THE LOOP

CAVE DIVE FLORIDA
(352) 363-0013
www.CaveDiveFlorida.com

The Breathing Loop

Jim Wyatt

Probably one of the most difficult things for a new rebreather diver in training to fully understand is what is happening to the gases in the loop during a dive.

This presentation is designed to look at the gases in the loop and explain what is happening and how to deal with and recognize it.

While on open circuit not much changes with the gas you are diving except that as you descend the gas becomes more dense and PPO2 increases. This is not the case when diving a Closed Circuit Rebreather. (CCR)

REVIEW OF OPEN CIRCUIT GASES

- As a review lets look at open circuit gases and how they respond to changes in depth. Lets' consider EAN30 as our open circuit breathing gas. This gas is essentially 30% Oxygen and 70% Nitrogen.
- At the surface the PPO2 is 0.3 ata – Density = 1X
- At 33 fsw the PPO2 is 0.6 ata – Density = 2X
- At 66 fsw it is 0.9 ata – Density = 3X
- At 99 fsw it is 1.2 ata – Density = 4X
- At 121 fsw it is 1.4 ata – Density = 4.6X
- 121 fsw is the MOD for this gas.

THE LOOP

- The PPO2 of EAN30 constantly changes with changes in depth directly proportional to the depth.
- In the rebreather loop we are able to keep the PPO2 constant throughout the dive either by manually adding O2 or by allowing the electronics to add O2 for us.
- In the electronically controlled CCR a few things have to happen in order for the machine to maintain the constant PPO2 for us. The O2 cells must be working properly, the batteries for the solenoid and the controller have to be good. The controller has to be configured properly. There are several other things that will be covered by your Choptima instructor.

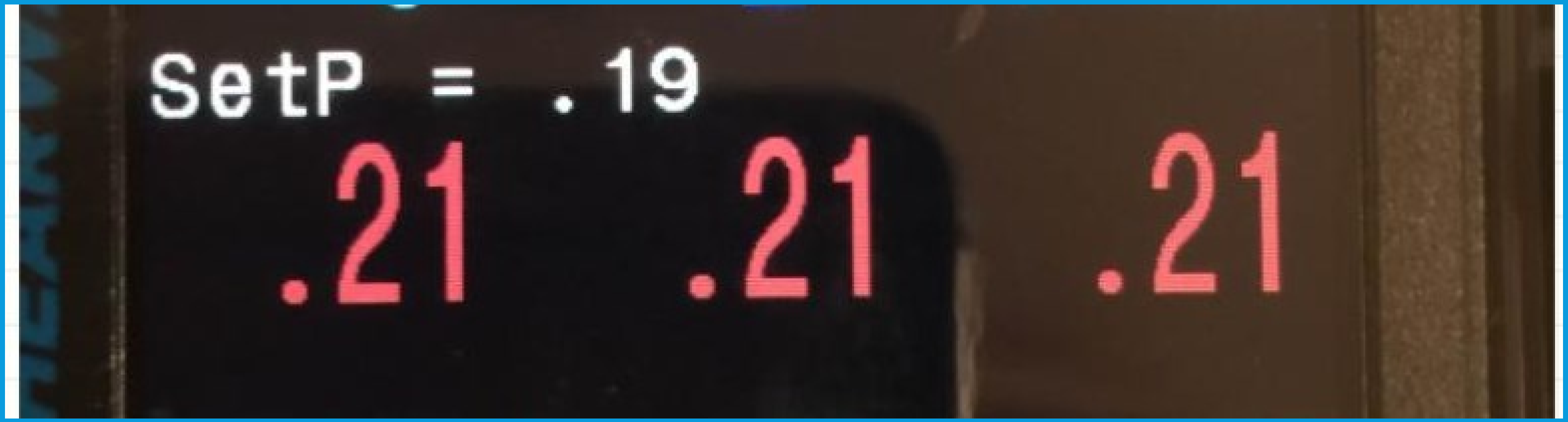
WHY DO WE WANT A CONSTANT PPO_2?

