

Arterial Bubble Model
Suggested Protocol for Emergency
In-water Recompression
Did Haldane Really Use His “2:1”?
Living the Dream?
Diving Ras Atantur

Contents

Editorial

2

Arterial Bubble Model

By Asser Salama

3

Suggested Protocol for Emergency In-water

Recompression

By Bret Gilliam

7

Did Haldane Really Use His "2:1"?

By Albrecht Salm

13

Living the Dream?

By Simon Pridmore

21

Diving Ras Atantur

By Ayman Khaled

29

Editorial

Welcome to the 25th issue of Tech Diving Mag.

It's our anniversary. We started this journey together 6 years ago! If you've missed out on any issue, all the back issues could be found at www.techdivingmag.backissues.html

The contributors for this issue have brought together a wealth of information along with interesting first-hand experiences. Our generous contributors are world renowned industry professional Bret Gilliam, technical diving instructor Albrecht Salm (PhD), best-selling author Simon Pridmore and technical diving enthusiast Ayman Khaled. Take a look at their brief bio at www.techdivingmag.com/contributors.html.

Tech Diving Mag is based on article contribution, so you're always welcome to volunteer a piece and/or some photos. The guidelines could be found at www.techdivingmag.com/guidelines.html.

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Asser Salama
Editor, Tech Diving Mag



Arterial Bubble Model

By Asser Salama

“If small bubbles are carried through the lung capillaries and pass, for instance, to a slowly desaturating part of the spinal cord, they will there increase in size and may produce serious blockage of the circulation or direct mechanical damage.”

— J.S. Haldane. The prevention of compressed air illness. J. Hygiene Camb. 1908 p. 352

The Arterial Bubble (AB) model assumes that the filtering capacity of the lungs is a critical issue. As a bubble filter, the lungs get rid of the bubbles on the venous side through ventilation. However, smaller bubbles are suspected to pass to the arterial side of the circulation. A study using a contrast agent called Levovist was conducted in 2002,¹ confirming this assumption. Levovist contained stable gas bubbles with calibrated sizes between 3 and 8 micron trapped in galactose. Levovist was then injected intravenously, and measurements were made a few minutes later in the cerebral, renal and lower limb arteries. Levovist bubbles were found in the arterial side of the circulation, which indicates that decompression bubbles could also travel through the lungs and cross to the arterial side, especially at the beginning of the ascent where the bubbles are still small. The threshold radius is suspected to be the size of a blood cell. During the ascent, the bubbles grow, so the lungs trap them more efficiently.

Just like both the dissolved-gas and the dual-phase models, AB presumes that when the ascent starts, the compartments start to off-gas as soon as a gradient is created. The bubbles are then transported through the venous system to the lungs, which in turn filter the bubbles by trapping them in the capillaries according to their respective diameters then eliminating them through the alveoli. However, small bubbles may cross the lungs, passing to the arterial side of the circulation. The distribution of the blood at the aorta is such that a crossing bubble is likely to reach a neurological location such as the

brain or the spinal cord; both are fast, well-perfused tissues, and both have the capability of acting as gas reservoirs and diffuse gas into the crossing bubble. The crossing bubble would either proceed to the venous side or grow onsite, causing serious neurological DCS, not just limb pain or skin rash.

The main advantage of AB is that trying to simulate the efficiency of the lungs and associating it with the DCS susceptibility responds to many questions with unquantified answers. A better diver is a better bubble filter, one with more efficient lungs. Regarding the individual susceptibility, simulating the efficiency of the lungs would account not only for the interindividual variability (age, obesity, smoking, etc.) but also for the intraindividual variability (fatigue, dehydration, etc.). Regarding the CO₂ production during the dive, it is reasonable to assume that excess CO₂ would reduce the filtering capacity of the lungs and thus would cause bubbles to pass to the arterial system. So diving situations associated with the production of excess CO₂ (anxiety, stress, temperature variation, exhaustion, hyperventilation, high breathing resistance, etc.) would be automatically accounted for.

Another advantage of the AB is that trying to simulate the efficiency of the lungs and associating it with the DCS susceptibility is consistent with the accidental production of arterial bubbles found in several cases such as patent foramen ovale (PFO), for example. It also offers an explanation for the occurrence of neurological DCS (also known as CNS DCS).

A proposed scenario is that when the ascent commences, some bubbles are trapped in the lungs waiting to be filtered out with the exhalation. If the diver descends again, these bubbles will experience size reduction due to the excess pressure exerted on them. Some would pass through the lung capillaries and eventually dump into the

arterial bed. This might explain why divers should avoid multilevel recompression (sawtooth) profiles. This hypothesis also suggests a probable explanation of the “undeserved” hits.

AB provides a possible explanation for the criticality of the initial ascent phase. Symptomatic bubbles are not necessarily generated onsite. AB assumes that the process of small bubbles passing to the arterial system during the initial ascent phase is an early prediction of possible DCS symptoms. Once the bubbles reach a critical size, they are either filtered in the lungs or stopped at the tissue level.

AB also provides another interesting presumption. When the last decompression stop is at 3 meters (10 feet), the slight variation in depth due to less-than-perfect buoyancy skills or rough seas would produce sufficient pressure changes to reduce the bubble size, facilitating its escape to the arterial bed. That is why the AB model advocates performing the last stop at 6 meters (20 feet), as the same variation in depth will result in less change in pressure. It is interesting to note that Hills had the same observation in the early 1960s when he was investigating the decompression procedures followed by the pearl divers. They used to drop the last stop(s) and ascend directly to the surface from 6-9 meters (20-30 feet).

