

# AEROSPACE INFORMATION REPORT

AIR825™/14

Issued 2010-06  
Reaffirmed 2021-08

## Basic Aircraft Oxygen Systems Design

### RATIONALE

AIR825/14 has been reaffirmed to comply with the SAE five-year review policy.

### FOREWORD

The third revision of AIR825, Oxygen Equipment for Aircraft, generated such a large volume of information that the document became cumbersome to use. See AIR825/1 for a full list of slash documents, topics and history. This document is one of 14 slash documents that are comprised of existing AIR825 documents plus new information. Anyone who is new to oxygen requirements for aircraft will find all slash 14 documents beneficial. In contrast, someone with extensive experience may want to only obtain one or two of the slash documents.

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## 1. SCOPE

This slash document collects general reference material related to gaseous oxygen system flow requirements and sizing calculations. This document will assist oxygen system equipment designers and operators to establish systems and equipment requirements. The document consists of charts, tables, system schematics, system requirements, and sample calculations for system sizing.

### 1.1 Purpose

This slash document presents analytical methods for calculating the gaseous oxygen supply required for cabin occupants and crew. The first section addresses the design of a continuous-flow passenger system and evaluation of the component performance requirements. The oxygen system is designed to provide all passengers with at least the minimum tracheal oxygen partial pressure specified by the Code of Federal Regulations (CFRs), the Joint Aviation Requirements (JARs) and Certification Specifications (CSs) parts 25.1441 through 25.1453. The second section addresses the crew oxygen system source sizing with an example using theoretical equipment. Although the analyses are based on official regulations, the system designs used for these illustrations are based on both a hypothetical airplane and hypothetical oxygen system components. These examples should not be used for airplane design. Accordingly, in analyzing a particular system, performance capabilities of the actual equipment should be considered.

The choice as to which system components are to be the system's independent variables and which are to be dependent variables is somewhat arbitrary. For this example, the performance of both the passenger mask and the passenger outlet orifice are considered to be the independent variables; their performance will be determined empirically. The establishment of these values will allow the calculation of the dependent variables, the regulator performance curves, and an oxygen requirement curve. The oxygen requirement curve is then used to evaluate the oxygen quantity requirements. The required oxygen flow is that quantity of oxygen flow required by the system to ensure that all passenger masks will have at least the minimum oxygen required.

Once the required quantity of oxygen has been established, an average or overall value of system oxygen utilization efficiency can be determined. For overall system design, it is desirable to achieve the highest efficiency level possible. This will be discussed in Section 3.3.6, System Efficiencies

This passenger system evaluation and calculation does not include an analysis of the quantity of first aid oxygen required for commercial transport operations under CFR 121.333 or JAR OPS 1.760.

The passenger system analysis begins with the requirements of the airplane system's most remotely located passenger oxygen mask where the oxygen distribution line pressure drop is at its maximum (See Figure 1, point E). This person's mask must provide the CFR required minimum quantity of oxygen, but may be the least amount of any one mask associated with the distribution system. The specific mask performance characteristics will determine the minimum flow required at the mask. The flow that is delivered is based on the outlet's orifice performance, which determines the pressure control regulator's pressure required to the outlet orifice (See Figure 1, point E). The pressure required at the outlet adjusted for the distribution system pressure drop will determine the pressure schedule of the pressure control regulator (See Figure 1, point B).

