WKPP Articles

WKPP Articles

By George Irvine

Why the WKPP and G.U.E. Do Bottle Marking the Way They Do

The big risk in gas diving is breathing the wrong gas. The WKPP developed as part of its overall system a simple methodology for preventing this.

Bottles are marked horizontally on either side in the orientation of the diver as to the maximum operating depth of the bottle in three inch high numbers. It's that simple.

Since "20" can look like "70" the 20 foot bottle is also marked "OXYGEN" horizontally under the "20" (not necessary in the metric system). The diver's name is also on the bottles.

With thousands of man dives of decompression results in the field, we settled on standard decompression gasses: oxygen from 20 feet, 50% oxygen from 70 feet, 35% oxygen from 120 feet, and 18% oxygen from 240 feet for deco, with all gases conforming to a minimum standard of 120 feet AED and 1.6 maximum ppo2 for deco (with 100 AED and 1.4 maximum ppo2 for diving). Bottom tanks are labeled for maximum operating depth as well.

There is no excuse for not permanently and properly marking bottles no matter what gas is used. It is your life we are betting. Painted numbers can be knocked off with a swipe of PVC cleaner, and new ones painted on instantly. Tape can be used also, but nothing should be on the tank as to the contents other than the MOD and the dated analysis. Clean, uncluttered tanks are safer. They say a lot about the person diving them.

With the tanks correctly marked, we fill them according to the following regimen. Two pieces of tape are placed on the empty tank. After adding one gas, but before disconnecting it from the whip, one tape is marked with the date and the gas psi just added. The whip is removed and the next gas added. The same procedure is followed, marking the addition of the gas. The tank can then be analyzed if heliox or to see what the helium percent is by getting the oxygen percent, or the tank is topped with air. At that point the tank is analyzed and the analysis is written on the other piece of tape along with the date, the first piece of tape is then used to cover the tank valve mouth indicating a full tank.

For all tanks the analysis is left on until ready to dive, but can be removed at that point since the identification is by MOD only. Doubles whether used or not and unused stages must re-taped and dated as to analysis for traveling and storage. More smart people have been killed by failing to observe this rule than any other. To keep it simple, don't dive anything that does not have a current analysis. When in doubt, check it out.

With MOD it makes no difference where the bottles are located on the diver, but there should be no effort to identify a gas by its position - this leads to error. Both the diver and his buddies would be able to clearly see the MOD of the gas being breathed as a check on each other. The correct procedure when ready to breathe a gas is to locate the correct bottle by the MOD, remove the reg, place that reg around the neck and into the mouth, then go back and re-locate the correct bottle, and turn it on. IF YOU CAN BREATHE, YOU ARE BREATHING THE RIGHT GAS.

All bottles are turned off and the regs parked on the bottle when not in use - ALWAYS. This also makes buddy identification of your breathing gas easier in wreck diving where all bottles are carried. In cave, we NEVER carry a bottle past its MOD. Trying to maximize PPO2 past a depth for purposes of fear of decompression is too stupid to contemplate given the risk assumed in the process.

If you can not see the bottle, and can not identify the gas, you DON'T breathe it. You stick with what you know is ok until you can make a positive id. Missing a little deco gas is better than dying. Betting on a system where any error could have been made (like putting the wrong cover on a reg) is inadequate for life bets.

All of our regs look the same - we do not take the chance of trying to code regs for gases. This allows putting the wrong reg on the wrong bottle, or the wrong cover on the wrong reg, among other things. It is akin to loading one gun with blanks and one with real bullets, and then trying to identify them in a dark closet before putting one to your head and pulling the trigger. Sound preposterous? This is exactly what you are doing if you code regs in any way. Oxygen kills you as dead as any gun.

On a more practical note, we leave our second stages hand tight on the hoses so we can change them out if one starts free flowing. This way the main regs can be replaced with the stage regs (which bottles are turned off anyway until used), and then the stage regs switched around to provide something that works without killing the dive. This is SOP on long dives. This identical reg business also prevents any problem of switching seconds before a dive and then forgetting about it.

With the back gas, ALWAYS our deepest gas, we can always identify those regs. The backup is hung around the neck in the DIR system, and the other is attached to the long hose - both easy to identify. In cave diving, we do not carry a gas through or past it rated depth. You can see that for ocean diving, keeping the bottles turned off is the next best thing.

You can see that in teaching gas diving of any kind, the convenience of the MOD check on each other becomes paramount. Trying to id a student's gas by little labels, stickers, or a plethora of "nitrox" banners or little markings everywhere with reg jackets and colors and bands is not going to make it safer - it is going to make it a mess. I know that Jarrod Jablonski, in his training agency, GUE (Global Underwater Explorers) uses the WKPP method, as he should; he helped develop it and uses it in all of his diving.

WKPP Articles

Part of what makes a great system like this work is the ease of working it, and the perceived benefits thereof. The GUE/WKPP method requires doing nothing that takes you out of your way at all - it is just there, and provides so many solutions. Long drawn out convoluted systems break down in action and never work underwater, and in the end get discarded or poorly observed. This one is not only easy to do right, it is self-correcting in that it only falls together one way -you either do it or you do not know what you've got.

Efforts to complicate and "technify" diving make it more dangerous. Try a little simple logic.

Gas Mixing Less the BS

Let's assume all bottles are correctly marked - that means MOD only, horizontally, in three inch high letters, on either side of the upper bottle in the orientation of the tank. All tanks turned off, all regs parked. To deploy, we locate the bottle by MOD, we remove the reg and put it in our mouth, we then relocate the bottle by MOD, and turn if on. If we can breathe, we are breathing the right gas.

Now mixing: first put two pieces of tape or one GUE split tape on the empty bottle. Hook up to either gas, but I do helium first since I want my oxygen addition to be more in the middle of the operating range of the gauge, but it can be done either way. Figure the correct amount of helium for your mix considering coefficient of expansion and heat expansion. Helium will need about 17% overfill to get the % you seek. Let's say we want 50% and we are filling to 3000. Fill the tank first to 1750 to get to half, but then add another 10% or so for heat expansion, so go to a total of 1900 roughly. It should cool back to 1750 or so. No sense getting real anal here, the heat expansion is simply equal to the ratio of absolute temperature change, using the Kelvin scale - just guess at it. Turn the bottle off, but do not remove the whip until you have written down the contents of the tank and the date. Now remove the whip.

