HELIAR

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1. HeliAir

HeliAir is exactly what the term says a gas mixture of helium and air, the latter being made up of oxygen and nitrogen. The same three constituents are also found in the gas mixture called Trimix, were the difference is in the way the two are mixed. Were Trimix is blended by a three way mix (first by decanting helium and oxygen into the scuba cylinder before finally being topped off with air via a conventional compressor), HeliAir is simply blended by filling the scuba cylinder with the desired amount of helium then topping off with air. Like Trimix, HeliAir is commonly used as a breathing mixture to reduce narcosis to an acceptable level whilst operating at depth. The practices of diving HeliAir are exactly the same as those of Trimix, however, HeliAir offers several advantages which are discussed in the following sections.

1.1 Advantages of Trimix over HeliAir

- If the target depth of a dive is known then the optimum Trimix can be custom blended to suit the maximum safe pp02 (normally taken as 1.4 for a bottom gas), as well as the personal narcotic level. Adding the optimum quantity of oxygen reduces the helium and nitrogen levels to a safe minimum, not only reducing the END (Equivalent Narcotic Depth) but also the decompression times. However, this reduced decompression time is only small percentage compared to an equivalent HeliAir mix, and is typically only a matter of a few minutes.
- Training agencies offer courses in the use of Trimix !

1.2 Advantages of HeliAir over Trimix

- Analysing a HeliAir is much simpler, as the reduced oxygen content measured using an oxygen analyser is only due to the dilution caused by the added helium. Therefore, the exact helium content is known as it is a fixed mathematical relationship to the oxygen content. For example, a HeliAir analysed to have 14% oxygen, implies 33% helium content and 53% nitrogen (see HeliAir Top-Off Table for other examples).
- Analysing a HeliAir is much simpler because it can be established directly by measuring the reduced oxygen content of the mix with an oxygen analyser. This only works because the change in the oxygen content is only caused by the thinning effect of adding helium. As more helium is added the oxygen content continues to drop according to a fixed mathematical relationship. As soon as oxygen is added to make a Trimix it is not possible to accurately tell what caused the oxygen reading to change, the added helium, or the added oxygen.
- The quantity of oxygen that has to be added in making a Trimix is typically small (eg 12 bar, for a 250 bar final fill). In practice, it is difficult to accurately add this small quantity of oxygen.
- Any errors in adding the oxygen during Trimix blending will inevitably corrupt the ability to determine the correct helium content because it is no longer known whether the oxygen reading taken is due to dilution by the helium or the oxygen added.
- Since at least 1/3rd of the gas should remain after a dive, and helium is expensive, it is desirable to reuse as much of it as possible. Since HeliAir can always be accurately analysed, there is no limit to the number of times the remaining mix can be topped off with air and helium to generate the same, or even another mix. It is generally considered not a good idea to top off a Trimix fill more than once due to the problems of accurate analysis.
- Since no pure oxygen is added to HeliAir bottom cylinders, there is no requirement for oxygen cleanliness. This has the further advantage that the cylinder valves do not require constant maintenance caused by the breakdown and crystallisation of oxygen compatible greases. Clearly this also reduces the risks associated with handling pure oxygen.
- Compared to Trimix, blending HeliAir is less hassle and time consuming, and is far better suited to large expeditions where the turnover of gas is high.

- Trimix training together with this manual teaches all that is required to dive HeliAir safely.
- Since no additional oxygen is added the ppO2 on the bottom is always less than optimum for a sensible END. Consequently, exploration dives can be safely extended beyond their anticipated maximum depth, with acceptable oxygen and narcotic exposure levels. For example, a good mix for a 65m maximum depth is HeliAir 14/33 (14% oxygen, 33% helium) which gives a anticipated bottom ppO2 of 1.05 and an END of 40m. However, if desired exploration could be continued down to 85m while keeping the ppO2 at 1.33 (within the safe level of 1.4) and the END to an acceptable 54m. This gives plenty of scope for on the spot dive plan changes as is typical with exploration diving.
- On very long or deep dives the central nervous system oxygen toxicity clock (CNS%) can exceed the accepted safe limits, mainly due to the high oxygen mixtures used for decompression. A reduced HeliAir ppO2 at depth can be advantageous.

1.3 HeliAir Formulas

The following simple formulas can be used to determine which HeliAir to use on a particular dive.

