DPV Cave Dive Planning

Basic calculations provide a rationale for gas planning and bailout

by Ken Sallot

Cave dive planning using a dive propulsion vehicle (DPV) is fraught with misconceptions. I'll attempt to dispel some persistent myths and to highlight some considerations that may not have been covered in previous training. We'll look at issues that divers should considere when planning DPV cave dives.

Caveats

This article is not intended to replace formal DPV Cave Pilot training. It should be viewed as supplemental material to a formal class.

It does not cover emergency scenarios, such as sharing gas or towing a disabled diver.

Some individuals may find my tone blunt or even take offense at the wording.

If you find my recommendations onerous, you may need to critically evaluate whether DPV cave diving is an activity that you're ready to conduct carefully and safely.

Gas planning misconceptions

Let's shoot a hole upfront through one of the biggest misconceptions. Some divers still believe that carrying twice the amount of gas required to swim out from the furthest point of penetration ensures their safety.

The thought process behind this notion is simple: Scooters may become disabled for any of a number of reasons. Prop blades can break, electronic control systems can fail, o-ring seals can fail, and more. According to this incorrect mindset, you'd need to be prepared to swim out of the cave when (not if) your scooter dies at the maximum point of penetration.

The planning model below shows that a diver swimming at approximately 15 meters/50 feet per minute with a surface air consumption rate of approximately 0.75ft^3 per minute will need to reserve approximately 250ft^3 of gas for a dive to 671 meters/2200 feet at an average depth of 27 meters/90 feet.

Mathematically, this can be shown by applying some basic formulas to calculate

(a) the amount of gas a diver uses in any given minute at depth and

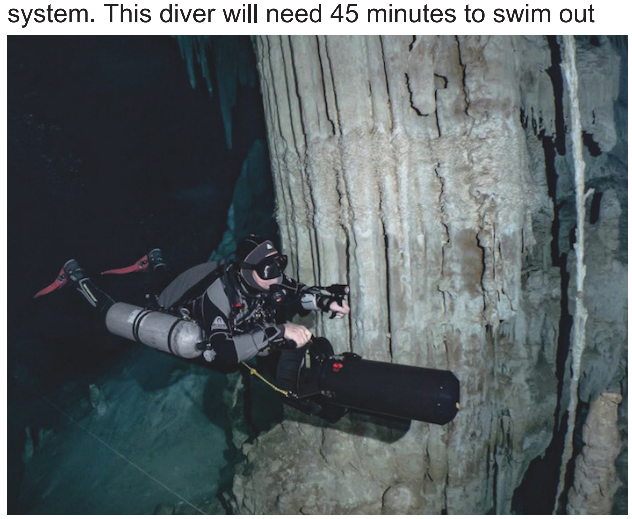
(b) the amount of time it will take to swim a given distance.

Using these two pieces of information, we can calculate

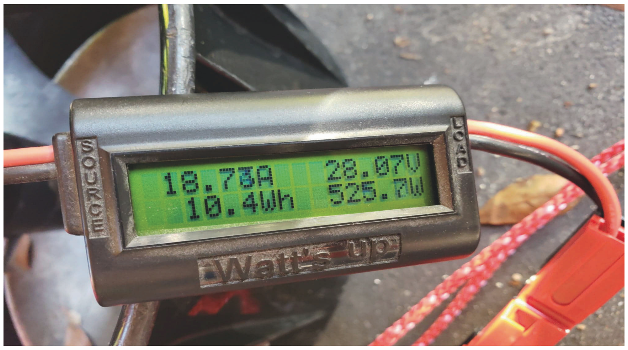
(c) the amount of gas the diver will need to keep in reserve (see sidebar).

The amount of gas a diver consumes every minute at depth is defined as Residual Minute Volume (RMV). A diver with a Surface Air Consumption (SAC) rate of 0.75 ft^3 of gas per minute has an RMV of 2.8 ft^3 at a depth of 90 feet.

