Planning Decompression Diving
Gas Requirements in Open Water

1 Background

During our Open Water classes we were taught that we should be on the surface with an amount of gas remaining, usually 35-50bar. In recreational diving, a simple gas management strategy is fine due to the option of the swimming emergency ascent. Interestingly, a number of recreational divers still manage to run out of gas.

Technical diving often involves situations where there is no direct access to the surface. This may be due to an overhead environment or decompression obligations. Thus, issues that arise during the dive have to be handled underwater and thus require much stricter gas management planning. A dive team should always carry all the gas they require to safely complete the dive allowing for a number of gas failures.

The "rule of thirds" is often used by divers for gas planning in overhead environments. This basically involves using a third of the available gas supply for penetration, a third for the return and a third available for emergencies. This is modified depending upon currents, diver experience and the volume of gas that individual team members have. See later section on the "rule of thirds" on page 18.

For dives with no physical overhead, planning gas reserves should be done slightly differently. In a number of situations, especially when doing decompression on back-gas only, using the 3^rds^ rule and ascending on the last 3^rd^ may not allow for adequate gas reserves.

Doing decompression dives with a single tank and regulator setup is not recommended due to the lack of redundancy available to the individual diver. In this situation, the only redundancy a diver has is his buddy's gas supply.

These examples and calculation procedures are for use with G.U.E DecoPlanner software. The inability for DecoPlanner to specify multiple ascent rates requires an extra calculation step for the recommended slow ascent of 1-2m/min from 6m to the surface.

2 Calculations and Formulae

2.1 Surface Air Consumption (SAC Rate)

The Surface Air Consumption Rate (also known as RMV or Respiratory Minute Volume) is used to provide a measure of a diver's gas usage. This is necessary for planning of gas reserves. The SAC calculation is expressed in Litres/Minute. This can then be used to calculate expected gas consumption on different dives.

Calculation of SAC requires knowing the amount of gas used during a specific period of time for a specific depth. This may be done several ways. I typically work my SAC out based on total dive time, average depth during the dive and total gas used. The more dives you calculate your SAC for, the better idea you will have of your normal gas consumption rates in differing circumstances.

The formula to calculate SAC is:

SAC = Free Gas Volume (Litres) / Depth (ATA) / Dive Time (mins)

Example:

For our example dive, we used twin tanks with a WC of 12.2 Litres. We started the dive with 220 Bar. At the end of the dive we had 80 Bar. Our dive time was 90 minutes and the depth gauge shows that we had an average depth of 8.8 meters.

1. Calculate Gas Used in Free Litres

Since different cylinder sizes will contain different volumes of gas at the same pressure, we convert our gas pressure used (Bar) to a volume (Free Litres). This means that we can relate our gas consumption to any size of cylinder. In the metric system, tanks are marked with a "Water Capacity" volume rating.

Free Gas Volume (Litres) = Cylinder Volume (WC) * Gas Used (Bar)

WC Volume	= 2 * 12.2 litre tanks **= 24.4 Litres**
Gas Pressure Used	= 220 Bar – 80 Bar = 220-80 **= 140 Bar**
Free Gas Volume	= 24.4 WC * 140 Bar Used = 24.4 * 140 **= 3416 Litres**

So, during our dive, we used 3416 Litres of gas.

2. Convert Depth to ATA

Our average depth needs to be converted into Atmospheres Absolute (ATA).

Atmospheres Absolute = (Depth in Metres / 10) + 1

ATA = (8.8 / 10) + 1
= 0.88 + 1
= 1.88

So our average depth of 8.8 metres is 1.88 ATA.

3. Calculate our SAC

Once we have the amount of gas we used during the dive, and have converted the average depth into ATA, we can then calculate our SAC rate.

SAC = Free Gas Volume (Litres) / Depth (ATA) / Dive Time (mins)

SAC = 3416 Litres / 1.88 ATA / 90 minutes
= 3416 / 1.88 / 90
= **20.18**

Therefore our Surface Air Consumption on this dive was 20.18 Litres/Minute.
We will round this to 20L/min for future calculations in this set of examples.

2.2 Gas Usage at Constant Depth

This formula is used to calculate the amount of gas used (Free Litres) for a specific time at a specific depth. We use this to calculate gas usage for the bottom portion of a dive and for the gas usage at deco stops.

Gas Usage = Depth (ATA) * Time (mins) * SAC (Litres/min)

Example:

How much gas will we use for a bottom time of 28 minutes at 40 metres, not including descent or ascent?

1. Calculate the ATA for depth of 40m.

ATA = (40 / 10) + 1 so ambient pressure is 5 ATA

2. Calculate the gas usage at 5 ATA for 20 mins.

Gas Usage = Depth (ATA) * Time (mins) * SAC
= 5 * 28 * 20
= 2800 Free Litres

Our bottom time of 28 minutes at 40 metres, given a SAC rate of 20L/min, would require 2800 litres of gas.

2.3 Gas Usage for Ascent/Decent

The method for calculating gas required during ascents or descents is to average the start and end depths and then to use this average depth to calculate gas use. The ascent/descent rate also needs to be known or defined. This formula is used to calculate the gas requirements for the initial descent from the surface as well as the ascents after completion of bottom time.

$$\textbf{Average Depth} = \frac{\textbf{Depth1} + \textbf{Depth2}}{2}$$

$$\textbf{Time} = \frac{\textbf{Depth1} - \textbf{Depth2}}{\textbf{Rate}}$$

Gas Usage = Average Depth (ATA) * Time (mins) * SAC (Litres/min)

Example:

How much gas will we use for a descent from the surface (0 metres) to 60 metres, assuming a descent rate of 20m/min?

1. Calculate Average Depth of the descent.

Avg Depth = (0 + 60) / 2
= (60) / 2
= 30 metres

2. Calculate ATA of Average Depth

ATA = (30 / 10) + 1
= (3) + 1
= 4 ATA

3. Calculate Time required for Descent

Descent of 60m at 20m/minute therefore takes 3 minutes (60/20 = 3)

4. Calculate Gas Usage of descent

Gas Usage = Average Depth (ATA) * Time (mins) * SAC (Litres/min)
= 4 ATA * 3 mins * 20
= 240 Litres

To descend from the surface to 60m at a rate of 20m/min would require 240 Litres of gas.

