

SUBSCRIPT

The newsletter of the BT Research Sub-Aqua Club, July 1998



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Further information:

Internet WWW

From inside BT:

<http://webservice.bt-sys.bt.co.uk/httpd/docs/BTRSAC/>

From outside BT:

<http://www.geocities.com/Colosseum/2473/>

Adline (01473) 644474

Wales May 98

David Garratt

Before I begin I must take this opportunity to thank Andy for organizing the trip. (WELL DONE ANDY , IT WAS A WELL ORGANIZED TRIP, AND GOOD COMPANY.) We started the evening off all meeting down at St. David's dive centre, having made our own way down on Friday afternoon.

A meal was first on the list followed closely by a glass of beer or other refreshment. Our hosts for the weekend were Clive and Cindy, Clive was the skipper and Cindy was wonder woman not only running the b&b almost single handed she also had time to drop off tanks of air and help coordinate the St. David's R.N.L.I. Clive also had a small part to play he is the lifeboat's coxswain .The weekend was the first time I had been on a trip with both B.S.A.C and P.A.D.I divers.

So I was sure there was going to be some friendly rivalry, I couldn't have been more wrong as it turned out the PADI divers were the same as us, no one had two heads or spoke in a demonic tongue, actually we got on very well.

Saturday morning was our first day out ,we loaded Clive's pickup with our gear and made our way down to the boat ,which was moored near to the life boat station in a cove at the bottom of a steep cliff .But no need to worry there were steps down and a winch for the gear.

After transferring the gear from the pickup to the winch, we had to then load it on a rib and finally on the dive boat, .this task was made a bit easier as we left most of our gear onboard each day.

VIZ

Our first dive on Saturday was a rocky outcrop called the Mare this was to be a scenic dive but viz was clouded by sand particles and spoilt the view but I suppose we got wet, tested ourselves and gear so it wasn't a total loss.

The second dive that day was a reef off Green-scar again a scenic dive the viz was a bit better, there were plenty of starfish, deadman's fingers, anemones, and some small ***????

Sunday morning again no rush to get going but eventually we set off ,unfortunately Mick Morley had to pull out due to an ear problem, he decided to take in

the beautiful Welsh scenery and take a walk along the coastline.

Clive took us to a rocky outcrop off Green-scar, this again was to be a scenic dive but unfortunately the wind had picked up and was stiffing up the water, as we had an odd number I decided not to dive and sat this one out I was not disappointed as all the divers said viz was not good.

The fourth dive in the afternoon was a small steam tug called the St. George it was sent with two other tugs to rescue a sailing boat which had ran aground unfortunately after it pulled the boat free it had engine problems got into trouble and sank without loss, and became a dive site.

My buddy for this dive was Daren Wood ,we dropped down the shot line which brought us onto the boiler after a brief look around this we set off around the rest of the wreck ,there were large lumps of rusting metal but no brass to be seen anywhere, fish life was minimal ,but still a pleasant dive.

S.O.S.

When we got back to the life boat station there was a real drama unfolding men and woman of the R.N.L.I. running to their stations and getting ready to launch the life boat.

As our skipper was also the coxswain, we had to wait a while to find out what was going on but we did not mind as this was the first time most of us had seen a lifeboat launch for real. These men and woman do this many times a year free of charge so next time you pass a collecting box don't be shy put in a few pence, it could be you needing assistance next time.

Monday morning dive was again off Green-scar the viz was good, lady luck seemed to be on our side for once. I buddied Andy Saunders and what a good dive we had we saw wrass, crab, lobster, dog fish, and even a large conger-eel, all the divers in the group had an equally good dive and came up with smiles and stories to tell, it goes to show that with a bit of viz British waters can be fun to dive

Monday afternoon's dive was to be the last dive of the weekend Clive told us it was a drift dive near to Ramsey sound, he gave us a brief outline on what to expect, the nearer the rock face the shallower and slower the drift would be, we were dropped off in pairs my buddy was Andy Wright, we decided that I should have the s.m.b. and Andy would hold onto the line as a safety precaution. We started the dive close to

the rock face so not to be in too much of a current, as we settled into the drift we descended to around 10 metres the current picked up and the dive had really begun.

The viz again was not too good but we were enjoying our first real drift and as they say we went with the flow, we told the dive marshal we would try for 30 mins so we knew we had plenty of time and hung onto the s.m.b. and used our time to the full, when we surfaced you should have seen Andy's face he was grinning from ear to ear so I think he enjoyed his dive.

NB. Highlights of the holiday

- Mike Worsley with the help of Steve Webb turning a dry suit into a wet suit.
- Steve and Kirsty doing a fine job of logging each others dives every night.
- All concerned for just being there.

