HAYNES® HR-120® alloy

Principal Features

HAYNES® HR-120® (UNS N08120) alloy is a solid-solution-strengthened heat-resistant alloy that provides excellent strength at elevated temperature combined with very good resistance to carburizing and sulfidizing environments. Its oxidation resistance is comparable to other widely used Fe-Ni-Cr materials, such as alloys 330 and 800H, but its strength at temperatures up to 2000 ºF (1095 ºC) is significantly higher, even in comparison to Ni-Cr alloys. The alloy can be readily formed hot or cold, and is commonly welded using HAYNES® 556® filler wire.

Applications

Applications include those which require high strength combined with good resistance to carburizing and sulfidizing environments such as the following:

- Bar Frame Heat Treating Baskets
- Wire Mesh Furnace Belts and Basket Liners
- Muffles, Retorts
- Heat Treating Fixtures
- Waste Incinerators
- Radiant Tubes
- Cast Link Belt Pins
- Recuperators
- Fluidized Bed Components

HR-120® alloy heat treat furnace basket and mesh liner. This 3/8 of an inch diameter rod frame basket has replaced 1/2 in diameter baskets in similar design in 330 and 600 alloys. The reduction in rod diameter is equivalent to a 43% weight deduction.

Heat-treatment

HAYNES® HR-120® alloy is furnished in the solution annealed condition, unless otherwise specified. Depending on the product form, the alloy is solution annealed at a temperature ranging from 2150 to 2250 ºF (1175 to 1230 ºC) and rapidly cooled. For more information on heat-treatment, please see our “Welding and Fabrication” brochure.

Applicable Specifications

HAYNES® HR-120® is covered by ASME Section VIII, Division 1. Plate, sheet, strip, bar, forging, tubing, pipe, and fittings are covered by ASME specifications SB 409, SB 408, SB 407, SB 514, SB 366, and SB 564 and ASTM specifications B 409, B 408, B 407, B 514, B 366, and B 564. The UNS number for the alloy is N08120. DIN designations are No. 2.4854 and NiFe33Cr25Co. Sheet, strip, and plate are also covered by AMS specification 5916.
## Nominal Composition

<table>
<thead>
<tr>
<th>Element</th>
<th>Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iron:</td>
<td>33 (Balance)</td>
</tr>
<tr>
<td>Nickel:</td>
<td>37</td>
</tr>
<tr>
<td>Cobalt:</td>
<td>3 max.</td>
</tr>
<tr>
<td>Chromium:</td>
<td>25</td>
</tr>
<tr>
<td>Molybdenum:</td>
<td>2.5 max.</td>
</tr>
<tr>
<td>Tungsten:</td>
<td>2.5 max.</td>
</tr>
<tr>
<td>Columbium:</td>
<td>0.7</td>
</tr>
<tr>
<td>Manganese:</td>
<td>0.7</td>
</tr>
<tr>
<td>Silicon:</td>
<td>0.6</td>
</tr>
<tr>
<td>Nitrogen:</td>
<td>0.2</td>
</tr>
<tr>
<td>Aluminum:</td>
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</tr>
<tr>
<td>Carbon:</td>
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</tr>
<tr>
<td>Boron:</td>
<td>0.004</td>
</tr>
</tbody>
</table>
Creep Rupture Data

**HR-120® Plate, Solution-annealed**

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Creep</th>
<th>Approximate Initial Stress to Produce Specified Creep in:</th>
</tr>
</thead>
<tbody>
<tr>
<td>℉  ℃</td>
<td>%</td>
<td>10 h</td>
</tr>
<tr>
<td>1200 649</td>
<td>0.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>68</td>
</tr>
<tr>
<td>1300 704</td>
<td>0.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>-</td>
</tr>
<tr>
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<tr>
<td>1400 760</td>
<td>0.5</td>
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<tr>
<td></td>
<td>1</td>
<td>22.2</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>30</td>
</tr>
<tr>
<td>1500 816</td>
<td>0.5</td>
<td>13.8</td>
</tr>
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<td></td>
<td>1</td>
<td>15.3</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>21.8</td>
</tr>
<tr>
<td>1600 871</td>
<td>0.5</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>11.4</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>14</td>
</tr>
<tr>
<td>1700 927</td>
<td>0.5</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>1</td>
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</tr>
<tr>
<td></td>
<td>R</td>
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</tr>
<tr>
<td>1800 982</td>
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</tr>
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<td></td>
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<tr>
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<td>1</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>-</td>
</tr>
<tr>
<td>2100 1149</td>
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<td>0.6</td>
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<tr>
<td></td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>R</td>
<td>-</td>
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</table>

