THE DIVERS BIBLE

$$TENSION = \frac{W \times L}{2R}$$

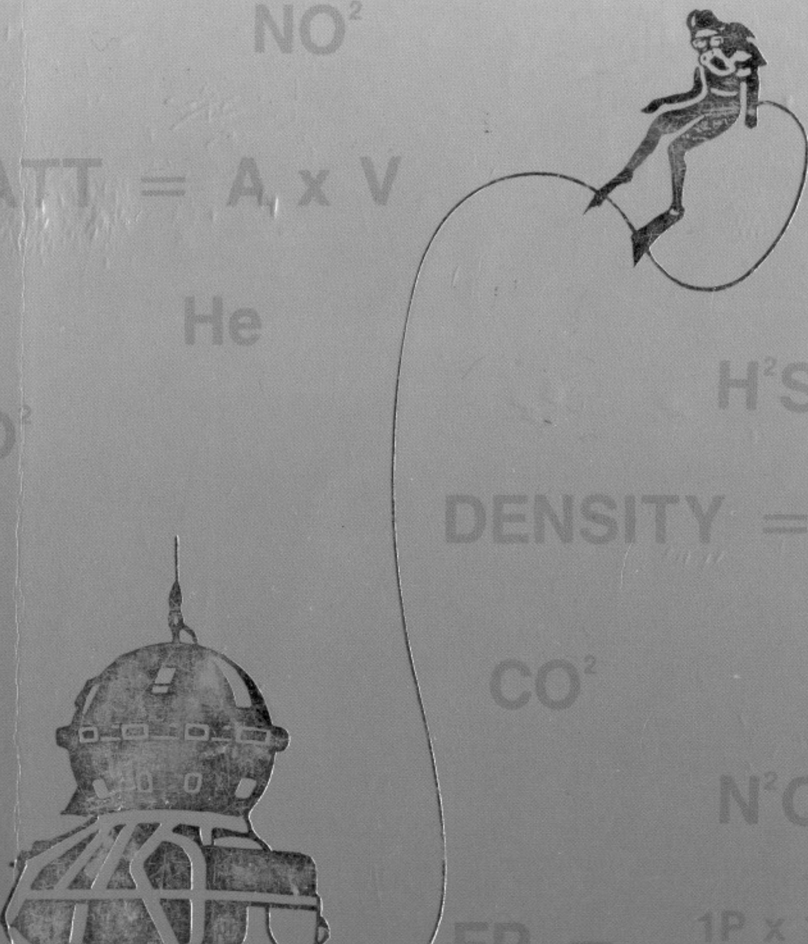
N^2

NO^2

$$WATT = A \times V$$

He

O^2



H^2S

$$DENSITY = \frac{M}{V}$$

CO^2

N^2O

$$FP = \frac{1P \times 100}{\%\ He\ Req.}$$

$$IP = \frac{FX \times \%\ He\ in\ Mix}{102}$$

by Phill Henderson

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FOREWORD

THIS BOOK HAS BEEN COMPILED OVER TWENTY FIVE YEARS OF DIVING, SIXTEEN OF WHICH HAVE BEEN COMMERCIAL. DESPITE THE VARIOUS "LARGE FORMAT" DIVING HANDBOOKS AND BOOKS ON THE MARKET TODAY, I FELT THERE WAS STILL THE NEED FOR A COMPREHENSIVE POCKET BOOK CONTAINING NOTHING BUT FACTS THAT COULD BE USED BY TENDER - DIVER, SUPERVISOR, SUPERINTENDENT, MANAGERS, ALIKE FOR "QUICK REFERENCE".

WHAT I HAVE TRIED TO DO IS PUT DOWN WHAT I HAVE FOUND TO BE THE MOST COMMONLY USED THINGS AND PROVIDE ACTUAL WORKING EXAMPLES, WHEREVER POSSIBLE, OF HOW THE INFORMATION IS USED. THERE ARE MOST PROBABLY NUMEROUS WAYS OF SOLVING ALL SOLUTIONS, FORMULA, METHODS OF DOING A GIVEN TASK, ETC. "OTHER THAN THOSE" GIVEN IN THIS BOOK. THIS IS NOT IN DISPUTE, WHAT I HAVE TRIED TO DO IS CORRELATE A BASIS. SOMETHING TO KEEP ALL ON THE RIGHT TRACK.

THIS BOOK IS DESIGNED TO HELP IN THE ABSENCE OF LAID-DOWN PROCEDURES. REMEMBER, ALL DIVING COMPANY'S HAVE THEIR LAID-DOWN PROCEDURES WHICH MUST BE ADHERED TO.

SAFETY, IS A STATE OF MIND. RATHER THAN THE BLIND OBEDIENCE TO LAID-DOWN PROCEDURES. HOWEVER, ALWAYS CHECK WITH YOUR SUPERVISOR FIRST.

I'D LIKE TO TAKE THIS OPPORTUNITY TO THANK JACK PANG AND HIS WIFE, EDNA WHOSE ENTHUSIASTIC SUPPORT HELPED MAKE THIS BOOK POSSIBLE.

ABBREVIATIONS

1.	ABS	=	ABSOLUTE
2.	ATS/ATMOS	=	ATMOSPHERE
3.	B.G.	=	BOTTLE GUAGE PRESS.
4.	BOP	=	BLOWOUT PREVENTER
5.	CNS	=	CENTRAL NERVOUS SYSTEM
6.	CONS.	=	CONSUMPTION
7.	D.A.M.	=	DEPTH ABSOLUTE IN METRES
8.	DDC	=	DECK DECOMPRESSION CHAMBER
9.	EAD	=	EQUIVALENT AIR DEPTH
10.	FP	=	FINAL PRESSURE
11.	HE	=	HELIUM
12.	IP	=	INITIAL PRESSURE
13.	L.D.	=	LIVING DEPTH
14.	LIT	=	LITRES
15.	L.P.M.	=	LITRES PER MIN.
16.	MBS	=	MILLIBARS (PARTS PER THOUSAND)
17.	MM	=	MILLIMETRES
18.	NITROX	=	$N_2 + O_2$ MIX
19.	NP	=	NEW PRESSURE
20.	OXY	=	OXYGEN
21.	PA	=	PRESSURE ABSOLUTE
22.	PG	=	PRESSURE GAUGE
23.	PP	=	PARTIAL PRESSURE
24.	PPM	=	PARTS PER MILLION
25.	PRESS.	=	PRESSURE
26.	PYO	=	PSEUDOMANAS AERUGINOSA
27.	REQ.	=	REQUIRED
28.	R.M.V.	=	BREATHING RATE
29.	SAT	=	SATURATION
30.	S.E.	=	SURFACE EQUIVALENT
31.	SWR	=	STEEL WIRE ROPE
32.	TEMP	=	TEMPERATURE
33.	T.U.P.	=	TRANSFER UNDER PRESSURE SECTION OF A DDC OR POSSIBLY A SEPARATE T.U.P. CHAMBER
34.	UPTD	=	UNIT PULMONARY TOXITY DOSE
35.	VOL	=	VOLUME
36.	W.D.	=	WORKING DEPTH

SECTION 1

FORMULA & CALCULATIONS

Formulas used in diving are very simple. With a few basic rules and a little practice, one can solve any problems involving mix gas diving. Every formula has a working example.

