XIII. TABLES AND FIGURES

TABLE XIII-1

PROPERTIES OF NITRIC OXIDE AND NITROGEN DIOXIDE

<table>
<thead>
<tr>
<th></th>
<th>Nitric Oxide NO</th>
<th>Nitrogen Dioxide NO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula weight</td>
<td>30.01</td>
<td>46.01</td>
</tr>
<tr>
<td>Density (gas)</td>
<td>1.3402</td>
<td>1.4494</td>
</tr>
<tr>
<td>Melting point °C</td>
<td>-163.6</td>
<td>-11.2</td>
</tr>
<tr>
<td>Boiling point °C</td>
<td>-151.8</td>
<td>21.2</td>
</tr>
<tr>
<td>Solubility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>per 100 cc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hot water (60 °C)</td>
<td>2.37 cc</td>
<td>----</td>
</tr>
<tr>
<td>cold water (0 °C)</td>
<td>7.34</td>
<td>soluble, decomposes</td>
</tr>
</tbody>
</table>

Derived from Handbook of Chemistry and Physics [1]
TABLE XIII-2

OXIDATION RATE OF NITRIC OXIDE IN AIR (20% O2) AT 20 C

<table>
<thead>
<tr>
<th>Concentration (ppm)</th>
<th>Oxidation Time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25%</td>
</tr>
<tr>
<td>10,000</td>
<td>8.4 sec</td>
</tr>
<tr>
<td>1,000</td>
<td>1.4 min</td>
</tr>
<tr>
<td>100</td>
<td>14 min</td>
</tr>
<tr>
<td>10</td>
<td>2.3 hours</td>
</tr>
<tr>
<td>1</td>
<td>24 hours</td>
</tr>
</tbody>
</table>

From Austin [167]
### TABLE XIII-3
NITROGEN OXIDES FROM CUTTING WITH OXYACETYLENE TORCH

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Collection Time (A.M.)*</th>
<th>NO2</th>
<th>NO</th>
<th>NO2 + NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6:55</td>
<td>25</td>
<td>165</td>
<td>190</td>
</tr>
<tr>
<td>2</td>
<td>6:55</td>
<td>--</td>
<td>--</td>
<td>210</td>
</tr>
<tr>
<td>3</td>
<td>7:06</td>
<td>--</td>
<td>--</td>
<td>260</td>
</tr>
<tr>
<td>4</td>
<td>7:11</td>
<td>--</td>
<td>--</td>
<td>300</td>
</tr>
<tr>
<td>5</td>
<td>7:18</td>
<td>--</td>
<td>--</td>
<td>290</td>
</tr>
<tr>
<td>6</td>
<td>7:20</td>
<td>90</td>
<td>180</td>
<td>270</td>
</tr>
<tr>
<td>7</td>
<td>7:21</td>
<td>--</td>
<td>--</td>
<td>300</td>
</tr>
<tr>
<td>8</td>
<td>7:27</td>
<td>--</td>
<td>--</td>
<td>330</td>
</tr>
<tr>
<td>9</td>
<td>7:27</td>
<td>--</td>
<td>--</td>
<td>310</td>
</tr>
<tr>
<td>10</td>
<td>7:28</td>
<td>--</td>
<td>--</td>
<td>340</td>
</tr>
</tbody>
</table>

*Cutting began at 6:40 A.M.

From Norwood et al [23]
TABLE XIII-4

FORMATION OF OXIDES OF NITROGEN BY VICTOR TORCH

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Torch Characteristics</th>
<th>Gas Evolution Rate (mg/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Nitrogen Dioxide</td>
</tr>
<tr>
<td>1m</td>
<td>Flame only</td>
<td>16</td>
</tr>
<tr>
<td>2m</td>
<td>Flame only</td>
<td>--</td>
</tr>
<tr>
<td>3m</td>
<td>Stainless-steel melting</td>
<td>--</td>
</tr>
<tr>
<td>5m</td>
<td>Stainless-steel melting</td>
<td>9</td>
</tr>
<tr>
<td>6m</td>
<td>Carbon steel cutting*</td>
<td>14</td>
</tr>
</tbody>
</table>

*More oxygen is used during cutting than during melting

From Norwood et al [23]
TABLE XIII-5
NITROGEN DIOXIDE CONCENTRATIONS FROM FLAME-CUTTING

<table>
<thead>
<tr>
<th>Minutes after Completion of Cut</th>
<th>Flame Only</th>
<th>Unprimed Plate</th>
<th>Polyamide-Cured Primer</th>
<th>Amine Adduct-Cured Primer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>594</td>
<td>86</td>
<td>82</td>
<td>95</td>
</tr>
<tr>
<td>2</td>
<td>518</td>
<td>90</td>
<td>99</td>
<td>97</td>
</tr>
<tr>
<td>3</td>
<td>493</td>
<td>68</td>
<td>78</td>
<td>91</td>
</tr>
<tr>
<td>4</td>
<td>465</td>
<td>78</td>
<td>87</td>
<td>67</td>
</tr>
<tr>
<td>5</td>
<td>437</td>
<td>70</td>
<td>93</td>
<td>91</td>
</tr>
<tr>
<td>6</td>
<td>382</td>
<td>74</td>
<td>79</td>
<td>68</td>
</tr>
<tr>
<td>7</td>
<td>346</td>
<td>62</td>
<td>82</td>
<td>81</td>
</tr>
<tr>
<td>8</td>
<td>333</td>
<td>64</td>
<td>77</td>
<td>67</td>
</tr>
<tr>
<td>9</td>
<td>308</td>
<td>62</td>
<td>77</td>
<td>72</td>
</tr>
<tr>
<td>10</td>
<td>288</td>
<td>68</td>
<td>70</td>
<td>59</td>
</tr>
<tr>
<td>15</td>
<td>196</td>
<td>45</td>
<td>48</td>
<td>60</td>
</tr>
<tr>
<td>20</td>
<td>100</td>
<td>30</td>
<td>32</td>
<td>37</td>
</tr>
</tbody>
</table>

From Steel and Sanderson [19]
<table>
<thead>
<tr>
<th>Days after Onset of Filling Silo</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>9</th>
<th>11</th>
<th>13</th>
<th>21</th>
<th>42</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Loads of Silage</td>
<td>12</td>
<td>18</td>
<td>22</td>
<td>32</td>
<td>48</td>
<td>64</td>
<td>90</td>
<td>93</td>
<td>93</td>
<td>93</td>
<td>93</td>
<td>93</td>
</tr>
</tbody>
</table>

