Allegheny Ludlum
An Allegheny Technologies Company

# Technical Data BLUE SHEET

Allegheny Ludlum Corporation ◆ Pittsburgh, PA

# Allegheny Ludlum Altemp® 625 Nickel-Base Superalloy (UNS Designation N06625)

## GENERAL PROPERTIES

Allegheny Ludlum Altemp® 625 alloy (UNS Designation N06625) is an austenitic nickel-base superalloy possessing excellent resistance to oxidation and corrosion over a broad range of corrosive conditions, including jet engine environments and in many other aerospace and chemical process applications. The alloy has outstanding strength and toughness at temperatures ranging from cryogenic temperature to 2000°F (1093°C). Altemp 625 alloy also has exceptional fatigue resistance.

The Altemp 625 alloy derives its strength from the solid solution strengthening effects of molybdenum and columbium on the nickel-chromium matrix. These elements also contribute to the alloy's outstanding corrosion resistance. Although the alloy was developed for high temperature strength, its highly alloyed composition provides a high level of general corrosion resistance to a wide range of oxidizing and non-oxidizing environments. The levels of chromium and molybdenum provide excellent resistance to chloride ion pitting and the high level of nickel provides resistance to chloride stress corrosion cracking.

The material possesses a high degree of formability and shows better weldability than many highly alloyed nickel-base alloys. The alloy is resistant to intergranular corrosion even in the welded condition.

Altemp 625 alloy can be produced by vacuum induction melting or AOD refining. Consumable electrode remelting procedures may be used to further refine the material.

## FORMS AND CONDITIONS AVAILABLE

The Altemp 625 alloy is available in plate, sheet and strip. The alloy is supplied in the annealed conditions generally specified.

## SPECIFICATIONS

Altemp 625 alloy is covered by the following widely published specifications:

| | |
|---|---|
| AMS 5401 | Castings |
| AMS 5402 | Castings |
| AMS 5581 | Seamless or Welded Tubing |
| AMS 5599 | Sheet, Strip and Plate |
| AMS 5666 | Bar, Forgings and Rings |
| AMS 5837 | Welding Wire |
| ASTM B 443<br>ASME SB 443 | Plate, Sheet and Strip |
| ASTM B 444<br>ASME SB 444 | Seamless Tube and Pipe |
| ASTM B 446<br>ASME SB 446 | Rod and Bar |
| ASTM B 704 | Welded Tube |
| ASTM B 705 | Welded Tube |

## TYPICAL ANALYSIS

| Element | Percent |
|---|---|
| Carbon | 0.05 |
| Manganese | 0.30 |
| Phosphorus | 0.010 |
| Sulfur | 0.003 |
| Silicon | 0.25 |
| Chromium | 22.0 |
| Nickel | Balance |
| Molybdenum | 9.0 |
| Columbium plus Tantalum | 3.5 |
| Titanium | 0.3 |
| Aluminum | 0.3 |
| Iron | 4.0 |

### ASME Maximum Allowable Stresses – Section VIII Division I

| | | Product Form Covered By Assigned Stresses | |
|---|---|---|---|
| | | Bar and Flat Products Containing Welds, and Bolting ASME SB 443 ASME SB 446 | Seamless Tube and Pipe ASME SB 444 |
| Specified Min. Tensile (psi) (MPa) | | 120,000 (110,000 over 4" thick) (827) (758) | 120,000 (827) |
| Specified Min. Yields (psi) (MPa) | | 60,000 (50,000 over 4" thick) (414) (345) | 60,000 (414) |
| Metal Temperature Not Exceeding | | Maximum Allowable Stress Listed in Table UNF 23.3 | |
| °F | °C | | |
| 100 | 38 | 27,500 | 30,000 |
| 200 | 93 | 27,500 | 30,000 |
| 300 | 149 | 27,500 | 30,000 |
| 400 | 204 | 26,800 | 28,200 |
| 500 | 260 | 26,100 | 27,000 |
| 600 | 316 | 25,400 | 26,400 |
| 700 | 371 | 25,000 | 26,000 |
| 800 | 427 | 24,600 | 26,000 |
| 900 | 482 | 24,000 | 26,000 |
| 1000 | 538 | 23,700 | 26,000 |
| 1100 | 593 | 23,400 | 26,000 |
| 1150 | 631 | 21,000 | 21,000 |
| 1200 | 649 | 13,200 | 13,200 |
| ASME Boiler and Pressure Vessel Code 1985, Table UNF 23.3 | | | |

## CORROSION AND OXIDATION RESISTANCE

The high level of chromium and molybdenum in the Altemp 625 alloy provides a high level of pitting and crevice corrosion resistance to chloride contaminated media, such as sea water, neutral salts and brines.