THE BASIC LAWS

DALTONS LAW OF PARTIAL PRESSURE. means that the partial pressure (PP) of a gas. It is the pressure a gas would exert if it occupied all the space presently occupied by a mixture of gasses. Further, that the (PP) of a gas is directly proportional to the % of gas in the mix.

CHARLES LAW means that at a constant press the volume of a gas is directly proportional to the temperature.
At a constant volume, the press is proportional to the temperature.

BOYLES LAW means that at a constant temperature the volume of a gas is inversely proportional to the press.

HENRY'S LAW OF SOLUBILITY states that the amount of gas that will dissolve into a liquid at a given temperature is directly proportional to the pressure of the gas.

GRAHAMS LAW' relates rates of diffusion to molecular weights of gas.

ARCHIMEDES PRINCIPLE states that when a body is immersed in liquid, it experiences an upthrust equal to the weight of the liquid displaced.

PASCALS LAW states that press. applied to a liquid is transmitted equelly throughout that liquid.

PARTIAL PRESSURE

The following two basic formula and rules are sufficient for solving nearly all formula related diving problems.

In the main my calculations will be done in metric. The answers, except for very minor discrepancies, will be the same as Imperial Formula. Simply use conversions,

PARTIAL PRESSURE (PP)

$$PP = \frac{\text{\% of gas in Mix x Pressure Absolute (PA)}}{100}$$

$$\text{\% GAS} = \frac{\text{P.P Gas x 100}}{\text{P.A. (BARS or ATS)}} \quad \text{or} \quad \frac{\text{PPO}^2\text{MBS}}{\text{D.A.M.}} \text{(Depth absolute in metres)}$$

$$\text{P.A.} = \frac{\text{PP GAS x 100}}{\text{\% GAS}} \quad \text{or} \quad \frac{\text{PPO}^2 \text{ MBS}}{\text{\% GAS}} = \text{METRE ABS}$$

EXAMPLES OF ABOVE FORMULA

We are diving at 300 Ft. or 91.5m. The diving gas must contain oxy to give diver a PPO2 of 1.6 What % of oxy in gas do we need?

$$\text{\% OXY} = \frac{1.6 \times 100}{\text{10 BAR or ATS ABS}} = 15.8\text{\% OXY}$$

$$= 16\%$$

We have an 8% oxy mix. What is the shallowest depth we can dive with this mix given we do not want to go lower than a P.P.O² of .16.

$$\text{P.A.} = \text{P.P.} \ \frac{.16 \times 100}{8\% \ \text{O}^2 \text{ IN GAS}} = 2 \text{ BAR ABS}$$

2 BAR or ATS ABS = 20M. As this is Pressure Absolute we must minus 1 BAR or 10M to get Gauge Press 10M or 33ft.

To check:

$$PP = \frac{8 \times 2}{100} = .16$$

---

1 BAR	=	10M	=	1,000 MBS	=	1,000,000 PPM.
.1 BAR	=	1M	=	100 MBS	=	100,000 PPM.
.4 BAR	=	4M	=	400 MBS	=	400,000 PPM.
1.6 BAR	=	16M	=	1,600 MBS	=	1,600,000 PPM.

EXAMPLE OF ABOVE

We know that Air is basically made up of 21% Oxy 79% Nitrogen.

That is :

210 MBS O² 790 MBS N² = 1000 MBS

Q. How much He. and O² do we put in a DDC to give .6 PPO² at 90 metres depth?

We need .6 or 600 MBS Oxy. DDC contains .21 or 210 MBS Oxy. Leaving .39 or 390 MBS Oxy missing.

.39 or 390 MBS = 3.9 Metres say 4M
90 M - 4 M = 86 M
Top up to 86 M with He. and 4 M Oxy.

GAS MIXING

The first thing to remember is when you are calculating the effect of gas mixes on divers. You have to take into account (P.A.) Pressure Absolute.

When you are moving gasses from cylinder to cylinder, you are only interested in Gauge Pressure. Following are some easy examples of mixing sometimes using P.A. other times just P.G. Be careful to note the difference.

Firstly, we will list some gases, their chemical symbols and molecular weight. Remember place the lighter gas in the mix first.

GAS	CHEM. SYMBOL	MOL. WEIGHT
OXYGEN	O²	32
HYDROGEN SULPHIDE	H²S	34.082
CARBON DIOXIDE	CO²	44.01
CARBON MONOXIDE	CO	28.016
HELIUM	He	4.003
NITROGEN	N²	28.013
HYDROGEN	H²	2.016
ARGON	Ar	39.94
NEON	NE	20.18
NITRIOUS OXIDE	N²O	44.016
AIR		28.96
NITRIOUS MONOXIDE	NO	30.0061
NITRIC DIOXIDE	NO²	46.0
OZONE	O³	47.998

I am going to top up DDC with impure gasses. I need .4 PPO2 at 105M. I have 2/98 and 18/82 available.

$$105M = \frac{10.5\ B \times 2\%\ oxy}{100} = .21\ PP$$

210 MBS in gas + 210 MBS in DDC = 420 MB

Since this is only 20 MBS over the 400 required, I would just top DDC with 2/98.

At 200Ft in DDC, I need .4 PPO2.

$$\frac{200}{33} = 6.06\ ATS \quad \text{Gas available } 2/98 + 18/82$$

$$\frac{6.06 \times 2\%}{100} = .121\ PPO^2$$

.121 + 210 already in DDC = 331 MBS

= .069 P.P. *or* 69 MBS missing

16% (not 18% as we have put already 2% in DDC)

$$.069\ PP = \frac{69\ MBS}{16} = 4.31\ m = .431\ BAR \text{ or } ATS$$

.431 x 33 Ft = 14.223 Ft (15 Ft)

= 15 Ft of 18% rest 2% to 200 Ft.