- In our O/C slide we reviewed how PPO2 changes with depth. So in the early stages of a dive the PPO2 is low which means the PPN2 is high which means we are loading more N2 and because of that our decompression obligation increases.
- With the CCR we can keep the PPO2 constant throughout the entire dive. I keep my PPO2 at a constant 1.2 ata while on my CCR.
- If diving OC EAN30 at 60 feet the PPO2 is .84 ata. Not until 100 fsw on OC does the PPO2 reach 1.2 ata. On the CCR the PPO2 is always at 1.2 ata whether at 40 feet, 60 feet or 100 feet deep!
- Hopefully you now understand this part of the differences between OC & CCR in terms of the gasses involved.

WHAT IS A SETPOINT?

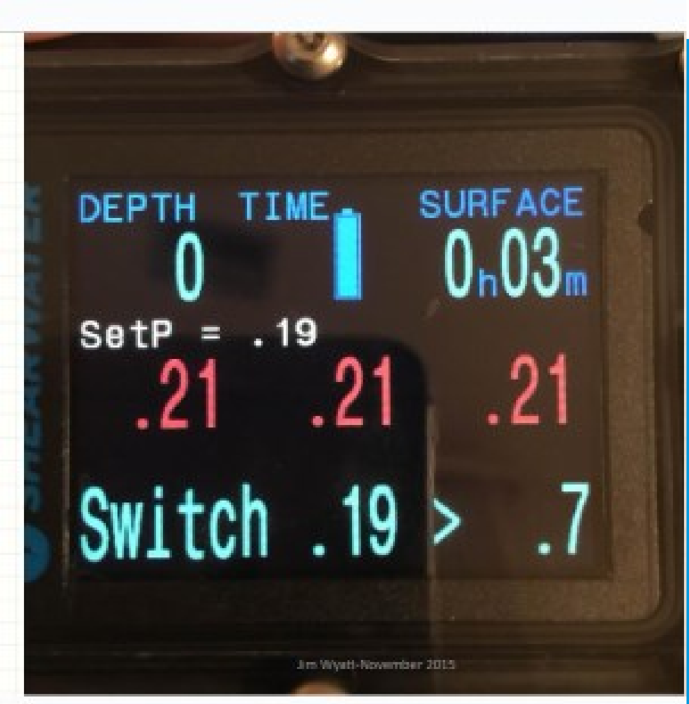
- The setpoint is the target PPO2 for the CCR to maintain for the dive. With a manual CCR it is the target PPO2 for the user to maintain with the assistance of a constant mass flow valve. I use a setpoint of 1.2 PPO2 for most of my dives. If dives are longer and deeper I may decrease the setpoint to 1.0 ata so as to slow down the oxygen clock. The tradeoff is longer decompression time since there is more N2 in the loop when we lower the setpoint.

WHAT HAPPENS IN THE LOOP PRIOR TO ENTERING THE WATER



This image of the controller shows the cells reading a PPO2 of 0.21 ata which is what they should read in air. The controller is set to maintain a setpoint of 0.19 ata. SP of 0.19 ata prevents the CCR electronics from injecting O2 into the loop. This SetP=.19 mode is only for use out of the water.