Editor's bit

Phil Sheppard



Thanks to everybody continuing to contribute - there never appears to be a shortage of material! This issue is even larger than usual partly because I let a bit more time go between this and the previous issue (that's a round about way of saying I'm late!). Even so there are two articles

held over for next time already. Also next issue there will I hope be an article, with pictures, about the excellent disabled sports event that the club supported with try dives at Bury St Edmonds. I only wish it was all happy news but the tragic death of Ewart whilst diving in May was a shock to all who knew him. Whilst Suzanne and I didn't know Ewart well we did spend a very enjoyable club diving holiday in Northern Ireland with him and in particular have great memories of running with him around Rathlin island - or more precisely running well behind him since he had run all the way across the island and back by the time we got halfway!

Treasurer post available!

Daren Wood - (Outgoing) BTRSAC Treasurer

Sad to say, come the AGM in November, I will have to stand down as Treasurer having served the full term permitted by our constitution. Whilst the AGM is some 6 months away, I need to find a potential

successor with a view to preparing him, or her, to take over from me (subject to membership approval at the AGM).

Can I ask all of you who are BT employees to consider whether you would like to take on this role - even if you've only just joined the club ? Sorry if you're not a BT employee but our affiliation with the RSSC means that the posts of Chairman, Secretary and Treasurer must be held by BT employees only !

You can find out more about the post by looking on the BT intranet at <http://www.mobile-systems.bt.co.uk/users/wooddv/btrsac/treasure.htm> or give me a call on 605406.

This post **MUST** be filled next year and so I would like to encourage you to consider this post seriously - otherwise I may have to lean on someone ! As a word of encouragement, I would say that whilst the role of Treasurer is a lot of work (most of which no-one, except maybe the auditor, sees) I have found it personally rewarding and have gained a lot of new experience - particularly in how to run a sizeable organisation as this club.

Thanks, and I look forward to a flood of enquiries !!!!

EXCLUSIVE - Divers can walk on water!



Caption Competition

Ed

A quality bottle of wine to the best caption(s) for either of the two pictures on this page (please say which Figure your caption is for).



Figure 1 ???

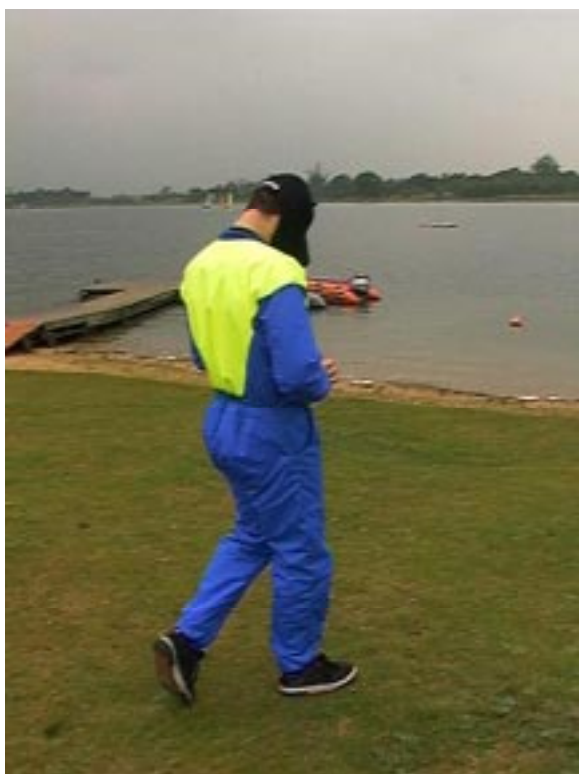


Figure 2 ???

Baltic diving?

Dave Lock



Does anyone else fancy the Baltic next year? I'm inspired (when I get the chance) by the article in Diver this month. I know some sites were visited a couple of years ago by some Northern UK Wreckheads, but there must be plenty still to find. I'm willing to set something up but I need early commitment and deposits! I like the idea of a liveboard as we don't have to find accommodation plus we can get further out. I guess there won't be enough interest from our club so I'll leave it until early August before I advertise elsewhere. I expect people who want to come to have experience to 35 metres in the sea, be dived up and to have the relevant equipment to undertake decompression diving. After the recent spate of incidents this is mandatory.

Buddy Inspiration Rebreather

Dave Lock

This article has been prompted by the people in the club whom I might have to dive with in the near future when I'm using my new toy. It will not describe how a closed circuit rebreather works, for that please look at Subscript February 1997 - or thereabouts. It will be concerned with the specific area of buddy checks and information the dive marshal is likely to need.

Components of the System

The yellow backpack contains the gas source, the scrubber unit and 2 reducing valves, normal first stages. In front of this sit a pair of wings which are used to adjust buoyancy. These are controlled by an Autoair or a normal AP200 inflator as a lot of you have on your BCDs. The front of the unit looks cluttered but is quite comfortable and easy to use. Over each shoulder is a breathing bag with a hose connected to the mouthpiece. There are pressure gauges for diluent and oxygen cylinders plus 2 controllers which indicate the partial pressure of the oxygen in the breathing loop.