The basic formula for most mixing is:

$$IP = \frac{FP \times \%\ He\ in\ mix}{102}$$

$$or\ IP = \frac{FP \times (Mix\ 2 - Final\ Mix)}{(Mix\ 2 - Mix\ 1)}$$

$$FP = \frac{IP \times 102}{\%\ He.\ Req.}$$

$$or\ FP = \frac{IP \times (Mix\ 2 - Mix\ 1)}{(Mix\ 2 - Final\ Mix)}$$

Basic Correction Formula:

Oxy to add $\dfrac{I.P. \times original\ \%\ He.}{\%\ He.\ req.}$

= NP (New Pressure)

NP - IP = Oxy to add

He. to add $\dfrac{I.P. \times \%\ Oxy\ in\ mix}{\%\ Oxy\ req.}$

NP - IP = He. to add

EXAMPLES

I have a bank containing 150 B of He. How much O^2 must I add to make 18% Oxy 82% He ?

$$FP = \frac{150 \times 102}{\%\ He.\ req\ 82} = 186.5\ BAR \text{ or } ATS$$

186.5 - 150 = 36.5 BAR O^2 to add

I need 200 B of 18% O^2. I have an empty mixing quad and quads of He and Oxy. What pressures of each gas do I need?

$$I.P. = \frac{200 \times 82}{102} = 160.7\ BAR\ He\ \&\ \text{the rest to 200B Oxy}$$

One can of course just use P.P. Formula:

$$PP\ of\ He = \frac{82 \times 200}{100} = 164\ BAR$$

It is a little different as 102 is used as a compressibility factor of H.E. Both methods are used frequently. Mix will vary little, within laid-down tolerances.

We need 200 BAR of 18/82 and we have 4/96 and 23/77 to mix with. How much 4/96 do I need initially?

$$IP = FP\ \frac{(Mix\ 2 - Final\ Mix)}{(Mix\ 2 - Mix\ 1)}$$

$$= 200\ \frac{(23 - 18)}{(23 - 4)} = \frac{200 \times 5}{19} = 52.6$$

= 52.6 BAR of 4/96 rest 23/77

We have a quad of 80B of 6% Oxy and need 13% Oxy. We have 23% Oxy to add. What would the Final Pressure be?

$$FP = IP\ \frac{(Mix\ 2 - \%\ Mix\ 1)}{(Mix\ 2 - Final\ Mix)}$$

$$= 80 \times \frac{(23 - 6)}{(23 - 13)}$$

$$= \frac{80 \times 17}{10} = 136\ BAR = F.P.$$

Some other mixing methods using P.P. and P.A. Formula.

An example of mixing with impure gasses.

We have H.E. at 5/95

Oxy at 4/96 (4% impurities)

We need a bank around 200 B of 16/84.

$$PP\ HE = \frac{84 \times 200B}{100} = 168\ B$$

$$PP\ OXY = \frac{16 \times 200}{100} = 32B$$

Therefore, the mix requires 168 B He and 32 B Oxy. How much impure He will equal 168 BAR of pure He? Use P.A. Formula:

$$PA = \frac{PP\ He \times 100}{\%\ He\ in\ gas} = \frac{118 \times 100}{95} = \underline{176.84\ B}$$

176.84 - 168 = 8.84 BAR of Oxy pumped in with impure He.

32 BAR Oxy - 8.84 B = 23.16 BAR Oxy req. but this is 4% impure

$$PA = \frac{23.16 \times 100}{96} = 24.12 \text{ of Oxy to pump into Bank}$$

We have 150 B of 20/80 and some pure He. We need 150 B of 16/84.

$$PP\ Oxy = \frac{16 \times 150}{100} = 24\ B$$ How much 20/80 makes 24B Oxy

$$PA = \frac{24 \times 100}{20} = 120\ B \text{ of } 20/80$$

150 B - 120 B = 30 B. So pump 30 B of pure He into Bank then top up to 150 B with 20/80.

We have 37 B of 18.6/81.4. A full bank of 23/77 and pure He. We need 150B of 16/84 and must mix into bank containing 37 B of 18.6/81.4.

$$PP\ O^2 = \frac{16 \times 150}{100} = 24 \text{ BAR Oxy needed in mix}$$

$$PP\ O^2 = \frac{37\ B \times 18.6}{100} = 6.8 \text{ B Oxy we have in bank}$$

24 - 6.8 = 17.2 B Oxy needed.

$$PA = \frac{17.2 \times 100}{23} = 74.78 \text{ BAR } 23/77 \text{ needed}$$

150 B - 74.78 B = 75.22 B to be pumped of pure He then top up to 150 B with 23/77.

A method of finding what two mixes will make if mixed together using P.P. Handy for finding out what you have got in bell bottles. Also a whole pile of mixes, say six mixes, can be calculated using this method.

We will mix 20 B of 16/84 and 50 B of 50/50

20 B of 16/84 PPO^2 = 3.36

$\underline{50\ B}$ of 50/50 PPO^2 = $\underline{25.5}$

70 B = 28.86

$$\frac{PPO^2\ MBS}{DA\ METRES} = \% \ \frac{28.860}{710} = 40.64\%$$

INITIAL PRESSURE OF DDC

Pressurizing D.D.C. with air or 20/80 for initial saturation pressurization with divers in DDC.

$$\text{Formula: } \frac{PPO^2\ MBS - 200\ MBS \text{ in } DDC}{\%\ Oxy \text{ in Gas}} = \text{Metres Depth}$$

		.6 PPO^2 600 MBS	.4 PPO^2 400 MBS
AIR or	20/80	20 M	10 M
	18/82	23	11
	16/84	26	13
	14/86	29	15
	12/88	34	17
	10/90	40	20
	8/92	50	25
	5/95	80	40

Maximum impurities allowed in diving oxygen.

OXYGEN

MAXIMUM PERMISSIBLE CONTAMINANTS 99.5%

NITROGEN	0.1%
ARGON	0.4%
HYDROCARBONS	3 PPM
METHANE	25 PPM
CO_2	5 PPM
CO	1 PPM
H_2O	25 PPM

MIX GAS EQUIVALENT TABLES are usually correlated by the different diving companies and set into tables. It is important to understand how these Equivalent Tables (ET) are obtained. It is simply the PP He.

We usually need to use E.T. when we have to use a mix which is richer in He than the proper mix for that depth. i.e. we have just moved to a shallower location and are stuck with the mix for the deeper location.

EXAMPLE

The dive at 84M should use 16/84 according to the Tables but we only have 12/88 mix.

$$\text{PP He using } 12/88 = \frac{88 \times 9.4 \text{ B ABS}}{100} = 8.27$$

We now need to know which Table will get rid of 8.27 PP He.

1) The 87M 16/84 Table
PP He $\frac{84 \times 9.7}{100} = 8.14$ no good.

2) The 90M 16/84 Table
PP He $\frac{84 \times 10}{100} = 9.4$ ok

So we can use the 90M Table although we will actually be diving at 84M using 12/88.