### Typical Data in Chloride Solutions

| Crevice Test in 10 Percent Ferric Chloride | Type 316 | Altemp® 625 |
|---|---|---|
| Onset Temperature °F (°C) for Attack in ASTM Procedure G-48 | <32 (<0) | 104-113 (40-45) |

### Panel Exposures in Sea Water

| Panel Location | Type 316 | Altemp® 625 |
|---|---|---|
| Flowing Sea Water | Crevice Attack 1 Month | No Attack 18 Months |
| Tidal Zone | Crevice Attack 1 Month | No Attack 18 Months |
| Partial Mud Burial | Crevice Attack 1 Month | No Attack 18 Months |

The alloy is resistant to a variety of corrosive media from highly oxidizing to moderately reducing.

Tests in geothermal brines indicate Altemp 625 alloy highly resistant to hot geothermal fluids comparable to Allegheny Ludlum Alloy AL 29-4-2® and Titanium Grade 2.

Tests in simulated flue gas desulfurization environments show Altemp 625 alloy highly resistant to the environment in comparison to alloys such as Type 316 or Alloy G and comparable to AL 29-4-2 and Alloy C-276.

The following data are illustrative. Typical corrosion rates are in mils per year (mm/a).

### Boiling Organic Acid Solutions

| Alloy | 45% Formic | 10% Oxalic | 88% Formic | 99% Acetic |
|---|---|---|---|---|
| Altemp® 625 | 5.0 (0.13) | 6.0 (0.15) | 9.0 (0.23) | 0.4 (0.01) |
| Type 316 | 11 (0.28) | 40 (1.02) | 9.0 (0.23) | 2.0 (0.05) |

Data shown are typical, and should not be construed as maximum or minimum values for specification or for final design. Data on any particular piece of material may vary from those shown herein.

### Dilute Reducing Acids - Boiling Solutions*

| Alloy | 1% Sulfuric | 5% Sulfuric | 10% Sulfuric | 1% Hydrochloric |
|---|---|---|---|---|
| Altemp® 625 | 2.2 (0.06) | 8.9 (0.23) | 25.3 (0.64) | 36.3 (0.92) |
| AL 29-4-2® | 2.6 (0.07) | 10.7 (0.27) | 18.2 (0.46) | 0.1 (<0.01) |
| Type 316 | 25.8 (0.65) | 107 (2.72) | 636 (16.2) | 226 (5.74) |

* Sulfuric acid test samples activated before tests and hydrochloric acid test samples tested without activation.

### Miscellaneous Environments

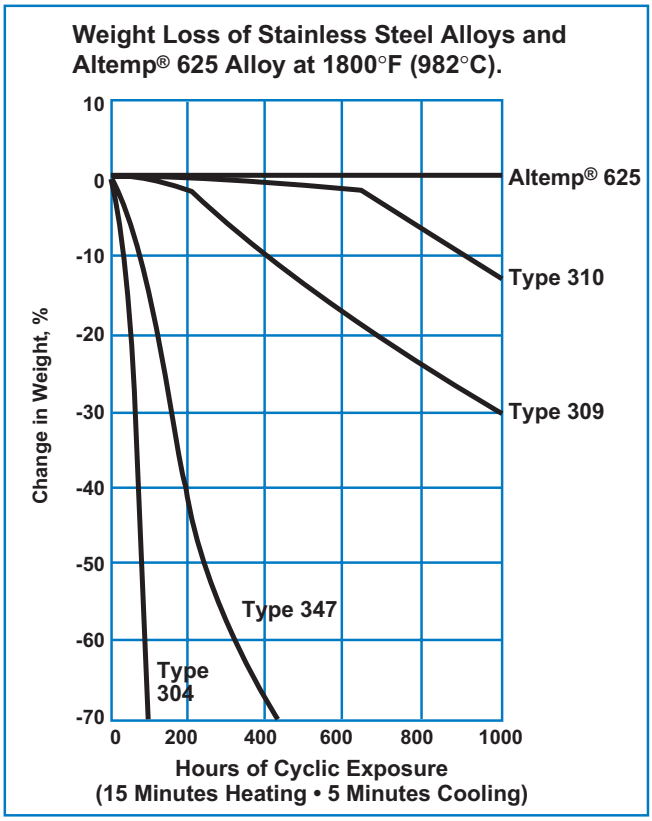
| Environment | Altemp® 625 | AL 29-4-2® | Type 316 |
|---|---|---|---|
| 20% Phosphoric Acid | 0.36 (<0.01) | 0.12 (<0.01) | 0.2 (<0.01) |
| 10% Sulfamic Acid | 4.80 (0.12) | 0.11 (<0.01) | 63.6 (1.61) |
| 10% Sodium Bisulfate | 3.96 (0.10) | 0.12 (<0.01) | 41.6 (1.06) |

