Ascending From A Dive
(Ascent Rates, Deep Safety/Deco Stops & Time Limits)

by
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Intro

The articles that follow are overly simplistic and are for illustrative purposes only. There are many different models including different models that account for bubbling. When the term bubbling is used it generally refers to "excessive bubbling" and not minute bubbling as there is such a concept as efficient bubbling. What also must be kept in mind is that decompression sickness and illness (DCI) can be unpredictable and can occur after any dive, even a conservative dive. Therefore divers must take responsibility for themselves and dive conservatively to lessen (but not eliminate) their chances of getting DCI. With this being said, let's start with . . .

Deep Safety and Deco Stops

It has long been known that deep stops benefit divers performing decompression dives. The same rationale behind deep decompression stops holds true for safety stops. What technical divers know, but many recreational divers don't, is that all dives are decompression dives whether the dive requires a mandatory stop or not. The reason all dives are decompression dives is simple - the diver is ascending from under pressure (i.e. decompressing). What must be kept in mind is that even though a dive is within NoStop time limits, the diver is probably experiencing asymptomatic bubbles (minor bubbling that does not cause DCI). This is not unusual and causes no harm since the body can be forgiving. This brings us to our first topic . . .

Why Safety Stops?

Every diver has been told to perform safety stops, yet the vast majority of divers I see never do one. Why? Probably because they are not understood. Many divers have been informed that performing a safety stop allows them to slowly eliminate nitrogen. This is simply not true. A safety stop assists the body in <u>rapidly</u> eliminating nitrogen! Why? The reason is very simple. Bubbling does not occur in a diver under pressure, it only occurs when the pressure is reduced "too much". Once bubbling occurs, gas elimination is reduced. This is because the driving force for nitrogen elimination has diminished. The bubble now has to be reabsorbed - which can be a time consuming process. However, if bubbling can be minimized or prevented, then the nitrogen stays in a gaseous solution (i.e. dissolved) in the body. If this can be maintained while surfacing, then the nitrogen pressure is maintained while the pressure surrounding the diver is reduced. When the nitrogen pressure is allowed to stay greater than the surrounding pressure, a driving force for nitrogen elimination is created and nitrogen will "zing" out of the body. To put it even simpler, a diver that performs a 3 minute safety stop after a dive will have less nitrogen in their body immediately upon surfacing as compared to a diver that did not perform a safety stop, but has been on the surface "offgassing" for 3 minutes. Therefore, one of the best things a diver can do for themselves is to perform a safety stop, no matter how short, after every dive.

How Deep?

Since the goal is to promote nitrogen elimination prior to surfacing so the risk of DCI is lessened, the next question is how to calculate the depth of a safety stop. Years ago, a safety stop was recommended at 10 feet after every dive. This recommendation wasn't so much a depth recommendation other than a recommendation to just perform a safety stop. The depth of 10 was chosen because the final stop on decompression tables was at 10 feet. Later, the recommendation turned to 15 feet and is now currently 15 to 20 feet for 3 to 5 minutes. A deeper depth of 15 feet was chosen for several reasons, but a driving force behind this deeper recommendation was overwhelming information that deeper stops promote greater nitrogen elimination. My favorite example was a fairly well controlled study where two control groups were taken to the same depth for the same time and then performed safety stops for the exact same time, but at different depths. One group performed a safety stop for 5 minutes at 10 feet while the other group performed a 1 minute stop at 20 feet and then a 4 minute stop at 10 feet. Even though both groups did 5 minutes of safety stops, the group that started at 20 feet had significantly less bubbling not only upon surfacing, but also over the hours that followed the dive. While this violates standard half-time theory, the evidence is in . . . deeper is better. But how deep? Again, one of the common recommendations is 15 feet. A rule I like to live by is "keep it simple" and picking one single depth that a diver can remember definitely keeps it simple and makes it easy to perform. However, when it comes to a simple task such as picking a safety stop depth, I like to give divers a little more credit and believe that the main difference between sport divers and technical divers is the amount of information each has been exposed to. Therefore, I believe that since technical divers perform decompression stops over multiple depths, so can sport divers especially considering that these stops are not mandatory, but merely safety stops. Therefore I don't recommend a single depth. Instead I recommend, performing safety stops over a range of depths - which is extremely easy to do. The only calculation that needs to be done is to pick the depth of the first safety stop. All that is needed is a rule of thumb. The rule I use is to take your deepest depth of the dive and divide it by one-third and round to a deeper depth if necessary. For example, after performing a dive to 100 feet, the depth of the first stop would be 33 feet - which could also be rounded to 35 feet if desired. This calculation can be performed easily in the diver's head while underwater. The question is . . .

