DECOMPRESSION THEORY AND THE RDP

The Haldanean Decompression Model:

Virtually all dive tables and dive computers calculate no decompression limits and decompression stops (when needed) based on a *Haldanean decompression model.* This is named after John Scott Haldane who developed the first such mathematical decompression model and based on it the first dive tables in 1906.

Modern decompression models are based on the same ideas.

When the diver descends to a given depth, the nitrogen pressure in his breathing air is higher than the nitrogen *tissue pressure* in his body, so more nitrogen dissolves into the body tissues.

With enough time, the nitrogen pressure equalizes, and the body cannot take on any more nitrogen. This is called *saturation*.

When the diver ascends the nitrogen *tissue pressure* in the body becomes higher than the nitrogen pressure in his breathing air, causing the tissues to release nitrogen to equalize the nitrogen pressure again.

The difference between the dissolved nitrogen tissue pressure and the nitrogen pressure in the breathing air is called the *pressure gradient*. Whether the diver is descending or ascending.

When the diver ascends the tissues can tolerate some gradient of high tissue pressure without causing decompression sickness.

If the *pressure gradient* exceeds acceptable limits (*supersaturation*), bubbles may form and cause decompression sickness.

Decompression sickness can be avoided by keeping the gradient within acceptable limits.

This means the diver must stay within the limits dictated by his table or computer and maintain a slow ascent rate as indicated by his tables or computer.

Haldane discovered that different parts of the body absorb and release dissolved nitrogen at different rates – *slow and fast compartments*.

To account for these differences he constructed a model consisting of five theoretical tissues.

These theoretical tissues do not directly correspond to any particular body tissue so they are called compartments or tissue *compartments*. The **RDP** has **14** compartments.

Each compartment has a ***halftime*** for the rate at which it absorbs and releases nitrogen.

Halftime is the time, in minutes, for a compartment to go halfway from its beginning tissue pressure to complete saturation.

After one halftime the tissue would be 50% saturated

After two halftimes the tissue would be 75% saturated

After three halftimes the tissue would be 87.5% saturated

After four halftimes the tissue would be 93.75% saturated

After five halftimes the tissue would be 96.875% saturated

After six halftimes the tissue would be 98.4375% saturated

It would never reach 100% using the halftime concept, so after *six halftimes the tissue compartment is considered full or empty.*

Haldane's original halftimes ranged from 5 to 75 minutes.

The RDP's halftimes range from 5 to 480 minutes, split over 14 compartments.

They are 5, 10, 20, 30, 40, 60, 80, 100,120, 200, 240, 300, 360 and 480 minutes.

Sometimes tissue pressure is expressed in metres of seawater (gauge) - msw.

Example: A 5 minute halftime compartment will have a tissue pressure of 9msw after 5 minutes in 18 metres of seawater.

Example: A 20 minute halftime compartment will have a tissue pressure of 18msw after 40 minutes in 24m of seawater.

Example: A 60 minute halftime compartment will take 360 minutes (6 hours) to saturate to a given depth. (60 x 6 halftimes).

Besides different halftimes each compartment has a different ***M-value****.*

The ***M-value*** is the maximum tissue pressure allowed in the compartment when surfacing to prevent exceeding the acceptable gradient.

There are actually different M-values for each compartment at different depths, these are used to calculate decompression schedules. *In no decompression diving we only use the one that applies to the surface*

The *slower* the compartment, the *lower* the M-value.

The *faster* the compartment, the *higher* the M-value.

The M-value is determined by test dives showing what does and what does not result in Doppler detectable bubbles.

Remember that the M-values are calculated for surfacing at sea level which is why you need to apply special procedures when diving at altitudes above 300m.

When any compartment reaches its M-value the dive ends or it becomes a decompression dive.

On deeper dives faster compartments will reach their M-values first, hence deeper dives have short no decompression limits.

On shallower dives, the depth is not enough for the faster compartments to reach their M-values. Therefore a slower compartment controls the dive and the model allows more no decompression time.

The compartment that reaches its M-value first is called the *controlling compartment.*

These models are mathematical extrapolations; there is no ***direct*** relationship between the decompression model and the human body. This is why divers learn that there is always some risk of DCS even within table/computer limits and are asked to dive conservatively within the limits.

US Navy tables:

The first dive tables to be widely used and adapted to recreational diving where the U.S.Navy tables designed in the 1950's.

Six compartments were used with a slowest halftime of 120 minutes.

While at the surface all compartments would lose nitrogen at a different rate depending on their halftime. Any compartment could control a repetitive dive, depending on the first dive, the surface interval and the second dive.

To solve this problem the U.S.Navy designed its surface interval credit on the worst case scenario, the slowest compartment (120 mins). This is why it takes 12 hours (720 mins. 6 x 120) to be "clean" when using their tables.