### Chloride Stress Corrosion Cracking Resistance

| Test | Altemp® 625 | Type 316 | AL 20™ |
|---|---|---|---|
| 42% Magnesium Chloride | No Cracks 1000 Hours | Cracks <24 Hours | Cracks <100 Hours |
| 26% Sodium Chloride | No Cracks 1000 Hours | Cracks 600 Cracks | No Cracks 1000 Cracks |

### Oxidation Resistance

Altemp 625 alloy has excellent oxidation and scaling resistance at temperatures up to 2000°F (1 093°C). It is superior to many other high temperature alloys under cyclic heating and cooling conditions. The following graph compares the weight loss of several stainless steel alloys to Altemp 625 alloy under cyclic oxidation at 1800°F (982°C).




## PHYSICAL PROPERTIES - Typical Values

### Physical Constants

| | |
|---|---|
| Density, lb./in.$^3$ | 0.305 |
| g/cm$^3$ | 8.44 |
| Specific Gravity | 8.44 |
| Melting Range, °F | 2350-2460 |
| °C | 1280-1350 |
| Specific Heat, Btu/lb. °F | 0.098 |
| Joules/kg-°K | 410 |
| Magnetic Permeability, 75°F, 200 oersted | 1.0006 |

## Electrical Resistivity

| Temperature | | Electrical Resistivity microhm–cm |
|---|---|---|
| °F | °C | |
| 70 | 21 | 128.9 |
| 100 | 38 | 129.6 |
| 200 | 93 | 131.9 |
| 400 | 204 | 133.9 |
| 600 | 316 | 134.9 |
| 800 | 427 | 135.9 |
| 1000 | 538 | 137.9 |
| 1200 | 649 | 137.9 |
| 1400 | 760 | 136.9 |
| 1600 | 871 | 135.9 |
| 1800 | 982 | 134.9 |
| 2000 | 1093 | 133.9 |

## Thermal Properties

| Temperature | | Linear Coefficient of Thermal Expansion (a) (Units of $10^{-6}$) | | Thermal Conductivity (b)(c) | |
|---|---|---|---|---|---|
| °F | °C | /°F | /°C | Btu-ft/ft² h-°F | W/m-°K |
| -250 | -157 | – | – | 4.2 | 7.3 |
| -200 | -129 | – | – | 4.3 | 7.4 |
| -100 | -73 | – | – | 4.8 | 8.3 |
| 0 | -18 | – | – | 5.3 | 9.2 |
| 70 | 21 | – | – | 5.7 | 9.9 |
| 100 | 38 | – | – | 5.8 | 10.0 |
| 200 | 93 | 7.1 | 12.8 | 6.3 | 10.7 |
| 400 | 204 | 7.3 | 13.1 | 7.3 | 12.6 |
| 600 | 316 | 7.4 | 13.3 | 8.2 | 14.2 |
| 800 | 427 | 7.6 | 13.7 | 9.1 | 15.7 |
| 1000 | 538 | 7.8 | 14.0 | 10.1 | 17.5 |
| 1200 | 649 | 8.2 | 14.8 | 11.0 | 19.0 |
| 1400 | 760 | 8.5 | 15.3 | 12.0 | 20.8 |
| 1600 | 871 | 8.8 | 15.8 | 13.2 | 22.8 |
| 1700 | 927 | 9.0 | 16.2 | – | – |
| 1800 | 982 | – | – | 14.6 | 25.3 |

(a) Average coefficient from 70°F (21°C) to temperature shown.
(b) Measurements made at Battelle Memorial Institute.
(c) Material annealed 2100°F (1149°C).