Example 2:

How much gas is required to ascend from 60m to our deco stop at 30m?

1. Calculate Avg depth of ascent

Avg Depth = (60 + 30) / 2
= 90 / 2
= 45m

2. Calculate ATA of Avg depth

ATA = (45 / 10) + 1
= 4.5 + 1
= 5.5 ATA

3. Calculate time required for ascent

Time = (60 – 30) / 10m/min
= 30 / 10
= 3 mins

4. Calculate Gas Usage for Ascent

Gas Usage = Average Depth (ATA) * Time (mins) * SAC (Litres/min)
= 5.5 * 3 * 20
= 330 Litres

So, our ascent from 60m to 30m at a rate of 10m/min would require 330 Litres of gas.

3 Planning Dives

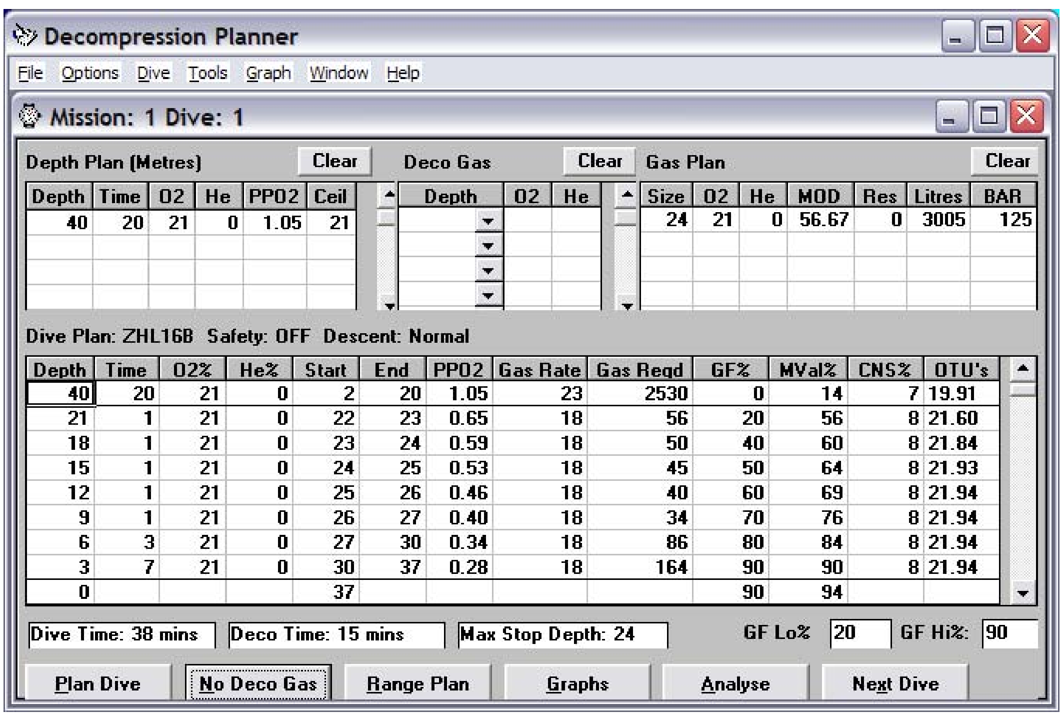
3.1 Diving with no Separate Decompression Gas

When diving with no separate decompression gas, contingency requirements need to allow for enough gas to cover a catastrophic failure of back-gas at max depth/time during the dive. You need provide enough reserve gas to allow you **and** your buddy to ascend and complete obligatory decompression stops.

Example:

Our example dive will be a max depth of 40 metres for 20 minutes, using only back-gas.
Back-Gas = 2 x 12Litre
Bottom SAC = 23
Deco SAC = 18
Descent rate = 20m/min
Ascent rate from 40m to 21 = 10m/min
Ascent rate from 6m to surface = max of 1m/min

1. **Plan the dive in DecoPlanner**



Depth	Time	O2	He	PPO2	Ceil
40	20	21	0	1.05	21

Depth	O2	He

Size	O2	He	MOD	Res	Litres	BAR
24	21	0	56.67	0	3005	125

Dive Plan: ZHL16B Safety: OFF Descent: Normal

Depth	Time	O2%	He%	Start	End	PPO2	Gas Rate	Gas Reqd	GF%	MVal%	CNS%	OTU's
40	20	21	0	2	20	1.05	23	2530	0	14	7	19.91
21	1	21	0	22	23	0.65	18	56	20	56	8	21.60
18	1	21	0	23	24	0.59	18	50	40	60	8	21.84
15	1	21	0	24	25	0.53	18	45	50	64	8	21.93
12	1	21	0	25	26	0.46	18	40	60	69	8	21.94
9	1	21	0	26	27	0.40	18	34	70	76	8	21.94
6	3	21	0	27	30	0.34	18	86	80	84	8	21.94
3	7	21	0	30	37	0.28	18	164	90	90	8	21.94
0				37					90	94		

2. Calculate Gas requirements for dive

This will demonstrate the manual way of calculating the gas requirements. Deco Planner will give slightly different results, usually more conservative.

Calculations for various segments of the dives are shown as examples below.

Descent

Avg depth of descent: (0+40)/2 = 20m
ATA of Avg depth: (20 / 10) + 1 = 3 ATA
Time required: (40 – 0) / 20m/min = 2 mins

Gas Use = ATA * Time * SAC = 3 * 2 * 23
Descent Gas Use = 138 Litres

Bottom

ATA of Depth = (40 / 10) + 1 = 5 ATA
Bottom Time = 20 mins – Descent time (2 mins) = 18 mins
Gas Use = 5 * 18 * 23
Bottom Gas Use = 2070 Litres

Ascent

Gas Use to ascend to first stop @ 21m

Avg depth of ascent: (40+21)/2 = 30.5m
ATA of Avg depth: (30.5 / 10) + 1 = 4.05 ATA
Time required: (40 – 21) / 10m/min = 2 mins (rounded)
Gas Use = ATA * Time * SAC = 4.05 * 2 * 18
Ascent Gas Use = 146 Litres (rounded)

Gas Use during 21m stop

ATA of Depth = (21 / 10) + 1 = 3.1 ATA
Time = Deco stop of 1 min
Gas Use = 3.1 * 1 * 18
21m Stop Gas Use = 56 Litres (rounded)

Gas Use at other stops would follow the same calculation procedures using the appropriate stop times and ambient pressures.