You should note that the counterlungs form a loop with the divers lungs, hence if the mouthpiece drops out in the open position they will collapse and there will be a loss of buoyancy.

Buddy Check

This will follow the same format Buoyancy, Releases, Air (BRA).

Buoyancy - this is my direct feed for my drysuit and the dump valve, the controls for the wing will be explained in the same way.

Releases - there is no difference in the releases of a normal wings style harness apart from a crutch strap, there's no truth that this prevents a hernia.

Air - normally I will be breathing from the large hoses but if I have a problem I can't solve I will breathe from a normal second stage which is strung around my neck. This is my buddies source of emergency gas but as it is fed from a 3 litre cylinder we will have to ascend immediately if the octopus is used. The pressure gauges should be regarded as normal i.e. 50 bar is the reserve.

Marshal Information

I personally would add the amount of scrubber life left as information supplied to the marshal. When diving with an open circuit buddy, their gas supply is your main limit so there is no need for more information. When 2 closed circuit divers dive together an ETA at the surface would be necessary but I believe this is a question the marshal should be asking any open circuit divers.

Summary

I believe this is the minimum that a buddy should know about a closed circuit diver. This is how to give buoyancy, how to ditch the equipment and how to get to an alternative air source. I will put together a more comprehensive description of the oxygen controllers and how to interpret them in the near future. If anyone has any questions about the unit please do not hesitate to contact me.

NB a full colour version will appear in the next issue of Subscript.

POINT MURAT NAVY PIER, EXMOUTH, WA [Western Australia - Ed]

Richard Lee; itinerant Chinaman

In the 1960s, at the height of the Cold War, the US Navy built five Very Low Frequency radio stations around the world to talk to their Polaris submarines. The most powerful of these was built at Exmouth, 1500km north of Perth, Western Australia at the tip of North West Cape. It is the only one capable of reaching a submerged nuclear submarine anywhere in the world. The 12 towers, of which the central one, at 388m is the tallest man-made structure in the Southern Hemisphere, dominate the harsh landscape of Cape Range National Park which forms the western side of Exmouth Peninsula.

There's nothing here. No water or trees. Just bush, desert, kangaroos and emus.

But Ningaloo, the world's largest Fringing Reef spans 250 km from the Muiron Islands to well past Coral Bay which is Snorkeller's Paradise. The coral spawns here in Mar and leads, two weeks later to the arrival of the Whale Sharks.

Paul & Tracey Skirrow can advise on these and Mantas and Dugongs and Turtles and Dolphins and other creatures which clutter up the scenery at Ningaloo ... but that's another story.

To serve the Naval Base which serves the Communication Station, the US Navy built a pier just north of Exmouth, which also grew up to serve the Naval Base. It's quite a non-descript structure of steel and wood but designed to withstand 10m cyclone waves.

But if you asked me what are the best things Exmouth has to offer, I would choose the Whale Sharks in season and diving the Navy Pier. It regularly appears in lists of "top 10 dives" for Australia and the world. Even Divemasters at Exmouth Diving Centre who dive it nearly every other day look forward to diving there. Last month, one paying customer dived it 5 times in the week he was here.

What makes this area, about the size of the 50m swimming pool in Exmouth, with often poor visibility so special?

The answer is fish, fish and more fish and fishy things.

A scientific survey in 1996 counted more than 150 species; some of which unique to this location. Do you remember large illustrated encyclopedias from your childhood, with double centrefold colour spreads of myriad species in unlikely juxtaposition? Well, that's what diving the pier is like including the unlikely juxtaposition in close proximity to each other.

Large Estuarine cod vie with our resident 2m Queensland grouper for attention. Don't crowd him! Parrot fish, butterfly fish, six banded angels, scribbled angels, threadfin pearl perch, flutemouthes, batfish, coral trout, many pairs of Moorish idols together the pylons are alive with fish and invertebrate life.

Hermit crabs and octopus need sharp eyes to find as are some of the nastier and uglier inmates; frogfish, crocodile fish and highly poisonous and almost invisible stonefish.

Black sailfin catfish use the pier as a nursery; shepherding their little ones in and out of old tins and holes in the rocks. A pod of dolphins visits quiet often and if you are very lucky, they will come up to you underwater. Like Divemaster trainees, they prefer pretty ladies.

At the north pylon, is a neat pile of tyres, usually filled and surrounded by yellow glass fish. Glassfish must have a special relation with tasselled wobbegongs. Swimming through a cloud of jewel like creatures, they often part to reveal these lazy sharks lying on the bottom looking like dirty white moth eaten rugs. Little shrimps and lobsters hide there; luminescent in the light of your torch. Several types of nudibranchs are also best seen at night.

At several places, packs of hunting lionfish do their graceful dance, herding more glassfish especially at night. Look under and in any rocks, holes and man made junk for moray eels. One rock has at least four different types in different sizes and colours!