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## Modulus Data

| Temperature | | Modulus of Rigidity (G) | | Elastic Modulus (E) | | Poisson's Ratio (a) (μ) |
|---|---|---|---|---|---|---|
| °F | °C | Units of $10^6$ psi | Units GPa | Units of $10^6$ psi | Units GPa | |
| 70 | 21 | 11.4 | 79 | 29.8 | 205 | 0.308 |
| 200 | 93 | 11.2 | 77 | 29.2 | 200 | 0.310 |
| 400 | 204 | 10.8 | 75 | 28.4 | 195 | 0.312 |
| 600 | 316 | 10.5 | 72 | 27.5 | 190 | 0.313 |
| 800 | 427 | 10.1 | 70 | 26.6 | 185 | 0.312 |
| 1000 | 538 | 9.7 | 67 | 25.6 | 175 | 0.321 |
| 1200 | 649 | 9.2 | 63 | 24.4 | 170 | 0.328 |
| 1400 | 760 | 8.7 | 60 | 23.1 | 160 | 0.329 |
| 1600 | 871 | 8.2 | 57 | – | – | – |

(a) Poisson's ratio (μ) computed from the relation:

$$\mu = \frac{E-2G}{2G}$$

# MECHANICAL PROPERTIES

### Typical Short Time Tensile Properties as a Function of Temperature.

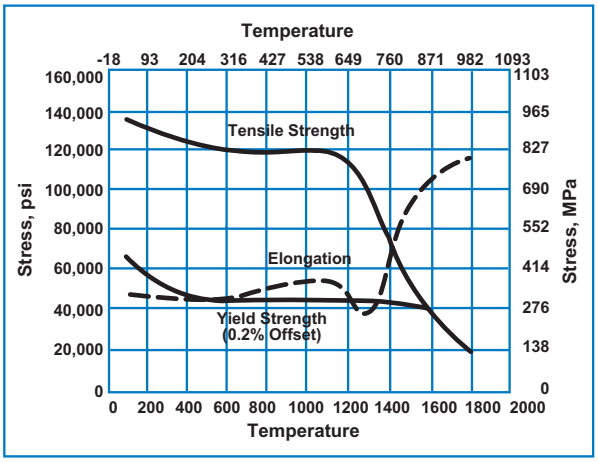
Typical room temperature tensile properties of material annealed at 1920°F (1065°C) follow.

| Yield Strength (0.2% Offset) | Ultimate Tensile Strength | Elongation (% in 2") |
|---|---|---|
| 63,000 psi (430 MPa) | 136,000 psi (940 MPa) | 51.5 |

The typical room temperature tensile properties of material solution annealed at 2150°F (1177°C) follow.

