DEEP STOPS AND DEEP HELIUM
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BASICS

Deep stops – what are they?

Actually, just what the name suggests. Deep stops are decompression stops made at deeper depths than those traditionally dictated by classical (Haldane) dive tables or algorithms. They are fairly recent (last 15 years) protocols, suggested by modern decompression theory, but backed up by extensive diver practicum with success in the mixed gas and decompression arenas - so called technical diving. Tech diving encompasses scientific, military, commercial, and exploration underwater activities. The impact of deep stops has been a revolution in diving circles. So have slower ascent rates across recreational and technical diving. In quantifiable terms, slower ascent rates are very much akin to deep stops, though not as pronounced as decompression stops. Deep stops plus slow ascent rates work together. And they work together safely and efficiently.

Many regard deep stops as a most significant development in modern diving. Here's why.

Deep stops usually reduce overall decompression time (hang time) too. And when coupled to the use of helium in the breathing mixture (trimix) to reduce narcotic effects of nitrogen, technical divers report feeling much better physically today when they leave the water. The reduction in hang time ranges from 10% to as high as 50%, depending on diver, mix, depth, and exposure time. Feeling better while decompressing for shorter periods of time is certainly a win-win situation that would have been thought an impossibility not too long ago. The basic tenets of conventional decompression theory (neo-classical dissolved gas theory) postulate that deeper exposures (deep stop plus bottom time) incur greater offgassing penalties in the shallow zone. Just look at those deco tables based upon Haldane methodolgy. You know, the ones you used before you bought a dive computer. Even the bulk of dive computers still stage divers using Haldane approaches. But that is changing too. New computers invoking the dual science of dissolved gases and bubbles are emerging. And deep stops are a natural result of their operation.

The depth at which the first deep stops are made can be dramatically deeper than those required by conventional tables. For instance, a dive to 300 ft on trimix for 30 minutes, with switches to progressively higher enrichments of nitrox at 120, 70, and 20 ft, calls for the first deep stops in the 250 ft range. Conventional tables require the first stops in the 100 ft range. If trimix is substituted for nitrox on the way up, total deco time can be further reduced, and divers today leave the water feeling *better* than they would on nitrox.

For most early technical divers, obtaining deep and mixed gas decompression tables constituted one of many road-blocks to safe deep and exploration diving. Existing tables ranged from ultra-conservative as an insulation against harm to a hodgepodge of protocols based on total misunderstanding. From this background, and driven by a need to optimize decompression schedules, deep stops steadily advanced as a safe and efficient change to diver staging. And this even though formal tests were usually not conducted in controlled environments, like hyperbaric chambers.

HISTORY

Haldane originally found that deep stops were sometimes necessary in his decompression tests and staging regimens, but either abandoned them, or could not incorporate them naturally into his (just) dissolved gas, critical tension ($M-value$) model on first principles. Too bad, he might have saved future generations of divers much deco scheduling trouble and unnecessary hang time. Deep stops do not emerge naturally in just dissolved gas models for deco scheduling. Probably Haldane also didn't go deep enough to see real diving differences and needs. Deep stops are really a *deep* protocol.

Though deep stops are regarded as a major development in diving, real meaningful experiments were more trial-and-error than scientific in nature. Just like so many other important developments in the real world. Underlying science with mechanistics would follow in the late 80s and 90s, albeit with considerable flack from the *experts* of the time. And so with helium breathing mixtures, the voodoo gas that *does not decompress*.

Maybe experiments is too strict a description. Individuals, particularly in the cave diving community, toyed with decompression regimens in hopes of mimimizing their decompression time. The cave exploration Woodville Karst Plain Project (WKPP), mapping subsurface topographies in Florida, pioneered deep stop technology, establishing many rule-of-thumb protocols to be imposed on conventional tables. Irvine and Jablonski stand at the forefront here, successfully conducting 6 hour dives at 280 ft in the Wakulla cave complex with deep stop decompression times of 8.5 hours versus traditional Haldane hang times of 20 hours. Also, the horizontal penetrations of 19,000 ft are world records (Guinness). Figure 1 sketches comparison profiles, along with mixtures, times, switches, and depths. Spectacular is a gross understatement. Certainly such contributions to diving science and spinoff model validation parallel Haldane a hundred years ago.

