AIR CALCULATIONS MADE EASY

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If you have ever had to cut an interesting dive short because you did not have enough air, you will appreciate the value of being able to make a reliable estimate of the amount of air required beforehand. This can be done by simple arithmetic or it can be achieved even more easily using a nomogram or graph. First, some theory.

Air available

The calculation

The quantity of air squeezed into your tank depends on the charge pressure (in bars) and the capacity of the tank (in litres).

$$P_1V_1=P_2V_2$$

A 100 cu ft tank has an internal capacity of 12.2 litres. It contains 12.2 x 232 (bars) = 2830.4 litres of pumped air. However, we are not supposed to drain the tank completely and current practice is to leave at least 40 bars at the end of the dive. So: -

$$2830.4 - (12.2 \times 40) = 2342.4 \text{ litres of useful air}$$

Two approximations are made in this: -

i) Atmospheres and bars are equivalent - there is about 1.3% error here.

ii) Air behaves as an 'ideal gas' at high pressure, which is nearly true. Minor molecular attractions at high pressure will get a few percent more air in the tank than you would normally expect from an 'ideal gas'. As it happens, these two approximations largely cancel one another. Characteristics of typical tanks are given below.

Cu ft	85	95	100	125
Internal capacity (litres)	10.5	11.6	12.2	15
Air capacity at 232 bar (litres)	2436	2691.2	2830.4	3480
Useful air capacity (litres)	2016	2227.2	2342.4	2880

The graph

Enter the bottom right quarter of the graph using the bars axis at the fill pressure and move right until the diagonal for the tank capacity is cut. Move up to the litres axis and read off the useful capacity - what could be easier? Common tanks are given but additional ones could be added.

Temperature drop

If you immerse a warm, freshly pumped tank in cold water there will be a pressure drop. This causes a loss of about 8 bars for each 10ºC drop. Generally less of a problem in warm Australia but it may be in Antarctica where you would have a nearly 20 bar loss with a drop of 25ºC.

Air required

The air required for an open circuit SCUBA dive depends on the depth of the dive, its duration and the rate at which air is consumed. Although some of these variables are not always known until the dive takes place, you can estimate them. This is the essence of good dive planning.

The calculation

The quantity of air required Q (in litres) is given by: -

$$Q = PTC$$

Where P is the ambient pressure at depth in absolute atmospheres, T is the duration in minutes and C is the rate of consumption of air in litres/minute. First the depth D in metres needs to be converted to atmospheres: -

$$P = D/10+1$$

The added atmosphere is for the atmospheric pressure at the surface.

A dive to 20 m for 30 minutes at an air consumption of 25 lit/min will require: -

$$(20/10+1) \times 30 \times 25 = 2250 \text{ litres of air}$$

This could be achieved safely with either a 100 or 125 cu ft tank but not with an 85.

The graph

Enter the top left sector of the graph on the minutes axis, and follow the 30 minutes line up to the required 20 m depth diagonal. Now move horizontally to the 25 lit/min air consumption diagonal and then vertically down to read off the 2250 litres of required air on the litres axis - what could be easier? You can even continue down to your tank capacity and then left to read off the minimum pressure required. It works both ways! Try some others but, if you fall off the graph, you're probably trying something unrealistic. A twin tank set? Try halving the time or the consumption rate.

Air consumptions

A broad selection of air consumptions has been given, but what do they mean in practice and what do you use?

Litres per minute	Cu ft per minute	Activity
10	0.35	Extreme rest
15	0.53	At rest
20	0.71	Light normal
25	0.88	Normal
30	1.06	Light work
40	1.41	Moderate work
50	1.77	Heavy work

Variations in air consumption are considerable and depend on experience, type of work, water temperature, suit insulation, depth and psychological state. Good initial estimates may be made using 25-30 litres/minute for normal sport diving and these diagonals are shown in green. Ten lit/min is only theoretically achievable. Heavy work causes erratic air consumptions, making estimates difficult.

Your individual air consumption may be estimated on any dive where a relatively constant depth is maintained for a reasonable time. Take a slate and on reaching the bottom, record tank pressure and time. Repeat this on leaving the bottom for the surface, where you can work it out. For example: -

At 15 m depth	Time (hrs and mins)	Pressure (bars)
On reaching bottom	1:05 pm	220
On leaving bottom	1:33 pm	53
Difference	28 mins	167

Assuming a 100 cu ft tank with a 12.2 litre capacity and a depth of 15 m: -

$$(12.2 \times 167) / ((15/10+1) \times 28) = 29.1 \text{ litres/min}$$

So 30 litres/min would seem reasonable for you *under a similar set of circumstances*. Deliberately overestimate air consumptions for deep dives because of the generally lower water temperatures, wet-suit compression and psychological stress.