Haynes International - HAYNES® HR-120® alloy
### Creep Rupture Data Continued

HR-120® Sheet, Solution-annealed, Limited Data

<table>
<thead>
<tr>
<th>Temperature °F</th>
<th>Temperature °C</th>
<th>Creep %</th>
<th>Approximate Initial Stress to Produce Specified Creep in:</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>100 h</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>ksi</td>
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<tr>
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<td></td>
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<td>21.6</td>
</tr>
<tr>
<td>1500</td>
<td>816</td>
<td>1</td>
<td>11.5</td>
</tr>
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<td></td>
<td></td>
<td>R</td>
<td>14.9</td>
</tr>
<tr>
<td>1600</td>
<td>871</td>
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</tr>
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<td></td>
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<td>R</td>
<td>10.3</td>
</tr>
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<td>1700</td>
<td>927</td>
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<td>6</td>
</tr>
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<td></td>
<td></td>
<td>R</td>
<td>7</td>
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<tr>
<td>1800</td>
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<td>1</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>R</td>
<td>4.4</td>
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### Tensile Data

#### Average Tensile Data, Solution Heat-treated Sheet

<table>
<thead>
<tr>
<th>Test Temperature °F</th>
<th>Ultimate Tensile Strength ksi</th>
<th>Ultimate Tensile Strength MPa</th>
<th>0.2% Offset Yield Strength ksi</th>
<th>0.2% Offset Yield Strength MPa</th>
<th>Elongation %</th>
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</thead>
<tbody>
<tr>
<td>RT</td>
<td>104.2</td>
<td>718</td>
<td>47.5</td>
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<td>46.3</td>
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<tr>
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<td>552</td>
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<td>73.5</td>
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<td>186</td>
<td>55</td>
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<tr>
<td>1400</td>
<td>57.4</td>
<td>396</td>
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</tbody>
</table>

RT= Room Temperature

#### Average Tensile Data, Solution Heat-treated Plate

<table>
<thead>
<tr>
<th>Test Temperature °F</th>
<th>Ultimate Tensile Strength ksi</th>
<th>Ultimate Tensile Strength MPa</th>
<th>0.2% Offset Yield Strength ksi</th>
<th>0.2% Offset Yield Strength MPa</th>
<th>Elongation %</th>
<th>Reduction of Area %</th>
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</thead>
<tbody>
<tr>
<td>RT</td>
<td>104.3</td>
<td>719</td>
<td>46.8</td>
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<td>49.8</td>
<td>63.3</td>
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<tr>
<td>1000</td>
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<td>554</td>
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<td>57.7</td>
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<td>65.6</td>
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<td>72.3</td>
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<td>7.4</td>
<td>51</td>
<td>84.1</td>
<td>69.4</td>
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</table>

RT= Room Temperature
<table>
<thead>
<tr>
<th>Temperature °F</th>
<th>HR-120®</th>
<th>800H</th>
<th>RA330®</th>
<th>600</th>
<th>601</th>
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</thead>
<tbody>
<tr>
<td>70</td>
<td>46.8</td>
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<td>42</td>
<td>41</td>
<td>35</td>
</tr>
<tr>
<td>1000</td>
<td>26.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1200</td>
<td>26</td>
<td>16.9</td>
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<td>30</td>
<td>25.4</td>
</tr>
<tr>
<td>1400</td>
<td>25.6</td>
<td>18.5</td>
<td>18.8</td>
<td>26</td>
<td>26.8</td>
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<td>26.4</td>
<td>18.5</td>
<td>15.9</td>
<td>11</td>
<td>19.2</td>
</tr>
<tr>
<td>1800</td>
<td>14.5</td>
<td>8.1</td>
<td>9</td>
<td>6</td>
<td>10.9</td>
</tr>
<tr>
<td>2000</td>
<td>7.4</td>
<td>3.3</td>
<td>-</td>
<td>3.1 est</td>
<td>5.1</td>
</tr>
</tbody>
</table>

