Revision of ACGIH® Guidelines on Minimum Oxygen Content and Simple Asphyxiants

DENNIS M. CASSERLY, Ph.D., CIH
University of Houston Clear Lake
ACGIH® TLVs® for Chemical Substances Committee
Notations Subcommittee

- Philip L. Bigelow, Ph.D., CIH, Colorado State University, Dept of Environ & Radiological Health Science
- Paul A. Demers, Ph.D., School of Occup. & Environ. Hygiene, University of British Columbia
- Linda M. Frazier, M.D., M.P.H., Dept of Preventive Med & Public Health, University of Kansas School of Medicine
- Michelle M. Schaper, Ph.D., USDOL/MSHA/EPD
- Darius D. Sivin, Ph.D., International Union UAW
- Robert Spirtas, Dr.PH., National Institutes of Health
This presentation will focus on factors and issues pertaining to the ACGIH guideline on Minimal Oxygen Content.

- Sensitive tissues and physiological response to oxygen deficiency
- Critical values
- Factors affecting response
- Factors affecting oxygen partial pressure
- Regulations and guidelines
- Work practices
Oxygen Deficiency

- Sensitive tissues: brain and myocardium
- Initial symptoms: increased respiration and cardiac output
- Ensuing symptoms: headache, impaired attention and thought processes, decreased coordination, impaired vision, nausea, unconsciousness, convulsions and death
Onset and severity of symptoms depend on:

- magnitude of the oxygen deficiency
- time of exposure
- work rate
- breathing rate
- health status
- age
- physiological acclimatization
Increased respiration and increased cardiac output occur when the:

- hemoglobin oxygen saturation is reduced below 90%.
- partial pressure of oxygen (pO\textsubscript{2}) in pulmonary capillaries drops below 60 torr.
Critical Value

- Alveolar $pO_2$ value of 60 torr is considered the physiological limit that establishes an $O_2$ deficiency.

- Corresponds to 120 torr $pO_2$ in the ambient air, due to anatomic dead space, $CO_2$ and $H_2O$ vapor.
Oxygen requirements often used

- ACGIH® (2003) 18% or 135 torr
- NIOSH 19.5%, adjusted for altitude
- OSHA 19.5%
- "IDLH" 100 torr or @ 14%
- 95 torr or @ 12.5%
Expressing oxygen requirements in percent can be problematic

- \(\%O_2\) does not change with altitude
- It is the \(pO_2\) in the lung that is important and therefore the ambient \(pO_2\), not the percent \(O_2\)
- \(pO_2\) of the atmosphere:
  - decreases with increasing altitude
  - decreases with the passage of low pressure weather events
  - decreases with increasing water vapor
19.5% $\text{O}_2$ equivalent at sea level

- Corresponds to 148 torr $p\text{O}_2$, dry air
- Provides an adequate amount of oxygen for most work assignments
- Includes a margin of safety for altitudes less than @ 5000 ft
- Represents a concentration of 7.5% (75,000 ppm) of displacing gases at sea level
- Some displacing gases may have flammable properties or may produce physiological effects, so their identity and source should be thoroughly investigated.
Barometric pressure, oxygen partial pressure and percent oxygen concentration variation with altitude and physiological effect. (0-6000 ft)

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>Barometric Pressure (torr)</th>
<th>pO₂ (torr)</th>
<th>%O₂ (equiv.)</th>
<th>Physiological Effect of pO₂ Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>760</td>
<td>159</td>
<td>20.9</td>
<td>None in healthy adults</td>
</tr>
<tr>
<td>1000</td>
<td>731</td>
<td>153</td>
<td>20.1</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>704</td>
<td>147</td>
<td>19.3</td>
<td></td>
</tr>
<tr>
<td>3000</td>
<td>677</td>
<td>142</td>
<td>18.7</td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td>652</td>
<td>137</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>5000</td>
<td>627</td>
<td>131</td>
<td>17.2</td>
<td></td>
</tr>
<tr>
<td>6000</td>
<td>603</td>
<td>126</td>
<td>16.6</td>
<td></td>
</tr>
</tbody>
</table>

Adapted from McManus (1999).
### Barometric pressure, oxygen partial pressure and percent oxygen concentration variation with altitude and physiological effect.