WKPP initially found that common decompression assumptions subjected divers to extremely long decompression obligations, and ones that, regardless of their length, were inefficient. Divers also felt badly upon surfacing from extended deco dives. Operationally (many dives over many years), WKPP divers found that the insertion of deep stops permitted shortening of shallower stops with an overall reduction in total decompression time. The decompression schedule was more effective, with effectiveness represented by subjective diver health and sense of well being. In so doing WKPP also dispelled the *voodoo helium* myth as switches away from nitrox to trimix deco schedules finalized. In lockstep mode, like strategies developed in military, security, and even some commercial sectors.

But even before these deep stop protocols emerged, utilitarian diving practices among diving fisherman and pearl gatherers suggested traditional staging was in need of rethinking. And early deco models, such as the so called thermodynamic model of Hills, suggested why and how. Deep stops likely evolved from cognizance of both by tech divers.

Pearling fleets, operating in the deep tidal waters off northern Australia, employed Okinawan divers who regularly journeyed to depths of 300 ft for as long as one hour, two times a day, six days per week, and ten months out of the year. Driven by economics, and not science, these divers developed optimized decompression schedules empirically. As reported by Le Messurier and Hills, deeper decompression stops, but shorter decompression times than required by Haldane theory, were characteristics of their profiles. Such protocols are entirely consistent with minimizing bubble growth and the excitation of nuclei through the application of increased pressure, as are shallow safety stops and slow ascent rates. With higher incidence of surface decompression sickness, as expected, the Australians devised a simple, but very effective, in-water recompression procedure. The stricken diver is taken back down to 30 ft on oxygen for roughly 30 minutes in mild cases, or 60 minutes in severe cases. Increased pressures help to constrict bubbles, while breathing pure oxygen maximizes inert gas washout (elimination). Recompression time scales are consistent with bubble dissolution experiments.

Similar schedules and procedures have evolved in Hawaii, among diving fishermen, according to Farm and Hayashi. Harvesting the oceans for food and profit, Hawaiian divers make beween 8 and 12 dives a day to depths beyond 350 ft. Profit incentives induce divers to take risks relative to bottom time in conventional tables. Repetitive dives are usually necessary to net a school of fish. Deep stops and shorter decompression times are characteristics of their profiles. In step with bubble and nucleation theory, these divers make their deep dive first, followed by shallower excursions. A typical series might start with a dive to 220 ft, followed by 2 dives to 120 ft, and culminate in 3 or 4 more excursions to less than 60 ft. Often, little or no surface intervals are clocked between dives. Such types of profiles literally clobber conventional tables, but, with proper reckoning of bubble and phase mechanics, acquire some credibility. With ascending profiles and suitable application of pressure, gas seed excitation and bubble growth are likely constrained within the body's capacity to eliminate free and dissolved gas phases. In a broad sense, the final shallow dives have been tagged as prolonged safety stops, and the effectiveness of these procedures has been substantiated *in vivo* (dogs) by Kunkle and Beckman. In-water recompression procedures, similar to the Australian regimens, complement Hawaiian diving practices for all the same reasons.

So deep stops work and are established. But why?

SCIENCE

The science is fairly simply. It's just a matter of how dissolved gases and bubbles behave under pressure changes. We use to think that controlling dissolved gas buildup and elimination in tissue and blood was the basis for staging divers and astronauts. And that bubbles didn't form unless dissolved gas trigger points were exceeded. At least that was the presumption that went into conventional (Haldane) tables. Chemists, physicists, and engineers never bought off on that. When *silent bubbles* were tracked in divers not experiencing any decompression problems, of course, this changed. And since bubbles need be controlled in divers, focus changed and switched from just-dissolved-gases to both-bubbles-and-dissolved-gases. Within such framework, deep stops emerge as a natural consequence. So do *dual* phase (bubbles plus dissolved gas) models.