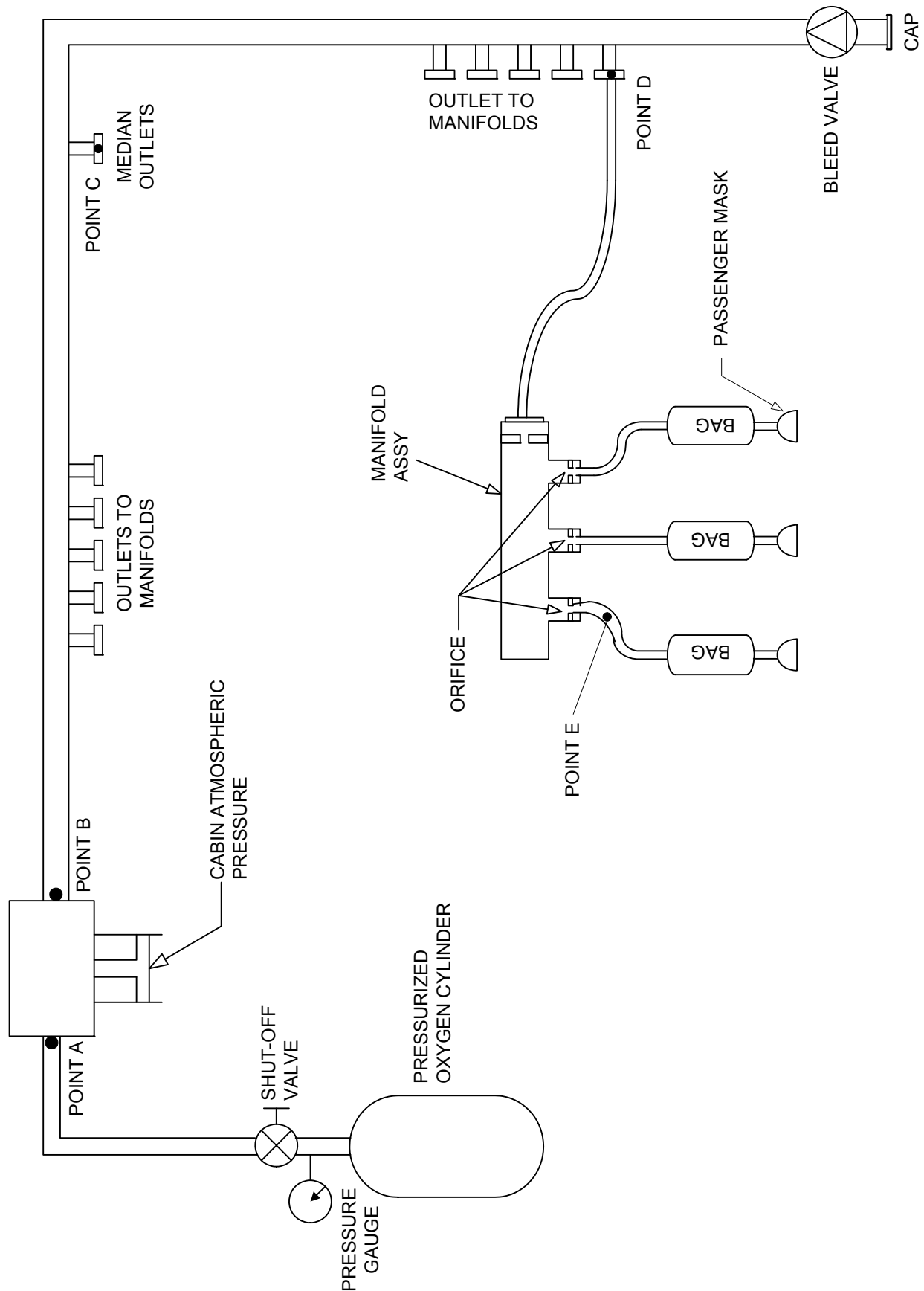


FIGURE 1 – PASSENGER SYSTEM SCHEMATIC

## 2. APPLICABLE DOCUMENTS

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

### 2.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-000, Telephone: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), [www.sae.org](http://www.sae.org).

AS8025 Passenger Oxygen Mask

### 2.2 CFR & FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, [www.faa.gov](http://www.faa.gov).

Code of Federal Regulations (CFR) Title 14, Aeronautics and Space Part 25, Airworthiness Standards: Transport Category Airplanes

FAA TSO-C64b Oxygen Mask Assembly, Continuous Flow, Passenger

### 2.3 JAR & JAA Publications

Available from Civil Aviation Authority, Printing and Publication Services, Greville House, 37 Gratton Road, Cleltenham, Glos. GL50 2BN, United Kingdom.

JAR OPS Joint Aviation Requirements - Operations

Joint Aviation Requirements (JAR) 25 Large Airplanes,

### 2.4 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Aerospace Technical Report.

|          |                                                                                         |
|----------|-----------------------------------------------------------------------------------------|
| AIR825/1 | Introduction to Oxygen Equipment for Aircraft                                           |
| AIR825/2 | Effects of Acute Altitude Exposure in Humans: Requirements for Physiological Protection |
| AIR825/3 | Gaseous Oxygen and Oxygen Equipment, Introductory                                       |
| AIR825/4 | Chemical Oxygen Systems                                                                 |
| AIR825/5 | Liquid Oxygen Systems                                                                   |
| AIR825/6 | On Board Oxygen Generator Systems (OBOGS) Molecular Sieve                               |
| AIR825/7 | Other On Board Oxygen Generating Technologies                                           |
| AIR825/8 | Continuous Flow Oxygen Systems                                                          |
| AIR825/9 | Demand Oxygen Systems                                                                   |

|           |                                                                      |
|-----------|----------------------------------------------------------------------|
| AIR825/10 | Protective Breathing Equipment for Flight Deck and Cabin Crewmembers |
| AIR825/11 | Closed-Cycle Protective Breathing Devices                            |
| AIR825/12 | Oxygen System Integration and Performance Precautions                |
| AIR825/13 | Guide for Evaluating Combustion Hazards in Aircraft Oxygen Systems   |

## 2.5 Definitions

“Air”: A homogeneous combinations of gases as described in Table 3.1 plus water vapor if not dry. It consists 21% Oxygen and 79% Nitrogen (approximately)

ALTITUDE COMPENSATED CONTROL REGULATOR: A regulator that varies the output pressure of a gas based on the atmospheric pressure to which it is exposed.

ATPD: Ambient temperature and pressure, dry (pH<sub>2</sub> 0 = 0).

BTPD: Body temperature, pressure, dry (37 °C, ambient pressure, pH<sub>2</sub> 0 = 0).

BTPS: Body temperature, pressure, saturated (37 °C, ambient pressure, saturated with water vapor at 37 °C - pH<sub>2</sub>0 at 37 °C = 6.27 kPa (47.00 mm Hg)).

CABIN PRESSURE ALTITUDE: The ambient pressure inside the pressure vessel at a given altitude, for the purposes of this document the atmosphere defined in U.S. Standard Atmosphere, 1962 (Geopotential altitude tables) will be used.

CONTINUOUS FLOW EQUIPMENT: Equipment which provides a continuous flow of oxygen to the mask.

