HIGH PERFORMANCE CARBURIZING STAINLESS STEEL
BEARING AND GEAR STEEL

CSS-42L™ is a case carburizable stainless steel alloy intended to be used at operating temperatures up to 800°F (427°C). The alloy is able to achieve and maintain a high surface hardness when carburized and heat treated that combines high fracture toughness, hot hardness, metal-to-metal wear resistance and corrosion resistance while retaining core ductility and strength. The alloy is particularly suited for use in bearing applications and also in cams, shafts, gears, bolts and like articles exposed to elevated temperature and corrosive atmospheres. This material is covered by U.S. Patent No. 5,424,028.

FIGURES AND TABLES

Table 1. CSS-42L™ Heat Treatment Page 2
Figure 1. CSS-42L™ Case and Core Microstructures Page 3
Figure 2. Comparison of Hot Hardness Page 4
Table 2. CSS-42L™ Core Mechanical Property Data Page 5
Table 3. Comparison of Core Fracture Toughness Data (ASTM E399) Page 5
Table 4. Comparison of Core Short Rod Fracture Toughness Data (ASTM E1304) Page 5
Figure 3. CSS-42L™ Core Charpy Impact and Hardness vs. Tempering Temperature Page 6
Figure 4. CSS-42L™ Core Impact Transition Temperature Page 6
Figure 5. CSS-42L™ Hardness Profiles After Vacuum Carburizing Page 7
Figure 6. CSS-42L™ Hardness Profile After Gas Carburizing Page 7
Figure 7. CSS-42L™ Hardness and Microstructure After Carburizing and Heat Treating Page 8
Table 5. CSS-42L™ Case Hardness and Residual Stress vs. Austenitizing Temperature Data Page 8
Figure 8. CSS-42L™ Carburized Case Tempering Page 9
Table 6. CSS-42L™ Rolling Contact Fatigue Data Page 10
Figure 9. CSS-42L™ Carburized Case Microstructure of Rolling Contact Fatigue Test Rod Page 10
Figure 10. Comparison of CSS-42L™ and 440C Corrosion Resistance Page 11
Figure 11. CSS-42L™ Physical Properties Page 12
### TABLE 1-- Suggested Guidelines for Carburizing and Heat Treating CSS-42L

**CSS-42L™**  
(U.S. Patent No. 5,424,028)

#### Carburizing Cycle:
- Preoxidize at 954°C (1750°F) (not required when vacuum carburizing)
- Carburize at 954°C (1750°F)
- Slow cool to 204°C - 260°C (400°F - 500°F) (or directly harden in vacuum)
- Condition at 593°C (1100°F) for 4 hours (not required when direct hardening in vacuum)

#### Hardening Cycle:
- Austenitize at 1093°C - 1121°C (2000°F - 2050°F)
- Oil quench (or gas/fan quench to 66°C (150°F) and cool to room temperature if vacuum furnace)
- Subzero cool to -79°C (-110°F) (or lower, whatever is convenient)
- Temper at 496°C (925°F) for 2 hours
- Deep cryogenically treat for 1 hour (minimum)
- Temper at 496°C (925°F) for 2 hours

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FIGURE 1. **CSS-42L™ MICROSTRUCTURE**

(U.S. Patent Number 5,424,028)

**CORE MICROSTRUCTURE**

- **Condition:** Heat Treated
- **Etchant:** Marble's etch
- **Magnification:** 500x

**CASE MICROSTRUCTURE**

- **Condition:** Gas Carburized and Heat Treated
- **Etchant:** Marble's Etch
- **Magnification:** 500x

Rev 12/95
FIGURE 2. Hot hardness of case carburized CSS-42LTM and comparative alloys (direct Rockwell C hardness measurements).
### TABLE 2-- Average Core Mechanical Property Data from Longitudinal Samples

