NorthWest Occupational Health & Safety

**Oxygen: Health Effects and Regulatory Limits**
**Part II: Consensus and Regulatory Standards and Realities of Oxygen Measurement**

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## Introduction

Probably the biggest source of confusion and controversy involving confined spaces is the acceptable limit for atmospheres deficient or enriched in oxygen. This confusion and controversy has arisen, in part, because oxygen is essential for life, and because people can adapt in both the short-term and the long-term to oxygen levels both greater than and less than they are at sea level. Sea level, of course, is merely a convenient altitude of reference. There is no particular significance to this altitude, as people live and work quite comfortably at attitudes far below and far above this height.

## Consensus and Regulatory Standards for Oxygen

As for limits set for permissible exposure to toxic substances, those set for oxygen reflect laboratory-based studies and human experience. The standard-setting process does not involve documented judgement of expert committees in toxicology or human physiology in the same manner as other toxic agents. To illustrate, there is no TLV for oxygen. The only mention of oxygen by ACGIH in older editions of the TLV booklet was contained in the preamble (ACGIH 1994). As well, there is no documentation for oxygen in older Documentation volumes (ACGIH 1991).

### Oxygen Limits Based on Concentration

Given the choice between concentration and partial pressure for setting limits for permissible exposure to oxygen, almost all respondents have opted for concentration. Sensor technology for measurement of oxygen based on partial pressure is also readily available. The latter sensors contain a large open diffusing surface, whereas the sensors used for measuring concentration contain a small opening. The larger opening of the partial pressure sensor is more sensitive because of the considerably larger surface through which diffusion can occur compared to the capillary pore sensor used for measuring oxygen concentration. The partial pressure sensor is sensitive to changes in barometric pressure, as well as altitude and weather, and requires adjustment to address these realities.

Almost universal in its adoption at this time is the regulatory limit of 19.5% for the lower level of oxygen permissible in confined spaces. This value applies irrespective of altitude and extent of acclimatization of the individual. The Occupational Safety and Health Administration (OSHA) of the US Department of Labor set the direction for other jurisdictions in adopting this value.

OSHA standards are unusual among regulatory standards. They provide dialogue to indicate the rationale for the decision. The dialogue also provides invaluable insight into concerns and comments raised by interveners to the process. However, the discussion is far from complete. The OSHA standards on confined spaces in general industry and shipyard employment are directed to situations that could be life-threatening following failure of the ventilation system or respiratory protection (OSHA 1993, OSHA 1994).

In the preamble to the Standard for general industry OSHA recommended 19.5% as the acceptable lower limit (OSHA 1993). OSHA stated its belief that concentrations less than 19.5% would be oxygen-deficient. Neither OSHA nor any of the interveners to the process provided any technical evidence about oxygen deficiency that could serve as the basis for informed discussion about this subject.

Interveners representing the ANSI Z88.2 Committee on respiratory protection argued that 19.5% as a lower limit was too high. They argued for a lower limit, namely 12.5%, using as the rationale, that no respiratory protection was needed at 16% oxygen. The value, 12.5%, should in their view be considered as Immediately Dangerous to Life and Health. The direction of reasoning shown by the ANSI Z88.2 Committee was considerably different from that taken by the ANSI Z117.1 Committee on confined spaces (ANSI 1989). The difference in approach taken by these Committees indicates the depth of the controversy that surrounds this issue.

In making its selection of 19.5% for the lower limit, OSHA indicated its heavy reliance on the judgement of the ANSI Z117.1 Committee on confined spaces and the NIOSH Respirator Decision Logic (ANSI 1989, NIOSH 1987). Neither of these documents provides technical justification for the value.

The OSHA Standard for shipyard employment raised the minimum acceptable level from the 16% contained in the previous version of the rule to 19.5% (OSHA 1994). Interveners to this process included a high proportion of individuals and groups with direct, on-going experience in assessment and control of oxygen-deficient atmospheres. This group were highly supportive of the change. However, neither OSHA nor the interveners provided any technical documentation in support of this change. The Standard on shipyard employment represents a special case in confined spaces, since affected sites are located at sea level or low altitudes.