DARCY-WEISBACH EQUATION: 
$$h_f = f * \frac{L * V^2}{d * 2g}$$

where:

$h_f$  is the friction-head loss include

major losses – due to the friction in the tubings,

minor losses – due to the losses at the bends, valves, tees, etc.

$L$  is the length of pipe

$d$  is the tube diameter

$f$  is the friction factor

$V$  is the velocity

$g$  is the acceleration of gravity

DEMAND EQUIPMENT: Equipment that provides oxygen flow to the mask only during the inhalation phase of the breathing cycle. The oxygen flow stops during the exhalation phase.

DILUTER DEMAND EQUIPMENT: Equipment which provides diluted oxygen flow upon demand. The mixture of oxygen and air varies depending on pressure altitude.

DOT: Department of Transportation.

**EMERGENCY DESCENT PROFILE:** The descent profile showing altitude versus time, which is prescribed for emergency use after a decompression. This is usually the airplane's fastest, safe descent that can be safely performed after a decompression of the main cabin, starting at maximum certified flight altitude down to 10,000 feet, or a sustaining altitude that is controlled by in-route terrain.

**FLIGHT ALTITUDE:** The pressure altitude of the airplane based on U.S. Standard Atmosphere, 1962 (Geopotential altitude tables).

**FLOW REGULATOR:** The device that regulates the volumetric flow depending on cabin pressure altitude.

**FREE FLOW:** Equipment which provides oxygen flow without controlled regulation.

**GAS MIXTURE:** Consists of a mixture of Oxygen and "Air" (see above for "Air" definition).

**HIGH PRESSURE CYLINDERS:** Cylinders that store gas as high as 1800 to 2100 psig\*.

**HYPOXIA:** A state of oxygen deficiency in the body which is sufficient to cause an impairment of function. Hypoxia is caused by the reduction in partial pressure of oxygen, inadequate oxygen transport, or the inability of the tissues to use oxygen.

**LOW PRESSURE CYLINDERS:** Cylinders that store gas at pressure as high as 400 to 500 psig\*.

**LPM:** Liters per minute.

**MINUTE VOLUME:** The volume of air breathed at ambient conditions in one minute.

**NTPD:** Normal temperature, pressure, dry (21 °C, pressure = 101 kPa (760 mm Hg), and  $p_{H_2O} = 0$ ).

**PACKED ORIFICE:** A method of restricting flow through an outlet by usage of dense, porous materials.

**P<sub>B</sub>:** Barometric pressure.

**P<sub>B</sub>-47:** The total pressure of dry gases in the trachea, by deducting the contribution due to gases saturated with water vapor in the trachea at body temperature (37 °C), expressed in mm Hg.

**PERCENT OXYGEN:** Parts of oxygen in 100 parts of dry gas by volume existing in a mixture saturated with water vapor at 37 °C.

**p<sub>H<sub>2</sub>O</sub>:** Partial pressure of water vapor ( $p_{H_2O}$  at 37 °C = 6.27 kPa (47.00 mm Hg)).

**pO<sub>2</sub>:** Partial pressure of oxygen.

**PRESSURE-DEMAND EQUIPMENT:** Equipment that delivers pure oxygen under positive pressure (i.e., pressure greater than ambient). This equipment, in effect, reverses the normal mechanics of breathing, in that exhalation requires effort by the diaphragm muscles and inhalation occurs as the muscle relax. This feature is used for smoke/toxic gases protective breathing. It is also used for high-altitude protection.

**PRESSURE REGULATOR:** A device that reduces and controls the pressure of a gas.

**PRESSURE SCHEDULE:** The performance parameters for the pressure control regulator based on system design.

**R:** Gas Constant for Oxygen = 259.8 Newton x meters/kilogram x K  
= 1554.9 ft lb per slug x °R.

**SCF:** Standard Cubic Foot.

**STPD:** Standard temperature, pressure, dry (0 °C, pressure = 101 kPa (760 mm Hg), and  $p_{H_2O} = 0$ ).

**SUPPLEMENTAL OXYGEN:** Oxygen added to ambient air via an individual oxygen mask prior to or during inspiration, to compensate for reduced partial pressure of oxygen encountered at altitude and to maintain an adequate tracheal oxygen partial pressure.

**SUSTAINING OXYGEN:** In a gaseous system, the oxygen that exceeds that quantity actually required for the demonstrated emergency descent profile. This quantity of oxygen typically is utilized in flight under conditions where the airplane cannot descend due to terrain or other operational configurations.

**TIDAL VOLUME:** The volume of gas inspired or expired during each respiratory cycle.

**TRACHEAL OXYGEN PARTIAL PRESSURE:** The total partial pressure of oxygen in the trachea. The saturation pressure of 6.27 kPa (47 mm Hg) (of water vapor) is reached at normal body temperature of 37 °C.

**TRANSPORT CATEGORY AIRPLANE:** All jets with 10 or more seats or greater than 12 500 lb. maximum takeoff weight and all propeller driven airplanes with greater than 19 seats or greater than 19 000 lb. maximum takeoff weight.

\* Multiply psig by 6.8948 to get kN/m<sup>2</sup> (kPa)

### 3. SYSTEM DESIGN

This section will go through the analysis, in detail, of a gaseous oxygen system design.

#### 3.1 Technical Information

Listed are assumptions used when going through this sample system analysis.

