Cu Sn5

Common names: 5% Phosphor Bronze
Phosphor Bronze, 5% A

A copper-tin alloy with an alpha phase structure and containing a small amount of phosphorus. The alloy has good cold-working properties and corrosion resistance, combined with somewhat higher strength and hardness than Cu Sn6. The most commonly used wrought forms are strip, rod, and wire.

**COMPOSITION (weight %)**

Cu : 95.7 - 96.5
Sn : 4.3 - 4.5
P : 0.05 - 0.40

**1 SOME TYPICAL USES**

Architectural
Mossey flanges.

Chemical
Tubes for acid mine waters; components for the chemical, textile and papermaking industries.

Electrical
Springs, clips, switch components and contacts.

Mechanical
Springs, bellows and diaphragms; cold-headed screws, rivets and bolts; nuts, washers and catter pins; wire brushes; Bourdon tubing; welding rods and arc-welding electrodes.

**2 PHYSICAL PROPERTIES**

<table>
<thead>
<tr>
<th>Metric Units</th>
<th>English Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density at 20°C</td>
<td>69°F</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.2 Melting range</th>
<th></th>
<th>920-960°C</th>
<th>1700-1740°F</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>2.3 Coefficient of thermal expansion (linear) at:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-25°C</td>
<td>-41°F</td>
<td>0.000 008 per °C</td>
<td>0.000 000 per °F</td>
</tr>
<tr>
<td>20°C</td>
<td>68°F</td>
<td>0.000 009</td>
<td>0.000 000</td>
</tr>
<tr>
<td>60°C</td>
<td>140°F</td>
<td>0.000 017</td>
<td>0.000 010</td>
</tr>
<tr>
<td>100°C</td>
<td>212°F</td>
<td>0.000 018</td>
<td>0.000 010</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.4 Specific heat (thermal capacity) at:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>80°C</td>
<td>68°F</td>
<td>0.09 cal/g°C</td>
<td>0.09 Btu/lb°F</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.5 Thermal conductivity at:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td>68°F</td>
<td>0.15-0.33 cal cm/cm² s °C</td>
<td>36-56 Btu ft² h °F</td>
</tr>
<tr>
<td>500°C</td>
<td>932°F</td>
<td>0.09-0.28</td>
<td>40-56</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.6 Electrical conductivity (volume) at:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td>68°F (annealed)</td>
<td>7.5-10 m/ohm mm²</td>
<td>10-18 % IACS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.7 Electrical resistivity (volume) at:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td>68°F</td>
<td>0.0190-0.046 ohm mm²/m</td>
<td>0.038-0.1 ohm cm</td>
</tr>
<tr>
<td>150°C</td>
<td>113°F (annealed)</td>
<td>0.013-0.036 ohm mm²/m</td>
<td>0.024-0.068 ohm cm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.8 Temperature coefficient of electrical resistance at:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>20°C</td>
<td>68°F (annealed)</td>
<td>0.000 7 per °C (1% (ACS))</td>
<td>0.000 4 per °F (1% (ACS))</td>
</tr>
<tr>
<td>30°C</td>
<td>86°F</td>
<td>0.000 8 (1% (ACS))</td>
<td>0.000 5 (1% (ACS))</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.9 Modulus of elasticity (tension) at 20°C</th>
<th>68°F</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>annealed</td>
<td></td>
<td>0.14 g/cm²</td>
<td>17 600 000 lb/ft²</td>
</tr>
<tr>
<td>cold worked</td>
<td></td>
<td>0.15 g/cm²</td>
<td>18 400 000 lb/ft²</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2.10 Modulus of rigidity (torsion) at 20°C</th>
<th>68°F</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>annealed</td>
<td></td>
<td>0.14 g/cm²</td>
<td>17 600 000 lb/ft²</td>
</tr>
<tr>
<td>cold worked</td>
<td></td>
<td>0.15 g/cm²</td>
<td>18 400 000 lb/ft²</td>
</tr>
</tbody>
</table>

**INDEX NUMBERS RELATE TO LITERATURE REFERENCES** (see page 17). INDEX LETTERS RELATE TO FOOTNOTES AT END OF TABLE.
### 3 FERRICATION PROPERTIES

The information given in this table is for general guidance only, since many factors influence fabrication techniques. The values shown are approximate only, since those used in practice are dependent upon form and size of metal, equipment available, techniques adopted and properties required in the material.