You are diving at 300Ft using 16/84. What E.T. should you use?

$$\frac{84 \text{ He} \times 333 \text{ Ft ABS}}{100} = 279 \text{ Ft Table}$$

HYPERBARIC RESEARCH CENTRE

DIVING TABLES FOR EQUIVALENT AIR DEPTH USE WITH NITROGEN OXYGEN MIXTURES

DEPTH	MIXTURE	EQUIVALENT DEPTH ON AIR
22 M	50/50	12 M
25 M	45/55	15 M
27 M	40/60	18 M
29 M		20 M
30 M		22 M
31 M	35/65	24 M
33 M		26 M
35 M		28 M
37 M	30/70	32 M
40 M		35 M
43 M		38 M
45 M	25/75	42 M
48 M		45 M
51 M		48 M
53 M		50 M

$$\text{EAD} = \frac{\% N^2 \text{ in Mix} \times \text{P. ABS.}}{\% N^2 \text{ in Air (79)}} = \text{Press. ABS.} = \text{Metres ABS.} - 10\text{m}$$

= Depth Gauge in meters

CO^2

CO^2 This always seems to be a never-ending topic of discussion among divers. Actually, Surface Equivalent (S.E.), P.P., MBS, PPM are one and the same.

Everything is based on P.P. Once you have that you have everything, CO^2 readings are basically the P.P. Formula.

We know that:

1 B	=	10M	=	1,000 MBS	=	1,000,000 PPM
.6 B	=	6M	=	600 MBS	=	600,000 PPM
.005B	=	.05M	=	5 MBS	=	5,000 PPM

SURFACE EQUIVALENT

The normal maximum allowance CO^2 level is .5% S.E. What is .5% S.E.?

As a P.P. = $\frac{5}{100}$ = .005 or 5 MBS 5000 PPM.

CO^2 tubes read in % SE of CO^2 in the ambient or surrounding gas. However, gas passed through analysis tube on the surface is decompressed gas. We therefore have to calculate to obtain the true P.P. effect on the divers.

Example

CO^2 tube reading on surface is .02 Divers are at 75M, 85M ABS, 8.5 B ABS.

$$PP = \frac{0.2 \times 8.5 \text{ B}}{100} = .0017$$

= 1.7 MBS = .17% S.E.

= 1,700 PPM

Likewise, if a diver takes a reading in the bell, a full calculation is not necessary as he has taken the reading at Press. ABS. But to prove it the tube reading is the same. For example .02

$$PP = \frac{.02 \times PA}{100} \text{ (not necessary he is at Press. ABS)}$$

$$= \frac{.02}{100} = .0002 \text{ or } .2 \text{ MBS } 200 \text{ PPM.}$$

To simplify things for the diver so he instantly knows his CO^2 level. It is only necessary for him to multiply his reading by 10 (i.e. move decimal point one point to the right) to get units of MBS. He knows his maximum should be 5 MBS.

So the scale of CO^2 tubes used on the surface would by unsuitable for the bell, where, because of the density of the gas a larger scale is needed. Bell needs CO^2 tubes CH 23501 with scale .1 to 1.2 which will read 1 MB to 12 MB.

Surface needs CO^2 tubes CH 30801 with scale .01 to .3 which is obviously too small for the bell.

Note. There are many types of tubes in use other than Drager Tubes which scales I have quoted for these examples. Read the instructing carefully as they may differ from one brand to another. Make sure the tube expiration date is still valid.

RELATING S.E., P.P., MBS, PPM

.5% SE = $\frac{5}{100}$ = .005 P.P. = 5 MBS 5000 PPM

Reverse situation - what is 5000 PPM as a S.E.?

$$\frac{5000 \times 100}{1{,}000{,}000} = \frac{5000}{10{,}000} = .5\%$$

What is 5000 PPM as a P.P.?

$$\frac{5{,}000}{10{,}000} = .5\% \text{ SE} = \frac{5}{100} = .005$$

What is PP as SE?

.005 x 100 = .5%

That is ok using tubes. What if we had a machine run off analysis which read PPM on decompressed gas. i.e. reading is 228 PPM.

$$\frac{228 \text{ PPM}}{10{,}000} = .0228\% \text{ SE on decompressed gas}$$

We are interested in P.P. effects on the diver, so:

$$\frac{228 \times 8.5 \text{ B ABS}}{10{,}000} = .193\% \text{ SE on diver}$$

$$\text{e.g. } \frac{.193}{100} = .00193 \text{ P.P.} = 1.93 \text{ MBS } 1930 \text{ PPM.}$$

O^2 AND CO^2 NOTES

Consumption and Output Levels.

RMV (RATE OF BREATHING)	OXY CONS.	CO^2 OUTPUT
10 L.P.M.	.5 LIT.	.5 LIT.
35 L.P.M.	1.5 LIT.	1.5 LIT.
70 L.P.M.	3.0 LIT.	3.0 LIT.

So your CO^2 output is directly related to O^2 absorption in your body.

AMOUNT OF SODASORB. USED IN DDC & BELL

1 Kilogram of Sodasorb will absorb 120 Litres of CO^2 gas breathed out by divers.

.5 LPM x 60 min x 24 hrs = 720

$$\frac{720 \text{ litres}}{120 \text{ litres}} = 6 \text{ kg per man per day}$$

Obviously you will have to calculate for bell use, and reclaim if being used. Calculate charcoal as <u>1 KG/MAN/24 HRS.</u>

A guide to diver exposure to CO^2.

30 MIN	50 MBS
under 2 HRS.	40 MBS
2 - 8 HRS.	30 MBS
8 - 24 HRS.	20 MBS
INDEFINITELY	10 MBS or BELOW

So 5 MBS normal level required as maximum offshore is pretty good.

U.P.T.D. UNIT PULMONARY TOXICITY DOSE

By calculation U.P.T.D. is defined as the degree of pulmonary toxicity produced by breathing pure oxy at 1 ATMOS ABS for 1 minute.

UPTD = TIME (T) x KP (KP being the factor which represents the toxity per min for given P.P.)

KP = T (2PP - 1) 0.833

Where PP = Partial Pressure. e.g. What is the UPTD for a diver exposed to pure O^2 for 3 hrs and 28 min at 40 Ft.?

UPTD = 208 min. (2 x 2.11 PP - 1) .833
= 208 x 3.42 x .833
= 592.56 Units

WHEN USING UPTD TABLES

a) Calculate PPO^2
b) Select corresponding KP value
c) Multiply by divers exposure time
d) If more than one dive, add together to get total UPTD

Example

Diver had 60 min of oxy at 60' PPO^2 = 2.8
From table KP value is 3.57

3.57 x 60 = 214.2 units

Maximum recommended exposure is:

Normal Bell Dive	450 Units
Type 1 (B) Bend	615 Units
Type 2 (CNS) Bend	1425 Units

i.e. Maximum allowable at 1.2 PP is 500 Units. According to table KP at 1.2 PP is 1.32.