Now, add the oxygen. Keep in mind that it will be heated and expanded, but not too badly. Go a little over your intended amount but not too much. Calculate this independently of the helium, and add it without regard for the "pressure" of the helium. If you added the oxygen fist, keep in mind that it will have expanded as well from the heat of the helium filling and be giving you a higher overall helium pressure reading than you really have, so add a touch there if that is the case over and above the other two reasons. Do not remove the whip until you have written down the new gas added and the date. Analyze it if you please, to solve for the helium later to satisfy yourself.

Now add the air, unless that was heliox and we are done. Immediately analyze the gas and write the analysis on the other piece of tape or the split tape, write the date on it as well, and take the original tape off the tank and cover the valve with it to indicate that the tank is full. Do not move the tank until this is done. Obviously, the analysis should jive with the MOD. To dive the tank, you can remove the tape so as not to litter (and obviously the only thing we go by in water by is MOD), but if you do not use the tank, retape it and the valve, rewrite the contents and date, and transport that way, including partially full tanks that you intend to reuse (I reuse my deco tanks for two dives usually, so I may write some thigh like "2000 psi 50% 10-18-00"). If you use it and are not going to reuse it, it is now assumed that the tank has some amount of that gas in it, but can not be used again unless reanalyzed, so is not retagged. It can not be stored full without a tape, and it can not be transported full without a tape. Doubles can not be stored untagged if they have gas in them, and if that mistake is made, dump the partial gas and remix rather than adding to a mix. A lot of people fool themselves this way on the helium %.

WKPP Articles

Decompression and the CNS Oxygen Clock

For oxygen decompression and back gas breaks:

We have found that 12 minutes on, 6 minutes off is the ideal. We only do oxygen at 30 feet in a habitat where we have caves that accommodate this. Otherwise we do oxygen at 20 feet or slightly less in the water with the same schedule. If anyone wants to go back over why we do this and how we determine bottom gas, deco gas and exposure (or how we arrived at what we do), I can repeat it.

The short version of the answer is that we came up with this (12 on, 6 off) by trying everything and arriving at that. We knew from any of our diving that long exposures to higher ppo2s left us feeling like we had a chest cold. We started out with the usual crap that is taught out there (20 on then break) and found that to be useless. We found loss of vital capacity with these regimens.

Now we have no such negative results. The oxygen takes less than 12 minutes to reach as high an effective saturation level as is useful. Beyond that the body reacts by constricting blood vessels everywhere which limits off gassing, by trying to protect the lining of the lungs and hence thickens the transfer area by adding cells and excreting mucous which impedes gas transfer, and by causing swelling of the lung tissue which further reduces gas exchange capability, not to mention scarring and long term damage that in my opinion will come back to haunt the agencies who teach the baloney.

Returning to a more normoxic ppo2 will reverse these effects. However, if you do not return soon enough, the effects take a lot longer to reverse. The big and important thing here is not to depend on reversing this action, but to preempt it and keep it from fully developing and thus make what does occur easier to reverse and at the same time actually improve your off gassing by opening the capillaries back up and allowing gas to escape from the tissues into the blood. This "toggling" back and forth has proven to be the absolute best method of gas use in decompression. DIR deco.

If you fail to do this at any point in the deco using high ppo2s you will merely be holding gas in tissues which may expand before it can be removed as you move up - another massive flaw in all of the existing deco programs. As you get higher in the water column, off gassing is more safely and effectively achieved by the moving the gradient and letting gas bubble into the bloodstream and be caught and removed by the lungs, but lower down this will not work - one more huge flaw in deco programs. You really should look on the WKPP site and read some of my profiles and decompressions on the longer dives to see all the massive deviations from what is thought to be correct by the agencies.

WKPP Articles

Helium

What is key with helium and why in real life it does shorten deco is that:

1) You do not get the damage with helium that you get with nitrogen,
2) It is far easier to breathe and causes you to develop less co2,
3) It is truly inert unlike nitrogen,
4) It lowers the narcotic effect and makes you more alert,
5) It does not precipitate the immune reaction that high partial pressures of nitrogen do and forms smaller bubbles,
6) It comes out of tissues more easily.

WKPP Articles

Why We Do Not Bounce Dive After Diving In the WKPP

It is ok to off gas from the tissues into the blood stream in bubble form in the later steps of decompression as it is a more efficient, faster way of getting rid of the remaining gas (by reduced pressure) than by elevated oxygen alone (which starts taking exponentially more time with greater risk). However, this depends on having a good lung filter and no shunts.

All of you have been PFO tested if you are diving with us. The correct way to ascend from the last stop is one foot per minute for the bigger dives.

The greatest potential for off gassing in bubble form is when the pressure is totally removed back to one ATA out of the water. Now you get a real shower of bubbles, relative to what was happening in the water. A good, clean deco with the foot per minute ascent reduces this dramatically.

In MOST people, the greatest bubbling occurs out of the water and continues for up to four hours, not even peaking for a couple of hours. In a well vascularized, fit person like me, it is over with in 30 minutes. Don't bet on that with most of you.

In ALL people, the bubbles continue to grow in size after the pressure is off. They accumulate like gas into themselves from the surrounding blood or tissues (if there are bubbles in the tissues or injury sites) and they grow bigger. This is why you feel pain later rather than earlier if the bubbles are in joints or tissues - they get bigger before they begin to shrink. This is why what starts out as micro bubbles can get by the lungs and grow and get lodged downstream, and you get neurological symptoms later.