##### 3.1.1 Pressure Altitude Relationships for Physiological Studies

The relationships between altitude, barometric pressure, volumetric ratios, and the partial pressures of oxygen based on the percentage of oxygen at these pressure altitudes, are required for oxygen system analysis. These relationships are shown on Table 1, columns 10 through 13 refer to tracheal oxygen partial pressure values as called for in CFR part 25.1443, JAR part 25.1443 and CS 25.1443.

TABLE 1 – ALTITUDE TABLE WITH PHYSICAL RELATIONSHIPS FOR PHYSIOLOGICAL STUDIES

| Altitude |        | Barometric Pressure |         |        | Volumetric Ratios* |               |               | %O2 at following Tracheal pO2 |              |             |             |             |
|----------|--------|---------------------|---------|--------|--------------------|---------------|---------------|-------------------------------|--------------|-------------|-------------|-------------|
| ft       | meters | kPa                 | lb/in^2 | mmHg   | BTPS/<br>BTPD      | BTPS/<br>STPD | BTPS/<br>NTPD | Pb-<br>47mmHg                 | 83.8<br>mmHg | 100<br>mmHg | 122<br>mmHg | 149<br>mmHg |
| 0        | 0      | 101.33              | 14.70   | 760.00 | 1.07               | 1.21          | 1.12          | 713.00                        | 11.75        | 14.03       | 17.11       | 20.90       |
| 1000     | 305    | 97.72               | 14.17   | 732.93 | 1.07               | 1.26          | 1.17          | 685.93                        | 12.22        | 14.58       | 17.79       | 21.72       |
| 2000     | 610    | 94.21               | 13.66   | 706.65 | 1.07               | 1.31          | 1.21          | 659.65                        | 12.70        | 15.16       | 18.49       | 22.59       |
| 3000     | 914    | 90.81               | 13.17   | 681.14 | 1.07               | 1.36          | 1.26          | 634.14                        | 13.21        | 15.77       | 19.24       | 23.50       |
| 4000     | 1219   | 87.51               | 12.69   | 656.38 | 1.08               | 1.42          | 1.31          | 609.38                        | 13.75        | 16.41       | 20.02       | 24.45       |
| 5000     | 1524   | 84.31               | 12.23   | 632.36 | 1.08               | 1.47          | 1.37          | 585.36                        | 14.32        | 17.08       | 20.84       | 25.45       |
| 6000     | 1829   | 81.20               | 11.78   | 609.05 | 1.08               | 1.54          | 1.43          | 562.05                        | 14.91        | 17.79       | 21.71       | 26.51       |
| 7000     | 2134   | 78.19               | 11.34   | 586.44 | 1.09               | 1.60          | 1.48          | 539.44                        | 15.53        | 18.54       | 22.62       | 27.62       |
| 8000     | 2438   | 75.26               | 10.92   | 564.52 | 1.09               | 1.67          | 1.55          | 517.52                        | 16.19        | 19.32       | 23.57       | 28.79       |
| 9000     | 2743   | 72.43               | 10.50   | 543.26 | 1.09               | 1.74          | 1.61          | 496.26                        | 16.89        | 20.15       | 24.58       | 30.02       |
| 10000    | 3048   | 69.68               | 10.11   | 522.66 | 1.10               | 1.81          | 1.68          | 475.66                        | 17.62        | 21.02       | 25.65       | 31.33       |
| 11000    | 3353   | 67.02               | 9.72    | 502.69 | 1.10               | 1.89          | 1.76          | 455.69                        | 18.39        | 21.94       | 26.77       | 32.70       |
| 12000    | 3658   | 64.44               | 9.35    | 483.35 | 1.11               | 1.98          | 1.84          | 436.35                        | 19.20        | 22.92       | 27.96       | 34.15       |
| 13000    | 3962   | 61.94               | 8.98    | 464.61 | 1.11               | 2.07          | 1.92          | 417.61                        | 20.07        | 23.95       | 29.21       | 35.68       |
| 14000    | 4267   | 59.52               | 8.63    | 446.47 | 1.12               | 2.16          | 2.01          | 399.47                        | 20.98        | 25.03       | 30.54       | 37.30       |
