Teaching Oxygen Tracking

by Kevin Gurr, IANTD UK

Having travelled most of Europe and parts of America teaching Nitrox, it has become apparent that there is a level of misunderstanding with regard to the rules for teaching students oxygen tracking at the various levels. This article is offered as the **definitive *safe* teaching standard** and as a provision for demarcation between the Nitrox qualifications.

Basic Nitrox

The EANx course is defined as a *replacement for air* program and assumes the diver will be undertaking no decompression diving. The course teaches the student the use of Nitrox tables or offers the use of air tables for safety while breathing Nitrox mixes. 28% through 36% Nitrox are introduced in tabular form as the *standard mixes* for use over the sport diving range. The NOAA oxygen exposure table is the prime calculation guide at Basic Nitrox level.

CNS Oxygen Toxicity is expanded upon from a signs and symptoms standpoint and *Pulmonary Toxicity* is mentioned in summary although pulmonary calculations do not take place as this problem is assumed to be within the safe limits of the NOAA table.

Rules

Oxygen Exposure Time

This *oxygen exposure time* for a dive is compared against the *Single Dive Exposure Limits* on the NOAA table.

If a diver reaches the limits of the Single Exposure Time on a single dive then they must take a two hour interval at the surface, breathing normal normoxic air.

If two dives are conducted with less than a two hour surface interval, the in water times are added together and compared against the *Single Exposure Time.* If one dive is at a greater PPO2 than the other, the greater PPO2 is taken using the NOAA table with the combined in water times of the two dives.

If two or more dives are conducted within a single 24 hour period with more than two hours at the surface between each dive, then the in water times are added and compared against the *Daily Limit* for the highest PPO2 dive of the day.

If a series of dives in a 24 hour period reaches the *Daily Limits,* then a 12 hour surface interval breathing normoxic air must be taken before diving again.

1.6 bar is the maximum PPO2 allowed providing no stop diving limits are adhered to, although 1.5 bar is recommended for Northern European waters. 1.4 bar is used where there is exertion on a dive.

Advanced Nitrox

This course is defined as a *Limited decompression* program and is aimed at the experienced diver who wishes to take the full advantage of recreational Nitrox without undertaking *technical level* exposures. The course teaches the student the *best mix concept* for ascertaining the optimum Nitrox mixture for a given depth and dive time. It also teaches the use of Nitrox

50 either as a safety decompression gas or for use with Nitrox 50 decompression tables to reduce decompression obligation.

The EAD concept is expanded upon, in order to customize air tables for a range of optimum EANx mixtures. This course defines both CNS and Pulmonary oxygen exposure toxicity as isolated problems and provides calculations for both. The NOAA oxygen exposure table is the source of the calculations for the CNS oxygen limits at Advanced Nitrox level.

Rules

Oxygen Exposure Time

This is taken as total *Decompression Bottom Time*(time from leaving surface to leaving the bottom) from the dive tables (Buhlmann/USN). Where a single gas is breathed throughout the duration of the dive (including decompression stops), it is assumed that any time at the stops can be ignored from a toxicity standpoint (as can the ascent to the stop/surface). This is possible because most of the decompression stops will have a PPO2 of less than 0.5 if this *Bottom Mix* is used. The Oxygen Clock is assumed to stop at a PPO2 of 0.5 on the ascent and actually start to reduce at a PPO2 of 0.35 and less. Hence allowing us to ignore *stops on Bottom Mix* and also allow for a reduction in the oxygen load as the surface interval increases.

Where a switch to a decompression gas (in this case, EANx 50) is made, then the CNS and Pulmonary (UPTD) additions must be calculated for individually at each decompression stop and added to the CNS and Pulmonary oxygen figures for the bottom portion to the dive.