**Haynes International - HAYNES® HR-120® alloy**


**Hardness Data**

### Solution-annealed Room Temperature Hardness

<table>
<thead>
<tr>
<th>Form</th>
<th>Hardness, HRBW</th>
<th>Typical ASTM Grain Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet</td>
<td>88</td>
<td>3.5 - 5</td>
</tr>
<tr>
<td>Plate</td>
<td>87</td>
<td>0 - 5</td>
</tr>
<tr>
<td>Bar</td>
<td>84</td>
<td>0 - 4.5</td>
</tr>
</tbody>
</table>

HRBW = Hardness Rockwell “B”, Tungsten Indentor.

### Thermal Stability

<table>
<thead>
<tr>
<th>Condition</th>
<th>Ultimate Tensile Strength ksi</th>
<th>0.2% Offset Yield Strength ksi</th>
<th>Elongation %</th>
<th>Reduction of Area %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution Heat-treated</td>
<td>108</td>
<td>745</td>
<td>49</td>
<td>338</td>
</tr>
<tr>
<td>+ 1200°F/8,000 h</td>
<td>109.2</td>
<td>753</td>
<td>52.5</td>
<td>362</td>
</tr>
<tr>
<td>+ 1200°F/20,000 h</td>
<td>112.4</td>
<td>775</td>
<td>53.5</td>
<td>369</td>
</tr>
<tr>
<td>+ 1200°F/30,000 h</td>
<td>112.7</td>
<td>777</td>
<td>52.3</td>
<td>361</td>
</tr>
<tr>
<td>+ 1200°F/50,000 h</td>
<td>113</td>
<td>779</td>
<td>53.1</td>
<td>366</td>
</tr>
<tr>
<td>+1400°F/8,000 h</td>
<td>101.8</td>
<td>702</td>
<td>47.9</td>
<td>330</td>
</tr>
<tr>
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<td>101.2</td>
<td>698</td>
<td>43.3</td>
<td>299</td>
</tr>
<tr>
<td>+1400°F/30,000 h</td>
<td>101.5</td>
<td>700</td>
<td>44.8</td>
<td>309</td>
</tr>
<tr>
<td>+1400°F/50,000 h</td>
<td>99.8</td>
<td>688</td>
<td>44.9</td>
<td>310</td>
</tr>
<tr>
<td>+ 1600°F/8,000 h</td>
<td>101</td>
<td>696</td>
<td>44.7</td>
<td>308</td>
</tr>
<tr>
<td>+ 1600°F/20,000 h</td>
<td>96.9</td>
<td>668</td>
<td>40.9</td>
<td>282</td>
</tr>
<tr>
<td>+ 1600°F/30,000 h</td>
<td>96.7</td>
<td>667</td>
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<td>94.3</td>
<td>650</td>
<td>39.8</td>
<td>274</td>
</tr>
</tbody>
</table>

*AGL, which tends to be lower; Other data are 4D Elong.
Oxidation Resistance

Static Oxidation

HAYNES® HR-120® alloy exhibits good resistance to oxidizing environments and can be used at temperatures up to 2100°F (1150°C). The following are comparative static oxidation test results at 1600°F (870°C), 1800°F (980°C), 2000°F (1090°C), and 2100°F (1150°C) for 1008 hours.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Metal Loss</th>
<th>Average Metal Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mils mm</td>
<td>mils mm</td>
</tr>
<tr>
<td>HR-120®</td>
<td>0.1 0</td>
<td>0.9 0.02</td>
</tr>
<tr>
<td>253MA</td>
<td>0.2 0.01</td>
<td>0.9 0.02</td>
</tr>
<tr>
<td>800HT</td>
<td>0.1 0</td>
<td>1 0.03</td>
</tr>
<tr>
<td>601</td>
<td>- -</td>
<td>0.4 0.01</td>
</tr>
<tr>
<td>600</td>
<td>- -</td>
<td>0.3 0.01</td>
</tr>
<tr>
<td>RA330®</td>
<td>- -</td>
<td>0.3 0.01</td>
</tr>
<tr>
<td>304SS</td>
<td>- -</td>
<td>5.5 0.14</td>
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<tr>
<td>RA85H</td>
<td>- -</td>
<td>0.5 0.01</td>
</tr>
</tbody>
</table>

