the CO2 produced by the diver's metabolism. Then the scrubbed gas enters the Head section where two Oxygen sensors transmit the PO2 to a display. The Pelagian DCCCR is used with two separate cylinders containing Oxygen and Diluent. The Diluent can be air, Trimix or Heliox. The Diluent cylinder is connected to an Automatic Diluent Valve, (ADV), which is opened as soon as the counter lungs "bottoms out". This means that in the event the diver wants to lower the loop PO2, he will have to exhale from his nose in order to lower the loop gas volume. The next inhalation will make the counter lungs bottom out and the ADV will ad Diluent gas into the inhale side of the Scrubber. This action lowers the loop PO2 as the Diluent is typically low in oxygen content.

Oxygen dosage system

Regarding the continuous flow of the oxygen dosage system the three physical factors that determine the dosage of oxygen to the diver are;

1. P1 - The pressure from the 1st stage regulator.
2. P2 - The pressure in the CCR, which is determined by the water depth.
3. The diameter of the orifice in the O2 manifold.

The pressure from the 1st stage regulator is 9 BAR intermediate pressure, (IP), plus ambient pressure, so at sea level the total pressure from the 1st stage is 10 BAR and at 40 m the total pressure is 14 BAR. Providing sufficient cylinder pressure exists a continuous flow of O2 is ensured at any depth as the differential is always 9 BAR. It would appear logical at first to assume the same mass flow, or dosage of oxygen would be delivered at various depths, but unfortunately this is not the case. Despite the same pressure differential of 9 BAR the dose of O2 will vary as both P1 and P2 varies with depth. This is the reason the Pelagian DCCCR has an adjustable orifice – the needle valve. At this stage it is warranted to have a closer look at some definitions;

Flow – Usually specified as a volume of gas or liquid per minute. As liquid is practically incompressible "Flow" could also be used to quantify amount of mass or molecules. As gas is compressible, for our purposes it gives only half the truth. In an hospital environment an individuals metabolic rate, or need of oxygen is given as Liters Per Minute, (LPM), as most hospitals are at sea level, or at least very few are deeper than sea level! What actually matters for our metabolism is a quantity of O2 molecules, but as they are hard to count during a dive, we will keep our eyes peeled on the pressure of O2 in the gas we breathe.

Mass – Describes the density of a matter but not its volume.

Mass Flow – This term refers to both volume and density and is therefore better suited to measure our oxygen needs while diving. A simple word that can substitute mass flow is “Dose” of oxygen.

CV Factor – The CV factor describes how much a flow increases by a given number of turns on a valve. The needle valve on the Pelagian DCCCR is a fine metering needle valve with a very linear CV factor.

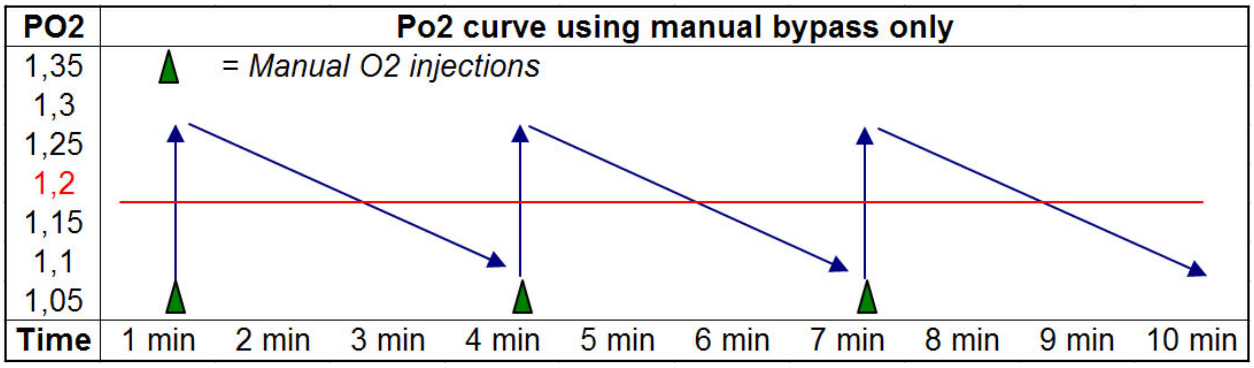
As the Pelagian DCCCR 1st stage regulator is responsive to the ambient pressure the mass flow of oxygen will increase as a diver descends deeper. Like wise the mass flow of oxygen will decrease on ascent. Providing the IP of the 1st stage is 9 BAR and no adjustment is made to the needle valve setting the increase / decrease is 1% per meter between the surface and 90 m. This is the depth range where the mass flow is sonic, or linear. Between 90 m and deeper the mass flow will become sub-sonic which simply means it will still always increase by diving deeper, but gradually less and less per meter. If you bring your Pelagian DCCCR O2 1st stage regulator for service you should point out that you would like to have the IP set to 9 BAR. If the IP would be set higher or lower the increase / decrease in mass flow will no longer be 1% per meter. The 1st stage regulators of the Pelagian are not environmentally sealed in order to prevent the inherent IP boost.

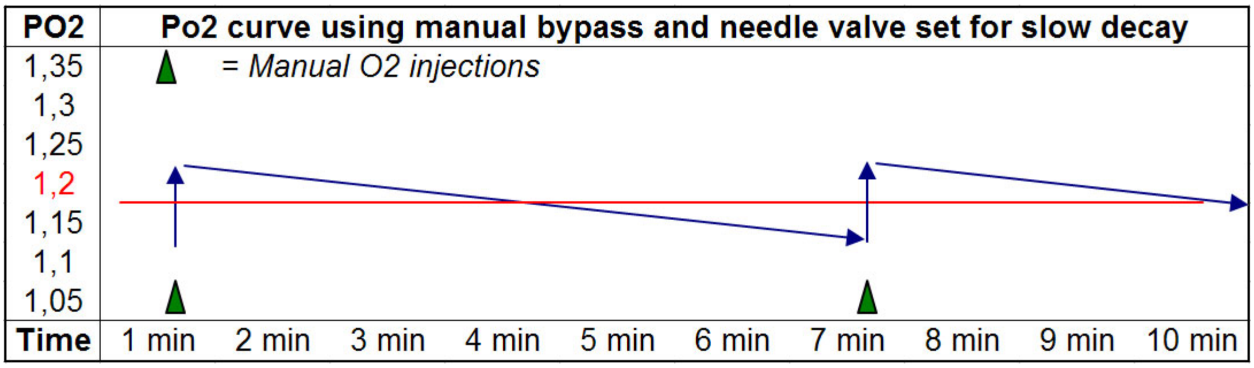
While many experienced Pelagian divers tend to favor adjusting the needle valve “on the fly”, there are times when this is impractical due to task loading, wearing dry gloves or simply due to highly variable work load. For these events a better option is to adjust the needle valve before the dive to match your metabolic rate at rest, at the maximum planned depth. As the PO2 drops during your ascent you can simply add more oxygen to the CCR by pressing the manual bypass valve while confirming the Po2 on the displays.

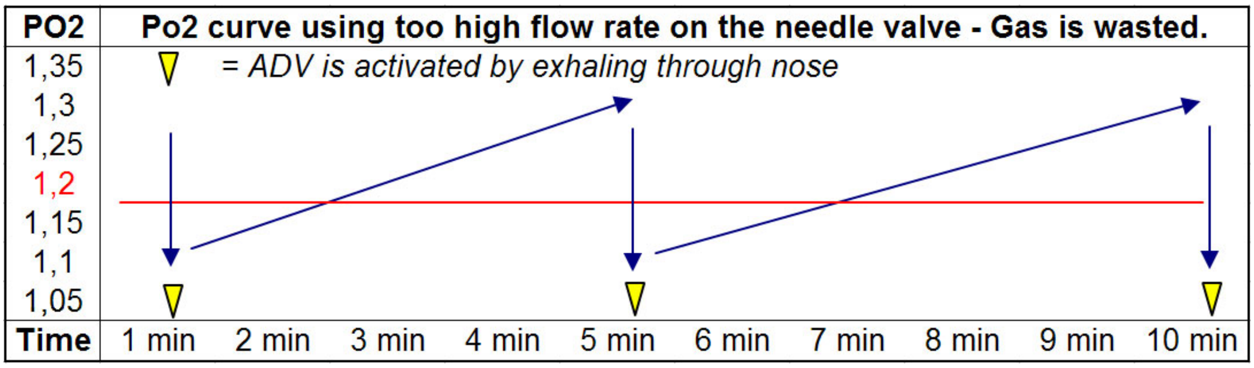
The correct way to add oxygen with the manual bypass is in short bursts mixed with 3 – 4 breaths in between every injection. Watch the display and you will see the Po2 rise after the initial breaths as the portion of O2 hits the O2 sensors. The Po2 will then drop with further breaths and balance out after the 4th breath to present the Po2 value in a more homogenized state. If you need to bring the Po2 up a lot and quick you should feed one short burst, then take a fast breath, then ad one more burst and repeat as needed. The idea is to distribute the larger amount of oxygen evenly though out the loop, rather than using long bursts from the manual bypass valve in order to prevent spikes of high Po2.
Anytime you add oxygen with the manual bypass you should watch the displays. Other than giving your current Po2 they will tell you a lot about the condition of your O2 sensors. The last decimal should always be dynamic as it registers the small pressure variations between inhalation and exhalation. The first and second breaths after manually adding will likely bring the Po2 higher than your set point and this gives you the opportunity to confirm that the sensors in fact CAN produce a Po2 higher than set point. Take note of any static behavior in the last decimal that could indicate a voltage limited O2 sensor.
In the event the Po2 is too high there are two rationales for bringing it back to set point;

PO2 is less than 1.6 BAR – Exhale from nose to bring down the loop volume.
The ADV will bring fresh DIL gas into the loop with next inhalation which will lower the PO2.