How Long?

You don't need to stay long at the first stop and 1 minute is fine. The next step is to calculate where to go from here and for how long. The answer is come up another 10 feet and stay there for 1 minute until 15 feet is reached. Once you reach 15 feet stay there for 3 to 5 minutes or longer . . . whatever you desire (within reason of course). A sample profile looks like this. After a NoStop dive to 90 feet for 20 minutes, surface to 30' for 1 min., then go to 20' for 1 min., then finish at 15 feet for 3 to 5 minutes. Another example is a dive to 100 feet. Make the first stop at 35' for 1 min., then stop at 25' for 1 min., then at 15' for 3 to 5 minutes. If a shallow dive is being performed such as a dive to 40 feet, you need only make a 15 foot stop. Once you reach 15 feet, slowly come to the surface. Creep your way up and maybe stop at 5 to 10 feet on the way up for 30 seconds.

Nitrox and Altitude

If you are diving on Nitrox, then you may use the Equivalent Air Depth of your dive to calculate the depth of your first stop and then follow the above procedure until you reach an actual depth of 15 feet. If diving at altitude, while you need to plan your diving using altitude procedures and Equivalent Ocean Depths (EOD's), you do not need to think in terms of EOD's when calculating safety stops. You need take only your actual depth (assuming you have an altitude adjustable depth gauge) and follow the same procedure until you reach the EOD of 15 feet at that altitude. For example, if you dive to 90 feet at Lake Tahoe (an elevation of 6229'), your first stop would be at 30 feet, your second stop would be at 20 feet and your last stop would be at 12 feet (Lake Tahoe's equivalent ocean depth of 15 feet).

If you haven't really performed safety stops before or haven't paid much attention to them, the procedure I just described may sound boring. Try it. I think you won't find it boring. When the stops are actually broken up into different depths, the time passes very quickly. If you also understand why safety stops are one of the best things you can do to reduce the risk of DCI, it shouldn't seem boring and a waste of time, especially when compared to the time that could be spent in a recompression chamber and knowing that you will be surfacing with less nitrogen in your body as compared to not performing a stop.

Tech Divers

While there is no rule of thumb for performing decompression stops, the above rationale for deep initial decompression stops apply. Most tech divers are familiar with Pyle Stops - the suggestions by Richard Pyle on how to add deep stops to current dive tables. While these suggestions are applauded and were much needed, tech divers need to go beyond these suggestions. There are different models that perform these calculations such as using a gradient factor. However, this method may not calculate the first stop as deep as this author would prefer. For this and other reasons, this author designed a different method of calculating decompression stops and designed a computer software program around this called Departure. For more information on this program, please visit Departure's web site.