| 15000    | 4572   | 57.18               | 8.29    | 428.90 | 1.12               | 2.26          | 2.10          | 381.90                        | 21.94        | 26.18       | 31.95       | 39.02       |
| 16000    | 4877   | 54.92               | 7.96    | 411.90 | 1.13               | 2.36          | 2.20          | 364.90                        | 22.97        | 27.41       | 33.43       | 40.83       |
| 17000    | 5182   | 52.72               | 7.65    | 395.44 | 1.13               | 2.48          | 2.30          | 348.44                        | 24.05        | 28.70       | 35.01       | 42.76       |
| 18000    | 5486   | 50.60               | 7.34    | 379.53 | 1.14               | 2.60          | 2.41          | 332.53                        | 25.20        | 30.07       | 36.69       | 44.81       |
| 19000    | 5791   | 48.55               | 7.04    | 364.14 | 1.15               | 2.72          | 2.53          | 317.14                        | 26.42        | 31.53       | 38.47       | 46.98       |
| 20000    | 6096   | 46.56               | 6.75    | 349.25 | 1.16               | 2.86          | 2.65          | 302.25                        | 27.73        | 33.08       | 40.36       | 49.30       |
| 21000    | 6401   | 44.65               | 6.48    | 334.87 | 1.16               | 3.00          | 2.78          | 287.87                        | 29.11        | 34.74       | 42.38       | 51.76       |
| 22000    | 6706   | 42.79               | 6.21    | 320.96 | 1.17               | 3.15          | 2.92          | 273.96                        | 30.59        | 36.50       | 44.53       | 54.39       |
| 23000    | 7010   | 41.00               | 5.95    | 307.53 | 1.18               | 3.31          | 3.07          | 260.53                        | 32.17        | 38.38       | 46.83       | 57.19       |
| 24000    | 7315   | 39.27               | 5.70    | 294.56 | 1.19               | 3.49          | 3.24          | 247.56                        | 33.85        | 40.39       | 49.28       | 60.19       |
| 25000    | 7620   | 37.60               | 5.45    | 282.03 | 1.20               | 3.67          | 3.41          | 235.03                        | 35.66        | 42.55       | 51.91       | 63.40       |
| 26000    | 7925   | 35.99               | 5.22    | 269.94 | 1.21               | 3.87          | 3.59          | 222.94                        | 37.59        | 44.86       | 54.72       | 66.83       |
| 27000    | 8230   | 34.43               | 4.99    | 258.27 | 1.22               | 4.08          | 3.79          | 211.27                        | 39.66        | 47.33       | 57.75       | 70.53       |
| 28000    | 8534   | 32.93               | 4.78    | 247.01 | 1.23               | 4.31          | 4.00          | 200.01                        | 41.90        | 50.00       | 61.00       | 74.50       |
| 29000    | 8839   | 31.49               | 4.57    | 236.16 | 1.25               | 4.56          | 4.23          | 189.16                        | 44.30        | 52.87       | 64.50       | 78.77       |
| 30000    | 9144   | 30.09               | 4.36    | 225.69 | 1.26               | 4.83          | 4.48          | 178.69                        | 46.90        | 55.96       | 68.27       | 83.38       |
| 31000    | 9449   | 28.74               | 4.17    | 215.60 | 1.28               | 5.12          | 4.75          | 168.60                        | 49.70        | 59.31       | 72.36       | 88.37       |
| 32000    | 9754   | 27.45               | 3.98    | 205.88 | 1.30               | 5.43          | 5.04          | 158.88                        | 52.74        | 62.94       | 76.79       | 93.78       |
| 33000    | 10058  | 26.20               | 3.80    | 196.52 | 1.31               | 5.77          | 5.36          | 149.52                        | 56.05        | 66.88       | 81.59       | 99.65       |
| 34000    | 10363  | 25.00               | 3.63    | 187.51 | 1.33               | 6.14          | 5.70          | 140.51                        | 59.64        | 71.17       | 86.83       |             |