You'll rush straight to the fish identification books after this dive.

For me, the best part of the dive is doing a safety stop under the pier surrounded by circling schools of trevally, jacks and chevron barracuda, near enough to touch. Make sure your Divemaster knows the exact time of slack water is so you can do this part of the dive without holding on to anything. Make yourself dizzy watching them go round.

An easy shallow dive of 12m maximum. Ask to stay longer than the usual 50 min or better still, do another one. I can't show someone round my favourite attractions in one dive without rushing.

Diving the Navy Pier at Point Murat, requires permission from the Royal Australian Navy usually organised through Exmouth Diving Centre. Booking recommended.

See their web site at www.exmouthdiving.com.au for other attractions and pretty pictures.

Want to dive the Red Sea in November?

Mick Morley

It's no good, I just cannot survive without my annual injection of coral diving.

I have made a few calls about Seychelles, Maldives, Thailand and the Caymans. Although much lower cost than they used to be, it still is about ?1k minimum and takes at least 10 days if you want to be awake whilst you are there. So this suggests that the best value is the Red Sea again (I dont think I could ever get fed up with it anyway).

Last time we had a number of non-divers who came to soak up a few rays (sunshine, not Manta) and do some snorkelling. This suggests a hotel with a pool rather than a safari in a tent. It is also better if there is a bit of culture and a few shops to browse rather than being in the middle of the desert.

I am therefore thinking along the lines of a medium quality hotel (one level up from last time); in Naama Bay, Sharm; diving with RedSea College; around 14th November for one week. This will probably be £500-£520 for B&B and diving. Transport to airport, insurance and evening meals normally adds about £70 to that.

Anyone interested in coming???

Ewart Lowe - the facts as we know them

Jonathan Legh-Smith

The following is a summary of the facts, as we know them, surrounding the tragic death of Ewart Lowe on the 22nd May this year. It also provides a summary of

the action taken by the Committee in response to the incident. It is worth noting up front that the excerpt from Howard Westlake's email is based on Rob Bailey's - Ewart's buddy - account of the build up to the incident; the Committee does not have any additional information about the cause of the incident as Rob did not see, and does not know why, Ewart ascended to the surface.

Neither Ewart or his buddy on the dive, Rob Bailey, were members of BTRSAC although both had been in the past. Ewart had in fact been a long-time member of the club and had held the post of Diving Officer; he had not re-joined this year as he was planning to take a year off from diving. A consequence of this was that he was not a member of BSAC either.

The following excerpt from Howard Westlake's original email about the incident provides background information leading surrounding the incident.

From: Westlake,HJ,NAT22,WESTLAHJ M
To: btrsac
Subject: Ewart Lowe
Date: 27 May 1998 14:41

Ladies and gents

I'm sure that by now you will be aware of the diving incident off France last weekend and the tragic loss of Ewart Lowe. Ewart was a past member of this club and a good friend to many of us. His loss is deeply felt. I guess as time progresses, we will find out more about the circumstances surrounding Ewart's death. The press reports are varied and unreliable and I give the following as the best information available so far... The trip was a dive charter out of Weymouth. 10 Divers made up the party, the majority being members of St Ives branch. The dive was the first of several planned for that weekend and took place on Friday 22 May around 2:00pm. The wreck was in a max depth of 42m and stood some 6-8m high. Underwater Viz was around 3-4m and the tide was at slack. It would appear that Ewart made a rapid ascent from around 35m around 10mins into the dive, following a normal descent. It is not clear at this stage what prompted the ascent. The max depth up to this point was 37m. It would appear that Ewart became unconscious at the surface. Despite attempts of others in the party to revive Ewart and the efforts of the French rescue services paramedics, Ewart did not regain consciousness.

A post mortem is planned although at time of writing it is not known when that will take place. There should

also be an examination of the equipment although it is not known if the French authorities have released the equipment yet. Consequently the cause of the accident is still a matter of speculation and, unless there is definitive evidence of what happened, is likely to remain so.

As far as action by the Committee goes, an emergency meeting was held on the 29th May to bring everybody up to speed and to consolidate the decisions taken so far. The main decision was that, since Ewart was no longer a member of the Club and it was not a Club dive, we should not get formally involved in dealing with the situation. The principal point of contact in BT was, and is, Ewart's manager Ian Hawker. Members of the Club did offer assistance to Ian and personal support to Ian Hawker. Recognition is due to Roy Lobbett and Howard Westlake in particular.

Members of the Club attended the Funeral in Bristol and Dave Lock also sent a letter of condolence to the family on behalf of the Club. A Memorial service was also held at the BT Labs and Martlesham Heath on the 22nd July to which all members of the Club were invited.