PO2 is higher than 1,6 BAR – Bail out to OC, then flush the loop while alternating pinching the inhale and exhale loop hoses behind the T-pieces for 5 seconds each.
Ideally the needle valve should be tuned so that it replaces metabolic needs at a low work load. This means manual additions should be required every 5 – 10 minutes, (depending on work load), in order to prevent a PO2 decay of more than 0,1 BAR. As long as the Po2 does decay gas is not wasted. If the Po2 decays too fast, it just means that a shorter interval of manual injections is needed. If the needle valve is adjusted for a too high mass flow, several loop flushes or ADV activations are needed. This usually brings the PO2 a bit below the set point, (depends on depth), which means further O2 will be needed to bring the Po2 back up to set point.







As you can see it is more important to quickly become proficient with the manual bypass than an expert on adjusting the needle valve. Therefore the initial training dives will be done using only the manual bypass valve and the ADV. As you progress with your training the needle valve will be introduced and you will learn both to pre adjust it for suitable mass flow at max depth as well as adjusting it on the fly. When you close the needle valve fully it is important to not use any force. Just close it with two fingers until it stops. The needle stem is located in a plastic orifice. If the needle stem is forced against the orifice seat it can damage both the orifice and the needle stem which would result in an altered CV factor, meaning it will be much more difficult to fine tune the valve for low flows. When you receive your Pelagian DCCCR the needle valve is pre adjusted so that a fully closed setting still leave approx 0,1 – o,2 LPM flow in order to protect the orifice and stem. Do not remove the lock screw on the handle as this will disrupt this setting and could cause the handle to fall off during a dive! Do not tighten the bonnet that is sealing against the O2 manifold as this will alter the flow setting and possibly damage the orifice and stem. With normal use and post dive rinsing in fresh water while making sure no water leaks in to the manifold there should not be much or any service required. The new generation O2 manifolds allows changing O2 cylinders by unplugging the onboard feed hose. However, there is no check valve on the nipple which means changing O2 cylinders during a dive WILL introduce water to the manifold and needle valve. Therefore, this should only be done in an emergency if the on board O2 cylinder is depleted and no bail out gas is available. After such an incident the O2 manifold should be sent for service by an authorized service technician. The main reason the nipple was introduced was not for swapping O2 supply, but rather to allow both hoses to and from the manifold to be replaced with standard BC inflator hoses.

As the increase / decrease in mass flow of O2 is 1% per meter it is easy to predict the flow at the planned depth before the dive. The diver needs to know his/her metabolic rate at light work, the planned depth and an easy to remember equation. The flow including the increase is calculated as a fraction so for example at 50 meters depth there would be a 50% increase in mass flow compared to the surface. If the surface flow was measured to 0,5 lpm the flow should be multiplied with 1,5 and the mass flow at 50 m would be the surface equivalent to 0,75 lpm. As it is more useful to know how to set the needle valve flow at the surface so it gives a suitable mass flow at depth, the equation is just inversed; A diver wants the surface equivalent of 0,75 lpm at 50 m. Again the flow increase is 50% and the fraction to use 1,5 so 0,75 divided by 1,5 equals 0,5 which is the flow to adjust the needle valve to before the dive. A suitable flow meter should be graduated from 0 – 1,2 LPM or similar and have an accuracy of +-4% across the scale or better.

Automatic Diluent Valve

The Automatic Diluent Valve, (ADV), of the Pelagian DCCCR sits on the top of the Scrubber Head right above the oxygen sensors. The main function the ADV is, like the name suggest, to automatically ad diluent gas to the CCR. During the descent the volume of your counter lungs compress just as the wing and dive suit does. As the ADV is triggered by pressure difference it will ad gas when the ambient water pressure is greater than the pressure inside the CCR breathing loop, such as when you descend. How much gas is added is governed by the depth of your inhalations and to some extent by your body position. As you reach the target depth the ADV will, at least in theory, have done its job for that dive. Providing you don’t go deeper, but stay at your max depth and then ascend, no additional diluent should be needed. Only more O2. Practically you will need more diluant gas after clearing your mask, to verify the function of the oxygen sensors and to give more loop volume in the event of higher work load which should result in deeper inhalations. Many seasoned CCR divers speak of ADV’s like a nuisance; “They trigger when I don’t want it, and don’t when I need it”. The perfect ADV would be activated by reading the divers mind, but unfortunately it has yet to be invented! An ADV works just the same as a familiar 2nd stage regulator. What can be done from a design stand point is to place it in a position where it is most useful. As the Pelagian DCCCR is designed to cater to divers who enjoy spending most of their dive in a sensible horizontal swimming position the ADV is noticeably hard to trip in this position. In a vertical position, which is more suitable for a descent it is much easier to draw a breath from it. If you are descending in a horizontal body position and feel too much inhalation resistance on the way down, simply assume a temporary vertical position when inhaling. If this doesn't help your ADV needs some tuning. A quick fix is to adjust it from the outside by using a dedicated tool used to tune 2nd stages while the ADV is pressurized from the diluent 1st stage. If you have access to such a tool, try the following;

1. Before turning the cylinder on, make a mental note of the starting position after feeling where the adjustment tool notch slips in to the slot of the ADV's adjustable crown.

2. Open the cylinder and slowly open the crown anti clock wise until a leak is heard. Then go back clock wise until the leak stops and an additional 1/8 clock wise turn.

3. Compare this setting with the initial. If your new setting is more anti clock wise than the old, it is worth to test this setting in the water. If not you will need to open the ADV cover and unscrew the small Nyloc nut a quarter turn. This reduces the tension on the lever spring, but will require additional adjustment of the crown to take up slack in the lever. If this step is omitted the lever's relaxed position will be too far from the membrane with a resulting "stuttering" gas delivery on activation.

If you have no prior experience adjusting regulators ask your instructor for advice during your course. For future fine tuning of the ADV a lot of trial and error is needed and every new adjustment needs to be tested in shallow water before any more challenging dives are attempted.

It is quite normal for novice CCR divers to feel the ADV is set too tight after the first pool session. Do not compare the sensation of inhaling from the ADV with a high performance 2nd stage. If the ADV would breathe that well it would be next to impossible to keep it from firing when you don't want it to. Breathing directly from the ADV for extended periods is not what it is designed for and only a very last resort in an emergency where all other options have failed. In this event you are heading for the surface. In a vertical position!

As you know by now, a CCR diver uses a fixed PO2 thought out the dive. As the ADV is particularly trigger happy in a vertical body position it can be challenging to prevent the ADV to ad diluent gas when you are ascending. As ambinent pressure drops, so does the loop PO2 so you will need to exhale from your nose in order to make space for additional manually added O2 to keep the loop at set point. As you exhale from your nose you are temporarily creating a lower pressure in the counter lungs, which will by design make the ADV fire so the PO2 drops even further below your set point. The closer you get to the surface, the harder it will be to maintain your set point. In order to prevent the ADV to be working against you on the ascent a few techniques should be considered;

1. Ascend as horizontal as possible.
2. Deflate your wing earlier than usual. If loop volume also accounts for what you need to be neutral it will usually mean a slightly over pressurized loop which will make the ADV less prone to trigger.
3. Providing your wing is connected from your off board bail out cylinder you could simply shut your diluent cylinder down to eliminate the ADV altogether. Note that if your Pelagian is equipped with the optional BOV this should also be feeding from the off board bail out cylinder.

So called in-line shut off valves are readily available from third party vendors and many CCR divers equip their ADV's with these devices. The main reason the Pelagian does not come with one is that few divers can reach them due to the location of the ADV. Another reason to not use them is that if the high pressure seat in the diluent 1st stage fails and the shut off valve is closed, the ADV hose would rupture and all remaining gas would be unavailable to the diver. In the same scenario with out a shut off valve the ADV would free flow and once the cylinder valve is shut the remaining gas would still be available by "feathering" the cylinder valve when diluent gas is needed. If you can reach an in-line shut off valve it could make things easier while exposing the O2 sensors in pure oxygen in the beginning of the dive, (3rd point linearity check), and on ascents, especially while doing O2 flushes. If you install an in-line shut off valve you should also install an over pressure relief valve on the diluent 1st stage.