### Sampling sites

<table>
<thead>
<tr>
<th></th>
<th>NO ppm</th>
<th>NO2 ppm</th>
<th>CO2 %v/v</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Periphery of tower</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 ft above surface</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>280</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.6</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>0.6</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.2</td>
<td>0.6</td>
<td>2</td>
</tr>
<tr>
<td><strong>5 ft above surface</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>150</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td>220</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td><strong>6 in. below surface</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>40</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
<td>0.0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>NO ppm</th>
<th>NO2 ppm</th>
<th>CO2 %v/v</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Center of tower</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 ft above surface</td>
<td>0</td>
<td>0.1</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>400</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>240</td>
<td>220</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>240</td>
<td>1920</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>630</td>
<td>360</td>
<td>78</td>
</tr>
<tr>
<td></td>
<td>580</td>
<td>580</td>
<td>0.2</td>
</tr>
<tr>
<td><strong>5 ft above surface</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0.2</td>
<td>23</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>35</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td><strong>6 ft below surface</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>23</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>25</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Load covered with polyethylene sheet after 6th day, removed before tests on 11th day.

From Commins et al [29]
<table>
<thead>
<tr>
<th>Concentration in ppm</th>
<th>Length of Exposure</th>
<th>Type of Exposure</th>
<th>Observed Effects</th>
<th>Remarks</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>38-345</td>
<td>Working lifetime</td>
<td>Occupational: Shotfiring operations in coal miners</td>
<td>Forced Respiratory Volume (FEV 0.75) and vital capacity reduced, residual volume and total lung capacity increased relative to controls</td>
<td>Inappropriate control sample. Exposure to high levels of carbon monoxide and carbon dioxide in addition to &quot;nitrous fumes&quot;</td>
<td>Kennedy [28]</td>
</tr>
<tr>
<td>62-150</td>
<td>3 separate exposures ranging from 10 min to 2 hrs</td>
<td>Experimental: Continuous inhalation</td>
<td>62 ppm for 1 hour: Laryngeal irritation, but no other effects. 25-100 ppm for 2 hours: Marked mucosal irritation, increased pulse and respiratory rates. 158 ppm for 10 minutes: Coughing, irritation of nasal and laryngeal mucosa, lacrimation, headache, nausea, and vomiting. No delayed or long-term illness</td>
<td>Probable exposure to nitric oxide and airborne nitric acid in addition to nitrogen dioxide</td>
<td>Lehman &amp; Hasagawa [39]</td>
</tr>
<tr>
<td>4-20</td>
<td>Acute, duration not stated</td>
<td>Occupational: Open arc welding</td>
<td>Conjunctivitis and pharyngitis which subsided 18 hrs after exposure</td>
<td>Exposure to oxides of nitrogen</td>
<td>Morley &amp; Silk [63]</td>
</tr>
<tr>
<td>2.0-10.3</td>
<td>Unknown</td>
<td>Occupational: Arc welding</td>
<td>Slight increase in methemoglobin levels in blood</td>
<td>Exposure to oxides of nitrogen</td>
<td>McDermid et al [56]</td>
</tr>
<tr>
<td>4-5</td>
<td>10 min</td>
<td>Experimental: Continuous inhalation</td>
<td>Decrease in effective lung compliance with corresponding increase in inspiratory and inspiratory maximum viscous resistance</td>
<td>5 healthy adult male subjects</td>
<td>Abe [67]</td>
</tr>
<tr>
<td>0.0-5.0</td>
<td>30 breaths or 15 min</td>
<td>Experimental: Continuous inhalation</td>
<td>Exposure at 1.5-5.0 ppm increased airway resistance. Significant decrease in arterial oxygen tension, and significant increase of end-expiratory arterial pressure at 4-5 ppm. No effects noted below 1.5 ppm</td>
<td>88 chronic bronchitis patients</td>
<td>Von Wieding et al [68]</td>
</tr>
<tr>
<td>0.5-5.0</td>
<td>15-60 min</td>
<td>Experimental: Continuous inhalation</td>
<td>Significant reduction in carbon monoxide diffusing capacity in 16 healthy male subjects exposed for 15 min at 5 ppm. Significant decrease in arterial oxygen partial pressure with corresponding increase in alveoloarterial oxygen pressure gradient in 14 chronic bronchitis patients exposed for 15 min at 5 ppm. Continued exposure to 60 min did not significantly change findings at 25 min. Increased airway resistance in 70 chronic bronchitis patients exposed at and above 1.5 ppm</td>
<td></td>
<td>Von Wieding et al [69]</td>
</tr>
</tbody>
</table>
TABLE XIII-7 (CONTINUED)