Speculation aside, if any member of the Club feels they would like to discuss the incident, in terms of implications for personal risk for example, please approach any member of the Committee or Club Instructor. The personal impact of this kind of incident sometimes only becomes apparent over time - BT provides a Counselling service that in this instance is available to all members of this Club. Contact Carol Dawson via 0800 780784.

The third and final part of the technical serial from John Cook for all you techies out there! Ed.

The finite compressibility of gasses and its impact on the mixing of Nitrox - part 3

John Cook

5. Interpolating van der Waals constants

In principle the solutions p_{Vvdw} and P_{vdw} can be used to provide input to the molar density mixing equation and interpret its output, as for the combined gas law. However there is a problem. The van der Waals constants are only known for *pure* gases. Both the initial content and of course the final content of the cylinder are likely to be gas *mixtures*.

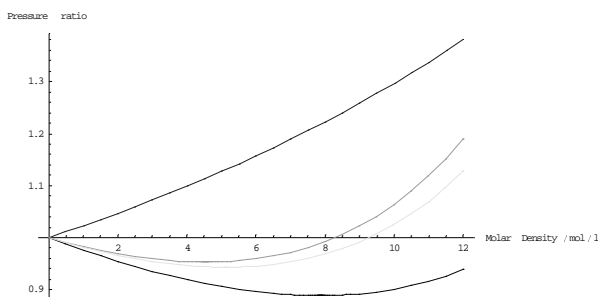
This problem must be solved by interpolating the values for the components of the gas mixture involved. The accepted method seems to be to use the linear interpolation of the square roots of the constants for the constituent gases.

$$\text{interprules} = \left\{ a \rightarrow \left(fO2 \sqrt{a / . Orules} + (1 - fO2) \sqrt{a / . Nrules} \right)^2, \right. \\ \left. b \rightarrow \left(fO2 \sqrt{b / . Orules} + (1 - fO2) \sqrt{b / . Nrules} \right)^2 \right\};$$

Using this method gives the following as estimates for the constants for air:

$$\text{airrules} = \text{interprules} / . fO2 \rightarrow 0.208 \quad \left\{ a \rightarrow \frac{1.40207 \text{ Bar Liter}^2}{\text{Mole}^2}, b \rightarrow \frac{0.0375195 \text{ Liter}}{\text{Mole}} \right\}$$

The results of this interpolation when plotted suggest that air will behave similarly to Nitrogen, with a slight bias towards the Oxygen curve, as might be expected. The air curve is shown in yellow.



In practise, at least for Nitrox mixtures, it has been found that simple linear interpolation of the constants gives almost identical results.

5.1 Mixing using van der Waals equation

All the components are in place now to use van der Waals equation for mixing calculations. The process will be illustrated by example. Suppose that a partly used cylinder of WP 232 bar contains EANX21 at 30 bar, and it is desired to fill it and bring the content up to a mix of EANX40. This can be described with the definitions:

fP = 232 Bar;
iP = 30 Bar;
ifO2 = 0.21;
ffO2 = 0.40;

Step 1. Use the initial mix fraction, **ifO2**, to derive a van der Waals constant pair for this mix using the interpolation equation:

$$\mathbf{irules} = \mathbf{interprules} / . \mathbf{fO2} \rightarrow \mathbf{ifO2} \quad \left\{ a \rightarrow \frac{1.40201 \text{ Bar Liter}^2}{\text{Mole}^2}, b \rightarrow \frac{0.0375045 \text{ Liter}}{\text{Mole}} \right\}$$

Step 2. Use these rules on the solution for **npVvdw** with the known initial pressure to compute the initial molar density, **inpV**.

$$\mathbf{inpVvdw} = \mathbf{PowerExpand}[\mathbf{npVvdw} / . \mathbf{irules} / . \mathbf{Rrule} / . \mathbf{temprule} / . \mathbf{P} \rightarrow \mathbf{iP}] \quad \frac{1.26034 \text{ Mole}}{\text{Liter}}$$

Step 3. Use the desired final mix fraction, **ffO2**, to derive a van der Waals constant pair for this mix.

$$\mathbf{frules} = \mathbf{interprules} / . \mathbf{fO2} \rightarrow \mathbf{ffO2} \quad \left\{ a \rightarrow \frac{1.39622 \text{ Bar Liter}^2}{\text{Mole}^2}, b \rightarrow \frac{0.0360896 \text{ Liter}}{\text{Mole}} \right\}$$

Step 4. Use these rules on the solution for **npVvdw** with the target working pressure to compute the target molar density, **fnpV**.

$$\mathbf{fnpVvdw} = \mathbf{PowerExpand}[\mathbf{npVvdw} / . \mathbf{frules} / . \mathbf{Rrule} / . \mathbf{temprule} / . \mathbf{P} \rightarrow \mathbf{fP}] \quad \frac{9.6929 \text{ Mole}}{\text{Liter}}$$