Here's how.

To eliminate dissolved gases, the driving *outgassing gradient* is maximized by reducing ambient pressure as much as possible. That means bringing the diver as close to the surface as possible. But, to eliminate bubbles (the gases inside them), the *outgassing gradient* is maximized by increasing ambient pressure as much as possible. That means holding the diver at depth when bubbles form. Deep stops accomplish the latter.

But the staging paradigm has a few more wrinkles.

Clearly, from all of the above, dominant modes for staging diver ascents depend upon the preponderance of free (bubbles) or dissolved phases in the tissues and blood, their coupling, and their relative time scales for elimination. This is now (will always be) a central consideration in staging hyperbaric or hypobaric excursions to lower ambient pressure environments. The dynamics of elimination are directly opposite, as stated and depicted in Figure 2. To eliminate dissolved gases (central tenet of Haldane decompression theory), the diver is brought as close as possible to the surface. To eliminate free phases (coupled tenet of bubble decompression theory), the diver is maintained at depth to both crush bubbles and squeeze gas out by diffusion across the bubble film surface. Since both phases must be eliminated, the problem is a playoff in staging. In mathematical terms, staging is a *minimax* problem, and one that requires full blown dual phase models, exposure data, and some concensus of what is an acceptable level of DCI incidence.

Enter dual phase models which generate deep stops consistently within free and dissolved gas phase constraints.

MODELS AND DIVING ALGORITHMS

Extreme WKPP divers make their first decompression stops at roughly 80% of actual depth for any dive. They dive helium exclusively and the deep stop schedules they generate (many diver years testing) are not remotely possible with air. Same for the LANL team. Schedules confirm and agree with reduced gradient bubble model (below) calculations of the staging regimen in both deco profile shape and duration.

Other prescriptions for deep stops were imbedded in conventional tables. Something like this was employed, trial and error, and this one is attributed to Pyle, an underwater fish collector in Hawaii:

1. calculate your decompression schedule from tables, meters, or software;
2. half the distance to the first deco stop and stay there a minute or two;
3. recompute your decompression schedule with time at the deep stop included as way time (software), or bottom time (tables);
4. repeat procdeure until within some 10 -30 ft of the first deco stop;
5. and then go for it.

Within conventional tables, such procedure was somewhat arbitrary, and usually always ended up with a lot of hang time in the shallow zone. Such is to be expected within dissolved gas deco frameworks. So, deep stop pioneers started shaving shallow deco time off their schedules. And jumped back into the water, picking up the trial and error testing where it left off.

Seasoned tech divers all had their own recipes for this process. And sure, what works works in the diving world. What doesn't is usually trashed.

Concurrently, full up dual phase models, spawned by the inadequacies and shortcomings of conventional tables, emerged on the diving scene. Not only did deep stops evolve self consistently in these models, but dive and personal computers put deco scheduling with these new models in the hands of real divers. And real on the scene analysis and feedback tuned arbitrary, trial and error, and theoretical schedules to each other.

One thing about these bubble models, as they are collectively referenced, that is common to all of them is deeper stops, shorter decompression times in the shallow zone, and shorter overall deco times. And they all couple dissolved gases to bubbles, not focusing just on bubbles or dissolved gas.

Without going into gory details, a few of the more important ones can be summarized. The thermodynamic model of Hills really got the ball rolling so to speak:

1. thermodynamic model (Hills, 1976) – assumes free phase (bubbles) separates in tissue under supersaturation gas loadings. Advocates dropout from deco schedule somewhere in the 20 ft zone.

2. varying permeability model (Yount, 1986) – assumes preformed nuclei permeate blood and tissue, and are excited into growth by compression-decompression. Model patterned after gel bubbles studied in the laboratory.

3. reduced gradient bubble model (Wienke, 1990) – abandons gel parametrization of varying parmeability model, and extends bubble model to repetitive, altitude, and reverse profile diving. Employed in recreational and technical diving meters, and basis for new NAUI nitrox, heliox, and trimix tables;

4. tissue bubble diffusion model (Gernhardt and Vann, 1990) – assumes gas transfer across bubble interface, and correlates growth with DCI statistics. Probably employed in the commercial diving sector.

