Estimating Your Air Consumption

By Mike Ange

Do you have enough breathing gas to complete the next dive? Here's how to find out.

It is a warm clear day, and the Atlantic Ocean is like glass. As you drop into the water for a dive on North Carolina's famous U-352 wreck, you can see that the captain has hooked the wreck very near the stern. It is your plan to circumnavigate the entire structure and get that perfect photograph near the exposed bow torpedo tube. You descend to slightly below 100 feet, reach the structure and take off toward the bow. Unfortunately, you are only halfway, just approaching the conning tower, when your buddy signals that he is running low on air. Putting safety first, you return with him to the ascent line — cursing the lost opportunity and vowing to find a new buddy.

If you've ever experienced the disappointment of ending a dive too soon for lack of breathing gas or, worse, had to make a hurried ascent because you ran out of air, it may surprise you to learn that your predicament was entirely predictable. With a little planning and some basic calculations, you can estimate how much breathing gas you will need to complete a dive and then take steps to ensure an adequate supply. It's a process that technical divers live by and one that can also be applied to basic open-water diving.

Determine Your SAC Rate

Surface air consumption (SAC), sometimes called surface gas consumption (SGC), is a measure of your rate of gas usage expressed in pounds per square inch (psi) or, for metric divers, in bars of pressure. It's the first thing you need to know to calculate your gas needs for any given dive.

You can determine your SAC on your next dive. When you enter the water, descend to a depth where you have a large set reference point like a smooth section of ocean bottom or the deck of a ship. Fine-tune your buoyancy, then record your bottom time, the depth and the pressure reading on your submersible pressure gauge (SPG). Swim at a comfortable pace for 10 minutes, maintaining a stable depth. At the end of your timed swim, record the pressure reading on your SPG again.

After your dive, get a sheet of paper, pencil and a calculator. The first step in determining your SAC is calculating how much gas you used for each minute of your timed swim. For example, let's assume your dive was at 33 feet, or 10

Advanced Diving

- Public Safety Diving
- Mastering Neutral Buoyancy and Trim
- Military Diving
- Technical Diving
- Scientific Diving and Safety Program Oversight
- Seeing the Reef in a New Light

meters; that your test segment was 10 minutes in duration and that you used 600 psi or 40 bar of pressure. [*Author's note: 600 psi actually equals 41.38 bar. We use 40 bar to simplify the math examples*.] So we start by dividing the total gas used by the number of minutes in the segment:

- Imperial: 600 ÷ 10 = 60 psi per minute
- Metric: 40 ÷ 10 = 4 bar per minute

We now know how much gas you used per minute during the timed swim. But that measurement was taken at depth. To know your SAC rate, we need to bring that measurement to the surface by adjusting for the absolute pressure of the dive. The formula for determining absolute pressure is:

- Imperial: Depth (in feet of sea water) ÷ 33 + 1 = atmospheres absolute of pressure (ATA)
- Metric: Depth (in meters of sea water) ÷ 10 + 1 = atmospheres absolute of pressure (ATA)

So for our example:

- 33 feet ÷ 33 + 1 = 2 ATA. If you use metric: 10 meters ÷ 10 + 1 = 2 ATA

Now we simply divide our usage in pressure by the absolute pressure at depth, and we have reached the first stop in our calculations, an accurate SAC rate.

- Imperial: 60 psi ÷ 2 ATA = 30; so our SAC is 30 psi per minute
- Metric: 4 bar ÷ 2 ATA = 2; so our SAC is 2 bar per minute

Determining Gas Needs

As long as you use a tank that has both the same volume and the same pressure rating as the one used in the timed swim, your SAC rate will tell you approximately how much gas you'll breathe each minute at a given depth. Simply multiply your SAC by the atmospheres of pressure at your planned depth. For example: You're planning a dive to 99 feet or 30 meters. That's 4 atmospheres of pressure (99 feet ÷ 33 + 1 = 4 ATA or 30 meters ÷ 10 + 1 = 4 ATA).

- Imperial: 30 psi x 4 ATA = 120 psi per minute at depth
- Metric: 2 bar x 4 ATA = 8 bar per minute at depth

To estimate your total gas needs for the dive, take the starting pressure of your cylinder, subtract a reserve amount of gas and then divide the remainder by the consumption rate to find out how many minutes of dive time you can expect. The safest rule of management for gas supply is to use the rule of thirds in any situation where it is preferable to come back to a set ascent point, such as the anchor line of a dive boat. The rule of thirds means that the diver uses one-third of his air supply for the descent and the swim away from the exit point and one-third for the swim back to the exit point, leaving one-third for any delays or emergencies. Most divers think of this emergency as sharing gas with a buddy, but in reality it could be used for getting lost, getting snagged in monofilament line or even something as simple as retrieving a lost piece of equipment.