The average diver swims at speeds up to 15 meters/50 feet per minute while exiting a high-flow system. This diver will need 45 minutes to swim out



©Ricardo Castillo



A "WattsUp"® (or other) watt meter can measure battery health.

from a distance of 2200 feet. However, s/he will swim more slowly, closer to 30 feet per minute, in low-flow systems and will require more time to exit.

The average technical diver uses approximately 125ft³ of gas swimming out from 2200 feet in a high-flow cave. Using the "twice the amount of gas needed to swim out" standard, this diver would carry 250ft³ of emergency reserve gas to be safe on the cave dive.

This sounds great on paper and is probably suitable for planning a scooter ride to the Henkel restriction in Devil's Ear. But I believe that this method of planning a DPV cave dive is overly simplistic and may lead people to think that they are safe simply by bringing twice the amount of gas they require to swim out. The problem is that this model breaks down rapidly once the DPV pilot ventures beyond the simple confines of relatively shallow caves and short penetrations.

Let's look at how this approach fails on a deep dive.

Many people have made deep DPV cave dives that involve scootering upstream Eagle's Nest to King's Challenge and the Green Room, a distance of roughly 2200' from the exit. The dive usually has a round-trip bottom time of less than 30 minutes with a total run time of around two hours. However, any diver who attempts to swim out from the Green Room will find that with little flow this swim will likely take 60 to 70 minutes. During this exit s/he will consume roughly 400ft³ of gas.

Using the "carry twice the gas to swim out" approach, divers would require 800ft³ of reserve gas for this exit, a ludicrous amount that could only be accomplished on open circuit using a full set of double 104s and six stage bottles. Additionally, with an average depth of 240', such a swim is likely to increase the mandatory decompression obligation incurred by the diver by four or five hours!

Woe is the diver who adds five hours to the decompression obligation but fails to add several hours' worth of emergency decompression gas.

The absurd amount of reserve gas needed and the increased decompression obligation this swim would incur make it obvious that the "carry twice your swim-out gas" will not work on this deep dive.

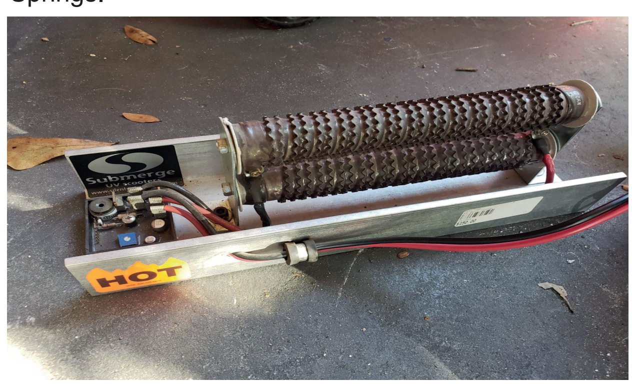
Is a swimming bail out safe in shallow caves?

Now let's shoot a hole through this same approach on a long-range scooter dive in a relatively shallow cave. Several modern scooters allow a diver to go 8000, 9000, or 10,000 feet into a cave (and out!) with no problems. Any person with the financial means to drop between $5k to $10k can own one. Isn't technology great?

With an average depth of 85 feet and miles of trunk passage, Manatee Springs beckons to the diver who just bought the new Zoom Zoom Extreme model DPV. The manufacturer rates this scooter for 20,000 ft of travel distance. Carry enough stage bottles, point the scooter in the right direction, and whoosh! You're heading off two miles away from Catfish Hotel.

Now imagine this scenario. You are 10,000 ft back, and the Zoom Zoom Extreme scooter's electronics package dies, rendering it nonfunctional. Thankfully, Manatee has a lot of flow. It may be possible to exceed a swim speed of 50 feet per minute and potentially even as fast as 60 or even 70 feet per minute. Although swimming out may sound easy enough, even at the ridiculously fast pace of 70 feet per minute, it will take you approximately 2.5 hours to swim out of the cave.

Let me repeat that for emphasis. Assuming you're able to sustain maximum effort and swim at 70 feet per minute, it will take you over two and one half hours to swim out from 10,000 feet in Manatee Springs.



A resistor pack is used during burn testing.