Instant Cell Validation

The second function of the ADV is provide a simple means to verify the accuracy of the oxygen sensors during a dive. As mentioned in the Set up chapter, oxygen sensors are unreliable and your best defense is to check them frequently. Additionally, during the course of a dive, every time the ADV triggers the diluent gas from the ADV ends up right in front of the O2 sensors. If you have a look at the display when this happens you will see how the Po2 is affected. A pro active way to really find out if the sensors make sense is to have the diluent FgO2 x ambient pressure pre calculated in 5 m increments on your wrist slate or wet notes. Then go to the nearest depth and exhale half a breath from your nose and inhale slowly. If you inhale very slow for 10 seconds you will get a very accurate reading. If your inhalation is a bit fast you will get a slightly higher reading than actual PO2 due to increased pressure caused by the flow. If you don't keep the inhalation long enough or interrupted the surrounding loop gas will rush in and affect the reading, again usually higher than actual. With some practice you will learn to keep a steady and slow inhalation and get accurate results. If you are at 40 m with air in your dil your display should read 0.21 x 5 BAR = 1.05 or close to it. Providing this works out, what exactly do you know? You know that your sensors ready accurately at 1.05 PO2 and you get an opportunity to compare the sensors response times against each other. If one cell shows abnormally long time to respond repeat, but this time you inhale forcefully to blow away moisture on the sensor membranes that could cause the slow response time.
Next repeat instant cell validation. If the sensor is still slow, make a mental note to replace it, finish the dive on the CCR, but use frequent cell validations and follow the good cell! If in doubt – Bail out. Needless to say if both sensors fail – BAIL OUT!!!
As instant cell validation is no guarantee a sensor works fine over its entire range, but only at the Po2 you expose it to it is important to always perform the 3rd point linearity check in the beginning of the dive. This means expose the sensors to a known gas at a known depth. After practicing flushing the loop with O2 at the surface for your 2nd point linearity check you will know it requires 4-5 flushes to get reasonable purity of O2 in the

CCR. If you do this step properly and then close the DSV and descend to 6 m while breathing from your off board bail-out regulator or BOV you will bring that known gas sample to a known depth and the result should be around 1.6 BAR Po2 which is quite a bit higher than your recommended set point of 1.2 BAR. This should ensure that each dive is started with a confirmation that the sensors are linear from 0.21 to 1.6 BAR PO2 plus confirm that they are not current limited. During the dive, each time you manually add O2 with the bypass valve the Po2 momentarily over shoots the set point during the initial breaths before the added O2 mixes with the loop gas. Pay attention as this also confirms that the sensors are able to produce a higher PO2 than set point. Exactly how linear they are above the set point cannot be confirmed during the dive, which reinforces the importance to always perform the 3rd point linearity check in the beginning of each dive.
Your instructor will make sure you do your linearity checks properly and make frequent use of the instant cell validation during your training dives. The Pelagian DCCCR together with these skills is a concept and a step towards making CCR diving safer.

Set Point Control or Confusion

Unfortunately there are many new factors in CCR diving that can confuse the novice rebreather diver while trying to figure out needle valve settings, manual O2 injections and ADV action. Knowing a few situations may serve to reduce confusion during your training dives;

1. A diver is at 30 m with a set point of 1.2 BAR. The needle setting seems fine as the previous 15 minutes of the dive only needed few manual injections of O2. He clears his mask with out thinking much of it, but this reduces the loop volume. Next inhalation triggers the ADV and the PO2 drops. Should he open the needle valve more? No. He should just take a few breaths to allow the newly added DIL to mix with the loop gas and then decide how much O2 to ad with the manual bypass.

2. A diver is at 20m with a set point of 1.2 BAR. She casually swims over a fan coral while checking the PO2 which drops as the ambient pressure drops. Should she inject more O2 or increase the mass flow on the needle valve? No. Just swim back down to 20 m, if that was the planned depth, and the set point should be back on track.

3. A diver is adjusting the needle valve on the fly and finds that even with an unusually high setting the PO2 is still below set point. Should he open the needle valve further? No. The needle valve is not a tool to bring the loop PO2 to set point. This should be done with the manual O2 bypass valve or the ADV. Once set point is reached the needle valve is adjusted to prolong the intervals between manual injections. If he finds that the needle setting now over shoots the set point he should reduce the flow of the needle and use the ADV to bring the loop back to set point. Then evaluate the new needle setting over the next few minutes and repeat if needed.

Finally, if you find yourself confused about what to do at what time a simple approach is to eliminate the needle valve setting by closing it fully. Next, get to set point using manual O2 bypass valve and ADV. Now you know that the Po2 will drop a bit faster than when using the needle valve and that means you have to push the manual bypass a bit more frequently. That's all!

Section 7 - Diving the Pelagian DCCCR

Pelagian DCCCR Skills Confined Water:

1 – **ORIENTATION** - Lay negative on bottom in shallow water to find min. loop volume, try ADV out and practice manually keeping set point of 0.8 bar Po2. Practise reducing Po2 by ADV. Adjust low anchor point of counter lungs as needed to reduce "float" and "spring effect". Needle valve closed. Bubble check.

2 - **Bail Out In Stationary Position** - Shallow water. Stress checking Po2 before going back to the loop.

3 - **Mask Clearing & Mask Removal** - Shallow water.

4 - **Hovering Stationary** - Shallow water.

5 - **Swim while keeping set point with closed needle.** Focus on trim, comfort and buoyancy. - Shallow water.

6 – **Descent** - Stress vertical position to reduce WOB during ADV addition - Deep water (max 6 m.)

7 - **Set Point Toggle**. Maintain 0,6 BAR Po2 for a few minutes while swimming and keeping depth constant. Then change to 0,9 BAR Po2 for a few minutes. Alternate as needed until able to stay within +-0,1 BAR of set point. Needle valve closed.

8 - **Instant Cell Validation** – Exhale through nose then one slow inhalation once the ADV triggers.

9 - **Cell Moisture Removal** – Exhale though nose and one fast inhalation once the ADV triggers.

10 – **Remove / replace DSV** – let go of DSV, secure and replace it. If unit is not equipped with optional BOV, this skill should be practiced before bail out drill.

11 - **Exhalation Hose Drain** - Push corrugations together, assume vertical trim, look up and tilt right.

12 - **Loop Flush** - Stress low ADV and high dump valve position. Do NOT pull the loop dump until the ADV is free flowing as to prevent water intrusion. Use left arm to pull the dump and right arm to alternate between crushing the inhalation and exhalation hoses above the T-pieces 10 seconds for each hose. This will drive high po2 from scrubber and inhalation counter lung while reducing positive buoyancy.

13 – **Loop Drain** - Assume vertical trim. Deflate Wing. Purge ADV while pulling loop dump vale. Note: Some divers will not be able to reach the ADV purge, especially wearing a dry suit or heavy wetsuit. If so, anchor leg to stationary object (pool ladder etc.) and draw air from bail out, exhale into loop and repeat until loop is sufficiently over pressurized to force water out of the dump.

14 – **Ascent** - Stress Po2 control, venting loop gas before adding O2. Deflating wing / dry suit early and keeping a larger loop volume will make it easier to prevent the ADV from triggering. Practice until you can stop and hover one foot under the surface. At the surface: 1 - inflate wing, 2 - close DSV, 3 - remove DSV.

15 - **Metabolic Rate** - Swim at surface in relaxed pace while keeping set point at 0,8 BAR Po2 and adjust needle until no manual additions are needed. Exit the water, measure flow with flow meter and note result on check sheet. Turn down needle slightly.

16 – **Descent Prep**. - Close DILUENT valve and purge DILUENT line pressure. Flush loop 4 times with O2. Reduce loop volume. Note loop FgO2.

17 - **Proper Descent** - Descend with DILUENT valve closed while breathing from bail out. Ad O2 to loop with manual bypass instead of inflating wing to control speed of descent.

18 - **3rd Point Cell Linearity Check** - At the bottom, (max 6 m), ensure loop is at ambient pressure and check that all cells read ATA X Loop FgO2. Ascend to safe switch depth or Diluent flush before going to loop.

19 – **Set Point Swim With Needle** – Needle should be set so Po2 decays slowly. Practice rolls and various body positions. Note where ADV fires.

20 - **Needle Valve Reference** - Reference the needle valve setting mechanically, i.e "how many turns open from fully closed"? Close needle valve and re-open to original setting. Repeat with eyes closed.

FAILURE RESPONSES

21 - **Buddy Bail** - Pass bail out to buddy. Switch donor / receiver.

22 - **Bail Out Ascent** - Bail out, shut DILUENT tank valve, ascend while venting loop from dump valve or DSV.

23 - **Cylinder Shut Down** - Gradually build up speed. Readjust harness or re-position cylinder valves for easy reach if needed.

24 - **SCR Mode** - Shut O2 tank valve. Swim while exhaling every 2nd breath from nose and monitor Po2 display continuously.

25 – **Open Loop Mode** – Inhale from mouth and exhale from nose. Stress vertical body position to reduce WOB.

26 - **O2 Leak** - Shut O2 tank valve, keep O2 bypass depressed to simulate leak, maintain set point by feathering O2 tank valve.

27 - **ADV Leak** – Flash card “ADV Leak”, Instructor purges students ADV, student shuts down DILUENT. Flash card "high O2". Student exhales from nose and feather DILUENT cylinder briefly to bring down Po2.

28 – **CCR Removal And Replace** – Shallow water – IMPORTANT! The DILUENT valve has to be shut and line pressure purged BEFORE skill is practiced to prevent the ADV from triggering which would make the unit positive. The needle valve has to be closed BEFORE skill is practiced to prevent Po2 build up. Practice skill while breathing from OC bail out. Flush DILUENT and check Po2 before breathing from the loop!

29 – **SMB Deployment** – Technique will vary with type of SMB and reel. However, under no circumstance shall the SMB be inflated direct from the mouth with the DSV / OC 2nd stage removed.

30 – **Rescue** – Approach "unconscious" CCR diver, evaluate, arousal, note Po2, secure DSV if not dislodged. If Bailout valve option is fitted, switch to OC. Do not remove DSV. Cradle tanks from behind. Initiate positively buoyant ascent by inflating casualty's wing. Once loop expands, vent it by tilting casualty's DSV or tilt casualty to the left and dump. At surface inflate wing, close and remove DSV, alert boat and commence resuscitation and tow.