An early attempt was made to turn this scenario into a decompression model. The resulting model (now called AB-1) developed by Jean Pierre Imbert incorporated the concept of compartment halftimes. For the safe ascent criteria, the formulation of arterial bubbles was suspected but not established in mathematical terms. Instead, an approximation was defined empirically by fitting mathematical expressions to selected exposures stored in the database of the French commercial diving giant Comex. AB-1 was used to compute a set of decompression tables, which were sent offshore for evaluation on

selected Comex worksites. In 1986, after some minor adjustments, the tables were included in Comex diving manuals and were used as standard procedures. In 1992 the tables were included in the French diving regulations under the name of Tables du Ministère du Travail 1992, or simply MT92 tables.

In the 1990s Imbert introduced a second version called AB-2, a dual-phase model. It amended the equation that describes the ascent criteria by adding the arterial inert gas tension as a parameter. It also incorporated the concept of varying compartment halftimes. The result is that it introduces a deeper first stop than neo-Haldanean models.² The generated schedules are comparable to Bühlmann's ZH-L16 with either gradient factors or RGBM folded over. Just like other models, AB-2 does not specify the ascent rate. It is a user input. For this parameter, AB-2 would expect an input between 6 and 9 meters/min (20 and 30 feet/min).

AB-2 was first calibrated by data fitting on both Comex database and experimental dives using air, nitrox and heliox. AB-2 was later recalibrated using experimental bounce dives conducted by the French Navy. Since 1999 it has been used by some sports divers in Tunisia and Corsica.

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Excerpted from *Deep Into Deco: The Diver's Decompression Textbook*. The title is available at:

https://www.bestpub.com/books/scientific-diving/product/428-deep-into-deco-the-diver-s-decompression-textbook/category_pathway-42.html

<http://www.amazon.com/Deep-Into-Deco-Decompression-Textbook/dp/1930536798>

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"*Deep Into Deco* is a stimulating read which covers almost every facet of diving from breathing to technical decompression. It is well referenced and dives into (forgive the pun) great detail concerning the past and present of diving theories. I recommend this book for all divers from novice to technical expert because Asser Salama makes even the most difficult topics seem easy and understandable. No diving collection is complete without this super overview book. I will keep mine on the coffee table as a discussion piece."

—Commander Joseph Dituri,
US Navy Saturation Diving Officer (ret) and Vice President of IANTD

"This book is long overdue. And it's worth the wait. What Asser Salama has accomplished with this book is remarkable. He has taken that early history of experimental trial and error and produced a stunning reference text that brings the science into sharp focus."

—Bret Gilliam, founder of TDI

"Asser's book is the best general overview of decompression modeling I have seen. The information it contains is relevant to divers of all levels, from the occasional sport diver who wants to know more about how their dive computer works to the technical diver planning extended decompression dives. It certainly is a welcome addition to my dive library!"

—Jeffrey Bozanic, PhD, author of *Mastering Rebreathers*



ASSER SALAMA, a technical diver and instructor, is founder of *Tech Diving Mag* and developer of Ultimate Planner decompression-planning software. He has a bachelor's degree in engineering and a master's degree in business administration. A software developer with an interest in decompression modeling, Salama plans to implement computational algorithms based on credible research papers to prevent some pioneering work from fading into academic obscurity.



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*Suggested Protocol for Emergency
In-water Recompression
By Bret Gilliam*

Overview

Decompression illness is a statistical inevitability. It will happen regardless of the relative “safety” of a dive profile and the algorithmic model embedded in a dive computer. The important thing is assessment, recognition of the signs and symptoms, and making a responsible decision as to the best contingency protocol to follow to get the optimal outcome for the victim. Obviously, the first choice would be admission to a hyperbaric treatment facility with a PVHO recompression chamber and attendant staff. Secondly, evacuation to such a facility would be the next best alternative.

However, reality also includes the scenario where evacuation is either too long in time duration or simply impossible due to remote location in the field where much of the exotic diving now takes place on a regular basis. If you are in a remote diving resort or aboard a diving vessel without immediate access to an evac flight, the hard situational reality is that treatment in the field is the best possible option. Delays in recompression of more than four hours risk permanent lasting injury that will not resolve with delayed treatment.

Oxygen and pressure (hydrostatic pressure from depth) are the necessary components with trained staff to supervise the process. These recommendations are the result of 45 years experience of procedures to treat patients in the field. The outcome record, if prompt recompression and administration of oxygen, is hugely successful.

The ultimate decision should fall to the patient... who should be fully informed of the risks and make an informed decision... but if unreasonable delays due to evacuation are foreseeable, it is likely that that in-water recompression treatment is the best route.

The fastest growing segment of dive travel is to remote exotic

locations such as Indonesia’s Raja Ampat islands and the Banda Sea, the Solomon Islands, Cocos Island nearly 400 miles offshore from Costa Rica, Papua New Guinea, etc. There are no hyperbaric facilities within any reasonable distance and traditional med-evac flights are not available. Evacuation by sea can exceed two days in duration. Faced with the actual reality of such circumstances, what would you opt for? Excessive delays that will likely result in permanent deficits from DCS or going back into the water for immediate treatment with proper support?

There’s no easy answer... but for most divers with an understanding of DCS the path would be in-water recompression.

This may be a term unfamiliar so some divers. Ideally, hyperbaric treatments are conducted in a clinical setting with a recompression chamber located on dry land. But that is not possible in isolated remote areas or aboard 95% of diving vessels. So the procedure must be conducted in the ocean in order to get the pressure component from the surrounding depth. Oxygen is still administered but the hydrostatic (water) pressure provides the essential compression of the inert gas bubbles instead of pneumatic pressure from the induction of compressed air into a recompression chamber. The end result is the same... but now the environment is water... not reclined in an air-filled recompression chamber. This presents some additional challenges but they are manageable and necessary.

To follow is a protocol for such procedures. I’d like to see the industry embrace such training and provide a foundation of awareness and expertise to deal with such contingencies.

Presentation of DCI Problems

If a diver surfaces and reports any signs or symptoms of decompression

illness (DCI), they should immediately be evaluated against the list of DCI symptoms and equipped for re-entry into the water as quickly as possible.