\* The values are calculated with pressure in mm Hg. These values are also valid when pressure is in kN/m<sup>2</sup> (kPa).

TABLE 1 – ALTITUDE TABLE WITH PHYSICAL RELATIONSHIPS FOR PHYSIOLOGICAL STUDIES (CON'T)

| Altitude |        | Barometric Pressure |         |        | Volumetric Ratios* |               |               | %O2 at following Tracheal pO2 |              |             |             |             |
|----------|--------|---------------------|---------|--------|--------------------|---------------|---------------|-------------------------------|--------------|-------------|-------------|-------------|
| ft       | meters | kPa                 | lb/in^2 | mmHg   | BTPS/<br>BTPD      | BTPS/<br>STPD | BTPS/<br>NTPD | Pb-<br>47mmHg                 | 83.8<br>mmHg | 100<br>mmHg | 122<br>mmHg | 149<br>mmHg |
| 35000    | 10668  | 23.84               | 3.46    | 178.83 | 1.36               | 6.55          | 6.08          | 131.83                        | 63.57        | 75.85       | 92.54       |             |
| 36000    | 10973  | 22.73               | 3.30    | 170.48 | 1.38               | 6.99          | 6.49          | 123.48                        | 67.86        | 80.98       | 98.80       |             |
| 37000    | 11278  | 21.66               | 3.14    | 162.48 | 1.41               | 7.47          | 6.94          | 115.48                        | 72.56        | 86.59       |             |             |
| 38000    | 11582  | 20.65               | 2.99    | 154.86 | 1.44               | 8.00          | 7.43          | 107.86                        | 77.69        | 92.71       |             |             |
| 39000    | 11887  | 19.68               | 2.85    | 147.59 | 1.47               | 8.58          | 7.96          | 100.59                        | 83.31        | 99.41       |             |             |
| 40000    | 12192  | 18.75               | 2.72    | 140.67 | 1.50               | 9.21          | 8.55          | 93.67                         | 89.47        |             |             |             |
| 41000    | 12497  | 17.87               | 2.59    | 134.06 | 1.54               | 9.91          | 9.20          | 87.06                         | 96.25        |             |             |             |
| 42000    | 12802  | 17.04               | 2.47    | 127.77 | 1.58               | 10.68         | 9.92          | 80.77                         |              |             |             |             |
| 43000    | 13106  | 16.24               | 2.35    | 121.78 | 1.63               | 11.54         | 10.71         | 74.78                         |              |             |             |             |
| 44000    | 13411  | 15.47               | 2.24    | 116.06 | 1.68               | 12.50         | 11.60         | 69.06                         |              |             |             |             |
| 45000    | 13716  | 14.75               | 2.14    | 110.62 | 1.74               | 13.56         | 12.59         | 63.62                         |              |             |             |             |
| 46000    | 14021  | 14.06               | 2.04    | 105.43 | 1.80               | 14.77         | 13.71         | 58.43                         |              |             |             |             |
| 47000    | 14326  | 13.40               | 1.94    | 100.48 | 1.88               | 16.14         | 14.98         | 53.48                         |              |             |             |             |
| 48000    | 14630  | 12.77               | 1.85    | 95.76  | 1.96               | 17.70         | 16.43         | 48.76                         |              |             |             |             |
| 49000    | 14935  | 12.17               | 1.76    | 91.27  | 2.06               | 19.49         | 18.09         | 44.27                         |              |             |             |             |
| 50000    | 15240  | 11.60               | 1.68    | 86.99  | 2.18               | 21.58         | 20.03         | 39.99                         |              |             |             |             |
| 51000    | 15545  | 11.05               | 1.60    | 82.90  | 2.31               | 24.03         | 22.31         | 35.90                         |              |             |             |             |
| 52000    | 15850  | 10.53               | 1.53    | 79.01  | 2.47               | 26.96         | 25.02         | 32.01                         |              |             |             |             |
| 53000    | 16154  | 10.04               | 1.46    | 75.31  | 2.66               | 30.49         | 28.30         | 28.31                         |              |             |             |             |
| 54000    | 16459  | 9.57                | 1.39    | 71.77  | 2.90               | 34.84         | 32.34         | 24.77                         |              |             |             |             |
| 55000    | 16764  | 9.12                | 1.32    | 68.40  | 3.20               | 40.32         | 37.42         | 21.40                         |              |             |             |             |
| 56000    | 17069  | 8.69                | 1.26    | 65.19  | 3.58               | 47.43         | 44.03         | 18.19                         |              |             |             |             |
| 57000    | 17374  | 8.28                | 1.20    | 62.13  | 4.11               | 57.02         | 52.93         | 15.13                         |              |             |             |             |
| 58000    | 17678  | 7.90                | 1.15    | 59.22  | 4.85               | 70.62         | 65.56         | 12.22                         |              |             |             |             |
| 59000    | 17983  | 7.52                | 1.09    | 56.44  | 5.98               | 91.41         | 84.86         | 9.44                          |              |             |             |             |
| 60000    | 18288  | 7.10                | 1.03    | 53.28  | 8.49               | 137.48        | 127.61        | 6.28                          |              |             |             |             |
| 61000    | 18593  | 6.84                | 0.99    | 51.27  | 12.01              | 202.22        | 187.71        | 4.27                          |              |             |             |             |
| 62000    | 18898  | 6.51                | 0.94    | 48.86  | 26.25              | 463.58        | 430.33        | 1.86                          |              |             |             |             |

\* The values are calculated with pressure in mm Hg. These values are also valid when pressure is in kN/m<sup>2</sup> (kPa).

### 3.1.2 Conversion Factors

Information available in the references and measurement standards for oxygen require frequent conversion to other units. The most frequently used conversion factors are listed on Table 2.

For the values in TABLES 2,

\* Formula is calculated for pressure in mm Hg

For calculation in Pascals (Pa), i.e kN/m<sup>2</sup>, 6.27 is the value used for the vapor pressure of water in the body