Now here is the important part. If you understand everything I have said above, then you know that bouncing to 20 feet or whatever to pick up a bottle and immediately returning to the surface is the like giving yourself a home-made PFO: the bubbles in the venous side compress enough to get past the lungs and then will re-expand on the arterial side and lodge in the worst places, the spine and brain blood supplies. You do not want this.

If you dive after dive, stay down and let everything reset. Get the bubbles all compressed, and then deco out and ascend accordingly.

I do not want support divers diving support within four hours of doing a real dive or deep support. This works out fine, since we have support activities lasting up to 18 to 24 hours and need to rotate everyone.

Let me assure you that we have found this out the hard way in the past. Parker used to get hot as hell when it would happen. In those days we had "volunteers", and they would all get bent diving to 20 feet to pick up bottles. We have also seen some severe cases of this where dives were done away from the project with no support, and the players went back for bottles later and got hammered.

Don't do it. Also, obviously, do not free dive after a dive. When you want to free dive, do that first and then go scuba diving.

Deco

In determining where to start your decompression, the logic is very simple: you want to let gas escape from the tissues prior to bubbling. Once it bubbles, it will not escape. Rising up rapidly from depth is a good way to trap gas in tissues by forming bubbles which will then grow when you are higher in the water column. On the other hand, gas that bubbles into the blood is generally trapped by the lungs, but those with any kind of pulmonary or cardiac shunt are at risk if this occurs. If it occurs to fast, and or the bubbles grow too large, they can block the effective lung function and will damage the capillary beds of the lungs. From depth, you want to remove gas in solution form.

The best way to do this is to begin your decompression stops at 80% of your profile in atmospheres rounded up. For a ten atmosphere dive, the first stop is 8 atmospheres, or about 240 feet. At the same time, the traveling time between 300 and 240 should be at 30 feet per minute max, so it should take you two minutes to get to 240.

There is a fine line between getting rid of gas and adding gas at this end of the deco. All you are trying to do is buy time to get the gas coming out in solution, and there is a point of diminishing returns for stops in the lower end of the deco range. The maximum deep stop is 5 minutes; the minimum is 20 seconds (30 FPM ascent). The best way to assure your ascent is at the correct speed is to physically stop every ten feet. That will get you your 20 seconds per ten feet. The range of bottom times that determine the length of the deep stops is 0-150 minutes. For 0, you still have the 30 foot rate, for 150 minutes you max out at 5 minutes per stop. Anything beyond this is effective saturation and the maximum applies.

These deep stops are equally divided at all depths up to 65 percent of the profile. At that point you begin lengthening the stops. Between 65% and 45%, the steps slightly lengthen, but max out at 10 minutes. Between 45% and 35%, the max is 20 minutes; between 35 and 25%, the max is 30 minutes, subject to certain parameters.

Going back to the deepest stop, if you switched gases, and 80% is where you need to switch gases on a long dive, you are maximizing the effect. If you use a helium based gas you further improve the results. Air is unacceptable as a deco gas as it causes damage that can not be fixed by decompressing, and further complicates the decompression due to the body's immune response to damage and the stress of rigid red cells jamming through small capillaries.

When you approach a gas change, you should be coming off of back gas. For the first deep switch, this is obviously the case. Having been on a low ppo2 operating gas, you can afford to spike the ppo2 with a deco gas, whereas you do not dare do that without breaking to back gas first. You do not use a full 1.6 ppo2 for any part of deep decompression. The risk is too high. You don't want an oxygen reaction at depth as you will not have any chance of recovering from this, or surfacing and going back down. Be smart and rely on helium and gradient more than ppo2 for these steps. Clearly, a 1.4 or

less is preferred for deep stops max, whereas shallower you can do the full 1.6 because you are able to break to a lower effective ppo2 shallow by using back gas. Some people stage a full face mask starting at these stops. JJ does this.

It takes a solid two minutes for gas to make its first pass through the body when you switch. The switch step should be the longest of the series that uses one gas. You are getting the best oxygen window for that gas at this point, and you just came from a low ppo2, and the gradient is not that severe. As you move up, the steps do not need to be longer on the same gas. In fact, you are best served to do your last step before gas switch on back gas and to make it the shortest of the steps. Here you are relying on gradient and the toggle effect.

The toggling effect is simply alternating between higher and lower ppo2's in order to prevent the onset of lung tissue damage, swelling, adding of protective layers, and constriction of the blood vessels. The reduced ppo2, especially the closer it gets to normoxic, will prevent and reverse these effects (other than the damage if it is already done). Using the gradient at this juncture is the best way to rid gas.

As you get up into the shallower areas prior to going to oxygen, you should take a full back gas break - what I call a "cleanup break". For instance, on a sat dive to 300, I will do 20-30 minutes on back gas at 50 feet. Cleanup breaks are effectively being done on long dives prior to gas switch if you do your last step on a gas by going back to the backgas.

In the 40-30 foot range from a deep dive with a long deco, it is unnecessary to extend the 40 and 30 foot stops at all. In fact these one can be sharply reduced if you have no shunts. You are better served by bubbling the gas into the blood stream sat these depths, a far more efficient and rapid way to get rid of it. Bubbles trapped here can be fixed by going back down slightly, but doing it just right means that will not happen to a well perfused diver For instance, on a sat dive to 300 that would call for 120-140 minutes at 40 feet on any deco program, I do 20 minutes and then move up.

Following each oxygen stint, you must break to back gas. If you were breathing oxygen dry, as in a habitat or trough, you must do a ten minute break before going back into the water. The ascent rate from your oxygen stop to the surface is one foot per minute for a long dive, a scaled down version of that for a short dive. The greatest case of bubbling off gassing occurs in the move from 10 or 20 feet to the surface. You want that to occur under some pressure and to be controlled by the slow ascent, so that when you are up, you will not get the sudden rush of bubbles that could shunt or cause other problems.

For shorter dives, the deco gases are added from the top down. In other words, your shortest dive might have just oxygen as the only different deco gas. A longer dive of the same profile may add the 50% gas. Still longer times would add the 35% gas and so forth. You weigh the advantage of the gas to the problem of carrying it. The effective shortening of the deco is not in play here because a shorter dive hits the minimum deco rules, so you have to do the time anyway. Longer dives demand the extra gases to stay

efficient. Toggling and alternating are key to decompression. There is no way you can beat this by maintaining a high ppo2.

