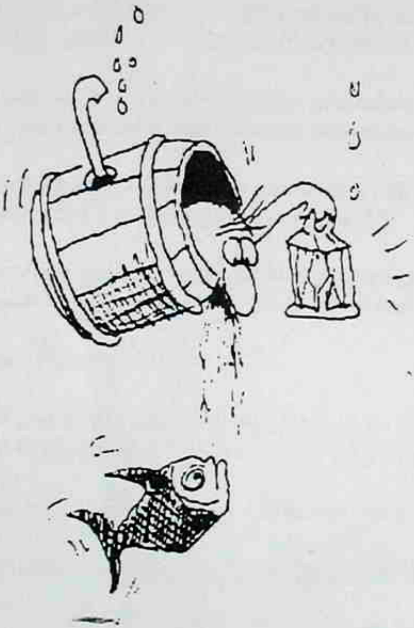

# Appendices

# SECTION EIGHT

# APPENDIX 1 - Equations

## Depth and Pressure

Absolute depth (msw) = depth (msw) + 10
Absolute depth (fsw) = depth (fsw) + 33

Gauge pressure = Depth (msw)/10 bar
Gauge pressure = Depth (fsw)/33 AT

Absolute pressure = Gauge pressure + 1
Gauge pressure = Absolute pressure - 1

Depth (msw) = Gauge pressure x 10
Depth (fsw) = Gauge pressure x 33

Absolute depth (msw) = absolute pressure (bar) x 10
Absolute depth (fsw) = absolute pressure (ATA) x 33

## Gas consumption

Gas consumption = Absolute pressure(bar) x 35 l/min
Gas consumption = Absolute pressure(ATA) x 1.25 $ft^3$/min

Free gas volume = floodable volume x pressure

$$\text{Free gas volume} = \text{Volume when full} \times \frac{\text{available pressure}}{\text{pressure when full}}$$

Free gas volume = floodable volume x volume factor
(for accurate volumes of helium - see Appendix 6)

$$\text{Time available} = \frac{\text{Gas available}}{\text{gas consumption}}$$

## Temperature

$$°C = \frac{5\,(°F-32)}{9}$$

$$°F = \frac{9°C}{5} + 32$$

Absolute Temperature (°K) = Temperature in °C + 273

Absolute Temperature ($^{\circ}R$) = Temperature in $^{\circ}F$ + 460

$$\text{Final pressure} = \frac{\text{Initial Pressure} \times \text{Final temperature } (^{\circ}K)}{\text{initial temperature} (^{\circ}K)}$$

## Partial Pressures

Partial pressure = absolute pressure x decimal percentage

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

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

## Gas Mixing

$$\text{Pressure of Mix 1} = \text{Final Pressure} \times \frac{(\%\ \text{Final Mix} - \%\ \text{Mix 2})}{(\%\ \text{Mix 1} - \%\ \text{Mix 2})}$$

$$\text{Final Pressure} = \text{Pressure of Mix 1} \times \frac{(\%\ \text{Mix 1} - \%\ \text{Mix 2})}{(\%\ \text{Final Mix} - \%\ \text{Mix 2})}$$

Final pressure =

$$\frac{\text{Pressure Mix 1}(\%\ \text{Mix 1} - \%\ \text{Mix 3}) + \text{Pressure Mix 2}(\%\ \text{Mix 2} - \%\ \text{Mix 3})}{(\%\text{Final Mix} - \%\ \text{Mix 3})}$$

## Chamber calculations

Depth of rich mix (msw) =

$$\frac{\text{PPO2 added(mb)} - (\text{Bottom depth} \times \%\ \text{weak mix})}{(\%\ \text{rich mix} - \%\ \text{weak mix})}$$

PPO2 increase (mb) = depth increase (msw) x percentage

$$\text{PPO2 increase (AT)} = \frac{\text{depth increase (fsw)}}{33} \times \text{decimal percentage}$$

$$\text{Free gas volume} = \text{Chamber volume} \times \frac{\text{depth added(msw)}}{10}$$

Free gas volume = Chamber volume x depth added(fsw)

10 cm of pure oxygen will increase the PPO2 by 10 mb
1 fsw of pure oxygen will increase the PPO2 by 0.03 AT

Oxygen used = ln(initial pressure) x PPO2(bar) x chamber volume

$$\text{Depth change} = \text{Absolute depth} \times \frac{\text{temperature change}}{\text{temperature}(^\circ K)}$$