Oxygen Limits Based on Partial Pressure

The second approach to setting of limits for acceptable levels of oxygen utilizes partial pressure. Table 7 summarizes recommendations contained in various standards and guidelines (ACGIH 1994, NIOSH 1979, ANSI 1980, ANSI 1992, CSA 1982, CSA 1993). Limits provided here are contained in the source documents and not converted from concentration units.

The limit of greatest interest from the perspective of acute exposures is the IDLH (Immediately Dangerous to Life or Health). IDLH originally was defined in the NIOSH Standards Completion Project for the purpose of selecting respiratory protection (NIOSH 1990). Under NIOSH usage, the term, IDLH, is the presumed minimum concentration from which a person could escape in 30 minutes in the event of respirator failure without experiencing any escape-impairing or irreversible health effects. Since then, other groups have adopted the acronym, IDLH. Each has modified the original meaning. Under ANSI usage, IDLH means an atmosphere that poses an immediate hazard to life or produces immediate, irreversible, debilitating health effects (ANSI 1980, ANSI 1992). Under CSA, IDLH means an atmosphere where the concentration of oxygen could cause a person without respiratory protection to be fatally injured or to suffer immediate irreversible or incapacitating health effects (CSA 1982, CSA 1993).

The rationale used by ANSI and CSA in their definitions of IDLH was to select the partial pressure of oxygen that would produce 90% saturation of haemoglobin in alveolar blood (ANSI 1980, CSA 1982, CSA 1993). In the current standard on respiratory protection the ANSI Z88.2 Committee chose 83% saturation for the IDLH (ANSI 1992). These saturation values are the minimum below which symptoms of oxygen deficiency are believed to become noticeable. Neither references duration of exposure, since onset of this condition would not necessarily be immediate.

Limits based on partial pressure require use of instruments containing the partial pressure sensor, and not

**Table 7**
**Partial Pressure Limits for Oxygen Deficiency and Enrichment**

| **Source** | **Atmospheric Pressure Limit** mm Hg | **Equivalent Concentration** (sea level, dry air) % | **Comments** |
|---|---|---|---|
| ACGIH | P ≤ 135 | ≤ 18 | minimum partial pressure without need for respiratory protection; normal atmospheric pressure |
| NIOSH | P ≤ 122 | ≤ 16 | immediately dangerous to life, normal atmospheric pressure, sea level |
| | P < 132 | < 17 | oxygen deficiency, normal atmospheric pressure, sea level |
| | 122 ≤ P ≤ 147 | 16 ≤ C ≤ 19 | dangerous, but not immediately life threatening ; respiratory protection determined by qualified person; normal atmospheric pressure, sea level |
| | 148 ≤ P ≤ 163 | 19.5 ≤ C ≤ 21 | no modification of work procedures, normal atmospheric pressure, sea level |
| ANSI Z88.2-1980 | P ≤ 106 | C ≤ 14 | atmospheric partial pressure of oxygen in dry air at sea level corresponding to partial pressure of 100 mm Hg in freshly inspired air in the upper portion of the lung that is saturated with water vapour at 37 °C; immediately dangerous to life or health |
| ANSI Z88.2-1992 | P ≤ 95 | C ≤ 12.5 | dry atmosphere, sea level, immediately dangerous to life or health; may occur through any combination of reduction in oxygen content or altitude |
| | 95 < P ≤ 122 | 12.5 < C ≤ 16 | oxygen deficient - not immediately dangerous to life or health; may occur through any combination of reduction in oxygen content or altitude |
| CSA Z94.4-M1982 | P ≤ 106 | C ≤ 14 | atmospheric partial pressure of oxygen in dry air at sea level corresponding to partial pressure of 100 mm Hg in freshly inspired air in the upper portion of the lung that is saturated with water vapour at 37 °C; immediately dangerous to life or health |
| CSA Z94.4-93 | P ≤ 106 | C ≤ 14 | atmospheric partial pressure of oxygen in dry air at sea level corresponding to partial pressure of oxygen in inspired air in the upper respiratory passages falls to 13.3 kPa (100 mm Hg) or less; immediately dangerous to life or health |

the capillary pore sensor. This would necessitate operator access to enable correction of readings to ensure operation in environments different from sea level.