Not all these models have seen extensive field testing, but since they are all similar, the following, addressing testing and validation of the reduced gradient bubble model (RGBM), holds in broad terms. The 1000s of tech dives on deep stops, of course, already validate deep stop technology and models to most, but the testing and validation described next spans deep stops to recreational diving in single model framework. And that is a very desired feature of any decompression theory and/or model.

TESTING AND VALIDATION

Models need validation and testing. Often, strict chamber tests are not possible, economically nor otherwise, and bubble models employ a number of benchmarks and regimens to underscore viability. The following are some supporting the RGBM phase model and NAUI released nitrox, heliox, and trimix diving tables:

1. counterterror and countermeasures (LANL) exercises have used the RGBM (full up iterative deep stop version) for a number of years, logging some 456 dives on mixed gases (trimix, heliox, nitrox) without incidence of DCI – 35% were deco dives, and 25% were repets (no deco) with at least 2 hr SIs, and in the forward direction (deepest dives first);

2. NAUI Technical Diving has been diving the deep stop version for the past 3 yrs, some estimated 500 dives, on mixed gases down to 250 ft, without a single DCI hit. Some 15 divers, late 1999, in France used the RGBM to make 2 mixed gas dives a day, without mishap, in cold water and rough seas. Same in the warm waters of Roatan in 2000 and 2001. A NAUI Instructor dived to 520 ft in the North Sea using RGBM tables;

3. modified RGBM recreational algorithms (Haldane imbedded with bubble reduction factors limiting reverse profile, repetitive, and multiday diving), as coded into ABYSS software and Suunto, Plexus, Hydrospace decometers, lower an already low DCI incidence rate of approximately 1/10,000 or less. More RGBM decompression meters, including mixed gases, are in the works;

4. a cadre of divers and instructors in mountainous New Mexico, Utah, and Colorado have been diving the modified (Haldane imbedded again) RGBM at altitude, an estimated 450 dives, without peril. Again, not surprising since the altitude RGBM is slightly more conservative than the usual Cross correction used routinely up to about 8,000 ft elevation, and with estimated DCI incidence less than 1/10,000;

5. within decometer implementations of the RGBM, only two DCI hits have been reported in nonstop and multidiving categories, beyond 40,000 dives or more, up to now;

6. extreme chamber tests for mixed gas RGBM are in the works, and less stressful exposures will be addressed shortly – extreme here means 300 ft and beyond;

7. probabilistic decompression analysis of some selected RGBM profiles, calibrated against similar calculations of the same profiles by Duke, help validate the RGBM on computational bases, suggesting the RGBM has no more theoretical risk than other bubble or dissolved gas models (Weathersby, Vann, Gerth methodology at USN and Duke).

8. all divers and instructors using RGBM decometers, tables, or NET software have been advised to report individual profiles to DAN Project Dive Exploration (Vann, Gerth, Denoble and others at Duke).

9. ABYSS is a NET sotware package that offers the modified RGBM (folded over the Buhlmann ZHL) and the full up, deep stop version for any gas mixture, has a fairly large contingent of tech divers already using the RGBM and has not received any reports of DCI,

10. NAUI Worldwide released a set of tested no-group, no-calc, no-fuss RGBM tables for recreational sea level and altitude air and nitrox diving, with simple rules linking surface intervals, repets, and flying-after-diving;

11. WKPP dives on trimix to 300 ft for 6 hours have served to calibrate RGBM parameters in the very extreme region.

It almost goes without saying that models such as these have reshaped our decompression horizons – and will continue doing so.

One last item concerning deep stops remains. What about controlled laboratory testing?

EXPERIMENTS

Doppler and utrasound imaging are techniques for detecting moving bubbles in humans and animals following compression-decompression. While bubble scores from these devices do not always correlate with the incidence of DCI, the presence or non-presence of bubbles is an important metric in evaluating dive profiles.

So let's consider some recent tests, and see how they relate to deep stops.