Open Water Dive 1

1 **Entry** – Student enters water breathing from bail out reg, 100% o2 in the loop, needle valve closed, DILUENT tank valve closed and DILUENT line pressure purged.
2 **Descent** – Descend to 6m while breathing the OC bail out. Ad O2 to loop to arrest descent speed.
3 **3rd Point Cell Linearity Check -** Ensure loop is at ambient pressure and check that all cells read ATA X Loop FgO2. Ascend to safe switch depth before going to loop. Open DILUENT and bring down PO2 to 0.7 BAR Po2.
4 **Bubble Check**
5 **Descent to max depth**, (see general CCR standards) – Watch out for O2 spikes. Encourage vertical trim to aid ADV.
6 **Instant Cell Validation**
7 **Setpoint** – Bring loop to set point 1,2 BAR Po2 while maintaining depth.
8 **Tour -** Maintain set point with max +- 0,2 BAR Po2 deviation. – Keep depth constant, watch out for nose breathing and overshooting set point.
9 **Bail out –** Stress checking Po2 before breathing from loop.
10 **Instant Cell Validation**
11 **Ascent** – A condensed multilevel ascent is recommended to allow time for buoyancy and Po2 control – Stress venting loop gas before adding O2 and deflating wing early on as keeping loop volume slightly over pressurized will prevent ADV from triggering.
12 **Safety stop -** 5 min at 6 meters.

13 **Surface** – Reinforce "step 1 inflate wing, step 2 shut DSV step 3 remove the loop". If surface is rough have students breathe their bail out.

Open Water Dive 2

1 **Entry** – Student enters water breathing from bail out reg, 100% o2 in the loop, needle valve closed, DILUENT tank valve closed and DILUENT line pressure purged.
2 **Descent** – Descend to 6m while breathing the OC bail out. Ad O2 to loop to arrest descent speed.

3 **3rd Point Cell Linearity Check -** Ensure loop is at ambient pressure and check that all cells read ATA X Loop FgO2. Ascend to safe switch depth before going to loop. Open DILUENT and bring down Po2 to 0.7 BAR Po2.
4 **Bubble Check**
5 **Descent to max depth**, (see general CCR standards)
6 **Instant Cell Validation**
7 **Setpoint** – Bring loop to set point 1,2 BAR Po2 while maintaining depth.
8 **Tour -** Maintain set point with max +- 0,1 BAR Po2 deviation.
9 **Cell Moisture Removal**
10 **Loop Flush**
11 **Remove / Replace DSV**
12 **Exhalation Hose Drain**
13 **Loop Drain**
14 **Instant Cell Validation**
15 **Ascent** – A slow continuous ascent is recommended to further practice buoyancy and Po2 control – Stress venting loop gas before adding O2 and deflating wing early on as keeping loop volume slightly over pressurized will prevent ADV from triggering. Student briefly stops 0,5 m under the surface to demonstrate 100% buoyancy control.
16 **Safety stop -** 5 min at 6 meters.
17 **Surface**

Open Water Dive 3

This is the first OW dive using the needle valve. Use flow chart to work out what surface flow makes up for metabolic rate of diver at rest at max depth. Set flow and reinforce taking a mechanical reference of the setting.

1 **Entry** – Enter water breathing from bail out reg, 100% o2 in the loop, DILUENT tank valve closed and DILUENT line pressure purged.
2 **Descent** – Descend to 6m while breathing the OC bail out. Ad O2 to loop to arrest descent speed.
3 **3rd Point Cell Linearity Check -** Ensure loop is at ambient pressure and check that all cells read ATA X Loop FgO2. Ascend to safe switch depth before going to loop. Open DILUENT and bring down Po2 to 0,7 BAR Po2.
4 **Bubble Check**
5 **Descent to max depth**, (see general CCR standards)
6 **Setpoint** – Bring loop to set point 1,2 BAR Po2 while maintaining depth.
7 **10 minute swim at constant depth -** Monitor Po2 continuously. Evaluate needle setting. Stress manual adjustments to get back to set point before trying a new needle setting. Watch out for depth deviations and mask clearing as it can easily confuse.
8 **Instant Cell Validation**
9 **10 minute swim at constant depth** – Use a 10 m shallower depth. Open the needle slightly.
10 **Valve shut downs** – Practice speed. Physically check that valves are open on completion!
11 **Flash cards: Hi / Low Po2** – Look for solution thinking. “Po2 is 1,4” – adjust Po2. “Po2 is 1,8” – bail out, check unit, flush, check Po2 and go back on loop etc.
12 **Instant Cell Validation**
13 **Ascent**

14 **O2 flush -** Ascend to 5 m, close DILUENT and purge loop with O2. Note: BEFORE skill practice commence, hold on to a shot line to prevent sinking with high set point in the loop!
15 **Safety stop -** 5 min at 6 meters at set point 1,5 BAR Po2.
16 **Surface**

Open Water Dive 4

Use flow chart to work out what surface flow makes up for metabolic rate of diver at rest at max depth. Set flow and reinforce taking a mechanical reference of the setting.

1 **Entry** – Enter water breathing from bail out reg, 100% o2 in the loop, DILUENT tank valve closed and DILUENT line pressure purged.

2 **Descent** – Descend to 6m while breathing the OC bail out. Ad O2 to loop to arrest descent speed.
3 **3rd Point Cell Linearity Check -** Ensure loop is at ambient pressure and check that all cells read ATA X Loop FgO2. Ascend to safe switch depth before going to loop. Open DILUENT and bring down Po2 to 0,7 BAR Po2.
4 **Bubble Check**
5 **Descent to max depth**, (see general CCR standards)
6 **Instant Cell Validation**
7 **Setpoint** – Bring loop to set point 1,2 BAR Po2 while maintaining depth.
8 **SCR Mode -** Shut O2 tank valve. Swim while exhaling every 3rd breath from nose and monitor Po2 display continuously.
9 **Open Loop Mode** – Inhale from mouth and exhale from nose. Stress vertical body position to reduce WOB.
10 **O2 Leak -** Shut O2 tank valve, open needle fully to simulate leak, maintain set point by feathering O2 tank valve.
11 **ADV Leak** – Flash card “ADV Leak”, Instructor purges students ADV, student shuts down DILUENT. Flash card "high O2". Student exhales from nose and feather DILUENT cylinder briefly to bring down Po2.
12 **Flash card “Cell 1 & 2 disagree”** – Student should use Instant Cell Validation. Signal “Cell 1 is out” or similar. Student should signal “end the dive” or bail out.
13 **SMB Deployment**
14 **Ascent**
15 **O2 flush** – At 5m.
16 **Safety stop -** 5 min at 6 meters.
17 **Surface**

Open Water Dive 5

Brief students that they are expected to perform skills like, Bubble check, 3rd Point Cell Linearity Check, needle valve adjustments, Po2 control and Instant Cell Validation with out prompt. For Failure Scenarios, do not use flash cards suggesting remedy, but rather describes a situation in order to gauge the students solution thinking ability.

1 **Entry** – Student enters water breathing from bail out reg, 100% o2 in the loop, DILUENT tank valve closed and DILUENT line pressure purged.

2 **Descent** – Descend to 6m while breathing the OC bail out. Ad O2 to loop to arrest descent speed.
3 **3rd Point Cell Linearity Check -** Ensure loop is at ambient pressure and check that all cells read ATA X Loop FgO2. Ascend to safe switch depth before going to loop. Open DILUENT.
4 **Bubble Check**
5 **Rescue** – At max depth 6 m, approach "unconscious" CCR diver, evaluate, arousal, note Po2, secure DSV if not dislodged. If OC/CC option is fitted switch to OC. Do not remove DSV. Cradle tanks from behind. Initiate positively buoyant ascent by inflating casualty's wing. Once loop expands vent by tilting casualty's DSV or tilt left and dump. At surface inflate wing, close and remove DSV, alert boat and commence resuscitation and tow.
6 **Descent**
7 **Co2 Breakthrough Scenario 1** – Flash card "head ache, increased breathing rate". Student should bail out. Flash card "bail out depleted". Student should check Po2, go back to the loop, flush loop, use open loop mode or on board OC and signal "end the dive". Cut. Note: If student signals "share air", give credit, but signal back "buddy gone".
8 **CCR Gas Leak Scenario 2 -** Flash card "GAS LEAK" while purging students ADV, student should shut down O2 and DILUENT valves, bail out to OC, vent loop volume and check SPGs and Po2 display. Instructor points to the "dropping" O2 SPG. Instructor use flash card for "Bail out gas depleted". Student should open the DILUENT valve, flush the loop, check Po2 display, go back to the loop, feather O2 valve back to set point and signal "end the dive". Cut. Note: If student signals "share air", give credit, but signal back "buddy gone".
9 **CCR Gas Leak Scenario 3 -** Flash card "GAS LEAK" while purging students ADV, student should shut down O2 and DILUENT valves, bail out to OC, vent loop volume and check SPGs and Po2 display. Instructor points to the "dropping" DILUENT SPG. Instructor use flash card for "bail out depleted". Student should open the O2 valve, check Po2 display, go back to the loop and signal "end the dive". Cut. Note: If student signals "share air", give credit, but signal back "buddy gone".
10 **O2 Depleted Scenario 4** – Flash card "O2 depleted". Student should bail out. Flash card "Bail out depleted". Student should check Po2, go back to the loop, use SCR mode and signal "end the dive". Cut
11 **Dead Display Scenario 5** – Flash card "All displays are dead". Student should bail out. Keep student on OC.
12 **SMB Deployment**
14 **OC Ascent**
13 **Safety stop -** 5 min at 6 meters.
14 **Surface**

Open Water Dive 6

Providing all previous skills are completed satisfactory, brief students that this last training dive will not contain any prompted skills and that they should regard it as a regular leisure dive. Are they in the driver's seat or not? If previous skills need more practice, at least allocate a portion of the dive for a final evaluation of the student's general readiness.