A quick mental estimate

Too much maths you say - too involved! This is the minimum you need to do. Take the dive duration in minutes, multiply it by the pressure of the dive in atmospheres and the air required is given in cu ft. Add 20% for safety. For a 25 minute dive to 20 m: -

$$25 \times (20/10+1) = 75 + 15 = 90 \text{ cu ft}$$

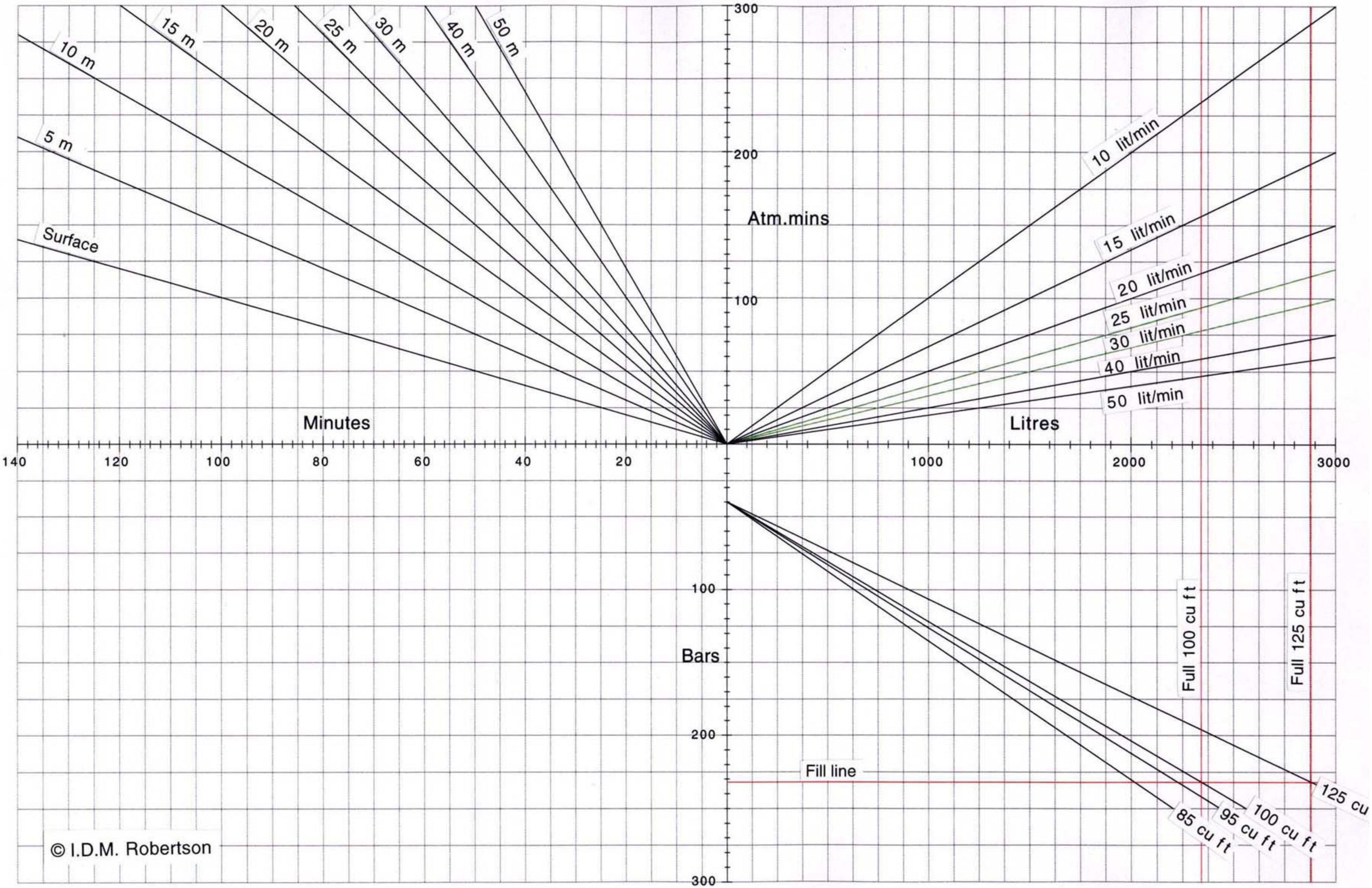
So, your 95 cu ft set should just manage and you should come out with your reserve intact. This assumes an air consumption of 1 cu ft per minute - an advantage of the imperial system!

Getting serious

Multi-level dives with long ascents, descents and decompression stops need a more involved 'air budget'. The dive can be broken into its components of descent, bottom time, ascent, decompression or safety stop etc and the components added up. Ascents and descents may be estimated using the average depth and the total ascent or descent time. Air budgets are essential if decompression is involved or significant penetrations are planned into a wreck or cave and this is just a small part of the required dive plan. Running out of air in these circumstances can spoil your day.

Acknowledgments

Barney Hutton and I published a similar article in 'TRITON', the then journal of the British Sub-Aqua Club, in December 1971. The nomogram was Barney's idea but it has been modernised to suit modern tank capacities, fill pressures and residual air requirements. This article was reviewed by Brad Gordon, Mark Stanniforth, Wendy Yorke and Luke Endacott - thanks to you all.



10 m
15 m
20 m
25 m
30 m
40 m
50 m
5 m
Surface
300
200
100
Atm.mins
10 lit/min
15 lit/min
20 lit/min
25 lit/min
30 lit/min
40 lit/min
50 lit/min
Minutes
Litres
140
120
100
80
60
40
20
1000
2000
3000
100
Bars
200
300
Full 100 cu ft
Full 125 cu ft
Fill line
85 cu ft
95 cu ft
100 cu ft
125 cu