I want everyone who is reading this article to stop for a minute and conduct an honest self assessment. How many of you can say honestly that you have the physical fitness and stamina to sustain a maximal effort swim for 2.5 hours?

I didn't think so.

If you are not regularly engaging in cardio workouts that last more than two hours at a crack, the likelihood that you will be able to swim out from 10,000 feet is NIL. In addition to the demands that this swim would place on your body, you would also go through over 400 cf^3 of gas during that swim. That's a set of 104s plus five stage bottles.

Some of you may be thinking, "well, we could get a tow from our buddy!" The reality is that towing a buddy over a distance of 10,000 feet is going to be challenging in the best of conditions. Add in the complexities of a cave with a large amount of vertical change and many restrictions along the way, and you may quickly realize getting a tow from 10,000 feet is not a viable option either.

So how do we make DPV cave diving truly safe?

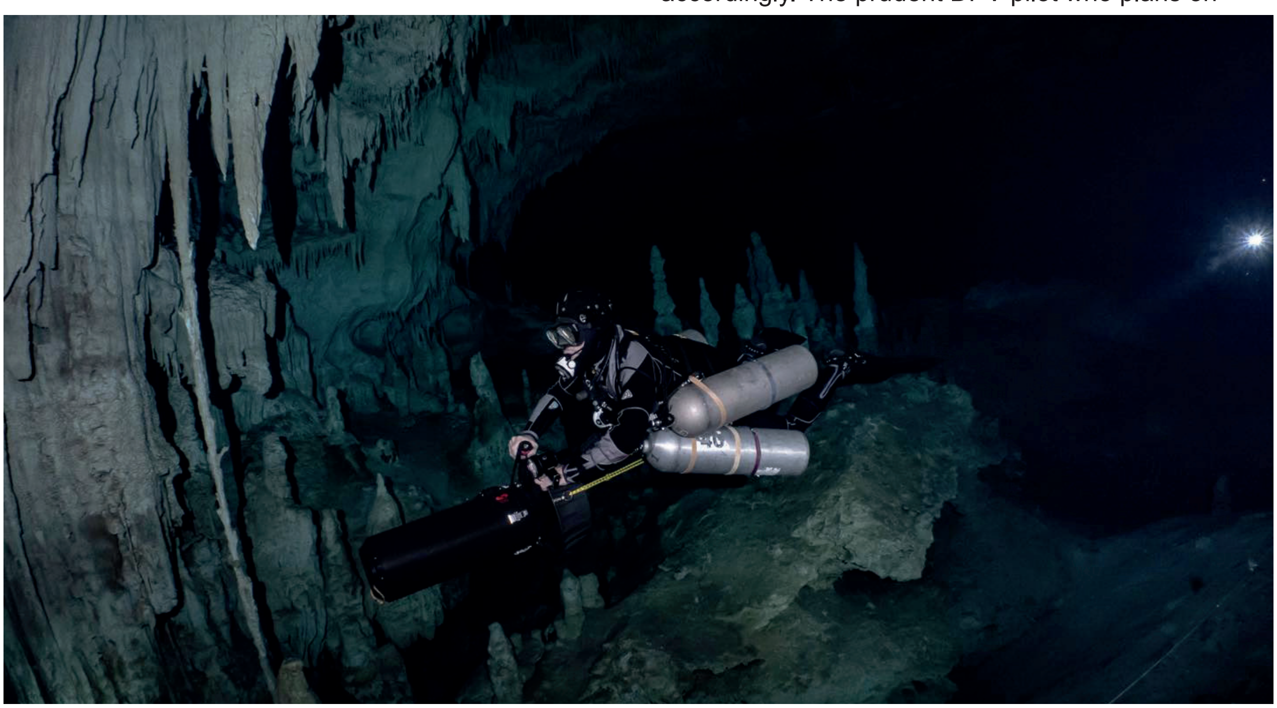
It sounds uncomfortable, but DPV cave dives will always carry an element of risk. They never will be 100% "safe." But we can minimize risk and make DPV cave diving safer by recognizing that swimming out of a cave should never be part of the dive plan. Therefore, we should plan our dives appropriately.

