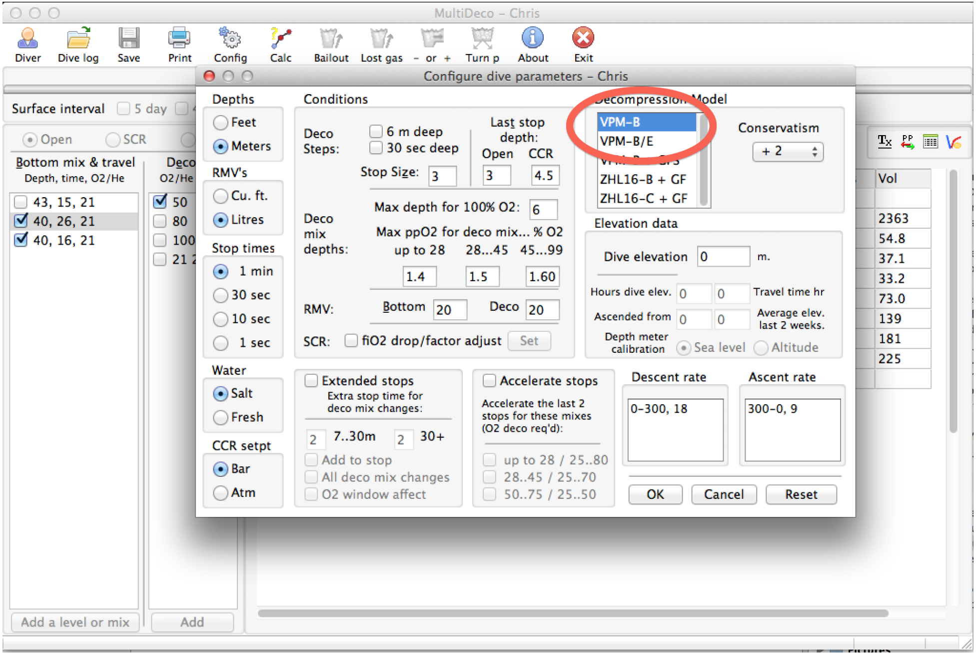
Chris Braissant

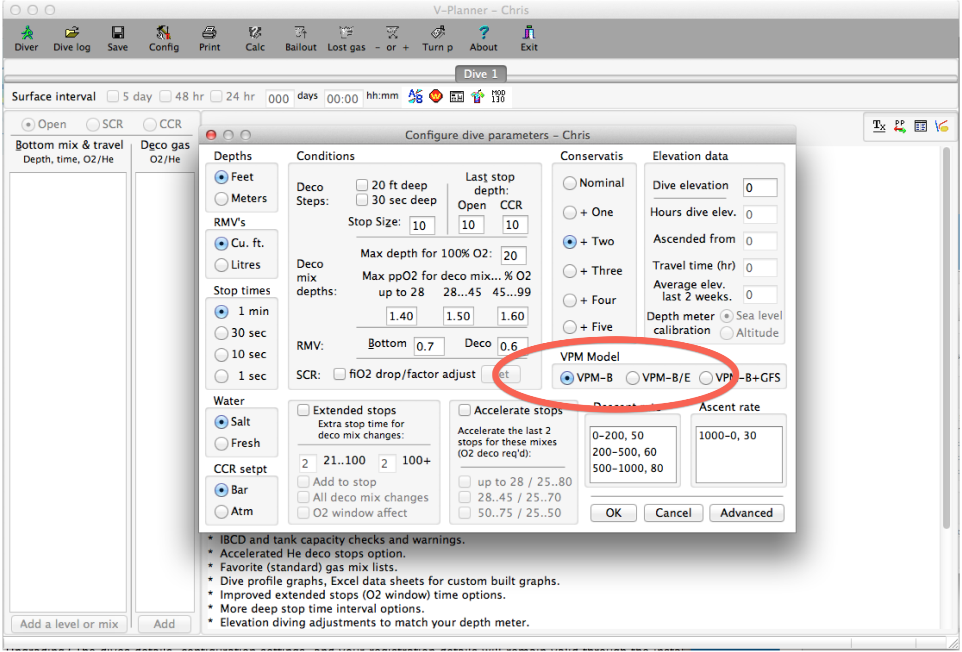
VPM - Variable Permeability Model

Ban’s Diving Resort

Introduction


MultiDeco - Chris
Diver
Dive log
Save
Print
Config
Calc
Bailout
Lost gas
- or +
Turn p
About
Exit
Surface interval
5 day
Open
SCR
Bottom mix & travel
Depth, time, O2/He
43, 15, 21
40, 26, 21
40, 16, 21
Deco
O2/He
50
80
100
21
Add a level or mix
Add
Vol
2363
54.8
37.1
33.2
73.0
139
181
225
Configure dive parameters - Chris
Depths
Feet
Meters
RMV's
Cu. ft.
Litres
Stop times
1 min
30 sec
10 sec
1 sec
Water
Salt
Fresh
CCR setpt
Bar
Atm
Conditions
Deco Steps:
6 m deep
30 sec deep
Last stop depth:
Open
CCR
Stop Size:
3
3
4.5
Deco mix depths:
Max depth for 100% O2:
6
Max ppO2 for deco mix... % O2
up to 28
28...45
45...99
1.4
1.5
1.60
RMV:
Bottom
20
Deco
20
SCR:
fiO2 drop/factor adjust
Set
Decompression Model
VPM-B
VPM-B/E
ZHL16-B + GF
ZHL16-C + GF
Conservatism
+ 2
Elevation data
Dive elevation
0
m.
Hours dive elev.
0
0
Travel time hr
Ascended from
0
0
Average elev. last 2 weeks.
Depth meter calibration
Sea level
Altitude
Extended stops
Extra stop time for deco mix changes:
2
7..30m
2
30+
Add to stop
All deco mix changes
O2 window affect
Accelerate stops
Accelerate the last 2 stops for these mixes (O2 deco req'd):
up to 28 / 25..80
28..45 / 25..70
50..75 / 25..50
Descent rate
0-300, 18
Ascent rate
300-0, 9
OK
Cancel
Reset

- Introduction
  - Multideco
  - Importance to understand VPM
  - Objective
  - Outline
- Presentation
- Summary




●●●○○ dtac E
03:17
41%
Dives
Settings
Next
Algorithm
Units
VPM-B
Metric
VPM-B/GFS
Imperial
ZHL16-B
RT: 40 DT: 24
7 decostops starting at 21
3msw/9min 6msw/5min 9msw/4min…
CNS: 7 OTUs: 18.1

Importance to understand VPM

What is that VPM-B and why is it important to know it?

- Popular decompression model
- Alternative to Buhlmann ZHL16
- Way to double check your schedule
- Understand your dive profile

Objective

Understand:

- Buhlmann dissolved model
- Bubbles behaviour
  - Diffusion with tissue compartment
  - Laplace pressure
  - Grow or shrink