Minimum Deco

The fastest on gassing occurs in the early stages of any dive, the slowest on gassing as time passes. Whenever you dive, you are loading up rapidly in the first few minutes. This gas needs to be eliminated in the proper fashion, not ignored. Sometimes, the proper fashion is merely a 30 FPM ascent rate, as in diving to 300 feet in a total run of 5 minutes and then back up in 10 minutes. As the dive gets longer, the deco at first jumps and then starts to slow its increase and eventually levels off at saturation. For dives in the 5-18 minute range, screwing up the deco is not necessarily a life threatening event, and anything will pretty much get you off the hook. However, it is best to treat these dives as "minimum" deco requirement dives and use no shorting of the schedule. Beyond 20-30 minutes you are in the "mandatory deco" range, where you must not blow off the deco or you will likely be severely injured from it. If you really screw up on a dive like this, but are able to get at least 20 minutes on oxygen at 20 feet, your survival rate will be acceptable.

The mandatory range merely requires "correct deco", not excessive of prolonged deco, just the correct shape and approximate time. It is here and beyond that you can start using the techniques outlined in my previous post. Maximum deco is outlined in an example of a dive that I did with JJ this year. It does no good, and actually more harm to go beyond maximum deco, both in terms of oxygen damage and in terms of how the tissues relatively load and unload. Spending too much time at intermediate steps will merely load up the wrong tissues and make the upper steps less successful.

Keep in mind in minimum deco that the body's reaction to pressure changes is not necessarily instantaneous. This is why commercial divers can get out of the water from 40 feet, change out of their suit, and get into a chamber if they do so within five minutes. I do not know if this is till practiced in, but this alone should give you some clue as to why "minimum" deco is a must. Passing through the depth ranges on the way up too fast does not give the body's tissues time to off gas into the blood stream. It takes at least two minutes for the blood to make a full pass through the body, and it takes a while for the gas to make it out. If you trap it, which is what happens when minimum deco is ignored, it will merely cause symptoms later when you are on the surface, sub-clinical symptoms, like tiredness, flu like symptoms, etc.

I am the fastest decompresser there is, but I do not do anything that is not the right shape or anything that is inadequate. When you look closely at what I do, you will find that for most dives, my deco will be more involved than what is prescribed by any program, will be longer for short dives, and shorter for long dives, will be shorter for helium, and infinite for nitrogen based gasses.

More on Minimum Deco

Decompression is a not linear event: twice the bottom time does not mean twice the deco, and half the bottom time does not mean half the deco. This is fairly intuitive, but for you Marines, the fact is that the fastest movement of gas occurs where there is the greatest differential. When you first go from one ATA to two for instance, there is a fast on gas rush, but as you stay there a while it slows down since the gradient factor powering the movement is lessening, like charging a battery.

On gassing is easy - you do not blow gas into the tissues in bubble form by on gassing. Off gassing is trickier, as you want to prevent bubble formation in the tissues at all depths, and in the blood deep. Off gassing in bubble form into the blood is extremely efficient time wise and allows faster decompressions that avoid building in one tissue while eliminating in another, but this is for non shunt people only. Unfortunately for the shunts, the greatest incidence of bubbling into the venous blood occurs after you get out of the water.

It takes a certain amount of time to circulate the blood, maybe about two minutes, and it can take as much as five to get gas in solution to begin to come out of solution in bubble form in the tissues or into the blood in response to a reduction in pressure. Most of the short on/offs are handled well by the body in terms of outright pain or obvious symptoms, but they may cause the body's immune system to respond to the insult that is actually occurring, and uneven off gassing from sensitive tendon attachment points and live bone surfaces as well as certain dense muscle may not be able to accommodate the super short cycles. Tissues that are hard to on gas are not as much of an issue on minimum deco, only on longer exposures.

We have found that the short schedules under 30 minutes are inaccurate predictors. What we do is set a shape for the deco as if it were a longer dive, complete with starting the stops at 80% of the profile in ATA's, and merely go to a minimum reading for each stop. The minimum deep stop is 20 seconds at each ten feet, which is effectively 30 feet per minute plus the moving time. The max for these is five minutes for saturation (or anything within 85% of technical saturation, which I assume to occur at 150 minutes bottom time). The stops indicated by the shape of the deco curve higher up need to be done to a minimum number, like 1 minute for the deeper ones and then more when the gas switches come in. Give the gas a chance to work, and then go back to the curve with the 1-2 or 3 minute stops. As you get higher up, the fact that you did the deeper part more meticulously will allow some abbreviation in the shallower steps.

In any of these decompressions, do your calculation and then discard the ten foot stop completely from the figures - throw it and its time out completely - that is total bullshit. Then ask yourself how much time do I need at 20. The answer is, enough to make it work if I did the deeper steps correctly. Two minutes on oxygen is not doing anything, ten is more like it. However, what you want to do is incorporate a slow ascent rate into the last 20 feet of the dive, so what was the 20 foot stop should be eased up from 20-6 in a steady

motion after you have sat at 20 and allowed a full circulation of the blood and the effects of the pressure change and the gas to begin to work and a relative time based on you real bottom time where the total of the 20 plus ascent to surface is at least equal to your bottom time, again assuming you have done the other steps correctly. Do not waste a bunch of pyramided time at steps where there is little partial pressure advantage; use the gradient more in these cases, again assuming you have conscientiously done the lower steps.

Don't be in any big hurry to get up from the bottom, and do not be in any big hurry to get up from 30 feet to the surface. These two areas need careful attention.

I think that if you discard the 10 foot silliness in any program and the unnecessary time, then put some of that time back into the correct shape and strategy, you will not only prevent the out right DCS, you will prevent the sub clinical DCS and the immune responses.