Additional Problems/Solutions

Po2 display shows different or static readings in 1 or 2 cells – Diluent Flush – Sensor validate – Check ext sensor (VR3) – Expected Results? Yes? Carry on, Monitor. No? Abort Possible Cause - Current Limited Cells

Po2 Rising above 1.3 - Back off needle valve, Diluent Flush, stabilize readings
Po2 Rising above 1.4 - Close Needle valve, Diluent Flush, stabilize readings
Po2 Still Rising – Diluent Flush, Close O2 cylinder valve – Feather valve – Abort dive

Oxygen Hose fitting rupture – Close O2 cylinder valve – bail out*

Po2 Falling – Exhale through Nose 1 breath, add O2 with manual add button.
Po2 Falling – Check O2 tank spg / valve. Empty? Bail-out.
Po2 Falling - Open Needle Valve further, manually add o2

Po2 Display Battery failure – Abort using External Sensor (vr3) No external sensor - Turn off O2 tank. Abort in SCR mode (exhale every third breath, listen for ADV trigger)

Buoyancy Gain – Check Po2, Exhale through nose, suggest ADV leak, close DILUENT valve, watch spg fall.

Buoyancy Gain – Check/High po2, think 02 add valve bypass, Diluent flush. Close Needle Fixed? Yes, monitor. No, close O2 tank valve and abort, feather o2 valve as needed

Buoyancy Loss – Loop leaking?, Leaking Mask?, Leaking exhale lung o/p valve? Bubble check Rig, BCD, Drysuit. Compensate ONCE, problem persists, Abort Dive.

OPV trigger on O2 1st stage – Look up, bubble check, monitor P02. Close 02 tank valve, feather as necessary

Free-flow on Inboard Bail-out reg/ ADV leak. Think 1st or 2nd stage failure. Close Diluent cylinder valve. Ascend, Prepare Off-board Bail-out regulator.

Buddy signals OOA – offer off-board Bail-Out regulator. Abort

Unconscious CCR Diver found – BOV present? Activate BOV if no BOV then check Po2 display, Add O2 manually or depress ADV to stabilise PO2 as necessary. Stimulate diver, assume diver IS breathing. Re-track to up line, ascend. Do not endanger self.

Convulsing diver - gain contact by grasping casualties arm or hand. Heading for shallower water will lower possibly excessive loop po2. Monitor loop volume during ascent to control buoyancy. Rock DSV downwards to dump excess loop gas, open drysuit over pressure valve and/or monitor BCD inflator. Re-track to up line if possible, watch Deco obligations, ascend. Do not endanger self.

Section 8 - CCR Dive Planning

Closed Circuit Rebreathers give us theoretical gas durations only dreamt about by our Open Circuit cousins. This can be a blessing and a curse as CCR divers can routinely plan and perform gas hungry dives that push the limits of their physiology often with little thought to the open circuit bail-out considerations and support logistics either. The human body is not a machine and generally only operates without problem within a fairly slim set of parameters with regard to oxygen, nitrogen, co2 and thermal exposures and insufficient bail-out could lead to the need of water breathing – not recommended!

PO2 Derivation

A major benefit of Closed Circuit equipment is the ability to maintain a fixed pressure of oxygen (known as Po2 or set-point) throughout the dive. Tradition has dictated using lower po2's such as 1.1-1.3 po2 for the bottom depth of the dive switching to higher pressures of oxygen (1.3-1.4) during the decompression or safety stop phase. Using the manual addition button or needle valve of the Pelagian unit allows the user to add and maintain a set point fairly easily with practice but users most pay extremely close attention to the dual Po2 display at all times to ensure that the set-point stays where needed.

Extensive dive time, particularly cave diving or wreck dives in relatively deep water will require lengthy decompressions and fall outside the scope of this user manual. New users of the Pelagian CCR should stay within the no-decompression limits of an air table for at least 20 hours of use. The no decompression limits recommended are those provided by a reliable air table such as the Buhlmann tables located in the appendix of this manual. New divers or those moving from electronic CCR to manual CCR should practice their po2 maintenance extensively using the manual addition and or needle valve so that they can reliably maintain their desired set-point accuracy throughout the entire dive with plus/minus 0.1 bar po2 variation. After 20 hours of use it would be acceptable to progress to using constant po2 tables generated by software or wrist worn dive computers allowing this feature.

Guidance note: Users following a fixed po2 dive plan should strive to keeping their inspired po2 at 0.1 above the setpoint used by the table.

For new users using open circuit air tables to plan a dive and wishing to get some decompression advantage for using a constant po2 the calculation for finding your EAD (equivalent air depth) formula is listed below.

Metric EAD = (P-Po2 / 0.79) -1 x 10 or Imperial EAD = P-Po2 / 0.79 -1 x 33

P = Pressure in ata's (target depth in metres divided by 10)

Examples with an o2 setpoint of 1.3 are as follows (target depth 32msw (106fsw)

(4.2 (32msw as ata) – 1.3 (po2) / 0.79) – 1 x 10 = 27 metres EAD

(4.2 (106fsw as ata) – 1.3 (po2)) / 0.79) -1 x 33 = 89 feet EAD

Use the EAD figure with an air table of your choice. Remember to maintain the po2 used during the calculation!

Guidance note: Desired Po2 should be maintained as closely as possible during the time at maximum depth. During the ascent manual CCR users should aim to keep set-point as close to 1.0 bar as possible before bringing set-point back to desired level during the decompression / safety stop phase.

BAIL-OUT

Let us spend some discussing Bail-out options. Numerous CCR divers have died because they either did not take sufficient bail-out volumes or they dithered deciding when to switch to bail-out. Switching to Bail-out early or even immediately is not a sign of weakness – it is the only way you can analyse a problem without continuing to breathe a gas that very likely will ultimately render you unconscious in seconds or minimally, confuse the hell out of you causing you to make the wrong choice or react inappropriately.

Guidance note: CCR divers should check the viability of all breathable Bail-out tanks throughout the dive, including clearing the BOV of water with every increase in depth. In-line shut-off valves have no place on any CCR unit – if you have leaks anywhere…fix them before diving!

The Team bail-out notion where only one set of OC bail-out tanks is split between the dive team is not recommended. While CCR problems are relatively rare it is advisable that every team member carry ALL the gas necessary to reach the surface. Problems with more than one diver are not unheard of! Bail-out cylinders are those completely isolated from the CCR, also deemed off-board.

Guidance note: Carrying a larger diluent tank and plumbing in an extra 2nd stage does not constitute redundant bail-out. Consider the implications of the diluent 1st stage failing in this case (or any other part connected to it – Lost Diluent = Lost ADV = Lost on board Bail-out = Lost buoyancy device. Using a larger diluent tank in conjunction with a BOV makes some sense though in that it offers extra breathing / thinking time to fix any problems related to off-board Bail-out tanks.

All CCR divers should take at least one cylinder of bottom mix to be used during an open circuit ascent in addition to any necessary decompression gases. During no-decompression users are advised to carry an Nitrox mix optimised for the maximum depth. The bail-out tank must be of a suitable size to allow the user to easily reach the surface. When calculating Bail-out tank volumes it would be wise to use a higher than normal RMV (upto 30litres per min) for calculations.

Guidance note: carrying suitable bail-out reserves for use by a buddy in need is a 'Grey Area' in CCR training. While in an ideal world we would all be completely self sufficient remember that both yourself and buddy are not likely suited to breathe water! 2 second stages on any Bail-out tanks is worthy of consideration unless you plan on beating off any out-of-air divers that approach you!

Planning a fixed set-point dive

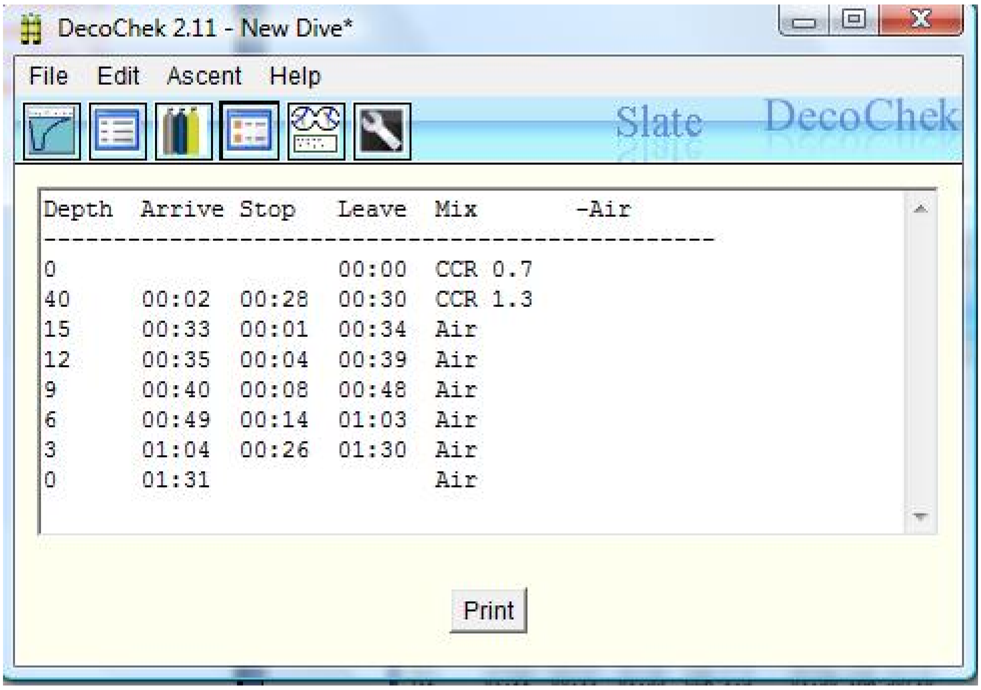
Depth	Arrive	Stop	Leave	Mix	-CCR
0			00:00	CCR 0.7	
40	00:02	00:28	00:30	CCR 1.3	
9	00:34	00:02	00:36	CCR 1.3	00:40 Air
6	00:36	00:05	00:41	CCR 1.3	00:49 Air
3	00:41	00:08	00:49	CCR 1.3	01:04 Air
0	00:49			CCR 1.3	01:31 Air

Using software to plan a CCR dive is straightforward. The example above uses a set-point of 1.3 po2. On leaving maximum depth manual CCR users should aim to keep the set-point around 1.0bar so as not to violate the ascent ceiling. On arriving at the ascent ceiling i.e. the first stop, users must stablise the set-point to that used to calculate the table. To offset any set-point violations made during the ascent users may wish to add a minute or two to the 1st deco stop time.