SUMMARY OF EPIDEMIOLOGIC AND EXPERIMENTAL STUDIES ON HUMAN EXPOSURE TO NITROGEN DIOXIDE

<table>
<thead>
<tr>
<th>Concentration in ppm</th>
<th>Length of Exposure</th>
<th>Type of Exposure</th>
<th>Observed Effects</th>
<th>Remarks</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4-2.7</td>
<td>4-6 years</td>
<td>Occupational: Chemical works</td>
<td>Complaints of sporadic cough, mucopurulent expectoration, and dyspnea on exertion. Normal chest X-ray, spirometry, and blood pH. Carbon dioxide partial pressure and total carbonic acid in blood increased. Significant decrease in serum proteins and significant increase in urinary amino acids and glycoproteins</td>
<td>Conflicting results on the presence of chronic obstructive pulmonary disease. Total lack of environmental data</td>
<td>Kosmider et al [71]</td>
</tr>
<tr>
<td>Less than 2.8</td>
<td>Unknown</td>
<td>Occupational: Printing shop and sulfuric acid plant</td>
<td>Dental erosion and gingivitis; emphysema and pulmonary tuberculosis; cardiovascular hypotonia and bradycardia; polycythemia rubra, granulocytosis, basophilia; decreased osmotic fragility of red blood cells, accelerated agglutination of the blood cells; reduced catalase index, reduced alkali reserve, reduced blood sugar</td>
<td>Workers probably exposed to sulfuric acid mist and sulfur dioxide at unknown concentrations</td>
<td>Vignorscak et al [70]</td>
</tr>
<tr>
<td>Low Exposure= 0.106</td>
<td>24 hrs/day</td>
<td>Community: Ambient air near TNT plant</td>
<td>Higher incidence of acute respiratory disease in high exposure community compared with low exposure community, particularly in children below age 12. No difference in chronic respiratory disease between communities</td>
<td>Suspended nitrates and total suspended particulates higher in high exposure community compared with other communities. Concentrations of sulfur dioxide and other contaminants not reported</td>
<td>French [74]</td>
</tr>
<tr>
<td>Concentration in ppm</td>
<td>Length of Exposure</td>
<td>Type of Exposure</td>
<td>Observed Effects</td>
<td>Remarks</td>
<td>Reference</td>
</tr>
<tr>
<td>----------------------</td>
<td>--------------------</td>
<td>-----------------</td>
<td>------------------</td>
<td>---------</td>
<td>-----------</td>
</tr>
<tr>
<td>#112</td>
<td>3 min</td>
<td>Anesthesia accident</td>
<td>One patient showed signs of cyanosis and methemoglobinemia, followed 18 1/2 hours later by death. Autopsy indicated severe pulmonary edema. Second patient showed signs of cyanosis, but recovered fully following proper medical treatment.</td>
<td>Accidents due to contamination of nitrous oxide by nitric oxide, the analysis of which was not described.</td>
<td>Clutton-Brock [58]</td>
</tr>
<tr>
<td>#3</td>
<td>Working lifetime</td>
<td>Occupational: Nitrogen fertilizer production</td>
<td>Exposed workers had higher carboxy- and methemoglobin levels in their blood compared with controls. Exposed workers developed pyridoxine deficiency.</td>
<td>Exposure to carbon monoxide, ammonia, and mixed oxides of nitrogen</td>
<td>Nizhagorodov &amp; Markhotoki [57]</td>
</tr>
<tr>
<td>2-10</td>
<td>Unknown</td>
<td>Occupational: Arc-welding</td>
<td>Slight increase in methemoglobin levels</td>
<td>Exposure to mixed oxides of nitrogen</td>
<td>McCord et al [36]</td>
</tr>
<tr>
<td>Concentration in ppm</td>
<td>Species</td>
<td>Duration of Exposure</td>
<td>Type of Exposure</td>
<td>Observed Effects</td>
<td>Reference</td>
</tr>
<tr>
<td>----------------------</td>
<td>---------------</td>
<td>----------------------</td>
<td>------------------</td>
<td>-----------------------------------------------------------------------------------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>5000-20000</td>
<td>Dog</td>
<td>Up to 50 min</td>
<td>Continuous</td>
<td>5000 ppm: Decreased arterial oxygen tension, rise in methemoglobin and arterial carbon dioxide tension. If exposure greater than 24 min, death occurred 7-120 min after exposure. 20000 ppm: Death in 15-50 minutes</td>
<td>Greenbaum et al [81]</td>
</tr>
<tr>
<td>2500-5000</td>
<td>White mice</td>
<td>Up to 12 min</td>
<td></td>
<td>Animals exposed at 5000 ppm died after 6-8 min. Animals exposed at 2500 ppm died after 12 min of exposure.</td>
<td>Plury and Zernik [86]</td>
</tr>
<tr>
<td>310-3500</td>
<td></td>
<td>Up to 8 hrs</td>
<td></td>
<td>LC50 = 320 ppm All animals survived an 8-hr exposure at 310 ppm. At high concentrations, nitric oxide 4 times more toxic than nitrogen dioxide</td>
<td>Pflesser [47]</td>
</tr>
<tr>
<td>175-2100</td>
<td>Mice, guinea pig</td>
<td>Up to 6 hrs</td>
<td></td>
<td>Mice exposed at 2100 ppm for 30 min produced 80% methemoglobin. Exposure at 322 ppm for 6 hrs produced 60% methemoglobin. No change in recovery of resting respiratory rhythm in guinea pigs at 175 ppm for 120-150 min</td>
<td>Paribok and Grokholskaya [87]</td>
</tr>
</tbody>
</table>
### TABLE XIII-10

**SUMMARY OF EFFECTS OF EXPOSURE TO NITROGEN DIOXIDE IN EXPERIMENTAL ANIMALS**

<table>
<thead>
<tr>
<th>Concentration in ppm</th>
<th>Species</th>
<th>Duration of Exposure</th>
<th>Type of Exposure</th>
<th>Dependent Variable(s)</th>
<th>Results</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>88-1445</td>
<td>Rats</td>
<td>2-240 min</td>
<td>Continuous</td>
<td>Mortality</td>
<td>Time</td>
<td>LC50</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gray et al [89]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2 min</td>
<td>1445 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5 &quot;</td>
<td>833 &quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15 &quot;</td>
<td>420 &quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30 &quot;</td>
<td>174 &quot;</td>
</tr>
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<td>60 &quot;</td>
<td>168 &quot;</td>
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<td></td>
<td>240 &quot;</td>
<td>88 &quot;</td>
</tr>
<tr>
<td>115-416</td>
<td>Rats, dogs, guinea pigs</td>
<td>5-60 min</td>
<td>&quot;</td>
<td>&quot;</td>
<td>Time</td>
<td>LC50</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Carson et al [90]</td>
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<td></td>
<td></td>
<td></td>
<td>5 min</td>
<td>416 ppm</td>
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<td>15 &quot;</td>
<td>201 &quot;</td>
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<td>30 &quot;</td>
<td>162 &quot;</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>60 &quot;</td>
<td>115 &quot;</td>
</tr>
</tbody>
</table>

Guinea Pig

15 min 315 ppm

Threshold of toxicity approximately 25% of LC50 levels for rats. At these levels, dogs showed no gross or microscopic changes, rats showed some pulmonary edema.

| 12.5-100             | Rats             | Until animals died or arbitrary termination of exposure | Continuous | Microscopic changes in pulmonary system | Exposure at 100 ppm resulted in death within 24 hrs. Rats exposed at 12.5 ppm had moderate hypertrophy and hyperplasia of bronchial and bronchiolar epithelium as well irregular alveolar ducts and alveoli after 40 days of exposure. | Freeman and Haydon [97] |

20-70

Guinea pigs 30 min Continuous Antigen sensitization Exposure at 70 ppm enhanced sensitization, 40 ppm and less did not. Matsushima [122]

50

Hamsters 1-10 wks Intermittent: 21-25 hrs/day Microscopic changes in lung tissue 1/3 of animals died within first 3 days. Epithelial hyperplasia and hypertrophy of bronchial and alveoli noted in animals killed immediately after exposure. Regression of inflammatory and epithelial hyperplastic changes observed in animals killed 4 wks after termination of exposure. Kleinerman and Cowdry [91]