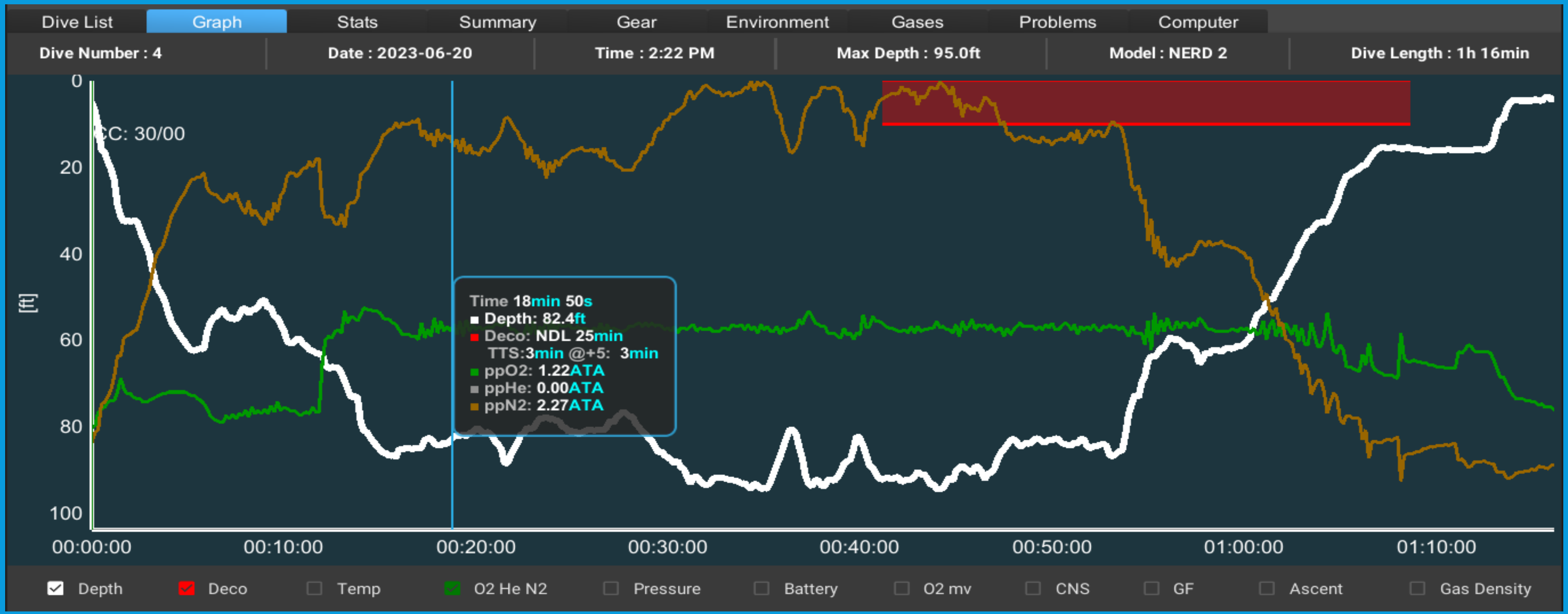
WHAT HAPPENS IN THE LOOP WHEN ENTERING THE WATER



This is where you change the Setpoint to 0.7 ata. This must be done prior to entering the water. The controller will tell the solenoid valve to open and inject O2 into the loop after the Switch is performed.

After a few moments the PPO2 readings should switch to 0.7 ata, you should be able to hear the solenoid "firing" during this PPO2 increase from 0.21 ata to 0.7 ata

GRAPH SHOWING CONSTANT PPO2



The **green line** shows a constant PPO2 of 1.2 ata throughout the dive.
The **orange line** shows varying PPN2 with depth changes.

WHAT HAPPENS AS WE DESCEND?

- As we descend we go ahead and switch to SP 1.2 ata. I generally make that switch at or around 30-60 fsw if target depth is around 100 fsw.
- During your descent the gas volume in the loop decreases due to the increased water pressure. When this happens it feels as though you cannot get a full breath. It feels that way because you cannot get a full breath because the volume of that gas has decreased. To compensate for this loss of volume the Automatic Diluent Valve (ADV) will automatically add diluent to the loop. You can manually add diluent to the loop by pressing on the Manual Addition Valve (MAV).

ADV & MAV OPERATION

Automatic Diluent Addition Valve (ADV) / Manual Addition Valve (MAV)

The ADV/MAV is mounted to the side of the inhalation counterlung. It utilizes a built in demand valve that is activated by negative loop pressure against a diaphragm in the same manner as a standard second stage regulator. It can also be manually activated by pressing directly on the diaphragm.

The ADV's position allows it to feed diluent gas directly to the DSV. This provides a fast, hands-free method of receiving a known breathable gas as well as supplying additional gas to increase loop volume.