**Discussion**

Selection of acceptable limits for exposure to oxygen is one of the most difficult and controversial of decisions. As indicated in previous discussion, oxygen level is influenced by barometric pressure (weather), humidity, altitude, and atmospheric composition.

Limits based on concentration are altitude independent, since concentration remains constant in normal air at the depths and altitudes normally accessible without respiratory protection. These limits, therefore, only reflect atmospheric composition caused by local contamination. However, the body responds to the partial pressure of oxygen and not to concentration. Limits based on partial pressure are altitude, barometric pressure, weather, and composition dependent. Saturation of haemoglobin depends only on partial pressure of oxygen in the local atmosphere. Therefore, altitude, barometric pressure, weather conditions, and local contamination all combine inseparably to affect performance and safety.

Previous discussion has identified the individual elements that influence atmospheric pressure, as well as the physiological basis for response to oxygen level. This discussion highlights the dichotomy between concentration- and pressure-based limits for assessing oxygen level in consensus and regulatory standards. Table 8 summarizes this information in order to provide the basis for further discussion (Anonymous 1991, Kemball 1985, McIntyre 1987, McManus 1999).

Humidity can vary from hour to hour and often from day to day in a location. As indicated in Table 7, 10 mm Hg would be a conservative value for the vapour pressure of water under most situations. This indicates that the contribution of water vapour to total atmospheric pressure is small. This contribution easily could become lost in fluctuations of barometric pressure. Hence, the contribution of humidity on total pressure is so small as to be ignorable under most conditions.

Based on standard total atmospheric pressure associated with the standard (dry) atmosphere and 19.5% as a regulatory limit, oxygen deficiency would occur at altitudes as low as 2000 ft (610 m), based on standard atmospheric pressure. However, atmospheric pressure varies continuously in a location from sometimes from hour to hour and often day to day.

During a period of typical high pressure at this altitude, the atmospheric pressure easily could increase from 707 mm Hg to 707 + 28 = 735 mm Hg. This would increase the oxygen concentration from 19.5% to 735/760 x 20.95% = 20.3%, relative to sea level. Under this weather condition, this location would not be oxygen-deficient according to the regulatory limit. During a period of typical low pressure at this altitude, the atmospheric pressure would decrease from 707 mm Hg to 707 - 32 = 675 mm Hg. This would decrease the oxygen concentration to 675/760 x 20.95% = 18.6%, relative to sea level. Under this weather condition, oxygen-deficiency would be more severe compared to the standard atmosphere. An unusual low would further exacerbate the oxygen-deficient condition.

It could be argued that the true altitude at which oxygen deficiency should be considered to occur would be that whose normal low pressure would be 707 mm Hg. This would correspond to a standard atmospheric pressure of 707 + 32 = 739 mm Hg and an altitude of 795 ft (242 m).

The second approach would be more protective since this would minimize the chance that oxygen deficiency could occur due simply to variation in atmospheric pressure. Adoption of this approach would permit use of an instrument that is altitude and weather independent.

