

**The Mathematics Behind Partial Pressure Gas Blending  
or  
"Why You Shouldn't Calculate Your Mix in Your Head"**



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## Foreword

My undergraduate degree is in mathematics. As graduation approached, several of my math friends and I discussed why we chose this major and one common theme was that we found it to be... easy. We were wired to see the world in terms of numbers and symbols, and so problem solving revolved around the "story" rather than the "formulas."

When I took my divemaster and instructor courses—and my Nitrox gas blending class—I tried to convey to my fellow students to concentrate on the problems we were being asked to solve rather than merely on which formula to apply, and many had trouble with that; they couldn't "see" the problem in symbolic terms, so the formulas were their only lifeline.

The physics of gas is an essential science for SCUBA divers and, yet, most divers don't understand the science behind our sport. This is just as true for mixed-gas divers, even many who dive with Nitrox.

This paper was not written to explain gas physics, *per se*, but to step through the math—actually, the algebra!—of how gases with varying amounts of oxygen are mixed together to prepare the specific blend that we request (or are offered). I won't explain how to *use* Nitrox but I will attempt to step through the essential formulas used by gas blenders to prepare the Nitrox. While the various textbooks do a varying job providing the formulas to the reader, most divers don't read the blender manual and the manuals often skip essential intermediate steps. I'll try not to.

*Suggestions, corrections, and/or any other comments about this manual are welcome.*

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## Part 1: The Basics

Although not a treatise on physics and gas laws, this section will introduce the scientific basis for *partial pressure blending*, one of the most common ways in which Enhanced Air Nitrox gas is blended. It will introduce Dalton's Law, which shows how a gas comprises its component elements, and show how it can be applied to the combination of gases to create nitrox mixes.

### 1.1. Gas Composition and Dalton's Law

All SCUBA divers—particularly those certified to use Nitrox—know that air is composed primarily of two gases, namely, oxygen (O<sub>2</sub>) and nitrogen (N<sub>2</sub>).<sup>1</sup>

Dalton's Law<sup>2</sup> is a law of physics that states, in essence, that the pressure of a gas is the sum of the pressure of all of its component gases. So, for example, if a gas is composed of elements A, B, and C, then the total pressure of the gas (P) is the sum of the pressure of the three component gases:<sup>3</sup>

$$P_{\text{TOTAL}} = P_A + P_B + P_C$$

This formula shows that the total pressure is the sum of the individual gas pressures but does not tell us what percentage of the total pressure each gas contributes to the whole. We can calculate the *fractional pressure* of each gas if we know the fraction of the whole that each component gas occupies. Note that the sum of the fractional percentage (F) of all of the component gases will come to 100%:

$$F_{\text{TOTAL}} = 100\% = F_A + F_B + F_C$$

For discussion purposes, let's say that we have some gas mixture that is composed of 42% gas A, 27% gas B, and 31% gas C. This would be denoted:

$$F_A = 42\% = 0.42$$

$$F_B = 27\% = 0.27$$

$$F_C = 31\% = 0.31$$

Armed with this information, we can calculate the fractional pressure of each gas, which is merely the product of the total pressure of the gas and the fractional percentage of each individual gas:

$$P_A = P_{\text{TOTAL}} \cdot F_A$$

$$P_B = P_{\text{TOTAL}} \cdot F_B$$

---

<sup>1</sup> For this discussion, we will ignore the trace elements in air such as argon, carbon dioxide, etc.

<sup>2</sup> Named for John Dalton, who discovered this principle in 1801.

<sup>3</sup> Dalton's Law assumes a constant temperature of all of the component gases.

$$P_C = P_{\text{TOTAL}} \cdot F_C$$

As an example, suppose that our theoretical gas is in a tank at a pressure of 900 pounds per square inch (psi), or 60 bar.<sup>4</sup> The fractional pressure of gases A, B, and C would be:

#### IMPERIAL

$$P_A = 900 \text{ psi} \cdot 0.42 = 378 \text{ psi}$$

$$P_B = 900 \text{ psi} \cdot 0.27 = 243 \text{ psi}$$

$$P_C = 900 \text{ psi} \cdot 0.31 = 279 \text{ psi}$$

#### METRIC

$$P_A = 60 \text{ bar} \cdot 0.42 = 25 \text{ bar}$$

$$P_B = 60 \text{ bar} \cdot 0.27 = 16 \text{ bar}$$

$$P_C = 60 \text{ bar} \cdot 0.31 = 19 \text{ bar}$$

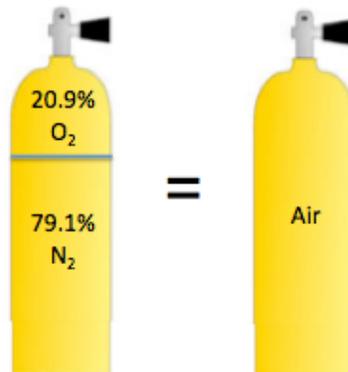
This is relevant to SCUBA divers because of the composition of air. According to Dalton's Law, the pressure of air is the sum of the pressure of the nitrogen plus the pressure of the oxygen:

$$P_{\text{AIR}} = P_{\text{N}_2} + P_{\text{O}_2}$$

SCUBA divers know that the pressure of air at sea level is 14.7 psi (imperial) or 1 bar (metric), also denoted as 1 atmosphere (ATM). We know that oxygen comprises 20.9% of air; since we are ignoring trace elements in air, this leaves the remaining 79.1% of air to be composed of nitrogen (Figure 1.1). The fraction (F) of oxygen and nitrogen in air could then be denoted:

$$F_{\text{O}_2} = 20.9\% = 0.209$$

$$F_{\text{N}_2} = 79.1\% = 0.791$$



**Figure 1.1.** Fraction of the component gases of air. (The separation of the  $\text{O}_2$  and  $\text{N}_2$  is for readability only; the gases are thoroughly blended in the tank.)

We can now calculate the *fractional pressure* of oxygen and nitrogen in the air at one atmosphere:

$$P_{\text{O}_2} = P_{\text{AIR}} \cdot F_{\text{O}_2}$$

$$P_{\text{N}_2} = P_{\text{AIR}} \cdot F_{\text{N}_2}$$

---

<sup>4</sup> 1 bar = 14.7 psi.

**IMPERIAL**

$$P_{O_2} = 14.7 \text{ psi} \cdot 0.209 = 3.1 \text{ psi}$$

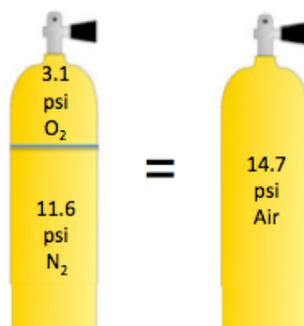
$$P_{N_2} = 14.7 \text{ psi} \cdot 0.791 = 11.6 \text{ psi}$$

**METRIC**

$$P_{O_2} = 1 \text{ bar} \cdot 0.209 = 0.209 \text{ bar}$$

$$P_{N_2} = 1 \text{ bar} \cdot 0.791 = 0.791 \text{ bar}$$

Figure 1.2 shows the fractional pressure concept graphically. Air is a mixture of its component gases, oxygen and nitrogen. What is true for air is also true for the gases used for SCUBA, including Nitrox and Heliox;<sup>5</sup> all are blends of different gases with different compositions of each component gas.



**Figure 1.2.** Fractional pressure of the component gases of air.

This concept will be extended in later sections since SCUBA divers see gases at pressures up to 3000 psi (204 bar) and above. But the composition of a given gas remains the same, regardless of the pressure.

## 1.2. Air Plus Oxygen Equals EAN

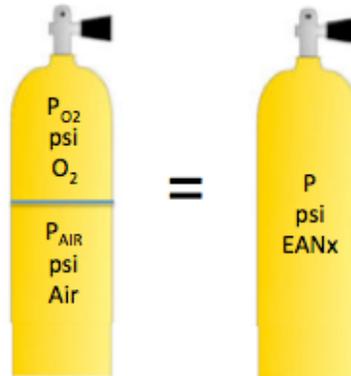
Enhanced Air Nitrox is simply air with a higher percentage of oxygen than air's 20.9%. A common nomenclature is to denote EAN<sub>x</sub>, where x is the desired O<sub>2</sub> percentage (e.g., EAN32 would be Nitrox with a 32% O<sub>2</sub> mix). In EAN, oxygen is used to displace (or dilute) the amount of nitrogen.

We know that the total pressure of the mix is the sum of the pressures of the component gases; in this case, the component gases are air and oxygen (Figure 1.3). For some desired pressure (denoted P<sub>D</sub>) of a particular EAN<sub>x</sub> mix (denoted M<sub>D</sub>), we know that:

$$P_D \cdot M_D = P_{O_2} \cdot 100\% + P_{AIR} \cdot 20.9\%$$

where P<sub>O<sub>2</sub></sub> and P<sub>AIR</sub> are the pressure of oxygen and air, respectively.

<sup>5</sup> Heliox is a SCUBA gas composed to oxygen, nitrogen, and helium. It will not be discussed further in this paper.



**Figure 1.3.** A given EANx mix at a given pressure is a combination of some pressure of air and some pressure of oxygen.

So, how much air and oxygen do we need to mix to obtain the right blend for our desired EANx? Let's go back to the formula:

$$P_D \cdot M_D = P_{O_2} \cdot 100\% + P_{AIR} \cdot 20.9\%$$

If we know the desired gas pressure and EANx mix, then the only things we don't know are the pressure of oxygen and air. But we do know one more thing; namely, that the total pressure of the EANx gas will be the sum of the pressures of the component gases, or:

$$P_D = P_{O_2} + P_{AIR}$$

$$P_{AIR} = P_D - P_{O_2}$$

Armed with this information, we can solve for  $P_{O_2}$  as follows:

$$P_D \cdot M_D = P_{O_2} \cdot 100\% + P_{AIR} \cdot 20.9\%$$

$$P_D \cdot M_D = P_{O_2} \cdot 1.0 + (P_D - P_{O_2}) \cdot 0.209$$

$$P_D \cdot M_D = P_{O_2} \cdot 1.0 + P_D \cdot 0.209 - P_{O_2} \cdot 0.209$$

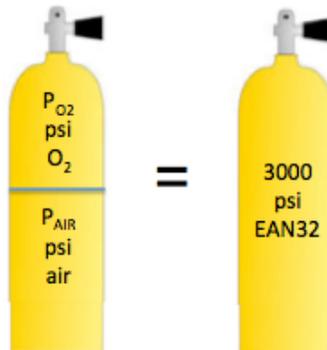
$$P_D \cdot M_D = P_{O_2} \cdot (1.0 - 0.209) + P_D \cdot 0.209$$

$$P_D \cdot M_D - P_D \cdot 0.209 = P_{O_2} \cdot 0.791$$

$$P_D \cdot (M_D - 0.209) = P_{O_2} \cdot 0.791$$

$$\frac{P_D \cdot (M_D - 0.209)}{0.791} = P_{O_2}$$

Using some real numbers might help make this appear more practical.