**Chemical sampling tubes**

$$\text{Correct percentage} = \frac{\text{Scale reading}}{\text{absolute pressure}}$$

$$\text{Partial pressure (bar or AT)} = \frac{\text{scale reading}}{100}$$

Partial pressure (mb) = scale reading x 10

SEP or PSE = scale reading

**Buoyancy**

Upthrust = volume of water displaced x density of water

**Useful Numbers**

Density of fresh water 1 kg/L 1 $t/m^3$ 10 lbs/gal 62.5 $lbs/ft^3$

Density of sea water 1.03 kg/L 1.03 $t/m^3$ 10.3 lbs/gal 64.38 $lbs/ft^3$

Divers gas consumption 35 L/min 1.25 $ft^3/min$

(Recovery systems) 5 L/min 0.18 $ft^3/min$

Divers gas consumption from a bail out bottle in an emergency;
40 L/min 1.5 $ft^3/min$

Metabolic oxygen consumption in chambers
0.7 $m^3/day$ or 0.5 L/min per diver
25 $ft^3/day$ or 0.018 $ft^3/min$ per diver

Oxygen Partial Pressure Limits (Check company policy)

| | |
|---|---|
| Therapeutic treatment | 1.6 to 2.6 bar |
| Bounce Dive | 1.2 to 1.6 bar |
| Saturation (in water) | 0.5 to 0.75 bar |
| Saturation (in chamber) | 0.4 bar (0.6 bar maximum) |

Carbon Dioxide Partial Pressure Limits (Check company policy)

| | |
|---|---|
| Chamber | 5 mb, 0.005 bar maximum or 0.5% PSE |
| Bell | 20 mb, 0.02 bar maximum or 2% PSE |

# APPENDIX 2 - Depth and Pressure

Every 10 metres (33 feet) of water depth increases the pressure on the diver by 1 bar (1 AT).

If the depth gauge shows the diver's depth as 20 metres (66 feet), the **gauge pressure** is 2 bar. The **absolute pressure** will be 3 bar - 2 bar from the water and 1 bar from the atmosphere.

At 140 metres (462 feet) the gauge pressure will be 14 bar, the absolute pressure will be 15 bar - 14 bar from the water and 1 bar from the atmosphere.

Note that on the foot-pound system of measurement, gauge pressure is given as AT (atmosphere) and absolute pressure is given as ATA (Atmosphere Absolute)

$$\textbf{Gauge pressure} = \frac{\textbf{Depth (msw)}}{10}\ \textbf{bar}$$

$$\textbf{Gauge pressure} = \frac{\textbf{Depth (fsw)}}{33}\ \text{AT}$$

Absolute pressure = Gauge pressure + 1
Gauge pressure = Absolute pressure - 1

Depth (msw) = Gauge pressure x 10
Depth (fsw) = Gauge pressure x 33

On some occasions, it's convenient to work with absolute depth.

**Absolute depth (msw) = depth (msw) + 10**
**Absolute depth (fsw) = depth (fsw) + 33**

## APPENDIX 3 - Units of Measurement

Two systems of measurement are commonly used in diving. The metric system, also known as the MKS (Metre, Kilogram, Second) system or S.I. (Systeme International), is used by most of the continental companies. It is very easy to use since all the units are based on a scale of 10. European decompression tables and the Royal Navy tables are in metres.

The Imperial or FPS (Foot, Pound, Second) system is used by American companies and those using the US Navy tables. There are slight variations between Imperial and US units on the FPS system. These are noted below.

### The Metric System

| | |
|---|---|
| Length | metres (m) |
| | Depth is often expressed as metres of seawater (msw) |
| Area | square metres (m2) |
| Volume | litres (l) or cubic metres ($m^3$) |
| | $1000\ L = 1\ m^3$ |
| Weight or Force | kilograms (kg) or tonnes (t) |
| | 1000 kg = 1t |
| Density | kilograms/litre (kg/L) tonnes/cubic metre($t/m^3$) |
| Pressure | millibars (mb) or bar (bar) |
| | 1000 mb = 1 bar |

10 m of seawater exert a pressure of 1 bar.

### The FPS System

| | |
|---|---|
| Length | foot (ft). |

| | |
|---|---|
| | Depth is often expressed as feet of seawater (fsw) |
| Area | square feet (ft2) |
| Volume | cubic feet ($ft^3$) or gallons (gal) |
| | 1 Imperial Gallon = 1.2 US Gallons<br>1 US Gallon = 0.83 Imperial Gallons |
| Weight or Force | pounds (lb) or tons (ton) |
| | 2240 lbs = 1 imperial ton<br>2000 lbs = 1 US ton |
| Density | pounds/cubic foot ($lb/ft^3$) |
| Pressure | pounds per square inch (psi) or atmospheres (AT) |
| | When dealing with absolute pressure this is sometimes expressed as atmospheres absolute (ATA) |
| | 14.7 psi = 1 AT |

33 ft of seawater exert a pressure of 1 AT.