$\frac{500}{1.32}$ = 378.7 or <u>379 max. units allowed</u>

Be aware of Oxygen Toxicity Symptoms which is usually a burned out feeling in the chest or one can not take a deep breath without thinking your chest is dry and tight.

Do not confuse these symptoms with Oxy Poisoning Symptoms. i.e. refer to Section Two V.E.N.T.I.D. GUIDE.

U.P.T.D. TABLE

FORMULA = T(2PP-1)O.833

PPO^2 PO_2	Kp	PPO^2 PO_2	Kp	PPO^2 PO_2	Kp	PPO^2 PO_2	Kp	PPO^2 PO_2	Kp	PPO^2 PO_2	Kp	PPO^2 PO_2	Kp	PPO^2 PO_2	Kp	PPO^2 PO_2	Kp
0.50	0.00	0.78	0.61	1.06	1.10	1.34	1.54	1.62	1.96	1.90	2.36	2.18	2.74	2.46	3.12	2.74	3.49
0.51	0.03	0.79	0.63	1.07	1.11	1.35	1.56	1.63	1.97	1.91	2.37	2.19	2.76	2.47	3.13	2.75	3.51
0.52	0.05	0.80	0.65	1.08	1.13	1.36	1.57	1.64	1.99	1.92	2.39	2.20	2.77	2.48	3.14	2.76	3.52
0.53	0.08	0.81	0.67	1.09	1.14	1.37	1.59	1.65	2.00	1.93	2.40	2.21	2.78	2.49	3.16	2.77	3.53
0.54	0.10	0.82	0.69	1.10	1.16	1.38	1.60	1.66	2.01	1.94	2.42	2.22	2.80	2.50	3.17	2.78	3.54
0.55	0.13	0.83	0.70	1.11	1.18	1.39	1.62	1.67	2.03	1.95	2.43	2.23	2.81	2.51	3.18	2.79	3.56
0.56	0.16	0.84	0.72	1.12	1.19	1.40	1.63	1.68	2.04	1.96	2.44	2.24	2.83	2.52	3.20	2.80	3.57
0.57	0.18	0.85	0.74	1.13	1.21	1.41	1.65	1.69	2.06	1.97	2.46	2.25	2.84	2.53	3.21	2.81	3.58
0.58	0.21	0.86	0.76	1.14	1.22	1.42	1.66	1.70	2.07	1.98	2.47	2.26	2.85	2.54	3.23	2.82	3.60
0.59	0.23	0.87	0.78	1.15	1.24	1.43	1.68	1.71	2.08	1.99	2.49	2.27	2.87	2.55	3.24	2.83	3.61
0.60	0.26	0.88	0.79	1.16	1.26	1.44	1.69	1.72	2.10	2.00	2.50	2.28	2.88	2.56	3.25	2.84	3.62
0.61	0.29	0.89	0.81	1.17	1.27	1.45	1.71	1.73	2.12	2.01	2.51	2.29	2.90	2.57	3.27	2.85	3.64
0.62	0.30	0.90	0.83	1.18	1.29	1.46	1.72	1.74	2.13	2.02	2.53	2.30	2.91	2.58	3.28	2.86	3.65
0.63	0.32	0.91	0.85	1.19	1.30	1.47	1.74	1.75	2.15	2.03	2.54	2.31	2.92	2.59	3.30	2.87	3.66
0.64	0.34	0.92	0.86	1.20	1.32	1.48	1.75	1.76	2.16	2.04	2.56	2.32	2.94	2.60	3.31	2.88	3.67
0.65	0.37	0.93	0.88	1.21	1.34	1.49	1.77	1.77	2.18	2.05	2.57	2.33	2.95	2.61	3.32	2.89	3.69
0.66	0.39	0.94	0.90	1.22	1.35	1.50	1.78	1.78	2.19	2.06	2.58	2.34	2.96	2.62	3.34	2.90	3.70
0.67	0.41	0.95	0.92	1.23	1.37	1.51	1.80	1.79	2.21	2.07	2.60	2.35	2.98	2.63	3.35	2.91	3.71
0.68	0.43	0.96	0.93	1.24	1.38	1.52	1.81	1.80	2.22	2.08	2.61	2.36	2.00	2.64	3.36	2.92	3.72
0.69	0.45	0.97	0.95	1.25	1.40	1.53	1.83	1.81	2.23	2.09	2.63	2.37	3.00	2.65	3.38	2.93	3.74
0.70	0.47	0.98	0.97	1.26	1.42	1.54	1.84	1.82	2.25	2.10	2.64	2.38	3.01	2.66	3.39	2.94	3.75
0.71	0.49	0.99	0.98	1.27	1.43	1.55	1.86	1.83	2.26	2.11	2.65	2.39	3.03	2.67	3.40	2.95	3.76
0.72	0.51	1.00	1.00	1.28	1.45	1.56	1.87	1.84	2.28	2.12	2.67	2.40	3.04	2.68	3.41	2.96	3.77
0.73	0.52	1.01	1.02	1.29	1.46	1.57	1.89	1.85	2.29	2.13	2.68	2.41	3.05	2.69	3.43	2.97	3.78
0.74	0.54	1.02	1.03	1.30	1.48	1.58	1.90	1.86	2.30	2.14	2.69	2.42	3.07	2.70	3.44	2.98	3.80
0.75	0.56	1.03	1.05	1.31	1.50	1.59	1.92	1.87	2.32	2.15	2.70	2.43	3.08	2.71	3.45	2.99	3.81
0.76	0.59	1.04	1.06	1.32	1.51	1.60	1.93	1.88	2.33	2.16	2.72	2.44	3.09	2.72	3.47	3.00	3.82
0.77	0.60	1.05	1.08	1.33	1.53	1.61	1.94	1.89	2.35	2.17	2.73	2.45	3.11	2.73	3.48		

OXY MAKE UP IN THE BELL

The two main reasons for carrying oxy on the bell are:

a) To enable the Supervisor to keep up the O^2 content inside the bell and thus avoid costly flushing of He/O^2 mix.

b) To enable divers trapped inside a bell to have an efficient form of life support. (Obviously the prime reason in an emergency). To remove the oxy from the bell is to place lives in jeopardy.

