# Oxygen Toxicity Calculations

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Management of exposure to oxygen toxicity is an important element of technical diving. Most often this is accomplished during the dive planning stage through the use of a dive/decompression planning program on a computer. Having developed such a program myself using the good ole' FORTRAN programming language, I found that incorporating oxygen toxicity calculations was more involved than just a straightforward application of the established equations. Obtaining "exact" calculations during ascent or descent segments of a dive profile presented the main challenge. So I did some more research, dusted-off my calculus book, and came up with some calculation methods which I would like to share with the technical diving community. The information presented in this article is intended to serve as a primer or review for some and to offer programming suggestions for others.

## Background

Two oxygen toxicity parameters are typically "tracked" in technical diving calculations. The first is pulmonary oxygen toxicity which primarily concerns the effects to the lungs of long-term exposures to oxygen at elevated partial pressures. The second is central nervous system (CNS) oxygen toxicity which primarily concerns the effects to the brain of short-to-medium-term exposures to oxygen at elevated partial pressures. Both oxygen toxicity parameters are a function of the partial pressure of oxygen ( $PO_2$) in the inspired breathing gas and the time of exposure. CNS oxygen toxicity is usually the parameter of most concern and greatest impact in technical diving, however some "mega-dives" undertaken in the recent past (Bushmansgat, Zacatón, etc.) have pushed the limits of pulmonary oxygen toxicity as well.

The equation for calculating pulmonary oxygen toxicity was developed from empirically derived pulmonary oxygen tolerance curves such as represented in Figure 1. The curves were based on measurements of rate of decrease in vital capacity in "normal men" during oxygen breathing at elevated partial pressures. Vital capacity is the maximum volume of air (or gas) that a person can expel from his/her lungs after first filling the lungs to their maximum extent and then expiring to the maximum extent. The tolerance curves are hyperbolic with asymptotes of zero time and $PO_2$ = 0.5 which is the approximate threshold for detectable pulmonary effects. The curve representing a 4% decrement in vital capacity was used to develop technical diving exposure limits for pulmonary oxygen toxicity.

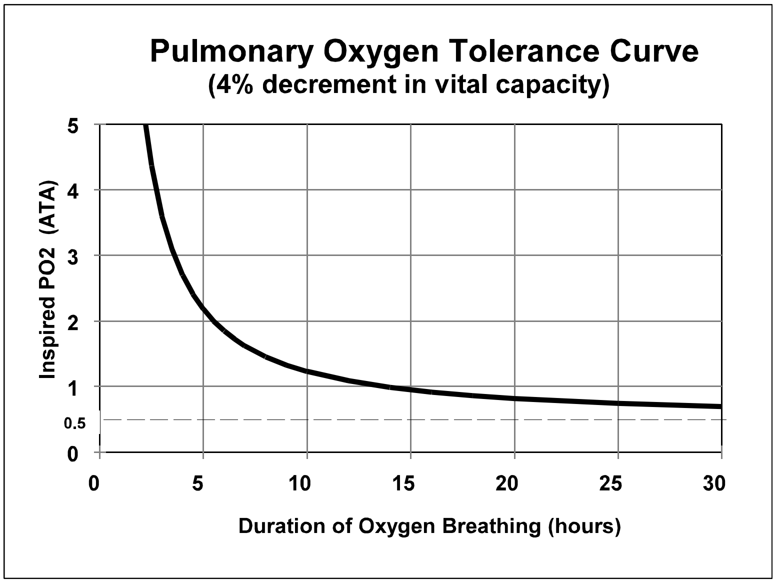

Figure 1

Along with the tolerance curves, Dr. Christian J. Lambertsen and colleagues at the Institute for Environmental Medicine, University of Pennsylvania, developed the current "tracking" method for pulmonary oxygen toxicity in the form of the unit pulmonary toxic dose (UPTD) and the cumulative pulmonary toxic dose (CPTD). The UPTD is more commonly referred to in the diving community as the oxygen toxicity unit (OTU). One UPTD (or OTU) is the degree of pulmonary oxygen toxicity produced by breathing 100% $O_2$ continuously at a pressure of 1 atmosphere absolute (ATA) for 1 minute. The CPTD calculation (see Equation 1 below) converts any continuous oxygen exposure ($PO_2$ above 0.5) and time combination to be expressed as UPTD's (or OTU's). The CPTD calculation is carried out for each segment of the dive profile and the results (expressed as OTU's) are summed up to produce the total number of OTU's for the dive. This number can then be compared against the daily and multi-day limits established by Dr. Bill Hamilton and colleagues in the NOAA Repetitive Excursions (REPEX) Procedures Report. These published limits have been widely adopted by the technical diving community.