Formula 1:- To determine helium content (as a fraction) given a planned maximum depth (metres) and desired END (metres).

$$Fraction\_He = 1.0 - \frac{(END + 10)}{(Max\_depth + 10)}$$

Example 1:- A dive is planned to 65m and an END of 40m is desired.

$$Fraction\_He = 1.0 - \frac{(40 + 10)}{(65 + 10)}$$

$$Fraction\_He = 1.0 - 0.667$$

$$Fraction\_He = 0.333$$

Therefore, the helium content of the desired HeliAir is 33%.

Formula 2:- To determine oxygen content (as a fraction) given a planned maximum depth (metres) and desired END (metres).

$$Fraction\_O2 = \frac{(END + 10)}{(Max\_depth + 10)} \times 0.21$$

Example 2:- A helium content of 33%, is desired with a final cylinder pressure of 232 bar.

$$Fraction\_O2 = \frac{(40 + 10)}{(65 + 10)} \times 0.21$$

$$Fraction\_O2 = 0.667 \times 0.21$$

$$Fraction\_O2 = 0.140$$

Therefore, the oxygen content of the desired HeliAir is 14%.

Formula 3:- To determine oxygen partial pressure at the expected maximum depth (metres)

$$ppO2 = Fraction\_O2 \times \frac{(Max\_Depth + 10)}{10}$$

Example 3:- The above determined HeliAir 14/33 is to used on the 65m dive.

$$ppO2 = 0.140 \times \frac{(65 + 10)}{10}$$

$$ppO2 = 1.05 \text{ bar}$$

Formula 4:- Given a particular HeliAir mix what is its END at a given depth.

$$END = (1.0 - Fraction\_He) \times (Max\_depth + 10) - 10$$

Example 4:- The above determined HeliAir 14/33 is to used on the 65m dive.

$$END = (1.0 - 0.33) \times (65 + 10) - 10$$

$$END = (0.67 \times 75) - 10$$

$$END = 40\ m$$

For your convenience the results of the above formulae for END (Equivalent Narcotic Depth, metres) and Oxygen Partial Pressures (bar) have been calculated for the commonly used HeliAir mixes over a wide range of depths and are presented in a single HeliAir END and ppO2 Tables given in the following sections.

Please scroll down to next table.