Dynamic Oxidation

Burner rig oxidation tests were conducted by exposing samples of 3/8” x 2.5” x thickness (9mm x 64 mm x thickness), in a rotating holder to the products of combustion of 2 parts No. 1 and 1 part No. 2 fuel burned at a ratio of air to fuel of about 50:1. Gas velocity was about 0.3 mach. Samples were automatically removed from the gas stream every 30 minutes and fan-cooled to near ambient temperature and then reinserted into the flame tunnel.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Metal Loss</th>
<th>Average Metal Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mils</td>
<td>µm</td>
</tr>
<tr>
<td>556®</td>
<td>3.9</td>
<td>99</td>
</tr>
<tr>
<td>HR-120®</td>
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<td>160</td>
</tr>
<tr>
<td>RA 330®</td>
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<td>165</td>
</tr>
<tr>
<td>800H/800HT</td>
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<td>226</td>
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<tr>
<td>310 SS</td>
<td>16.0</td>
<td>406</td>
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<tr>
<td>253MA</td>
<td>16.6</td>
<td>422</td>
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</table>
### Oxidation Resistance Continued

#### Long-term Oxidation

Amount of metal affected for high-temperature plate (0.25") alloys exposed for 360 days (8,640 hours) in flowing air. Cycled once per month.

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Exposure Duration</th>
<th>1600°F</th>
<th>1800°F</th>
<th>2000°F</th>
<th>2100°F</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>h number of cycles</td>
<td>Metal Loss</td>
<td>Average Metal Affected</td>
<td>Metal Loss</td>
<td>Average Metal Affected</td>
</tr>
<tr>
<td>214®</td>
<td>8640</td>
<td>0.1</td>
<td>0.2</td>
<td>0.01</td>
<td>0</td>
</tr>
<tr>
<td>230®</td>
<td>8640</td>
<td>0.2</td>
<td>0.01</td>
<td>1.4</td>
<td>0.04</td>
</tr>
<tr>
<td>HR-120®</td>
<td>8640</td>
<td>0.3</td>
<td>0.01</td>
<td>1.6</td>
<td>0.04</td>
</tr>
<tr>
<td>556®</td>
<td>8640</td>
<td>0.3</td>
<td>0.01</td>
<td>1.9</td>
<td>0.05</td>
</tr>
<tr>
<td>617</td>
<td>8640</td>
<td>0.3</td>
<td>0.01</td>
<td>1.6</td>
<td>0.04</td>
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<td>8640</td>
<td>0.4</td>
<td>0.01</td>
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<td>0.07</td>
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#### Water Vapor Testing

<table>
<thead>
<tr>
<th>Alloy</th>
<th>1008 hours at 1600°F Cycled 1x/week in air+10% H2O</th>
<th>1008 hours at 1600°F Cycled 1x/week in air+20% H2O</th>
<th>6 months at 1400°F Cycled 1x/week in air+10% H2O</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Meal Loss</td>
<td>Average Metal Affected</td>
<td>Meal Loss</td>
</tr>
<tr>
<td>HR-120®</td>
<td>0.09</td>
<td>0.002</td>
<td>0.68</td>
</tr>
<tr>
<td>253MA</td>
<td>0.66</td>
<td>0.017</td>
<td>1.59</td>
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<tr>
<td>347SS</td>
<td>0.86</td>
<td>0.022</td>
<td>1.48</td>
</tr>
<tr>
<td>800HT</td>
<td>-</td>
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</table>

#### Schematic Representation of Metallographic Technique used for Evaluating Oxidation

1. Metal Loss = (A-B)/2
2. Average Internal Penetration = C
3. Maximum Internal Penetration = D
4. Average Metal Affected = ((A-B)/2) + C
5. Maximum Metal Affected = ((A-B)/2) + D
Carburization Resistance

HAYNES® HR-120® alloy has good resistance to carburization. Results from 1800°F (982°C) carburization testing show HR-120® alloy to be better than stainless steels. Both pack and gaseous carburization test results are presented.
Carburization Resistance of Various Alloys at 1800°F (982°C) for 55 Hours in Ar-5%H₂-1%CH₄