Guidance note: Ascending on a manual CCR can cause large set-point fluctuations with new users. A useful option to minimize decompression risk would be to increase CCR set-point to 0.1 bar over and above the set-point used during planning of the dive. Users with dive computers with a fixed po2 decompression option may wish to set the set-point of the wrist computer at 0.1 bar lower than the planned set-point – this will add some useful conservatism.

Any divers considering following the previous example should consider the following with regard to Bail-out.

Worst case scenario is leaving maximum depth at maximum time and the CCR failing at the beginning of the ascent – these things happen.

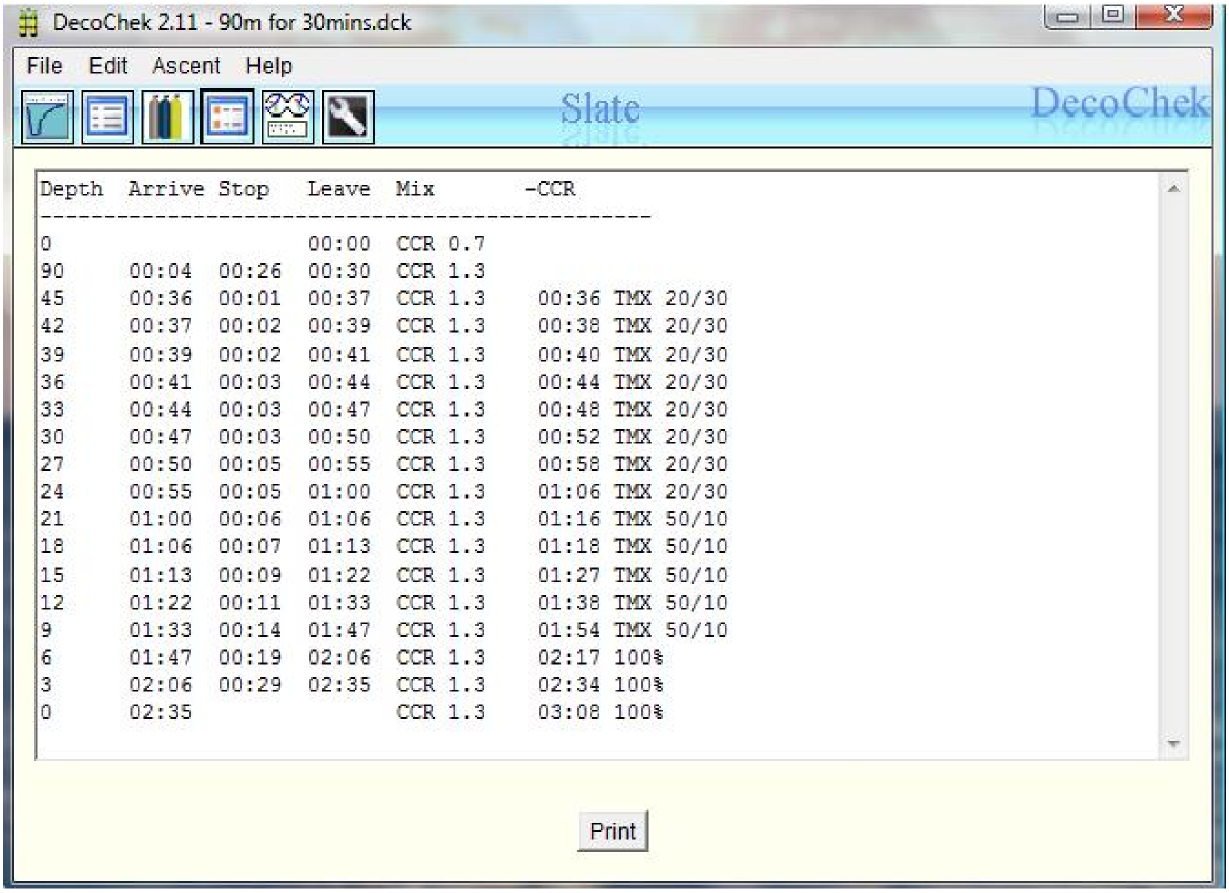


Depth	Arrive	Stop	Leave	Mix	-Air
0			00:00	CCR 0.7	
40	00:02	00:28	00:30	CCR 1.3	
15	00:33	00:01	00:34	Air	
12	00:35	00:04	00:39	Air	
9	00:40	00:08	00:48	Air	
6	00:49	00:14	01:03	Air	
3	01:04	00:26	01:30	Air	
0	01:31			Air	

By losing the fixed set-point afforded by the CCR the decompression obligation increases dramatically. The extra ascent and decompression neccessitates taking a 12 litre tank for bail-out – this tank must be filled to a minimum of 200 bar if using a breathing rate of 20 litres per minute. If the CCR was to suffer a co2 hit at the end of the bottom time (surely elevating the breathing rate to 40 litres or more per minute for an extended time then staying close to a buddy also carrying a 12litre tank and hopefully not experiencing the same problem as you would be prudent!

Filling the bail-out cylinder with Nitrox 32 and having a plan to suit could shave 15minutes from the decompression and leave a bit remaining in the tank – well worth considering.

The following example is a 90metre dive with 30minute bottom time. Setpoint is 1.3.


DecoChek 2.11 - 90m for 30mins.dck

File Edit Ascent Help

Slate DecoChek

Depth	Arrive	Stop	Leave	Mix	-CCR
0			00:00	CCR 0.7	
90	00:04	00:26	00:30	CCR 1.3	
45	00:36	00:01	00:37	CCR 1.3	00:36 TMX 20/30
42	00:37	00:02	00:39	CCR 1.3	00:38 TMX 20/30
39	00:39	00:02	00:41	CCR 1.3	00:40 TMX 20/30
36	00:41	00:03	00:44	CCR 1.3	00:44 TMX 20/30
33	00:44	00:03	00:47	CCR 1.3	00:48 TMX 20/30
30	00:47	00:03	00:50	CCR 1.3	00:52 TMX 20/30
27	00:50	00:05	00:55	CCR 1.3	00:58 TMX 20/30
24	00:55	00:05	01:00	CCR 1.3	01:06 TMX 20/30
21	01:00	00:06	01:06	CCR 1.3	01:16 TMX 50/10
18	01:06	00:07	01:13	CCR 1.3	01:18 TMX 50/10
15	01:13	00:09	01:22	CCR 1.3	01:27 TMX 50/10
12	01:22	00:11	01:33	CCR 1.3	01:38 TMX 50/10
9	01:33	00:14	01:47	CCR 1.3	01:54 TMX 50/10
6	01:47	00:19	02:06	CCR 1.3	02:17 100%
3	02:06	00:29	02:35	CCR 1.3	02:34 100%
0	02:35			CCR 1.3	03:08 100%

Print

The above table shows to the left the dive-plan to be followed when all goes to plan but in addition the modified plan necessary when performing an open circuit bail-out ascent, to the right. The plan is followed by leaving the appropriate stop depth at the new ‘run-time’.

It is interesting to note the open circuit gas requirements for an ascent at end of bottom time: RMV 18litres per min with zero reserves.

Trimix 14/56 ascending from 90m to 70m = 180bar in 3 litre
Trimix 20/30 ascending from 70m to 21m = 292bar in 12 litre!
Trimix 50/10 ascending from 21m to 6m = 208bar in 12 litre
Oxygen used at 6m and 3m = 185bar in 7 litre

Dives to trimix depths should include sufficient Bail-out for each diver personally to reach the surface without the often frantic search for a team mate who might be carrying the gas you need!

On all CCR dives optimised Bottom Mix is advised rather than using Hypoxic Trimixes such as 10/50 for all dives – this practice is popular with internet experts and has led to many hypoxic deaths some even in a swimming pool!

Some decompression software titles penalise the user for using Helium, good ones don't. With software that does increase decompression times users should avoid the practise of changing Diluents with lower Helium fractions during ascent planning. This practise simply tricks the software into producing shorter decompressions with little regard to actual the physiological processes involved. It is recommended that 'Diluent' switches are not incorporated into dive plans or attempted during actual dives. Should the diver need to change diluent while ascending then careful consideration should be given to the END changes that could occur with Diluents containing diminishing Helium fractions.