If you execute deco correctly and are in good shape and have no preconditions, you should be clean and ready for anything 30 minutes after you get out of the water. You can tell if you have not done what I am saying here, you will not feel so good. It will be subtle, but if you want to test it, try going for a run. If you are immediately short of breath, you blew the deco. If you can rock, you did it right. If you get bent trying this, then tough luck, blame JJ. In reality, you will feel a little sluggish and heavy just putting your gear away if you did an inadequate deco.

Now, if there are questions that can help with the understanding, bring them on. If anyone wants to argue with me, save your breath and be ready to show me your logbook, and don't bother with the IANTD, TDI, PADI, DAN or any other form of nonsense that is floating around out there. Nobody understands this like I do, and nobody can execute it like I do, and nobody has done it this way for as long as I have, not even my own team. I know for a fact that this is not only correct, it is correct beyond a shadow of a doubt. I remember getting Exley to get out of the water with me at Wakulla one time on my schedule. That was easy to do with him because he responded very well to peer pressure - I could get him to do anything I dreamed up. He spent the next four hours in the lobby of the Lodge getting FSU to Doppler him over and over just waiting for the big bends hit - never happened. That was nine years ago. We have really perfected it now.

Simple Explanation of the Oxygen Window

As a dope's explanation of the oxygen window concept for you Marines, the best gas differential would be a vacuum relative to a partial pressure, right? Oxygen is the next best as it creates a similar effect in that the sum of the gas partial pressures is unbalanced by the fact that some of the oxygen is metabolized, more in a fit person. The greater the difference between the oxygen and the other gases up to the max differential described by the metabolism (maximum window), the greater the propensity for whatever is in the cells to come out and be displaced. For a fit person, the window is wider and by definition so is his vascularity and perfusion, so he decompresses better. These things are all tied together.

You open the window as wide as possible subject to 1) risk of tox or damage, 2) how long before the vasoconstrictive effect offsets the benefit, 3) how long before the asthma like reaction sets in. You then alternate the process back to open up the vessels and lungs again, and repeat. All part of a good deco. Also it can be said that the sum of the inert gases is the other side of the oxygen window minus the metabolism drop of oxygen - there is no benefit to combining inerts - they act like one gas. Oxygen can be pushed to above its partial pressure effectiveness as a result of this imbalance for a "window" that then exceeds what would be the net effect of the partial pressures of the gases, and this is especially important in diminishing bubbles of inert gas as the pressure of the bubble can always be faced with a negative gradient or "tension" on the outside due to the fact that metabolized oxygen is creating a "vacuum" in the total sum of the partial pressures of the gases, leaving a consistent imbalance between bubble pressure and surrounding tension of any given inert.

This is why oxygen (pure, not 80/20) works so well in DCS cases after the fact to reduce bubbles, as well as the fact that saturation with oxygen tends to move that gas to where it is needed even if the vessels are blocked by damage.

Capice? For you geeks, see Eddie Bryan's explanation. When you are done with all that, go back and see what I said about how to decompress. How is all that matters.

Deco 101

Decompression has two basic components: 1) physiological and 2) the decay curve. The curve attempts to describe the on and off gassing vs. time and pressure, is very simple and basic, has a standard look that mimics most such curves where they apply to nature (right down to the ratio of the distances that arms of galaxies are spiraled from each other).

Very simply, the reason number two does not account for all diving is because of number one. Some divers get great results with anything that fits into the midrange of all the curve's parameters, i.e., not too deep, not too long, not too short, and a deco that would work theoretically many data points away from the profile being done. Then they get hurt on a real deep short dive, or a long shallow one, or whatever. That is not the fault of the "model"; it is the fault of the application in the absence of considering the physical.

WKPP Articles

Repetitive Diving 1

Mike, I will put out my repet post and the others in sequence, but first let me mention something here that is being missed.

Gas does not transfer from tissues into arteries or veins, it does so into capillaries. The arteries coming from the heart are huge, thick, elastic, pulsing conduits that get smaller as they branch out until they become capillaries, and then the return to the heart is through veins which are also thick and get larger as they combine to return blood to the right side of the heart.

That blood is then sent to the lungs, where the massive network of tiny capillary beds located in about 45,000 square feet of surface area, act as a "filter" for bubbles. The "filtered" and now oxygenated blood, which has passed its co2 and other excess gasses to the lung space, goes back to the heart to be pumped through the system again. The whole trip takes about two minutes to happen.

You do not bubble into the arteries. If bubbles get into the arteries it is because they passed the filter or were "shunted" over through a PFO in the arterial walls, or because they were momentarily compressed enough to get past the lungs and then re-expanded as the pressure dropped prior to reaching the capillaries, in which case they lodge in the smaller and smaller vessels and block them. This occurs in bounce diving, as in doing a dive and then bouncing back down to retrieve something, like a deco bottle. This is why we do not allow bouncing in the WKPP, and why we require our support divers to stay out for 4 hours before diving shallow for support.

(See Why We Do Not Bounce Dive After Diving In the WKPP)

Most people get the greatest rush of bubbles from the tissues into the blood stream upon surfacing from 20 feet or so. This is why we do that differently, post to follow. Most people tend to bubble for hours after a dive. Most bubbles tend to grow from the surrounding supply of gas before they get smaller and disappear.

If the bubbles are in the tissues, you have pain. The way to prevent bubbles in the tissues is to properly decompress starting deep and at a rate that allows the bubbles to escape to the blood stream. Deep this needs to be done carefully and in solution, shallow you can press the gradient and allow off gassing in bubble form into the blood stream. The difference is that if you screw up shallow, you can go back a little and fix it. If it occurs deep, that makes it impractical and a huge waste of time for nothing. For people with cardiac or pulmonary shunts, off gassing in bubble form is super dangerous. For those without, it is far more efficient. For those with PFO's, the risk is greatest AFTER they get out of the water for the reasons stated above (growth of bubbles and continuation of bubble off gassing).

I think you can see where I am going to tell you that you need to do your shallowest dives first, do your drills before you do your dives, and why you can basically ignore repetitive dives using the correct deco. You can NOT ignore them with respect to oxygen exposure.