Be certain that the victim is functionally responsive, mentally aware, and capable of answering questions such as “What day is it?”; “How old are you?”; “Where are you?”; etc.

Do not delay re-entry to the water but examine their dive computer for its last dive profile and see if any required decompression was omitted. Also note the maximum depth and total run time of the dive.

Whatever the breathing mix (nitrox or air) do not worry about calculating OTU or CNS oxygen exposure. OTU loading will be incidental and CNS O2 exposure will be in the range of 20% at most. The immediate priority is return to depth to compress inert gas bubble development and aggregation.

Contingency Equipment

The following should be kept ready for usage and readily available on the dive deck:

- Two oxygen-clean scuba cylinders filled with 100% oxygen... pressure may be limited to approximately 2000psi due to storage pressure in H tanks.
- Two oxygen clean regulators with submersible pressure gauges. No extra second stages or low-pressure inflator hose should be attached.
- A ½-inch or 5/8-inch line at least 80 feet in length should be deployed with approximately 40-50 pounds of weight attached to the bottom to hold the line steady and vertical in the water column.

Ideally, the line should be deployed from the main vessel’s amidships boarding area or stern platform and extended so the bottom of the line is as close to an exact depth of 60 feet as possible. The extra line length can be coiled on the deck and the line made fast to a cleat or other fixed point.

Treatment

The symptomatic diver should enter the water as quickly as possible accompanied by another diver as tender. Descent should be made on the oxygen cylinder and breathing 100% oxygen. (Diver should wear a wet suit due to the prolonged period underwater.)

A slate and writing marker should be with the tending diver to communicate with the patient.

Another dive tender should accompany the two divers with a scuba cylinder filled with normoxic (standard) air at 21% oxygen. This will be used by the patient to breathe from during air breaks from the oxygen treatment. It can be worn by another diver with an extra long hose second stage to share with the patient. Do not burden the patient by having to change cylinders. Change the patient’s oxygen cylinder mounted to his BCD as necessary but ideally during the air breaks so no unnecessary interruption of oxygen breathing is done.

A clip or carabineer is helpful with corresponding eyes configured in the vertical line so that the patient can simply clip in and relax hanging motionless during the treatment. The clip can be on the diver’s BCD or other harness.

While there are several tables that have been in use for in-water recompression treatments, a standard Table 5 is effective and relatively easy to conduct.

Get bent in a remote area like this and you will have to deal with the treatment yourself.



Descend to a depth of 60 feet as quickly as comfortable for the patient to equalize ear pressure. Depth should be measured at the center of the diver's chest.

Upon arrival at 60 feet, the patient should breathe 100% for a 20-minute period. It is likely that most symptoms will resolve during the initial 20-minute breathing period at 60 feet. A PO₂ of 2.8 ATA will exist at 60 feet.

After 20 minutes on oxygen, the patient should switch to compressed air for a five-minute breathing period.

Repeat another 20-minute oxygen breathing period followed by a five-minute air break.

At all times, the patient should remain at rest with no physical exertion.

At the conclusion of the second 20-minute oxygen breathing period and the five-minute air break, begin ascent from 60 feet to 30 feet at a rate of one foot per minute while breathing oxygen.

Upon arrival at a depth of 30 feet, have the patient do a five-minute air break.

Then begin another 20-minute oxygen breathing period followed by another five-minute air break. PO₂ at 30 feet will be nearly 2.0 ATA.

Now the ascent to the surface will begin while oxygen breathing. Ascent rate will be one foot per minute. This will take 30 minutes.

It is now time to remove the patient from the ocean. Remove all equipment except the thermal suit so the patient is not physically

stressed.

Upon surfacing, have the patient drink as much water as they are comfortable with. Inquire about any remaining symptoms. Let the patient take a fresh water shower, towel off, dress in comfortable shorts or lightweight cotton pants with a tee shirt or sweat shirt.

Take them to a well-ventilated (preferably air conditioned) cabin located in an area of the vessel with as little motion as possible to minimize any seasickness. They should lay flat on their back with their head on a pillow and be comfortable.

Have the patient begin breathing 100% oxygen via oral-nasal demand mask. Continue for two hours. Patient may drink water as needed.

Following two hours, do another field examination for CNS or pain DCI symptoms. It is likely that all symptoms will have completely resolved during the in-water phase of treatment.

Continue to have the patient breathe oxygen via demand mask for 24 hours with breaks as needed for hydration and bathroom relief.

Following the 24-hour surface oxygen breathing period, the patient may resume normal activity but with no physical exertion. Diving should be suspended completely.

Notes

Although unlikely, there is the possibility of a CNS oxygen reaction during the oxygen treatment breathing period underwater. If any symptoms are observed, the patient should immediately be placed on compressed air breathing for ten minutes before resuming the prescribed oxygen/air breathing protocol. While not an absolute

requirement, having a full-face mask for the patient during O2 breathing would be desirable since any possible contingency reactions from oxygen toxicity would be minimized and lessen the possibility of losing the breathing source from a standard scuba second stage.

Tending divers should breathe a nitrox mixture of 40% oxygen. They will not need air breaks. Tenders may be rotated during the treatment.

Patients may exhibit anxiety and stress during the treatment. Every effort should be made to keep them calm and relaxed. It is also likely that treatment will continue after sunset and in darkness. Have lights available underwater and have a tender observe for any marine life threats.

If the vessel anchorage or mooring site is not calm, conduct the recompression in a protected lee area near an island, if available. Ideally, the motion in the vertical water column should be an absolute minimum.

Time is of the essence from the initial reporting or symptoms to re-entry to the ocean and return to a depth of 60 feet. Most patients will resolve completely if treated within 30 minutes to one hour.

