

## Battlefield Calculations

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### Introduction

Picture yourself on the road, driving to a dive site. Suddenly you notice a sign that reads, “Next Gas 65 Miles.” A quick glance at your gauge reveals that it is one-third full; do you need to stop now and fill your tank, or do you have enough to make it to the dive site? To be able to answer confidently, you need to know your gas mileage and how much a full tank holds. The gas mileage may change with the terrain and how many scooters and tanks you’ve loaded into the back. With the right information, you can do a quick calculation and know if you need to stop, even if you’re driving a rental.

The same applies to diving. Once you get to the dive site, you can do simple “battlefield calculations” to properly manage your breathing gas supply before and during the dive. Battlefield calculations build on a basic understanding of pressure in the water column and in your tanks to give you effective ways to do math on the boat, on shore, and even underwater to make diving safer and more fun.

### Working with Pressure

Pressure, and its relationship to depth, is at the core of a number of calculations we use in planning and executing dives. The relationship is so straightforward in metric units that it is worth every diver knowing. Simply put, the pressure at the surface is 1 atmosphere, (atm) and it increases with depth, by 1 atm for every 10 meters of seawater (msw). In imperial units, it is certainly possible to convert directly between depth (feet of sea water (fsw)) and pressure, but the work is made easier by first converting depth to metric (msw) using the following easy-to-use formula:

$$\frac{\text{depth(fsw)}}{10} \times 3 = \text{depth(msw)}$$

For example, to find the pressure at 60 fsw, first convert to metric:

$$\frac{60 \text{ fsw}}{10} \times 3 = 6 \times 3 = 18 \text{ msw}$$

Then, easily find the pressure in atmospheres:

$$\frac{18 \text{ msw}}{10} + 1 = 1.8 + 1 = 2.8 \text{ atm}$$

This is certainly easier to do in your head than the direct conversion,  $60 \text{ fsw}/33 + 1 = 2.8 \text{ atm}$ . The path may be longer, but it is far less steep!

Another sort of pressure we must deal with is that of the gas in our tanks. Unfortunately, just like our car gauge reading one-third full and us not knowing exactly how much gas we have unless we know the size of our tank, monitoring our breathing gas in bar or psi requires us to be cognizant of the size of our tanks. In metric, the problem is again solved quite simply. Rated tank capacities are given in liters (L) at atmospheric pressure (1 atm or 1 bar). For example, double 12L tanks hold  $2 \times 12 = 24\text{L}$  per bar of fill pressure. Filled to 200 bar, then, they contain 4800 L of gas. In imperial units, life is made more challenging by tanks rated in cubic feet (cf) of capacity at their rated fill pressure (rather than 1 atm) and by pressures in units of psi. Nonetheless, calculations involving tank pressure can be simplified by using GUE tank factors, which relate the pressure in psi to the actual volume of gas. For example, an Al 80 holds approximately 77 cf at its rated pressure of 3000 psi. Its GUE tank factor is:

$$\frac{77 \text{ cf}}{3000 \text{ psi}} \approx 0.025 \text{ cf per psi} \Rightarrow 2.5 \text{ cf per 100 psi}$$

Pressure gauges typically read in increments of 100 psi. Hence, the tank factor tells you how many cubic feet of gas each tick of the pressure gauge actually represents. Using rounded numbers, you can easily do calculations in your head at least to the accuracy you have in reading your gauge.

Occasionally, it is useful to convert between metric and imperial tank pressures, like when diving in teams with individual divers accustomed to different systems. The exact relationship here is  $14.7 \text{ psi} = 1 \text{ bar}$ , but this is not so easy to do in your head in 10-foot (3-meter) seas or at 1200 feet (360 meters—catching on yet?) of penetration. To quickly convert bar to psi, take  $1 \frac{1}{2}$  times the pressure in bar, and then add a zero. For example, your buddy has 220 bar in his stage bottle. Start with  $220 + 110 = 330$ , then add a zero = 3300 psi. To go in the other direction, drop a zero and take  $\frac{2}{3}$  of what you get. For instance, your bottle is filled to 3000 psi. Two thirds of 300 is 200, so you have 200 bar.

### **Gas Management**

Ever see half of the wreck and find yourself too low on gas to go see the real highlight? Or get back to the anchor line, having cruised around the whole pinnacle, with a ton of gas left? Just as you can figure out whether a third of a tank of gas is enough to get you to the next gas station, so you can estimate the amount of gas you need for any dive you want to do and adjust the plan ahead of time to match the amount of gas you have.

For example, your team is planning to dive a wreck at 100 fsw (30 msw). To see what you would like to, you estimate you need about thirty minutes of bottom time. How much gas do you need at the beginning of the dive in order to safely do this? An average surface consumption rate (SCR) for a working diver (checking out the wreck) is 0.75 cf per minute (20 L per minute). In order to find out how fast you'll go through your gas supply while diving the wreck, you need to determine your consumption rate at your planned depth (DCR). The pressure at 100 fsw (30 m) is  $30/10 + 1 = 4 \text{ atm}$ . So, your DCR will be:

$$\frac{0.75 \text{ cf per minute}}{1 \text{ atm}} \times 4 \text{ atm} = 3 \text{ cf per minute}$$

or, in metric,

$$\frac{20 \text{ L per minute}}{1 \text{ atm}} \times 4 \text{ atm} = 80 \text{ L per minute}$$

So, for thirty minutes of bottom time, you will need 90 cf or 2400 L of gas. Setting aside sufficient gas for ascent and a possible out-of-gas emergency, each team member will need to start the dive with a minimum of 120 cf or 3200 L to accomplish the dive. This requirement will impact your cylinder selection and may cause you to reconsider your dive plan if you don't have enough gas.

