Isobaric Counterdiffusion (ICD)

By Lance Briner & Jeff Loflin

Basic Decompression Theory

- At the surface our bodies are saturated with gas, i.e. they are at a point of equilibrium, i.e. they are not ongassing or offgassing.

- As we descend, the pressure on our body increases, so we ongas per Henry's Law.

  Henry's Law. The amount of a gas that dissolves in a liquid is proportional to the partial pressure of the gas exerted on the liquid.

- At depth our tissues continue to ongas. The deeper and longer we stay down, the more our tissues ongas.

- If we stayed at depth long enough, our tissues would become saturated, i.e. our tissues would nolonger ongas and our decompression obligation would cease to increase for that depth.

- As we ascend, our tissues begin to offgas. The faster we ascend, the faster our tissues will offgas. As long as we ascend slow enough, the offgassing gas will stay in solution. (i.e. we should not get bent)

- Because our tissues can only handle so much over pressurization, we must make stops along our ascent to allow our tissues to offgas before they exceed their point of maximum overpressurization, i.e. their M-value.

- For a given stop, once the controlling tissue is below its M-value, we are allowed to proceed up to our next decompression stop.

- The process of stopping and offgassing repeats itself until we are out of the water.

Isobaric Counterdiffusion (ICD)

- ICD was first studied in 1975. (by Lambertsen and Idicula)

- Isobaric ? equal ambient pressure
  Counterdiffusion ? 2 or more gases diffusing in opposite directions

- For divers, the 2 gases of concern are Helium (He) and Nitrogen (N_2).

- ICD can occur when He ongases faster than N_2 offgasses, OR when N_2 ongasses faster than He offgasses at a given depth – hence isobaric.

- If one gas ongasses faster than the other offgasses AND the tissue pressure exceeds the M-value for that depth, gas can bubble out of solution and the diver can get bent.

Is ICD a Real Concern???

- PADI's (and most others) stance:

  "ICD has so far proved more of a theoretical risk than a real one, but you can't ignore it."

- Bruce Wienke's (and a handful of others) stance:

  ICD is a real gas transport mechanism. Please pay attention to it in mixed gas deco diving.

- This author's stance:

  - Vestibular hits from ICD are really scary. It was once thought that bubbles in the ear caused vestibular hits – which are characterized by loss of balance, extreme vertigo and vomiting.

  - It is now believed that the cerebellum is taking a massive hit and the vestibular symptoms are only the most noticeable ones. In severe cases, it can leave the survivor (if the diver does survive) a quadriplegic!

  - With new technologies, e.g. rebreathers and scooters, divers are now going deeper and staying down much longer than their counterparts years ago, steps to minimize ICD should be included in your dive plan.

- With all the things that the dive industry has been wrong about, e.g.

  - Deep air diving is safe.
  - US Navy tables are safe for decompression.
  - Helium is dangerous.
  - Low He high O_2 mixes are good.
  - Etc.

  Do we really want to be wrong about ICD???

How to Avoid ICD

- PADI (and others) suggests the following:

  (1) Do not switch to a trimix decompress gas after breathing air or Nitrox at depth.

  (2) All divers in a team use the same gasses so that an out of air (OOA) diver who was breathing air or Nitrox at depth doesn't share air with a diver breathing trimix.

  (3) Inflate your drysuit with air or Argon – not back gas.

- PADI states on page 55 of its Tec Trimix book:

  "ICD can even happen, in theory, switching the other way [trimix to air or Nitrox], but that is NOT [emphasis added] a huge issue or timix diving would not be possible."

- To PADI's credit, they do qualify this statement in the next paragraph by stating, "[Inner ear DCS] has happened on some extreme trimix dives."

- Since after class this certification does NOT have a depth limit*, this author thinks it's prudent to understand what an extreme trimix dive is.

* This can NOT be emphasized enough. Build your experience (depth) slowly. Exceeding the limits of one's training and/or comfort is one of the leading causes of tech diver deaths!

Bruce Wienke's 4th Suggestion

- Bruce Wienke recommends the same 3 as PADI and suggests a 4th consideration:

  Minimize the use of N_2 (even for deco), and washout with O_2 in the shallow zone.