Gas Use to ascend from 3m to surface at 1m/min ascent rate

Avg depth of ascent: (3+0)/2 = 1.5m

ATA of Avg depth: (1.5 / 10) + 1 = 1.15 ATA
Time required: (3 – 0) / 1m/min = 3 mins
Gas Use = ATA * Time * SAC = 1.15 * 3 * 18
Ascent to surface Gas Use = 63 Litres (rounded up)

The above calculations can be condensed down into a spreadsheet format as per below.

Segment	Time	Start Depth	Finish Depth	Avg Depth	ATA	SAC	Gas Reqd	Reserve	
Descent	2	0	40	20	3	23	138		
Bottom	18	40	40	40	5	23	2070		
Ascent	2	40	21	30.5	4.05	18	146	292	
21m Stop	1	21	21	21	3.1	18	56	112	
18m Stop	1	18	18	18	2.8	18	51	102	
15m Stop	1	15	15	15	2.5	18	45	90	
12m Stop	1	12	12	12	2.2	18	40	80	
9m Stop	1	9	9	9	1.9	18	35	70	
6m Stop	3	6	6	6	1.6	18	87	174	
3m Stop	7	6	6	6	1.6	18	202	404	
Surface	3	3	0	1.5	1.15	18	63	126	
	40						**2208**		**Bottom**
							725	**1450**	**Ascent**
								Litres	**Bar**
							Total 21%	**4383**	**183**

The Formulas in Excel are as follows. I have used the second row (Descent) for the formulas.

Avg Depth = (B2+C2)/2
ATA = (D2/10) +1
Descent Time =ROUND((C2-B2)/20,0) (from Row 2)
Gas Reqd =ROUNDUP(E2*F2*G2,0)

The Time formulas change depending on ascent or descent or rate
Normal Ascent Time =ROUND((B4-C4)/10,0) (from Row 4)
Slow Ascent Time =ROUND((B4-C4)/1,0) (from Row 11)

3. Calculate Gas Required For Complete Loss of One Back-Gas

We calculate this gas requirement to assist our buddy to ascend from a catastrophic back-gas failure at max depth and bottom time. We have to allow for the buddy breathing from your gas supply and also the increased SAC rates that will be probably experienced as a result of the emergency. Calculating this reserve should also allow for you to complete your dive on your own back-gas in the event of having to shutdown a side of your twin-set at max depth/time.

We find our required reserves by multiplying the ascent gas calculated in Step 2 (see spreadsheet) by TWO. We then ADD this result to the initial gas calculations. This means that we are effectively multiplying our ascent gas by THREE to obtain our required ascent gas, including reserves.

Bottom Gas	= 2208 Litres
Ascent Gas	= 725 Litres
Ascent Reserve	= 1450 Litres
Total Gas Reqd	**= 4383 Litres**

We then convert this into Bar to get the final gas pressure required to complete the dive with sufficient reserves.

Gas Pressure Required (Bar) = Total Gas Required (Litres) / Cylinder Volume (WC)

GP (Bar) = 4383 / 24
Gas Pressure Required = 183 Bar.

The fill pressure of our twin-set is 220 Bar. Our calculations show that we need 183 Bar to allow sufficient reserves to deal with several preconceived emergencies. Therefore, we have sufficient gas to complete the dive safely.

Because we are effectively multiplying our required ascent and deco gas by three (to allow for a gas sharing ascent), we know that if we shut down one half of our gas supply using our manifold, we would still have sufficient gas to ascend and complete our decompression safely.

Using the above example, we have calculated that we need 725L for the ascent and deco phases of the dive. This represents 61 Bar of a single 12L cylinder (725 / 12 = 61). Even if we had to shut down one half of our gas supply at the very end of the bottom phase of the dive, we would still have ample gas to ascend safely. At that point of the dive we have used 92 Bar (2208 / 24 = 92). The ascent and deco phases require 61 Bar, giving a total of 153 Bar. By having over 200 Bar of gas we have plenty of back-gas for this dive even allowing a margin for a slightly extended bottom time and raised SAC rate.

(Note: the 12L Fabers we use are actually 12.2 Litres, therefore giving us a total of 24.4 Litres WC. Ignoring the extra 0.4 Litres during our calculations allows for small variations such as minor pressure gauge inaccuracies)

3.2 Single Deco Gas

Diving with a single deco gas requires additional planning to ensure adequate reserves of both back-gas and the deco gas. Further contingency planning is required when using deco gases to allow for loss of the deco gas and buddy separation. When using deco mixes, it is possible to plan dives where it isn't feasible to complete deco on back-gas alone. This must be taken into account when doing a risk assessment of the dive.