HeliAir END & ppO2 Table

HeliAir END & ppO2 Table © Leigh Bishop Dec 1996

% 02	17	16	15	14	13	12	11	10	9
% He	**19**	**24**	**28**	**33**	**38**	**43**	**47**	**52**	**57**
% N2	**64**	**60**	**57**	**53**	**49**	**45**	**42**	**38**	**34**
Depth m	Equivalent Narcotic Depths (m) and Oxygen Partial Pressures (bar)								
44	34m 0.92	31m 0.86	29m 0.81	26m 0.76	23m 0.70	21m 0.65	19m 0.59	16m 0.54	13m 0.49
46	35m 0.95	32m 0.90	30m 0.84	28m 0.78	25m 0.73	22m 0.67	20m 0.62	17m 0.56	14m 0.50
48	37m 0.99	34m 0.93	32m 0.87	29m 0.81	26m 0.75	23m 0.70	21m 0.64	18m 0.58	15m 0.52
50	39m 1.02	36m 0.96	33m 0.90	30m 0.84	27m 0.78	24m 0.72	22m 0.66	19m 0 60	16m 0.54
52	40m 1.05	37m 0.99	35m 0.93	32m 0.87	28m 0.81	25m 0.74	23m 0.68	20m 0.62	17m 0.56
54	42m 1.09	39m 1.02	36m 0.96	33m 0.90	30m 0.83	26m 0.77	24m 0.70	21m 0.64	18m 0.58
56	43m 1.12	40m 1.06	38m 0.99	34m 0.92	31m 0.86	28m 0.79	25m 0.73	22m 0.66	18m 0.59
58	45m 1.16	42m 1.09	39m 1.02	36m 0.95	32m 0.88	29m 0.82	26m 0.75	23m 0.68	19m 0.61
60	47m 1.19	43m 1.12	40m 1.05	37m 0.98	33m 0.91	30m 0.84	27m 0.77	24m 0.70	20m 0.63
62	48m 1.22	45m 1.15	42m 1.08	38m 1.01	35m 0.94	31m 0.86	28m 0.79	25m 0.72	21m 0.65
64	50m 1.26	46m 1.18	43m 1.11	40m 1.04	36m 0.96	32m 0.89	29m 0.81	26m 0.74	22m 0.67
66	51m 1.29	48m 1.22	45m 1.14	41m 1.06	37m 0.99	33m 0.91	30m 0.84	27m 0.76	23m 0.68
68	53m 1.33	49m 1.25	46m 1.17	42m 1.09	38m 1.01	34m 0.94	31m 0.86	27m 0.78	24m 0.70
70	55m 1.36	51m 1.28	48m 1.20	44m 1.12	40m 1.04	36m 0.96	32m 0.88	28m 0.80	24m 0.72
72	56m 1.39	52m 1.31	49m 1.23	45m 1.15	41m 1.07	37m 0.98	34m 0.90	29m 0.82	25m 0.74
74	**58m 1.43**	54m 1.34	51m 1.26	46m 1.18	42m 1.09	38m 1.01	35m 0.92	30m 0.84	26m 0.76
76	60m 1.46	55m 1.38	52m 1.29	48m 1.20	43m 1.12	39m 1.03	36m 0.95	31m 0.86	27m 0.77
78	61m 1.50	**57m 1.41**	53m 1.32	49m 1.23	45m 1.14	40m 1.06	37m 0.97	32m 0.88	28m 0.79
80	63m 1.53	58m 1.44	55m 1.35	50m 1.26	46m 1.17	41m 1.08	38m 0.99	33m 0.90	29m 0.81
82	64m 1.56	60m 1.47	56m 1.38	52m 1.29	47m 1.20	42m 1.10	39m 1.01	34m 0.92	30m 0.83
84		61m 1.50	**58m 1.41**	53m 1.32	48m 1.22	43m 1.13	40m 1.03	35m 0.94	30m 0.85
86	*	63m 1.54	59m 1.44	54m 1.34	49m 1.25	45m 1.15	41m 1.06	36m 0.96	31m 0.86
88	*	64m 1.57	61m 1.47	56m 1.37	51m 1.27	46m 1.18	42m 1.08	38m 1.00	32m 0.88
90	*	66m 1.60	62m 1.50	**57m 1.40**	52m 1.30	47m 1.20	43m 1.10	39m 1.02	33m 0.90
92	*	*	64m 1.53	58m 1.43	53m 1.33	48m 1.22	44m 1.12	40m 1.04	34m 0.92
94	*	*	65m 1.56	60m 1.46	54m 1.35	49m 1.25	45m 1.14	41m 1.06	35m 0.94
96	*	*	66m 1.59	61m 1.48	56m 1.38	50m 1.27	46m 1.33	42m 1.08	36m 0.95
98	*	*	*	62m 1.51	**57m 1.40**	51m 1.30	47m 1.19	43m 1.10	36m 0.97
100	*	*	*	64m 1.54	58m 1.43	53m 1.32	48m 1.21	44m 1.12	37m 0.99
102	*	*	*	65m 1.57	59m 1.46	54m 1.34	49m 1.23	45m 1.14	38m 1.02
104	*	*	*	66m 1.60	61m 1.48	55m 1.37	51m 1.25	46m 1.16	39m 1.03
106	*	*	*	*	62m 1.51	56m 1.39	52m 1.28	47m 1.18	40m 1.04
108	*	*	*	*	63m 1.53	**57m 1.42**	53m 1.30	48m 1.20	41m 1.06
110	*	*	*	*	64m 1.56	58m 1.44	54m 1.32	49m 1.22	42m 1.08
112	*	*	*	*	66m 1.59	59m 1.46	55m 1.34	50m 1.24	42m 1.10
114	*	*	*	*	*	61m 1.49	56m 1.36	50m 1.24	43m 1.12
116	*	*	*	*	*	62m 1.51	57m 1.39	51m 1.26	44m 1.13
118	*	*	*	*	*	63m 1.54	**58m 1.41**	51m 1.28	45m 1.15
120	*	*	*	*	*	64m 1.56	59m 1.43	52m 1.30	46m 1.17
122	*	*	*	*	*	65m 1.58	60m 1.45	53m 1.32	47m 1.19
124	*	*	*	*	*	*	61m 1.47	54m 1.34	48m 1.21
126	*	*	*	*	*	*	62m 1.50	55m 1.36	48m 1.22
128	*	*	*	*	*	*	63m 1.52	56m 1.38	49m 1.24
130	*	*	*	*	*	*	64m 1.54	**57m 1.40**	50m 1.26
132	*	**BOLD FIGURES = MAX WORKING PPO2**				*	65m 1.56	58m 1.42	51m 1.28
134	*	**RED FIGURES = MAX PPO2**				*	66m 1.58	59m 1.44	52m 1.30
136	*	*** = MAX PP02 EXCEEDED**				*	*	60m 1.46	53m 1.31
138	*	*	*	*	*	*	*	61m 1.48	54m 1.33
140	*	*	*	*	*	*	*	62m 1.50	54m 1.35