Analysis of more than 16,000 actual dives by Diver's Alert Network (DAN), prompted Bennett to suggest that decompression injuries are likely due to ascending too quickly. He found that the introduction of deep stops, without changing the ascent rate, reduced high bubble grades to near zero, from 30.5% without deep stops. He concluded that a deep stop at half the dive depth should reduce the critical fast gas tensions and lower the DCI incidence rate.

Marroni concluded studies with DAN's European sample with much the same thought. Although he found that ascent speed itself did not reduce bubble formation, he suggested that a slowing down in the deeper phases of the dive (deep stops) should reduce bubble formation. He will be conducting further tests along those lines.

Brubakk and Wienke found that longer decompression times are not always better when it comes to bubble formation in pigs. They found more bubbling in chamber tests when pigs were exposed to longer but shallower decompression profiles, where staged shallow decompression stops produced more bubbles than slower (deeper) linear ascents. Model correlations and calculations using the reduced gradient bubble model suggest the same.

Cope studied 12 volunteer divers performing conventional (Haldane tables) dives with and without deep stops. His results are not available yet – but should be very interesting.

DEEP STOPS BOTTOM LINE

To most of us in the technical and recreational diving worlds, the bottom line is simple.

Deep stop technology has developed successfully over the past 15 years or so. Tried and tested in the field, now some in the laboratory, deep stops are backed up by diver success, confidence, theoretical and experimental model underpinnings, and general acceptance by seasoned professionals.

Amen.

And dive on.

HELIUM MISFACTS

God gave us helium for diving, but the devil replaced it with nitrogen. At least he tried replacing it and giving it a bad name.

Helium is a noble gas for deep diving, but was not always thought so. In the early days of technical and recreational diving, the use of helium for deep diving was discouraged, indeed, really feared. Based on misinformation and a few early problems in the deep diving arena, helium acquired a voodo gas reputation, with a hands off label.

Unjustly so.

Some misapprenhension stemmed from the Hans Keller trajedy on helium mixes in 1962, some from misconceptions about isobaric switches ala light-to-heavy gases, some from tales of greater CNS risk, and some from a paucity of published and reliable decompression tables. Some concerns arose because 80/20 heliox no-deco time limits (NDLs) for short and shallow dives were longer than air limits. So people assumed helium decompression was longer, and more hazardous, than nitrogen.

In short, helium was getting a bad rap for a lot of wrong reasons.

It was also religion that switches from helium bottom mixtures to nitrox or air should be made as early as possible, and that so doing, would reduce overall deco time the most.

Not exactly so, at least according to modern decompression theory, and even classical Haldane theory if deep stops are juxtaposed on the profile. If helium and nitrogen are decreased in roughly same proportions as oxygen is increased until a big isobaric switch is made in the shallow zone to an enriched nitrox mix, deco differences between early switches to nitrogen versus riding lighter helium mixes longer are small. Small according to modern decompression theory and practice, but more important, such helium protocols leave the deco diver feeling better. As witnessed under field conditions, the collective experiences of technical and scientific diving operations support that assertion today. And so do modern decompression theories that have seen field testing, like the RGBM, and ad hoc deep stop protocols used by saavy divers.

Indeed there may be no need to switch to nitrogen mixtures at all. Riding helium mixtures to the surface, with a switch to pure oxygen in the shallow zone can be deco efficient, and safer too. So much so, that NAUI Technical Diving Operations has built a training regimen for divers and instructors based on helium for technical diving, and even offers a heliotrox (enriched heliair) course. And a full set of RGBM Tables supports helium based training and tech diving.

In the same vein, the operational experiences of WKPP and LANL dive teams underscore many years of safe and efficient helium based deco diving. And that couples to a modern revolution in decompression theory and practice. In fact, WKPP exploits on helium could fill a book. LANL too. NAUI Tec Ops has been utilizing helium based training for the past four years, or so, without problems. All this means many, many 1000s of tech dives with helium based mixes.

