Ascent to Altitude After Diving

On many occasions, divers have a need to ascend to a higher altitude after diving, and they need guidance on how long they need to wait before doing so. The reason they have to wait is that ascending to altitude has essentially the same effect as performing another dive. A surface interval is needed to allow the residual nitrogen in the body to off-gas sufficiently to make that ascent safe. Several guidelines are available to divers for some ascents to altitude, especially for flying after diving, but they are not consistent with one another. In other kinds of ascents, such as hiking or driving, there are nearly no guidelines whatsoever.

The need to have a surface interval of some length before ascending to altitude can be seen by the procedures followed by astronauts and high altitude pilots before their flights. Even though these people have not been diving, they breathe oxygen prior to the flights to remove enough nitrogen from their bodies to keep them from getting decompression sickness when they make their very rapid ascent to altitude.

Warning: *Much of the information on this page indicates a state of uncertainty about ascending to altitude. It suggests questions a diver might have before beginning such an ascent and gives information that may help the diver make a personal decision. In no way is the author of this article offering advice on what the diver should do.*

Flying After Diving

Flying after diving has been studied by several organizations, and there are conflicting views on how long a diver should wait before flying. This is a question that arises commonly in diving resorts, where divers have flown in for a vacation and will fly out some time after their final dives. They want to know when they need to start packing before their flights.

An important part of the thinking in these recommendations is that commercial aircraft are pressurized to some degree. Although that varies, the common assumption is that the planes are pressurized to 8,000 feet/2,500 meters. Additionally, it is usually assumed that an ascent of 2,000 feet/600 meters or less can be taken at any time. That generally means that if dives are completed at greater than 6,000 feet/1,800 meters, the ascent in altitude will be less than 2,000 feet/600 meters and will be safe without a surface interval. The US Navy says that dives at 8,000 feet/2,500 meters or above do not need a surface interval.

DAN America and PADI recommendations

The Divers Alert Network in the Americas has conducted studies that concluded that following single dives, divers should wait 12 hours before flying, and they should wait 18 hours after doing multiple NDL dives. They suggest longer waits for longer exposures. PADI has accepted those guidelines.

DAN Europe Recommendations

DAN Europe recommends a 24 hour wait after flying. They recently conducted a study to see if that surface interval was sufficient. They tested divers 24 hours after their last dives using Doppler bubble imaging to look for traces of venous gas emboli, which is a common research indicator for

decompression stress. They found that the divers were bubble free. Unfortunately, they did not test them earlier to see if that 24-hour period was necessary. There is no way of telling from their data at what point in that 24-hour period those divers became bubble free. Thus, their research showed that a 24-hour wait was sufficient, but it did not show if it was necessary.

US Navy Recommendations

The US Navy recommendations are much more complex, because they create a table that gives the amount of time individual divers should wait before ascending specific distances following dives of differing depths and durations. Like the DAN America and PADI recommendations, divers with an average experience should wait 12 hours, and divers with more significant experiences should wait 18 hours, but there are many other more specific options. For example, a diver doing a 50 foot/15 meter dive for 34 minutes would have to wait less than 5 hours before flying, and divers doing shorter and shallower dives would not have to wait at all.

Those tables say that divers should wait 24 hours after decompression diving and 48 hours after "exceptional exposure," which is not defined.

The US Navy table will be discussed in much more detail in the following section on other ascents to altitude.

Other Ascents to Altitude

Every day throughout the world, divers ascend to altitude after diving by means other than flying, typically by driving or walking. Such divers are usually told to follow the flying after diving guidelines mentioned above. For example, divers visiting the Caribbean island of Saba are frequently told that they can fly to the nearby island of Ste. Maarten after a day of diving because the planes are not supposed to exceed 2,000 feet/600 meters in altitude, but they should not take the scenic hike to the top of the volcano at 2,900 feet/900 meters.

Many divers find those guidelines impractical. Divers who need to drive over a mountain pass with a 3,000-foot ascent to get home are not going to want to spend the night at the dive site to wait the required 18 or 24 hours. People vacationing on tropical islands with volcanos will often want to visit a volcano within a day of diving. Consequently, the flying after diving rules are widely ignored around the world on a daily basis by divers driving or walking to altitude. Few of these divers are getting DCS, and if they did get DCS, it would be hard to tell if they got the DCS because of the ascent to altitude or because the symptoms of the DCS they got on the dive took some hours to appear, which happens frequently.

So if the flying after diving guidelines are perceived to be too severe because they are designed for ascents of 8,000 feet/2,500 meters, what guidelines can be used instead? The US Navy Ascent to Altitude table can give some guidance. Unfortunately, it is based upon the US Navy tables, which are rarely used by non-Navy divers these days. Divers who are familiar with other tables, like the PADI tables, should be warned that the pressure groups in the Navy tables are *very* different from the PADI tables, and the surface intervals are also *very* different. Divers who review these tables can get a general sense of the kind of ascents it considers safe, though.