  - Critical radius
- Principle of VPM model
  - How the model is made
  - Variable permeability
  - Bubble crushing
  - Algorithm
  - Variants

Outline

Topics:

- Dissolved Gas Model (Buhlmann ZHL16)
- Bubble behaviour
- VPM model

Presentation

Dissolved Gas Model

Dissolved Gas Model

Buhlmann ZHL16

- Gas dissolved in tissue
- 16 tissue compartments
- Compartments on-gas and off-gas a different rates (Half-Time)
- Track supersaturation in the tissue compartments
- Decompression stop when a compartment reaches the M-Value
- Pressure in a tissue compartment ("tissue tension") vary for each compartment

Bubble Behaviour

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A bubble will grow if the pressure pushing out is greater than the pressure pushing in

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Pressure pushing in:

- Ambiant Pressure
- Surface tension (Laplace pressure)

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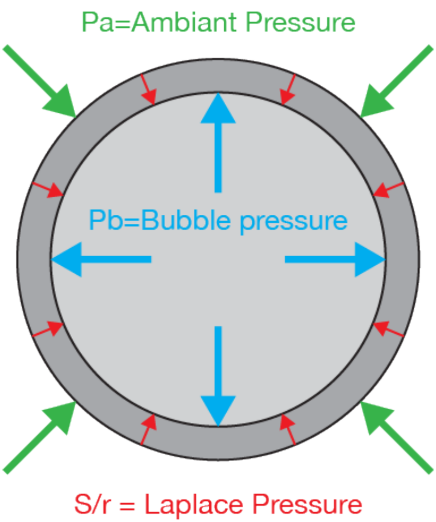

Comportment at saturation:

Equilibrium of pressure: (Stable bubble)

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Equilibrium of pressure: (Stable bubble)

$$P_{bubble} = P_{ambiant} + P_{Laplace}$$

Tissue tension around the bubble:

$$P_{tissue} = Partial\ pressure\ of\ inert\ gas$$

If the pressure in the bubble is greater than the tissue tension, gas will diffuse out.
The bubble would then shrink!

$$P_{bubble} > P_{tissue} \rightarrow Bubble\ shrinks$$

Exemple:

A diver breating air at 40m:

$$P_{ambiant} = 5bar$$
$$P_{Laplace} = 0.5bar$$
$$P_{bubble} = P_{ambiant} + P_{Laplace} = 5.5bar$$

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Pressure in the tissue compartment:

$$P_{tissue} = FN_2 * P_{ambiant} = 0.79 * 5 = 3.95bar$$

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The bubble pressure in greater than the tissue tension, the bubble would then diffuse out and shrink

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Ascent:
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The gas will diffuse in and the bubble will grow.