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1.4 Mixing HeliAir

The process of blending HeliAir as opposed to its Trimix counterpart is relatively straightforward. The helium content required for a particular HeliAir mix can be calculated using the following two simple formula.

Formula 5:- To determine helium content of desired mix (in bar).

He_pressure = Fraction_He x final_pressure

Example 5:- A helium content of 33%, is desired with a final cylinder pressure of 232 bar.

He_pressure = 0.33 x 232
= 77 bar

Therefore, 77 bar of helium should be decanted into an empty cylinder and then topped off to 232 bar with air.

Formula 6:- To calculate the expected oxygen content in the final mix.

Fraction_O2 = (1.0 - Fraction_He) x 0.21

Example 6:- The oxygen of an HeliAir with 33% helium content.

Fraction_O2 = (1.0 - Fraction_He) x 0.21
= (1.0 - 0.33) x 0.21
= 0.141

Therefore, the expected oxygen content during analysis would be 14.1%

As already stated one of the main advantages of HeliAir is that any remaining cylinder contents may be used with the next mix as opposed to emptying any contents prior to re-mixing as with Trimix. This process is easily done by calculating the helium remaining within the cylinder using Formulae 5 above. Again using Formulae 5, calculate the helium content of the desired new mix, and simply add in the difference.

Example 7:- HeliAir 14/33 was used on a previous dive resulting in a final cylinder content of 80 bar.

He_pressure = 0.33 x 80 remaining

He_pressure = 26 bar remaining

The next dive is shallower and only requires a HeliAir 16/24 to a final fill pressure of 232 bar,

He_pressure = 0.24 x 232 from empty

He_pressure = 56 bar from empty

Therefore, the extra helium to add is 30 bar. Top off the original cylinder from 80 to 110 bar with helium, and finish by toping off with air to 232 bar.

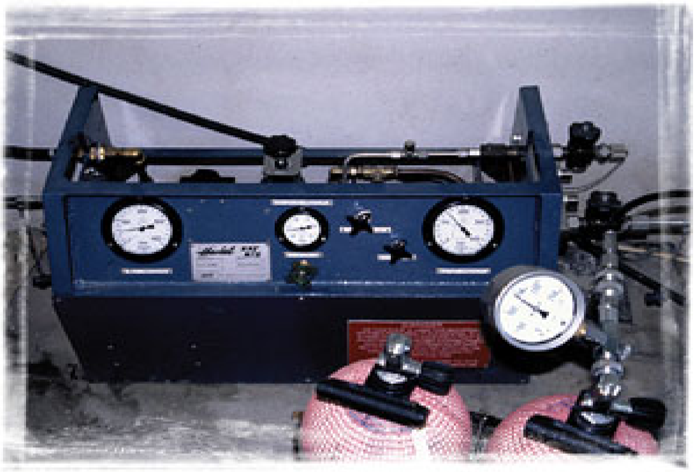
Example 8:- It is desired to use the same remaining mix as in example 7 above on a much deeper dive requiring a HeliAir 10/52, again to a final fill pressure of 232 bar.

He_pressure = 0.52 x 232 from empty

He_pressure = 121 bar from empty

This time the additional helium to add is 95 bar, which requires the original cylinder to be topped off from 80 to 175 bar with helium prior to being topped off to 232 bar with air.

Although Example 8 is theoretically possible, unless high pressure helium banks or a gas booster pump (eg a Haskel) are available the higher helium pressures may become impossible to meet. Therefore, it may be necessary to reduce the original cylinder pressure down to a level (possibly empty) whereby the desired helium pressure is attainable.