**Figure 1.4.** Mixing air and oxygen to prepare a 3000 psi mix of EAN 32.

Suppose we start with an empty tank and want to combine oxygen and air to prepare a 3000 psi (204 bar) tank of EAN32 gas. We know:

$$P_D = 3000 \text{ psi} = 204 \text{ bar}$$

$$M_D = 32\% = 0.32$$

Using our formula and these values, we can calculate:

$$P_{O_2} = \frac{P_D \cdot (M_D - 0.209)}{0.791}$$

#### IMPERIAL

$$P_{O_2} = \frac{3000 \cdot (0.32 - 0.209)}{0.791}$$

$$= 3000 \cdot 0.111 / 0.791$$

$$= 421 \text{ psi}$$

#### METRIC

$$P_{O_2} = \frac{204 \cdot (0.32 - 0.209)}{0.791}$$

$$= 204 \cdot 0.111 / 0.791$$

$$= 29 \text{ bar}$$

Now that we know the pressure of the oxygen, we can calculate the necessary pressure of regular air using the formula  $P_{AIR} = P_D - P_{O_2} = 2579 \text{ psi}$  (175 bar) (Figure 1.5).

We can test these computed values by putting everything back into the original formulas:

#### IMPERIAL

$$P_D \cdot M_D = 3000 \cdot 0.32 = 960 \text{ psi}$$

$$P_{O_2} + P_{AIR} \cdot M_{AIR} = 421 + 2579 \cdot 0.209$$

$$= 421 + 539$$

$$= 960 \text{ psi}$$

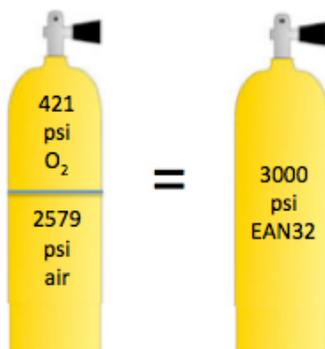
#### METRIC

$$P_D \cdot M_D = 204 \cdot 0.32 = 65 \text{ bar}$$

$$P_{O_2} + P_{AIR} \cdot M_{AIR} = 29 + 175 \cdot 0.209$$

$$= 29 + 36$$

$$= 65 \text{ bar}$$



**Figure 1.5.** *The oxygen and air mix required to form EAN32.*

### 1.3. SIDENOTE: What's In An Empty Tank?

Divers are always told to not end a dive with less than some amount of gas in their tank, generally 500 psi (34 bar). One reason, of course, is that divers are ill-advised to use all of their air without a reserve. More pragmatically, however, is the fact that if the pressure gets too low, there is opportunity for moisture to accumulate in the tank.

There are many reasons, however, that a blender may start with an empty tank. Some blenders empty the tank because it is easier to calculate the required mixture of component gases and, in some cases, it makes financial sense to start with an empty tank (this is due to the type of component gases being employed). A tank may also be empty after an annual visual exam.

But is a tank ever really "empty"? Empty implies that there is nothing in the tank; i.e., 0 psi/bar. But unless there's a vacuum, that's not really the case; we live at 1 ATM of pressure. Therefore, everything else being equal, an "empty" tank really contains 20.9% O<sub>2</sub> at 14.7 psi (1 bar).

## Part 2: Blending A Nitrox Tank

This section will introduce *partial pressure blending*, one of the most common ways in which Nitrox gas is blended. Using the basics of Dalton's Law, as described in Part 1, we will derive the formulas necessary to understand how to mix oxygen and air -- or any combination of gases -- to prepare a desired Nitrox blend.

### 2.1. Partial Pressure Blending

Nitrox -- more formally known as Enhanced Air Nitrox -- is a SCUBA gas blend containing more oxygen -- and, therefore, less nitrogen -- than ordinary air.<sup>6</sup> For a number of reasons beyond the scope of this paper, Nitrox blends for recreational divers are limited to 40% oxygen (i.e.,  $F_{O_2} = 0.4$ , aka EAN40).

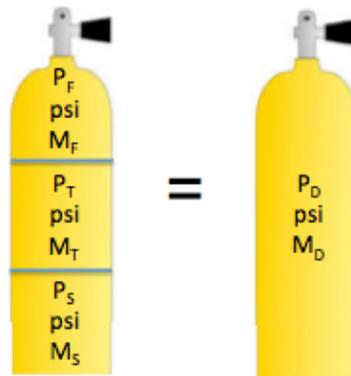
Although there are several ways in which a Nitrox tank can be prepared, one of the most common ways is called *partial pressure blending (PPB)*. Understanding Dalton's Law is essential to understanding PPB, which basically works as follows:

1. Measure the pressure and fraction of oxygen of the gas currently in the tank. This is called the starting pressure ( $P_S$ ) and starting mix ( $M_S$ ), respectively.
2. Determine the pressure and fraction of oxygen of the gas to be in the tank after filling; this is the desired pressure ( $P_D$ ) and desired mix ( $M_D$ ), respectively. These values are supplied to the gas blender by the diver who, in turn, determines these values based upon their dive plan.
3. The gas blender will employ two gases, called the *fill gas* and *top-off gas*, in order to prepare the desired Nitrox mix. The fill and top-off gases will contain a fixed fraction of oxygen, denoted  $M_F$  and  $M_T$ , respectively. The most common fill gas is pure oxygen ( $M_F = 100\% = 1.0$ ) and the most common top-off gas is air ( $M_T = 20.9\% = 0.209$ ).
4. The blender adds some amount of fill gas followed by some amount of top-off gas to the tank; the pressure of the two gases is denoted  $P_F$  and  $P_T$ , respectively. The blending formulas tell the blender how much fill gas to add to the tank.
5. The blender adds the top-off gas to the tank to achieve the proper desired pressure and mix.

This exercise in Dalton's Law -- and algebra! -- is shown in Figure 2.1. The tank containing the desired gas mixture ( $M_D$ ) at the desired tank pressure ( $P_D$ ) is prepared by measuring the fractional pressure of the gas in the tank at the start (i.e.,  $P_S \cdot M_S$ ) and then calculating the necessary fractional pressures of the fill gas (i.e.,  $P_F \cdot M_F$ ) and the top-off gas (i.e.,  $P_T \cdot M_T$ ).

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<sup>6</sup> Nitrox allows divers with a longer no-decompression dive time at a given depth than air because it contains less nitrogen. The depth, however, is limited by the amount of oxygen due to potential oxygen toxicity. Details in the use of nitrox, its limitations, and dive planning are covered in Nitrox certification courses. This paper just touches on how the gas is prepared.



**Figure 2.1.** *The desired gas mixture (D) is a combination of the gas at the start (S) plus the top-off gas (T) and fill gas (F).*

## 2.2. A Formula For Blending EANx

The discussion in Section 1 showed how oxygen and air can be combined to form a desired EANx mix from an empty tank. In real situations, however, we usually add the mixing gases to whatever is currently in the tank. To create a formula for EANx, then, we need to accommodate the starting pressure and mix of the tank prior to filling (denoted  $P_S$  and  $M_S$ , respectively). The total pressure of the desired mix, then, is the sum of the fractional pressures of the starting, fill, and top-off gases:

$$P_D \cdot M_D = P_S \cdot M_S + P_F \cdot M_F + P_T \cdot M_T$$

As before, we have a formula with a bunch of variables. Since we know the starting pressure and mix (i.e.,  $P_S$  and  $M_S$ ), the desired pressure and mix (i.e.,  $P_D$  and  $M_D$ ), and the mix of the fill and top-off gases (i.e.,  $M_F$  and  $M_T$ ), we have only two unknowns, namely the pressure of the fill gas ( $P_F$ ) and the pressure of the top-off gas ( $P_T$ ). And, as before, those two values are related to each other since we know the desired total pressure and starting pressure:

$$P_S + P_F + P_T = P_D$$

$$P_T = P_D - P_S - P_F$$

Our blending formula is slightly more complicated than the mixing formula discussed above because a) we need to deal with the starting gas and b) our fill and top-off gases might not be air and oxygen. Nevertheless, the new formula is just as straight-forward (don't worry, we'll use actual numbers later!):

$$P_S \cdot M_S + P_F \cdot M_F + P_T \cdot M_T = P_D \cdot M_D$$

$$P_S \cdot M_S + P_F \cdot M_F + (P_D - P_S - P_F) \cdot M_T = P_D \cdot M_D$$

$$P_S \cdot M_S + P_F \cdot M_F + P_D \cdot M_T - P_S \cdot M_T - P_F \cdot M_T = P_D \cdot M_D$$

$$P_F \cdot M_F - P_F \cdot M_T = P_D \cdot M_D - P_S \cdot M_S - P_D \cdot M_T + P_S \cdot M_T$$

$$P_F \cdot (M_F - M_T) = P_D \cdot (M_D - M_T) - P_S \cdot (M_S - M_T)$$

$$P_F = \frac{P_D \cdot (M_D - M_T) - P_S \cdot (M_S - M_T)}{(M_F - M_T)}$$

Again, now that we know the fill gas pressure, we can calculate the top-off gas pressure:

$$P_T = P_D - P_S - P_F$$

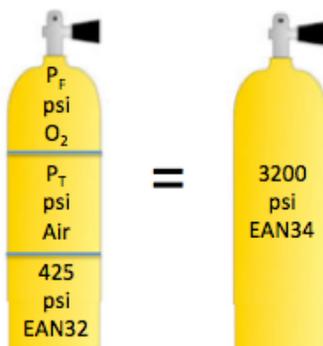
As before, the formulas will make more sense with real values, so we'll look at three examples.