So if you start the dive with a full cylinder at 3,000 psi, or 206 bar, the planning math looks like this:

- Imperial: 3,000 psi ÷ 3 = 1,000 psi as 1/3 of our cylinder. 3,000 – 1,000 = 2,000 psi of useable gas. A rate of 120 psi per minute means you'll have approximately 16.6 minutes of gas at depth (2,000 ÷ 120 = 16.6).

- Metric: 206 bar ÷ 3 = 68.7 bar as 1/3 of our cylinder. 206 – 69 = 137 bar of useable gas. 137 ÷ 8 = 17.1 minutes of dive time.

Calculating an RMV
In the event that you are diving a tank of a different size or operating pressure, you will need to take two more steps to make your calculations useful. Because pressure ratings on cylinders can vary dramatically — from 2,400 psi to 3,500 psi, or 165 bar to 240 bar — we have to convert cylinder pressures into equivalent volumes of gas and then modify our SAC into a measurement called a Respiratory Minute Volume (RMV). The method of converting these pressures varies depending on whether the diver is using the imperial or metric measurement. For simplicity we will demonstrate each method separately starting with the imperial system.

The first step is to find out how much gas volume is contained in each psi of gas in the cylinder used to determine our SAC. We call this number a cylinder conversion factor (CF). To calculate the CF, divide the rated volume of the cylinder in cubic feet by the rated pressure of the cylinder (CF volume ÷ rated psi).

So for an aluminum 80 (the cylinder used in our test dive scenario) the CF is .0267 (80 ÷ 3,000 = .0267).

To convert our SAC (30 psi per minute) to an RMV we need to multiply the pressure of gas used by the CF of the cylinder.

- RMV = 30 x 0.0267 = 0.8 cubic feet per minute

For divers using the metric system, there is no need to find a conversion factor because the rating on metric cylinders is the volume at 1 bar of pressure. To convert a SAC in bar to an RMV, simply multiply the rated volume by the SAC. In our example, the diver's SAC was 2 bar, and he was using an 11-liter cylinder.

- RMV = 2 x 11 = 22 liters per minute

With these numbers a diver can select any cylinder and estimate how many minutes of dive time the cylinder will yield for his personal RMV. To calculate dive duration for our sample divers, we take the rated cylinder volume, take away the one-third of the volume for our reserve and then divide the remainder by the RMV of the diver at depth.

Let's assume a 108-cubic-foot (17-liter) cylinder rated at 2,640 psi (180 bar) on our same dive to 99 feet (30 meters) or 4 ATA of pressure.
Imperial system

- 108 cubic feet ÷ 3 = 36 cf. 108 – 36 = 72 cubic feet of useable gas volume
- 0.8 x 4 = 3.2 RMV in cubic feet
- 72 ÷ 3.2 = 22.5 minutes of available dive time
  Metric system
- 17 ÷ 3 = 5.6; 17 – 5.6 = 11.3 liters of useable water volume
- 11.3 x 180 bar of rated pressure = 2,034 liters of usable gas
- 22 x 4 = 88 RMV in liters
- 2,034 ÷ 88 = 23 minutes of available dive time

Estimates vs. Reality
Using these calculations, you can estimate your available bottom time. However, this does not absolve a diver of the responsibility to monitor gauges and manage the dive based on actual air consumption (not to mention decompression

obligations). If you find yourself swimming into a current, for example, your air consumption rate will be higher than that used in your calculations. On a drift dive where you barely move a muscle, your gas consumption may be lower. To more accurately estimate gas supply needs for high- and low-exertion dives, repeat the SAC process swimming at a faster pace and again at a slower pace.
Use Less Air
These simple steps may significantly improve your gas consumption rates and make your dives more enjoyable.

Streamline Your Gear
When moving through a medium that is 800 times denser than air, even small efficiencies can reap big benefits. Avoid "danglies" by eliminating all unnecessary gear and tucking what you do need inside pockets. Secure gauges and your octopus regulator to your BCD, and route hoses close to your body. When you fin through the water, fold your arms together or clasp your hands behind your back while keeping your fins inside the slipstream created by your tank and torso.

Fine Tune Your Buoyancy and Trim
The air cell in most BCDs is located at or near the diver's shoulders, and the weight is located at or near the diver's waist. This alignment of forces pulls the shoulders toward the surface and pushes the lower body toward the bottom, giving the diver the swimming profile of a Mack truck. The more weight you carry, the more this effect is exaggerated. Take a buoyancy course or work with an instructor to fine-tune your weighting, and redistribute your ballast load to achieve a proper horizontal swimming position. Bonus: You'll be adding less air to your BCD to offset ballast, which means you'll have more in the tank to breathe.

Stop the Leaks
On every dive, scan your gear for air leaks. Small leaks from your octopus, gauge console or BCD inflator can add up over the course of a dive and, as a matter of safety, indicate gear long overdue for service. Another hidden air thief: a leaky mask. Every time you stop to clear water from your mask, you're wasting breathing gas.