<table>
<thead>
<tr>
<th>Metric Units</th>
<th>English Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Casting temperature range</td>
<td>1 110-1 180 °C</td>
</tr>
<tr>
<td>3.2 Annealing temperature range</td>
<td>500-700 °C</td>
</tr>
<tr>
<td></td>
<td>600-900 °C</td>
</tr>
<tr>
<td>3.3 Hot working temperature range</td>
<td>650-750 °C</td>
</tr>
<tr>
<td>3.4 Hot formability</td>
<td>Limited</td>
</tr>
<tr>
<td>3.5 Cold formability</td>
<td></td>
</tr>
<tr>
<td>3.6 Cold reduction between anneals</td>
<td></td>
</tr>
<tr>
<td>3.7 Machinability: Machinability rating (free-cutting brass = 100)</td>
<td></td>
</tr>
<tr>
<td>3.8 Joining methods:</td>
<td></td>
</tr>
<tr>
<td>Softening</td>
<td>Excellent</td>
</tr>
<tr>
<td>Brazing</td>
<td></td>
</tr>
<tr>
<td>Gas-arc welding</td>
<td>Fair</td>
</tr>
<tr>
<td>Carbon-arc welding</td>
<td></td>
</tr>
<tr>
<td>Gas-shielded arc welding</td>
<td></td>
</tr>
<tr>
<td>Coated metal-arc welding</td>
<td></td>
</tr>
<tr>
<td>Resistance welding: spot</td>
<td></td>
</tr>
<tr>
<td>seam</td>
<td></td>
</tr>
<tr>
<td>butt</td>
<td></td>
</tr>
<tr>
<td>Country</td>
<td>Designation of Standards</td>
</tr>
<tr>
<td>-------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>Australia</td>
<td>SAA</td>
</tr>
<tr>
<td>Belgium</td>
<td>BNM</td>
</tr>
<tr>
<td>Canada</td>
<td>CSA</td>
</tr>
<tr>
<td>Chile</td>
<td>INDIETECNOR</td>
</tr>
<tr>
<td>France</td>
<td>NF</td>
</tr>
<tr>
<td>Germany</td>
<td>DIN</td>
</tr>
<tr>
<td>India</td>
<td>IS</td>
</tr>
<tr>
<td>Italy</td>
<td>UNI</td>
</tr>
<tr>
<td>Japan</td>
<td>JIS</td>
</tr>
<tr>
<td>Netherlands</td>
<td>N or NEN&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>South Africa</td>
<td>SAASS</td>
</tr>
<tr>
<td>Spain</td>
<td>UNE</td>
</tr>
<tr>
<td>Sweden</td>
<td>SIS</td>
</tr>
<tr>
<td>Switzerland</td>
<td>VSM</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>BS</td>
</tr>
<tr>
<td>United States&lt;sup&gt;c&lt;/sup&gt;</td>
<td>ASTM</td>
</tr>
<tr>
<td>International Organization for Standardization</td>
<td>ISO</td>
</tr>
</tbody>
</table>

---

<sup>a</sup> Available when the chemical composition is not given in the specifications for wrought forms.
<sup>b</sup> Older specifications have parentheses if new specifications the NEN profile is used.
<sup>c</sup> In the United States, bars and wires are covered under the Plate-Sheet-Strip column.
<sup>d</sup> Included in imperial unity edition (1975) but deleted from metricated revision (1975).
5.1 MECHANICAL PROPERTIES AT ROOM TEMPERATURE

5.1.1 Typical Tensile Properties and Hardness Values—Metric Units

This table is representative of practice in many European countries. For British and American practices, see tables 5.1.2 and 5.1.3, respectively.

The values shown represent reasonable approximations for general engineering use, taking account of variation in composition and manufacturing procedures. For design purposes, national specifications should be consulted.

For a given temper, individual elongation values may show variation above or below the typical values indicated.

<table>
<thead>
<tr>
<th>Form</th>
<th>Temper</th>
<th>Tensile Stress</th>
<th>Elongation</th>
<th>Hardness</th>
<th>Shear Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>kg/mm²</td>
<td>Yield Stress</td>
<td>kg/mm²</td>
<td>%</td>
</tr>
<tr>
<td>Sheet</td>
<td>Annealed</td>
<td>13</td>
<td>55</td>
<td>50 mm</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Typical</td>
<td>43</td>
<td>20</td>
<td>38</td>
<td>5.05 x 10^3</td>
</tr>
<tr>
<td></td>
<td>Cold Worked Tempar</td>
<td>66</td>
<td>14</td>
<td>50 mm</td>
<td>170</td>
</tr>
<tr>
<td></td>
<td>Rod</td>
<td>35</td>
<td>55</td>
<td>4.65 x 10^3</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Typical</td>
<td>43</td>
<td>20</td>
<td>38</td>
<td>5.05 x 10^3</td>
</tr>
<tr>
<td></td>
<td>Cold Worked Tempar</td>
<td>55</td>
<td>5</td>
<td>5.05 x 10^3</td>
<td>190</td>
</tr>
<tr>
<td>Wire</td>
<td>Annealed</td>
<td>37</td>
<td>—</td>
<td>50</td>
<td>100 mm</td>
</tr>
<tr>
<td></td>
<td>Typical</td>
<td>85</td>
<td>—</td>
<td>3</td>
<td>120 mm</td>
</tr>
<tr>
<td></td>
<td>Cold Drawn Tempar</td>
<td>73</td>
<td>—</td>
<td>95</td>
<td>—</td>
</tr>
</tbody>
</table>

Cu 95s

---

---

ii) It is possible to obtain sizes outside the ranges given in this column, but information on their mechanical properties should be obtained from the metal manufacturer.

iii) The mechanical properties will be largely dependent upon the size and cross-sectional area or complexity of the product.
# 5.1.2 Typical Tensile Properties and Hardness Values—SI and English Units

This table is based on British practice. For other European and American practices, see tables 5.1.1 and 5.1.3, respectively. The values shown represent reasonable approximations for general engineering use, taking account of variations in composition and manufacturing procedures. For design purposes, national specifications should be consulted. For a given temper, individual elongation values may show some variation above or below the typical values indicated.