The NOAA limits for CNS oxygen toxicity (normal, single exposure) are plotted in Figure 2. These limits are based on research by Drs. F.K. Butler and Edward D. Thalmann, U.S. Navy Experimental Diving Unit, and by Drs. Christian J. Lambertsen and Russell E. Peterson, Institute for Environmental Medicine, University of Pennsylvania. These limits take operational safety into consideration and have been widely adopted by the technical diving community. The common method in use to "track" CNS oxygen toxicity is to compute a "CNS fraction" for each segment of the dive profile and then sum up these results to produce a total CNS fraction for the dive. These fractions are often multiplied by 100 and expressed as a percentage (CNS %). A CNS fraction is calculated by taking the time spent at a given $PO_2$ and dividing by the NOAA time limit for that $PO_2$. When the CNS fractions from all segments of the dive profile add up to 1 (or 100%) then the overall limit for CNS oxygen toxicity has been reached for that dive.

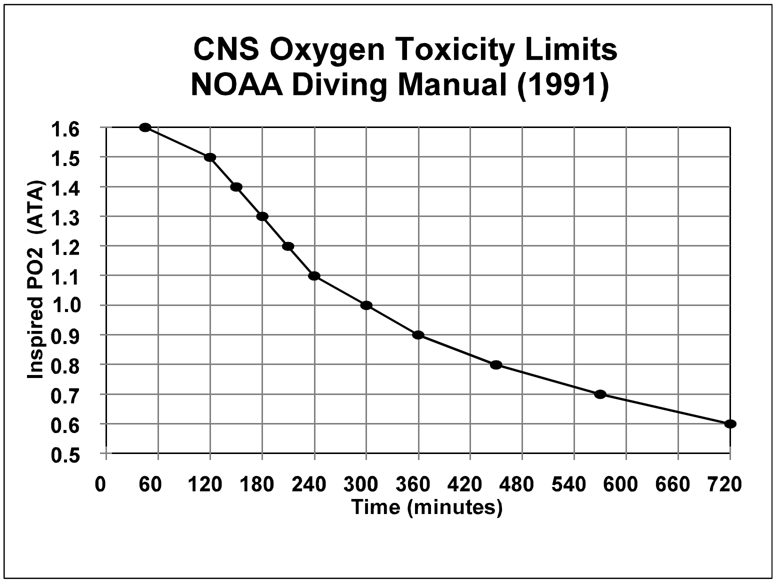

**Figure 2**

Since the NOAA limits for CNS oxygen toxicity are simply given as discrete data points, and not by a continuous mathematical function, it is convenient to "connect the dots" with straight lines as represented in Figure 2. In this manner, it is possible to create a series of linear equations which describe the CNS time limits for various ranges of $PO_2$. As demonstrated later in this article, this manipulation facilitates the calculation process, particularly by computer program.

For calculation purposes, oxygen toxicity is not defined at or below a $PO_2$ of 0.5. Whenever the $PO_2$ goes above 0.5 during a dive profile, either at a constant depth or during ascent or descent at a constant rate, the two oxygen toxicity parameters can be calculated.

One subject area regarding oxygen toxicity that this article does not address is that of "extension of oxygen tolerance." There is some limited data in the academic literature which indicates that the practice of intermittent oxygen breathing (i.e. 20 minutes on $O_2$, then 5 minute air break) can extend the limits of pulmonary oxygen tolerance by a factor of more than 2. Presumably, the CNS oxygen limits are extended by some factor as well. The problem is that, to my knowledge, a reliable method has not yet been developed to calculate the rate of recovery from oxygen exposure **during these periods of intermittent oxygen breathing**. This is an area for future research by the academicians. It is, however, a common practice in technical diving to calculate a decay in the CNS fraction **during surface intervals** using an exponential decay equation with a half-time of 90 minutes.