Table 9-6. Required Surface Interval Before Ascent to Altitude After Diving.

Repetitive Group Designator	Increase in Altitude (feet)									
	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000
A	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00
B	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	1:42
C	0:00	0:00	0:00	0:00	0:00	0:00	0:00	0:00	1:48	6:23
D	0:00	0:00	0:00	0:00	0:00	0:00	0:00	1:45	5:24	9:59
E	0:00	0:00	0:00	0:00	0:00	0:00	1:37	4:39	8:18	12:54
F	0:00	0:00	0:00	0:00	0:00	1:32	4:04	7:06	10:45	15:20
G	0:00	0:00	0:00	0:00	1:19	3:38	6:10	9:13	12:52	17:27
H	0:00	0:00	0:00	1:06	3:10	5:29	8:02	11:04	14:43	19:18
I	0:00	0:00	0:56	2:45	4:50	7:09	9:41	12:44	16:22	20:58
J	0:00	0:41	2:25	4:15	6:19	8:39	11:11	14:13	17:52	22:27
K	0:30	2:03	3:47	5:37	7:41	10:00	12:33	15:35	19:14	23:49
L	1:45	3:18	5:02	6:52	8:56	11:15	13:48	16:50	20:29	25:04
M	2:54	4:28	6:12	8:01	10:06	12:25	14:57	18:00	21:38	26:14
N	3:59	5:32	7:16	9:06	11:10	13:29	16:02	19:04	22:43	27:18
O	4:59	6:33	8:17	10:06	12:11	14:30	17:02	20:05	23:43	28:19
Z	5:56	7:29	9:13	11:03	13:07	15:26	17:59	21:01	24:40	29:15
Exceptional Exposure	Wait 48 hours before ascent									

NOTE 1 When using Table 9-6, use the highest repetitive group designator obtained in the previous 24-hour period.

NOTE 2 Table 9-6 may only be used when the maximum altitude achieved is 10,000 feet or less. For ascents above 10,000 feet, consult NAVSEA 00C for guidance.

NOTE 3 The cabin pressure in commercial aircraft is maintained at a constant value regardless of the actual altitude of the flight. Though cabin pressure varies somewhat with aircraft type, the nominal value is 8,000 feet. For commercial flights, use a final altitude of 8,000 feet to compute the required surface interval before flying.

NOTE 4 No surface interval is required before taking a commercial flight if the dive site is at 8,000 feet or higher. In this case, flying results in an increase in atmospheric pressure rather than a decrease.

NOTE 5 For ascent to altitude following a non-saturation helium-oxygen dive, wait 12 hours if the dive was a no-decompression dive. Wait 24 hours if the dive was a decompression dive.

As an example, a diver in pressure group G can ascend 4,000 feet immediately after diving but must wait 4 hours before ascending 7,000 feet. A diver in group H can ascend 3,000 feet immediately, but must wait and 8 hours before ascending 7,000 feet.

So how do these pressure groups correspond to diving? It is hard to make a real comparison, not only because most people do not use the US Navy tables, but also because tables in general use a square profile. Most people using computers are instead doing multilevel dives. A computer diver may be at maximum depth for only a few minutes, and the computer will know that. A table user, however, computes the dive is if every minute were at the maximum depth.

To give a sense of what the numbers on this table mean, here are some examples of specific single dives to specific depths and the resulting US Navy pressure groups using the current US Navy tables. Divers wishing more precise information should get a copy of the US Navy tables and use them for their dives.

Group C: 35 feet/11 meters - 32 minutes; 60 feet/18 meters - 17 minutes; 100 feet/30 meters - 9 minutes

Group E: 35 feet/11 meters - 52 minutes; 60 feet/18 meters - 28 minutes; 100 feet/30 meters - 15 minutes

Group F: 50 feet/15 meters - 41 minutes; 80 feet/24 meters - 24 minutes; 100 feet/30 meters - minutes

Group G: 50 feet/15 meters - 48 minutes; 80 feet/24 meters - 28 minutes; 100 feet/30 meters - 21 minutes

Group J: 50 feet/15 meters - 71 minutes; 80 feet/24 meters - 39 minutes

Group L: 35 feet/11 meters - 148 minutes; 50 feet/15 meters - 89 minutes

Group N: 35 feet/11 meters – 195 minutes; 45 feet/15 meters - 125 minutes

Unstudied Factors

Warning: *The material that follows deals with aspects of diving and human physiology that will be factors in an ascent to altitude following diving, but the exact impact cannot be predicted with accuracy. There are no published studies on these topics, in large part because the variables make formal research a challenge. Nothing in this section should be considered advice. Divers planning an ascent to altitude may want to consider these factors when making their decisions, but they will have to make those decisions without formal guidance.*