<table>
<thead>
<tr>
<th>Form</th>
<th>Temper</th>
<th>Tensile Strength (MPa)</th>
<th>Proof Stress 8.15% offset (MPa)</th>
<th>Elongation</th>
<th>Vickers Hardness</th>
<th>Hardness at 1000 kgf</th>
<th>Typical SRR for Properties Shown (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>hbar tonf/in²</td>
<td>hbar kgf/mm²</td>
<td>%</td>
<td>gauge</td>
<td>length</td>
<td>bar</td>
<td>tonf/in²</td>
</tr>
<tr>
<td>Plate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Annealed</td>
<td>32</td>
<td>21</td>
<td>11</td>
<td>7</td>
<td>55</td>
<td>5.85 × 10⁵</td>
</tr>
<tr>
<td></td>
<td>Hot Rolled</td>
<td>34</td>
<td>22</td>
<td>14</td>
<td>9</td>
<td>50</td>
<td>5.85 × 10⁵</td>
</tr>
<tr>
<td></td>
<td>Cold Rolled</td>
<td>42</td>
<td>27</td>
<td>17</td>
<td>12</td>
<td>50</td>
<td>5.85 × 10⁵</td>
</tr>
<tr>
<td></td>
<td></td>
<td>43</td>
<td>28</td>
<td>21</td>
<td>20</td>
<td>50</td>
<td>5.85 × 10⁵</td>
</tr>
<tr>
<td></td>
<td>Annealed</td>
<td>34</td>
<td>22</td>
<td>12</td>
<td>60</td>
<td>50</td>
<td>2.3 (in.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td>50 mm (2 in.)</td>
<td>16-20 mm (0.6-0.8 in.) thick</td>
<td></td>
</tr>
<tr>
<td>Sheet</td>
<td>Cold Rolled</td>
<td>39</td>
<td>25</td>
<td>23</td>
<td>15</td>
<td>50</td>
<td>2.3 (in.)</td>
</tr>
<tr>
<td></td>
<td>Quarter Hard</td>
<td>54</td>
<td>35</td>
<td>42</td>
<td>23</td>
<td>50</td>
<td>2.3 (in.)</td>
</tr>
<tr>
<td></td>
<td>Hot Hard</td>
<td>63</td>
<td>41</td>
<td>31</td>
<td>33</td>
<td>50</td>
<td>2.3 (in.)</td>
</tr>
<tr>
<td></td>
<td>Extra Hard</td>
<td>75</td>
<td>45</td>
<td>36</td>
<td>50</td>
<td>50</td>
<td>2.3 (in.)</td>
</tr>
<tr>
<td></td>
<td>Annealed</td>
<td>34</td>
<td>22</td>
<td>12</td>
<td>8</td>
<td>55</td>
<td>5.85 × 10⁵</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td>50 mm (2 in.)</td>
<td>0.3-3 mm (0.012-0.125 in.) thick</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>43</td>
<td>28</td>
<td>28</td>
<td>18</td>
<td>50</td>
<td>5.85 × 10⁵</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td>50 mm (2 in.)</td>
<td>20-40 mm (0.8-1.6 in.) diam. or equivalent area</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>60</td>
<td>50 mm (2 in.)</td>
<td>6-20 mm (0.25-0.79 in.) diam. or equivalent area</td>
<td></td>
</tr>
<tr>
<td>Wire</td>
<td>Cold Rolled</td>
<td>42</td>
<td>27</td>
<td></td>
<td>25</td>
<td>100 mm (4 in.)</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Quarter Hard</td>
<td>54</td>
<td>38</td>
<td></td>
<td>8</td>
<td>100 mm (4 in.)</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Hard</td>
<td>74</td>
<td>46</td>
<td></td>
<td></td>
<td>100 mm (4 in.)</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Extra Hard</td>
<td>85</td>
<td>55</td>
<td></td>
<td></td>
<td>100 mm (4 in.)</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Hot Hard</td>
<td>90</td>
<td>60</td>
<td></td>
<td>6</td>
<td>100 mm (4 in.)</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Extra Hard</td>
<td>40</td>
<td>40</td>
<td></td>
<td></td>
<td>100 mm (4 in.)</td>
<td>250</td>
</tr>
<tr>
<td></td>
<td>Annealed</td>
<td>36</td>
<td>23</td>
<td>15</td>
<td>10</td>
<td>50</td>
<td>5.85 × 10⁵</td>
</tr>
<tr>
<td></td>
<td>Cold Rolled</td>
<td>40</td>
<td>25</td>
<td>23</td>
<td>15</td>
<td>50</td>
<td>5.85 × 10⁵</td>
</tr>
<tr>
<td></td>
<td>Quarter Hard</td>
<td>42</td>
<td>40</td>
<td>45</td>
<td>30</td>
<td>50</td>
<td>5.85 × 10⁵</td>
</tr>
<tr>
<td></td>
<td>As Drawn</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### 5.1.3 Typical Tensile Properties and Hardness Values—American Units