This post is long enough, basic enough and preliminary enough. Now we can go on to the whole bit.

Repetitive Diving 2

First, what is the real risk? It is not DCS, it is CNS toxicity. The risk of pulmonary toxicity is also an issue more so than DCS.

Repetitive diving needs to be done with this in mind. You do not want to run high ppo2s over and over, and you certainly do not want to do multiday diving on high ppo2s. So the first things we need to do are back off the working ppo2, and then plan the decompressions such that we are not accumulating an excess exposure.

If you do you decompression the way I outlined it in the other posts, including the way I ascend to the surface, you will greatly reduce the heavy bubble-form off gassing that generally occurs post-dive. If you are basically clean, you can dive again without penalty. If you are using the correct gas, the "residual" effect is greatly reduced. This effect is more designed to explain accumulation of gases in tissues which are not well perfused and as such tend to trap gas which becomes a battery for supplying gas to formed bubbles later on, so repetitive diving with a gut, or battery which holds gas, could contribute to making any bubbles on the next dive worse and contribute to them growing well after the dive.

This does not apply to most of us.

If you do the decompression for the subsequent dives correctly, there is no reason to belabor the issue.

From a logistical standpoint in the ocean, it is far safer to do a couple of back to backs than one long dive which requires a long mandatory decompression.

From a decompression point of view, we have seen that repetitive diving makes no difference, so we ignore the first dive in calculating the second. The only trick is that the second dive should be deeper than or equal to the first, and you can not bounce dive after a dive of any kind. We have done back to back 300's with 60 minute bottom times with no change of deco schedule. In the WKPP we have discontinued that practice due to the oxygen exposure risk, however.

WKPP Articles

Separation Protocol

This is how we handle buddy separation issues. It is the responsibility of the front diver to know if the next guy is there or not. If he is not, the front stops, turns, and retraces. If the third guy stops, the second guy must stop and deal with him. It is still the responsibility of the front guy to know if the second guy is there. A light flash would be great, but the protocol must work in the event that a light flash is not possible.

It is the responsibility of the guys in back to hold light on the person in front of them such that the front person can see the beam and know the buddy is there. We stay close in all caves, regardless of size, but in small cave this prevents losing buddy at every turn, and it allows the buddy to ride through any silt or halocline or whatever stirred by the front guy without stopping and starting. If the vis gets really bad, the back guy's responsibility is to either be in touch contact with the front swimming or to bump the fins with the vehicle if scootering. This is standard WKPP stuff and I expect everyone to know this and adhere to it. I hate diving with people who can't play by these rules as it results in a slinky dive and a stress out. I personally thumb any dive where this or other breaches of protocol occur.

The front guy can do a sidewave signal if he can not see the back guy, which tells the back guy to swing his beam across the front guy's mask, showing that he is there. If the line is buried, the front guy must signal no line with his light (slow back and forth), and the back guy must automatically stop and hold his position on the line that he can still see. When the front guy finds the line ahead, he signals a fore and aft sweep of the light indicating he has regained the line, and the back guy can then proceed by returning the signal (not an "ok" signal).

We have no excuses for buddy separation lasting more than seconds. We stay as close as possible at all times. If you are not bumping into your buddy from time to time, you are too far away. The trick to what we do is team execution. The reason nobody can touch us in this game, including what are considered the "best" in the world, is that they don't get this part. When Sheck Exley started diving with me, he was so amazed at what can be done our way that he talked to me every night at home and called me every day on his lunch break to talk about what dive we could do the next weekend. What Exley used to tough out by himself or with strokes over periods of weeks of aborted CFs, he could do with me in one day.

Just by way of comparison of philosophies, the USDCT (made of up some of the most horrific idiots in Florida cave diving as well as the "best" from Europe and other places) took 90 days of diving to get halfway out JJ and my line in the main tunnel of Wakulla, and JJ and I went back after they were booted out and added to the end of our own line (twice as far as their max pen) in one dive in one day. The difference is in the ability to work a dive as a cohesive team. The little details are what make this happen.

WKPP Articles

The Bakers Dozen - 13 reasons why we do not use 80/20

1. This gas was introduced in an effort to overcome the inability of unqualified student "tech" divers to control their buoyancy in open water, and is as such is yet one more concession to doing things in a convoluted fashion to offset a self-inflicted set of problems brought on by the "doing it wrong" thinking that pervades diving today.

2. A heavy sea is not a problem for a deco stop if it is not posing a lung-loading problem. Look at your depth gauge in a heavy sea and "see" for yourself what the changes are - insignificant, and if they are not, you should either not have been diving or incurring a decompression liability of this magnitude in the first place. In the event of a change in conditions during the dive, see below where the 80/20 becomes a liability rather than an asset.

3. In the interest of using a standardized set of gases for which you can permanently mark your bottles, it is a poor concession to inability to sacrifice the benefits of pure O2 to accommodate a real or perceived lack of skill - learn to dive before taking up techdiving.

4. In this same interest you will find that when you graduate to real diving, as in caves, you will not want to accelerate your ppo2 at lower depths while still being faced with a long decompression at shallower depths, and making bizarre mixes to do this is a dangerous mistake (just like the fantasy of holding an accelerated ppo2 on a rebreather throughout a deco). I am anticipating the thinking that the 80/20 crowd would then go to an additional oxygen in cave without accounting for total exposure, and subject themselves to the risk of tox in the final deco steps. Tox you do not get out of - bends you do.

5. The 80/20 mix is in fact totally useless and contraindicated as a deco gas. At thirty feet it is only a 1.52 ppo2 (the real 1.6 ppo2 gas would be 84/16) and as such does not either provide the right oxygen window, nor does it does it work as well as pure oxygen without an inert gas at any depth. The gas mixing in your lungs has already lowered the effective ppo2 enough to prevent spiking at 20 feet anyway with the use of pure oxygen - in other words, we are dealing with a simplistic misunderstanding here, or "old wives tale" that is typical in diving.