Time of treatment on Table 5 is two hours and fifteen minutes underwater. If deemed necessary, extra 20-minute O2 breathing periods can be added at either 60 or 30-foot depths but this should not be required. However, if any doubts exist about resolution of symptoms add the O2 extensions. As long as the supply of O2 is available, it can't hurt and serves as an additional outgassing gradient for elimination of inert gas bubbles especially in areas of aggregation.

Finally, inevitably controversy always arises in this discussion. But the same was true originally with standard surface oxygen administration, diving computers, nitrox, etc. Most of the cautionary reactions come from issues of liability and risk management... not from the likely outcome of in-water treatment. Nothing is perfect. There will always be risk. But "reality" is a huge influence on practical response.

My experience with in-water recompression has produced 100% resolution for all divers that I've treated over the last 45 years. The risks were acceptable in the circumstances. It's your call...

Bret Gilliam is a licensed U.S. Merchant Marine Master and has run hyperbaric treatment facilities and recompression chambers since 1971. He is credentialed as a Recompression Chamber Supervisor through NOAA, UHMS, ISAM, SPUMS, IBUM, and ERDI. His papers and articles on emergency diving treatment have been published by these groups as well as the American Academy of Underwater Science, the Divers Alert Network, and in the international press. He has presented his formal work at a variety of conferences and symposia since 1972.





*Did Haldane Really
Use His "2:1"?*
By Albrecht Salm

© ALBI (when he was young, ca. 45 years ago, using his DRÄGER helmet, checking the come-home bottle, which is integrated into the breast-weight)

Preamble

The following is along the traditional lines of a serious scientific paper, i.e.:

Introduction

Methods

Results

Discussion

References

The contents, however, may be regarded as something winkingly...

Introduction

The famous scottish physiologist John Scott Haldane (1860 – 1936) and his co-workers published in 1908 a ground-breaking paper [1]. This is generally considered and accepted as the foundation of staged decompression diving. The paper featured twodiving tables in the attachment. The first of these tables became very successfull. In deed, Table I (loc. cit. p. 442) was adopted for regular use in the Royal Navy ca. a year (p.367) before and was so wildly successfull, that Haldane later on wrote ([2], p. 350):

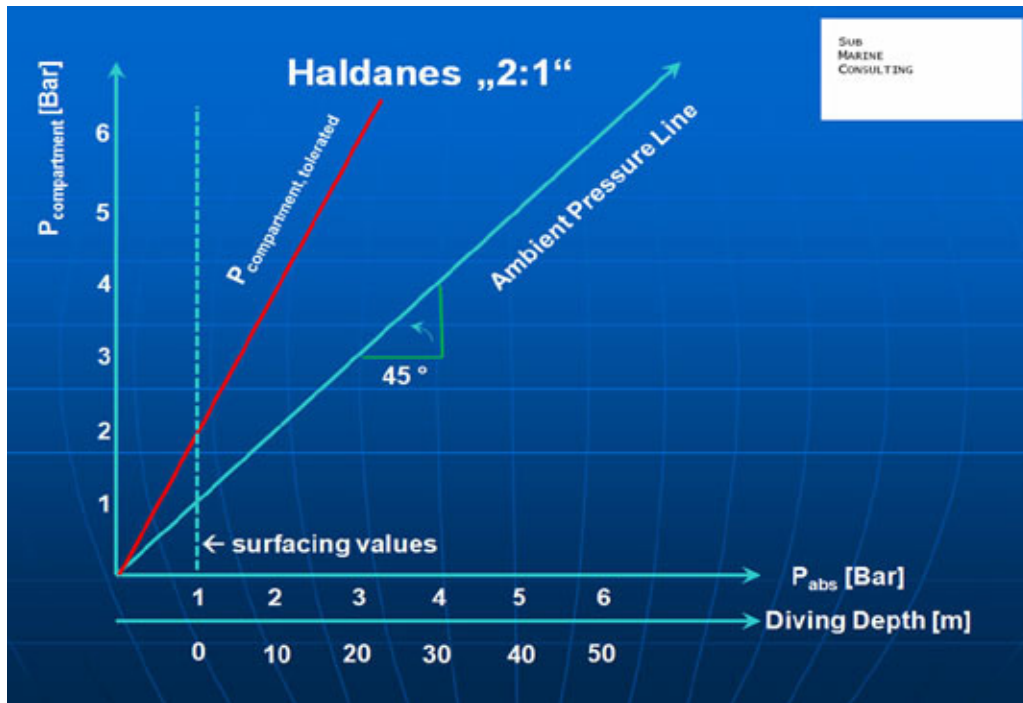
Since the introduction into the British Navy twelve years ago of the method of decompression embodied in the tables, with the corresponding regulations as to air supply and testing of the pumps, deep diving has been conducted with comfort and safety to the divers, so that compressed-air illness has now practically disappeared except in isolated cases where from one cause or

The work of these 3 gentlemen and their 85 goats and hundreds of smaller animals ([1], p. 379) is still the basis of most modern decompression tables, desktop deco-software and diver-carried dive computers: more than 800 dives with goats and more than 300 with

the smaller animals have been analysed carefully. In the refs. [3] – [7] is ample material. The basic assumptions to calculate the tables have been:

- the model of a human body can be divided into 5 theoretical compartments with halftimes from 5 to 75 min
- inert gas uptake and elimination is exponential with the above halftimes and thus:
- symmetrical, provided no inert gas bubbles have been formed upon pressure reduction
- these compartments can withstand a certain supersaturation. Below this threshold value the risk of contracting decompression sickness is relatively low
- this particular threshold, the tolerated supersaturation, for these 5 compartments follows a „2:1” rule, that is: ([1], p. 424):

No symptoms are produced by rapid decompression from an excess pressure of 15 pounds, or a little more, to atmospheric pressure, i.e. from two atmospheres absolute to one. In the same way it is safe to quickly reduce the absolute pressure to one-half in any part of the pressure scale up to at least about seven atmospheres: e.g. from six atmospheres (75 pounds in excess) to three (30 pounds), or from four atmospheres to two.



