The CHRONIFER® 465 KL is a premium precipitation hardening martensitic stainless steel. It is VIM melted and VAR remelted. This steel has been designed to provide in the cold worked and H900 aged an UTS strength up to 2090 MPa with an excellent tensile notch resistance coupled to a high toughness. In the H1000 condition it has a most favorable combination of high strength, stress corrosion resistance and toughness. Its corrosion resistance is similar to this of the AISI 304 (1.4301) stainless steel.

This steel is the material of choice for high requirements for medical instruments, and in the aerospace, automotive, chemical, pharmaceutical, and the agro-food industries.

### Applicable standards
- Material Number: 1.4614

### Chemical composition (%wt)

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Mo</th>
<th>Ni</th>
<th>Ti</th>
<th>Fe</th>
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</thead>
<tbody>
<tr>
<td>max.</td>
<td>0.02</td>
<td>0.25</td>
<td>0.25</td>
<td>0.015</td>
<td>0.010</td>
<td>12.50</td>
<td>1.25</td>
<td>11.25</td>
<td>1.80</td>
<td>balance</td>
</tr>
<tr>
<td>max.</td>
<td>11.00</td>
<td>0.75</td>
<td>10.75</td>
<td>1.50</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

### Dimensions and tolerances
- Ø < 2.50 mm: cold drawn
- Ø ≥ 2.50 mm: cold drawn, ground h8, rugosity Ra 0.4 (N5)

Tighter tolerances on request

### Executions and delivery conditions
- Standard: 3 m bars in the annealed condition, Ø 1.50 to 63.5 mm
- Ø ≥ 6.00 mm: **SWISSLINE** execution

Other executions on request

### Availability
- Standard dimensions on stock, see: Sales program

### Mechanical properties of wires

<table>
<thead>
<tr>
<th>Condition</th>
<th>Rm  (MPa)</th>
<th>R0.2 (MPa)</th>
<th>A4 (MPa)</th>
<th>Reduction of area (%)</th>
<th>Hardness HRc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution annealed</td>
<td>950</td>
<td>770</td>
<td>20</td>
<td>75</td>
<td>29.5</td>
</tr>
<tr>
<td>71% cold drawn</td>
<td>1200</td>
<td>1125</td>
<td>12</td>
<td>74</td>
<td>38.5</td>
</tr>
<tr>
<td>Solution annealed + aged H900 (482°C)</td>
<td>1779</td>
<td>1703</td>
<td>14</td>
<td>51</td>
<td>50</td>
</tr>
<tr>
<td>Solution annealed KV CD + aged H900 (482°C)</td>
<td>2090</td>
<td>2020</td>
<td>10</td>
<td>57</td>
<td>53</td>
</tr>
</tbody>
</table>

### Cutting conditions
- Machinability: relatively difficult
- The machinability of CHRONIFER® 465 KL is similar to those of maraging steels.
- Cutting speed: \( V_c \approx 20 - 30 \) m/min.
- Lubricant-coolant: individual choice
  - An H1150M over aging treatment prior to machining improves the machinability.
  - But, the machined parts must be annealed before the final age hardening treatment.
  - The optimal cutting conditions depend on the machine tool, the cutting tools, the chip dimensions, the lubricant-cooling fluid, as well as the tolerances and surface the roughness to be achieved.
CHRONIFER® 465 KL

1.4614 - Precipitation hardening martensitic stainless steel

**Forming**

Warm: forging: 1010 – 1095°C, air cooling
- An annealing made after the hot forming operations permits to obtain an optimal combination of strength and corrosion resistance.

**Cold deformation**

Cold: Easy in the annealed condition
- In the annealed condition this steel has a low cold work hardening. High cold drawing reductions can easily be achieved, i.e. 90%, (true deformation $\varepsilon = 2.2$) without intermediate anneal.
- A prior cold deformation permits to reach still higher strength, < 2090 MPa, after age hardening.

**Welding**

Suitable.
- The parts to weld are usually in the solution anneal condition. In this case, the age hardening of the welded assembly can be carried out without any further treatments.
- Take care not to carburize the weld.
- Solution anneal made after welding permits to obtain an optimal combination of strength and corrosion resistance of the welded assemblies.
- If the welding should lead to excessive internal stresses, it would be preferable to first over aged the parts at 620°C before welding, and then solution anneal the welded structure before its final age hardening.

**Annealing**

Solution anneal: 982 ± 8°C / 1h / oil or water quench
Optimum: Solution anneal + refrigeration at -80°C/≥8h
- To obtain the best results, the refrigeration treatment should preferably be made within 24h after annealing.
- The purpose of the -80°C refrigeration treatment is to reduce the thermal sensitivity of the properties obtained by the previous treatments.

**H1150M over aging for machinability improvement**

H1150M: Suffix M stands for machining
1$^{\text{st}}$ age hardening treatment: 760 ± 8°C / 2h / air cooling
2$^{\text{nd}}$ age hardening treatment: 621 ± 8°C / 4h / air cooling
- After machining, an annealing must be made before the final age hardening.