TABLE 2 – CONVERSION FACTORS

| To Obtain           |                   | Multiply               | By                    | To Obtain                   | Multiply    | By       |
|---------------------|-------------------|------------------------|-----------------------|-----------------------------|-------------|----------|
| Standards of Volume |                   |                        |                       | Pressure                    |             |          |
| BTPS                | BTPD              | $P_B/(P_B-47)^*$       | mm Hg @ 0°C           | Inch Hg @ 0°C               |             | 25.40    |
|                     | STPD              | $862.95/(P_B-47)^*$    |                       | Inch H <sub>2</sub> O @ 4°C |             | 1.868    |
|                     | NTPD              | $801.04/(P_B-47)^*$    |                       | cm. H <sub>2</sub> O @ 4°C  |             | 0.7354   |
| BTPD                | BTPS              | $(P_B-47)/P_B^*$       |                       | Lb / ft <sup>2</sup>        |             | 0.3591   |
|                     | STPD              | $862.95/P_B^*$         |                       | Lb / in <sup>2</sup>        |             | 51.71    |
|                     | NTPD              | $801.04/P_B^*$         |                       | Millibars                   |             | 0.7500   |
| STPD                | BTPS              | $0.0011588 (P_B-47)^*$ |                       | Atmospheres                 |             | 760.00   |
|                     | BTPD              | $0.0011588 (P_B)^*$    |                       | N/m <sup>2</sup> (Pa)       |             | 0.007501 |
|                     | NTPD              | $0.92826^*$            |                       | Inch Hg @ 0°C               |             | 3386.    |
| NTPD                | BTPS              | $0.0012484 (P_B-47)^*$ |                       | Inch H <sub>2</sub> O @ 4°C |             | 249.07   |
|                     | BTPD              | $0.0012484 (P_B)^*$    |                       | cm. H <sub>2</sub> O @ 4°C  |             | 98.06    |
|                     | STPD              | $1.0773^*$             |                       | Lb / ft <sup>2</sup>        |             | 47.880   |
| Volume              |                   |                        | N/m <sup>2</sup> (Pa) | Lb / in <sup>2</sup>        |             | 6894.8   |
| Liters              | Cubic Centimeters | 0.001                  |                       | Millibars                   |             | 100.     |
|                     | Cubic Inches      | 0.01639                |                       | Atmospheres                 |             | 101325.  |
|                     | Cubic Feet        | 28.32                  |                       | mm Hg                       |             | 133.3228 |
|                     | Gallons (liq.)    | 3.785                  |                       | Lb / in <sup>2</sup>        |             | 0.01934. |
| Cubic Centimeters   | Liters            | 1000                   |                       | Inch Hg @ 0°C               |             | 0.4912   |
|                     | Cubic Inches      | 16.39                  |                       | Inch H <sub>2</sub> O @ 4°C |             | 0.03613  |
|                     | Cubic Feet        | 28320.                 |                       | cm. H <sub>2</sub> O @ 4°C  |             | 0.01422  |
|                     | Gallons (liq.)    | 3785.                  |                       | Lb / ft <sup>2</sup>        |             | 0.006944 |
| Cubic Inches        | Liters            | 61.02                  |                       | Millibars                   |             | 0.01450  |
|                     | Cubic Centimeters | 0.06102                |                       | Atmospheres                 |             | 14.696   |
|                     | Cubic Feet        | 1728.                  |                       | N/m <sup>2</sup> (Pa)       |             | 0.000145 |
|                     | Gallons (liq.)    | 231.                   | Feet                  |                             | 0.3048      |          |
| Cubic Feet          | Liters            | 0.03531                | Meters                |                             | 0.0254      |          |
|                     | Cubic Centimeters | 0.00003531             | Centimeters           |                             | 0.01        |          |
|                     | Cubic Inches      | 0.0005787              | Millimeters           |                             | 0.001       |          |
|                     | Gallons (liq.)    | 0.1337                 | Feet                  |                             | 304.8       |          |
| Gallons (liq.)      | Liters            | 0.2642                 | Millimeters           |                             | 25.4        |          |
|                     | Cubic Centimeters | 0.0002642              |                       |                             | 10000.      |          |
|                     | Cubic Inches      | 0.004329               |                       |                             | Centimeters | 10.      |
|                     | Cubic Feet        | 7.481                  |                       |                             | Feet        | 0.08333  |
| Volume Flow Rate    |                   |                        |                       | Inches                      |             | 0.003281 |
| Liters / Minute     | Cubic Feet / Hour | 0.4717                 | Inches                | Feet                        |             | 12.      |
| Cubic Feet / Hour   | Liters / Minute   | 2.120                  |                       | Meters                      |             | 39.37    |
| Temperature         |                   |                        |                       | Centimeters                 |             | 0.3937   |
| °C = (5/9)(°F – 32) |                   | K=(5/9)(°R)            | Millimeters           |                             | 0.03937     |          |
| °R = °F + 459.67    |                   | K=°C+273.15            |                       |                             |             |          |

### 3.1.3 Percent Oxygen at Mask Versus Air

To assure a given percentage of oxygen at the mask it is necessary to mix the supplemental oxygen and ambient air in proper proportions. The required oxygen air supply mix needed is shown in Table 3. The equivalent altitude breathing gas mixtures are shown on Figure 2. The recommended percent of oxygen concentration versus altitude is also shown on Figure 2. Because the commonly used Figure 2 can be difficult to interpret, the following question and answer are given for purposes of example.

#### Question:

If an individual is at 25 000 feet elevation, what percentage of added oxygen is required for an individual to feel the physiological equivalent of being at 10 000 feet altitude?

#### Answer:

Using Figure 2, first locate 25 000 on the x-axis. Next, locate 10 000 feet on the y-axis. Find the point of intersection of the lines that correspond to these two values. The diagonal lines represent the percentage of oxygen required in the gas mixture. For this example, our intersection point falls just to the right of the 40% line – we will estimate 42%. This means that 42% of the final gas mixture delivered to the user must be oxygen. This is equivalent to a user at 10 000 feet with no supplemental oxygen.

TABLE 3 - PERCENT OXYGEN AT MASK VERSUS AIR AND SUPPLEMENTAL OXYGEN

| % Oxygen at mask                                                    | 21  | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|---------------------------------------------------------------------|-----|----|----|----|----|----|----|----|-----|
| O <sub>2</sub> Volume drawn from supply<br>(% O <sub>2</sub> Added) | 0   | 11 | 24 | 37 | 49 | 62 | 75 | 87 | 100 |
| Air Volume drawn from ambient                                       | 100 | 89 | 76 | 63 | 51 | 38 | 25 | 13 | 0   |

Fraction of Flow that is O<sub>2</sub> (percentage of added O<sub>2</sub>) -- Derivation of Equation 7

Where;