Step 5. Make a guess at the operations required to complete the fill:

$$\mathbf{afO2} = 1.000; \text{ (*for adding Oxygen*)}$$

$$\mathbf{bfO2} = 0.208; \text{ (*for adding air*)}$$

Step 6. Substitute the values for **ifO2**, **inpV**, **ffO2** and **fnpV** into the solution for **blendsol**:

$$\mathbf{blendvdw} = \mathbf{blendsol} / . \mathbf{inpV} \rightarrow \mathbf{inpVvdw} / . \mathbf{fnpV} \rightarrow \mathbf{fnpVvdw}$$

$$\left\{ \mathbf{lnpV} \rightarrow \frac{2.34661 \text{ Mole}}{\text{Liter}}, \mathbf{mnpV} \rightarrow \frac{6.08595 \text{ Mole}}{\text{Liter}} \right\}$$

These have both come out positive, as expected for add Oxygen and add air, so these are a valid pair of operations for this fill. (If they hadn't it would be necessary to go back to step 5 and make a better guess for the two operations required.)

Step 7. Use the solution to find the required intermediate molar density:

$$\mathbf{vnpVvdw} = \mathbf{vnpV} / . \mathbf{blendvdw} / . \mathbf{inpV} \rightarrow \mathbf{inpVvdw} \quad \frac{3.60695 \text{ Mole}}{\text{Liter}}$$

Step 8. Compute the corresponding intermediate mix:

$$\mathbf{vstate} = \mathbf{inpVvdw} \{ \mathbf{ifO2}, 1 - \mathbf{ifO2} \} + (\mathbf{vnpVvdw} - \mathbf{inpVvdw}) \{ \mathbf{afO2}, 1 - \mathbf{afO2} \}$$

$$\left\{ \frac{2.61128 \text{ Mole}}{\text{Liter}}, \frac{0.995666 \text{ Mole}}{\text{Liter}} \right\}$$

$$\mathbf{vfO2vdw} = \mathbf{vstate}[[1]] / \mathbf{Plus@@vstate} \quad 0.723959$$

Step 9. Find the Van der Waals constants for this mix:

$$\mathbf{vrules} = \mathbf{interprules} / . \mathbf{fO2} \rightarrow \mathbf{vfO2vdw} \quad \left\{ a \rightarrow \frac{1.38638 \text{ Bar Liter}^2}{\text{Mole}^2}, b \rightarrow \frac{0.0337398 \text{ Liter}}{\text{Mole}} \right\}$$

Step 10. Use the solution for **Pvdw** to derive the required intermediate pressure for the first operation.

$$\mathbf{vPvdw} = \mathbf{Pvdw} / . \mathbf{Rrule} / . \mathbf{temprule} / . \mathbf{npV} \rightarrow \mathbf{vnpVvdw} / . \mathbf{vrules} \quad 82.0092 \text{ Bar}$$

So the conclusion is to carry out the aoperation (adding Oxygen) until the pressure stabilises at 82 Bar, then carry out the boperation (adding air) till the pressure stabilises at the working pressure, 232 bar.

The mix computation using van der Waals equation may appear complex, but has been successfully programmed into a 15 year old pocket calculator (HP41C). The program takes about 40 seconds to run, so is

fairly slow, but this time is probably less than most people could accurately make a mixing calculation using tables (which are invariably based on the ideal gas laws).

5.2 Comparison with the combined gas law

Step 1. Use the solution for `npVcg1` with the known initial pressure to compute the initial molar density, `inpV`.

$$\text{inpVcg1} = \text{PowerExpand}[\text{npVcg1} / . \text{Rrule} / . \text{temprule} / . \text{P} \rightarrow \text{iP}] \quad \frac{1.23145 \text{ Mole}}{\text{Liter}}$$

Step 2. Repeat for the target working pressure to compute the target molar density, `fnpV`.

$$\text{fnpVcg1} = \text{PowerExpand}[\text{npVcg1} / . \text{Rrule} / . \text{temprule} / . \text{P} \rightarrow \text{fP}] \quad \frac{9.52322 \text{ Mole}}{\text{Liter}}$$

Step 3. Make a guess at the operations required to complete the fill:

```
afO2 = 1.000; (*for add Oxygen*)
bfO2 = 0.208; (*for add air*)
```

Step 4. Substitute these into the solution to the mixing equation:

$$\text{blendcg1} = \text{blendsol} / . \text{inpV} \rightarrow \text{inpVcg1} / . \text{fnpV} \rightarrow \text{fnpVcg1}$$

$$\left\{ \text{inpV} \rightarrow \frac{2.30555 \text{ Mole}}{\text{Liter}}, \text{fnpV} \rightarrow \frac{5.98622 \text{ Mole}}{\text{Liter}} \right\}$$

These have both come out positive, as expected, so these are a valid pair of operations for this fill.