**Age hardening**

Temperature comprised between: 480 – 620°C/ 4-8h, oil or water quench to obtain the optimal toughness achievable at each temperature.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Yield strength $R_{0.2%}$ L - T (MPa)</th>
<th>UTS Rm L - T (MPa)</th>
<th>Elongation 4d L - T (%)</th>
<th>Contraction* L - T (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solution annealed</td>
<td>683 – 683</td>
<td>951 - 951</td>
<td>20</td>
<td>–</td>
</tr>
<tr>
<td>H900 (482°C)</td>
<td>1641 – 1613</td>
<td>1772 – 1772</td>
<td>13 – 12</td>
<td>0.08 – 0.07</td>
</tr>
<tr>
<td>H950 (510°C)</td>
<td>1620 – 1586</td>
<td>1751 – 1724</td>
<td>14 – 12</td>
<td>0.11 – 0.10</td>
</tr>
<tr>
<td>H1000 (538°C)</td>
<td>1496 – 1455</td>
<td>1593 – 1585</td>
<td>15 – 15</td>
<td>0.14 – 0.13</td>
</tr>
<tr>
<td>H1050 (566°C)</td>
<td>1365 – 1351</td>
<td>1482 – 1469</td>
<td>18 – 17</td>
<td>0.16 – 0.16</td>
</tr>
<tr>
<td>H1075 (580°C)</td>
<td>1234 – 1241</td>
<td>1400 – 1393</td>
<td>20 – 19</td>
<td>–</td>
</tr>
<tr>
<td>H1100 (593°C)</td>
<td>1096 – 1089</td>
<td>1310 – 1310</td>
<td>22 – 21</td>
<td>0.23 – 0.23</td>
</tr>
<tr>
<td>H1150M (621°C)</td>
<td>531 – 538</td>
<td>1076 – 1096</td>
<td>25 – 22</td>
<td>0.53 – 0.53</td>
</tr>
</tbody>
</table>

*Contraction: L stands for longitudinal, T for transversal
The prefix H indicates age hardening at the XXXX temperature in °F
The numbers between brackets are the age hardening temperature in °C. Conversion °C = (°F-32)*0.5555
Effect of Cold Work and aging on the yield strength and UTS

Smooth Rotating Beam Fatigue Behavior (RR Moore)
CHRONIFER® 465 KL

1.4614 - Precipitation hardening martensitic stainless steel

Microstructures
- Delivery conditions: “Solution annealed” or “annealed + cold drawn”: Martensite
- Machining microstructure: Martensite and age hardening precipitates

Polishing
- Well suited for mirror polishing

Laser marking
- The Heat Affected Zone (HAZ) of the laser marking may modify the local microstructure, and affect negatively its corrosion resistance. More info.

Pickling and passivation
- It is strongly recommended to use pickling and passivation procedures and products effectively adapted to the treatment of age hardening martensitic stainless steels.
- To avoid staining by a “flash back” reaction, it is strongly recommended to always pickle the surfaces before the passivation procedure. More info.

Corrosion resistance
- Surface oxidation:
  - The possible formation of colored oxides or scaling during heat treatments may drastically reduce the corrosion resistance. These oxidations should be eliminated, either mechanically or chemically.

Elementary precautions
- Elementary precautions:
  - The simplest and easiest precautions to apply are to always keep the parts clean, free of working residues, polished, and properly dried.
  - Use only chloride free disinfection solutions, cleaning and washing solutions and products. More info.

Physical properties

<table>
<thead>
<tr>
<th>Properties</th>
<th>Units</th>
<th>Annealed</th>
<th>H900</th>
<th>H1000</th>
<th>H1050</th>
<th>H1100</th>
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</thead>
<tbody>
<tr>
<td>Density</td>
<td>g cm⁻³</td>
<td>7.82</td>
<td>7.83</td>
<td>7.85</td>
<td>7.85</td>
<td>7.87</td>
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<tr>
<td>Elastic modulus E</td>
<td>GPa</td>
<td>202.7</td>
<td>199.8</td>
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<tr>
<td>Electrical resistivity</td>
<td>µohm-mm</td>
<td>946</td>
<td>824</td>
<td>822</td>
<td>772</td>
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<tr>
<td>Thermal expansion:</td>
<td>10⁻⁶ (m m⁻¹ K⁻¹)</td>
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<td></td>
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<tr>
<td>20 – 100°C</td>
<td></td>
<td>10.30</td>
<td>10.40</td>
<td>10.60</td>
<td>11.30</td>
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<tr>
<td>20 – 200°C</td>
<td></td>
<td>10.80</td>
<td>11.10</td>
<td>11.10</td>
<td>12.00</td>
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<tr>
<td>20 – 400°C</td>
<td></td>
<td>11.10</td>
<td>11.70</td>
<td>11.70</td>
<td>12.70</td>
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<tr>
<td>20 – 600°C</td>
<td></td>
<td>9.86</td>
<td>11.20</td>
<td>12.20</td>
<td>13.10</td>
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<tr>
<td>Thermal conductivity at 23°C</td>
<td>W m⁻¹ K⁻¹</td>
<td>14.06</td>
<td>14.85</td>
<td>15.83</td>
<td>15.80</td>
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<tr>
<td>Magnetic properties:</td>
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<tr>
<td>- Coercivity Hc</td>
<td>Oe</td>
<td>25.5</td>
<td>23.3</td>
<td>28.1</td>
<td>34.2</td>
<td>53.0</td>
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<td>- Saturation induction Bs</td>
<td>kG</td>
<td>13.4</td>
<td>13.8</td>
<td>13.3</td>
<td>12.4</td>
<td>10.1</td>
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</table>

Reference
ALLOY Data, Custom 465® Stainless, Carpenter Technology Corporation

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