%O<sub>2</sub> = Percentage of added O<sub>2</sub>

Air = Total mixture air

%Air = Percentage of air added

O<sub>2</sub> = Total Fraction of Oxygen in the Nitrogen-Oxygen Mixture

$$\%O_2 \text{ Added} = \frac{\text{Oxygen Added}}{\text{Air} + \text{Oxygen}}$$

$$\%O_2 + \%Air = 1$$

$$\%Air = 1 - \%O_2$$

$$\text{Total } \%O_2 \text{ at mask} = \%O_2 + 0.2095\%Air$$

$$O_2 \text{ at mask} = \%O_2 + 0.2095 (1 - \%O_2)$$

$$\%O_2 \text{ Added} = \frac{O_2 \text{ at mask} - 0.2095}{0.7905}$$

Or

$$\text{Fraction of Added Oxygen} = \frac{(\text{Total \% Oxygen} - 20.95)}{79.05} \quad \text{See (Eq 7)}$$

TABLE 3.1 - COMPOSITION OF THE ATMOSPHERE (DRY AIR)

| Constituent Gas                   | Molecular Fraction<br>Percent | Molecular Weight |
|-----------------------------------|-------------------------------|------------------|
| Nitrogen (N <sub>2</sub> )        | 78.08                         | 28.0134          |
| Oxygen (O <sub>2</sub> )          | 20.95                         | 31.9988          |
| Argon (A)                         | 0.93                          | 39.948           |
| Carbon Dioxide (CO <sub>2</sub> ) | 0.03                          | 44.009510        |
| Air (mixture)*                    | 100.00                        | 28.9644          |

Values based on the 1999 table *Pure Appl. Chem.*, or *Pure Appl. Chem.* Vol. 73, No. 4, pp. 667-683 (2001)

\* includes trace element

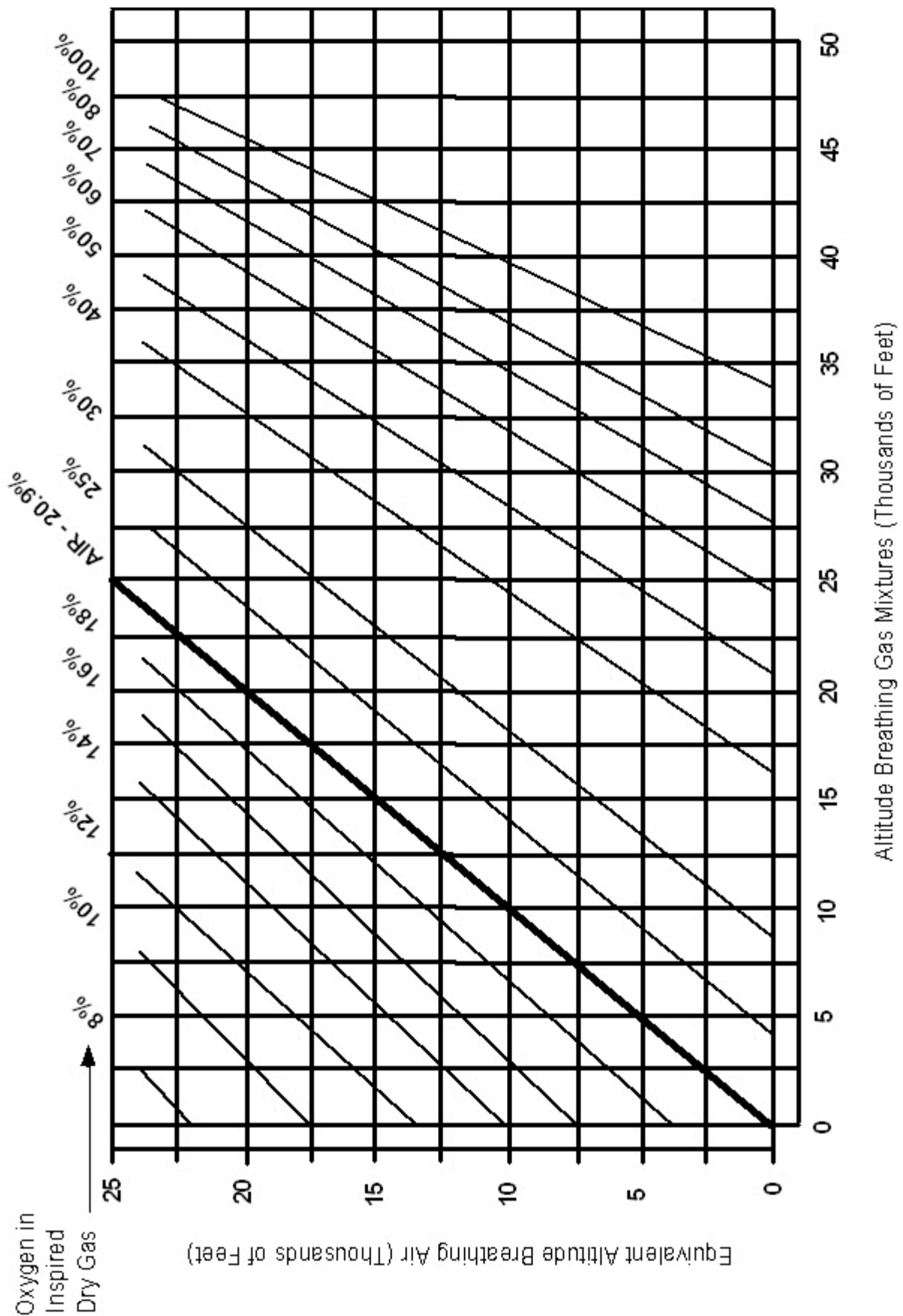


FIGURE 2 – EQUIVALENT ALTITUDES