### 2.3. Example 1: $M_D$ Greater Than $M_S$

In this example, the desired gas mixture ( $M_D$ ) has a higher percentage of oxygen than the starting mix ( $M_S$ ). Suppose an EAN32 tank currently at 425 psi (29 bar) needs to be filled to an EAN34 mix at 3200 psi (218 bar). In this case, we know (Figure 2.2):

$$\begin{aligned} P_S &= 425 \text{ psi} = 29 \text{ bar} \\ P_D &= 3200 \text{ psi} = 218 \text{ bar} \\ M_F &= 100\% = 1.0 \end{aligned}$$

$$\begin{aligned} M_S &= 32\% = 0.32 \\ M_D &= 34\% = 0.34 \\ M_T &= 20.9\% = 0.209 \end{aligned}$$



**Figure 2.2.** Tank at 425 psi of EAN32 needs to be filled to 3200 psi of EAN 34.

Calculate the required pressure of fill gas using the formula above:

$$P_F = \frac{P_D \cdot (M_D - M_T) - P_S \cdot (M_S - M_T)}{(M_F - M_T)}$$

<b>IMPERIAL</b>	<b>METRIC</b>
$P_F = \frac{3200 \cdot (0.34 - 0.209) - 425 \cdot (0.32 - 0.209)}{(1.0 - 0.209)}$ $= \frac{(3200 \cdot 0.131) - (425 \cdot 0.111)}{0.791}$ $= (419.2 - 47.175) / 0.791$ $= 372.025 / 0.791$ $= 470 \text{ psi}$	$P_F = \frac{218 \cdot (0.34 - 0.209) - 29 \cdot (0.32 - 0.209)}{(1.0 - 0.209)}$ $= \frac{(218 \cdot 0.131) - (29 \cdot 0.111)}{0.791}$ $= (28.558 - 3.219) / 0.791$ $= 25.339 / 0.791$ $= 32 \text{ bar}$

Since we started with 425 psi (29 bar) in the tank, this means we add 470 psi (32 bar) of O<sub>2</sub>, bringing the tank pressure to 895 psi (61 bar).

$$P_T = P_D - P_S - P_F$$

$$P_T = 3200 - 425 - 470$$

$$= 2305 \text{ psi}$$

$$P_T = 218 - 29 - 32$$

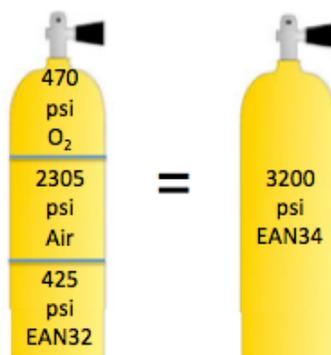
$$= 157 \text{ bar}$$

After the previous step, the tank pressure was 895 psi (61 bar). After now adding 2305 psi (157 bar) of air, we achieve our desired final pressure of 3200 psi (218 bar).

The pressure/mix product of the desired gas is ( $P_D \cdot M_D$ ), yielding a value of 1088 psi (74 bar). Check the calculated fill pressure by summing the partial pressure/mix products of the start, fill, and top-off gases (Figure 2.3):

$$(P_S \cdot M_S) + (P_F \cdot M_F) + (P_T \cdot M_T)$$

<b>IMPERIAL</b>	<b>METRIC</b>
$= (425 \cdot 0.32) + (470 \cdot 1.0) + (2305 \cdot 0.209)$ $= 136 + 470 + 482$ $= 1088 \text{ psi}$	$= (29 \cdot 0.32) + (32 \cdot 1.0) + (157 \cdot 0.209)$ $= 9 + 32 + 33$ $= 74 \text{ bar}$



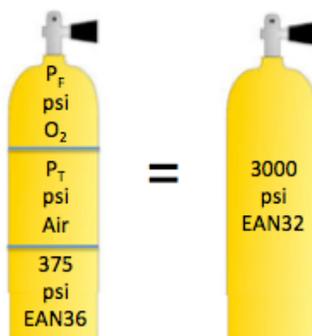
**Figure 2.3.** Adding 470 psi of oxygen and 2305 psi of air to a starting tank of 425 psi of EAN32 will create a 3200 psi EAN34 blend.

#### 2.4. Example 2: $M_D$ Less Than $M_S$

In this example, the desired gas mixture has a lower percentage of oxygen than the starting mix. Nothing actually changes here with respect to the use of the formulas or the process; that's all the same. Suppose an EAN36 tank currently at 375 psi (26 bar) needs to be filled with an EAN32 mix to 3000 psi (204 bar). In this case, we know (Figure 2.4):

$$\begin{aligned} P_S &= 375 \text{ psi} = 26 \text{ bar} \\ P_D &= 3000 \text{ psi} = 204 \text{ bar} \\ M_F &= 100\% = 1.0 \end{aligned}$$

$$\begin{aligned} M_S &= 36\% = 0.36 \\ M_D &= 32\% = 0.32 \\ M_T &= 20.9\% = 0.209 \end{aligned}$$



**Figure 2.4.** Tank at 375 psi of EAN36 needs to be filled to 3000 psi of EAN 32.

Calculate the required pressure of fill gas using the blending formula:

$$P_F = \frac{P_D \cdot (M_D - M_T) - P_S \cdot (M_S - M_T)}{(M_F - M_T)}$$

**IMPERIAL**

$$P_F = \frac{3000 \cdot (0.32 - 0.209) - 375 \cdot (0.36 - 0.209)}{(1.0 - 0.209)}$$

$$= \frac{(3000 \cdot 0.111) - (375 \cdot 0.151)}{0.791}$$

$$= (333.0 - 56.625) / 0.791$$

$$= 276.375 / 0.791$$

$$= 349 \text{ psi}$$

**METRIC**

$$P_F = \frac{204 \cdot (0.32 - 0.209) - 26 \cdot (0.36 - 0.209)}{(1.0 - 0.209)}$$

$$= \frac{(204 \cdot 0.111) - (26 \cdot 0.151)}{0.791}$$

$$= (22.644 - 3.926) / 0.791$$

$$= 18.718 / 0.791$$

$$= 24 \text{ bar}$$

After adding the fill gas, tank pressure is now 734 psi (50 bar).

$$P_T = P_D - P_S - P_F$$

$$P_T = 3000 - 375 - 349$$

$$= 2276 \text{ psi}$$

$$P_T = 204 - 26 - 24$$

$$= 154 \text{ bar}$$

The pressure/mix product of the desired gas is ( $P_D \cdot M_D$ ), yielding a value of 960 psi (65 bar). Check the calculated fill pressure by summing the partial pressure/mix products of the start, fill, and top-off gases (Figure 2.5):

$$(P_S \cdot M_S) + (P_F \cdot M_F) + (P_T \cdot M_T)$$

**IMPERIAL**

$$= (375 \cdot 0.36) + (349 \cdot 1.0) + (2276 \cdot 0.209)$$

$$= 135 + 349 + 476$$

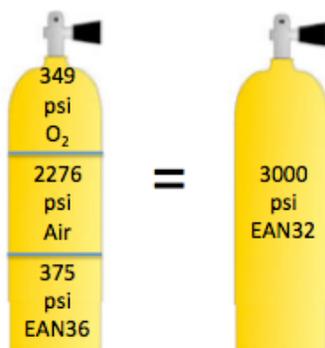
$$= 960 \text{ psi}$$

**METRIC**

$$= (26 \cdot 0.36) + (24 \cdot 1.0) + (154 \cdot 0.209)$$

$$= 9 + 24 + 32$$

$$= 65 \text{ bar}$$



**Figure 2.5.** Adding 349 psi of oxygen and 2276 psi of air to a starting tank of 375 psi of EAN36 will create a 3000 psi EAN32 blend.

### 2.5. Example 3: Bleeding The Tank

It is sometimes necessary to remove gas from the tank in order to obtain the desired blend; this is usually necessary when the desired mix is much lower than the starting mix and the tank pressure is relatively high. In this example, suppose an EAN36 tank currently at 1500 psi (102 bar) needs to be filled to 3000 psi (204 bar) with an EAN28 mix. In this case, we know (Figure 2.6):

$$P_S = 1500 \text{ psi} = 102 \text{ bar}$$

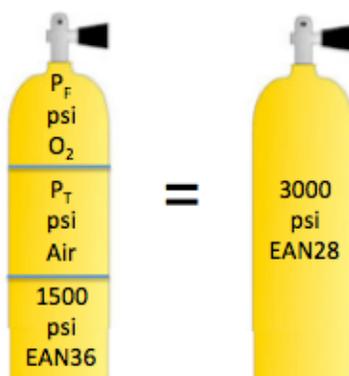
$$P_D = 3000 \text{ psi} = 204 \text{ bar}$$

$$M_F = 100\% = 1.0$$

$$M_S = 36\% = 0.36$$

$$M_D = 28\% = 0.28$$

$$M_T = 20.9\% = 0.209$$



**Figure 2.6.** Tank at 1500 psi of EAN36 needs to be filled to 3000 psi of EAN 28.

Calculate the required pressure of fill gas using the standard blending formula:

$$P_F = \frac{P_D \cdot (M_D - M_T) - P_S \cdot (M_S - M_T)}{(M_F - M_T)}$$

<b>IMPERIAL</b>	<b>METRIC</b>
$P_F = \frac{3000 \cdot (0.28 - 0.209) - 1500 \cdot (0.36 - 0.209)}{(1.0 - 0.209)}$ $= \frac{(3000 \cdot 0.071) - (1500 \cdot 0.151)}{0.791}$ $= (213.0 - 226.5) / 0.791$ $= -13.5 / 0.791$ $= -17 \text{ psi}$	$P_F = \frac{204 \cdot (0.28 - 0.209) - 102 \cdot (0.36 - 0.209)}{(1.0 - 0.209)}$ $= \frac{(204 \cdot 0.071) - (102 \cdot 0.151)}{0.791}$ $= (14.484 - 15.402) / 0.791$ $= -0.918 / 0.791$ $= -1 \text{ bar}$

A negative  $P_F$  value indicates that the starting mix/pressure is too high to be able to obtain the desired mix/pressure using the fill gas that we have. Therefore, some of the gas in the tank must be removed -- or *bled off* -- prior to blending the desired mix.

We need a new formula in order to determine how much gas to bleed off in order to find the correct starting pressure ( $P_S$ ) of the current mix. In the general blending formula that we are using, we can only get a negative value for  $P_F$  when:

$$P_S \cdot (M_S - M_T) > P_D \cdot (M_D - M_T)$$

When that situation occurs, it is necessary to balance the two terms (i.e., make the two terms equal). The two sides in the equation will be equal only if the term on the left is made smaller or the term on the right is made larger. Of the five variables in the formula, the only one that can actually be changed is the starting pressure; to compute a new  $P_S$  value:

$$P_S \cdot (M_S - M_T) = P_D \cdot (M_D - M_T)$$

$$P_S = \frac{P_D \cdot (M_D - M_T)}{(M_S - M_T)}$$

Using the numbers from this example:

<b>IMPERIAL</b>	<b>METRIC</b>
$P_S = \frac{3000 \cdot (0.28 - 0.209)}{(0.36 - 0.209)}$ $= (3000 \cdot 0.071) / 0.151$ $= 1411 \text{ psi}$	$P_S = \frac{204 \cdot (0.28 - 0.209)}{(0.36 - 0.209)}$ $= (204 \cdot 0.071) / 0.151$ $= 96 \text{ bar}$

This means that the tank needs to be bled off to 1411 psi (96 bar) and then filled only with the top-off gas; no fill gas will be needed after the tank is bled down. Thus, in this example, the tank would be filled with 1589 psi (108 bar) of air.