**CARBON ABSORPTION**

<table>
<thead>
<tr>
<th>Material</th>
<th>Carbon Absorption (mg/cm²)</th>
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<tbody>
<tr>
<td>HR-120</td>
<td>10</td>
</tr>
<tr>
<td>800H</td>
<td>8</td>
</tr>
<tr>
<td>600</td>
<td>7</td>
</tr>
<tr>
<td>RA330</td>
<td>9</td>
</tr>
<tr>
<td>310SS</td>
<td>10</td>
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**AVERAGE INTERNAL PENETRATION**

<table>
<thead>
<tr>
<th>Material</th>
<th>Average Internal Penetration (m/s)</th>
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<tr>
<td>HR-120</td>
<td>25</td>
</tr>
<tr>
<td>800H</td>
<td>40</td>
</tr>
<tr>
<td>600</td>
<td>45</td>
</tr>
<tr>
<td>RA330</td>
<td>35</td>
</tr>
<tr>
<td>310SS</td>
<td>30</td>
</tr>
</tbody>
</table>

1. Metal Loss = (A-B)/2
2. Average internal Penetration = C
3. Maximum Internal Penetration = D
4. Average Metal Affected = ((A-B)/2) + C
5. Maximum Metal Affected = ((A-B)/2) + D
Comparative Sulfidation Resistance

Independent outside testing laboratories have also verified the superior performance of HR-120® alloy in sulfidizing environments. Petten Establishment in the Netherlands found that HR-120® alloy performed significantly better than alloys 800H, 347SS and 321SS at 1290°F (700°C) in hydrogen plus 7 percent carbon monoxide plus 1.5 percent water vapor plus 0.6 percent hydrogen sulfide. The HR-120® alloy was found to be magnitudes better than the other alloys.

\[
\begin{align*}
H_2 + 7% CO + 1.5% H_2O + 0.6% H_2S & \text{ at 1290°F (700°C)} \\
P_{O_2} = 1 \times 10^{-3} \text{ atm.} \\
P_{S_2} = 1 \times 10^{-9} \text{ atm.} \\
a_c = 0.3-0.4
\end{align*}
\]
Hot Corrosion Comparison

Hot corrosion is an accelerated oxidation or sulfidation attack due to a molten salt deposit. This form of corrosion is seen in gas turbines as well as in other industrial environments. The hot corrosion resistance of the HR-120® alloy was evaluated by performing laboratory burner rig testing. The burner rig used No. 2 fuel oil with a sulfur content of about 1 weight percent and air to generate the test environment. The air-to-fuel ratio was maintained at 35 to 1. The test was run at 1650°F (900°C) for 500 hours with a two-minute cooling cycle to less than 400°F (205°C) every hour. During testing a synthetic sea salt solution (ASTM D1141-52) was continuously injected into the combustion zone. The following photographs show the appearance of the specimens after testing. Specimens of 253 MA, RA 85H, RA330®, and 800H alloys were either severely corroded or partially destroyed. On the other hand, the HR-120® alloy specimen still looks extremely good, showing little attack.

![HR-120, 800H, RA330, and 800H alloys after testing.](image)

Hot corrosion test specimens after exposure at 1650°F (900°C) for 500 hours using 50 ppm sea salt injection and 1 percent sulfur fuel.
# Hot Corrosion Comparison

**Burner Rig Hot Corrosion Data for Alloys at 1650°F (900°C)**

exposed for 500 hours

<table>
<thead>
<tr>
<th>Alloy</th>
<th>Time</th>
<th>% S in Fuel</th>
<th>Salt ppm</th>
<th>Metal Loss mils/mm</th>
<th>Average Metal Affected mils/mm</th>
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<tbody>
<tr>
<td>HR-120®</td>
<td>500</td>
<td>1</td>
<td>50</td>
<td>0.9/0.02</td>
<td>5.2/0.13</td>
</tr>
<tr>
<td>RA330</td>
<td>500</td>
<td>1</td>
<td>50</td>
<td>1.4/0.04</td>
<td>5.8/0.15</td>
</tr>
<tr>
<td>800H</td>
<td>500</td>
<td>1</td>
<td>50</td>
<td>1/0.03</td>
<td>10.3/0.26</td>
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<tr>
<td>253MA</td>
<td>500</td>
<td>1</td>
<td>&gt;25</td>
<td>&gt;0.64</td>
<td>&gt;25/0.64</td>
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<tr>
<td>RA85H</td>
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<td>1</td>
<td>&gt;25</td>
<td>&gt;0.64</td>
<td>&gt;25/0.64</td>
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</tbody>
</table>

