Sports Diver Theory Lesson – ST5

BREATHING GAS PLANNING AND SYSTEMS

Lesson Objectives

Sport Divers will be extending their diving horizons and are beginning to update or expand their equipment. For the type of diving they want to do or progress towards, this lesson looks at breathing gas planning for deeper or more adventurous diving together with appropriate equipment configurations.

Achievement Targets

At the end of this lesson students will:

- Understand, in considering deeper or more challenging diving, possibly including decompression stops, that breathing gas planning and systems will be important
- Understand how to ensure they carry sufficient breathing gas to undertake a planned dive by being able to determine suitable cylinder size including the reserve supply
- Understand that a back up, alternate breathing gas supply is a must and that its capacity must be sufficient for the type of dive being undertaken
- Understand the different configurations of kit that are available and their appropriateness for types of diving being planned
- Understand that equipment, which is their life line, needs maintenance to ensure it is in good working order
- Understand that updating or expanding their equipment needs careful consideration so that it is appropriate for their current or intended future diving
- Understand that adding or updating equipment needs to be considered as part of their overall equipment system, as must its weight and implications on buoyancy
- Understand that any use of new equipment should be practiced in shallow water before being taken on a real dive
- Understand that practice is extremely important, not only with new kit, but to ensure all skills are kept 'in practice' so they are not ignored - they should not be used for the first time when an emergency arises

The following items will be needed

It is appreciated that all cylinder configurations may not be available but a single cylinder with octopus (generally used as training kit) and a single cylinder with pony AS as a minimum should be shown, to demonstrate the difference between the two and that the latter demonstrates an independent back up breathing gas supply.

BREATHING GAS PLANNING & SYSTEMS

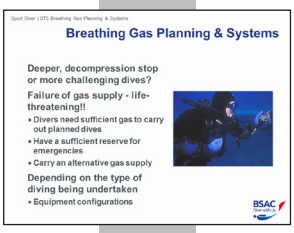
This lesson is going to cover breathing gas planning for carrying out more adventurous diving, whether it is deeper, includes decompression stops, or is in more challenging conditions.

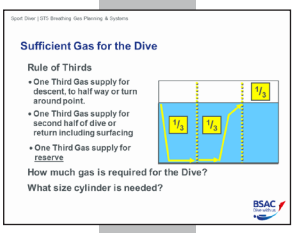
The most life-threatening incident that can occur to a diver is failure or exhaustion of their breathing gas supply.

It is therefore common sense (for self preservation) that divers must ensure they carry

- Sufficient breathing gas to carry out planned dives
- Sufficient reserve for emergencies should they arise
- An Alternative Supply as a back up/bail out system if gas problems arise for the diver or their buddy

  The equipment required depends on the type of diving being undertaken, so this lesson also includes
- Advice on choosing appropriate equipment configurations





SUFFICIENT BREATHING GAS FOR THE DIVE

Ensuring that there is sufficient gas for the planned dive is part of pre-dive planning. As a general principle, using the rule of thirds when carrying out the dive will ensure that the diver has sufficient gas for the dive being undertaken and an adequate reserve should any problems arise at the end of the dive.

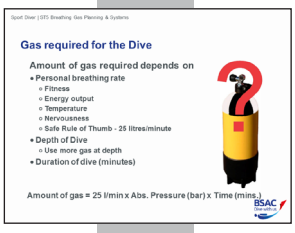
The Rule of Thirds

- One third of the cylinder contents used for the descent and half way or to turn around point.
- One third of the cylinder contents used for the second half of the dive or return journey, including surfacing.
- One third of the cylinder contents kept as a reserve.

The main objective is for all divers to return to the surface with a cylinder containing one third of the original breathing gas.

In breathing gas planning for the range of diving that sports divers may undertake, there are two questions that need to be addressed:

1. How much breathing gas is required for the dive and,
2. What size (capacity) cylinder is needed?



BREATHING GAS REQUIRED FOR THE DIVE

From students' prior experience, ask if they have noticed any difference in gas consumption since they first began diving. The point to draw upon is that:

The amount of breathing gas to take on a dive depends on a number of factors:

- Personal breathing rate

  Not only are divers different sizes, some with large lung capacity and others with less but also other factors affect personal breathing rates
  - Fitness levels - quite often at the beginning of a dive season personal breathing rates may be higher than later in the season, when "dive fitness" has improved.
  - Energy output - such as finning fast or against a current, will increase breathing rates
  - Temperature - if a diver begins to get cold on a dive, the breathing rate will increase - sometimes this is quite noticeable towards the end of the dive
  - Nervousness - in some instances, the beginning of the dive is where

the breathing rate is higher until the diver settles into the dive and the breathing rate slows down. In other instances, unfamiliar conditions may cause breathing rates to increase

- Because of the variables mentioned above, when working out how much breathing gas to use, a safe rule of thumb is to base calculations on 25 litres per minute at the surface.