A diver in the bell will consume .5 LPM of oxy = 30 LP hour. Therefore oxy make up dumps must be made at the following rates:

1 MAN	30 LIT.	EVERY 60 MIN.
2 MEN	30 LIT.	EVERY 30 MIN.
3 MEN	30 LIT.	EVERY 20 MIN.

If divers are trapped in bell they should remove wet suits, etc. and get into survival packs, don emergency CO^2 re-breathers. (The action of breathing through the Sodasorb itself creates heat). And monitor oxy and CO^2 levels.

Comex's patented system is almost foolproof and fast to use. Ambient pressure is always compensated for and exactly correct amount of oxy is dumped into bell.

For systems using a simple flowmeter in bell the diver has to time his dump to his flow. After opening the flow valve do not remove hand from valve until dump is complete and valve is closed.

BAIL-OUT BOTTLES AND BELL UMBILICALS

In a lot of areas of the world, there is no restriction on the length of a divers umbilical. However, the gas requirements of the bailout is a self regulating measure.

The minimum requirement for divers bailout gas is 40 LPM for every 10M of umbilical or 1.5 Ft^3 for every 33Ft. And believe me in an emergency you will need all of it.

Example

We are diving at 120 M with a 40 M umbilical.

$\frac{40\ M}{10\ M} = 4$

4 x 40 LPM x 13 B ABS = 2080 LITRES 2.08 M^3

50 Ft^3 BB = 1.4M^3 7 litre bottle

70 Ft^3 BB = 1.9 M^3 9.5 litre bottle

80 Ft^3 BB = 2.23 M^3 11.15 litre bottle

90 Ft^3 BB = 2.54 M^3 13 litre bottle

At first glance it looks like an 80 Ft^3 scuba bottle will suffice however.

We have 200 B bottle charge minus 13 B ambient press. and 10 B regulator = 177 B

177 B x 11.15 litres = 2035 litres = 2.035 M^3
just short.

How long does the diver get before running out of gas?

40 LPM x 13 B ABS = 520 LPM

$\frac{2035\ \text{litres}}{520}$ = 3.9 min.

Imperial Example

Diving at 279 Ft. 8.45 ATS gauge 9.45 ATS ABS. We have a 100 Ft. umbilical.

$\frac{100\ Ft}{33\ Ft.} = 3.03$

1.5 Ft^3/.min. x 3.03 x 9.45 ATS ABS = 42.9 Ft^3 of gas required.

If we take a 70Ft^3 BB at 3000 psi

3000 psi
- 138.9 psi ambient
150 psi regulator
2711.1 psi

$\frac{2711.1}{3000}$ x 70 Ft^3 = 63.25 Ft^3 ok.

How long will his gas last?

1.5 Ft^3/min x 9.45 ATS ABS = 14.17 Ft^3/min.

$\frac{63.25\ Ft^3}{14.17\ Ft^3}$ = 4.46 min.

It is a divers responsibility to make sure he has enough gas to return to the bell safely.

LIMITS OF A DIVERS SURVIVAL IN A BELL

Assuming for this example two divers are stuck in a bell after cable & umbilical have been lost. Someone took the oxy. off the bell? and nobody charged the bottles? with no means of rejuvenating their environment how long can they survive? We will assume .14 PPO^2 their lowest level. As at this PPO^2 things are getting critical. (What a team) Depth is 121 M, PPO^2 at W.D. was .6 (Long version first) Bell is 3 M^3.

121 M = 131 M. ABS. =13.1 B. ABS. @ .6 PPO^2

BOTT. MIX = $\frac{600 \text{ MBS}}{131 \text{ M}}$ = 4.6% also .6 - .14 = .46 PPO^2 usable

3 M^3 = 3000 litres x 13.1 B. ABS = 39,300 litres

of which $\frac{4.6 \times 39{,}300}{100}$ = 1808 litres are oxy.

.46 of this = .46 x 1808 = 831.68 litres usable

Diver uses .5 LPM of oxy x 2 men = 1 LPM

$\frac{831.68 \text{ litres}}{60}$ = 13.86 hrs or 13 hrs 51 min.

Another Method (Short Version:)

Bell is 3 M^3	=	3000 litres
.6 x 3000	=	1800 litres of oxy present
.46 x 1800	=	828 litres usable
$\frac{828}{60 \text{ min}}$	=	13.8 hrs or 13 hrs 48 min.

LIFTING CALCULATIONS

The weight of fresh water.

1000 kg for 1 M^3
= 1000 kg for 1000 litres
= 1 kg/1 litre

or 62.5 lbs Ft^3 = 10 lbs gallon

We can therefore work out how much we can lift with gallon or litre drums.

The weight of salt water.

1030 kg for 1M^3

1030 kg for 1000 litres

1.03 kg/litre

or 64.38 lbs Ft^3 = 10.3 lbs gallon

Example

Concrete block displacing .4M^3 weighs 960 kg.

water displaced = 412 kg

.4 M^3 x 1030 kg

960 kg - 412 kg = 548 kg negatively 1 buoyant

Therefore we will need a 600 kg lift bag to lift it minimum.

A wooden shattering with wood density of 600 kg/M^3

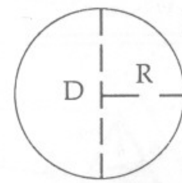
Vol of shattering 7 M^3 x .2 M^3 x .2 M^3 = .28 M^3

.28M^3 x 600 kg	=	168 kg weight of shattering
.28M^3 x 1030 kg M^3	=	280 kg water displaced.

= 112 kg positively buoyant

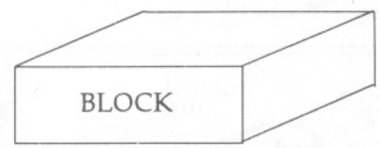
SOME BASIC MATHS

π = 22/7 or 3.142
A = 3.142 x R x R
C = 3.142 x D
D = 2 x R
R = D/2

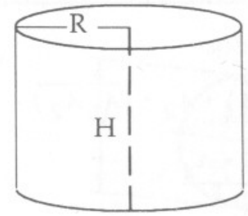


CIRCLE

V = L x B x H



A = 6.283 x R x H + 6.283 x R x R
V = 3.142 x R^2 x H



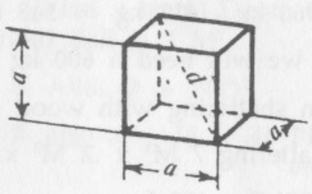
CYLINDER

cube

$V = a^3$

$A_o = 6a^2$

$d = \sqrt{3}\,a$

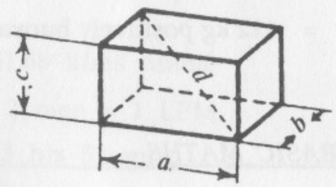


cuboid

$V = a\,b\,c$

$A_o = 2(ab + ac + bc)$

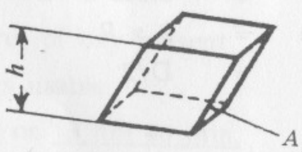
$d = \sqrt{a^2 + b^2 + c^2}$



parallelpiped

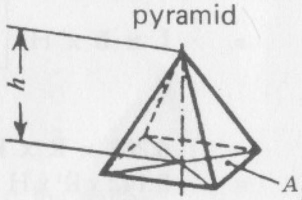
$V = A_1 h$

(Cavaliert principle)