CNS%/minute

Again based on the NOAA single exposure times, the CNS% load for every minute of exposure at that PPO2 is extrapolated and found in tabular form in the Advanced Manual.

a**Ex.** If a diver spends 45 minutes at a PO2 of 1.6 bar (ref. NOAA single exposure limit), then they can be said to have used 100% of their *Oxygen Clock.* Hence 1 minute of the total allowed exposure as a % would be:

1/45 x 100 - 2.22% for every minute at a 1.6 bar PPO2

The table in the manual shows a %/minute for most PPO2s. This %/minute is multiplied by the *Decompression Bottom Time* to give the % CNS for the dive (assuming no decompression gas with a high FO2 (above 40%) is used at the decompression stops). Any decompression stops conducted on an elevated FO2 compared to *bottom mix* must have their CNS and pulmonary load calculated for separately and added to the bottom time oxygen exposure of the dive. As a rule, an 80% CNS exposure is the maximum planned for. If a diver reaches an exposure of 80% on a single dive then they must take a two hour interval at the surface, breathing normoxic air.

Multiple dives may be conducted providing that the final CNS exposure in a 24 hour period does not exceed 80%. If the 80% figure is reached, then a 12 hour surface break breathing normoxic air must be taken. Where repeat dives are conducted with a surface interval, a 50% surface reduction in the CNS load (breathing normoxic air) is assumed for every 90 minutes at the surface. **Ex.** Dive 1 generates a load of 40%. After 90 minutes this falls to 20%. After a further 90 minutes this falls to 10% etc. This *Residual CNS* load is added to the next dives CNS load to give the two dive total at the end of the second dive.

If the 90 minute period has not been reached, then no reduction is assumed and the CNS loads for each dive are just added together. **Ex.** Dive 1 generates 40% CNS load. After an 80 minute surface interval there is another dive which generates a load of 20%. The total CNS at the end of dive 2 is 60%. No reduction is assumed (80 minute surface interval).

Pulmonary toxicity is calculated for using the Unit of Pulmonary Toxicity Dose (UPTD). The UPTD/minute table in the manual is used. The UPTD/minute value is again multiplied by the decompression bottom time and stops added separately if Nitrox 50 is used during decompression. There is assumed to be no surface reduction of UPTD's and UPTD's/dive are simply added to give a daily or mission total.

The maximum number of UPTD's allowed for a day's diving is 850. A recommended planning limit of 300 units/day is offered to allow for continuous, safe Nitrox diving. It must be stressed at this point that the UPTD differs from the OTU (Oxygen Tolerance Unit) by the method with which continuous diving is monitored (the OTU relates to the REPEX method pioneered by Dr. Bill Hamilton). At Advanced EANx level no calculation method is taught for multiple days of diving at elevated oxygen exposures. Hence the above recommendation of 300 units per day is proposed as a simple tracking method.

A PO2 limit of 1.5 bar is recommended for planning *best mix dives,* with 1.4 for a working dive. A limit of 1.6 is taught to define the *Maximum Operating Depth*(MOD) of the mix as opposed to the *Target Operating Depth*(TOD) set by the 1.5 limit. Students are encouraged to plan for the TOD and MOD on a dive and know where each depth occurs.

Technical Nitrox

This course is defined as an *Extended Range, Technical Diver* program and is aimed at the Basic or Advanced Nitrox Diver who wishes to maximize the use of Nitrox or progress to Cave, Wreck or Trimix Diver level. The course teaches the student extended range oxygen exposure management. It also teaches the use of single or multiple decompression gasses to reduce decompression obligation and stay within the oxygen clock.

The EAD concept is expanded upon, in order to customize air tables, for a range of optimum Nitrox mixtures. Various decompression tables are offered along with teaching the use of PC decompression software programs.

The course defines both CNS and Pulmonary oxygen toxicity as isolated problems and provides calculations for both. The Technical Nitrox oxygen exposure table is the source of the calculations for the CNS oxygen limits and exposure limits to a maximum PPO2 of 1.82 bar are detailed. OTUs and the REPEX (REPetitive EXposure) method of tracking multiple days of elevated oxygen exposure are used as the source for Pulmonary oxygen toxicity calculations.