The values can be checked as before. The pressure/mix product of the desired gas is ( $P_D \cdot M_D$ ), yielding a value of 840 psi (57 bar). Check the calculated fill pressure by summing the partial pressure/mix products of the start, fill, and top-off gases (Figure 2.7):

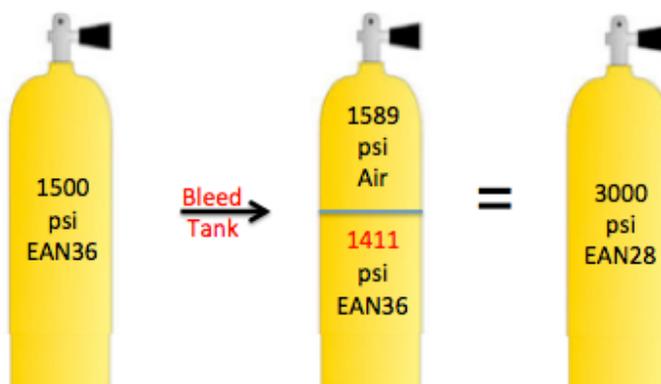
$$(P_S \cdot M_S) + (P_F \cdot M_F) + (P_T \cdot M_T)$$

#### IMPERIAL

$$\begin{aligned} &= (1411 \cdot 0.36) + (0 \cdot 1.0) + (1589 \cdot 0.209) \\ &= 508 + 0 + 332 \\ &= 840 \text{ psi} \end{aligned}$$

#### METRIC

$$\begin{aligned} &= (96 \cdot 0.36) + (0 \cdot 1.0) + (108 \cdot 0.209) \\ &= 35 + 0 + 23 \\ &= 58 \text{ bar}^7 \end{aligned}$$



**Figure 2.7.** Tank at 1500 psi of EAN36 needs to be bled down to 1411 psi and then filled with air to create a 3000 psi blend of EAN 28.

<sup>7</sup> The difference between the expected and actual values is due to rounding error.

## Part 3: A Spreadsheet for Blending

The intent of this paper is to provide a basis for the mathematics behind gas blending calculations, whether done in the blender's head, using tables, or employing software. The calculations are a straight-forward application of Dalton's Law although one can argue that life-giving -- and potentially life-threatening -- gases should not be mixed using arithmetic that is not being validated! And just as Nitrox-certified divers are trained to check the mix in their tanks prior to diving, perhaps they should also know how the blending is accomplished and calculated.

To that end, this section will introduce a spreadsheet and a Web-based calculator for determining Nitrox gas mixes using the partial pressure blending method.

### 3.1. Downloading The Spreadsheet

The gas blending spreadsheet described here can be downloaded from:

<https://scuba.garykessler.net/resources.html>

Scroll down to the EAN Partial Pressure Mixing Calculator to obtain the latest version of the spreadsheet (v3.1 as of this writing). This page also has a JavaScript version of the calculators that can run directly from your browser (see Appendix B for more information).

### 3.2. Opening The Spreadsheet

Open the spreadsheet by doubling-clicking the .xlsx file, as you would any spreadsheet. By default, the sheet will open to the *Gas Mix Calculator (PSI)* tab, showing calculations in psi (Figure 3.1).

The bottom of the page is the **Parameters** section and has five cells with a yellow background. With these cells, the user can define:

- The minimum  $pO_2$  (i.e., minimum  $M_S$  and  $M_D$ ), as a percent. The default is 20.9%, or air.
- The maximum  $pO_2$  (i.e., maximum  $M_S$  and  $M_D$ ), as a percent. The default is 40%, the highest recreational Nitrox mix.
- The fill gas  $pO_2$  ( $M_F$ ), as a percent. The default is 100% oxygen.
- The top-off gas  $pO_2$  ( $M_T$ ), as a percent. The default is 20.9% (air).
- The maximum tank pressure ( $P_D$ ), in psi. The spreadsheet default is 4000 psi.

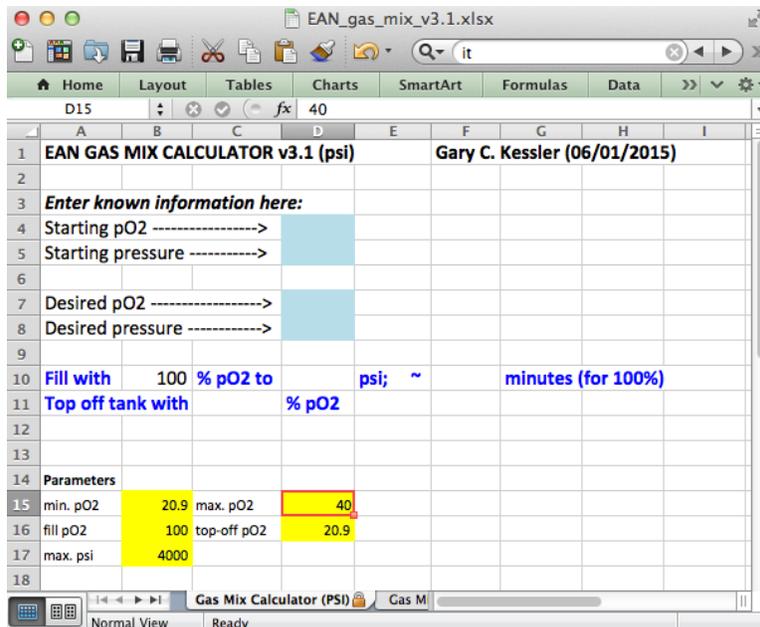


Figure 3.1. Gas Mix Calculator (psi) tab.

There are also four data entry fields with a light blue background where the starting pO<sub>2</sub> ( $M_s$ ), starting pressure ( $P_s$ ), desired pO<sub>2</sub> ( $M_D$ ), and desired pressure ( $P_D$ ) can be entered. More on data entry below.

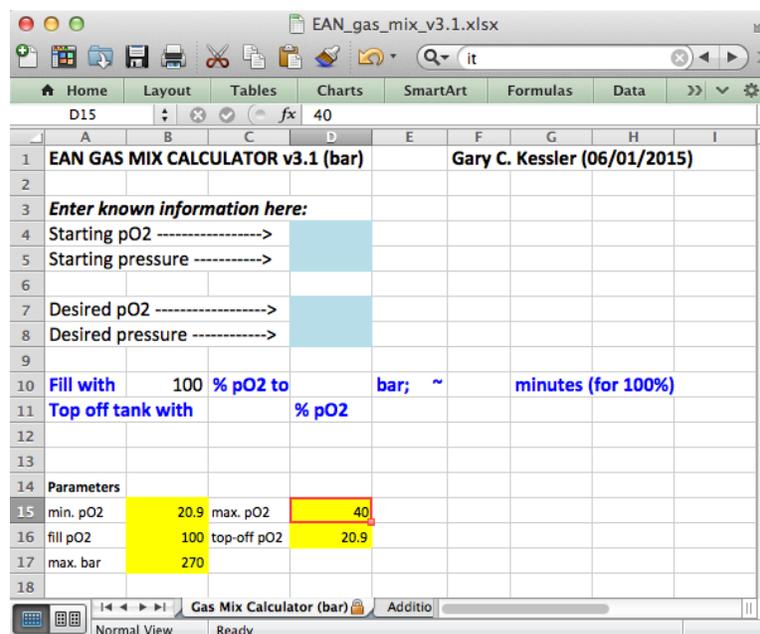


Figure 3.2. Gas Mix Calculator (bar) tab.

The *Gas Mix Calculator (bar)* tab is an identical spreadsheet page for metric calculations (Figure 3.2). The only difference between the metric and imperial pages is that pressure values are expressed in bar rather than psi.

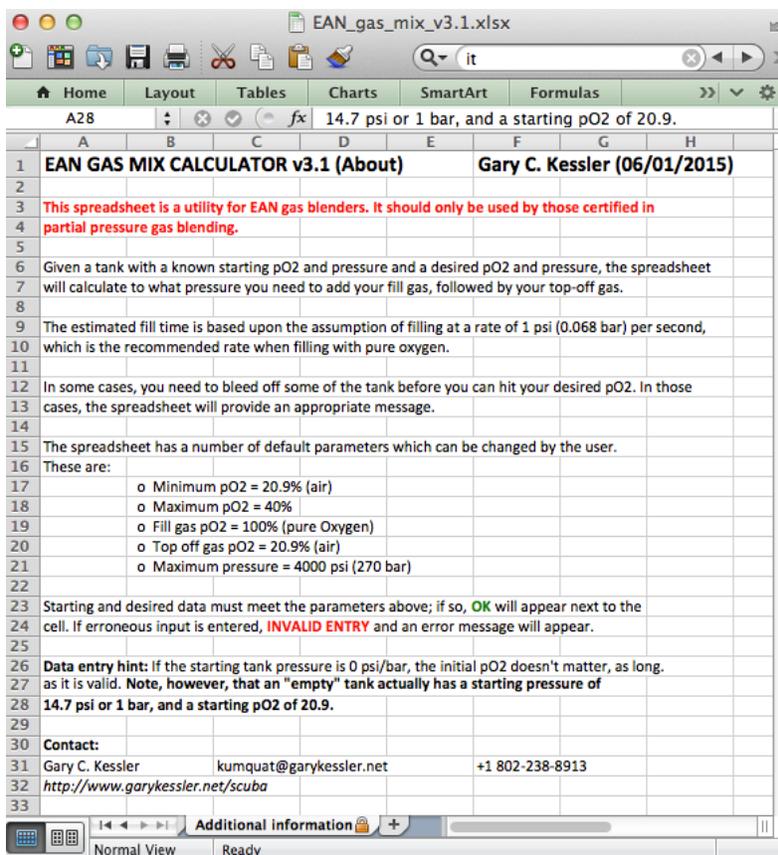


Figure 3.3. Additional information tab.