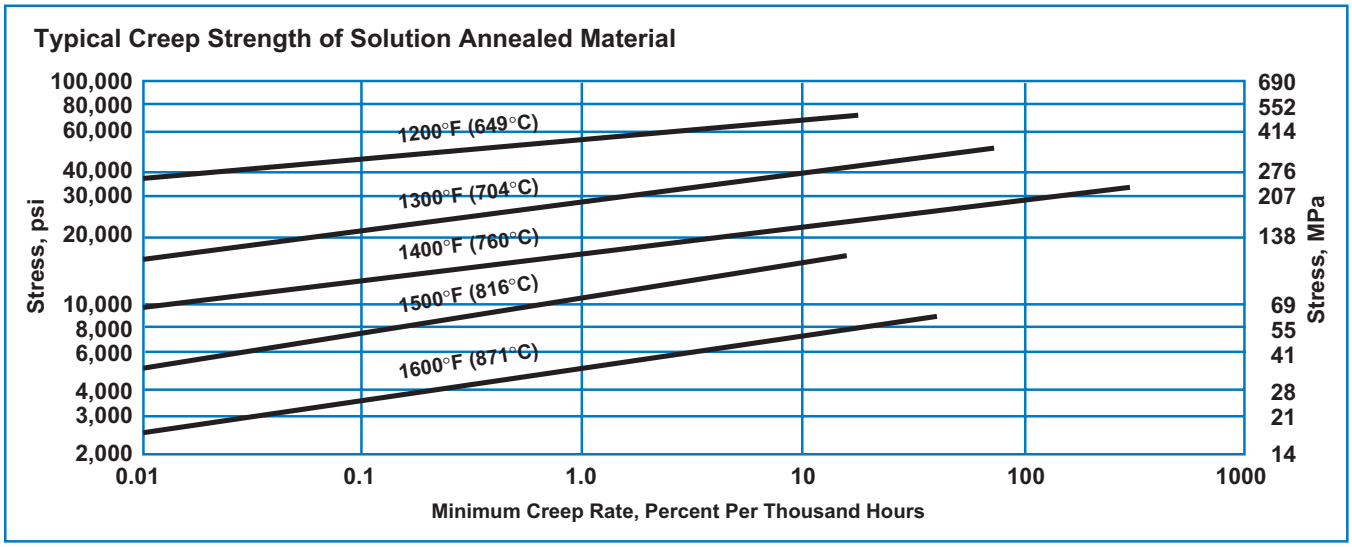
| Yield Strength (0.2% Offset) | Ultimate Tensile Strength | Elongation (% in 2") |
|---|---|---|
| 49,500 psi (340 MPa) | 115,500 psi (800 MPa) | 67 |

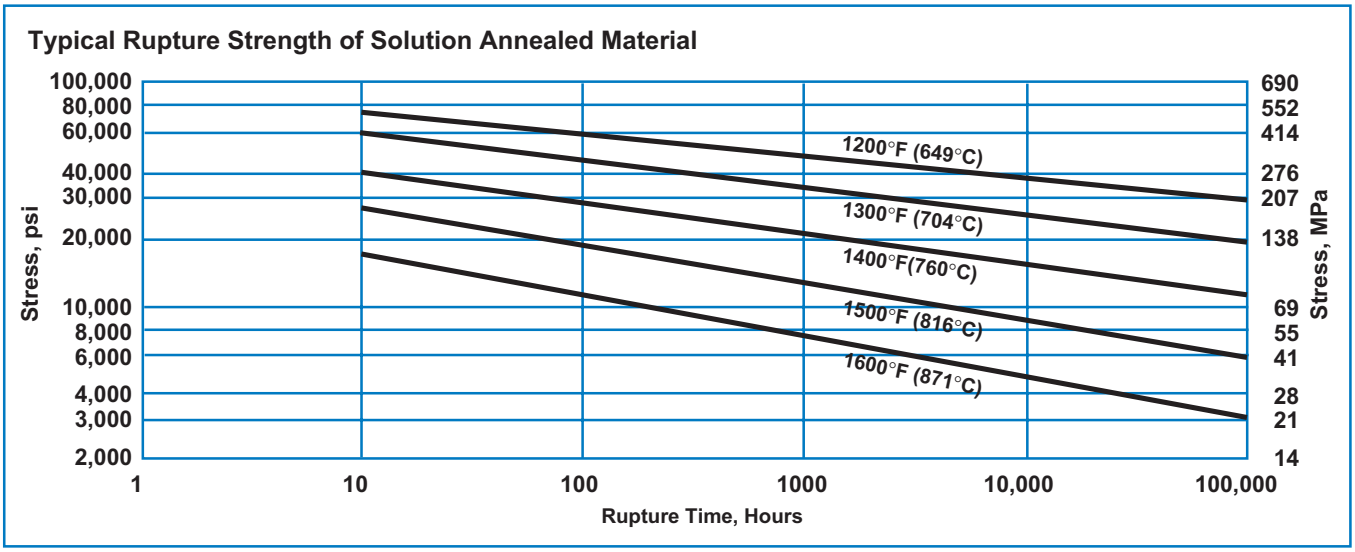
The short time elevated temperature tensile properties of the Altemp 625 alloy annealed at 1950°F (1066°C) are shown in the following graph.



### Creep and Stress Rupture Properties

Typical creep and rupture strengths of solution annealed (refer to the section on heat treatment) Altemp 625 alloy follow.

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### Impact Resistance

The Altemp 625 alloy maintains high impact resistance at low temperature as shown below.