The first element of proper DPV dive planning is knowing the true capabilities of your scooter and not exceeding them. Just as sane divers would never consider entering a cave without a working pressure gauge or knowing how much gas is in their tanks, only fools would begin a long or deep DPV cave dive without knowing how far their scooters can safely travel round-trip.

To know how far your scooter can safely travel, you need two pieces of information:

- how much energy your scooter uses under maximal work (load) and
- how much energy your batteries can currently store (capacity).

Obtaining this information involves conducting some tests on the motor and periodically burn-testing the batteries. I cannot overstate this: periodically burn-testing your batteries is very important for safe DPV cave diving. Batteries lose their capacity to store energy as they age, and their effectiveness diminishes. A battery that held 1000 W of capacity when it left the factory may only be able to hold 860 W two years later, and you would need to limit your dive plans accordingly. The prudent DPV pilot who plans on



© Ricardo Castillo. *Scootering in one of the Yucatán caves.*

pushing a scooter close to its limits will burn test its batteries at least once a year.
Armed with the knowledge of how many watts your battery pack can hold and the load your scooter generates, you can get an idea of its real range. A battery pack that holds 860 watts of energy will realistically last for 170 minutes in a DPV that consumes 300 Wh under load.

If you know that your scooter batteries will only last for 170 minutes, then hopefully you understand that you cannot ride that scooter into a cave for 150 minutes and expect a positive outcome when you turn to exit. You will come up short and kill your battery on your way out. Never plan a dive that uses all of your battery capacity. Planning a dive that kills your battery leaves you with zero safety margin and risks damaging the battery too.

need to bring spare scooters whenever you either go deep or go long. Only you can decide when spare scooters become a part of the dive plan.

Let's be frank: All cave divers must be responsible adults. Good judgment becomes particularly important when using equipment such as DPVs. Divers make their own decisions about the threshold at which "buddy tow" ceases to become an option and "spare scooter" becomes mandatory. However, I would suggest that any time that you are going deeper than 120 feet or further than 3000 ft, it's time to start packing a spare scooter. How many spare scooters a team brings will depend on the dive's complexities and the capabilities of every member in the team. If you are not practicing towing techniques regularly, you should probably plan on bringing a spare scooter for each diver in case two scooters wind up becoming disabled.

...periodically burn testing your batteries is essential for safe DPV cavediving. Batteries lose their capacity to store energy as they age, and their effectiveness diminishes.

I try to plan my dives so that I use no more than 70% of my battery life for the entire time I am on the trigger. This leaves me with a little bit of extra capacity in the event I need to tow extra equipment or, for brief periods, a buddy. Planning to use no more than 70% of the capacity also minimizes the risk of harming the battery.

Several factors may impact how I distribute the time between penetration and exit. Things I consider include diving in a siphon versus a spring, the amount of flow in the system, and how much additional equipment I will be carrying. Generally speaking, as a starting point you can split the time in half whenever you are diving into a spring. This means that if you have a battery pack that can run for 170 minutes and plan to use 70% of the capacity, you can use the scooter for 60 minutes while going in and 60 minutes while exiting.

When to Bring Backup

The second thing we can do to make DPV cave diving safer is to consider bringing a spare DPV. Hitching a tow from a buddy may be sufficient for a short penetration in a shallow cave, but it is not a realistic option for a long or deep cave dive. This means you

I know this part stings because it means that if you have any intention of using your newly bought Zoom Zoom Extreme DPV to the limits of its capabilities, you also need to have a second scooter as a backup. The good news is that you do not need to buy two Zoom Zoom Extreme DPVs. But the bad news is that your tow scooter had better be reliable, because it has to be more than sufficient to get you out from the furthest point of your dive.

Swimming out is not an acceptable exit plan

DPV cave diving is a lot of fun, but doing it safely is not as simple as carrying twice the amount of gas as you need to swim out. While swimming a scooter out or catching a tow from a buddy may work for relatively short distances in shallow caves, that model breaks down rapidly once you start taking your scooter deep and/or on long cave dives. If your plans include deep or long penetrations, you need to consider other options and give up the idea of swimming out.