This table is based on American practice and the temper designations shown are those referred to in ASTM and other American standards. For British and other European countries' practices, see tables 5.1.2 and 5.1.1, respectively.

The values shown represent reasonable approximations for general engineering use, taking account of variations in composition and manufacturing procedure. For design purposes, national specifications should be consulted.

For a given temper, individual elongation values may show some variation above or below the typical values indicated.

<table>
<thead>
<tr>
<th>Form</th>
<th>Temper</th>
<th>Tensile Strength psi</th>
<th>Yield Strength 0.5% off-axis under head psi</th>
<th>Elongation % length</th>
<th>Retention Hardness</th>
<th>Shear Strength psi</th>
<th>Typical Size Related to Properties Shown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Products (Plate, Sheet, Strip and Bar)</td>
<td>Annealed (grain size 0.085 mm)</td>
<td>50 000</td>
<td>21 000</td>
<td>52</td>
<td>2 in.</td>
<td>77</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Cold Worked</td>
<td></td>
<td>60 000</td>
<td>55 000</td>
<td>28</td>
<td>2 in.</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Half Hard</td>
<td></td>
<td>80 000</td>
<td>75 000</td>
<td>10</td>
<td>2 in.</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Hard</td>
<td></td>
<td>100 000</td>
<td>60 000</td>
<td>4</td>
<td>2 in.</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Extra Spring</td>
<td></td>
<td>107 000</td>
<td>60 000</td>
<td>3</td>
<td>2 in.</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Rod (10)</td>
<td></td>
<td>75 000</td>
<td>65 000</td>
<td>26</td>
<td>2 in.</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Half Hard (60%)</td>
<td></td>
<td>70 000</td>
<td>58 000</td>
<td>25</td>
<td>2 in.</td>
<td>—</td>
</tr>
<tr>
<td>Wire</td>
<td>Annealed (grain size 0.035 mm)</td>
<td>50 000</td>
<td>—</td>
<td>56</td>
<td>2 in.</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Cold Worked</td>
<td></td>
<td>65 000</td>
<td>—</td>
<td>8</td>
<td>2 in.</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Half Hard</td>
<td></td>
<td>110 000</td>
<td>—</td>
<td>5</td>
<td>2 in.</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Spring (94%)</td>
<td></td>
<td>140 000</td>
<td>—</td>
<td>5</td>
<td>2 in.</td>
<td>—</td>
</tr>
</tbody>
</table>

(1) It is possible to obtain sizes different than those given in this column, but information on their mechanical properties should be obtained from the metal manufacturer.

(2) The mechanical properties will be largely dependent upon the size and cross-sectional area or complexity of the product.
### 5.2 MECHANICAL PROPERTIES AT LOW TEMPERATURE

