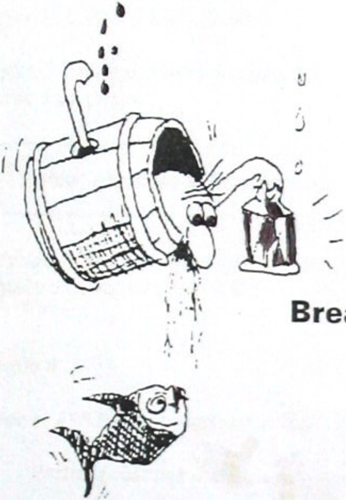

Breathing the right gas

SECTION TWO

Partial Pressures

Air contains, roughly, 21% oxygen, 79% nitrogen. On the surface, the **partial pressure** of oxygen is 0.21 x 1 bar = 0.21 bar or 210 mb (0.21 AT). The partial pressure of nitrogen is 0.79 bar or 790 mb (0.79 AT).

At 30 msw, the absolute pressure is 4 bar. The partial pressure of oxygen is 0.21 x 4 bar = 0.84 bar or 840 mb (0.84 AT). The partial pressure of nitrogen is 0.79 x 4 bar = 3.16 bar.

The partial pressures added together should equal the absolute pressure. Use this as a check.

Partial pressure = absolute pressure x decimal percentage

The decimal percentage is the percentage divided by 100. Just move the decimal point back 2 spaces. 15% is 0.15, 8% is 0.08, 0.4% is 0.04 and so on.

Example 8

A diver at 250 fsw is breathing a 15% mix. What is the PPO2 in his mix?

Partial pressure = absolute pressure x decimal percentage

$$\text{Absolute pressure} = \frac{\text{Depth(fsw)}}{33} + 1 \text{ ATA}$$

$$= \frac{250}{33} + 1 \text{ ATA}$$

$$= 8.58 \text{ ATA}$$

Percentage = 15%
Decimal percentage = 0.15

Partial pressure = 8.58 x 0.15 AT
= 1.287 AT

The PPO2 is 1.287 AT

On the metric system, partial pressures less than 1 bar are usually given in millibars.

If you're using the metric system, an alternative formula is

Partial pressure(mb) = absolute depth(msw) x percentage

Absolute depth(msw) is (depth + 10) msw. And, just to make life difficult, the percentage is the percentage, not the decimal percentage.

Example 9

In a chamber at 80 msw, the oxygen percentage reading is 4.5%. What is the PPO2 in the chamber?

Partial pressure(mb) = absolute depth(msw) x percentage

Absolute depth = depth + 10 msw

= 90 msw

Percentage = 4.5%

Partial pressure = 90 x 4.5 mb

= 405 mb

The PPO2 is 405 mb

Safe Partial Pressures

Diving companies have their own safe levels for the various gases, so the figures below are just guidelines.

Let's start with oxygen. Partial pressure is usually abbreviated to PP, oxygen is O2, so we're looking at the PPO2.

Anoxia (no oxygen)

If you're breathing gas with a PPO2 of 0 mb, you're in serious trouble. And it's even worse than it looks. The PPO2 in your body is higher than the PPO2 in the gas. Whatever oxygen you have in your body will flow out. The normal situation is reversed, oxygen is dumped rapidly from your bloodstream and unconsciousness and death follow very quickly.

This has happened on several occasions when a diver has been supplied with pure helium by mistake. It shouldn't happen now, because the use of pure helium is restricted. But don't start taking life easy, low PPO2s can be just as dangerous.

Always analyse gas before you send it to the diver, always have an on-line analyser, with audio alarms, to monitor the gas all the time the diver is using it. And be careful about going into chambers that have been bled to surface. See Section 4 on chambers and bells.

Hypoxia (not enough oxygen)

The minimum safe PPO2 is usually considered to be about 160 mb (0.16 AT), if you don't exert yourself too much. If you sit still and take it easy, you can stay alive for quite a while on less than 100 mb (0.1 AT).