Example 9:- HeliAir 10/52 was used on a previous dive resulting in a final cylinder content of 120 bar. A second dive only requires a HeliAir 17/19 mix at a final pressure of 232 bar.

He_pressure = 0.52 x 120 bar remaining

He_pressure = 63 bar remaining

He_pressure = 0.19 x 232 bar from empty

He_pressure = 44 bar from empty

This time the required helium to add is minus 19 bar (44-63). Clearly this is impossible. One alternative is to drain the original cylinder down to a level whereby it only contains 44 bar of helium (85 bar in this example), and then top with air. Since the helium drained is effectively free, it may be better to use a stronger mix and benefit from a lower END, and suffer from slightly longer decompression. Most active mixed gas divers have several cylinder sets in an attempt to avoid unnecessary helium wastage.

Once again, the results of the above calculations have been incorporated into a single HeliAir Top Off Table found in the following section. The above examples demonstrated that most of the work involved using *Formulae 5* to calculate the quantity of helium required to make, or present within a given pressure of a particular HeliAir mix. The only remaining task was to subtract two helium content numbers when a partially filled cylinder was being topped off.

The HeliAir Top-Off Table simply gives the helium content (bar) present within a particular HeliAir mix, given by oxygen and helium percentages in the left hand column for the given fill pressures in the first row.

Prior to diving any HeliAir mix is imperative that the cylinder contents are allowed to cool, mix and are carefully analysed to ensure the correct contents have been achieved. Since helium suffers from a degree of compression during decanting, if time permits it is better to under fill the air top off slightly, and then add further air once the cylinder has cooled and initial analysis has been performed.

Don't forget to label all mixed gas cylinder contents. Trimix stickers are suitable for HeliAir cylinders.

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Air to HeliAir 12/43 Top-Off Table

O2	He	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200	210	220	230	240	250
20.9	**0**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20.7	**1**	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2
20.5	**2**	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5
20.3	**3**	1	1	1	2	2	2	3	3	3	3	4	4	4	5	5	5	6	6	6	6	7	7
20.1	**4**	1	2	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	10
19.9	**5**	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12
19.6	**6**	2	3	3	4	4	5	6	6	7	7	8	9	9	10	10	11	12	12	13	13	14	15
19.4	**7**	2	3	4	4	5	6	7	7	8	9	9	10	11	11	12	13	14	14	15	16	16	17
19.2	**8**	3	4	4	5	6	7	8	8	9	10	11	12	12	13	14	15	16	16	17	18	19	20
19.0	**9**	3	4	5	6	7	8	9	9	10	11	12	13	14	15	16	17	18	18	19	20	21	22
18.8	**10**	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
18.6	**11**	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	22	23	24	25	26	27
18.4	**12**	4	6	7	8	9	10	12	13	14	15	16	18	19	20	21	22	24	25	26	27	28	30
18.2	**13**	5	6	7	9	10	11	13	14	15	16	18	19	20	22	23	24	26	27	28	29	31	32
18.0	**14**	5	7	8	9	11	12	14	15	16	18	19	21	22	23	25	26	28	29	30	32	33	35
17.8	**15**	6	7	9	10	12	13	15	16	18	19	21	22	24	25	27	28	30	31	33	34	36	37
17.6	**16**	6	8	9	11	12	14	16	17	19	20	22	24	25	27	28	30	32	33	35	36	38	40
17.3	**17**	6	8	10	11	13	15	17	18	20	22	23	25	27	28	30	32	34	35	37	39	40	42
17.1	**18**	7	9	10	12	14	16	18	19	21	23	25	27	28	30	32	34	36	37	39	41	43	45
16.9	**19**	7	9	11	13	15	17	19	20	22	24	26	28	30	32	34	36	38	39	41	43	45	47
16.7	**20**	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
16.5	**21**	8	10	12	14	16	18	21	23	25	27	29	31	33	35	37	39	42	44	46	48	50	52
16.3	**22**	8	11	13	15	17	19	22	24	26	28	30	33	35	37	39	41	44	46	48	50	52	55
16.1	**23**	9	11	13	16	18	20	23	25	27	29	32	34	36	39	41	43	46	48	50	52	55	57
15.9	**24**	9	12	14	16	19	21	24	26	28	31	33	36	38	40	43	45	48	50	52	55	57	60
15.7	**25**	10	12	15	17	20	22	25	27	30	32	35	37	40	42	45	47	50	52	55	57	60	62
15.5	**26**	10	13	15	18	20	23	26	28	31	33	36	39	41	44	46	49	52	54	57	59	62	65
15.3	**27**	10	13	16	18	21	24	27	29	32	35	37	40	43	45	48	51	54	56	59	62	64	67
15.0	**28**	11	14	16	19	22	25	28	30	33	36	39	42	44	47	50	53	56	58	61	64	67	70
14.8	**29**	11	14	17	20	23	26	29	31	34	37	40	43	46	49	52	55	58	60	63	66	69	72
14.6	**30**	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72	75
14.4	**31**	12	15	18	21	24	27	31	34	37	40	43	46	49	52	55	58	62	65	68	71	74	77
14.2	**32**	12	16	19	22	25	28	32	35	38	41	44	48	51	54	57	60	64	67	70	73	76	80
14.0	**33**	13	16	19	23	26	29	33	36	39	42	46	49	52	56	59	62	66	69	72	75	79	82
13.8	**34**	13	17	20	23	27	30	34	37	40	44	47	51	54	57	61	64	68	71	74	78	81	85
13.6	**35**	14	17	21	24	28	31	35	38	42	45	49	52	56	59	63	66	70	73	77	80	84	87
13.4	**36**	14	18	21	25	28	32	36	39	43	46	50	54	57	61	64	68	72	75	79	82	86	90
13.2	**37**	14	18	22	25	29	33	37	40	44	48	51	55	59	62	66	70	74	77	81	85	88	92
13.0	**38**	15	19	22	26	30	34	38	41	45	49	53	57	60	64	68	72	76	79	83	87	91	95
12.7	**39**	15	19	23	27	31	35	39	42	46	50	54	58	62	66	70	74	78	81	85	89	93	97
12.5	**40**	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92	96	100
12.3	**41**	16	20	24	28	32	36	41	45	49	53	57	61	65	69	73	77	82	86	90	94	98	102
12.1	**42**	16	21	25	29	33	37	42	46	50	54	58	63	67	71	75	79	84	88	92	96	100	105
11.9	**43**	17	21	25	30	34	38	43	47	51	55	60	64	68	73	77	81	86	90	94	98	103	107