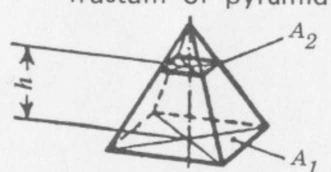
pyramid

$$V = \frac{A_1 h}{3}$$



frustum of pyramid

$$V = \frac{h}{3}\left(A_1 + A_2 + \sqrt{A_1 A_2}\right) = h\frac{A_1 + A_2}{2}$$

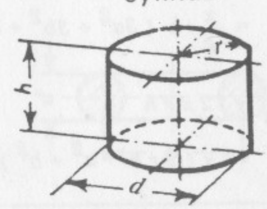


cylinder

$$V = \frac{x}{4} d^2 h$$

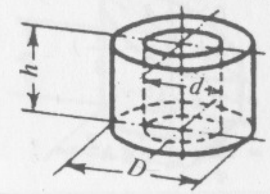
$A_m = 2\,x\,r\,h$

$A_o = 2\,x\,r\,(r + h)$



hollow cylinder

$$V = \frac{x}{4} h\,(D^2 - d^2)$$



cone

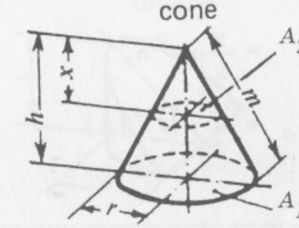
$$V = \frac{x}{3} r^2 h$$

$A_m = x\,r\,m$

$A_o = x\,r\,(r + m)$

$m = \sqrt{h^2 + r^2}$

$A_2 : A_1 = x^2 : h^2$

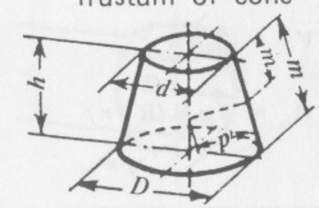


frustum of cone

$$V = \frac{x}{12} h\,(D^2 + Dd + d)$$

$$A_m = \frac{x}{2} m\,(D + d) = 2\,x\,p\,h$$

$$m = \sqrt{\left(\frac{D - d}{2}\right)^2 + h^2}$$

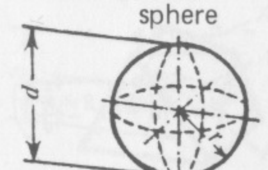


sphere

$$V = \frac{4}{3} x\,r^3 = \frac{1}{6} x\,d^3$$

$= 4 \cdot 189\,r^2$

$A_o = 4\,x\,r^2 = x\,d^2$



SOLID BODY FORMULAS

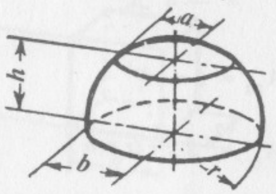
SOLID BODIES — C3

zone of a sphere

$V = \frac{\pi}{6}\, h\,(3a^2 + 3b^2 + h^2)$

$A_m = 2\pi r h$

$A_o = \pi\,(2rh + a^2 + b^2)$



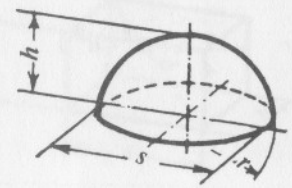
segment of a sphere

$V = \frac{\pi}{6}\, h\,(\frac{3}{4} s^2 + h^2)$

$= \pi h^2\,(r - \frac{h}{3})$

$A_m = 2\pi r h$

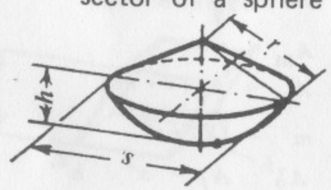
$= \frac{\pi}{4}\,(s^2 + 4h^2)$



sector of a sphere

$V = \frac{2}{3}\pi r^2 h$

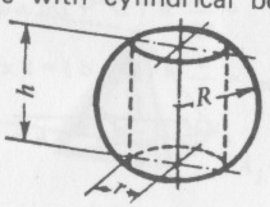
$A_o = \frac{\pi}{2}\, r\,(4h + s)$



sphere with cylindrical boring

$V = \frac{\pi}{6} h^3$

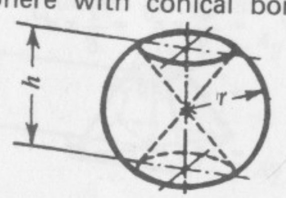
$A_o = 2\pi h\,(R + r)$



sphere with conical boring

$V = \frac{2}{3}\pi r^2 h$

$A_o = 2\pi r\left(h + \sqrt{r^2 - \frac{h^2}{4}}\right)$



SOLID BODIES — C4

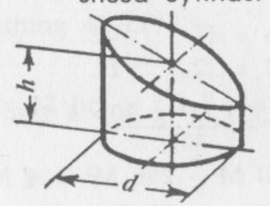
torus

$V = \frac{\pi^2}{4} D d^2$

$A_o = \pi^2 D d$

sliced cylinder

$V = \frac{\pi}{4} d^2 h$

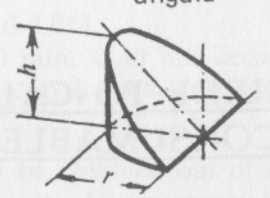


ungula

$V = \frac{2}{3} r^2 h$

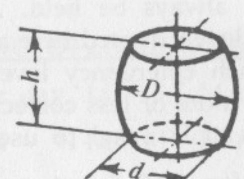
$A_m = 2 r h$

$A_o = A_m + \frac{\pi}{2} r^2 + \frac{\pi}{2} r \sqrt{r^2 + h^2}$



barrel

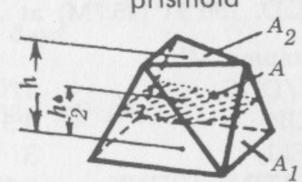
$V = \frac{\pi}{12}\, h\,(2D^2 + d^2)$



prismoid

$V = \frac{h}{6}\,(A_1 + A_2 + 4A)$

This formula may be used for calculations invol– ving solids shown in fig. C1. . . C3 and thus spheres and parts of spheres



VOLUME AND TEMPERATURE CALCULATIONS

Example

For these calculations we have to use Absolute Temperature.

