Technical Datasheet CARPENTER TECHNOLOGY

# CarTech® 31V Alloy

## Identification

UNS Number

• N07032

## Type Analysis

*Single figures are nominal except where noted.*

| | | | |
|---|---|---|---|
| **Carbon** | 0.04 % | **Manganese (Maximum)** | 0.20 % |
| **Phosphorus (Maximum)** | 0.015 % | **Sulfur (Maximum)** | 0.010 % |
| **Silicon (Maximum)** | 0.20 % | **Chromium** | 22.70 % |
| **Nickel** | 57.00 % | **Molybdenum** | 2.00 % |
| **Titanium** | 2.30 % | **Columbium/Niobium** | 0.85 % |
| **Aluminum** | 1.30 % | **Boron** | 0.005 % |
| **Iron** | Balance | | |

## General Information

Description

CarTech 31V alloy is a sulfidation and corrosion resistant precipitation hardenable alloy possessing an unusual combination of corrosion resistance and strength to temperatures as high as 1500°F (816°C).

This alloy displays good resistance to hot sulfidizing and oxidizing environments such as those encountered in diesel engine service, as well as sour environments such as those encountered in deep sour gas and oil wells.

Applications

Because of its excellent balance of properties, CarTech 31V alloy has been considered a candidate for many demanding applications, including rapid fire military gun barrels, hardware in coal gasification units and exhaust valves in heavy-duty internal combustion engines.

## Corrosion Resistance

Laboratory crucible tests aimed at assessing the capability of Pyromet alloy 31V to withstand high temperature sulfidation attack were carried out in a mixture of 10 $CaSO_4$ - 6 $BaSO_4$ - 2 $Na_2SO_4$ - 1 C at 1600°F (871°C) for up to 80 hours. The results shown in the hyperlink titled "Comparative Sulfidation Test Results-Various Alloys" indicate that Pyromet alloy 31V has superior resistance compared to commercial diesel valve alloys like Pyromet alloys 751 and 80A, which suffered catastrophic attack. All three alloys have excellent resistance to hot corrosion by lead oxide at 1675°F (913°C).

In a molten mixture of 90% $Na_2SO_4$ / 10% NaCl at 1700°F (927°C) / 100 hours, Pyromet alloy 31V showed only slight attack while alloy 751 suffered catastrophic attack.

Evaluations in both laboratory and field environments have been conducted to establish Pyromet alloy 31V as a candidate for consideration as a sulfide stress cracking resistant material for oil field applications in sour environments.

Comparative tests have shown that Pyromet alloy 31V is superior to Pyromet alloy X-750 (an established alloy for sour service) in the NACE TM-01-77 solution, which consists of an acidified, deoxygenated sour brine solution saturated with hydrogen sulfide.

**Important Note:** *The following 4-level rating scale is intended for comparative purposes only. Corrosion testing is recommended; factors which affect corrosion resistance include temperature, concentration, pH, impurities, aeration, velocity, crevices, deposits, metallurgical condition, stress, surface finish and dissimilar metal contact.*

| | | | |
|---|---|---|---|
| Nitric Acid | Excellent | Sulfuric Acid | Good |
| Phosphoric Acid | Good | Acetic Acid | Good |
| Sodium Hydroxide | Good | Salt Spray (NaCl) | Excellent |
| Sea Water | Moderate | Humidity | Excellent |

**Comparative Sulfidation Test Results—Various Alloys**
1600°F (871°C)

| Alloy | Duration (hours) | Weight Loss (g/dm²) |
|---|---|---|
| Pyromet 80A | 5 | 1 |
| | 30 | 72 |
| | 80 | Catastrophic (>100) |
| Pyromet 751 | 5 | 1 |
| | 30 | 58 |
| | 80 | Catastrophic (>100) |
| Pyromet 31V | 5 | 0 |
| | 30 | 1 |
| | 80 | 52 |

# Properties

## Physical Properties

| | | |
|---|---|---|
| Density | 0.2890 | lb/in³ |
| Mean Specific Heat (70 to 150°F) | 0.1200 | Btu/lb/°F |
| Mean CTE | | |
| 70 to 300°F | 6.17 | x 10 $^{-6}$ in/in/°F |
| 70 to 500°F | 7.66 | x 10 $^{-6}$ in/in/°F |
| 70 to 700°F | 7.92 | x 10 $^{-6}$ in/in/°F |
| 70 to 900°F | 8.09 | x 10 $^{-6}$ in/in/°F |
| 70 to 1100°F | 8.28 | x 10 $^{-6}$ in/in/°F |
| 70 to 1300°F | 8.50 | x 10 $^{-6}$ in/in/°F |
| 70 to 1500°F | 8.96 | x 10 $^{-6}$ in/in/°F |