---

1. Metal Loss = \((A-B)/2\)
2. Average Internal Penetration = \(C\)
3. Maximum Internal Penetration = \(D\)
4. Average Metal Affected = \(((A-B)/2) + C\)
5. Maximum Metal Affected = \(((A-B)/2) + D\)
## Physical Properties

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</tr>
<tr>
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<td>100°C</td>
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<td>1400°F</td>
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<td>800°C</td>
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<td>50.3 µohm.in</td>
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<td>400°F</td>
<td>5.4 x 10⁻³ in²/s</td>
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<td>6.3 x 10⁻³ in²/s</td>
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</tr>
<tr>
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## Physical Properties Continued

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<tr>
<td><strong>of Elasticity</strong></td>
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</tr>
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<tr>
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# Physical Properties Continued

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<tr>
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<td>RT</td>
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</tr>
<tr>
<td>2000°F</td>
<td>0.37</td>
<td>0.36</td>
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</tbody>
</table>

RT = Room Temperature
Welding

HAYNES® HR-120® alloy is readily welded by Gas Tungsten Arc Welding (GTAW), Gas Metal Arc Welding (GMAW), Shielded Metal Arc Welding (SMAW), and resistance welding techniques. Submerged Arc Welding (SAW) is not recommended as this process is characterized by high heat input to the base metal and slow cooling of the weld. These factors can increase weld restraint and promote cracking.

Base Metal Preparation

The welding surface and adjacent regions should be thoroughly cleaned with an appropriate solvent prior to any welding operation. All greases, oils, cutting oils, crayon marks, machining solutions, corrosion products, paint, scale, dye penetrant solutions, and other foreign matter should be completely removed. It is preferable, but not necessary, that the alloy be in the solution-annealed condition when welded.

Filler Metal Selection

HAYNES® 556® filler metal (AMS 5831, AWS A5.9 ER3556) and MULTIMET® (AMS 5794) coated electrodes are recommended for joining HR-120® alloy. When dissimilar base metals are to be joined, such as HR-120® alloy to a stainless steel, HAYNES® 556® filler metal and MULTIMET® coated electrodes are again recommended. Please see the “Welding and Joining Guidelines” or the Haynes Welding SmartGuide for more information.

Preheating, Interpass Temperatures, and Post-Weld Heat-treatment

Preheat is not required. Preheat is generally specified as room temperature (typical shop conditions). Interpass temperature should be maintained below 200°F (93°C). Auxiliary cooling methods may be used between weld passes, as needed, providing that such methods do not introduce contaminants. Post-weld heat-treatment is not generally required for X alloy. For further information, please see the “Welding and Joining Guidelines” Heat-treatment section.

Nominal Welding Parameters

Details for GTAW, GMAW and SMAW welding are given here. Nominal welding parameters are provided as a guide for performing typical operations and are based upon welding conditions used in our laboratories.

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<th>Test Temperature</th>
<th>0.2% Yield Strength</th>
<th>Ultimate Tensile Strength</th>
<th>Elongation</th>
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<td>°C</td>
<td>ksi</td>
<td>MPa</td>
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<td>RT</td>
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RT=Room Temperature
Welding Continued

![Graph showing properties of 556 weld metal and HR-120 plate at various test temperatures.](image-url)
Welding Continued

Transverse Tensile Tests, HR-120® Base Metal Welded with Haynes 556® filler

<table>
<thead>
<tr>
<th>Temperature</th>
<th>0.5 Inch Plate</th>
<th>0.125 Inch Sheet</th>
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<tbody>
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<td>°F</td>
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<tr>
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<td>760</td>
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Transverse Tensile Tests, HR-120® Plate Welded with Haynes 556® filler

<table>
<thead>
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<th>0.5 Inch Plate</th>
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<tr>
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<td>1900</td>
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<tr>
<td>2000</td>
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</table>
Restrained 1/2 inch thick HR-120® plates have been successfully joined using 556® weld wire and MULTIMET® coated electrodes. The results below indicate an absence of hot cracking and microfissuring related weldability problems under the test conditions.