C	+	273 KELVIN
F	+	460 RANKINE

i.e. We wish to reduce the temp. of the DDC from 34^{0}C to 30^{0}C. What volume of gas will we add to maintain a constant press.?

DDC is now at 15 B ABS 140M gauge
DDC is 20 M^3 volume

Temp 1 = 34^{0}C + 273 K = 307 K
2 = 30^{0}C + 273 K = 303 K

$$\frac{V1}{V2} = \frac{T1}{T2} \qquad V2 = \frac{V1 \times T2}{T1}$$

$$= \frac{300\ M^3 \times 303}{307} = 296\ M^3$$

300 M^3 - 296 M^3 = 4 M^3 to make up.

$$\text{DDC Depth Change} = \frac{\text{Absolute Depth} \times \text{Temp Change}}{\text{ABS. TEMP.}}$$

A GUIDE TO CALCULATING GAS AND CONSUMABLES FOR A SAT JOB.

NOTE

There are usually laid down procedures for the emergency levels of gas which should always be held. Any laid down procedures should be followed. The levels quoted here are what I adhered to on my own behalf. Before any such emergency levels were stipulated, my experience has found it to be more or less correct. However in areas under N. Sea Rules & Regulations, it is usual to use the recommended A.O.D.C. levels.

Gas required for a 15 day 4 man Sat.

W.D.215 Ft (65.5M) at .6 PPO^2 8%
L.D. 150 Ft (45.7M) at .4 PPO^2 7%

System Volume M^3

M/DDC	17
TUP	4.3
BELL	3
MATING TRUNK	0.226
M/LOCK	0.056
	24.582 = 25 M^3 SYSTEM.

Emergency Level:

1) One 12 hr lockout
2) 1 press to W.D. whole system
3) Enough oxy for decompression
4) Therapeutic bibs gas at recommended levels.

Co-efficient for Calculating Oxy Consumption:

0 - 50 M	K =	1.8
50 M - 100 M	K =	2.4
100 M - 150 M	K =	2.8
150 M - 200 M	K =	3.0
200 M - 250 M	K =	3.3
250 M - 300 M	K =	3.5

Emergency Level. Assuming diver breathing 45 LPM.

A) 12 hr lockout
.045 M^3/min x 60 min x 12 hrs x 7.5 B ABS
= 243 M^3 (8%)

B) Press to W.D.
25 M^3 x 6.5 B. Gauge = 162 M^3 (He) or (7%)

C) Oxy for decomp.
Divers consumption is .5 LPM
.5 LPM x 4 divers x 60 min. x 40 hrs decomp = 4.8
.6 PPO^2 x 25M^3 x (K = 2.4) + 4.8 net. consumption
= 172.8 M^3 (Oxy)

When levels of usable gas i.e. that can be obtained out of quads reach above stated levels, diving stops. One must add emergency levels of gas plus amount calculated for general consumption to obtain total amount to be ordered.

GENERAL CONSUMPTION ASSUMING OPEN CIRCUIT DIVING

15 Sat, 4 men, 2 x 10 hr lockouts per day, LD 45.7 M, WD 65.5 M.

A) Press. to L.D. 4.57 B. Gauge = 114.25 M^3 (He) or 7%
25 M^3 x 4.57 B Gauge

B) 20 hrs Diving per day
.045 M^3/min x 60 min = 6115.5 M^3 (8%)
x 20 hrs x 7.55B ABS x 15 days

c) 10 med lock transfers p/day
.056 M^3 x 10 x 15 days = 38.3 M^3 (7%)
x 4.57 B Gauge

D) 2 tansfers per day of TUP
trunk to surface = 30.98 M^3 (7%)
30 X .226 M^3 X 4.57 B G

E) 2 transfer p/day of bell
from L.D. to W.D. = 178.2 = 180 M^3 (7%)

F) Approx 4 toilets flushes p/day
.030 M^3 x 15 days = 8.25 M^3 (7%)
x 4 times x 4.57 B G

G) Bellmans oxy cons.
.0005 M^3/min x 60 min = 67.95 M^3. (oxy)
x 20 hrs x 15 days x 7.55 B ABS

H) 2 divers in DDC 20 hrs p/day = 135.9 M^3 oxy

I) 4 divers in DDC 4 hrs p/day = 40.10 M^3 oxy

J) Oxy for decomp = 172.8 M^3 oxy
add 5 - 10% for leaks

RECOMMENDED LEVELS OF THERAPEUTIC GAS, MINIMUM QUANTITIES IN M^3

AIR/NITROX BOUNCE

MAX DEPTH	OXY	50/50	20/80
50 M	90 M^3	90 M^3	90 M^3

AIR OR NITROX SAT

MAX DEPTH	
MAX DEPTH 45 M	90 M^3

HELIOX SAT	OXY	50/50	20/80	10/90	5/95
40 M	90 M^3	90			
110 M	90	90	220		
210 M	90	90	220	400	
360 M	90	90	220	400	650

All Mixes Heliox. Calibration gas to suit. 2 bottles.

SODASORB 6 kg p/man, p/day
= 6 x 4 x 15 = 360 kg
add 10% for bell = 400 kg
calculate reclaim if using ?
400 kg

1 drum Purafil

Consider if there will be surface gas diving and calculate accordingly. Use 45 LPM for metabolic consumption by diver.

If using gas reclaim simply reduce divers gas consumption by % of reclaim expected.

GAS USAGE CONT'D

GASMIX OXY/HE	THERAPEUTIC DEPTH OF USE
4/6	265 M - 415 M
6/94	175 M - 280 M
7/93	150 M - 275 M
8/92	130 M - 250 M
9/91	115 M - 220 M
11/89	90 M - 170 M
12/88	85 M - 170 M
13/87	75 M - 155 M
14/86	70 M - 150 M
15/85	65 M - 135 M
16/84	60 M - 130 M
17/83	55 M - 120 M
18/82	50 M - 115 M
19/81	45 M - 110 M

In general try to keep therapeutic mix P.P. of oxy from 1.3 to 2.0.

0-100 100-220 220-410 410-860

CHART GAS USAGE	OXY	50/50	20/80	10/90	5/95	3/97	2/98
BOTTOM MIX	-----	-----	0 - 30M	30 - 70	70 - 125	125 - 260	260 - 390
EMERGENCY PRESSURIZATION	-----	-----	0 - 30M	30 - 70	70 - 125	125 - 260	260 - 390
EMERGENCY BREATHING GAS	-----	-----	0 - 30M	30 - 70	70 - 125	125 - 260	260 - 390
THERAPEUTIC	0 - 18M	18 - 45M	45 - 115	115 - 200	200 - 350	350 - 450	-----