The preceding is one approach to this question. Another is to incorporate all losses in partial pressure of oxygen. These would include elevation, weather pattern, and local atmospheric contamination caused by the work to be performed. This approach would require an instrument responsive to both altitude and weather conditions. Calibration could occur at sea level during an average day. Using this approach, hazard assessment could be subjected to day-to-day variability, as weather conditions and local

**Table 8**
**Altitude and Weather Effects on Atmospheric Conditions**

| | **Atmospheric Pressure** sea level, dry atmosphere | **Oxygen Concentration** | **Altitude Equivalent** | |
|---|---|---|---|---|
| **Condition** | mm Hg | % | ft | m |
| **Atmospheric** | | | | |
| dry atmosphere | 760 | | | |
| water vapour | ≈ 10 | | | |
| typical high pressure | (+ 28) | | | |
| record high pressure | (+ 53) | | | |
| typical low pressure | (- 32) | | | |
| record low pressure | (- 107) | | | |
| | | | | |
| **Geographic** | | | | |
| highest mine (Chile) | 357 | 9.8 | 20 262 | 6 176 |
| La Paz (Bolivia) | 493 | 13.6 | 11916 | 3 632 |
| Bogota (Colombia) | 555 | 15.3 | 8724 | 2659 |
| Mexico City | 581 | 16 | 7487 | 2282 |
| Denver | 630 | 17.4 | 5280 | 1609 |
| deep mine (Sudbury, ON Canada) | 950 | 26.2 | -6317 | -1925 |
| Dead Sea (Jordan) | 799 | 22 | -1337 | -408 |
| Qattara Depression (Egypt) | 772 | 21.3 | -440 | -134 |
| Death Valley (California, US) | 768 | 21.2 | -282 | -86 |
| | | | | |
| **Aviation** | | | | |
| cabin pressurization | 571 | 15.7 | 8000 | 2440 |
| | | | | |
| **Regulatory Limits** | | | | |
| 16% oxygen (previous) | 580 | | 7500 | 2286 |
| 18% oxygen (previous) | 653 | | 4288 | 1307 |
| 19.5% oxygen (present) | 707 | | 2000 | 610 |

| | | | | |
|---|---|---|---|---|
| 22 % oxygen (present) | 798 | | -1394 | -425 |
| 23.5 % oxygen (present) | 853 | | -2871 | -875 |

contamination experienced change. This would be an especial concern at altitudes where partial pressures would be close to regulatory oxygen-deficient conditions and where weather conditions alone could necessitate control measures.

Instruments designed for measuring oxygen in confined spaces display in units of concentration. Some sensors function independently of altitude and variations in partial pressure of oxygen due to weather. Physiologically based oxygen deficiency may not be obvious to users of this type of equipment, because concentration would remain constant at all altitudes of normal use. The other type of sensor is sensitive to partial pressure of oxygen (and therefore, altitude and barometric pressure). Calibration of this type of instrument at sea level for use at higher altitude, or calibration at higher barometric pressure than present during actual use could cause underestimation of concentration. An ambient condition easily could be falsely identified as oxygen-deficient by an oxygen-monitoring instrument containing a sensor that is sensitive to partial pressure. On the other hand, an instrument containing this type of sensor provides the best potential for estimating adverse conditions, since the body responds to partial pressure of oxygen, not concentration.

The question of oxygen deficiency is more complex even than discussed thus far. Demands of today's industrialized society also must be considered. Individuals acclimatize to the conditions of a particular altitude. Acclimatization brings about physiological change that occurs over a period of time. However, many people routinely work at altitudes considerably different from that to which they are acclimatized. Travel to a worksite could entail a flight in a commercial airplane whose cabin is pressurized to 8000 ft (2438 m). This corresponds to 570 mm Hg total pressure or 15.7% oxygen, relative to sea level, dry atmosphere (Bancroft 1971). For a person travelling during work time, or for the flight crew, this level technically represents an occupational exposure to an oxygen-deficient atmosphere. For long flights, this exposure can occur for most of the work day. For individuals acclimatized to sea level, travel to a location at a higher altitude coupled with work in an office tower or stay in a high-rise hotel could constitute exposure to an oxygen-deficient atmosphere. The mere act of moving from ground level to a worksite in a high-rise building in a geographic location at a higher altitude could lead to exposure to an oxygen-deficient condition.