Today, helium is proving its worth as a safe and reliable technical mix. Its use is changing technical and exploration diving. Exit deep air, and enter deep helium and deep stops. It seems about time. Plus time for modern decompression theory to flush the dissolved gas theory entrenching diving for a hundred years.

Let's look at why. And begin with comparative gas properties as they affect divers.

HELIUM PROPERTIES

Nitrogen is limited as an inert gas for diving. Increased pressures of nitrogen beyond 130 fsw can lead to euphoria, reduced mental awareness, and physical disfunctionality, while beyond 500 fsw loss of consciousness results. Individual tolerances vary widely, often depending on activity. Symptoms can be marked at the beginning of a deep dive, gradually decreasing with time. Flow resistance and the onset of turbulence in the airways of the body increase with higher breathing gas pressure, considerably reducing ventilation with nitrogen-rich breathing mixtures during deep diving. Oxygen is also limited at depth for the usual toxicity reasons. Dives beyond 150 fsw requiring bottom times of hours need employ lighter, more weakly reacting, and less narcotic gases than nitrogen, and all coupled to reduced oxygen partial pressures.

A number of inert gas replacements have been tested, such as hydrogen, neon, argon, and helium, with only helium and hydrogen performing satisfactorily on all counts. Because it is the lightest, hydrogen has elimination speed advantages over helium, but, because of the high explosive risk in mixing hydrogen, helium has emerged as the best all-around inert gas for deep and saturation diving. Helium can be breathed for months without tissue damage. Argon is highly soluble and heavier than nitrogen, and thus a very poor choice. Neon is not much lighter than nitrogen, but is only slightly more soluble than helium. Of the five, helium is the least and argon the most narcotic inert gas under pressure.

Saturation and desaturation speeds of inert gases are inversely proportional to the square root of their atomic masses. Hydrogen will saturate and desaturate approximately 3.7 times faster than nitrogen, and helium will saturate and desaturate some 2.7 times faster than nitrogen. Differences between neon, argon, and nitrogen are not significant for diving. Comparative properties for hydrogen, helium, neon, nitrogen, argon, and oxygen are listed in Table 1. Solubilities, S, are quoted in atm^{-1}, weights, A, in $atomic\ mass\ units\ (amu)$, and relative narcotic potencies, p, are dimensionless (referenced to nitrogen in observed effect). The least potent gases have the highest index, p.

Table 1. Inert Gas And Oxygen Molecular Weights, Solubilities, and Narcotic Potency

	H_2	He	Ne	N_2	Ar	O_2
A (amu)	2.02	4.00	20.18	28.02	39.44	32.00
S (atm^{-1})						
blood	0.0149	0.0087	0.0093	0.0122	0.0260	0.0241
oil	0.0502	0.0150	0.0199	0.0670	0.1480	0.1220
p	1.83	4.26	3.58	1.00	0.43	

The size of bubbles formed with various inert gases depends upon the amount of gas dissolved, and hence the solubilities. Higher gas solubilities promote bigger bubbles. Thus, helium is preferable to hydrogen as a light gas, while nitrogen is perferable to argon as a heavy gas. Neon solubility roughly equals nitrogen solubility. Narcotic potency correlates with lipid (fatty tissue) solubility, with the least narcotic gases the least soluble. Different uptake and elimination speeds suggest optimal means for reducing decompression time using helium and nitrogen mixtures. Following deep dives breathing helium, switching to nitrogen is without risk, while helium elimination is accelerated because the helium tissue-blood gradient is increased when breathing nitrogen. By gradually increasing the oxygen content after substituting nitrogen for helium, the nitrogen uptake can also be kept low. Workable gas switches depend on exposure and tissue compartment controlling ascent.

While light-to-heavy gas switches (such as helium to nitrogen) are safe and common practices, the reverse is not generally true. In fact, all heavy-to-light switches can be dangerous. In the former case, decreased tissue gas loading is a favorable circumstance following the switch. In the latter case, increased tissue gas loading can be disastrous. This is popularly termed the *isobaric* playoff.