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The pressure in the bubble would drop below the tissue tension.

The gas will diffuse in and the bubble will grow.

Hence the decompression stop to allow the tissue compartment and the bubble size to adjust

Exemple:

Same diver as the before, ascending quickly to 20m:

$$P_{ambiant} = 3bar$$
$$P_{Laplace} = 0.5bar$$
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Pressure in the tissue compartment (don't have time to offgas):

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The bubble pressure is lower than the tissue tension, the bubble would then on-gas and grow

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Another factor will affect the growth of a bubble: its radius

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The bubble pressure will also decrease, and the bubble will grow faster!

Large bubbles grow, small bubbles shrink

Critical radius:

Maximum radius a bubble can have to maintain an adequate Laplace pressure

Bubble Behaviour

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Maximum radius a bubble can have to maintain an adequate Laplace pressure

Bubbles models try to control the size of the bubbles

Under a critical radius, bubble will shrink as the diver ascent

VPM: Variable Permeability Model

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- Same idea as Buhlamnn dissolved gas model
- 16 compartment tracking dissolved inert gases
- Add a single bubble to each compartment
- 16 bubbles in those compartments
- Dissolved gas and free gases (bubbles) interacting

VPM: Variable Permeability Model

Specific properties:

- Specific size indicated by its radius
- Varying permeability
- Defined skin
- Eleasticity and memory
- Gas pressure inside the bubble

Variable Permeability:

- "Skin" made of tiny balls (molecules)
- Dissolved gases from the tissue compartment diffuse through the skin (around the tiny balls)
- When the ambiant pressure increase, the bubble is compressed and the skin becomes impermeable
- Further crushing becomes more difficult
- Hence its name: Variable Permeablilty Model

Bubble crushing:

During the descent:

- Ambiant pressure increase
- Compartments on-gas follwing Buhlmann model
- Tissue tension in the compartment increase
- Bubbles are crushed
- Bubbles in slow compartement crush faster than in fast compartment

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Remark:

The bubble’s size is linked to difference of pressure between the ambiant pressure and the tissue tension

VPM: Variable Permeability Model

VPM Algorithm:

- Buhlmann track dissolved gases in the tissues compartment (tissu tension)
- VPM track the bubbles' radius
- VPM calculates bubbles' pressures during the ascent
- Bubbles grow only when pressure of the bubble exceed the tissue tension (VPM vs Buhlmann)
- Decompression stop before a bubble starts to grow

Original VPM algorithm

- Too conservative
- "no-bubble-growth model"

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Modifications made:

- Body can handle a certain amount of free gas
- DCS over a critical volume
- Allow bubbles from a certain size (critical radius) to grow
- "not-too-much-bubble-growth model"

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Bubble population:

- Numerous small bubble, few large bubbles

VPM: Variable Permeability Model

Latest modifications:

VPM-B:

- Incorporates Boyle's law to the bubbles behaviour
- Note bubbles' size at the first stop
- Increase the radius of each bubbles for next stop according to Boyle's law
- Tissue tension allowed for the next stop is reduced due to the larger bubble radius
- Add conservatism to the profile

VPM-B/E:

- Add conservatism for extreme dives

Summary

Key points

Key Points:

- Buhlmann dissolved model
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  - Diffusion with tissue compartment
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Quizz

Question 1:
How many tissue compartment does VPM use for it's Buhlmann model?

(a) 8
(b) 12
(c) 16
(d) 24

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Answer:(c)
The model in that presentation is the Buhlmann ZHL16

Quizz

Question 2:
To what kind of model does the Buhlmann ZHL belongs to?

(a) Dissolved Model
(b) Bubble Model
(c) Reduced Gradient Model
(d) Variable Permeability Model

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Answer:(a)

Question 3:

Why would a bubble grow

(a) Pressure pushing in greater than pressure pushing out

(b) Tissue tension greater than bubble pressure

(c) Skin becomes impermeable

(d) Ambiant pressure increase

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Answer:(b)

Question 4:

Why does a bubble becomes impermeable?

(a) High pressure squeezes molecules against each other

(b) The thickness of the skin is too small

(c) Tissue tension exceed the M-Value

(d) Bubble pressure in null

Quizz

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Why does a bubble becomes impermeable?

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Answer:(a)

Question 5:
What is the main reason of DCS according to VPM model?

(a) Tissue tension exceeding the M-Value
(b) Amount of free gas in the body
(c) Supersaturation of the tissue compartment
(d) The size of the bubble in the slow compartment

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Answer:(b)