### Typical Altemp® 625 Alloy Impact Properties

| Test Temp. | | Orientation | Impact Energy (a) | |
|---|---|---|---|---|
| °F | °C | | Ft-lbs | Joules |
| 85 | 30 | Longitudinal | 49 | 66 |
| 85 | 30 | Transverse | 49 | 66 |
| -110 | - 79 | Longitudinal | 44 | 60 |
| -110 | - 79 | Transverse | 41.5 | 56 |
| -320 | -196 | Longitudinal | 35 | 47 |
| -320 | -196 | Transverse | 35 | 47 |

(a) Charpy Keyhole Specimens (Mean Value of 3 Tests)

Impact properties may be expected to decrease with extended service in 1200 to 1600°F (649 to 871°C) range.

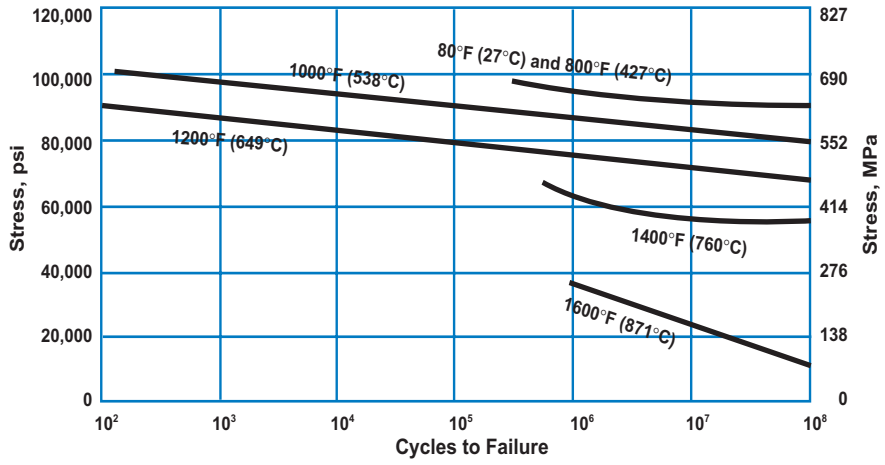
## FATIGUE RESISTANCE

The room temperature endurance limit for cold rolled sheet, mill annealed (1950°F-1066°C) and tested in completely reverse bending (constant deflection) was found to be 46,000 psi (315 MPa) or about 35 percent of tensile strength. The constant load rotating beam test provides a higher estimate of fatigue limit (approximately 65 percent of tensile strength). The latter may be influenced by the work hardening behavior of the Altemp 625 alloy. Typical room and elevated temperature fatigue properties (rotating beam test) for mill annealed bar and plate products are shown below.

### Formability

The Altemp 625 alloy is capable of being formed like the standard austenitic stainless steels. The material is considerably stronger than conventional austenitic stainless steels and consequently requires higher loads to cause the material to deform. During cold working, the material work hardens more rapidly than austenitic stainless steels. The combination of high initial strength and work hardening rate may necessitate need for intermediate anneals if the cold deformation is extensive.

**Rotating-Beam Fatigue Strength of Hot Rolled Bar, Grain Size, 0.0006 in.; Hardness, 24.5 $R_C$ (Bar Annealed at 1800°F (982°C)-1 Hour).**

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### Effect of Cold Reduction on Properties of Plate Annealed at 2150°F (1177°C)