Mixed gas diving dates back to the mid 1940s, but proof of principle diving experiments were carried out in the late 1950s. In 1945, Zetterstrom dove to 500 fsw using hydrox and nitrox as a travel mix, but died of hypoxia and DCS when a tender hoisted him to the surface too soon. In 1959, Keller and Buhlmann devised a heliox schedule to 730 fsw with only 45 *min* of decompression. Then, in 1962, Keller and Small bounced to 1,000 fsw, but lost consciousness on the way up due to platform support errors. Small and another support diver, Whittaker, died as a result. In 1965, Workman published decompression Tables for nitrox and heliox, with the nitrox version evolving into USN Tables. At Duke University Medical Center, the 3 man team of Atlantis III made a record chamber dive to 2250 fsw on heliox, and Bennett found that 10% nitrogen added to the heliox eliminated high pressure nervous syndrome (HPNS).

Nice work, guys.

All the above properties favor helium for deep diving, but what do divers report after actually using helium?

HELIUM VIBES

Consensus among helium divers is that they feel better, less enervated, and subjectively healthier than when diving nitrogen mixtures. WKPP, LANL, and NAUI Technical Operations strongly attest to this fact. Though a personal and subjective evaluation, this remains very, very important. Physiological factors cannot be addressed on first principles always, and for some, just feeling better is good justification. Works for many. Postdive deco stress on helium appears to be less than postdive nitrogen stress.

Another positive benny about helium diving scores the minimum-bends depth (MBD), that is, the saturation depth on a mix from which immediate ascension to the surface precipitates decompression sickness (DCS). For helium mixes, the MBD is always greater than that for proportionate nitrogen mix. For instance, the MBD for air (80/20 nitrox) is 33 fsw, while the MBD for 80/20 heliox is 38 fsw. This results from helium's lesser solubility compared to nitrogen as it impacts deeper and longer diving.

And (coming up last) helium decompression is efficient and fast. In fact, many helium deco dives are not possible with nitrogen mixtures. That should give us all good vibes.

On most counts, helium appears superior to nitrogen as a diving gas. Helium bubbles are smaller, helium diffuses in and out of tissue and blood faster, helium is less narcotic, divers feel better when they leave the water after diving on helium, and helium MBDs are greater than nitrogen MBDs.

That, plus efficient and maybe less deco time, are strong endorsements. Great. But how does this translate into actual diving practice? Here's how.

Helium NDLs are actually shorter than nitrogen for shallow exposures, as seen comparatively in Table 2 for 80/20 heliox and 80/20 nitrox (air). Reasons for this stem from kinetic versus solubility properties of helium and nitrogen, and go away as exposures extend beyond 150 fsw, and times extend beyond 40 *min* or so.

Table 2. Comparative Helium And Nitrogen No Decompression Limits

depth (fsw)	heliox (80/20) NDL (min)	nitrox (80/20) NDL (min)
30		
40	260	200
50	180	100
60	130	60
70	85	50
80	60	40
90	45	30
100	35	25
110	30	20
120	25	15
130	20	10
140	15	8
150	12	5
160	10	4
170	8	3

Helium ingasses and outgasses 2.7 times faster than nitrogen, but nitrogen is 1.5 to 3.3 times more soluble in body aqueous and lipid tissue than helium. For short exposures (bounce and shallow), the faster diffusion rate of helium is more important in gas buildup than solubility, and shorter NDLs than nitrogen result. For long bottom times (deco and extended range), the lesser solubility of helium is a dominant factor in gas buildup, and helium outperforms nitrogen for staging. Thus, deep implies helium bottom and stage gas. Said another way, transient diving favors nitrogen while steady state diving favors helium as a breathing gas.

Top of all this, modern decompression theory (like the RGBM) requires deep stops which do not fuel helium buildup as much as nitrogen in addressing both dissolved gas buildup and bubble growth. And helium deep stops, like nitrogen deep stops, usually couple to shorter and safer overall deco.

Nice symbiosis, and just one more reason to use helium.