#### 5.2.1 Tensile Properties—Impact Properties

<table>
<thead>
<tr>
<th>Form</th>
<th>Temper</th>
<th>Testing Temperature</th>
<th>Tensile Strength</th>
<th>Proof Stress 0.2% offset</th>
<th>Elongation %</th>
<th>Reduction of Area %</th>
<th>Impact Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>°C</td>
<td>°F</td>
<td>kg/mm²</td>
<td>lb/in²</td>
<td>psi</td>
<td>%</td>
<td>kg/m² cm²</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sheet</strong></td>
<td>1.5 mm</td>
<td>0.06 in.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Annealed</strong></td>
<td>27–30</td>
<td>80–86</td>
<td>35.5</td>
<td>25</td>
<td>52,000</td>
<td>15.8</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>—18–30</td>
<td>0–86</td>
<td>39.5</td>
<td>25</td>
<td>56,000</td>
<td>16.9</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>—40–40</td>
<td>40–55</td>
<td>43.5</td>
<td>25</td>
<td>57,000</td>
<td>17.0</td>
<td>72</td>
</tr>
<tr>
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<td>—70–70</td>
<td>70–55</td>
<td>48.5</td>
<td>25</td>
<td>59,000</td>
<td>17.0</td>
<td>74</td>
</tr>
<tr>
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<td>—100–70</td>
<td>100–70</td>
<td>53.5</td>
<td>25</td>
<td>62,000</td>
<td>18.9</td>
<td>78</td>
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<tr>
<td><strong>Cold Worked</strong></td>
<td>61%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>27–30</td>
<td>80–86</td>
<td>69.0</td>
<td>44</td>
<td>99,000</td>
<td>61.3</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>—10–30</td>
<td>10–86</td>
<td>70.5</td>
<td>44</td>
<td>100,000</td>
<td>62.3</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>—40–40</td>
<td>40–55</td>
<td>75.5</td>
<td>44</td>
<td>110,000</td>
<td>64.7</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>—70–70</td>
<td>70–55</td>
<td>81.5</td>
<td>44</td>
<td>110,000</td>
<td>65.7</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>—100–70</td>
<td>100–70</td>
<td>88.0</td>
<td>44</td>
<td>120,000</td>
<td>69.0</td>
<td>11</td>
</tr>
<tr>
<td><strong>Rad</strong></td>
<td>5 mm diam.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>27–30</td>
<td>80–86</td>
<td>64.5</td>
<td>33</td>
<td>74,000</td>
<td>—</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>—10–30</td>
<td>10–86</td>
<td>69.0</td>
<td>33</td>
<td>77,000</td>
<td>—</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>—40–40</td>
<td>40–55</td>
<td>75.5</td>
<td>33</td>
<td>83,000</td>
<td>—</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>—70–70</td>
<td>70–55</td>
<td>81.5</td>
<td>33</td>
<td>103,000</td>
<td>—</td>
<td>80</td>
</tr>
<tr>
<td></td>
<td>—100–70</td>
<td>100–70</td>
<td>88.0</td>
<td>33</td>
<td>120,000</td>
<td>—</td>
<td>86</td>
</tr>
<tr>
<td><strong>Rad</strong></td>
<td>18 mm diam.</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>27–30</td>
<td>80–86</td>
<td>54.5</td>
<td>34.5</td>
<td>77,000</td>
<td>50.8</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>—18–30</td>
<td>0–86</td>
<td>58.5</td>
<td>34.5</td>
<td>85,000</td>
<td>50.3</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>—40–40</td>
<td>40–55</td>
<td>64.5</td>
<td>34.5</td>
<td>100,000</td>
<td>62.7</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>—70–70</td>
<td>70–55</td>
<td>70.5</td>
<td>34.5</td>
<td>110,000</td>
<td>73.7</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>—100–70</td>
<td>100–70</td>
<td>76.5</td>
<td>34.5</td>
<td>120,000</td>
<td>76.6</td>
<td>34</td>
</tr>
</tbody>
</table>

(1) This value was originally reported in psi; in this table it is given in kg/mm² to 3 significant figures.
(2) Standard Charpy specimens, W-notch; cross-sectional area at the notch (5.8 mm²); fracture area 95%.
(N.B.) — Original values are printed in bold type; other values are converted.
— All converted values for impact strength are to be taken as indicative only; the impact energy has been converted from ft lb into kg m² cm² (in terms to account the actual cross-sectional area of the specimen at the notch.
— Data not available: Proof stress 0.2% offset.
— Yield strength, 0.5% extension under load.
— Further data can be obtained from the following papers:

---

Car S56
## 5.3 MECHANICAL PROPERTIES AT ELEVATED TEMPERATURE
### 5.3.1 Short-Time Tensile Properties

<table>
<thead>
<tr>
<th>Form</th>
<th>Temper</th>
<th>Testing Temperature °C</th>
<th>Tensile Strength kg/m²</th>
<th>Proof Stress kg/m²</th>
<th>Yield Stress 0.5% offset kg/m²</th>
<th>% Gauge Length</th>
<th>Elongation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rod (a)</td>
<td>2.2 mm diam.</td>
<td>Annealed</td>
<td>24</td>
<td>30.5</td>
<td>23</td>
<td>52 000</td>
<td>20 000</td>
</tr>
<tr>
<td></td>
<td>3.125 in. diam.</td>
<td>(grain size 0.005 mm)</td>
<td>204</td>
<td>40</td>
<td></td>
<td>17 000</td>
<td></td>
</tr>
<tr>
<td>Rod (b)</td>
<td>8 mm diam. and 0.3 in. diam.</td>
<td>Cold Worked</td>
<td>27 (b)</td>
<td>31</td>
<td>32</td>
<td>74 000</td>
<td>48 000</td>
</tr>
<tr>
<td></td>
<td>Stress Relieved</td>
<td></td>
<td>277</td>
<td>31</td>
<td>38</td>
<td>75 000</td>
<td>45</td>
</tr>
<tr>
<td>Rod (c)</td>
<td>6.35 mm diam.</td>
<td>Cold Worked</td>
<td>250</td>
<td>40</td>
<td>40</td>
<td>96 000</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>6.325 in. diam.</td>
<td></td>
<td>250</td>
<td>40</td>
<td>40</td>
<td>96 000</td>
<td>40</td>
</tr>
<tr>
<td>Rod (d)</td>
<td>13 mm diam.</td>
<td>Cold Worked</td>
<td>250</td>
<td>40</td>
<td>40</td>
<td>96 000</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>0.375 in. diam.</td>
<td></td>
<td>250</td>
<td>40</td>
<td>40</td>
<td>96 000</td>
<td>40</td>
</tr>
<tr>
<td>Rod (e)</td>
<td>16 mm diam.</td>
<td>Annealed</td>
<td>17</td>
<td>33</td>
<td>34</td>
<td>60 000</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>0.325 in. diam.</td>
<td></td>
<td>17</td>
<td>33</td>
<td>34</td>
<td>60 000</td>
<td>33</td>
</tr>
<tr>
<td>Wire (f)</td>
<td>6.35 mm diam.</td>
<td></td>
<td>15</td>
<td>34</td>
<td>35</td>
<td>72 000</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>6.325 in. diam.</td>
<td></td>
<td>15</td>
<td>34</td>
<td>35</td>
<td>72 000</td>
<td>35</td>
</tr>
</tbody>
</table>