The old Open Circuit practice of removing or minimising Helium in decompression gases is to be avoided on CCR (and OC) but don't add ridiculous Helium concentrations either in an attempt to look fashionable. Helium is far less forgiving after ascent speed violations and excessive Helium use can complicate OC bail-out choices with possibly dire consequences.

Guidance note: It is you the diver that will face the difficulties and dangers of taking insufficient bail-out reserves, often alone. All the internet advice and pub banter in the world will not help you underwater. Remember that the traditional advice about 'going semi-closed' and 'open loop' etc ignores the potential consequences of a catastrophic co2 hit.

Regarding Carbon Dioxide absorbent – If in doubt, throw it out!

Remember also that while underwater…If in doubt – Bail Out and oh yes, If in doubt – Bail Out . That is some free advice that might save your life!

Section 9 – Post-Dive Maintenance

After diving it is normal for condensation to be present in the head of the unit. Easy to reach moisture may be removed by patting with kitchen towel etc. Do not blow moisture away with compressed air. Allow all moisture to evaporate overnight while sealing the scrubber with a plastic bag or similar. Do not leave head in place for extended periods if obviously damp.

Section 10 – General Pelagian Maintenance

Optional parts from Rebreather Lab:

Explorer Scrubber – Scrubber mid section that accept 4.5 kg of Sofnolime 797 for up to 8 hours dive time (in warm water)

OC/CC DSV (BOV) –Switch between high performance balanced OC bailout and loop with out removing the mouth piece.

Full face mask adapter - For use with the Draeger Panorama Dive full face mask.

Pelagian Wing – 50 Ib wing with low top profile and length designed for the Pelagian DCCCR.

Spares Kit – Complete loop o-ring kit, 4 scrubber lock pins and scrubber sticker.

Flow rate meter – 0.2 – 1.2 lpm graduation and inflator nipple for easy connection from Pelagian DCCCR O2 addition unit.

▲WARNING! Failure to buy ALL options WILL result in personal injury / death or worse!

Bail-Out Valve (BOV)

Pelagian DCCCR Diver Final Exam – rev.1.1

Name: ___________________________________ Date: _______________________________

This exam helps to identify weak areas of understanding. It is open book, open tables and should be used as a learning tool.

Conventions: Some questions use a set point of 1.5 BAR PO2. For real dive planning the highest recommended set point is 1.3 BAR PO2 during the bottom phase of the dive. For air computations, use 21% O2 and 79% N2. Use formulas for all questions. Leave two decimals in your answer. Do not round up or down. All questions assume using the Pelagian DCCCR without a PO2 reading dive computer and bail out regulator, wing / dry suit connected to off board cylinder(s).

1. What is the meaning of SETPOINT? Explain the difference of set point with an electronically controlled CCR and the Pelagian DCCCR.

2. Can you calibrate your PO2 Displays to 1.3 BAR O2 on the surface?

3. If you have 90% oxygen in your oxygen cylinder and calibrate your PO2 Displays to read 1.000 BAR PO2 at the surface, would the real PO2 value be higher, lower, or the same as your display readout?

4. When running a set point of 1.2 BAR PO2 what do you use as the "worst case" PO2 value for:
   A) CNS management? B) Decompression / NDL management?

5. By what means is the set point on the Pelagian DCCCR maintained?

   A) Tools provided with the rebreather:

   B) List the most important tool that is not included with the rebreather.

6. When manually adding oxygen it takes a few breaths for the oxygen to blend with the gas in the breathing loop.

   A) Describe the proper way of adding O2 to prevent a too high PO2.

   B) In the event you ad too much oxygen, how do you bring the PO2 down?

7. If you are at 20 meters running a 1.2 set point, what is the % of oxygen in the breathing loop?

8. Why would a pure oxygen rebreather be unsuitable for recreational diving?

Pelagian DCCCR Diver Final Exam

9. You are at 20 meters. Your buoyancy is neutral and suddenly it becomes very positive. List the possible reasons and your actions in order of importance.

10. You are at 20 meters. Your buoyancy is neutral and suddenly it becomes very negative. List the possible reasons and your actions in order of importance.

11. You are running a 1.3 set point. What are the % values of oxygen in the breathing loop at these following depths?

    38 meters

    26 meters

    16 meters

    12 meters

    6 meters

12. You plan a shallow 9 meter dive on a set point of 1.5, (not recommended). Your scrubber material is fresh and the battery is newly replaced. What will be the limiting factor of the dive?

13. If the set point of the above dive was 1.1, what would be the limiting factor?

14. With how many fuel cells (oxygen sensors) is the Pelagian DCCCR used?

15. If the battery for your PO2 display for one fuel cell fails during a dive what will happen to the PO2 display for the other cell(s)?

Pelagian DCCCR Diver Final Exam

16. Can you continue the dive? Describe your actions.

17. When is it recommended to change the battery?

18. Why is it recommended NOT to change all fuel cells on the same date?

19. A) Describe the complete recommended procedure for calibrating the Pelagian DCCCR before the dive.

    B) Describe an easy way to, with reasonable accuracy, validate sensor linearity between 0.21 – 1.6 BAR PO2 and to detect a current limited sensor.

20. You start to experience breathing resistance 20 minutes into the dive on a Pelagian DCCCR with newly changed scrubber material.

    What would be the likely cause?

    What other indications would exist?

    What are your actions?

21. What CAN be the indicators of an exhausted CO2 absorbent canister while diving?

22. What is the medical term for increased level of CO2?

23. If you surface from a dive, switch your PO2 displays and O2 cylinder off and swim 100 meters to an anchored boat while breathing off the loop, what could happen?

24. What is the medical term for this?

25. List two physical benefits of rebreather diving compared with open circuit diving.

26. Explain the differences between Semi-Closed Circuit and Closed Circuit rebreathers.

    A) Semi-Closed Circuit:

    B) Closed Circuit:

Pelagian DCCCR Diver Final Exam

27. Sketch the mechanical layout of a Pelagian DCCCR. Be detailed. Make sure to put all components in its correct position.

28. What is the EAD for a dive to 30 meters using a 1.5 set point corrected for nitrogen?

29. What is the EAD for a dive to 30 meters using a 1.3 set point corrected for nitrogen?

30. What products can be used to disinfect the rebreather? What parts should be disinfected?

31. What is the by-product of the reaction process across the scrubber granular bed?

32. Why is it necessary to calibrate the oxygen sensors and how often should it be done?

33. A) Explain a simple way of validating the sensor read outs during a dive on a Pelagian DCCCR.

Pelagian DCCCR Diver Final Exam

B) In what events should you validate your sensor read outs?

C) How does moist on the sensor faces affect the PO2 display read outs?

D) During a dive, what can be done to remove moist from the sensor faces?

35. What is the minimum PO2 of oxygen needed to prevent hypoxia?

36. A diver undertakes a dive to 25 meters for 25 minutes with a set point of 1.3 BAR PO2. What is the divers CNS % loading?

37. If the diver increased the set point to 1.5 for the same dive, what would be the new values for the CNS % loading?

38. List your pre-dive safety checks on a Pelagian DCCCR. Be detailed and list WHY you are doing a certain check. List the checks in the correct order for the sake of efficiency.

	.
	.

39. List your actions for a post-dive rinsing, break down and maintenance.

40. What is the correct intermediate pressure of the Pelagian DCCCR oxygen regulators first stage?

Pelagian DCCCR Diver Final Exam

41. How would setting the intermediate pressure higher than recommended affect the O2 dosage?

42. Is the oxygen first stage regulator on a Pelagian DCCCR depth compensating, (like a normal SCUBA regulator), or is it not responsive to ambient pressure changes, (like a medical O2 regulator)?

43. Providing the needle valve setting is un-altered, how does this affect the dosage of oxygen as you go deeper?

44. Providing the needle valve setting is un-altered, how does this affect the dosage of oxygen as you go shallower?

45. In what way can you compensate for this, (what you answered in question 44), using the needle valve?

46. List the three physical factors of the O2 feed system which determine the dosage of oxygen to the breathing loop.

47. By how many percent / meter does the O2 dosage increase by diving deeper?

48. A diver's metabolic rate at rest is 0.6 lpm at the surface. He is planning a dive to 40 msw. Before the dive he wants to adjust the flow of the needle valve to supply an O2 dosage of the surface equivalent of 0.5 lpm at max depth. What flow should he adjust the needle valve to?

49. You are at 16 meters and your PO2 displays read 1.200. The needle is set perfect for 16 m. You intend to descend to 40 meters. What will you need to do to maintain your PO2 at 1.2?

50. You are at 40 meters and your PO2 display read 1.200. You intend to ascend to your safety stop and you have planned the dive with a set point of 1.2. What will you need to do through out the ascent to maintain your set point at 1.2?

51. What is the meaning of keeping a minimum counter lung volume?

52. What are the advantages with a minimum counter lung volume?

Pelagian DCCCR Diver Final Exam

53. How can you dive your Pelagian DCCCR in semi-closed mode and for what purpose would you do it?

54. Plan a dive to 30 meters for 15 minutes on a set point of 1.2 bar PO2. Your expected O2 consumption is 0,9 lpm. You want the needle valve to give a surface equivalent O2 dosage of 0,7 lpm at max depth. Your O2 cylinder is 2.7 liters and filled to 100 BAR. Your anticipated SAC rate under stress is 30 lpm. Plan for a 5 min safety stop at 3m. Show what surface flow rate you will set the needle to. Show your CNS% load, EAD and end pressure group using Bühlmann tables. Show how many BAR of O2 you will theoretically consume and how much O2 you think you will actually use. What size bail out cylinder will you carry?