<table>
<thead>
<tr>
<th>Tempering Temperature °C (°F)</th>
<th>UTS MPa (ksi)</th>
<th>YS MPa (ksi)</th>
<th>R.A. %</th>
<th>elongation %</th>
<th>Young’s modulus x 10^6 GPa (Msi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>496 (925)^1</td>
<td>1760 (255.2)</td>
<td>1336 (193.7)</td>
<td>56.2</td>
<td>18.5</td>
<td>207.9 (30.16)</td>
</tr>
<tr>
<td>524 (975)^1</td>
<td>1841 (267.0)</td>
<td>1340 (194.4)</td>
<td>54.6</td>
<td>16.0</td>
<td>211.3 (30.65)</td>
</tr>
<tr>
<td>496 (925)^2</td>
<td>1764 (255.8)</td>
<td>1200 (174.1)</td>
<td>59.4</td>
<td>21.0</td>
<td>--</td>
</tr>
</tbody>
</table>

1 Solution treated at 1052°C (1925°F), austenitized at 1038°C (1900°F), and tempered at the indicated temperature.
2 Heat treated per Table 1.

### TABLE 3-- ASTM E399 Fracture Toughness Data of Core Material (Pseudo Carburized)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Tempering Temperature °C (°F)</th>
<th>Hardness HRC</th>
<th>Orientation</th>
<th>K_{ij} MPa √m (ksi √in)</th>
<th>K_{ic} MPa √m (ksi √in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9310</td>
<td>149 (300)</td>
<td>39 TL</td>
<td>--</td>
<td>115</td>
<td>105</td>
</tr>
<tr>
<td>CSS-42L™ 2</td>
<td>316 (600)</td>
<td>44 TL</td>
<td>--</td>
<td>119.7</td>
<td>108.9</td>
</tr>
<tr>
<td>CSS-42L™ 3</td>
<td>316 (600)</td>
<td>43 TL</td>
<td>--</td>
<td>112.4</td>
<td>102.3</td>
</tr>
<tr>
<td>CSS-42L™ 3</td>
<td>496 (925)</td>
<td>50 TL</td>
<td>50.1 (45.6)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>CSS-42L™ 3</td>
<td>496 (925)</td>
<td>49 TL</td>
<td>50.7 (46.1)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>CSS-42L™ 3</td>
<td>496 (925)</td>
<td>47 TL</td>
<td>112.6 (102.4)</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>M50-NiL</td>
<td>524 (975)</td>
<td>44 CR</td>
<td>--</td>
<td>52</td>
<td>57.1</td>
</tr>
<tr>
<td>M50</td>
<td>538 (1000)</td>
<td>63 CR</td>
<td>--</td>
<td>17.6</td>
<td>16</td>
</tr>
</tbody>
</table>

2 Pseudo carburization included 1052°C (1925°F) solution treat followed by 1038°C (1900°F) austenitize and tempering at the indicated temperature.
3 Heat treated per Table 1.

### TABLE 4-- ASTM E1304 (Short Rod) Fracture Toughness Data of Core Material (Pseudo Carburized)

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Tempering Temperature °C (°F)</th>
<th>Hardness HRC</th>
<th>Orientation</th>
<th>K_{Iy} MPa √m (ksi √in)</th>
<th>K_{Ic} MPa √m (ksi √in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSS-42L™ 1</td>
<td>496 (925)</td>
<td>51 LT</td>
<td>62.6 (57.0)</td>
<td>64.8</td>
<td>(59.0)</td>
</tr>
<tr>
<td>CSS-42L™ 2</td>
<td>524 (975)</td>
<td>51 LT</td>
<td>--</td>
<td>71.1</td>
<td>(70.2)</td>
</tr>
<tr>
<td>CSS-2L™ 2</td>
<td>524 (975)</td>
<td>51 TS</td>
<td>--</td>
<td>81.9</td>
<td>(74.5)</td>
</tr>
<tr>
<td>M50-NiL</td>
<td>538 (1000)</td>
<td>44 LT</td>
<td>63.1 (57.4)</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

1 Solution treated at 1052°C (1925°F), austenitized at 1038°C (1900°F), and tempered at the indicated temperature.
2 Heat treated per Table 1.
3 Commercially reported data from Latrobe Steel Company.
FIGURE 3. Core impact and hardness measurements versus tempering temperature for CSS-42L™. CVN samples were taken from the LT orientation (hardness measurements were direct Rockwell C).