1.5 Basic Nitrox Formulae used in mix gas decompression planning.

1.5.1 Definitions

Fraction_Gas	= fraction of gas in the mix (as a decimal value between 0.00 and 1.00).
ppGas	= partial pressure of the mixture (bar)
Gas_pressure	= absolute pressure of a gas (bar)
fill_pressure	= final fill pressure of a blended cylinder (bar)
Max_depth	= maximum operating depth (m) of a gas based on ppO2
depth	= current operating depth (m)

1.5.2 To Find the Maximum Depth for a Given Mix

Max_depth = *(ppO2 ÷ Fraction_O2) x 10 - 10*

Example:- The maximum depth for air at 1.6 ppO2 is:
= *(1.6÷ 0.21) x 10 - 10*
= *66 metres*

1.5.3 To Find the Partial Pressure of a Gas at a Given Depth

ppGas = *Fraction_Gas x (depth + 10) ÷ 10*

Example:- The partial pressure of oxygen in air at 66m is:
= *0.21 x (66 + 10) ÷ 10*
= *1.596 ppO2*

1.5.4 To Find the Fraction of Oxygen Given the ppO2

Fraction_O2 = *ppO2 x 10 ÷ (depth + 10)*

Example:- The optimum Nitrox to start decompressing on at 40m given a maximum safe ppO2 of 1.6 is:
= *1.6 x 10 ÷ (40 + 10)*
= *0.32 ie 32% Nitrox*

1.5.5 To Find the 0xygen Quantity to Add to an Empty Cylinder to Make a Given Nitrox

O2_pressure = *fill_pressure x (Fraction_O2 – 0.21) ÷ 0.79*

Example:- The quantity of oxygen required to fill a 232 bar cylinder of Nitrox 50 from empty when topped off with air is:
= *232 x (0.50 - 0.21) ÷ 0.79*
= *232 x 0.367*
= *85 bar of oxygen to add*

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