(a) Temper not stated in original document, but probably annealed.
(b) Quoted as "0.2% permanent set stress" in original document. This value was originally reported in psi; in this table it is given in kg/m² to 3 significant figures.
(c) Quoted as "hard drawn" in original document but amount of cold work not defined.
(d) ASTM alloy "Phosphor Bronze Grade A" containing 4.25-4.85% Sn.
(e) Temper not listed in original document.

N.B.K. — Original values are printed in bold type; other values are converted.

— Tha 0.15% offset p/m² stress values are not available.

Further data can be obtained from the following sources:
## 5.3.2 Crown Properties

### 5.3.2.1 Original Crown Data

| Form | Temperature | Stress | Duration | Total Extension | Intercept | Min. Creep Rate
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>°C</td>
<td>°F</td>
<td>kg/mm²</td>
<td>m/ton/in²</td>
<td>psi</td>
<td>%</td>
</tr>
<tr>
<td>Annealed (grain size 0.005 mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>140 300</td>
<td>3.2</td>
<td>3.74</td>
<td>4.53</td>
<td>5.620</td>
<td>0.025</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>7.0</td>
<td>15.63</td>
<td>10.000</td>
<td>6.020</td>
<td>0.472</td>
<td>0.069</td>
</tr>
<tr>
<td></td>
<td>10.6</td>
<td>21.37</td>
<td>17.110</td>
<td>5.600</td>
<td>0.142</td>
<td>0.016</td>
</tr>
<tr>
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<td>12.0</td>
<td>25.63</td>
<td>20.060</td>
<td>4.700</td>
<td>0.970</td>
<td>0.008</td>
</tr>
<tr>
<td>204 460</td>
<td>1.4</td>
<td>2.58</td>
<td>1.980</td>
<td>4.100</td>
<td>0.036</td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td>2.2</td>
<td>3.96</td>
<td>4.000</td>
<td>4.100</td>
<td>0.040</td>
<td>0.018</td>
</tr>
<tr>
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<td>4.1</td>
<td>7.39</td>
<td>5.970</td>
<td>5.100</td>
<td>0.082</td>
<td>0.020</td>
</tr>
<tr>
<td></td>
<td>7.2</td>
<td>13.19</td>
<td>10.170</td>
<td>5.100</td>
<td>0.136</td>
<td>0.041</td>
</tr>
<tr>
<td>290 500</td>
<td>0.01</td>
<td>0.02</td>
<td>0.794</td>
<td>5.100</td>
<td>0.014</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>1.1</td>
<td>1.98</td>
<td>1.550</td>
<td>5.100</td>
<td>0.039</td>
<td>0.017</td>
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<tr>
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<tr>
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<td>3.65</td>
<td>2.970</td>
<td>5.100</td>
<td>0.216</td>
<td>0.005</td>
</tr>
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<td>4.7</td>
<td>8.52</td>
<td>11.550</td>
<td>5.640</td>
<td>1.191</td>
<td>-0.109</td>
</tr>
<tr>
<td>Rod 33 mm diam. 0.125 in. diam.</td>
<td>140 300</td>
<td>3.2</td>
<td>3.74</td>
<td>4.581</td>
<td>5.620</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td>10.5</td>
<td>18.93</td>
<td>14.950</td>
<td>5.620</td>
<td>0.179</td>
<td>0.059</td>
</tr>
<tr>
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<td>13.9</td>
<td>25.10</td>
<td>19.800</td>
<td>5.620</td>
<td>0.335</td>
<td>0.073</td>
</tr>
<tr>
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<td>28.900</td>
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<td>48.950</td>
<td>4.700</td>
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<td>0.359</td>
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<tr>
<td>Cold Worked 84 %</td>
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<td>3.78</td>
<td>3.010</td>
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<td>9.905</td>
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<td>13.19</td>
<td>10.600</td>
<td>4.100</td>
<td>0.240</td>
<td>0.009</td>
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<td>10.5</td>
<td>18.93</td>
<td>15.000</td>
<td>5.700</td>
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<td>5.640</td>
<td>0.280</td>
<td>0.069</td>
</tr>
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<td>0.39</td>
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<td>9.999</td>
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<td>8.895</td>
<td>0.839</td>
<td>-1.520</td>
</tr>
<tr>
<td>Rod 16 mm diam. 0.625 in. diam.</td>
<td>250 450</td>
<td>7.9</td>
<td>14.42</td>
<td>11.200</td>
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<td>0.008 60</td>
</tr>
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<td>23.87</td>
<td>18.690</td>
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<td>0.53 60</td>
<td>3.39 60</td>
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<td>14.0</td>
<td>25.52</td>
<td>20.100</td>
<td>5.000</td>
<td>0.16 60</td>
<td>4.3 60</td>
</tr>
<tr>
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<td>17.3</td>
<td>31.64</td>
<td>24.640</td>
<td>13.6</td>
<td>- -</td>
<td>7.6 60</td>
</tr>
<tr>
<td>350 650</td>
<td>1.6</td>
<td>1.49</td>
<td>2.240</td>
<td>5.620</td>
<td>0.03 60</td>
<td>0.033</td>
</tr>
<tr>
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<td>2.4</td>
<td>4.37</td>
<td>3.309</td>
<td>5.600</td>
<td>0.16 60</td>
<td>0.042</td>
</tr>
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<td>4.7</td>
<td>8.48</td>
<td>6.270</td>
<td>9.000</td>
<td>10.5 60</td>
<td>- -</td>
</tr>
<tr>
<td></td>
<td>6.3</td>
<td>11.39</td>
<td>8.995</td>
<td>3.800</td>
<td>10.5 60</td>
<td>- -</td>
</tr>
<tr>
<td></td>
<td>9.4</td>
<td>16.90</td>
<td>13.640</td>
<td>4.9</td>
<td>- -</td>
<td>67.6 60</td>
</tr>
<tr>
<td>500 922</td>
<td>0.10</td>
<td>0.19</td>
<td>0.269</td>
<td>5.600</td>
<td>0.17 60</td>
<td>0.0</td>
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<tr>
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<td>0.30</td>
<td>0.55</td>
<td>0.410</td>
<td>5.600</td>
<td>0.26 60</td>
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<td>0.70</td>
<td>1.27</td>
<td>1.120</td>
<td>5.600</td>
<td>16 60</td>
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</tr>
</tbody>
</table>