Finally, the *Additional information* tab provides summary information about the spreadsheet as well as contact information for comments, suggestions, etc. (Figure 3.3).

### 3.3. Data Entry

Data entry in the spreadsheet is straight-forward and no different from entering data into cells in any other type of spreadsheet. Merely enter the starting and desired pressure and O<sub>2</sub> mix, and the pressure of the tank after adding the fill gas will be displayed. Do note that all spreadsheet cells are locked except the four data entry cells and five parameter cells.

Some notes are worth mentioning. Data values entered into the four fields must pass a number of tests to be considered valid:

- The *Starting pO<sub>2</sub>* and *Desired pO<sub>2</sub>* values -- entered as a percentage -- must not be less than the *min. pO<sub>2</sub>* parameter or greater than the *max. pO<sub>2</sub>* parameter.
- The *Starting pressure* value -- entered in psi or bar -- must not be less than 0 or greater than the *max. psi/max. bar* parameter.

- The *Desired pressure* value -- entered in psi or bar -- must not be less than the *Starting pressure* value or greater than the *max. psi/max. bar* parameter.

### 3.4. Data Entry Examples

#### Example 1: Normal Data Entry

An EAN32 tank with 360 psi (25 bar) needs to be filled to 3200 psi (218 bar) with an EAN36 blend (Figure 3.4).

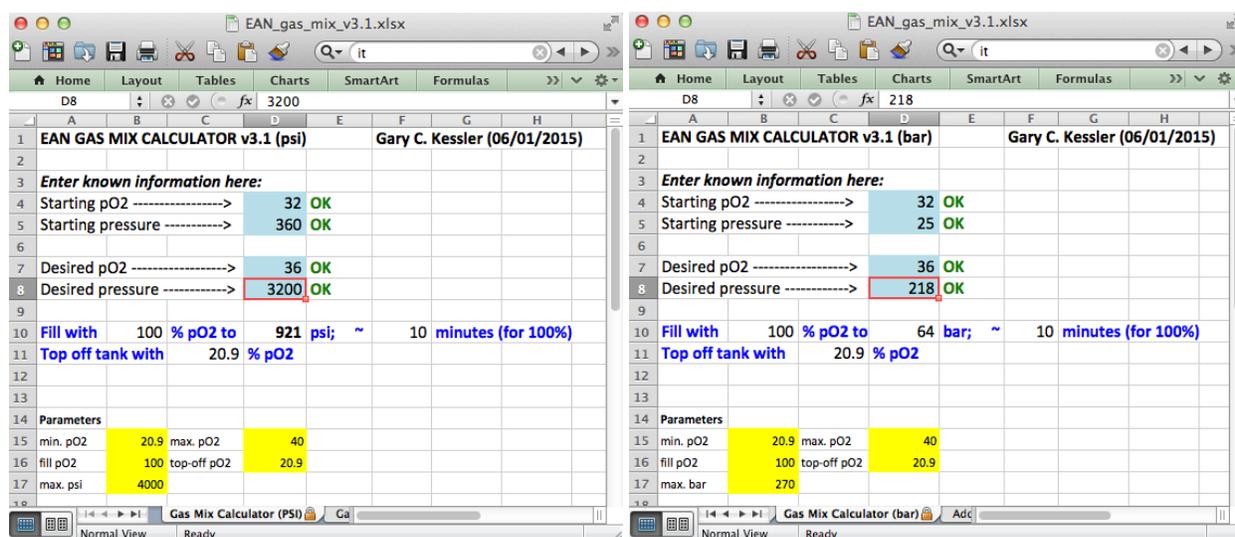


Figure 3.4. Normal data entry (psi and bar).

The spreadsheet indicates that this tank should be filled with 100% oxygen (the fill gas) to 921 psi (64 bar), which should take about 10 minutes at the safe fill rate for 100% O<sub>2</sub>. The tank should then be topped off to the desired pressure (i.e., 3200 psi or 218 bar) with air.

**NOTE** that the information here is *not* indicating that 921 psi (64 bar) be added to the tank but that the tank should be filled to that pressure. In other words, we actually *add* 561 psi (32 bar) to the starting pressure to get to the proper total pressure after the fill gas is added.

#### Example 2: Common Errors

The spreadsheet will provide an error message if data is entered that either doesn't make sense or cannot result in a valid result. For example, Figures 3.5 and 3.6 show the error messages that would appear if the start or desired pO<sub>2</sub>, respectively, are out of range (i.e., if the pO<sub>2</sub> value is less than the *min. pO<sub>2</sub>* parameter or greater than the *max. pO<sub>2</sub>* parameter).

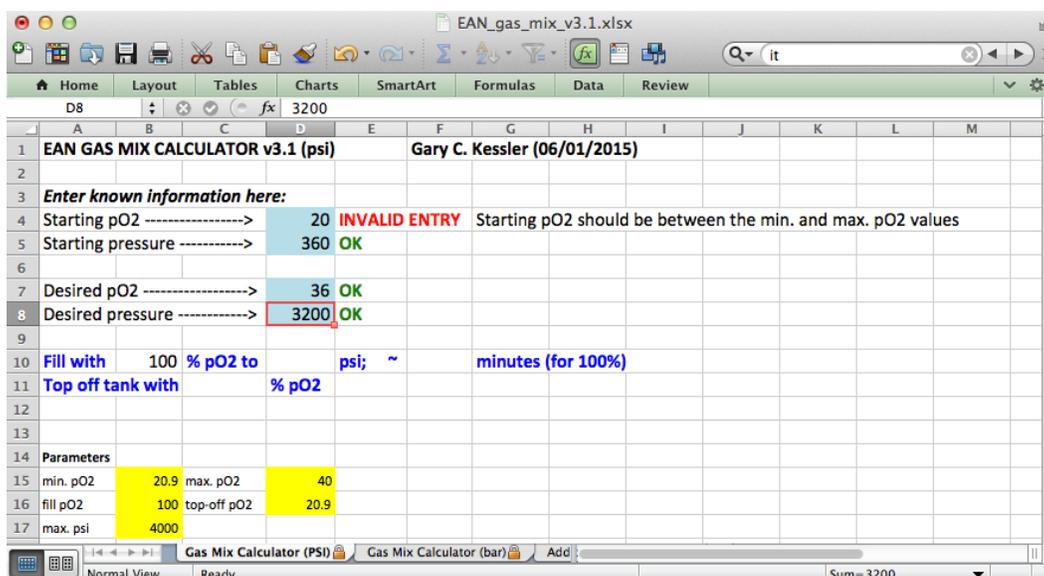


Figure 3.5. Starting pO2 entry out of range (psi).

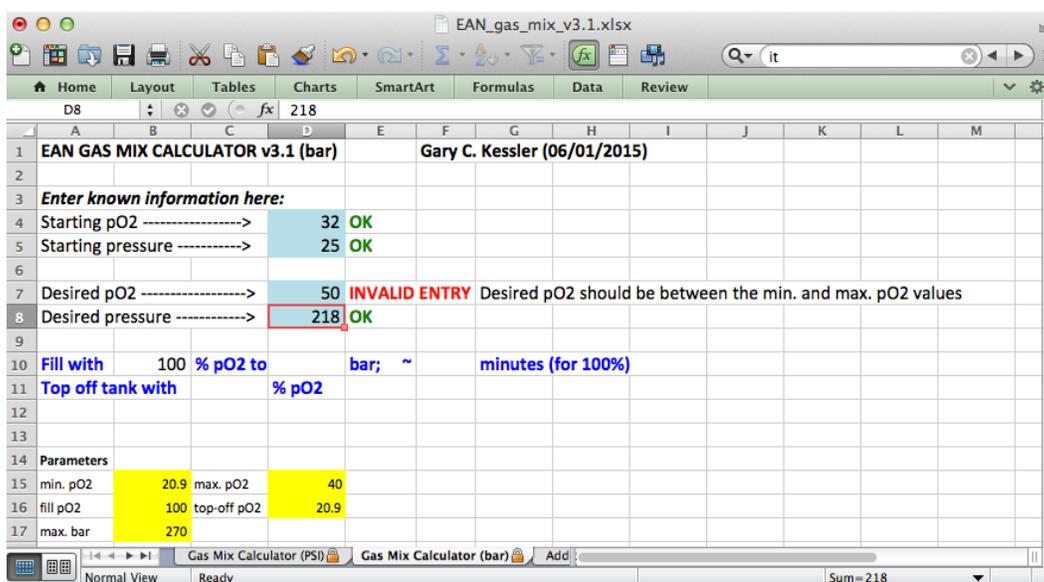


Figure 3.6. Starting pO2 entry out of range (bar).

Figure 3.7 shows the error message that will appear if the starting pressure value is out of range; i.e., if the starting pressure is less than 0 or greater than the *max psi* or *max bar* parameter. Note that if the starting pressure is out of range by being too high, it is likely that the desired pressure will also get flagged as an error even though it is valid (Figure 3.8). The second error message will disappear when the starting pressure value is fixed.

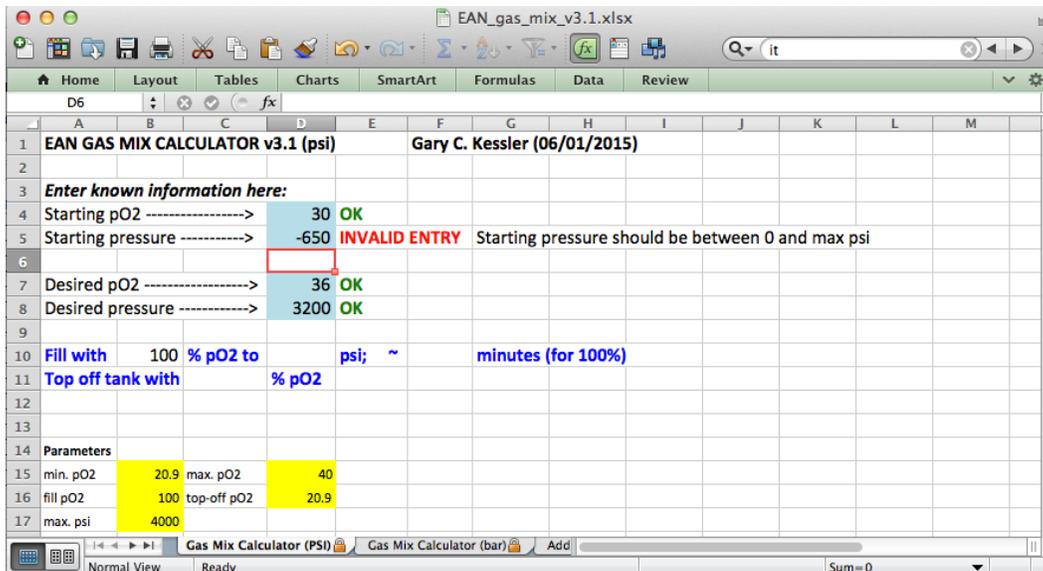


Figure 3.7. Starting pressure entry less than 0 (psi).