180
<table>
<thead>
<tr>
<th>Concentration in ppm</th>
<th>Species</th>
<th>Duration of Exposure</th>
<th>Type of Exposure</th>
<th>Dependent Variable(s)</th>
<th>Results</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>30-50</td>
<td>Guinea pigs</td>
<td>30-45 min</td>
<td>Continuous</td>
<td>Mortality due to inhaled acetylcholine</td>
<td>Exposure at 50 ppm resulted in significantly higher mortality in animals pretreated with nitrogen dioxide than in controls. No differences in mortality between controls and pre-treated groups at lower concentrations of nitrogen dioxide</td>
<td>Matsumura et al [123]</td>
</tr>
<tr>
<td>5-50</td>
<td>Rabbits</td>
<td>3 hrs</td>
<td>&quot;</td>
<td>Phagocytic activity</td>
<td>Suppression of virus-induced resistance and phagocytic activity</td>
<td>Acton and Myrvik [121]</td>
</tr>
<tr>
<td>10, 22, 36, 45</td>
<td>Rats</td>
<td>single 4-hr periods</td>
<td>&quot;</td>
<td>Microscopic changes in tracheal and lung tissue</td>
<td>Normal trachea and lungs 4-8 days after exposure</td>
<td>Diggie and Sage [94]</td>
</tr>
<tr>
<td>15 and 40</td>
<td>Guinea pigs</td>
<td>Continuous for 10 wks or interrupted for 4 1/2 hrs</td>
<td>15 ppm-cont. 40 ppm-int: 1/2 hr every 2 hrs for 4 1/2 hrs</td>
<td>Oxygen consumption of tissue homogenates</td>
<td>No increase in lung tissue, but marked increase in liver tissue</td>
<td>Buckley and Balchum [112]</td>
</tr>
<tr>
<td>8-40</td>
<td>Rabbits</td>
<td>3 hrs</td>
<td>&quot;</td>
<td>Cellular distribution in lung tissue</td>
<td>Significant increase in intravascular heterophilies from exposure at 8 ppm</td>
<td>Gardner et al [110]</td>
</tr>
<tr>
<td>40</td>
<td>Mice</td>
<td>6-8 wks</td>
<td>&quot;</td>
<td>Oxygen consumption and LDH activity in lung</td>
<td>Increase in oxygen consumption and LDH activity at sites of nitrogen dioxide lung lesions</td>
<td>Buckley and Losalfi [114]</td>
</tr>
<tr>
<td>4-30</td>
<td>Mice</td>
<td>14 days at 4-7 ppm, 24 hrs at 30 ppm</td>
<td>&quot;</td>
<td>Lung capillary permeability and epithelial cell damage</td>
<td>Leakage of tritiated serum into pulmonary lavage fluid</td>
<td>Sherwin and Richters [115]</td>
</tr>
<tr>
<td>26</td>
<td>Dogs</td>
<td>191 days</td>
<td>&quot;</td>
<td>Macro- and microscopic changes in pulmonary system</td>
<td>1 dog showed bullous emphysema. Others showed a striking increase in the firmness of the lungs and emphysema, microscopically.</td>
<td>Lewis et al [101]</td>
</tr>
<tr>
<td>20-25</td>
<td>Rats, rabbits, guinea pigs</td>
<td>3 wks-18 mo</td>
<td>Intermittent 2 hrs/day, 3-4 days/wk</td>
<td>Macro- and microscopic changes in pulmonary system</td>
<td>Changes judged equivalent to microbullous emphysema observed in guinea pigs exposed for 13-18 mo. No such changes observed in rats or rabbits.</td>
<td>Kleitnerman and Wright [96]</td>
</tr>
<tr>
<td>Concentration in ppm</td>
<td>Species</td>
<td>Duration of Exposure</td>
<td>Type of Exposure</td>
<td>Dependent Variable(s)</td>
<td>Results</td>
<td>Reference</td>
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</tr>
<tr>
<td>15-25</td>
<td>Rats, guinea pigs, rabbits</td>
<td>2-hr exposures for 1 or 5 days</td>
<td>Continuous</td>
<td>Macro- and microscopic pulmonary changes</td>
<td>Pulmonary edema noted after one 2-hour exposure. Repair noted 2 wks after exposure. Edema and inflammation less severe after multiple 2-hr exposures than to single 2-hr exposure. Degree of morphologic change related to exposure concentration</td>
<td>Kleigerman and Wright [95]</td>
</tr>
<tr>
<td>25</td>
<td>Mice</td>
<td>4 1/2 mon</td>
<td>Intermittent: 30 min/day, 5 days/wk</td>
<td>Microscopic changes of lung tissue due to exposure to nitrogen dioxide alone and to carbon particles with absorbed nitrogen dioxide</td>
<td>Lung lesions such as destruction of alveolar walls was apparent in animals exposed to combined carbon-nitrogen dioxide. No lesions noted in animals exposed only to nitrogen dioxide</td>
<td>Boren [124]</td>
</tr>
<tr>
<td>25</td>
<td>Dogs</td>
<td>6 mon</td>
<td>Continuous</td>
<td>Macro- and microscopic changes in pulmonary system</td>
<td>1 dog showed macroscopic bullous emphysema. All dogs showed enlargement of alveoli</td>
<td>Riddick et al [100]</td>
</tr>
<tr>
<td>2-25</td>
<td>Rats</td>
<td>Natural lifetime except for 1 experiment in which rats were sacrificed at daily intervals during the last week of exposure at 18 ppm</td>
<td>&quot;</td>
<td>Microscopic changes of pulmonary system and lung weights</td>
<td>Terminal bronchiolar epithelial hypertrophy was observed to begin on the 5th day of exposure at 18 ppm. Widespread hypertrophy of respiratory epithelium indicative of emphysema resulted from continuous exposure at 10-25 ppm. Exposure at 2 ppm resulted in a reduction of bronchiolar cilia, inhibition of normal exfoliation and blebbing of epithelial cells, and appearance of cytoplasmic crystalloid inclusions.</td>
<td>Freeman et al [99]</td>
</tr>
</tbody>
</table>
### TABLE XIII-10 (CONTINUOUS)