Mean coefficient of thermal expansion

| Temperature Range | | Coefficient | |
|---|---|---|---|
| 70°F to | 21°C to | $10^{-6}$/°F | $10^{-6}$/°C |
| 300 | 149 | 6.17 | 11.11 |
| 500 | 260 | 7.66 | 13.79 |
| 700 | 371 | 7.92 | 14.26 |
| 900 | 482 | 8.09 | 14.56 |
| 1100 | 593 | 8.28 | 14.90 |
| 1300 | 704 | 8.50 | 15.30 |
| 1500 | 816 | 8.96 | 16.13 |

| | | |
|---|---|---|
| Thermal Conductivity | | |
| 70 to 212°F | 86.73 | BTU-in/hr/ft²/°F |
| 70 to 700°F | 115.2 | BTU-in/hr/ft²/°F |
| 70 to 1099°F | 137.4 | BTU-in/hr/ft²/°F |
| 70 to 1501°F | 161.0 | BTU-in/hr/ft²/°F |

Thermal conductivity

| Temperature | | Btu•in/ft²•hr•°F) | W/m•K |
|---|---|---|---|
| 70°F to | 21°C to | | |
| 212 | 100 | 87 | 12.5 |
| 700 | 371 | 115 | 16.6 |
| 1100 | 593 | 138 | 19.8 |
| 1500 | 816 | 161 | 23.2 |

| Modulus of Elasticity (E) | | |
|---|---|---|
| 70°F | 30.1 | x 10 $^3$ ksi |
| 100°F | 30.0 | x 10 $^3$ ksi |
| 200°F | 29.5 | x 10 $^3$ ksi |
| 300°F | 29.2 | x 10 $^3$ ksi |
| 500°F | 28.1 | x 10 $^3$ ksi |
| 700°F | 27.1 | x 10 $^3$ ksi |
| 900°F | 26.1 | x 10 $^3$ ksi |
| 1100°F | 25.0 | x 10 $^3$ ksi |
| 1300°F | 23.8 | x 10 $^3$ ksi |
| 1500°F | 22.3 | x 10 $^3$ ksi |

Modulus of elasticity

| Temperature | | psi x $10^6$ | MPa x $10^3$ |
|---|---|---|---|
| °F | °C | | |
| 70 | 21 | 30.08 | 207 |
| 100 | 38 | 30.00 | 207 |
| 200 | 93 | 29.48 | 203 |
| 300 | 149 | 29.23 | 202 |
| 500 | 260 | 28.12 | 194 |
| 700 | 371 | 27.11 | 187 |
| 900 | 482 | 26.08 | 180 |
| 1100 | 593 | 25.04 | 173 |
| 1300 | 704 | 23.77 | 164 |
| 1500 | 816 | 22.32 | 154 |

| Electrical Resistivity | | |
|---|---|---|
| 70°F | 734.0 | ohm-cir-mil/ft |
| 212°F | 758.0 | ohm-cir-mil/ft |
| 700°F | 800.0 | ohm-cir-mil/ft |
| 1099°F | 830.0 | ohm-cir-mil/ft |
| 1501°F | 842.0 | ohm-cir-mil/ft |

Electrical resistivity

| Temperature | | ohm-cir/mil ft | microhm-mm |
|---|---|---|---|
| °F | °C | | |
| 70 | 21 | 734 | 1220 |
| 212 | 100 | 758 | 1260 |
| 700 | 371 | 800 | 1330 |
| 1100 | 593 | 830 | 1380 |
| 1500 | 816 | 842 | 1400 |

| | | |
|---|---|---|
| Melting Range | 2250 to 2420 | °F |

## Magnetic Properties

| | | |
|---|---|---|
| Magnetic Permeability (Solution Treated and Aged) | 1.0016 | Mu |

## Typical Mechanical Properties

**Elevated Temperature Creep Strength—Pyromet Alloy 31V**

Heat treated 2050°F (1121°C) 1 hour, air cooled + 1550°F (843°C) 4 hours, air cooled + 1350°F (732°C) 4 hours, air cooled.

| Test Temperature | | Stress to Produce 1% Total Creep in 100 Hours | |
|---|---|---|---|
| °F | °C | ksi | MPa |
| 1200 | 649 | 65 | 448 |
| 1350 | 732 | 40 | 276 |
| 1400 | 760 | 35 | 241 |

**Elevated Temperature Stress Rupture Strength—Pyromet Alloy 31V**

Heat treated 2050°F (1121°C) 1 hour, air cooled + 1550°F (843°C) 4 hours, air cooled + 1350°F (732°C) 4 hours, air cooled.

| Test Temperature | | Stress for Rupture in: | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10 Hours | | 100 Hours | | 1000 Hours | |
| °F | °C | ksi | MPa | ksi | MPa | ksi | MPa |
| 1200 | 649 | 100 | 690 | 85 | 586 | 68 | 469 |
| 1350 | 732 | 70 | 483 | 52 | 359 | 38 | 262 |
| 1500 | 816 | 40 | 276 | 27 | 186 | 17 | 117 |

**Rotating Beam Fatigue Properties at 1400°F (760°C)—Pyromet Alloy 31V**

Heat treated 2000°F (1093°C) 4 hours, air cooled + 1600°F (871°C) 4 hours, air cooled + 1350°F (732°C) 4 hours, air cooled.