The ADV/MAV comes with a standard LP inflator hose fitting to allow the use of any off-board diluent gas supply. For dives exceeding 130ft/40m, Dive Rite recommends upgrading this fitting to a high flow quick disconnect QC-6 fitting. Contact Dive Rite for details.

An inline shutoff is included to disable the ADV, however be aware that this also disables the MAV. The shutoff should also be used if the diluent gas supply is disconnected underwater to prevent wate[r] from entering the ADV/MAV.

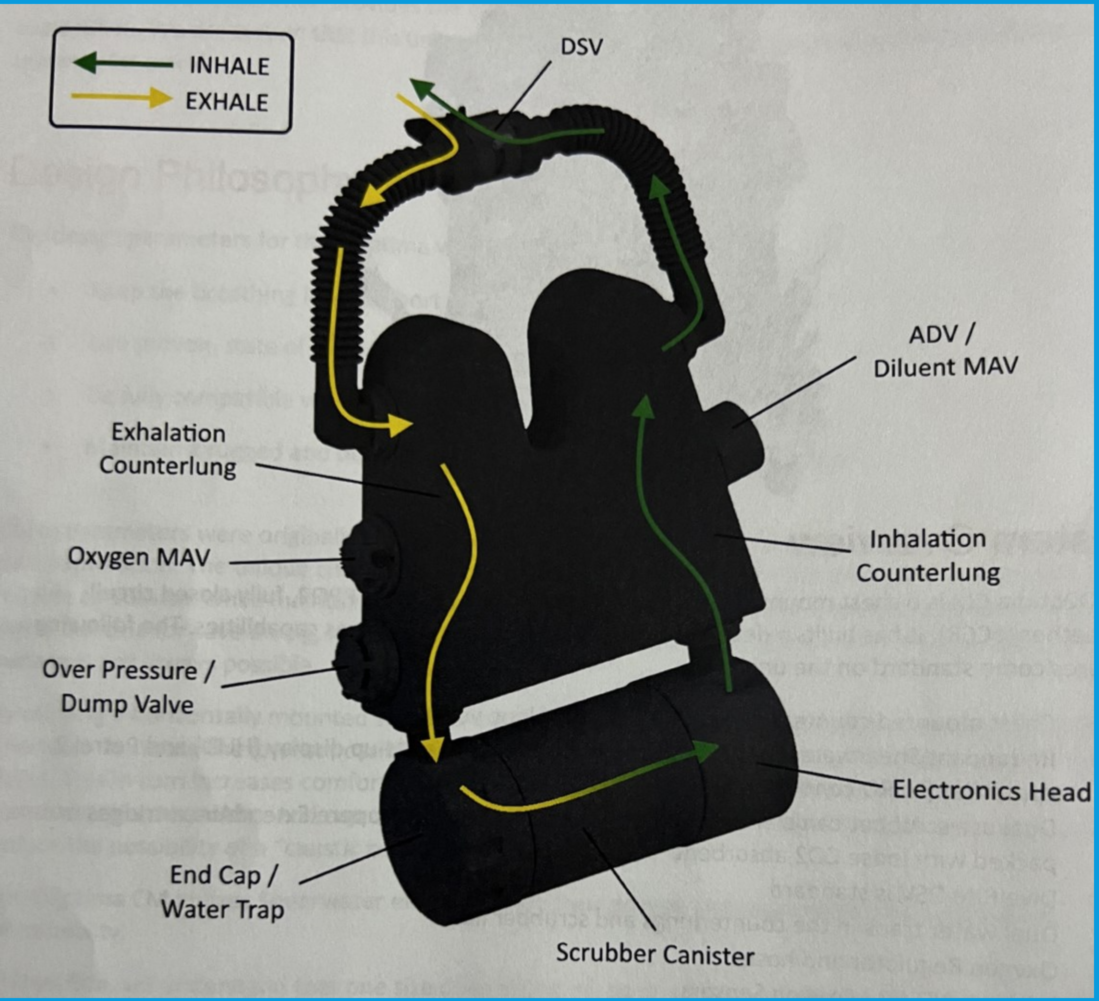
The base of the ADV/MAV is screwed into a welded flange on the counterlung inner bladder.