**SUMMARY OF EFFECTS OF EXPOSURE TO NITROGEN DIOXIDE IN EXPERIMENTAL ANIMALS**

<table>
<thead>
<tr>
<th>Concentration in ppm</th>
<th>Species</th>
<th>Duration of Exposure</th>
<th>Type of Exposure</th>
<th>Dependent Variable(s)</th>
<th>Results</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-25</td>
<td>Dogs, mice, rabbits, guinea pigs, rats, and hamsters</td>
<td>Up to 18 mon</td>
<td>Intermittent: 6 hrs/day, 5 day/wk</td>
<td>Macro- and microscopic changes of the pulmonary system</td>
<td>Dogs exposed at 1 ppm for 1 year had moderately dilated alveolar ducts and sacs which contained some edematous fluid and an occasional macrophage. After 18 mon of exposure some thickening of alveolar septa and chronic inflammatory cells were noted.</td>
<td>Wagner et al [95]</td>
</tr>
<tr>
<td>15-17</td>
<td>Rats</td>
<td>48 hrs</td>
<td>Continuous</td>
<td>Macrophage division</td>
<td>Large increase in no. of dividing macrophages, as well as total no. of macrophages.</td>
<td>Evans et al [111]</td>
</tr>
<tr>
<td>2 and 17</td>
<td>&quot;</td>
<td>1 hr - 43 days</td>
<td>&quot;</td>
<td>Microscopic changes in lung tissue</td>
<td>Increased lung weight and severe injury to bronchile epithelium in animals exposed at 17 ppm. Animals exposed at 2 ppm showed no increase in lung weights compared with controls. Loss of cilia, hypertrophy, and focal hyperplasia noted after 3 days of exposure. Tissue recovery observed in animals killed after 21 days of exposure</td>
<td>Stephens et al [130]</td>
</tr>
<tr>
<td>2 and 17</td>
<td>&quot;</td>
<td>Up to 360 days</td>
<td>&quot;</td>
<td>Microscopic changes in bronchioles and terminal alveoli</td>
<td>Increased cell proliferation during the first 3-5 days, returning to normal after this time</td>
<td>Evans et al [131]</td>
</tr>
<tr>
<td>5-16</td>
<td>Dogs and rabbits</td>
<td>1 hr</td>
<td>&quot;</td>
<td>Microscopic changes of capillary endothelium and alveolar epithelium</td>
<td>Exposure had greatest effect on capillary endothelium. Findings included bleb formation, endothelial cell organelles in the capillary lumens, and appearance of platelets and polymorphonuclear leukocytes in lumens of capillaries adjoining blebs.</td>
<td>Kilburn and Dowell [104]</td>
</tr>
</tbody>
</table>
### TABLE XIII-10 (CONTINUED)

**SUMMARY OF EFFECTS OF EXPOSURE TO NITROGEN DIOXIDE IN EXPERIMENTAL ANIMALS**

<table>
<thead>
<tr>
<th>Concentration in ppm</th>
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</tr>
</thead>
<tbody>
<tr>
<td>3-16</td>
<td>Dogs</td>
<td>1 hr</td>
<td>Continuous</td>
<td>Microscopic changes of endothelial cells, Bleb formation, loss of pinocytic vesicles, and mitochondrial swelling</td>
<td>Exposure at 3 ppm resulted in bleb formation without other changes.</td>
<td>Dowell et al [105]</td>
</tr>
<tr>
<td>15 ± 2</td>
<td>Rats</td>
<td>1, 2, &amp; 7 days</td>
<td>Ultrastructural changes of lung tissue</td>
<td>Bronchial epithelium was less columnar, brush cells increased in number, microvilli became smaller, and number of macrophages increased.</td>
<td>Parkinson and Stephens [107]</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Guinea pigs</td>
<td>3 mon</td>
<td>Quantitative change in alveolar cells</td>
<td>Both an increase in the number of alveolar cells and the number of cells per alveolar space resulted from exposure.</td>
<td>Sherwin et al [108]</td>
<td></td>
</tr>
<tr>
<td>5-15</td>
<td>Rats</td>
<td>1 year</td>
<td>Antibody titers</td>
<td>Minimal microscopic change of lung tissue, Serum antibodies appeared within 180 hrs, and increased with continued exposure.</td>
<td>Balchus et al [116]</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Rats</td>
<td>Natural life-time</td>
<td>Continuous</td>
<td>Pulmonary changes</td>
<td>Animals had voluminous dry lungs, microscopic signs of epithelial hyperplasty of emphysema, and loss of cilia.</td>
<td>Freeman et al [102]</td>
</tr>
<tr>
<td>15</td>
<td>Guinea pigs</td>
<td>26-40 days</td>
<td>Enzyme activity in lung</td>
<td>Decrease in aerobic isozyme and increase in anaerobic isozyme in lung tissue.</td>
<td>Buckley and Balchum [113]</td>
<td></td>
</tr>
<tr>
<td>1-14.8</td>
<td>Mice</td>
<td>1.9-14.8 ppm for 4 hours and 1, 2.3, 6.6 ppm for 19 hrs</td>
<td>Antibacterial activity of animals infected with radiophosphorus labeled Staphylococcus aureus</td>
<td>Decreased bacterial activity in animals infected then exposed to 7 ppm. Exposure at 2.3 ppm for 17 hrs prior to infection also resulted in reduced bacterial response.</td>
<td>Goldstein et al [139]</td>
<td></td>
</tr>
<tr>
<td>9.3-14.3</td>
<td>Rats</td>
<td>10-24 days</td>
<td>Pulmonary changes</td>
<td>Immediately after exposure, rats showed severe rhinitis and tracheitis with less severe pneumonitis. Animals killed 8 hrs after exposure showed signs that the inflammatory process had subsided. However, localized areas of emphysema were noted.</td>
<td>Gray et al [92]</td>
<td></td>
</tr>
</tbody>
</table>

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### TABLE XIII-10 (CONTINUED)