In the course of time and extensive usage it became clear, however, that there are operational shortcomings. Table I was overly conservative for short bounce dives and Table II was grossly inadequate for long and deep dives. This is discussed as well in [3], [7], [8 → 13] and the references therein. As well Haldane had caveats and mental preservations; one is there, [1] on p. 368:

In the case of men of exceptionally heavy build, and inclined to obesity, the time allowed after very prolonged exposures ought to be increased by about a third, although such men, particularly if over about 45 years of age, ought not to expose themselves to the risk of a prolonged stay in very deep water.

And another one in [1], p. 357 is this very clearly stated footnote:

Whether the law holds good for pressures much exceeding six atmospheres is still doubtful, as no experimental data exist.

It seems that these caveats have been forgotten, especially by designers of modern decompression software. Or, as Robert Henry Davis put it already that time [15], p. 8:

„In spite of this characteristic caution, later writers have mistakenly credited him with asserting that rapid decompression from *any* pressure „2n” to pressure „n” is safe.” And, on this particular page further down: „...10 atm, Haldane’s two to one law no longer held good, a finding for which he had prepared us.”

The basic shortcomings have been alleviated with:

- increased number of compartments, i.e.: 9, 14, 16, 20 or more
- greater spectrum of halftimes. i.e. from 2.5 min to 900; and
- variable supersaturations, i.e.: from ca. 3.4:1 to 1.1:1.

But despite these operational shortcomings there have been rumors about the internal design of the tables, i.e. if the calculations really follow the „2:1” principle; that is, what was stated on p. 355:

It seems perfectly clear that no symptoms occur with less than one atmosphere² of excess pressure, however long the exposure may be.

(Historical note: a lot of these calculations have been done by his son JBS Haldane, called Jack. Despite being a child, he co-authored already earlier papers with his father; he was considered a genius. As a reward he was allowed to take part in the diving experiments in open waters ([1], p. 436):

and Commander E. V. F. R. Dugmore, Lieutenant G. N. Hen Jack Haldane (age 13) all made descents in six fathoms of water.

Rumors

Since then, decompression researchers and divers have been speculating about this “2:1”. One explicit statement is from H. V. Hempleman in ref. [8], p. 233:

„One further important fact to be noted is that although the Haldane decompression ratio of 2:1 is much discussed by everyone studying this subject it was not used by Haldane for his calculations!”

1935

Already earlier this millenium Hawkings, Shilling and Hansen from the United States Navy (USN) had been writing in:

IN: U.S. Nav. Med. Bull. 1935; 33:327-338.

A SUGGESTED CHANGE IN CALCULATING DECOMPRESSION TABLES FOR DIVING^{1,2}

By **JAMES A. HAWKINS, D. Sc.**, **CHARLES W. SHILLING**, Lieutenant, Medical Corps, United States Navy,
and **RAYMOND A. HANSEN**, Lieutenant, United States Navy

(From the Laboratory of the Experimental Diving Unit, Navy Yard, Washington, D. C.)

(loc. cit: p. 333):

„Actually we find when we calculate many of Haldane’s tables (1922) that he often goes to a ratio of 2.1 or even 2.3 to 1, but this is well within the safety factor.”

1945

In a publication from 1945 about „explosive decompression” with more than 400 animals (mice, rats, guinea pigs and rabbits) we find the following statement:

„... it would seem that Haldane deliberately abbreviated the final equilibration period by 10 – 20 min...”

(Source: J. Physiol. (1945) A STUDY OF THE EFFECTS OF RAPID ‘DECOMPRESSION’ IN CERTAIN ANIMALS BY P. EGGLETON, S. R. ELSDEN, J. FEGLER AND C. O. HEBB)

1969

In a research paper from the Submarine Base Groton, Conn. (NSMRI Report No. 580, 1969: Decompression Patterns developed by an interdependent Electric Analog, Gary P. Todd) we find on p.4 (citation):

„... the original tables varied from 3,4 : 1 to 1,2 : 1 ...”

1984

A very similiar, but more detailed, really in-depth analysis of 2 profiles is there [8] on the pages 233 – 242! It looks like that the supersaturation ratios, used to build the tables, are varying from 2,5 : 1 to 1,7 : 1, as well during all the deco stages! In clear words: from deco stage to deco stage these ratios have been changed from „2:1” to something differently!

1992

Last, but not least: my friend Karl Huggins put in his famous deco workbook (ref. [9], p. 2-6):

It is interesting to note that in some cases Haldane allowed the ratio of 2.3:1 to occur on the final decompression step to the surface. This causes a slight discrepancy between schedules that are calculated using the 2:1 ratio and Haldane's published tables. This type of table "tweaking" is not at all uncommon in the development of decompression tables.

Methods

We have been curious if these rumors and, sometimes harsh comments, have been assessed correctly. You could do it yourself with virtually any desktop deco software there is, provided it allows for a certain flexibility described below. We set out to check with our [public free-ware version of DIVE](#).

The allowed / tolerated compartment supersaturation follows a simple linear relationship (see the graph above), as in all well-known decompression-models based on compartment perfusion:

$$P_{\text{compartment, tolerated}} = (P_{\text{ambient}} / b) + a$$

This is the formula found for eg. in Bühlmanns books ([13], p. 117); a very similar equation in the notation from Bob Workman looks like that [14]:

$$M = M_0 + \Delta M * \text{diving depth}$$

By combining the Bühlmann formula with the Haldane law and compare the 2 linear equations on the right hand-side you have now:

$$P_{\text{compartment, tolerated}} = (P_{\text{ambient}} / b) + a = P_{\text{ambient}} * 2$$