- Following this advice, NAUI Tec teaches / advocates only 1 gas switch for deco. [O_2 at 20 feet]

Minimizing the Use of N_2 During Deco

- Consider our dive to 240 ft at 40 Fathom Grotto.
  - We have 16/50 (N_2 = 34%) in our back gas.
  - We have 2 switches – 1 to EAN50 at 70 ft. and O_2 at 20 ft.
- Instead, to minimize the use N_2 (to minimize the risk of ICD), we could:
  - Option #1. Breathe our back all the way up to our O_2 switch.
  - Option #2. Put He in our 70 ft bottle. so we are not 'surfacing' our tissues loaded with He and we are not spiking our tissues with N_2. [When we are at 80 ft breathing 16/50, the ppHe = 1.68 and ppN_2 = 1.14]

EAN50 at 70 ft	Heliox 50/50 at 70 ft	TM 50/25 at 70 ft
$ppHe = 0 \times \left(\frac{70}{34}+1\right) = 0$	$ppHe = .50 \times \left(\frac{70}{34}+1\right) = 1.53$	$ppHe = .25 \times \left(\frac{70}{34}+1\right) = .76$
$ppN_2 = .50 \times \left(\frac{70}{34}+1\right) = 1.53$	$ppN_2 = 0 \times \left(\frac{70}{34}+1\right) = 0$	$ppN_2 = .25 \times \left(\frac{70}{34}+1\right) = .76$

  - Option #3. Dive open circuit like a rebreather. (see the following page)

What About Detox Breaks on Backgas???

- We are all taught to take 'air breaks' on our backgas – which happens to be Trimix.
- Isn't this breaking Rule #1, i.e. aren't we supposed to avoid switching from heavy-to-light??? Yes! But, according to Wienke, you should be okay if:
  - You are in the 200 fsw to 300 fsw range, and
  - Your bottom time does NOT exceed 60 minutes or so, and
  - Your cumulative detox times stay below 40 minutes roughly.

Deep Dives Exceeding 400 fsw

- Bruce Wienke suggests the following:
  - On the way up, increase O_2 content in roughly the same proportion that He is reduced.
  - Keep N_2 fairly constant and in the 15% to 25% range – the lower the better for deco, but higher than 10% to address HPNS concerns.
  - Keep the ppO_2 in the 1.2 region.

Diving Open Circuit (OC) like a Closed Circuit Rebreather (CCR)

In Bruce Wienke's and Timothy O'Leary's article 'Diving OC like a CCR' article published in Issue 22 of Advanced Diver Magazine, they suggest the best way to dive OC is to dive as though you are diving a CCR.

Note:

- CCR's hold the fraction of O_2 constant regardless of depth. This minimizes decompression since it maintains a constant partial pressure of O_2 (ppO_2) while reducing the fractions of N_2 and He.

- OC divers minimize their decompression obligation by making gas switch along or decent.

In their article, they had the reader consider a dive to 250 fsw for 15 minutes on TM 14/56/30 using a CCR and OC using 3 strategies, i.e.

- OC Strategy #1. Decompress using back gas.
- OC Strategy #2. Make 1 gas switch to TM 25/45 at 125 ft.
- OC Strategy #3. Make 4 gas switches: TM 17/43/40 at 200 ft
  TM 22/48/30 at 150 ft.
  TM 30/40/30 at 100 ft.
  TM 48/22/30 at 50 ft.

Note: The 3 OC strategies have a $ppO_2 = 1.2$ at the switch (to minimize the chance of Oxtox) and maintain the level of N_2 (to minimize the chance of ICD).

	Rebreather		OC Strategy #1		OC Strategy #2		OC Strategy #3	
Depth	Min	ppO_2	Min	ppO_2	Min	ppO_2	Min	ppO_2
250	15	1.2	15	1.2	15	1.2	15	1.2
160	0	1.2	.5	.9	.5	.9	.5	.9
150	0	1.2	1	.8	1	.8	.5	1.2
140	.5	1.2	1	.8	1	.8	.5	1.2
:	:	:	:	:	:	:	:	:
20	4	1.2	19.5	.2	15.5	.4	8.5	.8
10	7.5	1.2	33	.2	20.5	.3	12.5	.6
TDT	55.6 min		136.1 min		98.6 min		73.1 min	
OTU	58.8 min		23.4 min		36.4 min		56.1 min	
CNS	22%		9%		13%		19%	

What do you see??? As the number of switches increase, the total decompression time decreases. And, the chance of ICD is eliminated since we do not increase the ppN_2 or ppHe.

Note: OC strategy #3 is would be problematic and should be discouraged unless the divers have scooters and they use AL40's for deco bottles or have surface support.