In the water, working hard, there's a world of difference. You could easily pass out and drown. Your PPO2 should never get anything like as low as this.

Hyperoxia (too much oxygen)

You can, of course, have too much oxygen. Divers living for long periods in a chamber should not exceed a PPO2 of 500 mb (0.5 AT). It would cause lung damage, although the injury would heal when they got back to a normal atmosphere.

The higher the PPO2, the more quickly the damage occurs and the effects are cumulative.

Under normal conditions, it should never happen. It would take several days of serious incompetence. You might, however, get problems if a diver was subject to a bounce dive (PPO2 1.2 bar), a decompression (PPO2 2.0 bar) and decompression sickness treatment (PPO2 2.5 bar)

It's the higher PPO2s that you have to watch out for. The oxygen starts to affect the central nervous system (CNS) and causes convulsions and ultimately, death.

For decompression sickness treatment in the chamber, a doctor may recommend PPO2 as high as 2.5 bar, but watch for convulsions. In the water, for various physiological reasons, the diver is more susceptible and the maximum is usually 1.6 bar.

In saturation diving, the diver in the water should have a PPO2 of about 600 mb (0.6 AT), although he may go as high as 800 mb (0.8 AT). He'll be in the water for four hours and bellman for another four, and this level avoids lung damage.

In a short duration bounce dive, the limit is about 1.6 bar. This avoids CNS problems.

Getting narced

In air diving, if you stay at sensible depths, you won't have any PPO2 problems. It's the PPN2 (that's nitrogen) that starts to get important at about 3.5 bar. Beyond this level, you'll get nitrogen narcosis.

With training you can handle narcosis at a higher PPN2. At 50 msw (165 fsw), the maximum legal depth for air diving in the UK, the PPN2 is 4.74 bar.

Mild narcosis is just a pleasant buzz. At high PPN2, though, it can lead to loss of coordination, irrational behaviour, and hallucinations. Don't underestimate these effects. They can lead you to make mistakes which could be fatal.

Hypercapnia (too much CO2)

The other gas to watch out for is carbon dioxide. The maximum PPCO2 in a chamber is usually set at about 10 mb (0.01 AT). Poisoning symptoms don't usually show until the PPCO2 exceeds 20 mb (0.02AT) and the lethal level is about 100 mb (0.1 AT).

Problems in the water usually occur because of CO2 accumulation in the diver's lungs and bloodstream. You need training, not gas analysis, to deal with this one.

Choosing the right mix

A mixed gas diver may use a helium-oxygen mixture (heliox), a hydrogen-oxygen mixture (hydrox) or a mixture of three gases (trimix). A trimix usually consists of oxygen, helium and nitrogen.

The mix will be adjusted to supply a safe PPO2 at the working depth. But there are other considerations. The decompression time depends on the partial pressure of the inert gas in the mixture. In a heliox mix, for example, the lower the PPHe, the shorter the decompression. This means keeping the PPO2 as high as possible.

In saturation dives, where the diver might be in the water for four hours at a stretch, day after day, his lungs couldn't tolerate more than a maximum of about 800 mb (0.8 AT). Usually, the PPO2 lies between 500 and 800 mb (0.5 to 0.8 AT).

On a short duration bounce dive, the PPO2 can be raised to reduce the PPHe and shorten decompression. 1.2 to 1.6 bar is normal.