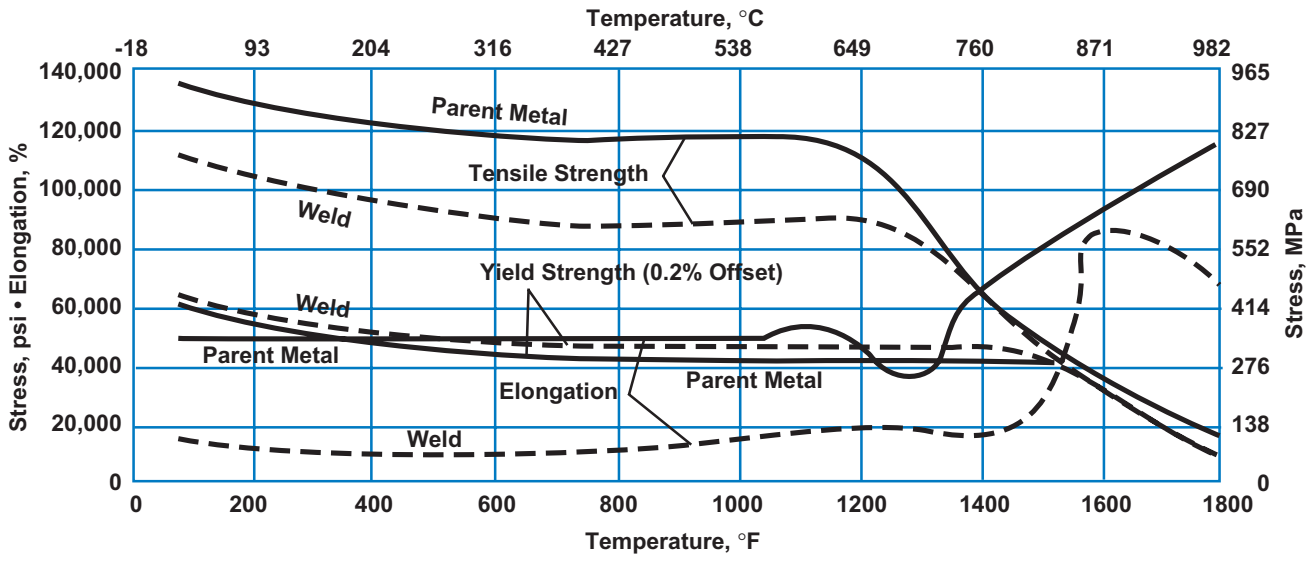
| Cold Reduction % | Hardness Rockwell C | Yield Strength (0.2% Offset) | | Tensile Strength | | Elongation, % | Reduction of Area, % |
|---|---|---|---|---|---|---|---|
| | | psi | (MPa) | psi | (MPa) | | |
| 0 | 88Rb | 49,500 | 341 | 115,500 | 796 | 67.0 | 60.4 |
| 5 | 94Rb | 77,500 | 534 | 121,000 | 834 | 58.0 | 58.1 |
| 10 | 25 | 102,500 | 707 | 130,000 | 896 | 47.5 | 54.6 |
| 15 | 32 | 112,500 | 776 | 137,000 | 945 | 39.0 | 51.9 |
| 20 | 34 | 125,000 | 862 | 143,000 | 986 | 31.5 | 50.0 |
| 30 | 36 | 152,000 | 1048 | 165,000 | 1137 | 17.0 | 49.3 |
| 40 | 39 | 167,000 | 1151 | 179,500 | 1238 | 12.5 | 41.9 |
| 50 | 40 | 177,000 | 1220 | 189,500 | 1307 | 8.5 | 38.0 |
| 60 | 44 | 180,500 | 1245 | 205,000 | 1413 | 6.5 | 32.7 |
| 70 | 45 | 201,000 | 1386 | 219,000 | 1510 | 5.0 | 25.4 |

## Welding

The Altemp 625 alloy can be readily welded by conventional processes used for austenitic stainless steel, including fusion and resistance methods. The material should be in the mill annealed condition and thoroughly descaled and cleaned before welding. Preheating is not required and postweld treatment is not needed to maintain or restore corrosion resistance.

Typical short-time elevated temperature tensile properties of welds made on mill annealed material by the gas tungsten-arc process are shown below.

**Autogeneous Butt Joint made by Gas Tungsten-Arc Process in 0.062 inch (1.6mm) Gage Cold Rolled, Annealed at 1800°F (982°C)-1 Hour-Air Cool, Sheet Tested As-Welded**

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## Heat Treatment

Altemp 625 alloy is furnished with one heat treatment for optimum properties up to 1200°F (649°C) and another for optimum properties above 1200°F (649°C). The standard anneal at a minimum of 1600°F (871°C) is used for service temperatures up to 1200°F (649°C). When optimum high temperature creep and rupture properties are required, as for service above 1200°F (649°C), a solution anneal at 2000°F (1093°C) minimum is used. In the solution annealed condition, a subsequent stabilization anneal at 1800°F (982°C) minimum is sometimes specified to further increase resistance to sensitization.

*Material Safety Data Sheets have been prepared prepared for this product and will be made available at or prior to the time of shipment.*

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