Step 5. Use the solution to find the required intermediate molar density `vnpV`:

$$\text{vnpVcg1} = \text{vnpV} / . \text{blendcg1} / . \text{inpV} \rightarrow \text{inpVcg1} \quad \frac{3.537 \text{ Mole}}{\text{Liter}}$$

Step 6. Use the solution for `Pcg1` to derive the required intermediate pressure for the first operation.

$$\text{vPcg1} = \text{Pcg1} / . \text{Rrule} / . \text{temprule} / . \text{npV} \rightarrow \text{vnpVcg1} / . \text{blendcg1} \quad 86.1667 \text{ Bar}$$

This differs from the van der Waals method by ~4 Bar.

5.3 Mix error due to assumption of ideal gases

It is interesting to use the van der Waals equations to work out the mix that would be expected if the intermediate pressure calculated using the combined gas law (`vPcg1`) were used.

The first step would be to calculate the molar density at the intermediate pressure, but here there is a difficulty. To calculate this requires a knowledge of what the intermediate mix will be, which is unknown. It is necessary to compute an expression with this quantity undefined:

$$\text{vnpVcf} = \text{PowerExpand}[\text{npVvdw} / . \text{interprules} / . \text{Rrule} / . \text{temprule} / . \text{P} \rightarrow \text{vPcg1}];$$

This expression, if written out, would be extremely complicated!

The next step is to compute an expression for the consequent fill state:

$$\text{vstatecf} = \text{inpVvdw} \{ \text{ifO2}, 1 - \text{ifO2} \} + (\text{vnpVcf} - \text{inpVvdw}) \{ 1.000, 0.000 \};$$

And from this the resulting intermediate mix, which takes the form of an equation in `fO2`:

$$\text{fO2} == \text{PowerExpand}[\text{vstatecf}[[1]] / \text{Plus}@\text{vstatecf}];$$

This equation can be solved numerically:

$$\text{fO2cf} = \text{fO2} / . \text{FindRoot}[\text{fO2} == \text{PowerExpand}[\text{vstatecf}[[1]] / \text{Plus}@\text{vstatecf}], \{ \text{fO2}, 0.82, 0.84 \}]$$

0.738105

And the result substituted back into the previous expression to obtain numerical values for **vnPV**:

$$\mathbf{vnPVcf} = \mathbf{PowerExpand}[\mathbf{vnPVcf} / \mathbf{.fO2} \rightarrow \mathbf{vfO2cf}] \quad \frac{3.80177 \text{ Mole}}{\text{Liter}}$$

The difficulty continues in exactly the same way for the final mix which is also unknown. An expression has to be formed for the final molar density in terms of this unknown mix:

$$\mathbf{fnPVcf} = \mathbf{PowerExpand}[\mathbf{npVvdw} / \mathbf{.interprules} / \mathbf{.Rrule} / \mathbf{.temprule} / \mathbf{.P} \rightarrow \mathbf{fP}] ;$$

This can then be used to calculate the unknown final state, **xstate**:

$$\mathbf{xstate} = \mathbf{vnPVcf} \{ \mathbf{vfO2cf}, 1 - \mathbf{vfO2cf} \} + (\mathbf{fnPVcf} - \mathbf{vnPVcf}) \{ 0.208, 1 - 0.208 \} ;$$

Which in turn allows the unknown final mix to be computed as:

$$\mathbf{PowerExpand}[\mathbf{xstate}[\mathbf{1}] / \mathbf{Plus@@xstate}] ;$$

This can be set equal to the unknown and solved:

$$\mathbf{fO2cf} = \mathbf{fO2} / \mathbf{FindRoot}[\mathbf{fO2} == \mathbf{PowerExpand}[\mathbf{xstate}[\mathbf{1}] / \mathbf{Plus@@xstate}], \{ \mathbf{fO2}, 0.49, 0.50 \}]$$

0.415515

Which leads to the conclusion that in this case the 4 Bar error in the intermediate pressure target resulting from the use of the ideal gas law would only result in about 1.5% error in the resulting mix (41.5% O2 instead of the intended 40%).

Similar calculations show that finite compressibility mix errors for fills of near-empty cylinders are of the following order:

- 232 Bar, 50% fill: 2.5%
- 300 Bar, 40% fill: 3.2%
- 300 Bar, 50% fill: 5.5%.