→ a = 0.0 , b = 0.5

With [DIVE Version 3](#) this check is now easy and straightforward. Take the coefficients matrix and modify it, according to Haldanes specifications; i.e.: overwrite the first half-times (TAU) with the ones, Haldane used (5, 10, 20, 40&75 min.), then put a = 0.0 and as well b = 0.50, as you may infer from the graph above or from the formulas. In order to ensure that DIVE Version 3 does not go nuts with these things, you have to copy to last line (compartment #5) and fill up the matrix up to #16 with the identical values:

#	TAU	A	B	HI	LO
01	5.0	0.0000	0.5000	1.0	1.0
02	10.0	0.0000	0.5000	1.0	1.0
03	20.0	0.0000	0.5000	1.0	1.0
04	40.0	0.0000	0.5000	1.0	1.0
05	75.0	0.0000	0.5000	1.0	1.0
06	75.0	0.0000	0.5000	1.0	1.0
07	75.0	0.0000	0.5000	1.0	1.0
08	75.0	0.0000	0.5000	1.0	1.0
09	75.0	0.0000	0.5000	1.0	1.0
10	75.0	0.0000	0.5000	1.0	1.0
11	75.0	0.0000	0.5000	1.0	1.0
12	75.0	0.0000	0.5000	1.0	1.0
13	75.0	0.0000	0.5000	1.0	1.0
14	75.0	0.0000	0.5000	1.0	1.0
15	75.0	0.0000	0.5000	1.0	1.0
16	75.0	0.0000	0.5000	1.0	1.0

(Ignore the values HI = LO = 1.0! These are reserved for the so-called

„Variable Gradient Method”, the VGM, which we do not use now. And, to be honest, nobody used except some strange divecomputers, obsolete since long ...)

But to reach at a meaningful comparison, you have to adapt as well the following values:

- Geometric diving depth / depth of decompression stages: from feet to m
- Rate of ascent; Haldane put it to ca. 30 feet / 1 min
- Density of seawater: most deco softwares use freshwater density or another cryptic, average value
- Inertgas content: deco software uses normally $fN_2 = 0.79$ or similar value +/- 2 % for air diving. Haldane et al. did not! They used instead $fN_2 = 1.00$! Regular desktop deco software may not allow $fN_2 = 1.00$ because this would imply a relatively unhealthy mixture without O_2 .

To get a grip on that one you could use something like an „inverted EAD” (inverted equivalent air depth). From your EAN / Nitrox courses you are familiar with the regular EAD concept. This one here is just the inverse in the metric version:

$$(\text{depth}_{\text{Haldane}} + 10.0) / 0.79 - 10.0 = \text{depth}_{\text{calculation}}$$

Results

As just one paradigm, let’s take the following dive from Table II to 132 – 144 feet for 90 min.

With the above adaptations in mind the results for the calculated inert gas partial pressures pN_2 in the leading compartments (the one with the highest N_2 pressures) looks like that:

Procedure	Leading Cmpt	$p N_2$ [Bar]	Ratio
on reaching the 12 m stage, after the 10 min stop	# 3	4.1390	1.88136
on reaching the 9 m stage, after the 10 min stop	# 4	3.6671	1.93005
on reaching the 6 m stage, after the 20 min stop	# 4	3.1195	1.94960
on reaching the 3 m stage, after the 30 min stop	# 5	2.5801	1.98460
on reaching the surface, after the 35 min stop	# 5	2.2058	2.20580
(extending the last stop to 52 min)			2.0150)

For this dive, the deeper stops are more conservative and giving thus a reduced supersaturation, e.g. the first ratio of 1.88 gives something like a „Gradient Factor” of 94 %, aka „GF Lo = 0.94”; but the surfacing value is ca. 2.2 : 1 instead of 2.0 : 1. If the last stop at the 10 feet stage is extended from 35 to ca. 52 min, then a nearly „2:1” would have been reached.

Haldane 2.0

A couple of other dives end up in ratios for the deeper stops with ca. 1.6. This would give sometimes a GF Lo of 80%. So Gradient Factors are already in place since then! As well things like „accelerated deco” (p. 354, 371, 376), „EAN36” (p. 379), linear decompression only for saturation dives (p. 366), more and longer compartment halftimes (p. 376) and asymmetric de-saturation (p. 344, 350) have already been contemplated. So some diving magazines sell you these things as the latest cry from the TEC-scene: but obviously it’s not. It has been around now for more than 105 years, just the terminus technicus, Haldane’s wording, has been quite different.

Discussion and Conclusion

Basically we could confirm the above cited rumors, but as well Haldane's own caveat, which was clearly pronounced on p. 355:

Whether any distinct symptoms ever occur with less than about 1.25 atmospheres (18½ lbs. per square inch or 41 feet of sea water) seems very doubtful: at any rate they are very exceptional. At pressures a little above 1.25 atmospheres occasional slight cases begin to be observed, and their frequency and gravity rapidly increase with higher pressures unless the time of exposure is limited or slow decompression is resorted to. The lowest pressure at which we have been able to find any record of a death occurring from caisson disease is 23 lbs. or 1.6 atmospheres².

In [1], p. 367 the authors state:

only case in which these limits are allowed to be slightly exceeded is with short exposures in comparatively shallow water.

As well, on p. 361:

The possible occurrence of slight symptoms after surface had been reached would not, however, be a serious matter: for this reason half of the last stop at 10 feet from surface might be dispensed with, which would save half an hour.

And, on p. 374:

and the stoppages recommended during the divers' ascent after exceptionally long periods of exposure are somewhat shorter than would be desirable apart from the risks entailed by the long stay under water.

In summary, some of the last stopshave been obviously truncated, but, as well, it is clear from all these statements above copied from [1], that the tables *have been designed clearly with that in mind!*

Given the mathematical / operational possibilities of the time and the depth / time intervals of the tables, the „2:1” ratio is clearly followed, say by approx. +/- 20 % in Table II and by approx. +/- 10 % in Table I. This would be perfectly in-line with the accuracy of the available measurement methods for depth and time, and, as well with the clumsiness of a diving operation (dry suit + helmet + weights + boots + come home bottle + ... at approx. 100 kg; lowering & lifting the diver with a stage, i.e. manually geared elevator).