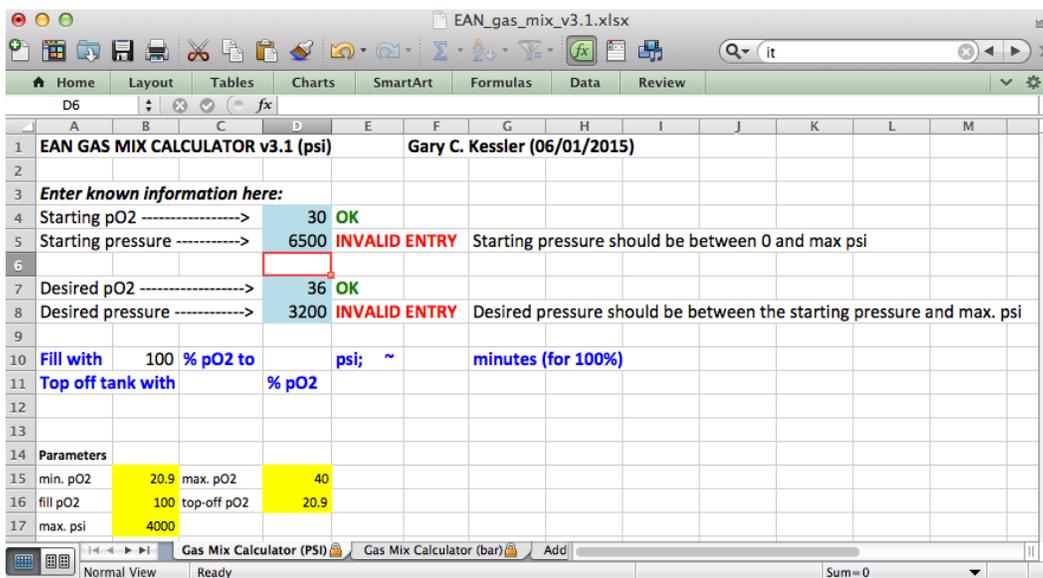


Figure 3.8. Starting pressure entry greater than the max. psi parameter value, causing the (valid) desired pressure entry to be flagged as an error (psi).

Figure 3.9 shows the error message when the desired pressure is invalid, in this case with a value greater than that of the starting pressure.

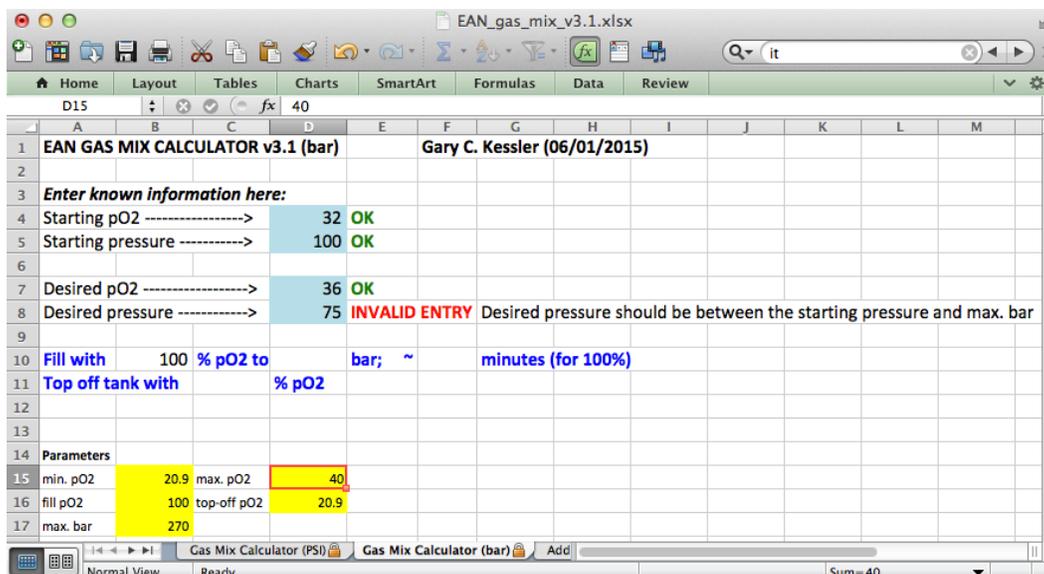


Figure 3.9. Desired pressure entry less than starting pressure entry (bar)

### Example 3: Bleeding a Tank

Having a situation where the tank needs to be bled is not an error condition, but provides information in a slightly different way than previous valid data entry screenshots have shown.

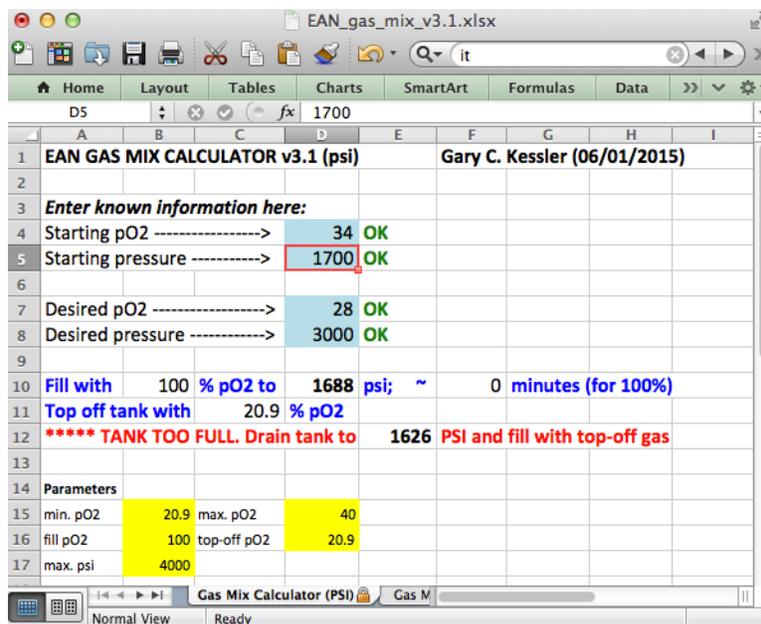


Figure 3.10. Achieving the proper blend requires bleeding the tank (psi).

Figure 3.10 shows a situation where the tank needs to be drained of gas. In this case, the starting tank already contains an EAN34 blend at 1700 psi and the diver wants a new blend of EAN28 at 3000 psi. The spreadsheet is only solving an equation for which there is an answer -- a

*wrong* answer! Therefore, the spreadsheet also makes it pretty clear that the tank needs to be first bled to 1626 psi and then filled only with the top-off gas (i.e., no fill gas will be required in this circumstance).

## APPENDIX A: The Spreadsheet and Examples

This Appendix shows spreadsheet screenshots for solving the sample problems given in Section 1.

In Example 1, we start with a 425 psi (29 bar) tank of EAN32 and wish to fill it to 3200 psi (218 bar) of EAN34. The formula shows that 470 psi (32 bar) of fill gas needs to be added to the tank followed by 2305 psi (157 bar) of top-off gas needs to be added. The spreadsheet does not show these values explicitly but does the addition for you. In particular, if the tank started at 425 psi (29 bar) and needs 470 psi (32 bar) to be added, then the blender is merely using fill gas to get the pressure up to ~895 psi (~62 bar), as shown in Figures A.1 and A.2, respectively.

	A	B	C	D	E	F	G	H	I
1	<b>EAN GAS MIX CALCULATOR v3.1 (psi)</b>				<b>Gary C. Kessler (06/01/2015)</b>				
2									
3	<i>Enter known information here:</i>								
4	Starting pO2 ----->			32	OK				
5	Starting pressure ----->			425	OK				
6									
7	Desired pO2 ----->			34	OK				
8	Desired pressure ----->			3200	OK				
9									
10	Fill with	100	% pO2 to	896	psi; ~	8	minutes (for 100%)		
11	Top off tank with		20.9	% pO2					
12									
13									
14	<b>Parameters</b>								
15	min. pO2	20.9	max. pO2	40					
16	fill pO2	100	top-off pO2	20.9					
17	max. psi	4000							

**Figure A.1.** Example 1 calculation (psi).

EAN GAS MIX CALCULATOR v3.1 (bar)				Gary C. Kessler (06/01/2015)	
<b>Enter known information here:</b>					
Starting pO2 ----->		32	OK		
Starting pressure ----->		29	OK		
Desired pO2 ----->		34	OK		
Desired pressure ----->		218	OK		
Fill with	100 % pO2 to	62 bar;	~	8 minutes (for 100%)	
Top off tank with	20.9 % pO2				
<b>Parameters</b>					
min. pO2	20.9	max. pO2	40		
fill pO2	100	top-off pO2	20.9		
max. bar	270				

Figure A.2. Example 1 calculation (bar).

In Example 2, we start with a 375 psi (26 bar) tank of EAN36 and wish to fill it to 3000 psi (204 bar) of EAN32. The formula shows that 349 psi (24 bar) of fill gas needs to be added to the tank, yielding a tank pressure of ~725 psi (50 bar) after adding the fill gas, as shown in Figures A.3 and A.4, respectively.

EAN GAS MIX CALCULATOR v3.1 (psi)				Gary C. Kessler (06/01/2015)	
<b>Enter known information here:</b>					
Starting pO2 ----->		36	OK		
Starting pressure ----->		375	OK		
Desired pO2 ----->		32	OK		
Desired pressure ----->		3000	OK		
Fill with	100 % pO2 to	725 psi;	~	6 minutes (for 100%)	
Top off tank with	20.9 % pO2				
<b>Parameters</b>					
min. pO2	20.9	max. pO2	40		
fill pO2	100	top-off pO2	20.9		
max. psi	4000				

Figure A.3. Example 2 calculation (psi).

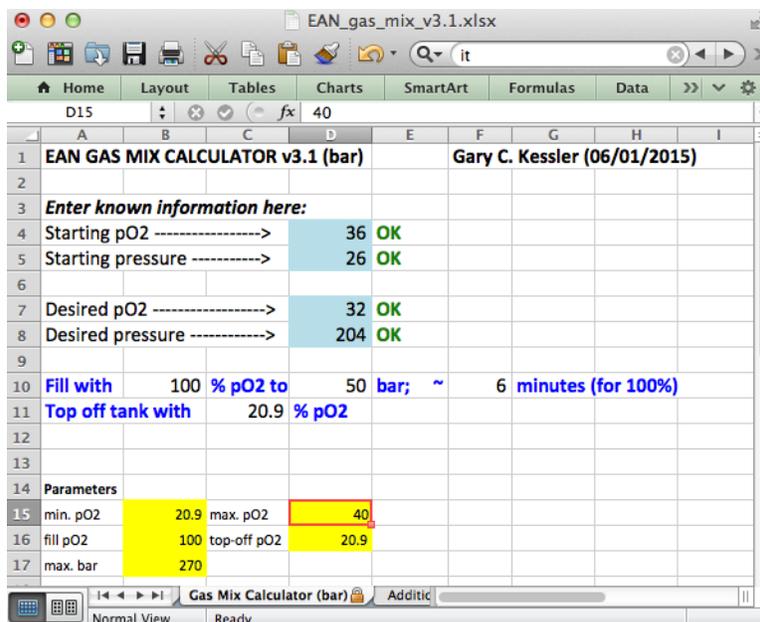


Figure A.4. Example 2 calculation (bar).

Finally, we start with a 1500 psi (102 bar) tank of EAN36 and wish to fill it to 3000 psi (204 bar) of EAN28 in Example 3. The formula here shows that we need to bleed the tank to 1411 psi (96 bar) and just add top-off gas to the tank. This is shown in Figures A.5 and A.6, respectively.

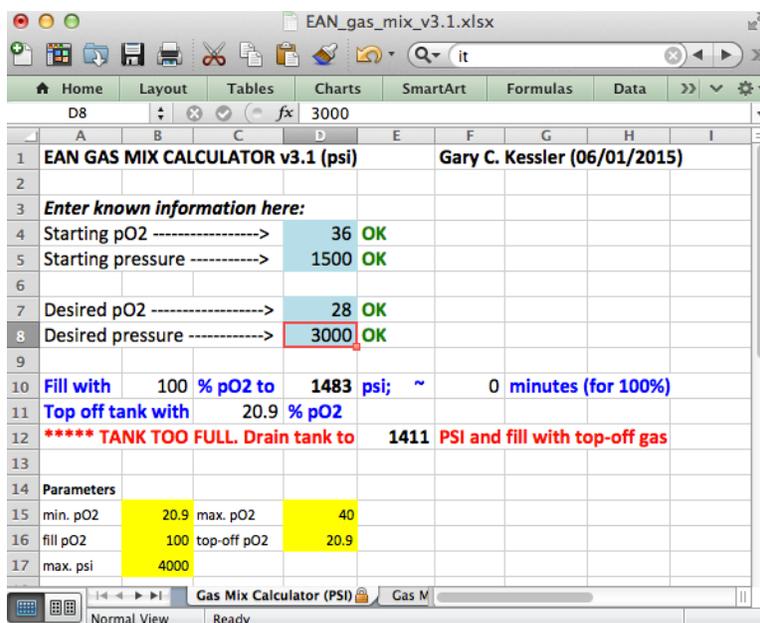


Figure A.5. Example 3 calculation (psi).

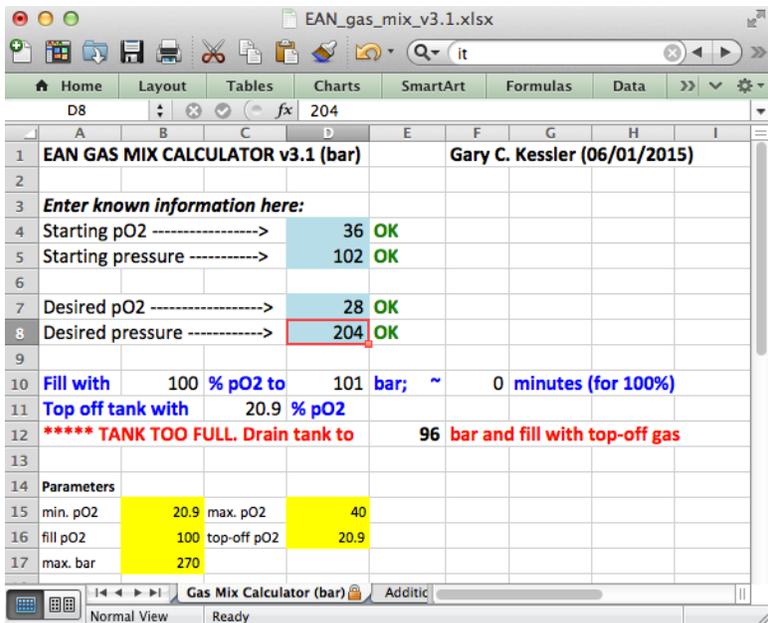


Figure A.6. Example 3 calculation (bar).

## APPENDIX B: The Web-Based Calculator

This Appendix describes the Web-based calculator, which can be found at <https://scuba.garykessler.net/resources.html>. The Web-based calculator works essentially like the spreadsheet. This appendix shows a few examples of calculations and error screenshots, also solving the sample problems given in Section 1.

The web-based version assumes a minimum and maximum blend of 21% and 40%, respectively; fill gas of 100% oxygen, top-off gas of air, and a maximum pressure of 4000 psi (270 bar). These items can be changed but it requires changing the JavaScript code. (Please contact the author if you need to customize the code.)

In Example 1, we start with a 425 psi (29 bar) tank of EAN32 and wish to fill it to 3200 psi (218 bar) of EAN34. The calculator shows that the blender needs to fill the tank to 896 psi (62 bar) with oxygen, then top-off the tank with air, as shown in Figures B.1 and B.2, respectively.

### OXYGEN MIX CALCULATOR FOR USE WITH ENHANCED AIR NITROX (PSI)

Starting mix (21–40%) |  %

Starting pressure (0–4000 psi) |  psi

Desired mix (21–40%) |  %

Ending pressure (0–4000 psi) |  psi

**Your starting pressure is 425 psi**  
**Fill with 100% O2 to 896 psi (~8 minutes at 60 psi/min)**  
**Then top-off with air to 3200 psi**

GCK (07/2020)

**Figure B.1.** Example 1 calculation (psi).

### OXYGEN MIX CALCULATOR FOR USE WITH ENHANCED AIR NITROX (BAR)



Starting mix (21-40%) | 32 %

Starting pressure (0-270 bar) | 29 bar

Desired mix (21-40%) | 34 %

Desired pressure (0-270 bar) | 218 bar

Reset Calculate

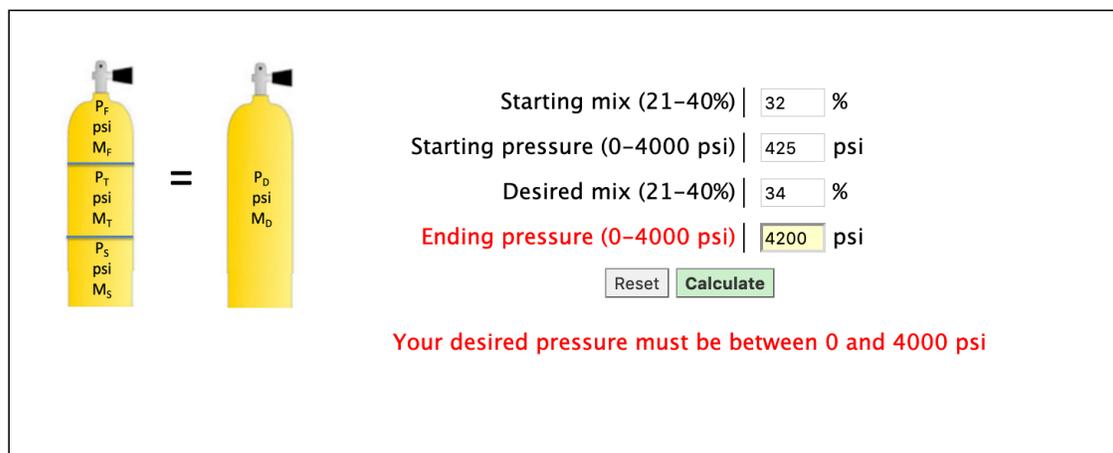
**Your starting pressure is 29 bar**  
**Fill with 100% O<sub>2</sub> to 62 bar (~9 minutes at 4 bar/min)**  
**Then top-off with air to 218 bar**

GCK (07/2020)

**Figure B.2.** Example 1 calculation (bar).

If the user enters an invalid value into any of the fields, the calculator will show the field with the error and indicate the nature of the error.

### OXYGEN MIX CALCULATOR FOR USE WITH ENHANCED AIR NITROX (PSI)



Starting mix (21-40%) | 32 %

Starting pressure (0-4000 psi) | 425 psi

Desired mix (21-40%) | 34 %

Ending pressure (0-4000 psi) | 4200 psi

Reset Calculate

**Your desired pressure must be between 0 and 4000 psi**

GCK (07/2020)

**Figure B.3.** Error message (invalid desired pressure entry).

## APPENDIX C: Using the Tables

The spreadsheet and calculator described in this document is meant to provide an alternative to using the EAN Partial Pressure Fill Tables (Figures C.1 and C.2) and manually doing the math every time you fill a tank. Using the tables are, in fact, pretty straight-forward and understanding them actually reinforces what the automatic methods are doing. By matching a row (pressure) and column (O<sub>2</sub> percent) in the table, you learn the amount of oxygen needed to provide a particular EAN mix. (The tables, by the way, are not as general purpose as the formulas that we derived above; the tables assume that the fill gas is 100% O<sub>2</sub> and that the top-off gas is air.)

Doing a Niyrox fill using the tables employs a so-called *want/have/need* method that determines how much oxygen to add to a tank given the requirements of the fill and current content of the tank. Consider this example:

1. A customer brings in a tank and requests a fill of EAN34 at a pressure of 3,000 psi. The table shows that you *want* 497 psi O<sub>2</sub>.
2. You analyze the tank to find that it currently holds 500 psi of EAN32. The table shows that you *have* 70 psi O<sub>2</sub> already in the tank.
3. Since you *want* 497 psi O<sub>2</sub> and already *have* 70 psi, you *need* an additional 427 psi O<sub>2</sub>.
4. Your tank currently has 500 psi of gas in it and you need to add 427 psi O<sub>2</sub>. That means that you need to fill the tank to 927 psi with O<sub>2</sub> and then top it off to 3,000 psi with air.

This method is simple enough when the parameters match values that are in the tables. Things get harder when they don't line up, such as when someone brings in a tank with 463 psi (31.3 bar) and a 31.6% mix. In those circumstances, you need to extrapolate (i.e., estimate) the proper values to use.

Section 1.2 above derived the basic formula for the values in the tables below, namely:

$$\frac{P_D \cdot (M_D - 0.209)}{0.791} = P_{O_2}$$

With this formula, you can determine how much O<sub>2</sub> is needed for any EAN mix at any pressure, and then employ the *want/have/need* method described above to determine how much O<sub>2</sub> to add to any tank.

Enriched Air Nitrox Partial Pressure Fill Table (psi)																			
Pressure (psi)	Oxygen (O2) Percentage																		
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
3200	45	85	125	166	206	247	287	328	368	409	449	490	530	570	611	651	692	732	773
3100	43	82	121	161	200	239	278	317	357	396	435	474	513	553	592	631	670	709	749
3000	42	80	118	155	193	231	269	307	345	383	421	459	497	535	573	611	649	686	724
2900	40	77	114	150	187	224	260	297	334	370	407	444	480	517	554	590	627	664	700
2800	39	74	110	145	181	216	251	287	322	358	393	428	464	499	535	570	605	641	676
2700	38	72	106	140	174	208	242	276	311	345	379	413	447	481	515	550	584	618	652
2600	36	69	102	135	168	201	233	266	299	332	365	398	431	463	496	529	562	595	628
2500	35	66	98	130	161	193	224	256	288	319	351	382	414	446	477	509	540	572	604
2400	33	64	94	124	155	185	215	246	276	306	337	367	397	428	458	488	519	549	580
2300	32	61	90	119	148	177	206	236	265	294	323	352	381	410	439	468	497	526	555
2200	31	58	86	114	142	170	197	225	253	281	309	337	364	392	420	448	476	503	531
2100	29	56	82	109	135	162	188	215	242	268	295	321	348	374	401	427	454	481	507
2000	28	53	78	104	129	154	180	205	230	255	281	306	331	357	382	407	432	458	483
1900	26	50	74	98	123	147	171	195	219	243	267	291	315	339	363	387	411	435	459
1800	25	48	71	93	116	139	162	184	207	230	253	275	298	321	344	366	389	412	435
1700	24	45	67	88	110	131	153	174	196	217	239	260	282	303	325	346	368	389	410
1600	22	42	63	83	103	123	144	164	184	204	225	245	265	285	305	326	346	366	386
1500	21	40	59	78	97	116	135	154	173	192	210	229	248	267	286	305	324	343	362
1400	19	37	55	73	90	108	126	143	161	179	196	214	232	250	267	285	303	320	338
1300	18	35	51	67	84	100	117	133	150	166	182	199	215	232	248	265	281	297	314
1200	17	32	47	62	77	93	108	123	138	153	168	184	199	214	229	244	259	275	290
1100	15	29	43	57	71	85	99	113	127	140	154	168	182	196	210	224	238	252	266
1000	14	27	39	52	64	77	90	102	115	128	140	153	166	178	191	204	216	229	241
900	13	24	35	47	58	69	81	92	104	115	126	138	149	160	172	183	195	206	217
800	11	21	31	41	52	62	72	82	92	102	112	122	132	143	153	163	173	183	193
700	10	19	27	36	45	54	63	72	81	89	98	107	116	125	134	142	151	160	169
600	8	16	24	31	39	46	54	61	69	77	84	92	99	107	115	122	130	137	145
500	7	13	20	26	32	39	45	51	58	64	70	76	83	89	95	102	108	114	121
400	6	11	16	21	26	31	36	41	46	51	56	61	66	71	76	81	86	92	97
300	4	8	12	16	19	23	27	31	35	38	42	46	50	53	57	61	65	69	72
200	3	5	8	10	13	15	18	20	23	26	28	31	33	36	38	41	43	46	48
100	1	3	4	5	6	8	9	10	12	13	14	15	17	18	19	20	22	23	24

Figure C.1. Enriched Air Nitrox Partial Pressure Fill Table (psi).

Enriched Air Nitrox Partial Pressure Fill Table (bar)																			
Pressure (bar)	Oxygen (O2) Percentage																		
	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
220	3.1	5.8	8.6	11.4	14.2	17.0	19.7	22.5	25.3	28.1	30.9	33.7	36.4	39.2	42.0	44.8	47.6	50.3	53.1
210	2.9	5.6	8.2	10.9	13.5	16.2	18.8	21.5	24.2	26.8	29.5	32.1	34.8	37.4	40.1	42.7	45.4	48.1	50.7
200	2.8	5.3	7.8	10.4	12.9	15.4	18.0	20.5	23.0	25.5	28.1	30.6	33.1	35.7	38.2	40.7	43.2	45.8	48.3
190	2.6	5.0	7.4	9.8	12.3	14.7	17.1	19.5	21.9	24.3	26.7	29.1	31.5	33.9	36.3	38.7	41.1	43.5	45.9
180	2.5	4.8	7.1	9.3	11.6	13.9	16.2	18.4	20.7	23.0	25.3	27.5	29.8	32.1	34.4	36.6	38.9	41.2	43.5
170	2.4	4.5	6.7	8.8	11.0	13.1	15.3	17.4	19.6	21.7	23.9	26.0	28.2	30.3	32.5	34.6	36.8	38.9	41.0
160	2.2	4.2	6.3	8.3	10.3	12.3	14.4	16.4	18.4	20.4	22.5	24.5	26.5	28.5	30.5	32.6	34.6	36.6	38.6
150	2.1	4.0	5.9	7.8	9.7	11.6	13.5	15.4	17.3	19.2	21.0	22.9	24.8	26.7	28.6	30.5	32.4	34.3	36.2
140	1.9	3.7	5.5	7.3	9.0	10.8	12.6	14.3	16.1	17.9	19.6	21.4	23.2	25.0	26.7	28.5	30.3	32.0	33.8
130	1.8	3.5	5.1	6.7	8.4	10.0	11.7	13.3	15.0	16.6	18.2	19.9	21.5	23.2	24.8	26.5	28.1	29.7	31.4
120	1.7	3.2	4.7	6.2	7.7	9.3	10.8	12.3	13.8	15.3	16.8	18.4	19.9	21.4	22.9	24.4	25.9	27.5	29.0
110	1.5	2.9	4.3	5.7	7.1	8.5	9.9	11.3	12.7	14.0	15.4	16.8	18.2	19.6	21.0	22.4	23.8	25.2	26.6
100	1.4	2.7	3.9	5.2	6.4	7.7	9.0	10.2	11.5	12.8	14.0	15.3	16.6	17.8	19.1	20.4	21.6	22.9	24.1
90	1.3	2.4	3.5	4.7	5.8	6.9	8.1	9.2	10.4	11.5	12.6	13.8	14.9	16.0	17.2	18.3	19.5	20.6	21.7
80	1.1	2.1	3.1	4.1	5.2	6.2	7.2	8.2	9.2	10.2	11.2	12.2	13.2	14.3	15.3	16.3	17.3	18.3	19.3
70	1.0	1.9	2.7	3.6	4.5	5.4	6.3	7.2	8.1	8.9	9.8	10.7	11.6	12.5	13.4	14.2	15.1	16.0	16.9
60	0.8	1.6	2.4	3.1	3.9	4.6	5.4	6.1	6.9	7.7	8.4	9.2	9.9	10.7	11.5	12.2	13.0	13.7	14.5
50	0.7	1.3	2.0	2.6	3.2	3.9	4.5	5.1	5.8	6.4	7.0	7.6	8.3	8.9	9.5	10.2	10.8	11.4	12.1
40	0.6	1.1	1.6	2.1	2.6	3.1	3.6	4.1	4.6	5.1	5.6	6.1	6.6	7.1	7.6	8.1	8.6	9.2	9.7
30	0.4	0.8	1.2	1.6	1.9	2.3	2.7	3.1	3.5	3.8	4.2	4.6	5.0	5.3	5.7	6.1	6.5	6.9	7.2
20	0.3	0.5	0.8	1.0	1.3	1.5	1.8	2.0	2.3	2.6	2.8	3.1	3.3	3.6	3.8	4.1	4.3	4.6	4.8
10	0.1	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.2	1.3	1.4	1.5	1.7	1.8	1.9	2.0	2.2	2.3	2.4

Figure C.2. Enriched Air Nitrox Partial Pressure Fill Table (bar).

## Acronyms and Abbreviations

bar	One atmosphere of pressure (14.7 psi)
F <sub>x</sub>	Fractional portion of gas X in a gas mixture (%)
M	The gas mix, or F <sub>O<sub>2</sub></sub> in a gas blend (%)
N <sub>2</sub>	Nitrogen
O <sub>2</sub>	Oxygen
P	Pressure (psi or bar)
psi	Pounds per square inch

	Pressure (psi/bar)	F <sub>O<sub>2</sub></sub> in Mix (%)
<b>Start</b>	P <sub>S</sub>	M <sub>S</sub>
<b>Desired</b>	P <sub>D</sub>	M <sub>D</sub>
<b>Fill gas</b>	P <sub>F</sub>	M <sub>F</sub>
<b>Top-off gas</b>	P <sub>T</sub>	M <sub>T</sub>

## References and Further Reading

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## About the Author

Gary C. Kessler was certified as a SCUBA diver as a teenager in southern California in 1967. He was later certified as an Open Water Diver, Advanced Open Water Diver, and Rescue Diver by the Professional Association of Dive Instructors (PADI) as part of the Colchester (Vermont) Rescue Dive Team in 1991. In 2009, Gary became a PADI Divemaster and Open Water Instructor, becoming a Master SCUBA Diver Trainer in 2011, Tec Gas Blender in 2014, and Tec Gas Blender Instructor in 2015.

Living on Lake Champlain (the sixth largest freshwater lake in the U.S.) and wanting to dive whenever he wanted, Gary bought his first boat in 1994. He received his USCG Captain's license in 2012. He currently lives in Ormond Beach, Florida, where he is a member of the USCG Auxiliary Flotilla 44, Daytona Beach, and holds a coxswain qualification.

In his other life, Gary is a retired professor of cybersecurity and co-author of *Maritime Cybersecurity: A Guide for Leaders and Managers*. He is also an information security consultant, educator, practitioner, and researcher, with an emphasis on the maritime sector, and a coxswain in the USCG Auxiliary. Gary holds a B.A. in Mathematics, M.S. in Computer Science, and Ph.D. in Computing Technology in Education.