**SUMMARY OF EFFECTS OF EXPOSURE TO NITROGEN DIOXIDE IN EXPERIMENTAL ANIMALS**

<table>
<thead>
<tr>
<th>Concentration in ppm</th>
<th>Species</th>
<th>Duration of Exposure</th>
<th>Type of Exposure</th>
<th>Dependent Variable(s)</th>
<th>Results</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5-14</td>
<td>Mice</td>
<td>Ct = 7; continuous at 0.5, 1.5, 3.5 ppm; 7 hrs/day at 3.5 ppm for up to 288 hrs</td>
<td>Continuous and intermittent</td>
<td>Mortality due to challenge by Streptococcus pyogenes</td>
<td>Ct was not a constant. Lower mortality with intermittent exposure. Linear regression of % mortality versus exposure time significantly different from zero slope for exposure at 0.5 ppm, not so for exposure at 1.5 ppm</td>
<td>Coffin et al [140]</td>
</tr>
<tr>
<td>8-12</td>
<td>Rabbits</td>
<td>3-4 mon</td>
<td>Continuous</td>
<td>Microscopic changes of pulmonary system</td>
<td>Emphysema-like dilations of peripheral alveoli were noted.</td>
<td>Haydon et al [98]</td>
</tr>
<tr>
<td>0.5-12</td>
<td>Monkeys, dogs, rabbits, guinea pigs, rats</td>
<td>90 days</td>
<td>&quot;</td>
<td>Hematologic changes, weight gain, gross lung pathology</td>
<td>Bronchitis, broncho-pneumonitis, pneumonia, and focal of multinucleated cells noted in animals exposed at 12 ppm. No lung pathology observed in animals exposed at and below 5 ppm</td>
<td>Steadman et al [145]</td>
</tr>
<tr>
<td>10</td>
<td>Guinea pigs</td>
<td>6 wks</td>
<td>&quot;</td>
<td>Ultrastructural changes of lung tissue</td>
<td>Thickening of blood-gas barrier by replacement of ultrathin type 1 cells by cuboidal or columnar type 2 pneumocytes.</td>
<td>Yuen and Sherwin [106]</td>
</tr>
<tr>
<td>10</td>
<td>&quot;</td>
<td>7 wks</td>
<td>&quot;</td>
<td>Macrophage congregation</td>
<td>Exposed animals showed an increase in macrophage congregation as well as an increase in the number of macrophages/epithelial cell.</td>
<td>Sherwin et al [109]</td>
</tr>
<tr>
<td>5-10</td>
<td>Squirrel monkeys</td>
<td>5 ppm: 2 mon 10 ppm: 1 mon</td>
<td>&quot;</td>
<td>Susceptibility to infection</td>
<td>Increased susceptibility to infection by K. pneumonia and influenza virus</td>
<td>Henry et al [117]</td>
</tr>
<tr>
<td>5</td>
<td>Rats, mice, monkeys</td>
<td>90 days</td>
<td>&quot;</td>
<td>Mortality</td>
<td>No significant mortality. No remarkable changes in growth or blood chemistry</td>
<td>MacDowell and Geckler [128]</td>
</tr>
<tr>
<td>5</td>
<td>Squirrel monkeys</td>
<td>169 days</td>
<td>&quot;</td>
<td>Antibody production due to intratracheal injections of mouse-adapted influenza virus</td>
<td>Hemagglutination-inhibition antibody not affected. Serum neutralizing antibody increased initially, but no differences between experimental and control animals by 169th day.</td>
<td>Fenters et al [137]</td>
</tr>
<tr>
<td>Concentration in ppm</td>
<td>Species</td>
<td>Duration of Exposure</td>
<td>Type of Exposure</td>
<td>Dependent Variable(s)</td>
<td>Results</td>
<td>Reference</td>
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</tr>
<tr>
<td>Mean = 4.5</td>
<td>Rats, mice, monkeys</td>
<td>90 days</td>
<td>Continuous</td>
<td>Hematologic and urinary changes as well as microscopic changes of the liver, kidneys, lungs, heart, pancreas, spleen, adrenals, cortex, medulla, and spinal cord</td>
<td>Mortality was low. Reduced weight gain, but no other significant pathologic findings</td>
<td>House [127]</td>
</tr>
<tr>
<td>4</td>
<td>Rats, mice, guinea pigs</td>
<td>6 mon</td>
<td>Intermittent: 4 hrs/day, 5 days/week.</td>
<td>Incidence of pulmonary obstructive disease</td>
<td>No significant difference between experimental and control groups</td>
<td>Gray et al [126]</td>
</tr>
<tr>
<td>0.8-4</td>
<td>Rats</td>
<td>16 wks</td>
<td>Continuous</td>
<td>Macro- and microscopic changes of lung tissue</td>
<td>No macroscopic signs of chronic obstructive disease. Only minimal microscopic changes</td>
<td>Haydon et al [143]</td>
</tr>
<tr>
<td>2.5 and 3.5</td>
<td>Mice</td>
<td>2 hrs</td>
<td>&quot;</td>
<td>Susceptibility to Klebsiella pneumoniae</td>
<td>Increased susceptibility to 3.5 ppm, not at 2.5 ppm</td>
<td>Purvis and Erlich [135]</td>
</tr>
<tr>
<td>1.5, 2.5, 3.5</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
<td>Mortality due to challenge by Klebsiella pneumoniae</td>
<td>Significant increase at 3.5 ppm, but not at 2 lower levels.</td>
<td>Erlich et al [136]</td>
</tr>
<tr>
<td>0.5-3.5</td>
<td>&quot;</td>
<td>2 hrs and 9 mon</td>
<td>Continuous or intermittent: 6 hrs/day, 5 days/week.</td>
<td>Mortality resulting from exposure to airborne Klebsiella pneumoniae</td>
<td>No effect following 2-hr exposure at 3.5 ppm. Significant increase in mortality in animals exposed continuously for 3 mon or intermittently for 1 mon at 0.5 ppm</td>
<td>Ehrlitch [155]</td>
</tr>
<tr>
<td>2.9 ± 0.71</td>
<td>Rats</td>
<td>9 mon</td>
<td>24 hrs/day, 5 days/week.</td>
<td>Changes in lung weights and physiology</td>
<td>12.7% mean increase in lung weights. 13% mean decrease in lung compliance. Reduction of surface-active properties of lung-wash fluid</td>
<td>Arner and Rhodes [134]</td>
</tr>
<tr>
<td>2 ± 1</td>
<td>Natural lifetime</td>
<td>&quot;</td>
<td>Continuous</td>
<td>Changes in respiratory function as well as microscopic changes of lung tissue</td>
<td>Persistent tachypnea in all animals. No changes in airflow resistance or dynamic compliance. Microscopic changes including reduced blebbing of cytoplasm into airways, loss of cilia, and appearance of intracytoplasmic crystalloid inclinations.</td>
<td>Freeman et al [129]</td>
</tr>
<tr>
<td>2</td>
<td>Guinea pigs</td>
<td>1, 2, or 3 wks</td>
<td>&quot;</td>
<td>Ratios of lactate dehydrogenase-positive wall cells to alveoli</td>
<td>Exposed animals showed changes of LDH activity suggesting increases in type 2 pneumocytes as compared with controls</td>
<td>Sherwin et al [132]</td>
</tr>
</tbody>
</table>
### TABLE XIII-10 (CONTINUED)