Ascent Rate

As divers from a dive, they do so at a carefully controlled rate because they need to ensure that their tissue pressures are not significantly greater than ambient pressure. Their bodies lose nitrogen as they ascend because as the pressure decreases, the partial pressure of nitrogen in the air they breathe is less than it is in their tissues. Because that off-gassing is faster with the greatest possible safe gradient, it is in the diver's best interest to get to the shallowest safe depth at the fastest safe rate of ascent.

When driving or hiking to altitude, divers are not like astronauts or airplane passengers. Their ascents are much slower. During those slow ascents, they will be off-gassing faster than they would if they had stayed at the same altitude as the dive. A diver who drives while gradually ascending 1,000 feet/300 meters, arriving at that altitude in an hour, should have a lower tissue pressure at the end of that hour than a diver who stayed at the original altitude for that hour. It would therefore be beneficial to the diver to ascend to a safe altitude.

Decompression Stops

Since the earliest days of decompression theory, scientists have debated whether it is better to ascend at a steady, slow rate or ascend at a slightly faster rate, wait at that depth for a while, ascend, wait, ascend, wait, for as many stops as it takes to reach the surface. Most people today believe that stops are

superior to the slow ascent method. Here is an example of a decompression schedule a diver might follow using a popular decompression algorithm.

1. Ascend to 50 feet at 30 FPM and stop for 1 minute
2. Ascend to 40 feet at 30 FPM and stop for 3 minutes
3. Ascend to 30 feet at 30 FPM and stop for 4 minutes
4. Ascend to 10 feet at 30 FPM and stop for 13 minutes

In some cases, a diver driving or hiking to altitude might follow a schedule similar to a decompression diver. Here, for example, is what will happen to a driver leaving Santa Rosa, New Mexico, after a dive and heading toward Denver, Colorado.

1. Ascend 550 feet/150 meters in about 5 minutes and stay at that altitude for about 5 minutes.
2. Gradually ascend 300 feet/90 meters for 10 minutes, then continue at that altitude for 20 minutes.
3. Ascend 600 feet/180 meters and continue at that altitude for about 10 minutes.
4. Gradually ascend another 400 feet/120 meters over a 15-minute period. (At this point the driver has been on the road for an hour and has ascended about 1,800 feet/550 meters.)
5. Ascend 400 feet/120 meters for a few minutes, then descend to the previous altitude and continue for 1.5 hours.
6. Gradually ascend 1,000 feet, then ascend rapidly for 800 feet/240 meters.

In this case, the driving diver has completed a series of ascents and stops, the first hour of which are within normal guidelines for ascents, after which the diver did an extended surface interval/decompression stop before the final ascent.

Is that a safe profile? There are no published studies to indicate one way or another.

Accelerated Decompression

Decompression divers must do a series of stops as they ascend, and those stops can be lengthy. In order to lessen that time, they use *accelerated decompression*, switching to breathing rich nitrox mixtures and even pure oxygen as they get to the shallower stops. This has a powerful effect. Let's say a diver using a popular decompression program does a dive on air to 180 feet for 20 minutes. If the diver does all decompression stops on air, the diver will have to start doing decompression stops at 80 feet, and the total time spent on decompression stops will be 77 minutes. If the diver instead switches to 50% Nitrox at 70 feet, the total decompression time drops to 42 minutes. If the diver also switches to pure oxygen at 20 feet, the total time drops to 31 minutes.

Similarly, astronauts preparing to take off into space or go out on a spacewalk breathe pure oxygen for about 2 hours before doing so. The purpose is to eliminate nitrogen from their body prior to going rapidly to a low pressure environment. With less (or no) nitrogen in the gas being breathed, the gradient between the nitrogen pressure in the body and the nitrogen pressure in the gas being breathed increases, so the body loses nitrogen more rapidly.

A diver who breathes Nitrox or pure oxygen prior to an ascent to altitude will accelerate decompression the same way that decompression divers and astronauts do. The National Oceanic and Atmospheric Administration has in the past issued guidelines on how breathing pure oxygen during a surface interval can prepare a diver for an ascent to altitude. Those guidelines no longer appear on their web site.

According to those old guidelines, a diver finishing in the highest pressure groups could fly after 1.5 hours of breathing pure oxygen, a diver in the H-L pressure groups could do so after an hour, and a diver in the E-G pressure groups could fly after 30 minutes of breathing pure oxygen.