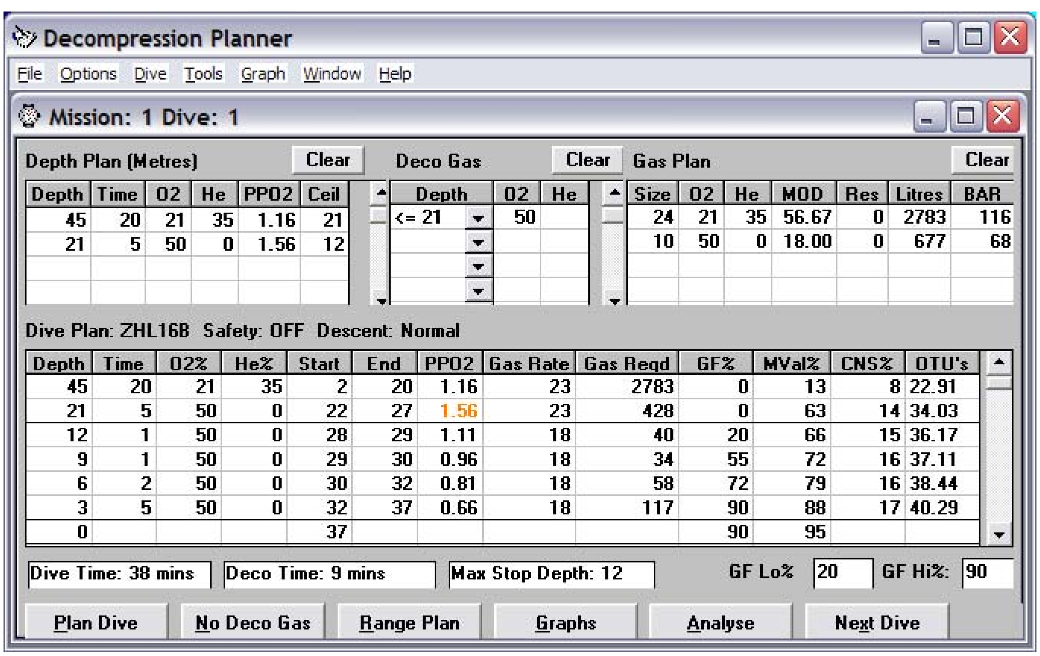
For a single deco gas, we use these contingency plans.

- Loss of one deco gas (buddies share deco gas)
- Loss of one back-gas at max depth/time (ascend to 1st gas switch stop sharing back-gas)
- Loss of deco gas and buddy (deco out on back-gas)

Example:
Our example dive will be a max depth of 45 metres for 20 minutes, using EANx 50% as our deco gas.

Back-Gas = 2 x 12Litre (Trimix 21/35)
Deco-Gas = 1 x 7Litre (EANx 50%)
Bottom SAC = 23
Deco SAC = 18
Descent rate = 20m/min
Ascent rate from depth to 1st stop = 10m/min
Ascent rate from 6m to surface = max 1m/min

1. **Plan dive with deco gas in Deco Planner**



Note the 5min stop added in at 21m to is to help maximize use of the oxygen window. Adding a 3m stop will typically reduce deco time when using EANx deco gases. The shallower depth lowers the inspired ppN2. This increases the N2 gradient, thus speeding up off-gassing. Thus when using EANx 50% we do our final stop at 3m.

If using oxygen as a second deco gas, there is no benefit in ascending to 3m as the inspired ppN2 is zero at any depth whilst breathing oxygen. There is no need to reduce ambient pressure to reduce the inspired ppN2 as it is already zero. It is therefore better to stay at 6m where the higher ambient pressure keeps bubbles smaller.

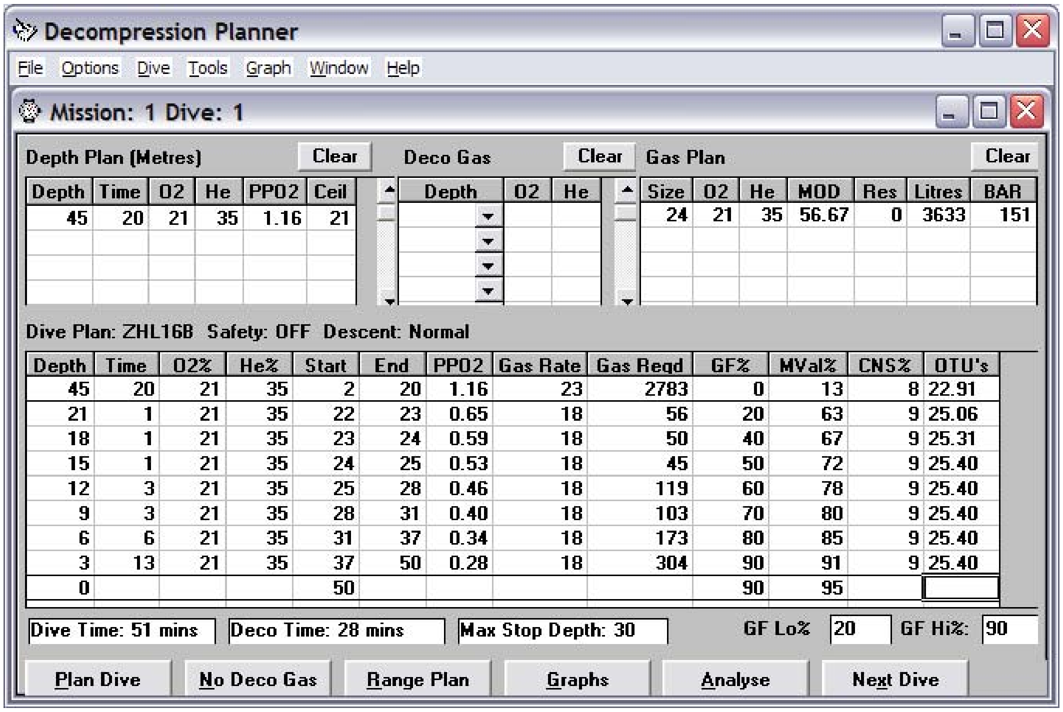
A 3m stop reduces deco time by 1 minute in Deco Planner. However, when we take into account our normal 1m/min ascent rate from 6m to the surface, we actually cut 4 minutes off the dive as we are able to do the first half of the ascent (3 minutes) during the 3m deco stop time.

2. Plan gas requirements for dive

Segment	Time	Start Depth	End Depth	Avg Depth	ATA	SAC	Gas	Gas Reqd	Reserves	
Descent	2.25	0	45	22.5	3.25	23	21/35	169		
Bottom	17.75	45	45	45	5.5	23	21/35	2246		
Ascent	2	40	21	30.5	4.05	18	21/35	146	292	
21m Stop	5	21	21	21	3.1	18	50%	279	279	
12m Stop	1	12	12	12	2.2	18	50%	40	40	
9m Stop	1	9	9	9	1.9	18	50%	35	35	
6m Stop	2	6	6	6	1.6	18	50%	58	58	
3m Stop	5	3	3	3	1.3	18	50%	117	117	
Surface	3	3	0	1.5	1.15	18	50%	63	63	
	39						**21/35**	**2561**	**292**	
							50%	**592**	**592**	
	Reqd		**Reserve**		**Total**					
	Litres	**Bar**	**Litres**	**Bar**	**Litres**	**Bar**				
21/35	2561	107	292	13	**2853**	**119**				
Deco	592	85	592	85	**1184**	**170**				

While planning the gas required for the dive under normal conditions, we also plan our first two contingencies, the loss of one deco gas and the loss of one back-gas at max depth/time.