## Pulmonary Oxygen Toxicity Calculations

### Constant depth profile:

For a constant depth profile (in which the $PO_2$ remains constant), the cumulative pulmonary toxic dose (CPTD), expressed as oxygen toxicity units (OTU), is calculated by Equation 1:

$$\mathrm{OTU} = t_x \cdot \left( \frac{0.5}{PO_2 - 0.5} \right)^{\frac{-5}{6}} \qquad \text{(Eq. 1)}$$

where $t_x$ is the time of exposure, $PO_2$ is constant, and $\frac{-5}{6}$ is an exponent $\simeq -0.8333$.

### Ascent or descent profile at a constant rate:

For an ascent or descent profile at a constant rate (in which the $PO_2$ varies at a constant rate), the CPTD, expressed as OTU's, can be calculated by Equation 2:

$$\mathrm{OTU} = \frac{\frac{3}{11} \cdot t_x}{PO_{2_f} - PO_{2_i}} \cdot \left[ \left( \frac{PO_{2_f} - 0.5}{0.5} \right)^{\frac{11}{6}} - \left( \frac{PO_{2_i} - 0.5}{0.5} \right)^{\frac{11}{6}} \right] \qquad \text{(Eq. 2)}$$

where $t_x$ is the time of exposure over the interval, $PO_{2_i}$ is the initial $PO_2$ of the interval, $PO_{2_f}$ is the final $PO_2$ of the interval, and $\frac{11}{6}$ is an exponent $\simeq 1.8333$.

### Computer format:

In the FORTRAN programming language, Equation 1 can be written as:

```
OTU = TIME*((0.5/(PO2-0.5))**(-5.0/6.0))
```

while Equation 2 can be written as:

```
OTU = 3.0/11.0*TIME/(PO2F-PO2I)*(((PO2F-0.5)/0.5)**(11.0/6.0)
      - ((PO2I-0.5)/0.5)**(11.0/6.0))
```

**Discussion:**

As mentioned above, Equation 1 was developed by Lambertsen and colleagues from the pulmonary oxygen tolerance curves. Equation 2 can be derived from Equation 1 as follows:

Since the $PO_2$ varies at a constant rate with respect to time during an ascent or descent at a constant rate, then

$$\frac{dPO_2}{dt} = k \qquad \int_{PO_{2_o}}^{PO_{2f}} dPO_2 = \int_{t_o}^{t_f} kdt \qquad PO_{2_f} = PO_{2_o} + kt$$

Equation 1 can now be expressed as a differential with $PO_2$ as a function of time:

$$dOTU = dt_x \cdot \left( \frac{0.5}{PO_{2_o} + kt - 0.5} \right)^{\frac{-5}{6}}$$

Setting $a = PO_{2_o} - 0.5$, Equation 2 is obtained from the following integration:

$$\int_{OTU_o}^{OTU_f} dOTU = \int_{t_o}^{t_f} dt_x \cdot \left( \frac{0.5}{a + kt} \right)^{\frac{-5}{6}}$$

**Calculation steps before using Equation 2 for ascent or descent profile:**

A few steps must be taken before Equation 2 can be applied for calculation. The following calculations are based on diving at sea level and are expressed in units of American usage:

1. Determine segment time for the ascent or descent profile (at a constant rate):

   Segment Time = (Final Depth − Starting Depth) ÷ Rate* of ascent or descent

   * Note: descent rate should be expressed as positive number (i.e. +60 fsw/min) while ascent rate should be expressed as a negative number (i.e. −30 fsw/min).

2. Determine initial and final pressures of the profile in atmospheres absolute (ATA):

   Initial Pressure (ATA) = (Starting Depth + 33) ÷ 33
   Final Pressure (ATA) = (Final Depth + 33) ÷ 33

3. Of the initial and final pressures (ATA), determine which is maximum and which is minimum:

   Maximum Pressure (ATA) = Max(Initial Pressure, Final Pressure)
   Minimum Pressure (ATA) = Min(Initital Pressure, Final Pressure)

4. Determine the maximum $PO_2$ and minimum $PO_2$ of the profile:

   Maximum $PO_2$ = Maximum Pressure (ATA) × Fraction of $O_2$ in breathing gas
   Minimum $PO_2$ = Minimum Pressure (ATA) × Fraction of $O_2$ in breathing gas

5. Determine if the maximum and minimum $PO_2$'s fall within the range for oxygen toxicity (i.e. greater than 0.5) and assign a new variable (Low $PO_2$) to describe the lowest $PO_2$ of the profile that is within the range for oxygen toxicity:

   If Maximum $PO_2 \leq 0.5$ then [calculation does not apply]
   If Minimum $PO_2 < 0.5$ then Low $PO_2 = 0.5$, else Low $PO_2$ = Minimum $PO_2$

6. Determine time of exposure within range for oxygen toxicity:

$$\text{Exposure Time} = \text{Segment Time} \cdot \left( \frac{\text{Maximum } PO_2 - \text{Low } PO_2}{\text{Maximum } PO_2 - \text{Minimum } PO_2} \right)$$

**Computer format:**

In the FORTRAN programming language, the above steps can be written as:

```
SGTIME = (FDEPTH - SDEPTH)/RATE
IPATA = (SDEPTH + 33.0)/33.0
FPATA = (FDEPTH + 33.0)/33.0
MAXATA = MAX(IPATA, FPATA)
MINATA = MIN(IPATA, FPATA)
MAXPO2 = MAXATA * FO2(GASMIX)
MINPO2 = MINATA * FO2(GASMIX)
IF (MAXPO2 .LE. 0.5) GOTO 000  [exit this calculation sequence]
IF (MINPO2 .LT. 0.5) THEN
      LOWPO2 = 0.5
ELSE
      LOWPO2 = MINPO2
END IF
O2TIME = SGTIME*(MAXPO2 - LOWPO2)/(MAXPO2 - MINPO2)
```

**Example Calculation:**

Consider the following dive profile using EAN 32 for gasmix (ignore decompression considerations for this example):

Segment 1 Descent from 0 fsw to 120 fsw at 40 fsw/min
Segment 2 Constant depth at 120 fsw for 22 min
Segment 3 Long, slow ascent from 120 fsw to 0 fsw at −4 fsw/min

How many OTU's are accumulated on this dive? Solution using computer format for equations:

For Segment 1

```
SGTIME = (120.0 – 0.0)/40.0 = 3.0 min
IPATA = (0.0 + 33.0)/33.0 = 1.0 ATA
FPATA = (120.0 + 33.0)/33.0 = 4.636 ATA
MAXATA = MAX(1.0, 4.636) = 4.636 ATA
MINATA = MIN(1.0, 4.636) = 1.0 ATA
MAXPO2 = 4.636*0.32 = 1.484 ATA
MINPO2 = 1.0*0.32 = 0.32 ATA
IF (1.484 .LE. 0.5) GOTO 000 [false, therefore continue]
IF (0.32 .LT. 0.5) THEN [true]
      LOWPO2 = 0.5
O2TIME = 3.0*(1.484 – 0.5)/(1.484 – 0.32) = 2.536 min
(using Equation 2)
OTU = 3.0/11.0*2.536/(1.484 – 0.5)*(((1.484 – 0.5)/0.5)
      **(11.0/6.0) – ((0.5 – 0.5)/0.5)**(11.0/6.0))
= 2.431 OTU's
```

For Segment 2

```
PATA = (120.0 +33.0)/33.0 = 4.636 ATA
PO2 = 4.636*0.32 = 1.484 ATA
(using Equation 1)
OTU = 22.0*((0.5/(1.484 – 0.5))**(-5.0/6.0)) = 38.664 OTU's
```

For Segment 3

```
SGTIME = (0.0 – 120.0)/-4.0 = 30.0 min
IPATA = (120.0 + 33.0)/33.0 = 4.636 ATA
FPATA = (0.0 + 33.0)/33.0 = 1.0 ATA
MAXATA = MAX(4.636, 1.0) = 4.636 ATA
MINATA = MIN(4.636, 1.0) = 1.0 ATA
MAXPO2 = 4.636*0.32 = 1.484 ATA
MINPO2 = 1.0*0.32 = 0.32 ATA
IF (1.484 .LE. 0.5) GOTO 000 [false, therefore continue]
IF (0.32 .LT. 0.5) THEN [true]
      LOWPO2 = 0.5
O2TIME = 30.0*(1.484 – 0.5)/(1.484 – 0.32) = 25.359 min
(using Equation 2)
OTU = 3.0/11.0*25.359/(0.5 – 1.484)*(((0.5 – 0.5)/0.5)
      **(11.0/6.0) – ((1.484 – 0.5)/0.5)**(11.0/6.0))
= 24.309 OTU's
```

Total OTU's for this dive = 2.431 + 38.664 + 24.309 = **65.404 OTU's**

## Central Nervous System (CNS) Oxygen Toxicity Calculations

### Constant depth profile:

For a constant depth profile (in which the $PO_2$ remains constant), the CNS fraction is calculated by Equation 3:

$$\text{CNS fraction} = \frac{\text{time at } PO_2}{\text{time limit for } PO_2} \qquad \text{(Eq. 3)}$$

### Ascent or descent profile at a constant rate:

For an ascent or descent profile at a constant rate (where the $PO_2$ varies at a constant rate), the CNS fraction for a given $PO_2$ range with a linear time limit function can be calculated by Equation 4:

$$\text{CNS fraction} = \frac{1}{mk} \cdot \left[ \ln \left| T_{\lim_i} + mkt_x \right| - \ln \left| T_{\lim_i} \right| \right] \qquad \text{(Eq. 4)}$$

where m is the the slope of the linear time limit function, k is the constant rate of change in $PO_2$ with time, $T_{\lim_i}$ is the initial time limit for the interval, and $t_x$ is the time of exposure over the interval.

### Computer format:

In the FORTRAN programming language, Equation 3 can be written as:

```
CNS = TIME/TLIM
```

while Equation 4 can be written as:

```
CNS = 1.0/MK*(LOG(ABS(TLIMI + MK*TIME)) - LOG(ABS(TLIMI)))
```

### Discussion:

As mentioned previously, it is convenient for calculation purposes to describe the NOAA CNS oxygen toxicity limits as a series of linear equations for various ranges of $PO_2$. These equations express the time limit, $T_{\lim}$ , as a function of $PO_2$ in the slope-intercept form of $y = mx + b$. A straight line can be drawn through more than two NOAA time limit points for the $PO_2$ ranges from 0.9 to 1.1 and from 1.1 to 1.5. I have made one extrapolation to describe a time limit equation for the $PO_2$ range from 0.5 to 0.6 in order to complete the series. An individual equation is written as:

$$T_{\lim} = mPO_2 + b \qquad \text{(Eq. 5)}$$

where m is the slope of the line and b is the intercept for the given $PO_2$ range. Coefficients for the series of linear equations are as follows:

| $PO_2$ Range | Slope | Intercept |
|---|---|---|
| 0.5 − 0.6 | −1800 | 1800 |
| 0.6 − 0.7 | −1500 | 1620 |
| 0.7 − 0.8 | −1200 | 1410 |
| 0.8 − 0.9 | −900 | 1170 |
| 0.9 − 1.1 | −600 | 900 |
| 1.1 − 1.5 | −300 | 570 |
| 1.5 − 1.6 | −750 | 1245 |

Calculation of $T_{lim}$ within a $PO_2$ range applies when the present $PO_2$ is greater than the lower limit of the $PO_2$ range and is less than or equal to the upper limit of the $PO_2$ range.

Equation 3 can now be expressed as:

$$\text{CNS fraction} = \frac{\text{time at } PO_2}{T_{lim}} = \frac{\text{time at } PO_2}{mPO_2 + b} \qquad \text{(Eq. 6)}$$

Equation 4 can be derived from Equation 6 as follows:

Since the $PO_2$ varies at a constant rate with respect to time during an ascent or descent at a constant rate, then

$$\frac{dPO_2}{dt} = k \qquad \int_{PO_{2_o}}^{PO_{2f}} dPO_2 = \int_{t_o}^{t_f} kdt \qquad PO_{2_f} = PO_{2_o} + kt$$

Equation 6 can now be expressed as a differential with $PO_2$ as a function of time:

$$\text{dCNS fraction} = \frac{dt}{m(PO_{2_o} + kt) + b} = \frac{dt}{mPO_{2_o} + mkt + b}$$

Setting $a = mPO_{2_o} + b$ $(= T_{lim_i})$ and $b = mk$, Equation 4 is obtained from the following integration:

$$\int_{CNS_o}^{CNS_f} dCNS\ fraction = \int_{t_o}^{t_f} \frac{dt}{a + bt}$$

### Computer programming method to access linear equations for $T_{lim}$:

A method to store and "look up" the $PO_2$ ranges and coefficients for the linear time limit equations must be provided in a program. In the FORTRAN programming language, this can be accomplished in a BLOCK DATA subprogram using one-dimensional arrays with subscripted variables:

```
 BLOCK DATA CNSLIM
 REAL PO2LO, PO2HI, LIMSLP, LIMINT
 DIMENSION PO2LO(7), PO2HI(7), LIMSLP(7), LIMINT(7)
 COMMON /A/ PO2LO, PO2HI, LIMSLP, LIMINT
 DATA PO2LO(1)/0.5/,PO2LO(2)/0.6/,PO2LO(3)/0.7/,PO2LO(4)/0.8/,
*     PO2LO(5)/0.9/,PO2LO(6)/1.1/,PO2LO(7)/1.5/
 DATA PO2HI(1)/0.6/,PO2HI(2)/0.7/,PO2HI(3)/0.8/,PO2HI(4)/0.9/,
*     PO2HI(5)/1.1/,PO2HI(6)/1.5/,PO2HI(7)/1.6/
 DATA LIMSLP(1)/-1800.0/,LIMSLP(2)/-1500.0/,LIMSLP(3)/-1200.0/,
*     LIMSLP(4)/-900.0/,LIMSLP(5)/-600.0/,LIMSLP(6)/-300.0/,
*     LIMSLP(7)/-750.0/
 DATA LIMINT(1)/1800.0/,LIMINT(2)/1620.0/,LIMINT(3)/1410.0/,
*     LIMINT(4)/1170.0/,LIMINT(5)/900.0/,LIMINT(6)/570.0/,
*     LIMINT(7)/1245.0/
 END
```

where
`PO2LO` = low end of $PO_2$ range
`PO2HI` = high end of $PO_2$ range
`LIMSLP` = slope coefficient for $PO_2$ range
`LIMINT` = intercept coefficient for $PO_2$ range

### Calculation steps for constant depth profile:

1. Determine if $PO_2$ is within the range for oxygen toxicity:

   If $PO_2 \leq 0.5$ then [calculation does not apply]

2. Find which $PO_2$ range the present $PO_2$ falls within in order to calculate $T_{lim}$. This step is accomplished by use of a program loop with the provision to exit the loop once the correct $PO_2$ range is found.

3. Calculate the time limit, $T_{lim}$, for the present $PO_2$.

4. Calculate the CNS fraction using Equation 3.

**Computer format:**

In the FORTRAN programming language, the above steps can be written as:

```
      IF (PO2 .LE. 0.5) GOTO 000  [exit this calculation sequence]
      DO 10  I = 1,7
      IF ((PO2 .GT. PO2LO(I)) .AND. (PO2 .LE. PO2HI(I)) THEN
            TLIM = LIMSLP(I)*PO2 + LIMINT(I)
            GOTO 000   [exit loop]
      END IF
10    CONTINUE
      CNS = TIME/TLIM
```

**Calculation steps for ascent or descent profile at a constant rate:**

The first six (6) steps in this sequence are identical to the OTU calculation for ascent or descent profile. The additional steps required are:

7. Determine how much of the oxygen exposure time is spent within each $PO_2$ range (each of which has different CNS time limit equation coefficients) and determine what the inital $PO_2$ and final $PO_2$ values are within each respective range. This step is accomplished using structured IF blocks within a program loop and assigns the oxygen exposure time, initial $PO_2$, and final $PO_2$ for each range to subscripted variables in arrays. The oxygen exposure time for a $PO_2$ range is given by: $O_2$ time for range = $O_2$ time for segment × absolute value (final $PO_2$ for range − initial $PO_2$ for range) ÷ (max $PO_2$ for segment − low $PO_2$ for segment).

8. Calculate the initial time limit and product of constants, m×k, for each $PO_2$ range. Calculate the CNS fraction for each $PO_2$ range using Equation 4. This step is accomplished with a program loop and skips the calculation for a particular $PO_2$ range if there was no oxygen exposure time within that range.

9. Sum up the CNS fractions for each $PO_2$ range to produce a CNS fraction for the dive segment. This step is accomplished with a program loop.

**Computer format:**

In the FORTRAN programming language, the above steps can be written as:

```
      SGTIME = (FDEPTH – SDEPTH)/RATE
      IPATA = (SDEPTH + 33.0)/33.0
      FPATA = (FDEPTH + 33.0)/33.0
      MAXATA = MAX(IPATA, FPATA)
      MINATA = MIN(IPATA, FPATA)
      MAXPO2 = MAXATA * FO2(GASMIX)
      MINPO2 = MINATA * FO2(GASMIX)
      IF (MAXPO2 .LE. 0.5) GOTO 000  [exit this calculation sequence]
      IF (MINPO2 .LT. 0.5) THEN
            LOWPO2 = 0.5
      ELSE
            LOWPO2 = MINPO2
      END IF
      O2TIME = SGTIME*(MAXPO2 – LOWPO2)/(MAXPO2 – MINPO2)
```

```
      DO 10  I = 1,7
      IF ((MAXPO2 .GT. PO2LO(I)) .AND. (LOWPO2 .LE. PO2HI(I))) THEN
            IF ((MAXPO2 .GE. PO2HI(I)) .AND. (LOWPO2 .LT. PO2LO(I))) THEN
                  IF (SDEPTH .GT. FDEPTH) THEN
                        PO2O(I) = PO2HI(I)
                        PO2F(I) = PO2LO(I)
                  ELSE
                        PO2O(I) = PO2LO(I)
                        PO2F(I) = PO2HI(I)
                  END IF
                  SEGPO2(I) =  PO2F(I) - PO2O(I)
            ELSE IF ((MAXPO2 .LT. PO2HI(I)) .AND. (LOWPO2 .LE. PO2LO(I))) THEN
                  IF (SDEPTH .GT. FDEPTH) THEN
                        PO2O(I) = MAXPO2
                        PO2F(I) = PO2LO(I)
                  ELSE
                        PO2O(I) = PO2LO(I)
                        PO2F(I) = MAXPO2
                  END IF
                  SEGPO2(I) =  PO2F(I) - PO2O(I)
            ELSE IF ((LOWPO2 .GT. PO2LO(I)) .AND. (MAXPO2 .GE. PO2HI(I))) THEN
                  IF (SDEPTH .GT. FDEPTH) THEN
                        PO2O(I) = PO2HI(I)
                        PO2F(I) = LOWPO2
                  ELSE
                        PO2O(I) = LOWPO2
                        PO2F(I) = PO2HI(I)
                  END IF
                  SEGPO2(I) =  PO2F(I) - PO2O(I)
            ELSE
                  IF (SDEPTH .GT. FDEPTH) THEN
                        PO2O(I) = MAXPO2
                        PO2F(I) = LOWPO2
                  ELSE
                        PO2O(I) = LOWPO2
                        PO2F(I) = MAXPO2
                  END IF
                  SEGPO2(I) = PO2F(I) - PO2O(I)
            END IF
            OTIME(I) = O2TIME*ABS(SEGPO2(I))/(MAXPO2 - LOWPO2)
      ELSE
            OTIME(I) = 0.0
      END IF
10    CONTINUE
      DO 20  I = 1,7
      IF (OTIME(I) .EQ. 0.0) THEN
            CNS(I) = 0.0
            GOTO 20
      ELSE
            TLIMI(I) = LIMSLP(I)*PO2O(I) + LIMINT(I)
            MK(I) = LIMSLP(I)*(SEGPO2(I)/OTIME(I))
            CNS(I) = 1.0/MK(I)*(LOG(ABS(TLIMI(I) + MK(I)*OTIME(I))) -
     *      LOG(ABS(TLIMI(I))))
      END IF
20    CONTINUE
      SUMCNS = 0.0
      DO 30  I = 1,7
            TMPCNS = SUMCNS
            SUMCNS = TMPCNS + CNS(I)
30    CONTINUE
```

**Example Calculation:**

Consider the following dive profile using EAN 32 for gasmix (ignore decompression considerations for this example):

Segment 1 Descent from 0 fsw to 120 fsw at 40 fsw/min
Segment 2 Constant depth at 120 fsw for 22 min
Segment 3 Long, slow ascent from 120 fsw to 0 fsw at −4 fsw/min

What is the CNS fraction accumulated on this dive? Program solution:

For Segment 1 Program calculates a CNS fraction = .0090

For Segment 2 Program calculates a CNS fraction = .1761

For Segment 3 Program calculates a CNS fraction = .0895

Total CNS fraction for this dive = .0090 + .1761 + .0895 **= .2746 = 27.5%**

## Conclusion

The information presented in this article is intended to suggest some precise methods to calculate oxygen toxicity parameters within the framework of their present usage in technical diving. I do not intend to suggest or imply any new physiological insight as the result of some mathematical manipulations. The idea is simply to make accurate calculations of oxygen toxicity as a function of the actual oxygen partial pressure ($PO_2$) and the actual time of exposure.

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