The problem of limits for oxygen deficiency was mentioned in the original NIOSH Guide to Respiratory Protection (NIOSH 1976a). This document indicated that oxygen deficiency could develop through decrease in oxygen content or through increase in altitude. Altitudes greater than 10,000 ft (3050 m) at the time of writing of the NIOSH report were considered to be oxygen deficient. However, as mentioned in the NIOSH report, workers at altitudes of 10,000 ft (3050 m) routinely used air-purifying respirators without apparent difficulty.

As the NIOSH report optimistically commented, this problem was under study, and eventually "oxygen-deficient atmosphere" will be redefined to eliminate the present discrepancies and account for the effect of altitude. The irony in this statement is only partly apparent. The NIOSH report listed the standards of the day for oxygen deficiency. By comparison, the permissible limit for oxygen deficiency has increased, that is, has become more stringent, thus making resolution of the discrepancy even more difficult to achieve.

The former version of the ANSI Standard on respiratory protection, ANSI Z88.2-1980, only obliquely approached the question of altitude (ANSI 1980). This occurred in example problems provided for clarification in use of the equation used for calculating oxygen partial pressure. The corresponding CSA Standard, CSA Z94.4-M1982, utilized the same criteria as the ANSI Standard, but introduced an altitude limit of 3.66 km (12,000 ft) for oxygen deficiency (CSA 1982). Standard atmospheric pressure at this altitude would be 491 mm Hg. Corresponding concentration of oxygen would be 13.5% relative to sea level.

CSA Z94.4-93 did not vary from the previous version in this respect (CSA 1993). By contrast, the ANSI standard on respiratory protection, Z88.2-1992 addressed this question head-on (ANSI 1992).

The direction taken by ANSI Committee Z88.2 was not shared by ANSI Committee Z117.1 on confined spaces or by regulatory agencies such as OSHA (ANSI 1989, OSHA 1993, OSHA 1994). The approach taken by ANSI Z117.1 and OSHA on this question provided no recognition about the altitude question nor a means to resolve it.

The ANSI Standard on respiratory protection embraced the concept of partial pressure rather than concentration for resolving the question of oxygen deficiency (ANSI 1992). By taking this approach, the ANSI Z88.2 Committee created a basis for technical dialogue about this question. ANSI Z88.2 established 95 mm Hg as the partial pressure of oxygen in air for the IDLH. This could be reached at an altitude of 14,000 ft (4267 m), in an atmosphere containing 12.5% oxygen at sea level, or in some combination of altitude and oxygen deficiency.

The Standard also provides additional important information. At and above 10,000 ft, an ordinary supplied-air respirator or SCBA provides oxygen at a partial pressure less than 121 mm Hg, even though the concentration is 20.9 %. This would be equivalent to a gas mixture that provides 16% oxygen at sea level. In cases where a supplied-air respirator or SCBA would be required at these altitudes, the gas mixture must contain at least 23% oxygen at 10,000 ft and 27% at 14,000 ft, relative to sea level. This situation would necessitate a specially designed respirator or rebreather. Compressed air tanks containing these mixtures could not be used at sea level due to the enriched atmospheres.

Thus far, discussion has considered oxygen-deficient atmospheres. Oxygen-enriched atmospheres also pose considerable hazard, for the reason of enhanced ignitability. In the average circumstance, the hazard of enrichment seems to be related to use of oxygen in flame-cutting processes, namely oxy-fuel equipment. Oxygen also could be present in confined spaces where it is generated for use as a process gas. Some work occurs under pressurized atmospheres. In these situations, pressurization increases the partial pressure of oxygen above that found under normal circumstances.