(This is even adressed in modern diving operations: the stage with the 2 divers, called „team red” and „team green” is lowered in the water to ca. 20 feet, they turn around, make a bubble check and only thereafter the bottom time starts.)

If you consider also the basic restraint of Table I, i.e. a maximum TTS (time-to-surface) of about 30 min and the operational difficulties of implementing a new procedure to a military organisation, which, normally, behaves sort of beef-witted ...

In clear and easy retrospect we would not join the choir of bleating from our colleagues but instead bow to these tables! Especially if you consider the lines of reasoning and the audacious transformation of the results from the goats in a deco-chamber to real human divers in water!

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-/- [a summary of all needed formula for decompression calculations](#)



*Living the Dream?
By Simon Pridmore*

An Interview with Alex Ford, owner of Villa Alba, a full service technical and recreational diving resort on the northeast coast of Bali, Indonesia

Have you always thought you might like to retire and start your own dive business? Well, here is a very revealing interview with someone who did just that.

Alex Ford and his wife Jessica own an extremely professionally run dive resort on the north coast of Bali. They enjoy a superb tropical climate. The sun shines every day. The sea is blue and they have a nice house reef on their doorstep. They have expert staff throughout the resort and two dogs for companionship and entertainment for the guests.

They are often told by friends and visitors that they are “living the dream.” Is that really the case? How did they get to where they are today? And what sort of obstacles did they have to overcome? These were just a few of the thoughts in my mind as I prepared to interview Alex the other day.

So, how did it all start, Alex?

Well, where to begin? For me the road to Bali began in the shipyards in Scotland. Jessica’s journey began in Beijing.

We already owned a villa with beachfront land close to the best of Bali’s diving. After a few friends passed away we realised that chasing the mighty dollar all around the world did not make for the happiest of lives so we decided that I should retire early and we would open up a dive resort.

Neither of us had ever actually worked in the tourism business so the decision was not an easy one. What (we thought) we knew was what guests would want, as we were both divers and had visited quite a few dive resorts over the years. So we decided to take the plunge.

We knew that there were no dive centres in Bali properly equipped to cater for the requirements of technical diving. I already had all the necessary equipment, compressors, oxygen boosters, CCRs, twin sets, wings, DPV systems etc. so we thought that was one thing we could do.

Another thing we realised was that Chinese-speaking divers were starting to travel more widely. Jessica is Chinese and we felt we had the knowledge, skills and connections to target that market as well.

My background was in the oil construction business and the knowledge and discipline that I acquired from that has been very useful as, in every endeavour, there are systems and schedules that need to be kept in mind and planned for. These are essential to ensure that everything goes well.

I kept working abroad on contracts and we planned the construction phases around the contracts. This solved the cash flow issue but it also meant that you were not there during the building process.

What are the major lessons you have learned?

The first lesson we learned was the importance of being there during the building process! After the build was completed we found various construction problems.

For example, some of the rooms did not have a P trap to the septic tank, so the smell of the tank was coming back up into the rooms. This meant that, at one point, the resort had to be closed for a week to give us time to find the waste pipes and install traps.



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↓↓

ALBA

ALBA
2

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I had designed the waste pipes with rodding points and no 90 degree bends but the builder decided that he could build it better and quicker without the rodding points and put in 90 degree bends. I discovered this after one guest blocked their toilet and a second guest simultaneously left their sink tap running. The resulting mess appeared in a downstairs changing room, so for the first and last time in Bali I had to don my dry suit and clean it all up while wading ankle deep in “waste.”

I’m sure you are thinking, why did we not get a supervisor in to monitor all of the construction? Well, we did, but we also made the mistake of giving him the contract to build our balustrades and he spent all his time doing this rather than supervising.

The second lesson we learned is that, in the beginning, we should have bought 50% more land than we thought we needed. Once your business is up and running and you find you need more land, your neighbours will see this as indicative of your success and the price will go up. We have just had someone offer to lease us land for 12 times the price we originally paid!

What about staff?

To create positive relationships with the local villagers we decided early on to employ as many people from the village as possible and, at the moment, around 30 of our 40 employees live less than 200m away from the resort.

However, even though we are doing our bit to help the community, it seems there is always someone who, for whatever reason, jealousy, badness, revenge whatever, will do their utmost to cause problems for you within the village. In one instance, we wanted to build an access ramp into the sea to make it easier and safer for divers to get into and out of the water.



One villager complained that the construction of this was outwith the local bylaws and persuaded the village elders that we could not use it. So we had to remove it. The person who complained had previously worked for us as our dive manager and had left us for what he saw as greener pastures elsewhere. Subsequently, after we had become the biggest employer in the area, he asked to come back but someone else had taken his post and was doing a great job. So the answer was “No.” Then the hate campaign began. After much negotiation, the access ramp has now been re-installed!

As for taking on overseas staff, the employment laws here are quite strict, as they are in many countries. So it costs you a lot of time and money to employ people from outside Indonesia legally. It is not always worth the effort and expense. You have to pick and choose with care and, even then, you may be surprised.

One instructor was asked to teach a course and flatly refused. Her bizarre excuse was that they were not students she had recruited, they were just guests at the resort. Another instructor left because he didn't “like being told what to do.” Yet another instructor fell in love with one of the guests and ran away with him. And finally, we had an instructor who, while he was working for us, as we later discovered, was spending all his days off building a rival dive centre down the coast!

What other advice would you give to someone wanting to embark on a journey like yours?

Buy the best equipment you can afford. It will prove its worth time and time again. Get it from a local supplier, even though it may be more expensive. You are more likely to be able to solve problems that arise and it is a good idea to develop as many good relationships in the local diving community as possible. Don't expect your staff to

look after the equipment as you would. Appoint someone reliable to maintain it and check it after use, or do it yourself.