This image was taken from the Choptima users' manual.

WHAT HAPPENS AS WE DESCEND?

- As the descent continues; loop volume continues to decrease unless the ADV/MAV replaces the volume that is lost. The diver will experience a difficulty inhaling if this volume is not replaced.
- During the descent the PPO2 in the loop naturally increases due to an ambient pressure increase. Consequently the electronics will likely NOT open the solenoid to inject O2 to replace that lost volume. The diver must ensure the volume is replaced.

COMPONENTS AND LOOP ROUTE



This image shows the loop route as well as the components MAV, and ADV discussed above. Note there is also a Oxygen Manual Addition Valve on the Choptima as well as all other CCR units on the market. The O2 MAV is of course used when O2 flushes are needed.

ON THE BOTTOM AT DEPTH

- The CCR works better while at a constant depth. The gas volume does not change significantly because there are no significant depth changes. Your body uses some of the O2 and in turn produces CO2. For practical purposes it is essentially a 1:1 ratio.
- As you metabolize O2 the PO2 in the loop will decrease. The O2 cells sense this PO2 drop and will in turn tell the solenoid to open and add more O2 to the breathing loop to replace what has been metabolized.

ON THE BOTTOM AT DEPTH

- Throughout this phase of your dive you should see the middle row of your Shearwater controller displaying 1.2 ata. You will see very little variance from 1.2 ata so long as you are at a relatively constant depth.
- During this phase of the dive you should compare the controller readings of PPO2 to the HUD readings of PPO2. They should always be the same.

THE ASCENT

- Lots of things are going on during the ascent that initially may cause some task loading.
- PPO2 will drop due to ambient pressure decreasing. As the PPO2 drops the CCR will add O2 to the loop. The loop can easily become overfilled causing an increase in buoyancy and since it is over full makes it difficult to breathe. The CCR diver must vent the excess gas through the nose NOT the mouth. There is a better likelihood of water getting into the loop when CCR divers vent excess gas through the mouth.
- CCR divers must ensure the PPO2 does not drop below 0.7 ata during the ascent.

THE ASCENT

- Some CCR divers will switch back to a setpoint of 0.7 ata during ascent to prevent overinflation of the loop.
- For more efficient decompression I feel it is better to maintain a setpoint of 1.2 ata during the ascent while knowing you must control overinflation of the loop/counterlungs. The best procedure is to exhale excess gas through your nose and allow the CCR to maintain a SP of 1.2 ata.

THE ASCENT

- Once we come close to our first decompression stop ensure that the ascent rate is appropriate and that the loop PPO2 is 1.2 ata.
- Once at that stop, lets say 20 fsw we can manually add O2 with the O2 MAV to keep the PPO2 up higher, say 1.6 ata during that 20 foot stop to ensure more efficient decompression. We can conduct both the 20 foot and 10 foot stops at 20 feet while maintaining a PPO2 as close to 1.6 ata as we can.

SOME GAS MATH

DEPTH IN FEET	Pressure ATA	PPO2	FO2
10	1.3	1.2	.92
20	1.6	1.2	.75
33	2	1.2	.60
66	3	1.2	.40
99	4	1.2	.30
132	5	1.2	.24

The PPO2 remains 1.2 ata throughout all depths. The FO2, which is the (Fraction) % O2 changes with depth as shown in the table.

PPO2/ATA=% O2 – 1.2/1.3=.92 (92% O2) So if we are at 10 feet deep with a PPO2 of 1.2 we have 92% O2 in the loop.

At 99 feet with a PPO2 of 1.2 we have 30% O2 / 1.2/4=.3 or 30% O2

At 132 fsw with a PPO2 of 1.2 we have 24% O2 / 1.4/5=.24 or 24% O2

The PPO2 remains constant but the % of O2 in the loop changes with depth.

CCR LOOP

- This PowerPoint presentation does not purport to be and cannot be a substitute for a certified Choptima instructor.