Computer Decompression Simplified

Draft version 1.0
Computer generated dive profiles

- History of decompression theory

- Computer algorithms
  - Buhlmann - tables
  - Pyle - deep stops
  - Baker - Gradient Factors
  - Yount, Maiken, Baker - Varying Permeability Model (YMB-VPM)

- Dive profile recommendations
History of decompression theory

• Haldane
  – Tissue compartments
  – "Ascent limiting criteria"
• Workman
  – M-values for US Navy
  – Fast compartments tolerate greater supersaturation than slow
• Keller
  – Mixed gas algorithms
• Schreiner
  – Total inert gas partial pressure in a compartment is the sum of the partial pressures of all inert gases
• Buhlman
  – Combined all the above in one book
  – Theories proved using experimental research
  – M-values do not represent a reliable line between no symptoms and massive symptoms
• Pyle, Baker, Yount, Maiken
  – New generation algorithms
Pyle deep stops

• Learned the importance of deep stops from own experience
• Calculation Method
  – Calculate normal decompression profile
  – Take bottom depth and first decompression stop depth and find the midpoint
  – Add a safety stop at the midpoint and recalculate the decompression profile
  – If the distance from the midpoint and first decompression stop is more than 10 meters add a second deep safety stop at the midpoint
  – Continue the above until there is less than 10 meters between the safety stop and first decompression stop
• Reduced excessive gradients in the fast compartments, but the gas loadings in the slower compartments may be closer to the M-values at shallow stops due to the increased uptake caused by the deep stops.
Buhlman table vs. Pyle deep stops

Graph: © Erik Baker

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by: petri.karjalainen@pp.inet.fi

Graph: © Erik Baker
Baker Gradient factors

- Assumes that large and/or rapid overpressure gradients in a decompression profile presumably create more bubbling
- Defined the decompression zone to be between the M-value line and the ambient pressure line. Algorithm modifies allowable overpressure gradients within this zone.
- Introduces user adjustable gradient factors with linear function (GF Lo controls deep stops, GF Hi controls surfacing value)
Yount Varying Permeability model

- Based on bubble mechanics
  - The bubble will shrink or grow depending on the relation of external vs. internal pressure and is affected by surface tension
- Assumes that oxygen window also controls the bubble elimination not only the pressure gradient
- Optimum depth to eliminate bubbles is as deep as the oxygen window can be opened (This in practice eliminates the 3m stop)
- Bubbles can form during stops due to the improper gas switches (Isobaric counter diffusion)

Equilibrium:
External Pressure = Internal Pressure
\[ P_A + P_S + P_E = P_{N_2} + P_{H_2O} + P_{CO_2} + P_{O_2} \]

Graph: © Eric Maiken
Varying Permeability model background

• Yount and Hoffman VPM
  – 1986: First single dive algorithm

• Yount-Maiken-Baker VPM
  – Extended the algorithm to support multiple dives
  – 2001: Sourcecode freely available
  – Work dedicated to Yount who passed away April 27th, 2000
  – Limited amount of testing data available to estimate the DCS occurrence for different settings.

• Wienke RGBM
  – Extension of VPM algorithm
  – Has some different assumptions about bubble formation and growth
  – Source code is proprietary
  – Used by Suunto
  – Tested over 8 years by NAUI
RGBM vs. VPM by B.R. Wienke

1) RGBM does NOT use (VPM) gel bubbles as model for tissue and blood bubbles;
2) RGBM deduces bubble persistence time scales (how long they hang around) FROM seed skin structures (lipid or aqueous), not a-priori weeks as ASSUMED in the VPM;
3) RGBM bubbles are permeable to gas transfer DEPENDING on their skin structure always, NOT at some cutoff pressure as in the VPM gel studies;
4) biophysical equations-of-state (EOS) for lipid and aqueous substances relate seed pressure, temperature, diffusivities to gas transfer, and skin structure in the RGBM, and, as such are OUTSIDE the VPM;
5) the RGBM transfers gas across the bubble interfaces, the VPM does NOT;
6) See new book "Technical Diving In Depth" by Wienke (Best) for more on same subject.
7) RGBM tables (NAUI Tec nitrox, heliox_trimix Tables), meters (Suunto, Plexus, HydroSpace, "new" ones), and commercial software (ABYSS and some Tim O'Leary and I will release) ABOUND (the past 3 - 4 years), and collectively have logged many 10,000s of technical and recreational dives with only 2 reported cases of DCS. So, RGBM DCS incidence rate is virtually zero, especially on the technical envelope where it matters most as a model test. NOT SO to my best knowledge for the VPM as far as validation, testing and use, though the crude dynamics are likely similar.
8) RGBM successes span technical deco, altitude, and mixed gas diving, which are the real test of any model. Recreational diving is a rather simple limit point for the RGBM -- albeit, an important one just considering diver numbers, but one that tests virtually nobody's deco or staging mode, except for repetitive and reverse profile diving maybe.
9) the RGBM bootstraps parameters to diving data (DCS rate) using maximum likelihood, the VPM does NOT.
10) NAUI RGBM Tables for the recreational diver on air, EAN32, EAN36, from sea level to 10,000 ft elevations have been tested over the past few years, and are being released as simple, no-calc, no group, no-bull tables with simple rules for reps, flying-after-diving, SIs, etc. Check with NAUI Hqts, or NAUI Tec Ops
11) NAUI RGBM Tec Tables have been forged over the past 8 yrs from operations of the LANL Countermeasures Team, NAUI Tec Instructor Training Courses, reported WKPP extreme diving profiles, and 100s of field reports graciously sent to me (us) by the technical community (see TDID for more here).
12) Deep stops are natural to both the RGBM and VPM, but RGBM deep stops have NAUI Tec tests and stamps of approval down to 300 fsw on trimix -- ditto for the LANL Team.
13) RGBM modified Haldane meter algorithms are bubble folded schemes that exist in some deco meters, and have been used very successfully for repetitive, reverse profile, and multiday apps, but NOT so with the VPM.