6. Mass estimates

Either the ideal combined gas law or van der Waals equation if necessary can be used to derive mass estimates for the gas in a cylinder. Rearranging the combined gas law to give the amount of substance, **n**, in terms of the other variables yields:

$$\mathbf{ncgl} = \frac{\mathbf{P V}}{\mathbf{R T}} ;$$

Taking a typical modern diving cylinder full of air of WC 12 l and WP 232 bar quickly gives an estimated molar content:

$$\mathbf{nair} = \mathbf{ncgl} / \mathbf{.P} \rightarrow \mathbf{232 \text{ Bar}} / \mathbf{.V} \rightarrow \mathbf{12 \text{ Liter}} / \mathbf{.Rrule} / \mathbf{.temprule} \quad 114.279 \text{ Mole}$$

The molar content of Oxygen and Nitrogen can then be quickly derived given the fraction of Oxygen in air

$$\mathbf{nO2} = 0.208 \mathbf{nair} \quad 23.77 \text{ Mole}$$

$$\mathbf{nN2} = (1 - 0.208) \mathbf{nair} \quad 90.5087 \text{ Mole}$$

Taking the atomic masses of Oxygen and Nitrogen of .016 and .014008 kg/mol respectively and remembering to multiply by two for the molecular weights, the air mass in the cylinder can be readily calculated:

$$\mathbf{mwO2} = 2 * .016 \text{ KiloGram} / \text{Mole} ;$$

$$\mathbf{mwN2} = 2 * .014008 \text{ KiloGram} / \text{Mole} ;$$

$$\mathbf{massair} = \mathbf{nO2} * \mathbf{mwO2} + \mathbf{nN2} * \mathbf{mwN2} \quad 3.29633 \text{ Gram Kilo}$$

Which can be converted to more familiar weight belt units.

Convert [massair, Pound]

7.26717 Pound

6.1 Mixing using mass estimates

It is obviously possible to use the mass estimates as a means of mixing gases. This has the advantage of being almost completely immune to the effects of temperature on the pressure on the cylinder, and also to the effects of finite compressibility of the gases involved (so long as sufficient account is taken so that the WP of the cylinder is not exceeded in the attempt to get the mass right!).

The conventional wisdom is that this method is far too difficult to get right to be practical even in a diveshop environment, but I wonder. The mass involved in the previous example is a total of over 3 Kg. A 1% variation on this is of the order 30 g. This is the order of error permitted on a cylinder which might typically weigh in at say 15 kg, requiring an accuracy of about 0.2%. This doesn't seem unattainable using modern and fairly simple electronic balances employing strain gauges. I'd like to try it sometime. I accept that it won't work on a rolling boat of course.

7. Further Study

In collecting this information together I have come across references to more general laws of physical state. There appear to be two kinds, "Virial Equations" and "Rules of corresponding states". I have not investigated these further. They may be of some assistance in generalising these ideas. The central issue for mixing seems to be getting a grip on the physical behaviour of a *mixture* of substances. I rather suspect that this problem will remain even for these higher theories.

Much of the information contained in this article has been obtained from the WWW. Here are the URLs:

Units: <http://www.npl.co.uk/npl/index.html>

Gas laws: <http://www.chem.uidaho.edu/~honors/gas.html>

<http://chem.bu.edu/101-fall-95/16.html>

Van der Waals interpolation: <http://gandalf.iap.physik.uni-tuebingen.de/kern/members/NSNgroup/Gross/net4.html>

Atomic weights: <http://www.csmt.ewu.edu/csmt/biol/atomic%20numbers.html>

<End>

Full contents:

Part 1

1. *Units*
2. *Gas mixing in terms of molar densities*

Part 2

3. *Ideal gas laws*
4. *Van der Waals equation*

Part 3

5. *Interpolating van der Waals constants*
6. *Mass estimates*
7. *Further study*

DIARY DATES

Subscript article submission deadline

26 September 1998.

Events, courses and holidays

Date	Events	Contact
August 1-2	Weybourne diving, all grades	John Cook (Buzo) ???? (Starfish)
August 13, 14	Eastbourne, Taurus diving	Pete Young
August 15-16	Norfolk diving	Dave Lock
August 29-31	Norfolk diving	???? (contact Pete Young if interested)
September ??	The Farnes	Raj Mistry
Sept. 14-19	National Free Try Dive Week	
October 3	60's dance, Trimley Social Club	Dave Garrett
October 17/18	Dive '98 Show, NEC	
November	Red Sea	Mick Morley
November 21/22	Underwater World '98, Harrogate	
December	Christmas Party	Dave Garrett
1999	The Baltic	Dave Lock

Eastern Region Skill Development Courses (SDCs) 1998

Dave Lock

<i>Date</i>	<i>Subject</i>	<i>Venue</i>
Sept 12/13	Chartwork and Position Fixing	Ipswich
October 3/4	Boathandling + Diver/Cox'n	Felixstowe
October 24/25	Combined Nitrox	Ipswich
November 21	Oxygen Administration	Norwich
November 22	First Class Prep. (T)	To be announced

Please note these courses have to be booked via the Regional Coach at least a month before the event, I will have the necessary forms if you want them.

In addition I'm willing to run local SDCs but I need to know what you want. The only suggestion I've had so far is for Marine VHF Radio, so please tell me what is needed.

I also have the dates and venues of all the Instructor Training Courses, entry level is Sport Diver. This is probably the best course you will ever do and shows you how to teach students to Novice 1 level, contact me for details.