That is another topic, so suffice it to close here with a comparison of helium versus nitrogen deco profiles. These are not academic, they have been actually dived (WKPP, LANL, NAUI Tech Ops). Profiles were generated with the RGBM (ABYSS software package, Abysmal Diving, Boulder). RGBM staging is always deeper, but shorter overall, than Haldane staging with Buhlmann ZHL or Workman USN parameters.

The first is a comparison of enriched air and enriched heliair deco diving, with a switch to 80% oxygen at 20 fsw. Dive is 100 fsw for 90 *min*, on EAN35 and EAH35/18 (nitrox 65/35 and tmix 35/18/47), so oxygen enrichment is the same. The deco profile (fairly light by tech standards, but manageable and easy for training purposes) is listed in Table 3. Descent and ascent rates are 75 fsw/min and 25 fsw/min.

Table 3. Enriched Air And Heliair Deco Profile Comparison

depth (fsw)	enriched heliair EAH35/18 stop time (min)	enriched air EAN35 stop time (min)
100	90	90
30	2	4
20	5	7
10	12	11
	119	122

Overall the enriched heliair deco schedule for the dive is shorter than for the enriched air. As the helium content goes up, the deco advantage for enriched heliair increases.

This may surprise you. But either way, now check out corresponding USN or ZHL deco requirements for these dives. In the enriched heliair case, ZHL deco time is 39 *min* versus 19 *min* above, and in the enriched air case, ZHL deco time is 33 *min* versus 22 *min* above. This not only underscores helium versus nitrogen misfact in staging, but also points out significant differences in modern deco algorithms versus the Haldane stuff of some 40 - 100 years ago. Recall that Haldane staging only addresses dissolved gases, while modern models track both dissolved gases and bubbles in staging.

Ludicrous differences? Maybe not so bad since differences are on the safe side.

Lastly consider a deep tmix dive with multiple switches on the way up. Table 4 contrasts stop times for two gas choices at the 100 fsw switch. The dive is a short 10 *min* at 400 fsw on 10/65/25 tmix, with switches at 235 fsw, 100 fsw, and 30 fsw. Descent and ascent rates are 75 fsw/min and 25 fsw/min.

Table 4. Comparative Helium And Nitrogen Gas Switches

depth (fsw)	stop time (min)	stop time (min)
	10/65/25 tmix	10/65/25 tmix
400	10.0	10.0
260	1.5	1.5
250	1.0	1.0
240	1.0	1.0
	18/50/32 tmix	18/50/32 tmix
230	0.5	0.5
220	0.5	0.5
210	0.5	0.5
200	0.5	0.5
190	1.0	1.0
180	1.5	1.5
170	1.5	1.0
160	1.5	1.5
150	1.5	2.0
140	2.0	1.5
130	2.0	2.5
120	4.0	4.0
110	4.5	4.0
	40/20/40 tmix	EAN40
100	2.5	2.0
90	2.5	2.0
80	2.5	2.0
70	5.0	4.0
60	6.5	5.5
50	8.0	6.5
40	9.5	7.5
	EAN80	EAN80
30	10.5	10.5
20	14.0	14.0
10	21.0	20.5
	——	——
	123.0	116.0

Obviously, there are many possibilities for switch depths, mixtures, and strategies. In the above comparison, the oxygen fractions were the same in all mixes, at all switches. Differences between a nitrogen or a helium based decompression strategy, even for this short exposure, are nominal. Such usually is the case when oxygen fraction is held constant in helium or nitrogen mixes at the switch.

Comparative calculations and experience seem to suggest that riding helium to the 70 fsw level with a switch to EAN50 is good strategy, one that couples the benefits of well being on helium with minimal decompression time and stress following isobaric switch to nitrogen. Shallower switches to enriched air (EAN) also work, with only nominal increases in overall decompression time.

Just a suggestion.

HELIUM BOTTOM LINE

Helium has been a mainstay, of course, in commercial diving. But its emergence and use in the technical diving community has been more recent, like the past 10 years or so. Some of this is due to cost certainly. It's not cheap to dive helium. But a lot of it is due to misconception. The activities of a very knowledgeable and vocal technical diving community are changing both.

Ride on helium.

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