Ascent Rates

Sport Diving

Different dive tables use different ascent rates. In the U.S., most divers are accustomed to a 60 foot per minute ascent rate. Unfortunately a lot of divers come up much faster than this. In fact, a 60 foot per minute ascent rate would seem slow to many divers if they actually measured and timed themselves during an ascent. This is an important topic to discuss - which leads into advocating for an even slower standard ascent rate. First a little history. The 60 foot per minute ascent rate originally came from the U.S. Navy. The original Navy Tables used a much slower ascent rate of 30 feet per minute. However, the divers did not like this ascent rate as they found it too slow. So they requested a much faster ascent rate of 100 feet per minute. A compromised was then reached of 60 feet per minute and it stuck. However, the majority of dive tables (not all) use slower ascent rates and 10 meters (33 feet) per minute is common in other countries. I would like to take this one step further and advocate for an even slower standard ascent rate of 20 feet per minute for sport divers (at altitude as well as sea level). Dr. Brian Hill's thermodynamic decompression ideas got me into this line of thinking and this slower ascent rate has its advantages and is used in Departure. The initial reaction of divers when they hear this is that it too difficult to be performed. In actuality it is very easy. An ascent rate of 20 feet per minute means that a diver will take 3 seconds to ascend 1 foot. But ascent rates can be viewed as "mini decompression stops" and can be performed in stages. There are two ways to perform this ascent rate in a very easy manner. The first is to come up 10 feet at wait until the time catches up. In other words, it should take 30 seconds to come up 10 feet. If takes the diver 3 seconds to come up 10 feet, the diver then waits another 7 seconds before going up another 10 feet. The ascent rate between the different 10 foot "mini stops" doesn't matter as long as one does not ascend more than 10 feet at one time. The same principal can be applied to doing this every 5 feet and waiting until 15 seconds elapses. I personally use the 15 seconds for every 5 feet method, but doing it every 10 feet is acceptable. If you read the above section on deep stops, you now can draw the analogy that the deep 1 minute stops are nothing more than drastically slowing your ascent rate down (i.e. to 10 feet per minute) during the final portion of your ascent. Likewise, slowing your ascent down is analogous to performing very brief "mini stops" on your way up.

The ascent rates can be modified even farther. The deeper the dive, the faster the ascent rate can be during the deeper portions of the ascent. For example, if diving deeper than 50 feet, the ascent rate to 50 feet can be sped up to 30 feet per minute. However, there is a drawback to this. You now must watch your depth on the ascent rates. This violates the "keep it simple" rule. Therefore I recommend just using the 20 feet per minute ascent rate.

Tech Diving

Notice I propose the 20'/min. ascent rate for sport divers. Tech divers need to modify this. While in sport diving there is really no such thing as coming up too slow as long as it is considered when planning the dive, tech divers need to minimize their exposure under pressure. Tech divers can also take advantage of variable ascent rates and come up faster during the deeper portions of their ascent. But again, it violates the "keep it simple" rule. However, the knowledge that coming up faster is allowed can give a tech diver piece of mind if they find that they accidentally exceeded their planned ascent rate. Since a tech diver can use a faster ascent rate the deeper the depth of the first stop, the maximum ascent rate chosen will always vary. Since I take a conservative approach to diving, including tech diving, the maximum ascent rates I choose may be slower than seen before, but I actually use a mathematical model to calculate these ascent rates. The following are some examples of possible sea level ascent rates. For example, a tech diver dives to 150' and has the first decompression stop at 80 feet. The diver's ascent rate to the first stop will be 40 feet per minute.

20'/min. (30 sec./10 ft.) from 50' to the surface
30'/min. (20 sec./10 ft.) from 70' to 50'
40'/min. (15 sec./10 ft.) from 130' to 70'
60'/min. (10 sec./10 ft.) from deep to 130'

NoStop Time Limits

The last topic is modeling and choosing NoStop time limits. While there is consistency among dive tables in the "mid range to deeper depths", there can be a lack of consistency in the shallow depths. While most divers never reach the NoStop limit on a shallow dive, the time limits can play a crucial role when it comes to repetitive diving and when modeling and calculating dives requiring mandatory decompression stops. The reason for the inconsistency in the shallow depths is the way in which these time limits are modeled or not modeled. No-stop time limits follow a pattern. If time limits are graphed on log-log coordinates, the time limits appear to be a straight line. However, the time limits deviate off this straight line at the shallow depths. The reason for this deviation is the time limits start approaching infinity as the depths get shallower and approaches the "minimum bends depth." The minimum bends depth (MBD) is the depth at which there is no time limit - the depth at which a diver may "saturate" and immediately surface.