**Altitude (feet)**

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>Barometric Pressure (torr)</th>
<th>( pO_2 ) (torr)</th>
<th>( %O_2 ) (equiv.)</th>
<th>Physiological Effect of ( pO_2 ) Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>7000</td>
<td>580</td>
<td>121</td>
<td>16</td>
<td>Increased pulmonary ventilation and cardiac output, incoordination, impaired attention and thinking</td>
</tr>
<tr>
<td>8000</td>
<td>559</td>
<td>117</td>
<td>15.4</td>
<td>Rapid exposure to altitudes over 8,000 feet may cause high altitude sickness (respiratory alkalosis, headache, nausea and vomiting) in unacclimatized individuals. Rapid ascent increases the risk of high altitude pulmonary edema and cerebral edema</td>
</tr>
<tr>
<td>9000</td>
<td>537</td>
<td>112</td>
<td>14.7</td>
<td></td>
</tr>
<tr>
<td>10000</td>
<td>517</td>
<td>108</td>
<td>14.2</td>
<td></td>
</tr>
</tbody>
</table>

Adapted from McManus (1999).
Barometric pressure, oxygen partial pressure and percent oxygen concentration variation with altitude and physiological effect.

(11000-14000 ft)

<table>
<thead>
<tr>
<th>Altitude (feet)</th>
<th>Barometric Pressure (torr)</th>
<th>(pO_2) (torr)</th>
<th>(%O_2) (equiv.)</th>
<th>Physiological Effect of (pO_2) Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>11000</td>
<td>498</td>
<td>104</td>
<td>13.7</td>
<td>Abnormal fatigue on exertion, faulty coordination, impaired judgment, emotional upset</td>
</tr>
<tr>
<td>12000</td>
<td>479</td>
<td>100</td>
<td>13.2</td>
<td></td>
</tr>
<tr>
<td>13000</td>
<td>461</td>
<td>97</td>
<td>12.8</td>
<td>Impaired respiration, very poor judgment and coordination, tunnel vision</td>
</tr>
<tr>
<td>14000</td>
<td>443</td>
<td>93</td>
<td>12.2</td>
<td></td>
</tr>
</tbody>
</table>

Adapted from McManus (1999).

Barometric Pressure (torr, dry air): \(P_{\text{re: sea level}} = 760 \times e^{-(\text{altitude in feet}/25970)}\)

\(\%O_2\) (equivalent, dry air at sea level): \(P_{\text{ambient oxygen}} = 20.948 \times e^{-(\text{altitude in feet}/25970)}\)
pO₂ (torr) dry air at 20.948% O₂

Extreme Danger

Danger

Warning

OK

Elevation (feet)
2004 ACGIH® Recommendation

- Considers the use of 19.5% O₂ equivalent at sea level (148 torr) a useful guide that is protective against inert displacing gases and oxygen-consuming processes for altitudes up to 5000 feet
- Oxygen deficiency: ambient pO₂ <132 torr
- Recommends additional work practices when the ambient oxygen partial pressure is less than 132 torr
When the ambient oxygen partial pressure is less than 132 torr, additional work practices are recommended:

- thorough evaluation of confined spaces
- use of continuous monitors integrated with warning devices
- use of workers acclimatized to altitude of work
- use of rest-work cycles with reduced work rates and increased rest periods
- training, observation and monitoring of workers
- easy and rapid access to properly maintained oxygen supplying respirators
Summary

- pO₂ of the atmosphere is important
- Critical values
  - 60 torr alveolar pO₂
  - 120 torr ambient pO₂
- 19.5% O₂ equivalent at sea level (148 torr) is protective for altitudes up to 5000 feet
- If O₂ <20.9%, find out why, take action
- If O₂ <132 torr, find out why, take action
- If O₂ <100 torr, life threatening
References