6. If 100% oxygen is a perceived buoyancy control risk at 20 feet, then why is the same ppo2 (intended) not a risk at 30 feet? This shows the total lack of reasonable logic involved in the decision to use this gas, as well as a lack of understanding of the whole picture (see the rest of this discussion).

7. Along those lines, all we hear is howling about "oxygen cleaning" above 40% mixtures, and dive shop proprietors on here complaining about scuba tanks with oxygen in them being filled in their shops. With a pure oxygen system, the tank only ever gets filled with oxygen from oxygen tanks, not from every dive shop compressor it sees. Again, this shows the total inconsistency of agency thinking, and reveals that the true reason for this gas is to pretend to lower liability for

teaching incompetents to dive, which is bull, and to attempt to accrue some inventive accomplishments to the dive agency pundits who themselves prove that they do no real diving by making this recommendation in the first place. This is like the colored regs, the stages on either side, the quick-release buckle, and the poodle jacket: nonsense of the most obvious nature developed through one-dimensional thinking by those whose universe of understanding is not only severely limited, but blinded by the hubris of not being the "inventor" of the techniques that work.

8. Any perceived decompression benefit of using a higher ppo2 at 30 feet with 80/20 is then given back by the lowered ppo2 at 20 feet, not to mention the fact that the presence of the inert gas in the breathing mixture defeats the purpose of using oxygen in the first place (see the Physiology and Medicine of Diving) . The ppo2 of 80/20 at 20 feet is 1.28, not much of an oxygen window, and at 10 feet it is 1.04 - useless for deco. To make matters worse, you can not get out from your 30 foot stop in an emergency (not doing the other stops) on the 80/20 mix without really risking a type 2 hit.

9. This is a dangerous method to achieve a greater total volume of gas for the bad breathers (another obvious reason the gas is in vogue), who should not be incurring these decos, and even that benefit of having more gas is lost since it is breathed at 30 feet, and then has to last for the other stops. The fact is that gas is effectively saved by using the lower deco gas up to this point, relying on the pressure gradient to both achieve the deco and provide a break from high the previous gas's higher PPO2 prior to going to pure oxygen where the spike could be a problem on an extreme exposure without an adequate low ppo2 break (again this shows that the 80% user is a neophyte diver with no real experience or understanding of the true risks of these dives).

10. The 20-30% longer 30 foot time on the lower ppo2 is not only overcome on the pure oxygen at the next stops, the breaks do not come into play until the initial good dose of pure oxygen has been absorbed, since you are not spiking from a high pervious dose without a break that is effectively achieved on the previous gas. These things need to be understood and taught by the agencies, not some superficial convolution that is designed to obfuscate the problem rather than openly acknowledge and deal with it in a responsible fashion.

11. In an emergency situation, getting onto the pure O2 for 20 minutes or so (for long dives something approximating the bottom time or a any decent interval) would give you a real good shot at getting out of the water having missed the rest of your deco and living through it with pain hits only. You have to think these things all the way though, not go for the transparent superficial thinking of those who merely are trying to "make their mark" with some "great" idea they can call their own. The acid test is, as always, is the caliber of the divers who adopt these practices.

12. If there is some problem with your deco or you otherwise develop symptoms and need oxygen either on the surface or back in the water, it is silly to have not had it there all along. 80/20 is a joke for that purpose, unless you have asthma, in which case any accelerated oxygen mix would be a nightmare. This is again part of the "thinking it all the way through" philosophy which is obviously missing from the 80/20 argument.

13. Only a card-carrying stroke would do something like this, and showing up with 80/20 is no different than wearing a sign on your back saying "I am a stroke, and have the papers to prove it". It announces to all the world that you have no clue, kind of like wearing clip-on suspenders or having dog dirt on your shoes.

WKPP Articles

By David Rhea

OOG Emergency Procedures While Scootering

Recently I have had several questions about OOG emergency procedures while scootering.

The only real option is for the two divers to get into a customary gas sharing position. The donor places the receiver in the front of him insuring close contact and easy hose management. The donor will place his DPV in the standard rear tow position and the receiver will tow the two of them out as is SOP. The exception to this would be if the receiver was overly shaken and the donor felt it best that he control the exiting navigation. In this case he could tow the receiver, clipping the receiver's DPV in the tow position behind the receiver.

Naturally they would never abandon a working scooter. Likewise, they would never tow a dead scooter out under these circumstances. While scootering we are exposed to several real threats that make it truly dangerous to operate two DPV'S simultaneously while sharing gas.

The pace would be extremely difficult to coordinate. If for any reason the reg was ripped from the receiver's mouth it would be almost impossible to retrieve it and return it to them in a reasonable time frame. If the long hose were accidentally pulled from the receiver's mouth it is highly likely that the reg would be sucked into the prop of one of the machines. This of course could be very catastrophic, as then additional gas would be lost from the only remaining resource. Navigating restrictive passages would be virtually impossible. Simultaneously trying to control buoyancy, while traveling at high speed in a high outflow cave, in tandem, is not realistic. All of these reasons make sharing gas with both divers scootering unsafe. When compounded with the significant distance and/or depths we are exposed to in the WKPP, the scenario becomes not only unsafe but unrealistic.

As always, proper judgment, practiced skills, and a calm demeanor are all paramount to the success of every emergency resolution. These, like all skills, must be practiced if they are truly to be a viable option in reality.

David W. Rhea
WKPP Training Coordinator
GUE Cave Training Director

WKPP Articles

By Todd Leonard

Towing Scooters

The current approach to towing scooters is to have a fixed cord with a bolt snap on the front. The cord is secured via the same hose clamps used to secure the webbing (carry handle), at the low point when the scooter is in its resting position. Length should be set so the scooter's nose isn't totally jammed up against the base of your tanks, so the scooter can float around a little and find the path of least resistance, but don't make it absurdly long either. While riding the scooter you stow it by wrapping it around to the "top" and clipping it off on the handle -- the nicest approach to this I've seen is to put a hole in the webbing with a punch or pencil-tip soldering iron, and just clip into that.