3. **Plan dive in Deco Planner with no 50% Deco gas**



4. **Plan gas requirements for no 50% deco gas**

Segment	Time	Start Depth	Finish Depth	Avg Depth	ATA	SAC	Gas	Gas Reqd		
Descent	2.25	0	45	22.5	3.25	23	21/35	169		
Bottom	17.75	45	45	45	5.5	23	21/35	2246		
Ascent	2	40	21	30.5	4.05	18	21/35	146		
21m Stop	1	21	21	21	3.1	18	21/35	56		
18m Stop	1	18	18	18	2.8	18	21/35	51		
15m Stop	1	15	15	15	2.5	18	21/35	45		
12m Stop	3	12	12	12	2.2	18	21/35	119		
9m Stop	3	9	9	9	1.9	18	21/35	103		
6m Stop	6	6	6	6	1.6	18	21/35	173		
3m Stop	13	3	3	3	1.3	18	21/35	305		
Surface	3	3	0	1.5	1.15	18	21/35	63		
	53							**3476**	**21/35**	
									Litres	**Bar**
								Total 21/35	**3476**	**145**

Planning the no-deco-gas dive gives us our requirements for the last contingency, loss of buddy AND deco gas. Note the lack of a 5min stop at 21m as we don't have any deco gas to switch to, which makes the extended stop redundant.

5. **Finalize Gas Requirements for Dive and Confirm Sufficient Reserves**

Once the dive plans and gas plans are completed, compare the back-gas volumes from Steps 2 & 4. Use which ever is the greater volume as your final back-gas value. In our example, the No-Deco-Gas plan required 145 Bar versus 119 Bar for the Ascent-From-Max-Depth (Step 2).

Our final gas requirements, including reserves for this dive are:

Back-Gas	3476 Litres	(145 Bar)
Deco-Gas	1184 Litre	(170 Bar)

Both of these volumes are less than the standard fill pressure of the cylinders being used, thus we have sufficient gas to do the dive safely.

3.3 Two Deco Gases

Diving with multiple deco gas cylinders gives us redundancy in deco gas, as we now have regulators that we can swap between cylinders and we plan to be able to complete the deco with loss of one deco gas by using the other. The dive profiles that use two deco gases typically make decompressing out on back-gas impractical and since we also have more redundancy in our deco gas, we don’t plan for an ascent on back-gas alone.

When planning for loss of a deco gas, we have to include planning for ascent from max time/depth to first stop that we are able to use the deco gas.

For two deco gases, we plan for the following failures:

- Loss of either deco gas (i.e. loss of EANx 50% or O2)
    1. Complete decompression using the remaining deco gas
    2. Complete decompression by sharing deco gas with buddy
    3. Swap regulator 1st stage from one deco bottle to the other
    4. Swap regulator 2nd stage from one deco hose to the other

- Loss of one back-gas at max depth/time (ascend to 1st gas switch stop sharing back-gas and then switch onto deco gas)

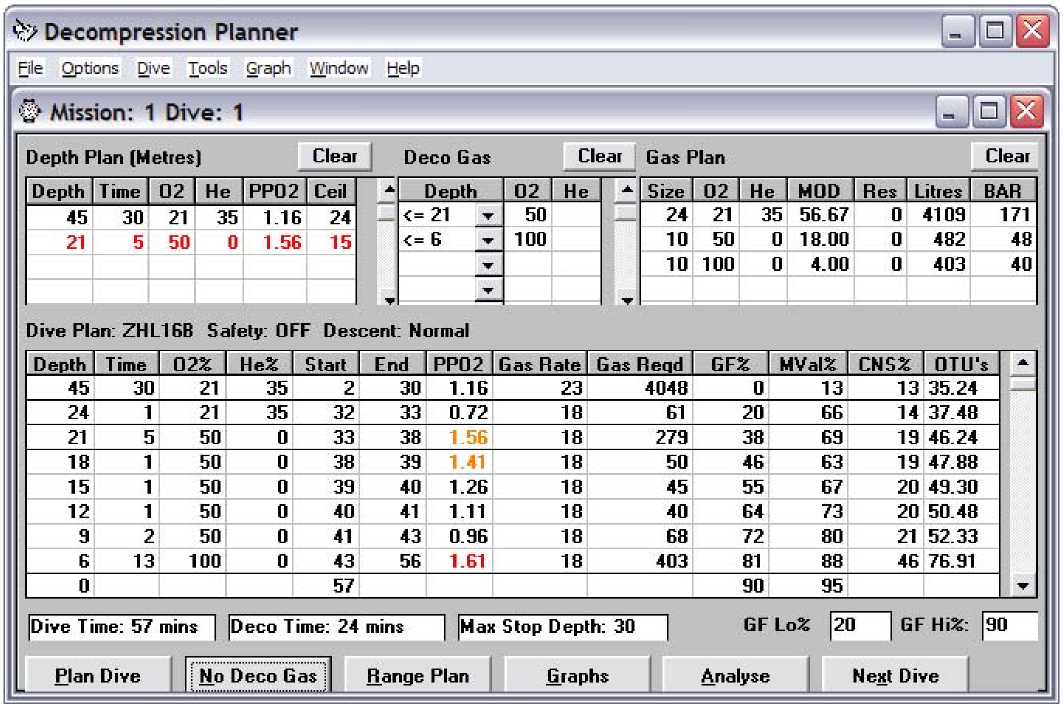
Example:

Our example dive will be a max depth of 45 metres for 30 minutes, using EANx 50% and 100% O2 as our deco gases.