Example 10

A diver at 125 msw is breathing a 4% mix. What is his PPO2?

$$\text{Partial pressure} = \text{absolute pressure} \times \text{decimal percentage}$$

$$\text{Absolute pressure (bar)} = \frac{\text{Depth (msw)}}{10} + 1$$

$$= \frac{125}{10} + 1$$

$$= 13.5 \text{ bar}$$

$$\text{Partial pressure} = 13.5 \times 0.04 \text{ bar}$$

$$= 0.54 \text{ bar}$$

$$= 540 \text{ mb}$$

His PPO2 is 540 mb

As an alternative, you could use the other formula:

$$\text{Partial pressure(mb)} = \text{absolute depth(msw)} \times \text{percentage}$$

$$\begin{aligned} \text{Absolute depth} &= \text{depth} + 10 \text{ msw} \\ &= 125 + 10 \text{ msw} \\ &= 135 \text{ msw} \end{aligned}$$

$$\text{Percentage} = 4\ \%$$

$$\begin{aligned} \text{Partial pressure} &= 135 \times 4 \text{ mb} \\ &= 540 \text{ mb} \end{aligned}$$

His PPO2 is 540 mb

Example 11

During a saturation dive at 600 fsw, divers require a PPO2 between 0.5 and 0.7 AT. What is a suitable mix?

$$\text{Partial pressure} = \text{absolute pressure} \times \text{decimal percentage}$$

In this case it's the percentage you want, so turn the formula round (if in doubt, look in the appendix).

$$\text{Decimal percentage} = \frac{\text{Partial pressure}}{\text{absolute pressure}}$$

Take the bottom end of the range:

$$\text{Absolute pressure (ATA)} = \frac{\text{Depth (fsw)}}{33} + 1$$

$$= \frac{600}{33} + 1$$

$$= 19.18 \text{ ATA}$$

$$\text{Decimal percentage} = \frac{0.5}{19.18}$$

$$= 0.026$$

Move the decimal point 2 spaces forward to turn this figure into a percentage.

The percentage at the bottom of the range would be 2.6%

Repeat for the top end of the range:

$$\text{Decimal percentage} = \frac{0.7}{19.18}$$

$$= 0.036$$

Move the decimal point 2 spaces forward to turn this figure into a percentage.

The percentage at the top of the range would be 3.6%

You could use anything between 2.6% and 3.6%

In practice, you'd probably use a 3% mix.

Example 12

If the PPO2 must lie between 1.2 and 1.6 bar, what is the greatest depth at which you could use a 15% mix?

Partial pressure = absolute pressure x decimal percentage

In this case it's the absolute pressure you want, so turn the formula round (if in doubt, look in the appendix).

$$\text{Absolute pressure} = \frac{\text{Partial pressure}}{\text{decimal percentage}}$$

You're looking for the maximum depth, so partial pressure would be at the maximum, that's 1.6 bar.

$$\text{Absolute pressure} = \frac{1.6}{0.15}\text{ bar}$$

$$= 10.67\text{ bar}$$

To turn an absolute pressure into a depth, take off 1 and multiply by 10.

Maximum depth = 96.7 msw

The US Navy Partial Pressure Tables

These heliox tables are still widely used. The best place to find out about them is in the USN diving manual. This is just a brief introduction.

Since decompression time depends on the PPHe, the tables are based on the PPHe, not the depth.

To confuse the issue slightly, the PPHe must be calculated in feet of sea water. This is done by using absolute depth instead of absolute pressure in the calculation. All units are fsw.

PPHe(fsw) = Absolute depth(fsw) x decimal percentage

Example 13

A dive is planned to 290 fsw, using a 15% mix. Which USN Partial Pressure Table should be used?

PPHe(fsw) = Absolute depth x decimal percentage

Absolute depth = depth + 33 fsw
= 290 + 33 fsw
= 323 fsw

Decimal percentage = 0.85

Remember that it's the percentage of helium you're concerned with. The oxygen percentage is 15%, helium is 85%.

PPHe = 323 x 0.85 fsw
= 274.6 fsw

As with any decompression tables, you'd choose the table with the next greatest PPHe and go another 10 fsw for safety. In this case it would be the 290 fsw table.

You can also find the correct table from the mix and depth chart in the USN manual. It won't necessarily agree with your calculation, because the chart includes a 2% oxygen loss for the USN recirculating helmet. It's not applicable to modern equipment, but the error is on the side of safety.