Surface flow:

CNS %:

EAD:

PG:

Theoretical O2 consumption:

Practical O2 consumption:

Bail out:

55. What dive planning tools could you use for the above dive other than traditional tables?

56. Do you consider yourself competent enough to undertake dives on a Pelagian DCCCR with out your instructor?

I have reviewed the questions with my instructor and completely understand the questions I may have missed. I am satisfied with my training and the information presented and I feel confident to make Pelagian DCCCR Closed Circuit Rebreather dives without supervision.

Signed______________________________________ Date________________________

Name ____

Address____

Age______________________ Phone____

APPENDIX

OXYGEN MASS FLOW CHART SHOWING POSSIBLE FLOW MODIFICATIONS AT DEPTH.

Depth	OXYGEN MASS FLOW CHART				
0 msw	0,4 LPM	0,45 LPM	0,5 LPM	0,55 LPM	0,6 LPM
5 msw	0,42	0,47	0,53	0,58	0,63
10 msw	0,44	0,50	0,55	0,61	0,66
15 msw	0,46	0,52	0,58	0,63	0,69
20 msw	0,48	0,54	0,60	0,66	0,72
25 msw	0,50	0,56	0,63	0,69	0,75
30 msw	0,52	0,59	0,65	0,72	0,78
35 msw	0,54	0,61	0,68	0,74	0,81
40 msw	0,56	0,63	0,70	0,77	0,84
45 msw	0,58	0,65	0,73	0,80	0,87
50 msw	0,60	0,68	0,75	0,83	0,90
55 msw	0,62	0,70	0,78	0,85	0,93
60 msw	0,64	0,72	0,80	0,88	0,96
65 msw	0,66	0,74	0,83	0,91	0,99
70 msw	0,68	0,77	0,85	0,94	1,02

To Calculate desired Flow consider the following - Example : Desired Mass Flow at 90msw is 0.7 lpm. What should the surface mass flow be adjusted to before the dive?

90 msw is a 90% increase
Or 1.9 as a fraction

0.7 lpm / 1.9 = 0.37 lpm at surface

Any flow rate required can be adjusted simply by using the needle valve and then verifying using a Dwyer (floating ball) gauge. Pelagian users are encouraged to obtain such a gauge.

Buhlmann Air Decompression Tables

BÜHLMANN DECOMPRESSION TABLES (AIR) TABLE 1																
Depth	**9M**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**33**	**36**	**39**	**42**	**45**	**48**	**51**	**RG**
m & ft	**30’**	**40’**	**50’**	**60’**	**70’**	**80’**	**90’**	**100’**	**110’**	**120’**	**130’**	**140’**	**150’**	**160’**	**170’**	
B -	25	19	16	14	12	11	10	9	8	7	7	6	6	**6**	**5**	**A**
O T	37	25	20	17	15	13	12	11	10	9	8	7	7	-	-	**B**
T I	55	37	29	25	22	20	18	16	-	-	-	-	**9**	-	-	**C**
T M	81	57	41	33	28	-	-	**17**	**14**	**12**	**10**	**9**	-	-	9/4	**D**
O E	105	82	59	44	**35**	**25**	**20**	25/5	15/3	15/3	15/4	12/4	12/5	9/3		**E**
M .	**130**	**125**	**75**	**51**	40/2	35/4	30/5									**F**
	150/4	150/4	90/7	60/5	50/8	40/8	35/10									**G**
PPO_2	**0.4**	**0.46**	**0.53**	**0.59**	**0.65**	**0.71**	**0.78**	**0.84**	**0.9**	**0.97**	**1.03**	**1.09**	**1.16**	**1.22**	**1.28**	

TABLE 2							**O Hrs**	**(Hrs**
Enter here from TABLE 1						A	2	2
using RG from previous dive.					B	20	2	2
Numbers are time in				C	10	25	3	3
minutes spent on			D	10	15	30	3	3
the surface.		E	10	15	25	45	4	3
	F	20	30	45	75	90	8	4
G	25	45	60	75	100	130	12	5
	F	E	D	C	B	A	“O”	FLY
	Take RG at end of surface interval to Table 3							

Re-Entry	TABLE 3 AIR (21% Oxygen) Next Dived Depth in metres & feet.											
Grp.	9m	12	15	18	21	24	27	30	33	36	39	42
	30’	40’	50’	60’	70’	80’	90’	100	110	120	130	140
A	25	19	16	14	12	11	10	9	8	7	7	6
B	37	25	20	17	15	13	12	11	10	9	8	7
C	55	37	29	25	22	20	18	16	14	12	11	10
D	81	57	41	33	28	24	21	19	17	15	14	13
E	105	82	59	44	37	30	26	23	21	19	17	16
F	130	111	88	68	53	42	35	30	27	24	21	19
G	154	137	115	91	72	57	47	40	35	31	27	25

Time limits for various oxygen partial pressures.

NOAA OXYGEN PARTIAL PRESSURE TABLE

PPO2 (bar/Ata)	Single dive limit in minutes	CNS % exposure per minute
1.6	45 minutes	2.22%
1.5	120 minutes	0.83%
1.4	150 minutes	0.65%
1.3	180 minutes	0.56%
1.2	210 minutes	0.47%
1.1	240 minutes	0.42%
1	300 minutes	0.33%
0.9	360 minutes	0.28%
0.8	450 minutes	0.22%
0.7	570 minutes	0.18%
0.6	720 minutes	0.14%

When the CNS % exposure from one or more dives added together reaches 80%, a 2 hour surface break should be taken. The residual oxygen dose falls by 50% every 90 minutes spent on the surface.

EQUIVALENT AIR DEPTH CHART

DEPTH		PERCENTAGE OXYGEN IN MIX (EQUIVALENT AIR DEPTHS IN METRES)																			
FT	MT	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
40	12	12	12	11	11	11	11	10	10	10	9	9	9	9	8	8	8	8	7	7	7
42	13	13	13	12	12	12	12	11	11	11	10	10	10	10	9	9	9	8	8	8	7
46	14	14	14	13	13	13	12	12	12	12	11	11	11	10	10	10	9	9	9	9	8
49	15	15	15	14	14	14	13	13	13	12	12	12	12	11	11	11	10	10	10	9	9
52	16	16	16	15	15	15	14	14	14	13	13	13	12	12	12	11	11	11	10	10	10
	17	17	17	16	16	16	15	15	15	14	14	14	13	13	13	12	12	12	11	11	11
59	18	18	18	17	17	17	16	16	16	15	15	14	14	14	13	13	13	12	12	12	11
62	19	19	19	18	18	18	17	17	16	16	16	15	15	15	14	14	13	13	13	12	12
66	20	20	20	19	19	18	18	18	17	17	17	16	16	15	15	15	14	14	14	13	13
69	21	21	21	20	20	19	19	19	18	18	17	17	17	16	16	16	15	15	14	14	14
72	22	22	22	21	21	20	20	20	19	19	18	18	18	17	17	16	16	16	15	15	14
75	23	23	23	22	22	21	21	20	20	20	19	19	18	18	18	17	17	16	16	15	15
77	24	24	24	23	23	22	22	21	21	21	20	20	19	19	18	18	18	17	17	16	16
82	25	25	25	24	24	23	23	22	22	21	21	21	20	20	19	19	18	18	17	17	17
85	26	26	26	25	25	24	24	23	23	22	22	21	21	21	20	20	19	19	18	18	17
89	27	27	27	26	26	25	25	24	24	23	23	22	22	21	21	20	20	20	19	19	18
92	28	28	28	27	27	26	26	25	25	24	24	23	23	22	22	21	21	20	20	19	19
95	29	29	29	28	28	27	27	26	26	25	25	24	24	23	23	22	22	21	21	20	20
98	30	30	29	29	28	28	27	27	26	26	25	25	24	24	23	23	22	22	21	21	20
102	31	31	30	30	29	29	28	28	27	27	26	26	25	25	24	24	23	23	22	22	
105	32	32	31	31	30	30	29	29	28	28	27	27	26	26	25	25	24	23	23		
108	33	33	32	32	31	31	30	30	29	29	28	28	27	26	26	25	25	24			
112	34	34	33	33	32	32	31	31	30	30	29	28	28	27	27	26	26	25			
115	35	35	34	34	33	33	32	32	31	30	30	29	29	28	28	27	26				
118	36	36	35	35	34	34	33	33	32	31	31	30	30	29	28	28					
121	37	37	36	36	35	35	34	33	33	32	32	31	30	30	29						
125	38	38	37	37	36	36	35	34	34	33	33	32	31	31							
128	39	39	38	38	37	37	36	35	35	34	33	33	32	32							
130	40	40	39	39	38	37	37	36	36	35	34	34	33								
134	41	41	40	40	39	38	38	37	36	36	35	35									
138	42	42	41	41	40	39	39	38	37	37	36	35									
141	43	43	42	42	41	40	40	39	38	38	37										
144	44	44	43	43	42	41	41	40	39	39	38										
147	45	45	44	44	43	42	42	41	40	39											
151	46	46	45	45	44	43	42	42	40												
154	47	47	46	45	44	43	43	42													
157	48	48	47	46	45	44	44														
161	49	49	48	47	46	45	45														
164	50	50	49	48	47	46	45														

Pelagian Unit used on 150metre dives during an Expedition to
HMS Victoria in Lebanon.
Scrubber is attached directly to Diluent / Bail-out twinset
alongside 5litre oxygen cylinder.
Additional decompression tanks worn for open-circuit
bail-out decompression.