With all due respects to my friend and decreased colleague, David Yount, I must go on record as NOT accepting that VPM gel dynamics apply routinely to the body, nor the properties he studied. Such VPM type bubble seeds have NEVER been found in the body -- nor outside of "gel-like" media. RGBM (EOS) bubbles do recover VPM bubbles in limiting circumstance of material strength and pressure, but that is not important to the RGBM. Naturally occurring bubble "seeds" in the atmosphere and oceans are NOT akin to VPM gel bubbles -- NOR should they be. The body, oceans, and atmosphere are NOT gel.
Oxygen window

- Gas in solution moves by diffusion from an area of higher partial pressure to an area of lower partial pressure.
- Blood that perfuse the lungs gives up CO₂ and absorbs O₂.
- Metabolically inactive gases such as He and N₂ are transported only in the dissolved phase in blood and the amount of gas present in blood is directly related to the gas partial pressure.
- When O₂ is bound to hemoglobin, it is no longer dissolved in solution and no longer contributes to the PO₂.
- O₂ is consumed and most of it is converted to CO₂ leaving a window (vacuum) which inert gasses can fill in.
- The principle factor in formation of the oxygen window is the a-v PO₂ difference.
- By reducing non-metabolic gas to a minimum and reducing tissue on-gassing, the oxygen window can be utilized to increase tissue off-gassing during decompression, but oxygen toxicity limits the utilisation of oxygen window.
Oxygen window effect at 6m stop

![Graph: © Eddie Brian](image)

**Figure 12**

**VENOUS BLOOD PARTIAL PRESSURES DURING DECOMPRESSION AT 20 FSW**

- Partial Pressure (mmHg)
  - 2000
  - 1600
  - 1200
  - 800
  - 400
  - 0

- Air Deco
- Oxygen Deco

- Ambient pressure at 20 FSW

Legend:
- Helium
- Nitrogen
- Oxygen
- Carbon Dioxide
- Water Vapor

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by: petri.karjalainen@pp.inet.fi

Graph: © Eddie Brian
Computer programs

- GAP (freeware)
  - v1.2 Gradient Factors
  - (v2.0 VPM)
  - Bailout scenarios
  - Graphical dive presentation
- V-Planner (freeware)
  - VPM
  - Stop time adjustments
  - Standard dives easy to access
- DPlan (59USD)
  - Palm software
  - Gradient factors
  - Ability to adjust stop times
Simplified summary
decompression theory findings

1. Bubbles are filtered in lungs
2. Small bubbles are easier to filter and less harmful, hence deep stops are recommended
3. Some elimination of bubbles is due to the venous-arterial pressure gradient difference through a process called diffusion
4. Therefore the oxygen window controls the bubble elimination, not only the pressure gradient, hence 6m/100% stop rather than 10m/80%
5. WKPP/GUE says that Nitrogen affects the rigidity of red blood cells, therefore for intermediate stops the diver should continue using Trimix with higher Oxygen content

- When breathing O2, the diver can reach a point where one do not anymore add the partial pressure difference - hence gas breaks with back gas can be calculated into the deco stop time.
- Some exercise and moving during recompression seems to be a good practice as if the circulation is reduced then the gas elimination is less efficient

These findings are based on a subjective research of the material listed at the end of this presentation, the author recommends that every diver needs to study and make their own decisions about these topics.
Practical recommendations and considerations

- Use of Gradient factors or VPM for deep stops is highly recommended based on the current knowledge.
- The dive plan with computer program only provides a framework for a plan and the user should include the following elements:
  - Maximize O2 window by defining at least 5 minute stop after Ean50 and Ean100 gas switches.
  - Use 6m as last stop, then slow ascent (1m/min) to the surface.
  - Between 21m and 6m use 3m/min (1 min stop in every 3 meters).
  - Deeper than 21m use max 10-18m min.
  - Stick to tested and widely used standard gasses to avoid isobaric counter diffusion and red blood cell damage caused by Nitrogen when planning and doing Trimix diving.

*These findings are based on a subjective research of the material listed at the end of this presentation, the author recommends that every diver needs to study and make their own decisions about these topics.*
Sources and references

- Pyle - The importance of deep safety stops
  www.bishopmuseum.org/research/treks/palautz97/index.html
- Baker - Understanding M-values
  Baker - Clearing up the confusion about “deep stops”
  Baker - Collection of narrative explanations of VPM
  ftp.decompression.org/baker
- Maiken - Bubble Decompression strategies
  www.decompression.org/maiken/home.htm
- Reinders - The varying permeability model
  ftp.decompression.org/reinders/
- Brian - Oxygen window
  Brian - Mechanisms of Hyperoxic seizures
  ftp.decompression.org/brian
- Winstanley, Korupka - Isobaric counter gas transport
  www.cavedivinggroups.org.uk/Articles/ICGT.html
- Deco discussion on GUE & tehciver discussion lists
  posts by G.Irvine
- GAP software
  www.gap-software.com
- V-Planner
  http://www.coastnet.com/~powercheck/vplanner/

- Special thanks to Erik Baker, Eric Maiken and Eddie Brian for comments and permission to use the graphics.