If you know your personal SCR, you can plan dives to reflect the actual gas needs of the team rather than that of the "average" diver. (While your buddy's Hummer might need to fill up, your van can easily make it to the next station!) In fact, you can monitor your SCR on the fly during dives to keep tabs on the impact of fitness, stress, task loading, or current. First, start with a baseline SCR that is fairly close to what you expect, and which makes the math easy. A baseline SCR of 0.8 cf per minute works well when diving double LP 104s (GUE tank factor 8 cf per 100 psi). Likewise, the average SCR of 20 L per minute serves well as a baseline for metric calculations. To determine your SCR during a dive, plan on checking your gauge in five-minute intervals. Applying the tank factor for double 104s, 0.8 cf per minute for five minutes works out to 50 psi for every atm of pressure. Your baseline consumption at 100 fsw (4 atm) would be:

$$\frac{50 \text{ psi}}{1 \text{ atm}} \times 4 \text{ atm} = 200 \text{ psi every five minutes.}$$

In metric units, you would expect to use 100 L in five minutes for every atm. In double 12L cylinders this is  $100/(2 \times 12) \approx 4$  bar every five minutes for each atm of pressure. At 30 msw (4 atm), your baseline would be

$$\frac{4 \text{ bar}}{1 \text{ atm}} \times 4 \text{ atm} = 16 \text{ bar}$$

or approximately 15 bar every five minutes.

You can reference your consumption to the baseline to figure out, on the fly, your personal SCR. For example, if you are on the wreck at 100 fsw and find you are using 250 psi from your 104s every five minutes, your SCR is 25% higher than the baseline (200 psi  $\Leftrightarrow$  0.8 cf per minute) and is a whopping 1.0 per minute. You should address the source of this high consumption rate. Are you kicking to maintain buoyancy when you could simply adjust the gas in your wing? Are you taking on too many tasks and dangerously overloading? Consider modifying the dive plan since you may need to turn

back earlier than you planned. If you find, on the other hand, that you are using only 12 bar from your double 12Ls every five minutes, your SCR is 20% lower than the baseline (15 bar  $\Leftrightarrow$  20 l per minute) and is only 16 L per minute. Maybe your effort in the gym is paying off! You may get further before hitting your turn pressure, so make sure you are prepared for a longer swim out of the overhead, or back to shore, in case you encounter an emergency.

### Quick EADs

Everywhere you look there is a chance to use battlefield calculations in your diving. Remember the Equivalent Air Depth (EAD) formula from your nitrox class? You can compare profiles with different mixes on common terms by relating them all to air; but you might want to have your calculator handy! For the GUE standard nitrox mix, 32%, we can simplify the EAD formula so we can use it effectively in real diving environments. The full EAD formula relates the fraction of nitrogen in your mix ( $f_{N_2}$ ) to that in air (0.79):

$$\text{EAD(fsw)} = \left( \frac{\text{depth} + 33}{0.79} \times f_{N_2} \right) - 33$$

But for 32% nitrox, this simplifies to taking 86% of your depth and subtracting 5 fsw. Or, in the useful depth range of 32%, your EAD can be found simply by subtracting 20% from your actual depth. In metric units, the full formula:

$$\text{EAD(msw)} = \left( \frac{\text{depth} + 10}{0.79} \times f_{N_2} \right) - 10$$

is equivalent, for 32%, to taking 86% of your depth and subtracting 2 msw. The quick EAD formula is the same (take 20% off your depth) in either set of units.

What about other nitrox mixes? Simplifying the EAD formula this way illustrates how little there is to gain by choosing 36% for somewhat shallower dives. In round numbers, a quick EAD for 36% is found by subtracting 25% from your depth. At the expense of consistency, flexibility, and simplicity, you gain only 5% off your depth!

### And More...

Battlefield calculations rely on a comfortable understanding of pressure in the water column and in your tanks. Building on this foundation, they allow you to match your breathing gas supply with your dive plan and keep track of your consumption rate and your EAD on-the-fly. But, these examples are only the beginning of how you can use battlefield calculations to make your diving safer, simpler, and more fun. For example, quickly convert your deco stop depths to pressure to understand how your ascent profile relates to the depth of your dive. Or, by incorporating an average swimming pace (fifty feet or fifteen meters per minute) you can estimate how far you might penetrate a cave with the gas you plan to use. Most calculations can be done before the dive, including contingency planning, to minimize task loading during the dive. Furthering your diving education is a unique way to incorporate battlefield calculations into your planning and diving in practical ways. The GUE Recreational Triox and Tech 1 courses, especially, develop applications of battlefield calculations to make the most of your brainpower and take your diving to the next level.