Many time limits at the shallow depths have been calculated with educated guesses to take into account the shallow depth deviations. Instead of educated guesses, I was able to come up with a model that predicts and models time limits at all depths including the shallow depths and their deviations. This model was derived by combining three different decompression models and theories. It calculates time limits when the following is plugged in: 1) the desired minimum bends depth, 2) the desired model slope on the log-log coordinates, and 3) a desired time limit at a known depth. This model results in time limits that maybe more conservative at the shallow depths than divers are used to. This is because this model does not show as much of a deviation at shallow depths as others allow. In fact, comparison of time limits at shallow depths is a good way to start evaluating tables, programs and models. While a brief safety stop can add a margin of conservatism after a deeper dive, a brief safety stop after a long shallow dive may not yield the same level of conservatism. Therefore, when safety stops are performed, the time limits at the shallow depths may be more critical than the time limits at the deeper depths (within reason). This also shows the importance of not deviating in too radical a manner at the shallow depths as too much of a deviation could result in a decompression profile that is not long enough. Many divers look at only the time limits at the deeper depths when evaluating tables and will notice a difference of 1 to 2 minutes at 130 feet, but do not notice a difference of 60 minutes or greater at 35 feet – which may actually be the more critical measurement. The reason the time limits used are so important is they are a product of the decompression model used and show the conservatism level of the model itself. So don't forget to critically evaluate the shallow time limits for two reasons 1) because a safety stop may not be as beneficial after a long shallow dive as compared to a deep short dive, and 2) because time limits at the shallow depths may be calculated by educated guesses.

Below are some example time limits showing consistency at the middle to deeper depths, yet big differences at the shallow depths depending upon what MBD is chosen for the model. The times in the first column were modeled with a minimum bends depth of 20 feet and a time limit of 55 minutes at 60 feet (a common table depth and time and MBD). The rest of the times were modeled with different minimum bends depths around a time limit of 50 minutes at 60 feet (the depth and time I like to model). The times generated can be compared to different dive tables and computers to compare conservatism, especially at the shallow depths. Whatever tables are being used, the time limits should be considered **MAXIMUMS** and should not be approached. While reducing a time limit by 5 minutes on a deep dive might be considered conservative, reducing the time limit at a shallow depth by 5 minutes may not add much conservatism at all. A better approach is to view reducing time limits by a percentage such as by 10 or 20 percent. In addition to reducing the time limits, safety stops should always be performed.

Minimum Bends Depth:	20'	20'	15'	12'
Depth (feet)	No-Stop Time Limits (in min. at sea level)			
30	274	252	222	213
35	184	169	157	153
40	134	122	117	115
50	81	74	73	72
60	**55**	**50**	**50**	**50**
70	39	36	36	36
80	30	27	27	27
90	23	21	21	21
100	19	17	17	17
110	15	14	14	14
120	13	12	12	12
130	11	10	10	10

The slope on all of the above examples is -.50.

Note: A starting minimum bends depth of 20 feet was chosen because this is the general consensus of what the depth is even though DCI has occurred at this depth. Times were also given down to a minimum bends depth of 12 feet. This depth was chosen for a couple of reasons. A depth in the range of 10 to 13 feet is probably the minimum bubble depth. While a diver may be able to dive to 12 feet and not bubble, this does not mean that the diver can dive to the full time limits above and not bubble. What the above times in the last column do mean is that more conservatism is reached in the shallow depths where safety stops may not be as effective as they are at the deeper depths. But again, safety stops should always be done even with conservative dive planning.

Whatever time limits you choose to dive, keep in mind that you must take responsibility for your dive plan. Decompression sickness has occurred on many conservative profiles. Therefore plan conservatively, manage your ascent rate, and always perform a safety stop.