To tow the scooter, pin the trigger and turn the blades to neutral, stow the normal "triangular" tow cord, then clip the short cord to your front (and hopefully only) crotch D-ring.

Even if you only have one scooter you should have this cord, as you will need to tow the scooter behind you if it fails and you need to be towed out by your buddy.

To be towed by your buddy, hold onto his crotch strap webbing, not the D-ring. Your hand will totally cramp up if you try to hang onto the D-ring for any period of time. Tuck your head down to maximize streamlining and trust your buddy to do the steering. He needs to be aware of the somewhat higher profile and not slam you into the ceiling, and may need to turn his pitch down a little to keep the motor turning at the right speed against the increased drag.

I haven't figured out if there's a standard terminology to differentiate between these two cords. I usually call one the "short cord" and the other the "tow cord", but who cares.

WKPP Articles

By Casey McKinlay and Jarrod Jablonski

WKPP Training / Preparation for Dives.

Casey McKinlay:

Several key elements - nutrition, fitness, gear maintenance, mental preparation and sleep to name a few are high on everyone's list. In addition to the following I focus more on the cardio as opposed to the strength training but fully recognize, like George and Jarrod, the need to have both due to the additional equipment and the wear and tear. I also spend a lot of time on gear maintenance and preparation. Scooter and light pack burn testing, regulator and RB maintenance and extra and backups of everything. Taking time to rebuild or repair something onsite is unrealistic. Pull another one out of the box and move on. Like George, I also tend to address the changes and repairs immediately following an outing while it's fresh in my mind. I also work towards giving my self a full or at least a half day off prior to the actual dive. Time to sort things out and focus without the distractions of work, kids, etc.

Exercise and sleep are the hardest and most important things to do regularly. I work out on average five days a week for roughly an hour. Some days I do a two a day work out but mostly I do one session with about 30 min anaerobic and 40 aerobic. At various points I will do much more but not usually a whole lot less. Be careful you do not over train if you are new to this. For exercise variety is a huge key, meaning that you need to vary both the type of anaerobic and aerobic work outs. If you are particularly tight on time then go cardio but try to do at least a couple weight-bearing sessions weekly. I usually just do one body part each session and then go to cardio but you could also do two quicker ones per session and do twice per week weights and the rest cardio. Make sure that you do at least one peak in your cardio and give yourself some cool down as well.

Food should be a good mixed diet. I am not a protein hound but due to American diets most people naturally eat WAY too many carbs so toning that tone is usually helpful. Eat smaller more regular meals and be sure to eat when you first get up even if it is a small meal and you are not hungry. 4-6 meals small meals daily is best and most find that if you are going to eat any larger meals that breakfast and lunch are best both from a recovery and weight gaining perspective.

Drink LOTS of water 1-2 gallons daily and try to avoid anything but water; other drinks make it hard to keep up the intake and usually contain caffeine which makes your job harder. A good daily multi vitamin is probably not a bad idea and I usually take some Vit C, CoQ10, B12, Mag/Ca (for cramps), on the day before, of, and after big dives.

Sleep is particularly key the day or two prior to the dive especially if you have any trouble sleeping the night before a big dive. Work very hard to clear your plate such that

the day before the dive is light both with respect to physical and mental exertion. You need to get focused on that day and start leaving all the life bullshit at home. It will be there when you get back.

I'll touch on some of the obvious sections.

Gear/Fills - I try to stay way out in front of this and not do any of this at the last minute. I'm really anal about gear and try to keep everything in a state of readiness. Rigging or fixing gear the morning of a big dive is not a good idea, and delays things. I spend many weekday evenings in the garage after the girls go to bed - repairing, burn testing, adjusting. By Thursday, the only thing I want to be worrying about is buying stuff for the food tube.

Fitness -- JJ covered this well. I personally work out 5-6 days per week, about 50 minutes per workout. I'm guilty of prioritizing cardio over strength training and probably need to mix it up a bit more. A typical cardio workout is 5-6 miles, with a 1 longer one on the weekend (when not diving). I also bike. I'm a big believer that cardio fitness makes deco more efficient and keeps your hoover rate manageable (less of an issue with the RBs).

Sleep - I rarely sleep really well the night before the dive, so I always make sure I get plenty of sleep on Thursday night.

Hydration - Lots of water the entire week.

Planning - I think we all spend a fair amount of time on the phone or email during the week to iron out the details of the plan to ensure it's fairly thought through. Not to say it never changes <g>.

Minimize Distractions - Easier said than done, but I try to cut out of work at noon on Friday to go home, load up, and drive to Tallahassee in time to grab dinner at a decent hour. Having a 2.5 hour drive versus a 12 hour drive previously makes a huge difference.

Game Day - A good breakfast, bland foods. Focus on getting the gear down to the water. Often set up the RB the night before. Minimize the socializing to focus at the task at hand.

Jarrod Jablonksi:

I prepare for the big dives much like yourself and the other guys. I begin by maintaining a regimented workout routine consisting of weight training plus cardio 4 days per week and I swim on Thursdays. I get to the gym at 6:15 Monday thru Friday and generally I get in a cave dive on the weekends. I teach a cave class every month and have done so pretty religiously for over 18 years now. This allows me the opportunity to stay in practice as well as constantly exposing me to some interesting and demanding situations.

I burn test the scooters prior to the dives, check the regulators, analyze the gas and recheck the tank markings and contents labels.

I do my best to eat well through the week with usually a splurge day on the weekends. I do my best to get proper rest the week of a big dive and especially the night before, (this doesn't always work out so well).:)

Mentally, I try and run the dive plan through my head several times starting the day I receive your email. I really try and go over this on the drive up and I always print out the email and bring it with me to read the night before and just prior to the dive. This allows me the opportunity to mentally establish my contingency plans and psychologically ramp up for the dive.

A big key for me is knowing that I am diving with the best of the best. The gas divers are truly solid both mentally and physically and are qualified to get the job done. This is number one for me, and the rest is a matter of being religious and meticulous about your routine.