**SUMMARY OF EFFECTS OF EXPOSURE TO NITROGEN DIOXIDE IN EXPERIMENTAL ANIMALS**

<table>
<thead>
<tr>
<th>Concentration in ppm</th>
<th>Species</th>
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<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1-2</td>
<td>Mice</td>
<td>3 1/2-7 mon</td>
<td>Continuous</td>
<td>Cellular morphology of lungs, phagocytic activity and oxygen consumption of alveolar macrophages</td>
<td>Cell counts, macrophage viabilities at isolation, and oxygen consumption of macrophages unaffected. In vitro phagocytic activity reduced in animals exposed intermittently at 0.5/2 ppm for 3 1/2 or 7 mon. No such change noted in animals exposed continuously at 2 ppm. Changes in morphology of macrophages noted in animals exposed intermittently at 0.5/2 ppm. No such changes observed in other exposure groups</td>
<td>Aranyi and Fort [147]</td>
</tr>
<tr>
<td>0.5-2.0</td>
<td>&quot;</td>
<td>Up to 40 wks</td>
<td>Continuous</td>
<td>Immune response</td>
<td>No difference between experimental and control animals in N1 antibody titers. SN titers significantly depressed in animals exposed at 0.5/2. Significant increase in IgA, IgM, IgG, and IgG2 immunoglobulin levels in animals exposed to nitrogen dioxide, particularly in those animals exposed at 0.5/2 ppm</td>
<td>Erlich et al [158]</td>
</tr>
<tr>
<td>1-1.5</td>
<td>&quot;</td>
<td>1 Mon</td>
<td>Continuous</td>
<td>Microscopic changes in trachea and lungs</td>
<td>Desquamative bronchitis observed in animals killed immediately after exposure. Infiltration of lymphocytes seen in lungs of animals killed 1 and 3 months after exposure. No controls</td>
<td>Chen et al [133]</td>
</tr>
<tr>
<td>1</td>
<td>Guinea pigs</td>
<td>180 days</td>
<td>8 hrs/day</td>
<td>Macro- and microscopic changes in the lung, Hematologic, urinary, and immunologic changes</td>
<td>Evidence of chronic respiratory disease such as bronchitis bronchopneumonia, extravasation of blood in lungs, and focus of emphysem. Urinary hydroxyproline and acid mucopolysaccharides were increased. Decreased serum proteins, immunoglobulins, and weight gain</td>
<td>Kosmider et al [71]</td>
</tr>
<tr>
<td>Concentration in ppm</td>
<td>Species</td>
<td>Duration of Exposure</td>
<td>Type of Exposure</td>
<td>Dependent Variable(s)</td>
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<td>------------------</td>
</tr>
<tr>
<td>1.0</td>
<td>Rabbits</td>
<td>1 hr</td>
<td>Continuous</td>
<td>Changes in protein structure of lung tissue</td>
<td>Peak shift in absorbance spectrum in animals killed immediately after exposure. Absorbance spectrum returned to normal in animals killed 24-48 hrs after exposure</td>
<td>Nuell et al [151]</td>
</tr>
<tr>
<td>1.0</td>
<td>Rats</td>
<td>1-6 days</td>
<td>4 hrs/day</td>
<td>Changes in lung lipid structure</td>
<td>Absorption spectra indicative of diene conjugation</td>
<td>Thomas et al [153]</td>
</tr>
<tr>
<td>1.0</td>
<td>Squirrel monkeys</td>
<td>493 days</td>
<td>Continuous</td>
<td>Microscopic changes in lung tissue and immune responses resulting from challenge with A/PR18/34 virus</td>
<td>No difference between experimental and control animals in hemagglutination-inhibition antibody titers, body temperatures, respiratory function, body weights, hematologic values, and ultrastructural changes. Monkeys exposed to nitrogen dioxide produced serum neutralization antibody within 21 days of exposure as well as signs of chronic pulmonary obstructive disease by the end of exposure.</td>
<td>Fantes et al [157]</td>
</tr>
<tr>
<td>0.5-1.0</td>
<td>Rats</td>
<td>1 hr at 1 ppm, 4 hrs at 0.5 ppm</td>
<td></td>
<td>Changes in mast cells of lung</td>
<td>Exposure at 1 ppm resulted in loss of cytoplasmic granules, rupture, and reduction in number of mast cells. Exposure at 0.5 ppm for 4 hours resulted in degranulation of mast cells.</td>
<td>Thomas et al [152]</td>
</tr>
<tr>
<td>0.2-1.0 in combination with 0.2-3.0 ppm nitric oxide</td>
<td>Dogs</td>
<td>4 1/2 years</td>
<td>16 hrs/day</td>
<td>Cardiovascular changes</td>
<td>No significant effects</td>
<td>Bloch et al [149]</td>
</tr>
<tr>
<td>0.1-1.0 in combination with 0.1-2.0 ppm nitric oxide</td>
<td></td>
<td></td>
<td>18 mon</td>
<td>Pulmonary function</td>
<td>No change in single-breath carbon monoxide diffusing capacity, dynamic pulmonary compliance, or total pulmonary resistance.</td>
<td>Vaughn et al [148]</td>
</tr>
<tr>
<td>0.8</td>
<td>Rats</td>
<td>Natural lifetime</td>
<td>Continuous</td>
<td>Respiratory physiology and microscopic changes of lung tissue</td>
<td>Sustained tachypnea 20% above controls. Minimal morphologic changes. No gross or microscopic signs of obstructive disease</td>
<td>Freeman et al [144]</td>
</tr>
</tbody>
</table>

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### TABLE XIII-10 (CONTINUED)