Back-Gas = 2 x 12Litre (Trimix 21/35)
Deco-Gas 1 = 1 x 7Litre (EANx 50%)
Deco-Gas 2 = 1 x 7Litre (100% O2)

Bottom SAC = 23
Deco SAC = 18
Descent rate = 20m/min
Ascent rate from depth to 1st stop = 10m/min
Ascent rate from 6m to surface = 1m/min

1. Plan the dive with Deco Planner



Decompression Planner

File Options Dive Tools Graph Window Help

Mission: 1 Dive: 1

Depth Plan (Metres)

Depth	Time	O2	He	PPO2	Ceil
45	30	21	35	1.16	24
21	5	50	0	1.56	15

Deco Gas

Depth	O2	He
<= 21	50	
<= 6	100	

Gas Plan

Size	O2	He	MOD	Res	Litres	BAR
24	21	35	56.67	0	4109	171
10	50	0	18.00	0	482	48
10	100	0	4.00	0	403	40

Dive Plan: ZHL16B Safety: OFF Descent: Normal

Depth	Time	O2%	He%	Start	End	PPO2	Gas Rate	Gas Reqd	GF%	MVal%	CNS%	OTU's
45	30	21	35	2	30	1.16	23	4048	0	13	13	35.24
24	1	21	35	32	33	0.72	18	61	20	66	14	37.48
21	5	50	0	33	38	1.56	18	279	38	69	19	46.24
18	1	50	0	38	39	1.41	18	50	46	63	19	47.88
15	1	50	0	39	40	1.26	18	45	55	67	20	49.30
12	1	50	0	40	41	1.11	18	40	64	73	20	50.48
9	2	50	0	41	43	0.96	18	68	72	80	21	52.33
6	13	100	0	43	56	1.61	18	403	81	88	46	76.91
0				57					90	95		

Dive Time: 57 mins | Deco Time: 24 mins | Max Stop Depth: 30 | GF Lo% 20 | GF Hi%: 90

Plan Dive | No Deco Gas | Range Plan | Graphs | Analyse | Next Dive

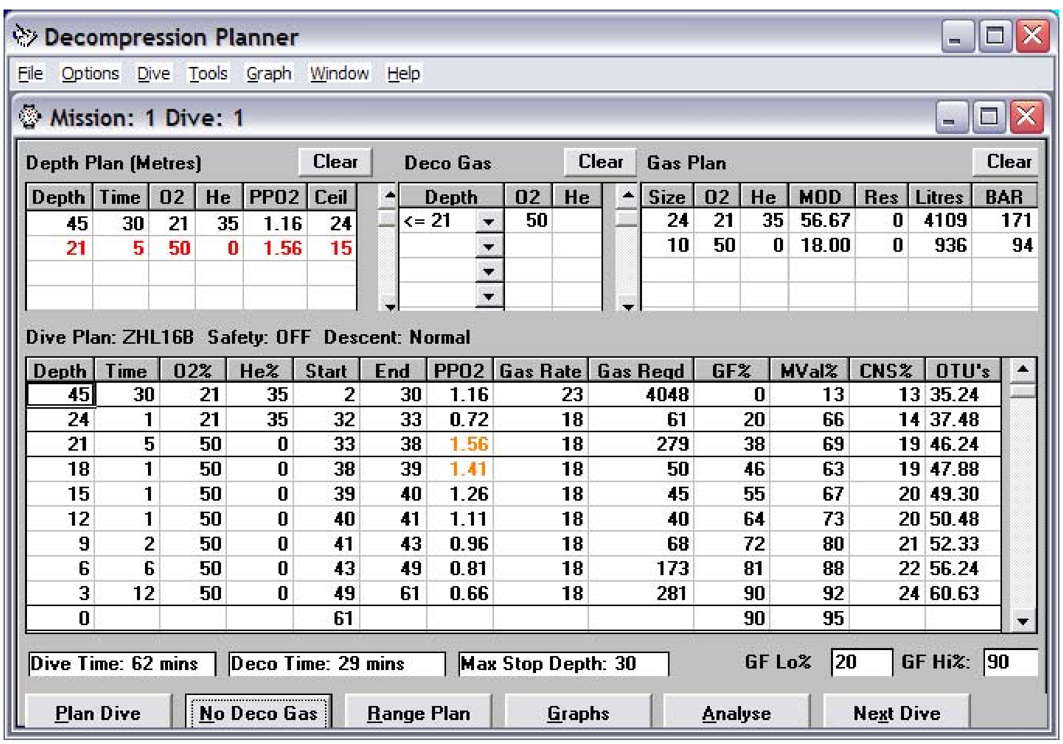
Again, note the 5min stop at 21m to allow for full circulation of the 50% gas through the body. This allows maximization of the oxygen window at high partial pressure of O2. When using O2 as a deco gas, there is no advantage in adding a 3m stop as there is no N2 in the inspired gas at 6m or 3m (or any depth for that matter).

2. Plan the gas requirements for the dive.

Segment	Time	Start Depth	End Depth	Avg Depth	ATA	SAC	Gas	Gas Reqd	Reserves
Descent	2.25	0	45	22.5	3.25	23	21/35	169	
Bottom	27.75	45	45	45	5.5	23	21/35	3511	
Ascent	2	40	24	32	4.2	18	21/35	152	304
24m Stop	1	40	24	32	4.2	19	21/35	80	240
21m Stop	5	21	21	21	3.1	18	50%	279	279
18m Stop	1	18	21	19.5	2.95	18	50%	54	54
15m Stop	1	15	21	18	2.8	18	50%	51	51
12m Stop	1	12	12	12	2.2	18	50%	40	40
9m Stop	2	9	9	9	1.9	18	50%	69	69
6m Stop	13	6	6	6	1.6	18	O2	375	375
Surface	6	6	0	3	1.3	18	O2	141	141
	62						**21/35**	**3912**	**544**
							50%	**493**	**493**
							O2	**516**	**516**
	Reqd		**Reserve**		**Total**				
	Litres	**Bar**	**Litres**	**Bar**	**Litres**	**Bar**			
21/35	3912	163	544	23	**4456**	**186**			
50%	493	71	493	71	**986**	**141**			
O2	516	74	516	74	**1032**	**148**			

When planning our gas requirements for the dive, we also calculate our ascent from max depth/time to first gas switch (21m) to allow for a back-gas failure. At the same time, we calculate reserves for both O2 and 50% to allow for loss of one 50% and one O2 deco gas.