### Room Temperature Tensile Strength of Transverse Welded Specimens

<table>
<thead>
<tr>
<th>Welding Process</th>
<th>Welding Product</th>
<th>Tensile Strength</th>
<th>Fracture Location</th>
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<tr>
<td>-</td>
<td>-</td>
<td>ksi</td>
<td>MPa</td>
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<tr>
<td>GTAW</td>
<td>556® Filler Metal</td>
<td>111</td>
<td>765</td>
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<tr>
<td>GMAW</td>
<td>556® Filler Metal</td>
<td>109.4</td>
<td>755</td>
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<tr>
<td>SMAW</td>
<td>MULTIMET® Electrodes</td>
<td>109.7</td>
<td>755</td>
</tr>
</tbody>
</table>

**HR-120® Plate and Transverse Weld Room Temperature Charpy Impact Tests**

<table>
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<tr>
<th>Condition</th>
<th>Energy</th>
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<tbody>
<tr>
<td>Parent Metal</td>
<td>ft-lb</td>
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<tr>
<td>GMAW SYN Mid Weld</td>
<td>155</td>
</tr>
<tr>
<td>GMAW SYN HAZ</td>
<td>147</td>
</tr>
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</table>
Machining and Grinding

HAYNES® HR-120® alloy can be readily machined using conventional techniques. Generally, the same practices are employed as those used with the 300 series austenitic stainless steels. Some minor adjustments in the machining parameters may be required to obtain optimum results. High speed steel tools are found to be satisfactory, although machining speeds can be substantially increased by using carbide cutting tools. As a general statement, grinding operations with HAYNES® HR-120® alloy are considered equivalent to those of the 300 series stainless steels. As with other alloys, grinding is recommended where a close tolerance is required. Basic “Do’s” and “Don’ts” that should be considered during machining are:

**Do:**

1. Use machine tools that are rigid and overpowered, where possible.

2. Insure work piece and tools are held rigid. In addition, minimize tool overhang.

3. Make sure tools are always sharp. Change to sharpened tools at regular intervals rather than out of necessity. Remember, cutting edges, particularly throw-away inserts, are expendable. Don’t try to prove how long they can last. Don’t trade dollars in machine times for pennies in tool cost.

4. Use positive rake angle tools for most machining operations. Negative rake angle tools can be considered for intermittent cuts and heavy stock removal.

5. Use heavy, constant, feeds to maintain positive cutting action. If feed slows and the tool dwells in the cut, work hardening occurs, tool life deteriorates and close tolerance is impossible.

6. Avoid conditions such as chatter and glazing. This can cause work hardening of the surface, making subsequent machining difficult.

7. Flood the work with premium-quality sulfochlorinated water soluble oil or water-base chemical emulsion oils with extreme pressure additives. Dilute per the recommendations of the manufacturer.

8. Use heavy-duty sulfochlorinated oil for drilling and tapping. Special proprietary tapping oils can also be used.

9. Use air jet directed on the tool when dry cutting. This can provide substantial increase in tool life.

**Don’t:**

1. Do not make intermittent cuts, if possible. This tends to work harden the surface, making subsequent cuts more difficult.
Machining and Grinding Continued

Detailed Machining Information

Turning, Boring and Facing

The table below represents a typical range of values for normal turning operations. The depth of cut (particularly for roughing operations) is quite large with relatively low feed rates. These parameters are equipment and component dependent. The larger depths of cuts and higher speeds are recommended only when using heavy, overpowered equipment on large rigid components.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Roughing</th>
<th>Finishing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth of Cut</td>
<td>0.125-0.250 in.</td>
<td>0.020-0.040 in.</td>
</tr>
<tr>
<td>Feed Rate</td>
<td>0.008-0.010 ipr</td>
<td>0.006-0.008 ipr</td>
</tr>
<tr>
<td>Speed-HSS</td>
<td>30-50 sfpm</td>
<td>40-60 sfpm</td>
</tr>
<tr>
<td>Speed-Carbide</td>
<td>100-170 sfpm</td>
<td>140-180 sfpm</td>
</tr>
</tbody>
</table>

Drilling

Standard high-speed steel bits are normally used. For drill bits larger than 3/8”, thinning the web may reduce thrust and aid chip control. The following are suggested speed and feed rates for various diameter drills.