**SUMMARY OF EFFECTS OF EXPOSURE TO NITROGEN DIOXIDE IN EXPERIMENTAL ANIMALS**

<table>
<thead>
<tr>
<th>Concentration in ppm</th>
<th>Species</th>
<th>Duration of Exposure</th>
<th>Type of Exposure</th>
<th>Dependent Variable(s)</th>
<th>Results</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>Mice</td>
<td>3-12 mon</td>
<td>6, 18, 24 hrs/day</td>
<td>Alveolar size</td>
<td>Lung alveoli expanded in all mice exposed to nitrogen dioxide as compared with controls</td>
<td>Blair et al [146]</td>
</tr>
<tr>
<td>0.5</td>
<td></td>
<td>1-12 mon</td>
<td>Continuous or intermittent (6 or 18 hrs/day)</td>
<td>Mortality, rate of bacterial clearance, serum lactate dehydrogenase resulting from exposure to Klebsiella pneumonia</td>
<td>Reduced rate of clearance. LDH showed shift from anaerobic to aerobic bands. Significant increase in mortality in animals continuously exposed for 3 mon or longer, and in animals intermittently exposed for 6 mon</td>
<td>Ehrlich and Henry [156]</td>
</tr>
<tr>
<td>0.4</td>
<td>Guinea pigs</td>
<td>1 wk</td>
<td>Continuous</td>
<td>Protein level in lung lavage fluid</td>
<td>Animals exposed to nitrogen dioxide showed higher protein levels in lung lavage fluid than controls</td>
<td>Sherwin and Carlson [154]</td>
</tr>
<tr>
<td>Duration of Exposure (hO)</td>
<td>5 ppm NO₂</td>
<td>Control</td>
<td>% Difference of Tumor Incidence in Exposed versus Control Animals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>-----------</td>
<td>---------</td>
<td>---------------------------------------------------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No. with Tumors / No. Examined</td>
<td>% Tumor Incidence</td>
<td>No. with Tumors / No. Examined</td>
<td>% Tumor Incidence</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>7/10</td>
<td>70</td>
<td>4/10</td>
<td>40</td>
<td>+30</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>7/15</td>
<td>47</td>
<td>8/15</td>
<td>53</td>
<td>-6</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>15/24</td>
<td>62</td>
<td>15/24</td>
<td>62</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

From Wagner et al [93]
TABLE XIII-12
CORRELATION OF OXIDES OF NITROGEN WITH TORCH SIZE

<table>
<thead>
<tr>
<th>Size of Tip</th>
<th>Acetylene Consumption (cu ft/hr)(1)</th>
<th>Time After Ignition of Torch (minutes)</th>
<th>Concentration of Nitrogen (as NO2) (ppm)</th>
<th>Average Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#4</td>
<td>15.9</td>
<td>1</td>
<td>25</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>#6</td>
<td>31.6</td>
<td>1</td>
<td>65</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>#8</td>
<td>60.0</td>
<td>1</td>
<td>150</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>240</td>
<td>210</td>
</tr>
<tr>
<td>#10</td>
<td>88.5</td>
<td>1</td>
<td>210</td>
<td>280</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>270</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>320</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>320</td>
<td>280</td>
</tr>
<tr>
<td>#12</td>
<td>175</td>
<td>1</td>
<td>240</td>
<td>352</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>370</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>430</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>7</td>
<td>370</td>
<td></td>
</tr>
</tbody>
</table>

(1) Rated capacity of tip

From Adley [11]
### TABLE XIII-13

**OXIDES OF NITROGEN IN LARGE, VENTILATED COMPARTMENTS**

<table>
<thead>
<tr>
<th>Volume of Compartment (cu ft)</th>
<th>Remarks</th>
<th>Number of Samples</th>
<th>Average Concentration (ppm)</th>
<th>Maximum Concentration (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7200</td>
<td>Operator shrinking intermittently. Fair natural ventilation.</td>
<td>5</td>
<td>48</td>
<td>89</td>
</tr>
<tr>
<td>8700</td>
<td>Operator working on deck plates adjacent to fresh air supply hose.</td>
<td>5</td>
<td>19</td>
<td>32</td>
</tr>
<tr>
<td>8700</td>
<td>Operator shrinking in compartment having one fresh air supply hose about 20 feet away.</td>
<td>3</td>
<td>34</td>
<td>38</td>
</tr>
<tr>
<td>9000</td>
<td>Operator shrinking near outside hatch. Good natural ventilation.</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>10000</td>
<td>Two operators shrinking. Two fresh air supply hoses introducing a total of about 1,000 cfm.</td>
<td>12</td>
<td>17</td>
<td>27</td>
</tr>
</tbody>
</table>

*Note: #10 torch tips being used during all sampling.*

*From Adley [11]*
TABLE XIII-14

NITROGEN OXIDES EXPOSURES FROM WELDING OPERATIONS IN SEVEN SHIPYARDS

<table>
<thead>
<tr>
<th>Location</th>
<th>Total Number Samples</th>
<th>Nitrogen Oxides (ppm)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0-4</td>
<td>5-9</td>
<td>10-14</td>
<td>15-19</td>
<td>20-24</td>
<td>25 or over</td>
</tr>
<tr>
<td>Hull</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner bottoms</td>
<td>172</td>
<td>98</td>
<td>51</td>
<td>18</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Fore- and after-peaks and small tanks</td>
<td>166</td>
<td>90</td>
<td>43</td>
<td>22</td>
<td>7</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Cargo holds, superstructure and other large spaces</td>
<td>661</td>
<td>364</td>
<td>180</td>
<td>68</td>
<td>22</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>Top deck and outside shell</td>
<td>104</td>
<td>58</td>
<td>23</td>
<td>10</td>
<td>6</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Sub-assembly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner bottoms</td>
<td>48</td>
<td>22</td>
<td>11</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Fore- and after-peaks</td>
<td>136</td>
<td>87</td>
<td>34</td>
<td>11</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Superstructure</td>
<td>69</td>
<td>34</td>
<td>24</td>
<td>4</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Open, flat sheets</td>
<td>257</td>
<td>170</td>
<td>59</td>
<td>13</td>
<td>10</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Shop</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fabrication</td>
<td>295</td>
<td>176</td>
<td>67</td>
<td>39</td>
<td>9</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Pipe</td>
<td>111</td>
<td>56</td>
<td>30</td>
<td>11</td>
<td>3</td>
<td>6</td>
<td>5</td>
</tr>
</tbody>
</table>

*From Dreessen et al. [13]*

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FIGURE XIII - 1. NITROGEN DIOXIDE/NITRIC OXIDE SAMPLING TUBE

15 cm OVERALL LENGTH OF GLASS TUBING

5 mm I.D.

12 mm

FIBERGLASS WOOL

SAMPLE FLOW

7 mm O.D.

A. 400 mg TRIETHANOLAMINE—IMPREGNATED TYPE 13 X, 30—40 MESH MOLECULAR SIEVE

B. 800 mg OF OXIDATION MATERIAL No.1900277 FROM DRAGER COMPANY OF GERMAN, SUPPLIED BY NATIONAL MINE SERVICE CO.
FIGURE XIII - 2. CALIBRATION SCHEME FOR PERSONAL SAMPLING PUMP AND SAMPLING TUBE

SOAP BUBBLE METER (INVERTED BURET)

SAMPLING TUBE

MANOMETER (WATER)

PERSONAL SAMPLING PUMP

BEAKER

SOAP SOLUTION