Barometric pressure increases with depth. The Dead Sea, the lowest surface feature on earth is situated at -1337 ft (-408 m). Partial pressure of oxygen at this depth corresponds to a concentration of 22% at sea level. Some deep mines exceed 1 mile (1.6 km) in depth below sea level. Oxygen partial pressure at these depths easily could exceed the partial pressure of 23.5% used in many regulatory limits.

Based on standard total atmospheric pressure associated with the standard (dry) atmosphere and 23.5% as a legal limit, oxygen enrichment would occur at a depth of -2871 ft (-875 m), based on standard atmospheric pressure. However, atmospheric pressure can vary in a location from hour to hour and usually from day to day.

During a period of typical low pressure at this depth, the atmospheric pressure easily could decrease from 853 mm Hg to 853 - 32 = 821 mm Hg (Moran and Morgan 1989). This would decrease the oxygen concentration from 23.5% to 821/760 x 20.95% = 22.6%, relative to sea level. Under this weather condition, this depth would not be oxygen-enriched. During a period of typical high pressure at this depth, the atmospheric pressure would increase from 853 mm Hg to 853 + 28 = 881 mm Hg. This would decrease the oxygen concentration to 881/760 x 20.95% = 24.3%, relative to sea level. Under this weather condition, oxygen-enrichment would be more severe compared to the standard atmosphere. An unusual high pressure system would further exacerbate the condition of oxygen-enrichment.

It could be argued that the true depth at which oxygen enrichment should be considered to occur would be that whose normal high pressure would be 853 mm Hg. This would correspond to a standard atmospheric pressure of 853 - 28 = 825 mm Hg and a depth of -2276 ft (-694 m).

The second approach would be more protective, since this would minimize the chance that oxygen enrichment could occur due simply to variation in atmospheric pressure. Adoption of this approach would permit use of an instrument that is altitude and weather independent.

The preceding is one approach to this problem. Another is to incorporate all gains in partial pressure of oxygen. These would include depth, weather pattern and local atmospheric contamination caused by the work to be performed. This approach would require an instrument responsive to both altitude and weather conditions. Calibration would occur at sea level during an average day. Using this approach, hazard assessment could be subjected to day-to-day variability, as weather conditions and local contamination changed. This would be an especial concern at depths where partial pressures would be close to oxygen-enriched conditions and where weather conditions alone could necessitate control measures.

**Issues, Realities, Applications and Opportunities in Oxygen Measurement**

Widespread availability of instruments containing oxygen sensors provides the opportunity to gain real-world experience in measuring oxygen. This extends the discussion considerably beyond the abstract of the table-top exercises discussed above.

The first reality is that oxygen has become very easy to measure. Older instruments typically were used just prior to entry into a confined space and periodically thereafter. The instrument was turned on for the measurement and then turned off. Hence, the measurement of the environment in the space thus was relative to the environment of the external surroundings at that moment in time.

The second reality is the means with which oxygen measurements now occur. Newer instruments can operate during the duration of the workshift and simultaneously measure other gases, such as carbon monoxide. At the same time, these instruments read oxygen level continuously. Some of the instruments contain a datalogger and store the measurement after predetermined intervals of time. These instruments were available at the time of the decision by OSHA to adopt 19.5 % as the regulatory limit and have become widely so during the intervening years.

An issue identified during continuous, shift-length measurement of oxygen is the baseline of the ambient oxygen level. Continuous operation of the instrument establishes an absolute level of oxygen compared to the relative one mentioned above and in previous discussion. Some instruments set the reference level of oxygen at start-up, while the operator can set the reference point of the others at any time, simply by pushing one or more buttons.

Actual workplace monitoring that accumulated 30,000 minutes of oxygen dosimetry during argon-shielded welding in the construction of large aluminum vessels (ships) indicated that the oxygen level is relative and not constant. The level of oxygen often decreased from 20.9% to a constant lower level as low as 20.6% on some days and increased to a constant upper level as high as 21.5% on others. This shift in baseline level appears to depend on weather conditions. The baseline decreased on days when rain was falling at the time of start-up and setting of the oxygen level and changed to sunny conditions later in the day. On days where the weather changed from sunny to rainy conditions during the day, the baseline is presumed to have increased.