**N.B.** — Original values are printed in bold type; other values are converted.

Further data can be obtained from the following papers:

### 3.3.2 Stress for Designated Creep Rate

<table>
<thead>
<tr>
<th>Form</th>
<th>Temper</th>
<th>Testing Temperature</th>
<th>Stress for Designated Creep Rate</th>
<th>0.001 % per 1000 h</th>
<th>0.01 % per 1000 h</th>
<th>0.1 % per 1000 h</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>°C</td>
<td>kg/mm²</td>
<td>ton/in²</td>
<td>psi</td>
<td>kg/mm²</td>
</tr>
<tr>
<td>Rod (a)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.2 mm diam.</td>
<td></td>
<td></td>
<td>140</td>
<td>300</td>
<td>7.7</td>
<td>4.9</td>
</tr>
<tr>
<td>0.025 mm (b)</td>
<td></td>
<td></td>
<td>954</td>
<td>400</td>
<td>2.9</td>
<td>1.7</td>
</tr>
<tr>
<td>0.025 mm (c)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.125 in. diam.</td>
<td></td>
<td></td>
<td>140</td>
<td>300</td>
<td>3.9</td>
<td>3.0</td>
</tr>
<tr>
<td>Rod (d)</td>
<td>16 mm</td>
<td></td>
<td>250</td>
<td>400</td>
<td>2.9</td>
<td>2.0</td>
</tr>
<tr>
<td>0.025 in. diam.</td>
<td></td>
<td></td>
<td>350</td>
<td>600</td>
<td>2.9</td>
<td>1.0</td>
</tr>
</tbody>
</table>

- **(a)** Extrapolated value.
- **(b)** Temper not stated in original document.
- **(c)** Designated creep rate: 0.04% per 1000 h.
- **(d)** Temper not stated in original document.

*N.B.:* Original values are printed in bold type; other values are converted.