3. Plan the dive in Deco Planner for loss of O2



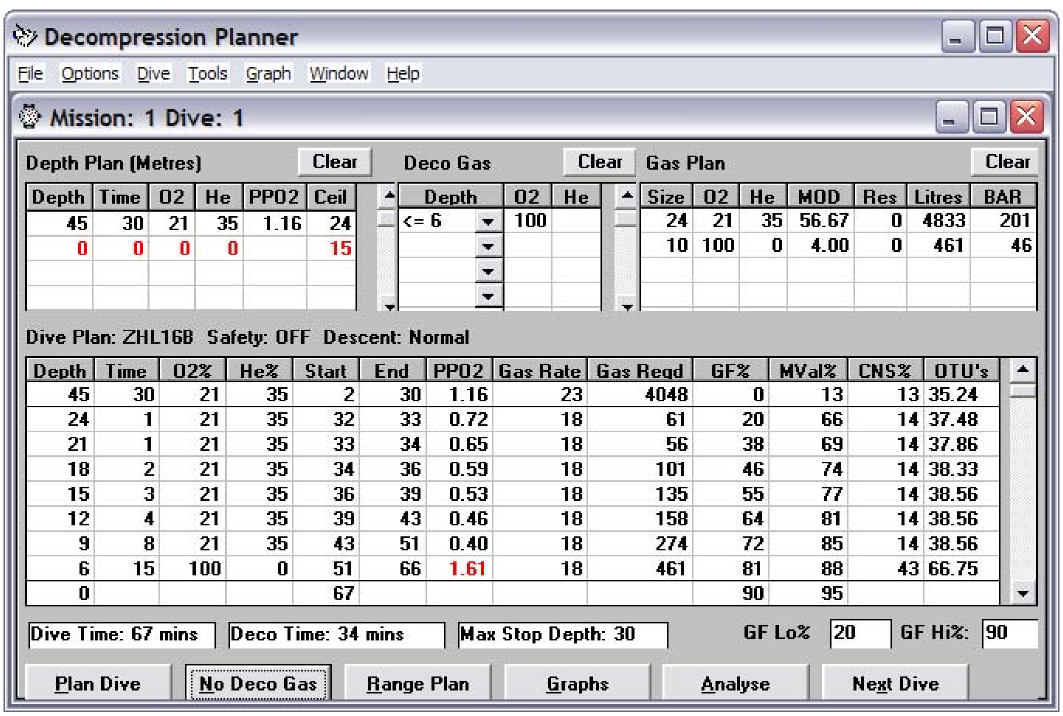
Note that we now do a 3m stop as we using EANx 50% rather than O2.

4. Plan the gas requirements for loss O2

Segment	Time	Start Depth	End Depth	Avg Depth	ATA	SAC	Gas	Gas Reqd	
Descent	2.25	0	45	22.5	3.25	23	21/35	169	
Bottom	27.75	45	45	45	5.5	23	21/35	3511	
Ascent	2	40	24	32	4.2	18	21/35	152	
24m Stop	1	40	24	32	4.2	18	21/35	76	
21m Stop	5	21	21	21	3.1	18	50%	279	
18m Stop	1	18	21	19.5	2.95	18	50%	54	
15m Stop	1	15	21	18	2.8	18	50%	51	
12m Stop	1	12	12	12	2.2	18	50%	40	
9m Stop	2	9	9	9	1.9	18	50%	69	
6m Stop	6	6	6	6	1.6	18	50%	173	
3m Stop	12	3	3	3	1.3	18	50%	281	
Surface	3	3	0	1.5	1.15	18	50%	63	
	64						**21/35**	**3908**	
							50%	**1010**	
								Total Reqd	
								Litres	**Bar**
							21/35	3908	163
							50%	1010	145

So we require 163 Bar of 21/35 and 145 Bar of EANx 50% to deco out on if we lose the O2.

5. Plan the dive in Deco Planner for loss of 50%



6. Plan the gas requirements for loss of EANx 50%

Segment	Time	Start Depth	End Depth	Avg Depth	ATA	SAC	Gas	Gas Reqd	
Descent	2.25	0	45	22.5	3.25	23	21/35	169	
Bottom	27.75	45	45	45	5.5	23	21/35	3511	
Ascent	2	40	24	32	4.2	18	21/35	152	
24m Stop	1	40	24	32	4.2	18	21/35	76	
21m Stop	1	21	21	21	3.1	18	21/35	56	
18m Stop	2	18	21	19.5	2.95	18	21/35	107	
15m Stop	3	15	21	18	2.8	18	21/35	152	
12m Stop	4	12	12	12	2.2	18	21/35	159	
9m Stop	8	9	9	9	1.9	18	21/35	274	
6m Stop	15	6	6	6	1.6	18	O2	432	
Surface	6	6	0	3	1.3	18	O2	141	
	72						**21/35**	**4656**	
							O2	**573**	
								Total Reqd	
								Litres	**Bar**
							21/35	4656	194
							O2	573	82

So we require 194 Bar of 21/35 and 82 Bar of O2 if we lose our EANx 50%.

7. Finalize Gas Requirements for Dive and Confirm Sufficient Reserves

The gas requirements for each scenario are:

- Loss of either deco gas and share with buddy

	Reqd		**Reserve**		**Total**	
	Litres	**Bar**	**Litres**	**Bar**	**Litres**	**Bar**
21/35	3912	**163**	544	23	**4456**	**186**
50%	493	71	493	71	**986**	**141**
O2	516	74	516	74	**1032**	**148**

- Loss of one backgas at Max Depth/Time.

	Reqd		**Reserve**		**Total**	
	Litres	**Bar**	**Litres**	**Bar**	**Litres**	**Bar**
21/35	3912	163	544	23	**4456**	**186**

- Loss of O2 deco gas

	Litres	**Bar**
21/35	3908	163
50%	1010	145

- Loss of 50% deco gas

	Litres	**Bar**
21/35	4656	194
O2	573	82

We then sort through and take out the largest value for each gas, which gives us our final gas requirements, including reserves, for the dive:

21/35	4656 Litres	194 Bar
50%	1010 Litres	145 Bar
O2	1021 Litres	148 Bar

All of the gas requirements for this dive are within standard fill pressures of the cylinders being used and therefore the dive can be completed safely.