# APPENDIX 4 - Temperature and Absolute Temperature

Temperature is measured in degrees Celsius (°C), degrees Fahrenheit (°F), degrees Kelvin(°K) or degrees Rankine(°R)

The Celsius and Fahrenheit scales are used for everyday temperature measurement.

The Celsius scale is named after the Swedish scientist Anders Celsius who introduced it in the 18th century. It is based on the freezing and boiling points of water, which are respectively 0°C and 100°C. It is often known, incorrectly, as the centigrade scale.

The Fahrenheit scale is named after Daniel Gabriel Fahrenheit. He based his scale on the lowest winter temperature he recorded, which he called 0°F and on human body temperature, which he called 100°F. This proved impractical for calibration. It is now also defined according to the freezing and boiling points of water. These are respectively 32°F and 212°F

To convert between the temperature scales:

$$°C = \frac{5\,(°F-32)}{9}$$

$$°F = \frac{9°C}{5} + 32$$

For gas calculations it is necessary to use an absolute scale of temperature. This is a temperature scale based on absolute zero.

Absolute Zero is the temperature when there is no heat energy left in a body. In other words it is impossible to get any colder. It has been calculated as - 273.16°C (-459.69°F) but this is a theoretical value and cannot be reached in practice.

Absolute Temperature is the temperature measured from absolute zero. If you count in degrees Celsius, the absolute temperature is in degrees Kelvin. If you count in degrees Fahrenheit, it's in degrees Rankine.

Absolute Temperature (°K) = Temperature in °C + 273
Absolute Temperature (°R) = Temperature in °F + 460

# APPENDIX 5 - Parts per million

Parts per million (ppm) is used for very small concentrations of gases. A chamber, for example, might contain 400 ppm of carbon dioxide.

Treat ppm just like a percentage. The only difference is that ppm is parts per million, percentage is parts per hundred.

You can carry out calculation directly in ppm, or convert ppm to percentage.

**To convert ppm to a decimal, move the decimal point back 6 places.**

**To convert ppm to a percentage, move the decimal point back 4 spaces.**

400 ppm is 0.0004

650 ppm is 0.065%

# APPENDIX 6 - How much gas have you really got?

For daily stocktaking, a look at the pressure gauge is enough to tell you how much gas you've got. If you're somewhere hot - 30°C at noon, 0°C at midnight - you'll have to make some allowance for temperature changes, but it's largely a matter of common sense.

But if you have to do a serious stock check, things are different. Helium is expensive stuff. Have you ever been on board a ship when it's changing contractors and handing over the gas stocks? It's all thermometers and calculations, and frenzied accountants firing off faxes and telexes.

For accurate gas volumes you have to take into account temperature, the fact that the gas cylinders expand slightly under pressure and the **compressibility** of helium.

Most gases follow Boyle's Law. If you double the pressure, you halve the volume. Helium isn't like that. Double the pressure and you don't quite halve the volume. The difference is only about 2%. It's not enough to cause problems in everyday calculations but significant when you're dealing with large volumes (or money).

You can deal with all these complicated factors by using a long and complicated formula, a computer program or a useful green book called "Computing the Volumes of Helium in Cylindrical Steel Containers". It's published by the US Bureau of Mines and its usually referred to as IC8367; Information Circular 8367.

You simply look up the temperature and pressure of your gas in the tables, and find a **volume factor**.

**Free gas volume = volume factor x floodable volume**

Strictly speaking, this only applies to pure helium, but it's OK for most mixes.

# APPENDIX 7 - The Laws of Diving Physics

Diving physics is based on a series of laws or principles. You don't need to know them, although you do need to know the equations that are derived from them.

## Boyles Law

For a fixed mass of gas at constant temperature volume is inversely proportional to pressure.

## Dalton's Law

In a mixture of gases each gas exerts the pressure that it would exert if it occupied that volume alone.

## Henry's Law

(This law governs the solution of inert gas in the diver's tissues)

At a constant temperature the amount of gas that will dissolve in a liquid is almost directly proportional to the partial pressure of the gas.

## Charles' Law

For a fixed mass of gas at constant volume pressure is directly proportional to the absolute temperature.

## Archimedes Principle

When a body is wholly or partially immersed in a fluid it experiences an upthrust equal to the weight of fluid displaced.