Rules

Oxygen Exposure Time This is taken as total *Decompression Bottom Time* from the dive tables (Buhlmann/USN). Where a switch to any decompression gas is made, then the CNS and Pulmonary (OTU) additions must be calculated for individually at each decompression stop and added to the CNS and Pulmonary oxygen figures for the bottom portion of the dive.

CNS% Minute The %/minute table is used in the Technical EANx manual. The table in the manual shows a %/minute is for most PPO2s. This %/minute is multiplied by the *Decompression Bottom Time* to give the %CNS for the dive (assuming a no decompression

gas switch dive). Any decompression stops conducted on an elevated FO2 compared to *Bottom Mix* must have their CNS and pulmonary load calculated for separately and added to the bottom time oxygen exposure of the dive. Up to 100% CNS exposures are managed and the concept of *Air Breaks* is introduced.

Where repeat dives are conducted with a surface interval, a chart in the Technical Manual allows for a range of surface intervals and calculates surface reduction of the CNS oxygen load for each.

Pulmonary toxicity (Oxygen Tolerance Units) are calculated for, using the OTU/minute table in the manual. The OTU/minute is again multiplied by the decompression bottom time and stops added separately if an elevated FO2 Nitrox is used during decompression (greater than 40%). There is assumed to be no surface reduction of OTUs. OTUs per dive are simply added to give a daily or mission total. Daily totals are compared against the REPEX table. A PO2 limit of 1.5 bar is used for planning *best mix* dives.

Certain reductions to the PPO2 limits for the bottom and decompression portions of the dive are taight if certain conditions prevail. These are: ***Bottom Portion*** A reduction of 0.05 PPO2 for each of: High PPO2 decompression Extreme Work Extreme Cold Hence a cold, hard working dive would use a PPO2 for the bottom mix of 1.4 bar(1.5-0.05 - 0.05). ***Decompression Portion*** A reduction of 0.025 PPO2 for each of: Extreme cold Extreme work Hence a cold, hard working decompression would use a maximum PPO2 1.55 bar (1.6 - 0.025 - 0.025). A limit of 1.6 is taught to define the *Maximum Operating Depth* (MOD) of the mix as opposed to the *Target Operating Depth* (TOD) set by the 1.5 limit.

1.6 bar is also taught as the maximum PPO2 to use at a resting decompression. For each decompression gas that is planned, this PPO2 would be used at the deepest stop on each gas, hence maximizing nitrogen outgassing while staying within the limits of the oxygen clock.

Should the oxygen clock exceed the recommended limit (80%), then 5 minutes on a lower PO2 is recommended for every 25 minutes of exposure. Hence while the total plan is to stay within 100% for the total decompression time, as the 80% figure is reached, a 5 minute *Air Break* is undertaken. At the next 25 minute interval or at the 100% oxygen clock (whichever is the sooner) another *Air Break* is taken. This process continues until the decompression is completed.

Ex. The bottom portion of the dive creates a 50% CNS oxygen load, after 30 minutes. The decompression is planned to be 100% oxygen at 6 msw/20 fsw for 22 minutes. The decompression phase will create almost a 50% load (2.22 x 22 0- 48.84%).

After approximately 13 minutes, 80% CNS is reached. The decompression timer is then stopped and a 5 minute air break is started. The *Run Time* is now 48 minutes (ignoring ascent time) after the *Air Break*. After a further 9 minutes on 100% the decompressin is 57 minutes, all decompression has been completed and the oxygen clock is at approximately 100%. Hence the total time spent at 6 msw/20 fsw is 27 minutes compared to the required 22 minutes of actual decompression.

Students are encouraged to plan for the TOD and MOD on a dive and know where each depth occurs. The TOD is also stressed for the decompression gasses. Extended oxygen exposure physiology is also taught at Technical Nitrox Diver level.