4 "Rule Of Thirds" Gas Planning

As briefly mentioned in the Background section on page 1, for overhead environment dives (such as a cave or wreck) we need to plan for enough gas for both our buddy and ourselves to make a safe exit. As a **minimum** we need to allow for twice as much gas for the exit as the entrance as two divers will be sharing the same gas source. This assumes a gas failure at maximum penetration but it also assumes that the SAC rates of each diver do not go up during the emergency exit. In reality, stress would be an important factor and so it is prudent to plan based on a more conservative rule, such as using only a quarter, fifth or sixth of our gas on the entrance. Some factors to be considered include:

- Flow/currents in cave or wreck – e.g. significant outward flow of a spring would aid an exit making the rule of thirds more acceptable, whereas for a siphon you would need to allow for more gas on the exit whilst going against the flow.
- Experience level of divers (for training dives the rule of sixths may be more appropriate to ensure a large reserve in case of a failure and to ensure short penetrations on early training dives).
- Complexity and extent of the dive – for longer cave dives it is often more appropriate to leave all back-gas intact and dive purely using stage bottles.
- Allowing for a slower exit should gas sharing be required or following the line in reduced visibility.

On the next page are some examples showing how the "rule of thirds" should be calculated. You will notice that differing SAC rates are catered for as the dive is "called / turned" when the first person hits their "turn pressure". Where people sometimes go wrong is with dissimilar tank sizes. The person with the larger tanks has to calculate their "turn pressure" based on one third of their buddy's gas volume, not theirs. This is because one third of their tanks is greater than one third of their buddy's. The following examples will make this clearer.

1) Same tanks and SAC rates

	Diver 1	Diver 2
Start Pressure	240	210
Planned Turn Pressure	160	140
Gas used on entry	70	70
Actual Turn Pressure	170	140
Gas used on Exit when sharing	70 + 70	70 + 70
Pressure on Final Exit	30 (170 – 140)	0 (140 – 140)

Under normal circumstances Diver 2 would "call the dive" as he reaches his turn pressure first. Diver 1 still has 10 Bar before reaching his planned turn pressure.

One can see how marginal it might be if Diver 1 was to have a catastrophic failure at the furthest penetration. That said, the vast majority of failures would enable some gas to be used given that both divers have isolation manifolds.

2a) Same tanks but Diver 1 has higher SAC rate and starting pressure

	Diver 1	Diver 2
SAC Rate (L/min)	20	15
Start Pressure	240	220
Planned Turn Pressure	160	150
Gas used on entry	80	60
Actual Turn Pressure	160	160
Gas used on Exit when sharing	80 + 60	60 + 80
Pressure on Final Exit	20 (160 – 140)	20 (160 – 140)

By the time Diver 1 has used 80 Bar and his planned turn pressure, Diver 2 has only used 60 Bar (80 x 15/20) – he only uses three quarters as much gas as Diver 1.

2b) Same tanks but Diver 1 has lower SAC rate and higher starting pressure

	Diver 1	**Diver 2**
SAC Rate (L/min)	15	20
Start Pressure	240	220
Planned Turn Pressure	160	150
Gas used on entry	52.5	70
Actual Turn Pressure	187.5	150
Gas used on Exit when sharing	52.5 + 70	70 + 52.5
Pressure on Final Exit	65 (187.5 – 122.5)	27.5 (150– 140)

Diver 1 only uses three quarters as much on entry as diver 2 (70 x 15/20 = 52.5).

So you can appreciate that different SAC rates present no problems if you work out the turn pressures correctly. Two thirds of 220 Bar is 146.67 Bar, but you should always round up the planned turn pressures.

3) Dissimilar tanks sizes – same SAC rates (this is where some people get it wrong!)

	Diver 1	**Diver 2**
Tank WC (Litres)	24	30
Start Pressure	220	210
Planned Turn Pressure	150	154*
Gas used on entry	70	56
Actual Turn Pressure	150	154
Gas used on Exit when sharing	70 + 70	56 + 56
Pressure on Final Exit	10 (150 – 140)	42 (154– 112)

* The key here is to remember that 70 Bar in twin 12's is only 56 Bar in twin 15's (70 x 24/30 = 56). Diver 2 must work out what 70 bar equates to in his tanks and only deduct that pressure from his starting pressure (i.e. deduct the 56 bar from the 210 bar).

In practice Diver 2 would have a planned turn pressure of 155 Bar if his SPG was calibrated in 5 Bar increments, or 160 Bar if calibrated in 10 Bar increments.

If you were not ignore the different tank sizes and allow Diver 2 to incorrectly calculate his turn pressure the following would result:

Incorrect calculation!

	Diver 1	**Diver 2**
Tank WC (Litres)	24	30
Start Pressure	220	210
Planned Turn Pressure	150	140*
Gas used on entry	70	70
Actual Turn Pressure	150	140
Gas used on Exit when sharing	70 + 87.5	70 + 56
Pressure on Final Exit	-7.5 (150 – 157.5)	14 (140– 126)

* Diver 2 mistakenly calculates his turn pressure based on HIS starting pressure, what he has forgotten is that the 70 bar he needs to exit in his twin 15's is 87.5 Bar in twin 12's (70 x 30/24 = 87.5). If diver 2 had a total loss of gas at maximum penetration then at least one of these divers would die.

In this particular example, diver 1 has a 20% lower SAC rate than diver 2 as he only uses 70 bar in twin 12's whereas diver 2 uses 70 bar in twin 15's. In fact, there are many cases where people work it out incorrectly and "get away with it" because nothing goes wrong or the diver with a better SAC rate is on the bigger tanks or the start pressures are such that the diver on the smaller tanks hits his turn pressure well before the other diver. Where the problems/deaths occur is when the diver on the bigger tanks is allowed to penetrate further to the point where the volume of gas used in his bigger tanks is greater than the reserve carried for him in his buddy's smaller tanks.

5 Acknowledgements

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