These tables were tested with US Navy divers, subjects were all male in their 20's and 30's and reasonably fit. The test criteria were bends/no bends.

The Recreational Dive Planner (RDP):

In the mid-1980's, Dr. Raymond Rogers recognized that the USN tables were not ideal for recreational diving.

The 120 minute half time used for surface interval credit, while appropriate for decompression diving, seemed excessively conservative for recreational divers making only no-decompression dives.

The test group the USN used didn't reflect recreational divers who include females and people of all ages.

New technology in the shape of Doppler ultrasound flowmeters had come into being ; these showed that silent bubbles often formed at USN table limits, suggesting lower M-values would be more appropriate for recreational divers.

With the help of DSAT (Diving Science & Technology), Rogers developed the RDP. It was tested in 1987/88 at the Institute of Applied Physiology & Medicine with Dr. Michael Powell as the principal investigator.

A 60 minute gas washout tissue was used. Multi-level diving was tested with a large range of *test subjects - recreational divers*. Limited to Doppler detectable bubbles instead of bends/no bends. Tested to the limits for 4 dives per day for 6 days. Though more conservative diving practices are recommended.

Dr. Rogers found that the old 120 minute gas washout tissue was too conservative for recreational diving and adopted *a 60 minute gas washout tissue*.
This means you get twice as much credit for surface intervals and are clean in 6 hours. The WXYZ rules make sure the slower compartments stay within limits.
Dr. Rogers also lowered the M-values to match recent Doppler data. These are sometimes called Spencer limits after the physician who first proposed them.

They produced different versions of the RDP. The table version, (because that's what divers were familiar with) and the multilevel electronic planner eRDPML version (originally the Wheel), to enable you to calculate multi level profiles. DSAT have also produced four tables for enriched air diving. Tables for using EANx32 and EANx36 an equivalent air depth table and an oxygen exposure table.
The pressure groups from all versions of the RDP are interchangeable.

The RDP works on 14 compartments, instead of the 6 used in making the U.S. Navy tables.

You cannot use PADI RDP pressure groups with other agencies' tables.

Dive Computers:

Dive computers offer maximum bottom time by essentially writing a custom dive table for the dive undertaken – this eliminates unnecessary rounding and therefore gives more dive time.
There are essentially 5 different groups of models or algorithms used in the many computers available to the recreational diver. This will normally be described in the instruction book for the particular computer. They are being developed all the time with diver safety in mind as more research is done.

1. Spencer limits, EE washout

- Same M-values as RDP
- All compartments release nitrogen at the surface at their underwater halftime rates.
- Can permit dives that are beyond what is safe, i.e. short deep repetitive dives with short surface intervals.

2. Spencer limits, 60 minute washout
    - Based on data for the RDP
    - Dives similar to what the RDP allows.

3. Buhlmann limits, EE washout
    - Further reduced M-values
    - All compartments release Nitrogen at the surface at their underwater halftime rates.
    - Because of the reduced M-values similar to what the RDP data supports despite the EE washout.

4. RGBM (Reduced Gradient Bubble Model) and others.
    - Research is providing lots of new information on the behavior of divers and micro bubble build up.
    - Most dive computer models take this into account
    - If a diver exceeds a safe ascent rate on one dive he will be penalized on repetitive dives, the same with yoyo profiles.
    - Some take the water temperature into account and adjust accordingly.
    - Nearly all have altitude settings and settings for conservatism.
    - Some are integrated with air supply and take the divers breathing rate into account.
    - Nearly all models now support Nitrox diving.
    - Some support gas switch extended range and technical diving.
    - Some support trimix and CCR diving.

PADI Recommendation for Diving with Computers:

- Divers should not attempt to share a dive computer.
- Each diver must use the same computer through a series of dives.
- Each diver must have his own computer.
- Computers have the same theoretical basis as tables so one is neither better nor safer than the other.
- All standard guidelines apply, such as deepest dives first.
- Follow all manufacturers' recommendations.
- End the dive based on the most conservative computer of a buddy team (you're supposed to stick together anyway)!
- If a computer fails whilst diving, ascend slowly to 5m and make a long safety stop as long as your air supply permits. You should then remain out of the water for 12 – 24 hours, so you can start clear again with another table or computer.
- Make sure it is capable of altitude diving if diving at altitude.

- Do not lend you computer to another diver if either of you have been diving.
- Do not use a computer from another diver if either of you have been diving.
- Do not try to change the battery between dives or underwater.
- If it caters for mixed gas make sure it is set to the gas you are using.
- Do not use the computer if it is displaying any error or not functioning correctly
- When you turn your dive computer on, do not turn your brain off, after all the latter is a better computer!