Where actual contamination is present, depression of oxygen from the normal level of 20.9% indicates the presence of another substance. The true concentration of the other substance is (20.9 - x)(100/20..9), where x is the reading of the instrument. (The oxygen sensor detects only one molecule out of every five in the atmosphere.) This depression in the oxygen level constitutes extremely important information.

Depression of oxygen to any level below 20.9% is functionally legal only in vary narrow circumstances. These include atmospheres enriched in nitrogen, atmospheres containing high levels of water vapour, mist or steam, and atmospheres containing the chemically inert gases (in practical terms, helium and argon). In all other situations there is reason to account for the substance(s) that depressed the oxygen for compliance with a regulatory exposure limit, for concerns regarding ignitability, or for toxicology that is unknown. This reality also opens the bigger question of setting the oxygen baseline prior to obtaining a reading in an atmosphere containing otherwise undetectable contamination

The issue here is the coincident insensitivity of other sensor(s) to the presence of the displacing or diluting gas or vapour. The depressed reading on the oxygen sensor could be the only indication that conditions are abnormal. That is, depression of the oxygen reading indicates the presence of some other agent at a level that poses concern .The identification and quantification of that agent are paramount to ensuring the continuing safety of workers affected by the reading.

This reality argues that the alarm of the oxygen should be set as close as possible to the ambient value of 20.9%, regardless of its lack of physiological significance. Experience gained with weather conditions, as described previously, indicated that an alarm setting of 20.5% for the oxygen sensor will not incur undue false positive alarms under ambient conditions of continuous operation.

The reality in many industries is that the reading of the oxygen sensor during work in confined spaces in which ventilation is occurring is almost always 20.9%. This almost always was the case during the ship construction, mentioned previously, in which argon was used as a shield gas during welding. No alarms occurred at 19.5% and alarms at levels below 20.5% were highly unusual and only very brief in duration. Alarms at the upwardly revised set-point in this particular example indicated lack of control over welding emissions or leakage of shield gas.

Why not then take advantage of normalcy to indicate abnormalcy? As a follow-up to this comment, the number of simple asphyxiants has decreased considerably in recent years with the adoption of Threshold Limit Values for many formerly included gases ($C_1$ to $C_4$ aliphatic hydrocarbons, in particular). In most industrial situations, there is nothing to be gained from using the current regulatory limit of 19.5%.

Despite all of the debate about acceptable limits, the reality is that people live and work over a wide range of altitudes. Healthy people live long and active lives at high altitudes where arterial saturation ranges from 85% to 95 %.

Oxygen deficiency and oxygen enrichment create a fundamental dilemma for the practicing industrial hygienist. One the one hand, exposure to an atmosphere containing a narrow range of concentration is essential for survival. Controlling or eliminating exposure through active intervention is not an option. Conversely, not permitting exposure beyond normal atmospheric concentrations, regardless of the wider range of permissible concentration is a conservative strategy. On the other hand, hygienists sanction exposure of workers to contaminants at nonzero concentrations. The question is whether oxygen deserves special consideration because of our relationship with it and the acute nature of action under hazardous conditions.

## Glossary of Terms

**ACGIH** = American Conference of Governmental Industrial Hygienists

**ANSI** = American National Standards Institute

**ASSE** = American Society of Safety Engineers

**CSA** = Canadian Standards Association

**mm Hg** = millimetres of mercury (Hydrargium = Hg); the normal height of a mercury barometer at sea level is 760 mm

**NASA** = National Aeronautics and Space Administration

**NFPA** = National Fire Protection Association

**NIOSH** = National Institute for Occupational Safety and Health

**OSHA** = Occupational Safety and Health Administration

**ppm** = parts per million, a unit of concentration in air

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