—Ken Sallot teaches cave diving in the Gainesville and High Springs, FL, area.

Figuring out the Maths

The information below is intended to help divers understand the mathematics discussed.

- To calculate the amount of gas used in any given minute at depth, multiply the individual Surface Air Consumption (SAC) rate by the depth, as measure in absolute pressure (ATA).

The formula is RMV = SAC * ATA.

In practice, the average experienced technical diver has a swimming SAC rate of $0.75ft^3$. If you don't know your SAC rate, you can probably use $0.75ft^3$ per minute as a starting point.

The formula for converting the depth of the dive into pressure (ATA) is calculated as follows: ATA = (DEPTH ÷ 33) + 1. If we plug 90' into our formula, (90 ÷ 33) + 1, we get an ATA of 3.7.

Therefore our average experienced technical diver has an RMV of 2.8 cubic feet of gas per minute while swimming at a depth of 90' (0.75 SAC * 3.7 ATA). This means that for every minute the diver is at 90', s/he is using 2.8 cubic feet of gas.

- Calculating the time it will take to swim a given distance involves knowing your realistic swim speed as measured in feet per minute. Many things can impact this, including the amount of drag from the gear that you are carrying, the amount of flow going either with you (exiting a spring) or against you (exiting a siphon), and your stamina and cardiovascular fitness. Generally speaking, most technical divers should be able to sustain a swim speed of up to 50 feet per minute when exiting a high flow spring. That rate may be reduced to as little as 30 feet (or less) per minute in a low-flow spring and even less in a siphon.

The formula for calculating the time it will take to swim a given distance is TIME = DISTANCE ÷ SWIM SPEED.

A diver exiting a high-flow cave, such as Devil's Ear, from 2200 feet of penetration can reasonably expect that swim to last almost 45 minutes (2200 ÷ 50) = 44.

The formula for calculating the amount of gas needed to swim out from any given distance is GAS = RMV * TIME.

This means that our average technical diver will use approximately $125ft^3$ of gas to swim 2200 feet out from a high flow cave (GAS = 2.8 cubic feet per minute RMV * 44 minutes TIME). Using our "twice the amount of gas needed to swim out" standard, the diver needs to carry $250ft^3$ of emergency reserve gas to be safe on the cave dive.

How to Perform a DPV Burn Test

Calculating the load that your scooter generates may be a little tricky. Many manufacturers are not forthcoming with that data. Many factors impact the load a motor generates, such as drag and speed.

One "hack" that many people have used is to begin with a fully charged scooter, ride it for 30 minutes on full, then recharge the battery while using a WattsUp meter (or similar) to measure how many watts went back into the battery while recharging. You can then double that number to get the load in Watt-Hours (Wh). So if your WattsUp meter records 150 watts when recharging a battery after you have ridden it for 30 minutes at full blast, then your scooter probably generates somewhere close to 300Wh of load on full.

To perform a burn test on your batteries, take a fully charged scooter and put a WattsUp meter in line between the battery pack and a resistor pack. The WattsUp meter will display the watts consumed as the resistor pack drains the battery.

Two points of warning:

1. You need to know what the low voltage cut-off threshold is for your battery pack and be prepared to remove the resistor pack before you hit that threshold, or you risk doing damage to the battery.

2. The resistor pack will get extremely hot while you are doing a burn test. You should conduct the burn test outside and away from flammable materials.

Once you know how many watts your battery pack can hold, you can get an idea of real burn time by using the formula HOURS = WATTS ÷ LOAD. You can multiple this result by 60 to calculate the number of minutes the scooter should be good for. So, a battery pack that holds 860 watts of energy will realistically last for 170 minutes in a DPV that has a motor that generates 300 Wh of load, (860 ÷ 300) * 60 = 172.

I never plan a dive to use more than 70% of the battery capacity. To calculate the dive plan upper limit, I use the formula TIME = REAL_BURN_TIME * 70%. So, if my battery is useful for 170 minutes, I would not plan a dive involving more than 120 minutes on the trigger. 172 * 70% = 120.