Listen to all complaints with an open mind but do not let the good or the bad comments get you too excited or bring you down. In this age of social interaction it only takes a few minutes of someone's time to discredit your resort but, if there is a valid complaint, go out of your way to rectify it.

A guest once complained on a travel page that they could not sleep at night due to the air conditioning unit. Was it too cold? Not cold enough? Was it leaking? Was it noisy? No, in the complaint was that the green “on” light was too bright. They stayed for 5 nights and did not mention it until they were already home, when they wrote the review. Had they mentioned it at the hotel, we could just have put masking tape over it.

There have been a few justified complaints too. While we were away, guests wrote and complained the the kitchen service was slow. It turned out that the kitchen staff were all engrossed in an episode of a soap where the main character was going to be killed off. The remedy? Tell the staff that guests always come first and move the TV elsewhere.

What about the diving aspects of running a resort?

Diving agencies will want you to become part of their network but choose carefully. Make sure that you buy into associations that will enhance your brand and confer a badge of quality. Avoid those that may seek to put restrictions on your ability to do business.



TRIMIX
CONTINUOUS BREATHING #3

Helium Mix	Helium %	Oxygen %
18-35	10.7	18
25-29	11	25
8-60	8.4	8
18-40	11.9	18
10-50	10.5	10
21-35	12.8	21

Some agencies confer recognition on you and then use your status as a lever to persuade you to tie yourself to them exclusively. Watch out also for agencies that vaunt their standards but then drop these standards in order to expand their network. As the agency's standards fall, so does your reputation, because you are part of their network.

Make safety your watchword, genuinely. Provide your staff with proper first aid training. Have fire extinguishers throughout the resort and have all staff trained in their use. Carry oxygen for divers in your boats and beach dive transport and make sure dive staff and boat and van drivers all know how to use it.

The Divers Alert Network carried out a survey in our area a few years ago. They went round all the dive centres and resorts and asked what safety equipment they carried. Many had no oxygen. The stock answer to the question "why not?" was, "we have never had an incident so why do we need it. It's expensive stuff and anyway, if we need it, the company next door will lend us theirs." This seems to be an all-too-common attitude in many dive destinations.

Make sure that this safety first approach applies to all aspects of your operations. Our dive gear is changed out every two years, our breathing gas is supplied only from our own compressors into our own cylinders. We regularly send air samples off to Singapore for independent gas analysis. We only use our own transport fleet, (again our vehicles are renewed every two years), and our own drivers to move our guests about. We have contingencies in place for all eventualities. This means, for example, two main compressors plus a back up petrol driven compressor: our own electrical generator in case the public supply is interrupted and our own water well for the same reason.

Make sure, right from the beginning, that your compressor and booster facilities are set up and laid out with the future in mind. If you have a well-organised and professional operation, word will get around, demand will increase and your capacity requirements will grow. If you build it WELL, they really will come! So you must design your systems so that you can grow and still remain efficient and functional. Many technical instructors in Southeast Asia and further afield have discovered our facilities and like to use them when they train their students, instead of investing in their own equipment or transporting it to Bali. They just come here and take advantage of ours. This, of course, is great for us, but it has put pressure on our systems in the past and we have had to expand to accommodate their needs as well as our own.

Why are there not more technical diving operations around?

On a percentage/return basis there is more profit running diving and doing courses for new divers than there is organising logistics and training for technical divers. We do it because it interests me and because, if you do it properly and your name gets around, you will find that a financial return on your investment will come, although it may take a long time.

If you had your time again, would you do the same thing?

We are often asked this question and the answer is a resounding yes. There have been moments we would not repeat but overall the plusses considerably outweigh the minuses.

You work long hours. Sometimes there are difficulties with guests and staff. However, when I get the two dogs ready to go for our 7 a.m. morning walk, I look out over that calm blue sea to where it meets the blue sky and see my dive boat sitting at anchor, I feel at peace with the world. After running the place for several years, all the problems

to date have been resolved and we have solutions in place to deal with future problems. And, something we didn't expect: when guests leave, we realise that they are guests no longer, but newly found friends.

There will always be times when you are up to your neck in the sort of stuff I found in that changing room but remember: keep your head up, smile and keep breathing!



Diving Ras Atantur
By Ayman Khaled



Ras Atantur is about 4 kilometers to the north of the most famous Nakhlet Altal site of Nabq protectorate. Just as we've done when we dove the *Maria Schröder* (more about that in my article in the 22nd issue of [Tech Diving Mag](#)), we entered the Nabq State Park from Sharm El Sheikh's gate with our Bedouin driver after loading his pickup with tanks, gear and O2/first aid kit. Nabq, the 600 square kilometer protected area located in the Sinai peninsula between Dahab and Sharm El Sheikh, is a very nice place for desert lovers, bird watchers and wild life photographers. It also hosts the most northern mangrove forest in the world.

Water entry is through walking on the reef table. There is no easy exit, so we scheduled our dive to end at high tide in order not to "climb" the reef table on exit. My buddy and I were geared with one air tank and a 50% nitrox sling, each.

The reef table has a very steep angle, literally forming a wall with a phenomenal diversity of dense coral life –mostly hard coral formations– that goes down to 16 msw to reach a sandy sea bed partially covered in sea grass and hosting sand eels. As our dive was in early June with some 25 meter visibility, we spotted some of the regular visitors on Nabq protectorate: eagle rays. After that lucky encounter, we continued exploring the scattered coral pinnacles down the steep sand slope to 45 msw. There's plenty of fishes out there. Jacks, groupers, triggers... you name it. Fish schools tend to concentrate on the coral heads. The slope goes down to probably more than 60 msw but we didn't plan on that.

To perform such a dive in a safe manner I recommend being least certified for light deco diving including using elevated oxygen content for accelerating the deco procedures.

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