<table>
<thead>
<tr>
<th>Diameter</th>
<th>Speed</th>
<th>Feed Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/8 in</td>
<td>250 RPM (max)</td>
<td>0.002 inch/rev.</td>
</tr>
<tr>
<td>1/4 in</td>
<td>250 RPM (max)</td>
<td>0.003 inch/rev.</td>
</tr>
<tr>
<td>1/2 in</td>
<td>250 RPM</td>
<td>0.005 inch/rev.</td>
</tr>
<tr>
<td>1 in</td>
<td>150 RPM</td>
<td>0.011 inch/rev.</td>
</tr>
<tr>
<td>1-1/2 in</td>
<td>100 RPM</td>
<td>0.013 inch/rev.</td>
</tr>
<tr>
<td>2 in</td>
<td>75 RPM</td>
<td>0.016 inch/rev.</td>
</tr>
</tbody>
</table>

For other diameters (above 1/2 inch diameter) the spindle speed may be calculated from the following: RPM = 150/Diameter (inches). This results in a cutting speed of about 40 sfpm. For drill diameters smaller than 1/2 inch, speed rates substantially below 40 sfpm are required.

Reaming

Standard fluted reamers of high-speed steel are generally used. Speeds should be about 20-25 sfpm for diameters above 1/2 inch. For small diameter reamers (less than 1/2 inch diameter) cutting speeds should be reduced substantially. Feed rates will range from 0.002 to 0.006 inch/revolution depending upon diameter. If carbide tipped reamers are used, the speed can be increased to 70 sfpm for reamers above 1/2 inch diameter. If chatter occurs, reduce speed.
Machining and Grinding Continued

**Tapping**

HAYNES® HR-120® alloy is tapped using the same tooling and conditions as used with type 316 stainless steel. High speed steel taps work well. Cutting speed can be up to 20 sfpm for taps above 1/2 inch diameter. For small diameter taps (less than 1/2 inch diameter) cutting speeds should be reduced substantially.

Thread engagement can be reduced because of the high strength of this alloy. Generally, thread engagement of 60 to 75 percent is considered acceptable. Thread engagement is considered a design parameter and therefore should be left to the design engineer. As a general statement, 75 percent thread engagement is common for low strength materials, but only leads to increased tool wear and possible breakage in high strength alloys. It does not increase the holding strength in these alloys.

**Milling**

High speed steel cutters, with good impact strength, are recommended due to the interrupted nature of the cutting action. A cutting speed of 30 to 40 sfpm with feed rates of 0.002 to 0.005 inch/tooth is generally recommended. If carbide cutters are employed, speeds of 60 to 80 sfpm are possible.

**Applications**

Corrugated boxes for carburizing furnaces operating at 1750°F. After 14 months of intensive field testing, HR-120® alloy was selected over RA 333 alloy.

HR-120® alloy Retort used to carburize large gears for ships at a commercial heat treat operation. The prior material of construction was Type 330 stainless steel.

Custom designed vacuum furnace basket fabricated in HR-120® alloy channel. The alloy replaced was alloy 601.

HR-120® alloy hazardous waste lifter plates were substituted for plates previously fabricated in Type 316 SS. The facility supervisor reported a substantial increase in equipment uptime and attributed it to the alloy change.
### Comparative Data

<table>
<thead>
<tr>
<th>Mechanical Property</th>
<th>HR-120®</th>
<th>214®</th>
<th>230®</th>
<th>556®</th>
<th>X</th>
<th>600</th>
<th>601</th>
<th>RA330®</th>
<th>253MA</th>
<th>800H</th>
<th>304 SS</th>
<th>310 SS</th>
<th>316 SS</th>
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</thead>
<tbody>
<tr>
<td>Typical ASTM Grain Size</td>
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<td>5 - 6</td>
<td>5 - 6</td>
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<td>Ultimate Tensile Strength, ksi</td>
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<tr>
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( ) Estimated
*Manufacturer's laboratory or published data
## Specifications

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## Codes

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\(^1\)Approved material forms: Plate, Sheet, Bar, Forgings, fittings, welded pipe/tube, seamless pipe/tube

\(^2\)Properties up to 1650°F (899°C) are found in the latest ASME BPV Code, and from 1650°F - 1800°F (899°C - 982°C) in ASME Code Case 2672
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