  By monitoring actual against planned breathing gas consumption as experience is gained, the rate of 25 litres per minute can be adapted accordingly

- Depth of the Dive

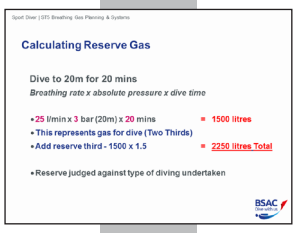
  The deeper the dive the denser the gas breathed, so more gas will be used at depth. Deeper dives may also incur decompression obligations and the gas required for the dive must include an appropriate volume for the time spent at the decompression stop depth(s)

- Duration of the dive

  The length of time spend underwater obviously affects how much gas is used

To calculate the amount of breathing gas required at any depth, there is a simple formula that can be used:

25 litres per min. (average breathing rate at the surface) x absolute pressure (bar) x time at that depth (minutes)



CYLINDER SIZE FOR THE DIVE

Cylinder contents

To work out the amount of breathing gas a cylinder holds

- The size of the cylinder (marked on the cylinder shoulder and given in litres) x bar pressure of the breathing gas in the cylinder (indicated by the cylinder contents gauge)
- For example:

  A 10 litre cylinder filled to 230 bar = 10 x 230 giving total breathing gas available of 2300 litres

  The plan is to do a dive to 20m for 20 minutes. Would the 10 litre cylinder hold sufficient breathing gas for the dive?

  Remember the formula

  Breathing rate x depth (absolute pressure) x time (mins.)

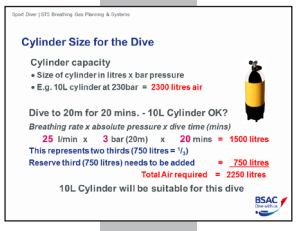
  For the planned dive this is:

- 25 x 3 x 20 = 1500 litres for the dive

  But remembering the Rule of Thirds, this only covers the first two thirds. The final third, for the reserve, needs to be added.

- The 1500 litres is two thirds so dividing this by 2 gives one third = 750 litres
- Add to the 1500 litres and the total gas required = 2250 litres

  With 2300 litres available in the 10L cylinder and 2250 required for the dive and reserve, the 10L cylinder will be suitable for this dive

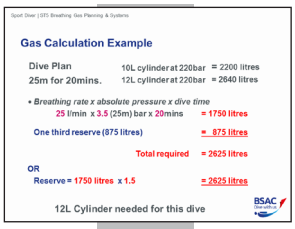


ALTERNATIVE ASCENT AND RESERVE CALCULATION

Another way to calculate the reserve is, using the same example as before, Dive to 20m for 20 mins.

- 25 x 3 x 20 = gas required for the dive = 1500 litres
- Calculating the ascent and reserve can also be done by:

  multiplying 1500 litres x 1.5 = 2250 total gas required



Judging Reserves

Any reserve needs to be judged against the type of diving being undertaken. It is a matter of common sense that the reserve is relative to the dive depth or conditions. Under some circumstances the reserve examples given may not be enough.

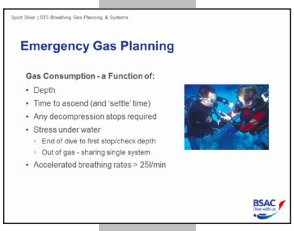
BREATHING GAS CALCULATION EXAMPLE

Get students to work on an example with as little assistance from the instructor as possible.

Dive Plan : 25m for 20 minutes. There are two cylinders available, a 10L filled to 220 bar and a 12L filled to 220 bar.

Which cylinder is suitable for the dive?

Working through the example shows that the 12L Cylinder is needed for this particular dive.



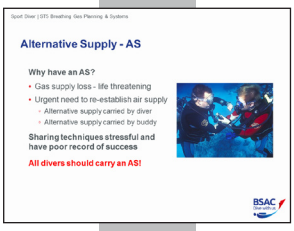
EMERGENCY GAS PLANNING

Gas Consumption

Gas planning becomes more significant the more advanced the dive plan. Greater depths and the time to ascend from those deeper depths require greater reserves of breathing gas.

Gas Consumption - considerations

- Increased gas consumption rates at the end of a dive to the first stop or check depth are common occurrences.
- Stress under water does cause the diver to breathe deeper accelerating breathing rates beyond 25 litres per minute (surface rate).
- Whilst it is difficult to give an exact figure for circumstances and conditions associated with stress underwater, breathing rates of 50 litres per minute during the initial phases of an emergency frequently occur.



ALTERNATIVE SUPPLY

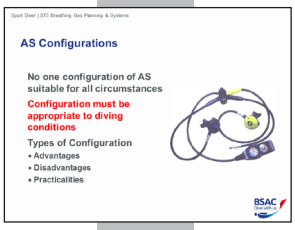
Why have an AS?

- The most life-threatening incident that can occur to a diver is a failure of their breathing gas supply
- The urgent need to re-establish a breathing gas supply is essential either from:
  - Another supply carried by the diver
  - Another supply carried by their buddy

Techniques involving the sharing of one primary regulator between two divers are very stressful and have a poor record of success

With the equipment available today there is no need to rely on such techniques

For this reason, all divers should carry an alternative supply



AS CONFIGURATIONS

There is no one configuration that is suitable for all types of diving

Consider the type of diving to be done and configure equipment appropriately

The more advanced the diving conditions, the more the impact of a breathing gas supply failure needs to be considered. A configuration of equipment that is adequate to resolve problems encountered in relatively shallow diving may be inadequate for deeper diving. For instance, a single cylinder of breathing gas may be adequate for two divers to breathe from while ascending following a breathing gas supply failure in shallow water. If the problem occurs towards the end of the dive, it may contain insufficient breathing gas for an ascent from greater depth.

There are many different configurations of breathing gas supplies, but what is appropriate for a particular dive needs to be considered against the likely implication of a breathing gas supply failure, either the diver's or their buddy's, at the most critical point of the dive.

Types of Configuration

In considering the various configurations, divers should be aware of:

- The advantages
- The disadvantages
- The practicalities

All of which should be taken into account when deciding upon the best configuration for the type of diving being planned

BC DEMAND VALVE

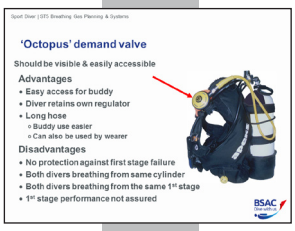
This is a dual-purpose unit that allows both oral inflation of the BC and breathing from the integrated regulator, which is connected to the first stage of the diver's regulator via the BC's medium pressure inflation hose

Advantage

- It minimises the number of hoses in the breathing set configuration

Disadvantages

- This unit only protects against a diver's primary regulator second stage failure. If the diver's breathing gas supply fails, a first stage failure will also affect the BC demand valve
- Where a diver's buddy suffers a breathing gas supply failure, due to the shortness of the hose on the integrated unit, it cannot be used by the buddy. The diver's primary regulator will have to be given to the buddy and the diver will have to change to the BC demand valve. While this may sound a simple procedure, in the stress of the moment it will be anything but and should be avoided if at all possible
- The short BC hose will restrict the diver's head movement
- The primary regulator hose length will necessitate both divers keeping very close together making position keeping and finning during the ascent less comfortable
- Both divers will be consuming breathing gas from the same cylinder. From any significant depth, and particularly towards the end of the dive, under the stress of the situation, what would otherwise have been an adequate supply for one diver, may be inadequate for both to regain the surface



'OCTOPUS' DEMAND VALVE

This is an additional demand valve fitted to a second, usually longer, medium pressure hose. Given that this demand valve is most likely to be used in times of high stress, its performance needs to be every bit as good as the primary demand valve. As the most likely user is another diver, it should be oriented for their use.

It should be highly visible and easily accessible

The 'octopus' should be stowed where it is clearly seen and can quickly and reliably be accessed by another diver when the wearer is in a normal swimming attitude. What works when standing face-to-face doing a buddy check does not necessarily work when the diver is swimming face down along the seabed.

Advantages of a properly configured 'octopus'

- A dedicated and easily accessible demand valve is available to a buddy diver in distress
- The diver does not need to give up their primary demand valve to the buddy
- The longer 'octopus' hose provides greater flexibility of position

- Buddy use is easier and this makes for a much more comfortable ascent for both divers
- With a long hose, the 'octopus' can also be used by the wearer if necessary

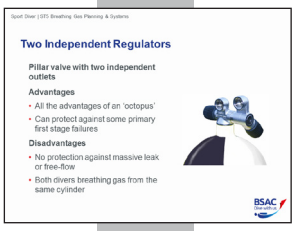
Disadvantages

- It does not protect the wearer against a regulator 1st stage failure
- Both divers are breathing from the same gas cylinder
- 1st stage performance not assured

Divers utilising this method of AS must be made aware of the fact that both divers, in a rescue situation, will be breathing from the same 1st stage (Octopus here being defined as: two second stage regulators attached to a single first stage regulator). This implies that the ventilatory demand, when two divers under stress are breathing from such a system, could place a demand for gas that exceeds the breathing performance of the first stage, therefore, the 1st stage performance is not assured under such circumstances. It is recommended that if octopus systems are to be used they should be based on a high performance first stage regulator, and configured with second stage regulators of similar performance.

Older regulators, whose performance may have degraded, should not be used.

Breathing in and out of phase are situations that cannot easily be monitored; especially when a diver is under stress.



TWO INDEPENDENT REGULATORS

This configuration uses one cylinder equipped with:

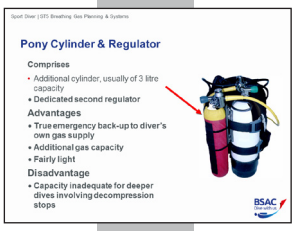
A pillar valve that has two completely independent outlets. A second regulator, fitted with a long hose, provides the AS function.

Advantages

- This configuration provides all the advantages of the 'octopus'
- It can provide a measure of protection against primary regulator first stage failure.

Disadvantages

- Unless the pillar valve can be reached when the set is being worn to turn off the supply to the failed regulator, this will not protect against a failure that results in a massive breathing gas leak (e.g. 'o' ring failure or free flow)
- This configuration still suffers from the limitation that both divers will be breathing from the same cylinder of breathing gas



PONY CYLINDER & REGULATOR

This configuration comprises:

- An additional cylinder, most commonly of 3 litre capacity, providing a totally independent breathing gas source
- A dedicated second regulator

Advantages

- It provides a true emergency back-up in case of failure of the diver's own breathing gas supply
- When assisting another diver, it provides a greater breathing gas capacity than a single cylinder
- It is fairly light considering the advantage it gives a diver

The configuration of the whole equipment needs to be considered. If the pony regulator is also to act as the AS it needs to be equipped with a long hose (which is suitably stowed) and be located in an easily accessible position to both the wearer and buddy.

Some divers, however, prefer to keep the pony regulator on a normal length hose

attached to a strap around their neck for their own use with the 'octopus' on a long hose fed from their primary regulator for their buddy's use. Should the buddy need to use the AS, once the stress of the initial emergency has been overcome and the buddy is breathing normally from the AS, the diver then swaps from the primary to the pony regulator. This can be done at a time of their own choosing, without stress and in a controlled manner to take advantage of the additional breathing gas supply.

Disadvantage

- The limitation of the pony configuration is that while it provides a truly independent breathing gas supply, its capacity is limited. For deeper diving, particularly where decompression stops are involved, the capacity may be inadequate to complete both an ascent and any decompression obligations.

TWIN CYLINDERS WITH INDEPENDENT REGULATORS

Advantages

As an extension of the pony cylinder configuration, but with the 'pony' capacity being increased to match the main cylinder, this configuration

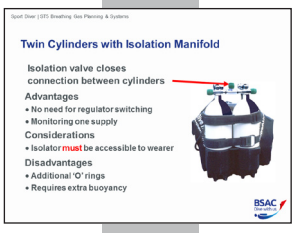
- Has the same advantages as a pony cylinder
- Has a greater breathing gas capacity - therefore more suitable for deeper diving
- With cylinders of equal size, gives a balanced trim underwater

Considerations

Dives, which by their very nature warrant such a configuration require a high degree of dive discipline, practice and more practice. They are not for the inexperienced because of:

- **The need to monitor two breathing gas supplies.** To make the most efficient use of the breathing gas supply, careful breathing gas consumption planning needs to be undertaken. The minimum pressure that needs to be retained in each cylinder, to provide sufficient breathing gas for both the wearer and buddy to ascend and complete any decompression stops (plus a reserve), needs to be determined.
- **Regulator switching**

  Using the 'Rule of Thirds' for each cylinder, during the dive the first cylinder is breathed from until the first third has been used. The diver then swaps regulators to breathe from the second cylinder using two thirds of its supply. The diver then swaps back to the original cylinder and when the second third has been breathed, the dive is terminated (assuming that other considerations such as dive time have not already dictated this). The ascent is thus commenced with sufficient breathing gas for the ascent and a reserve (a third remaining in each cylinder).



Disadvantages

- Should one regulator fail, the diver loses access to breathing gas in that cylinder
- The weight of this configuration requires a BC well able to support it together with good security by 'blocking' or 'banding' the cylinders

TWIN CYLINDERS WITH ISOLATION MANIFOLD

This is a further extension of the twin cylinder configuration. In addition to each being equipped with its own regulator, the cylinders are joined together by a manifold. This enables each regulator to access the contents of both cylinders. In case of regulator malfunction, the manifold incorporates an isolation valve that can close the connection between the cylinders.

Advantages

- Regulator switching is not required as the diver breathes from both

cylinders at once.

- Monitoring is therefore of one supply

Considerations

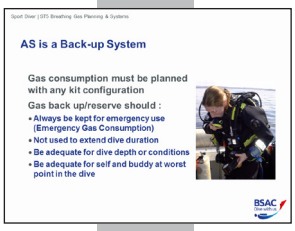
When providing support to a buddy via the AS, the total breathing gas supply remaining is accessible by both divers. Should the diver's own primary regulator fail, the diver swaps to the second regulator. If the failure results in a major leak or free flow, the valve on the manifold is used to isolate the second regulator from the leak, thus preserving the breathing gas supply.

- It is essential that the wearer is able to reach the isolation valve and, with a major leak or free flow, this needs to be done very quickly. In order to make them more easily operable by the wearer, many isolation valves are fitted with extensions that place the valve operating knob in a position that is easily accessible

Disadvantages

- The isolation valve introduces more 'O' ring seals and this configuration is more likely to suffer a breathing gas leak. However, with modern equipment, this is a rare occurrence
- The weight of this configuration requires a BC well able to support it together with good security by 'blocking' or 'banding' the cylinders to prevent strain on the manifold.

Picking up this configuration by the manifold should be avoided, use the BC handle or purpose fitted cylinder handles.



ALTERNATIVE SUPPLY IS A BACK-UP SYSTEM

Breathing gas consumption must be planned with any kit configuration

Breathing gas back up/reserve should:

- Always be kept for emergency use only
- Not be used to extend dive duration
- Be adequate for dive depth or conditions
- Be adequate for self and buddy at worst point in the dive

MAINTENANCE

Remember

Equipment is your lifeline

No matter what configuration of equipment is used, the ideal situation is not to have to use an AS at all. The greatest likelihood of achieving this is if:

- All equipment is washed in fresh water after use
  - To remove dirt
  - To prevent build up of salt crystals that can affect performance
- Equipment is regularly serviced by a competent technician
- Equipment is treated with respect

UPDATING OR BUYING NEW EQUIPMENT

If updating or purchasing new equipment, the temptation is to wear what everyone else is wearing. A very good way of seeking views on equipment from other divers is by listening to their opinions on performance and suitability for their type of diving. However, it is the diving that is being proposed for the future that needs careful consideration as to the most appropriate configuration.

Is the system right for you?

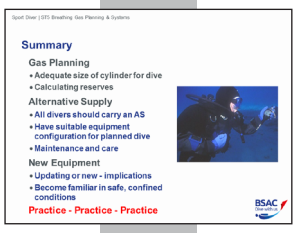
- Is it suitable for the diving the diver is beginning to enjoy?
- Will it be suitable for the diving being aimed for in the future?

- Can upgrades be done gradually rather than all in one go?

Consider the complete system

- Additional cylinders and regulators increase the weight the diver will be wearing. Will they be able to carry it all on dry land? Will they be able to climb a ladder or steps in it?

  If a diver thinks twin cylinders are necessary for the type of diving they want to do, consider the different sizes available from 5 to 15 Litres
- When updating equipment remember that it may affect overall weight distribution so the position of weights or equipment may need to be adjusted for a comfortable swimming posture. Also, check that the BC is suitable in buoyancy capacity and has suitable fixings to carry the additional equipment weight
- Before going on a dive with any new equipment, check it first in shallow protected water



Skills

- No matter how infrequent, failures do occur and no equipment configuration will be of any use if the techniques for using it are not continually practiced. The more complex the equipment, the more practice will be needed. Waiting until the stress of a real incident at depth to get your practice is a recipe for disaster

Practice - Practice - Practice

SUMMARY

Breathing Gas Planning

Includes

- Having an adequate size of cylinder for the planned dive
- Being able to calculate reserves needed for the planned dive

Alternative Supply - AS

- All divers should carry an AS
- Divers should employ the most suitable equipment configuration for the type of dive being planned
- Proper maintenance and care is important

New Equipment

- When updating or buying new equipment, consider all the implications
- Use new equipment in safe, confined conditions until familiar with its operation

Practice - Practice - Practice