---

*(Further data can be obtained from the following source:)*

### 5.4 FATIGUE PROPERTIES

#### 5.4.1 Fatigue Strength at Room Temperature

<table>
<thead>
<tr>
<th>Form</th>
<th>Temper</th>
<th>Number of Cycles (x 10^6)</th>
<th>Metric Units (lb/in²)</th>
<th>English Units (psi)</th>
<th>American Units (ksi)</th>
</tr>
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<tbody>
<tr>
<td>Strip</td>
<td>Cold Worked</td>
<td>10</td>
<td>19</td>
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<td>43.5</td>
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<tr>
<td>0.020 in.</td>
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<td>19</td>
<td>25.5</td>
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<tr>
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<td>100</td>
<td>20.5</td>
<td>17.5</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50</td>
<td>20.5</td>
<td>17.5</td>
<td>22</td>
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<tr>
<td>Strip</td>
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<td>100</td>
<td>40.5</td>
<td>29.5</td>
<td>30.5</td>
</tr>
<tr>
<td>0.040 in.</td>
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<td>40.5</td>
<td>29.5</td>
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<td></td>
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<td>45.5</td>
<td>31.0</td>
<td>35.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50</td>
<td>45.5</td>
<td>31.0</td>
<td>35.0</td>
</tr>
<tr>
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<td>100</td>
<td>55.5</td>
<td>36.5</td>
<td>38.5</td>
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<tr>
<td>0.060 in.</td>
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<td>55.5</td>
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<td>40.5</td>
<td>40.5</td>
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<td>60.5</td>
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<tr>
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<td>100</td>
<td>70.5</td>
<td>45.5</td>
<td>45.5</td>
</tr>
<tr>
<td>0.080 in.</td>
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<td>70.5</td>
<td>45.5</td>
<td>45.5</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
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<td></td>
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<td>50.5</td>
<td>50.5</td>
</tr>
<tr>
<td>Sheet</td>
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<td>100</td>
<td>80.5</td>
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<td>55.5</td>
</tr>
<tr>
<td>0.010 in.</td>
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<td>80.5</td>
<td>55.5</td>
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</tr>
<tr>
<td></td>
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<td>85.0</td>
<td>60.0</td>
<td>60.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50</td>
<td>85.0</td>
<td>60.0</td>
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</tr>
<tr>
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<td>Cold Worked</td>
<td>100</td>
<td>90.5</td>
<td>65.0</td>
<td>65.0</td>
</tr>
<tr>
<td>0.750 in. diam.</td>
<td></td>
<td>50</td>
<td>90.5</td>
<td>65.0</td>
<td>65.0</td>
</tr>
<tr>
<td></td>
<td>Annealed</td>
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<td>95.0</td>
<td>70.0</td>
<td>70.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50</td>
<td>95.0</td>
<td>70.0</td>
<td>70.0</td>
</tr>
<tr>
<td>Rod</td>
<td>Cold Worked</td>
<td>100</td>
<td>95.5</td>
<td>70.5</td>
<td>70.5</td>
</tr>
<tr>
<td>25.4 mm. diam.</td>
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<td>95.5</td>
<td>70.5</td>
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</tr>
<tr>
<td></td>
<td>Stress Relieved</td>
<td>100</td>
<td>90.0</td>
<td>65.0</td>
<td>65.0</td>
</tr>
<tr>
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<td></td>
<td>50</td>
<td>90.0</td>
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<td>65.0</td>
</tr>
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<td>70.5</td>
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<tr>
<td>25.4 mm. diam.</td>
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<td>95.0</td>
<td>70.5</td>
<td>70.5</td>
</tr>
<tr>
<td>Rod</td>
<td>Cold Worked</td>
<td>100</td>
<td>95.5</td>
<td>70.5</td>
<td>70.5</td>
</tr>
<tr>
<td>1.000 in. diam.</td>
<td></td>
<td>50</td>
<td>95.5</td>
<td>70.5</td>
<td>70.5</td>
</tr>
<tr>
<td></td>
<td>Stress Relieved</td>
<td>100</td>
<td>90.0</td>
<td>65.0</td>
<td>65.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>50</td>
<td>90.0</td>
<td>65.0</td>
<td>65.0</td>
</tr>
<tr>
<td>Wire</td>
<td>Cold Worked</td>
<td>100</td>
<td>75.5</td>
<td>50.5</td>
<td>50.5</td>
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<tr>
<td>0.08 in. diam.</td>
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<td>75.5</td>
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</tr>
<tr>
<td></td>
<td>Cold Worked</td>
<td>100</td>
<td>90.5</td>
<td>60.5</td>
<td>60.5</td>
</tr>
<tr>
<td>0.080 in. diam.</td>
<td></td>
<td>50</td>
<td>90.5</td>
<td>60.5</td>
<td>60.5</td>
</tr>
</tbody>
</table>

---

(1) Reverse-bending test. (2) Ready-to-finish grain size 0.005 in. (3) Ready-to-finish grain size 0.005 in. (4) Oil-quenched and tempered. (5) Oil-quenched and tempered. (6) Oil-quenched and tempered. (7) Oil-quenched and tempered. (8) Oil-quenched and tempered. (9) Oil-quenched and tempered. (10) Oil-quenched and tempered.

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**Note:** Original values are printed in bold type; other values are converted.

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**References:**


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- The authors are grateful to the many individuals and organizations who have supported this work, including the National Science Foundation, the United States Department of Energy, and the Office of Basic Energy Sciences.
REFERENCES


(5) Private communication from Thomas Robin and Sons, Ltd., England.


(13) Private Communication from Imperial Metal Industries, Ltd., England.