| Stress for Fracture in $10^8$ Cycles | | | |
|---|---|---|---|
| As Heat Treated | | Exposed 1350°F (732°C) for 1500 Hours | |
| ksi | MPa | ksi | MPa |
| 42 | 288 | 47 | 322 |

**Typical Room and Elevated Temperature Mechanical Properties—Pyromet Alloy 31V**

0.75" (19 mm) round bar

| Heat Treatment* | Test Temperature | | 0.2% Yield Strength | | Ultimate Tensile Strength | | % Elongation in 4D | % Reduction of Area |
|---|---|---|---|---|---|---|---|---|
| | °F | °C | ksi | MPa | ksi | MPa | | |
| 1 | 70 | 21 | 105 | 724 | 176 | 1214 | 25.0 | 27.4 |
| 2 | 70 | 21 | 100 | 690 | 166 | 1145 | 33.9 | 36.5 |
| 3 | 70 | 21 | 122 | 841 | 181 | 1248 | 30.0 | 38.5 |
| 1 | 1000 | 538 | 95 | 655 | 157 | 1083 | 19.2 | 30.6 |
| 2 | 1000 | 538 | 91 | 627 | 141 | 972 | 31.4 | 45.2 |
| 3 | 1000 | 538 | 108 | 745 | 155 | 1069 | 25.1 | 45.6 |
| 1 | 1200 | 649 | 94 | 648 | 153 | 1055 | 20.0 | 29.3 |
| 2 | 1200 | 649 | 92 | 634 | 139 | 958 | 22.8 | 33.7 |
| 3 | 1200 | 649 | 111 | 765 | 152 | 1048 | 18.5 | 25.2 |
| 1 | 1400 | 760 | 95 | 655 | 110 | 758 | 25.0 | 33.4 |
| 2 | 1400 | 760 | 82 | 565 | 112 | 772 | 23.8 | 25.2 |
| 1 | 1500 | 816 | 84 | 579 | 86 | 593 | 28.4 | 37.1 |
| 2 | 1500 | 816 | 79 | 544 | 94 | 648 | 24.6 | 30.6 |

*Heat Treatment

1 - 2050°F (1121°C) 1 hour, air cooled + 1550°F (843°C) 4 hours, air cooled + 1350°F (732°C) 4 hours, air cooled

2 - 2050°F (1121°C) 1 hour, air cooled + 1300°F (704°C) 24 hours, air cooled

3 - 1875°F (1024°C) 1 hour, oil quenched + 1300°F (704°C) 24 hours, air cooled

## Heat Treatment

Pyromet alloy 31V is strengthened by solid solution strengthening and by controlled precipitation of gamma prime phase of general composition Ni3 (Al, Ti, Cb). The optimum heat treatment for Pyromet alloy 31V varies with property requirements.

For a good combination of ambient and elevated temperature properties up to 1500°F (816°C), stock is solution treated in the range 1950/2050°F (1065/1120°C) for 0.5 to 4 hours and air cooled.

### Solution Treatment

A lower solution temperature, 1875°F (1025°C), will result in somewhat finer grain size and is sometimes employed to optimize properties below 1200°F (649°C).

Note: For lower temperature service, another version of this alloy, Pyromet alloy 31 which was specifically designed to resist sulfide-containing environments, should be considered.

### Age

Solution treated stock may be given a single or double age for optimum compatibility with manufacturing processes. The single-age cycle is 1300°F (704°C) for 24 hours, followed by an air cool. The double-age cycle includes a stabilizing age in the range from 1550/1600°F (843/871°C) for four hours, air cool, plus a final age at 1350°F (732°C) for four hours, air cool.

## Workability

### Hot Working

Pyromet alloy 31V can be hot worked within the temperature range of 1800/2100°F (980°/1150°C). Careful control of the forging temperature and frictional heat build-up should be maintained.

Large amounts of deformation below 1800°F (980°C) should be avoided.

Forgings may be air or fan cooled. Water quenching should be avoided, especially for large sections.

### Machinability

The machinability of this alloy is similar to other iron-nickel base precipitation hardened alloys, such as Pyromet alloy X-750.

The alloy can be machined in either the solution annealed or age hardened condition. Machine tools should have ample power, and cutting speeds should be slow.

For better chip action on chip breakers and an improved finish, use material in the age hardened condition.

### Weldability

Pyromet alloy 31V can be readily joined by the welding processes ordinarily used for high temperature precipitation hardening alloys.

For best results, the alloys should be in the solution annealed condition prior to welding and should be reannealed after welding. Matching filler metal should be used, if required.

The solution anneal plus age heat treatment procedures as described above are preferred for postweld heat treatment of welded structures.

## Other Information

### Forms Manufactured

- Bar-Rounds
- Billet

### Technical Articles

- A Designer's Manual On Specialty Alloys For Critical Automotive Components



Edition Date: 9/8/2003