FIGURE 4. Core impact transition temperature diagram for CSS-42L™. (CVN samples were taken from the LT orientation)
FIGURE 5. Vacuum carburizing results illustrate shallow and deep case aims and the effects of exposure at 427°C (800°F) (hardened from 1121°C (2050°F)).

FIGURE 6. Hardness profiles after gas carburizing at 1.3% carbon potential (hardened from 1038°C (1900°F)).
FIGURE 7. Hardness and microstructure of CSS-42L™ after carburizing and heat treating according to Table 1 (hardened at 1121°C (2050°F)). (original magnification 500x)

TABLE 5-- Effect of Austenitizing Temperature on Case Hardness and Residual Stress

<table>
<thead>
<tr>
<th>Austenitizing Temperature</th>
<th>Residual Stress Average from indicated depth</th>
<th>Effective Case Depth to 58 HRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>(°F)</td>
<td>0.25-0.50mm (0.01-0.02 in)</td>
</tr>
<tr>
<td>1038 (1900)</td>
<td>514.4 MPa</td>
<td>0.864 (0.034)</td>
</tr>
<tr>
<td>1093 (2000)</td>
<td>-44 MPa</td>
<td>0.711 (0.028)</td>
</tr>
<tr>
<td>1121 (2050)</td>
<td>-249 MPa</td>
<td>0.305 (0.012)</td>
</tr>
</tbody>
</table>

Note: All samples come from the same experimental carburizing cycle to illustrate the effects of austenitizing temperature.
FIGURE 8. CSS-42L™ carburized case tempering curve (direct Rockwell C hardness measurements).
TABLE 6-- Ball-on-Rod Fatigue Results of CSS-42L™

<table>
<thead>
<tr>
<th>Carburized Specimen #1</th>
<th>Carburized Specimen #2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hours</strong></td>
<td><strong>Cycles</strong> (Million)</td>
</tr>
<tr>
<td>294.4</td>
<td>151.9</td>
</tr>
<tr>
<td>212.4</td>
<td>109.6</td>
</tr>
<tr>
<td>438.0</td>
<td>226.0</td>
</tr>
<tr>
<td>853.7</td>
<td>440.5</td>
</tr>
</tbody>
</table>

1 Accumulated cycles is obtained by multiplying the accumulated test hours by 516,024 cycles/hour.

2 Reason test was discontinued.

0.050” (1.27mm) 26.4 HRC →
0.040” (1.02mm) 34.5 HRC →
0.030” (0.76mm) 44.5 HRC →
0.020” (0.51mm) 66.0 HRC →
0.010’ (0.25mm) 69.4 HRC →
Rolling Surface →

FIGURE 9. Carburized case microstructure of rolling contact fatigue CSS-42L™ test rod (original magnification 50X).
Corrosion Resistance

The potentiodynamic scanning curves shown below were generated according to the Standard Practice for Conducting Potentiodynamic Polarization Resistance Measurements (ASTM G59) and the Standard Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements (ASTM G102). The passive current density of the case is higher than 440C, while the core current density is significantly lower. Therefore, the corrosion rate for the case may be slightly higher than 440C while the core corrosion rate is predicted to be superior to 440C. The corrosion rate of the case is improved by lowering the tempering temperature.

FIGURE 10. Current density - potential curves for CSS-42L™ case and core and 440C steels in 3.5% NaCl solution using an Ag/AgCl Reference electrode. The CSS-42L™ samples were tempered at 925°F. The 440C was tempered at 350°F.
FIGURE 11. PHYSICAL PROPERTIES OF CSS-42L™

Coefficient of Thermal Expansion:

Density: 7.89 g/cm³ (0.28 lb/in³)

Thermal Conductivity: