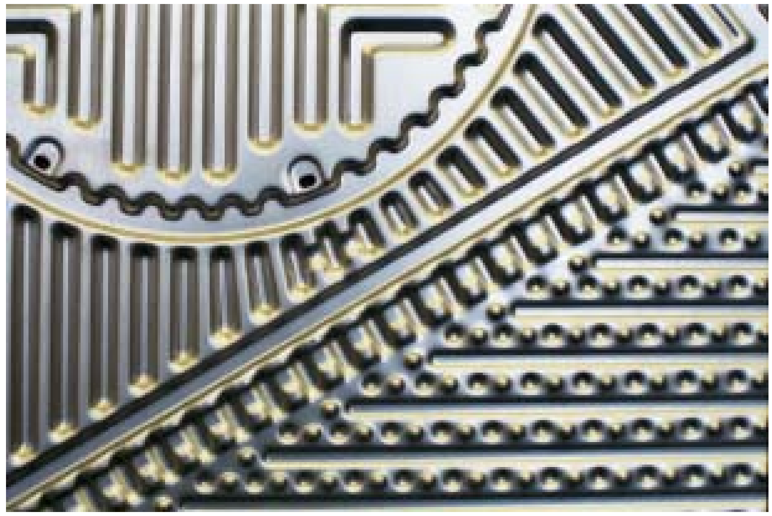
# Soonv® C-2000® alloy

SOONV C-2000 alloy heat exchanger plate made for service in concentrated sulfuric acid



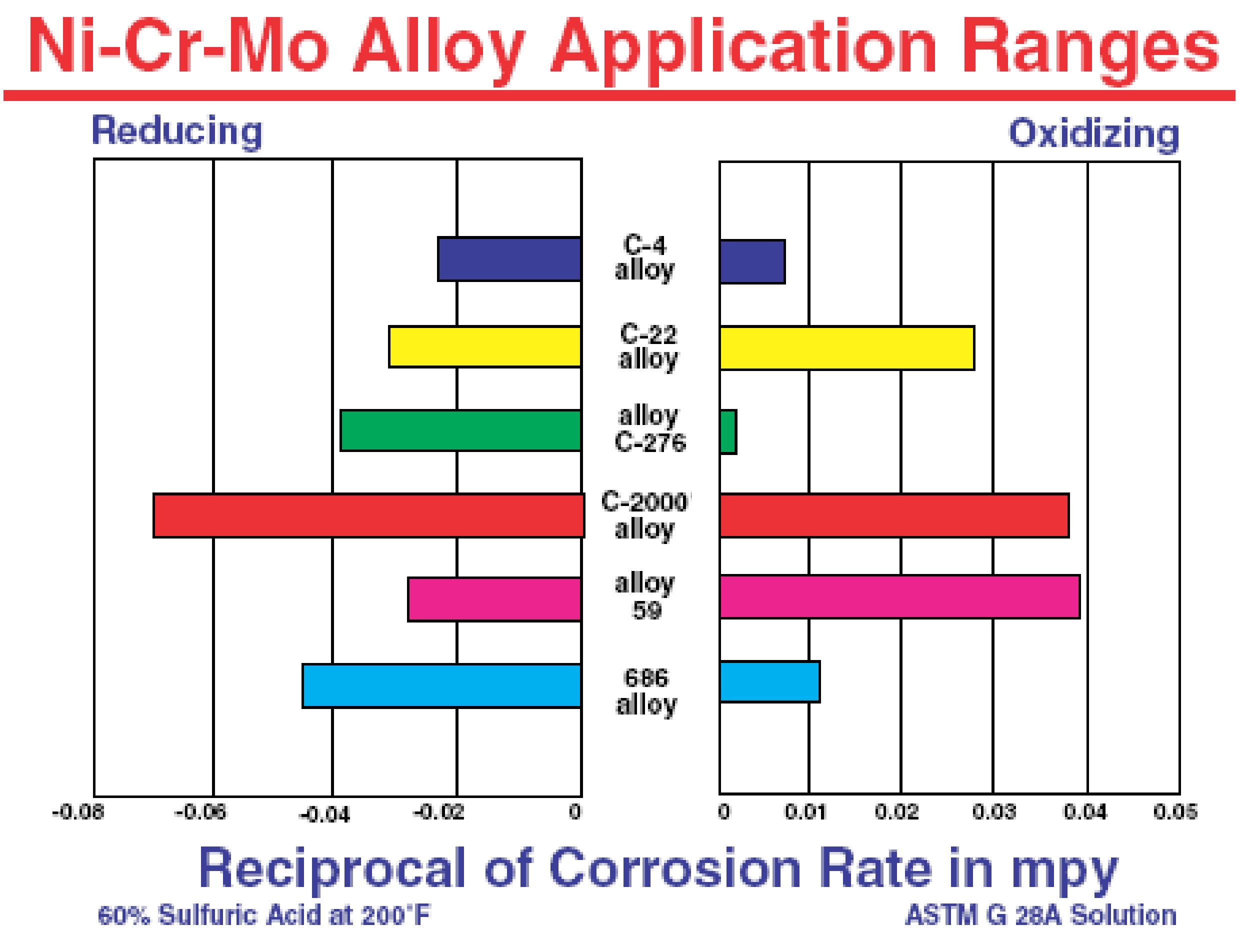



Illustration of versatility of Soonv C-2000 alloy using reciprocals of corrosion rates in reducing and oxidizing acids

# PRINCIPAL FEATURES

*Corrosion Performance*

The nickel-chromium-molybdenum (Ni-Cr-Mo) C-type alloys have a long history of use in the Chemical Process Industries and are known for their versatility. Not only do they resist all acids (especially hydrochloric, sulfuric, and hydrofluoric) over large temperature ranges, but they also resist the insidious types of attack induced by chlorides and other halide solutions, specifically pitting, crevice attack, and stress corrosion cracking.

The technical objective during the design of SOONV ® C-2000® alloy* was even greater versatility, as compared with the traditional Ni-Cr-Mo alloys. This was accomplished by use of a high chromium content (23 wt.%), a high molybdenum content (16 wt.%), and a small but effective addition of copper (1.6 wt.%). The copper was found to provide enhanced temperature capability in sulfuric acid, hydrofluoric acid, and dilute hydrochloric acid.

*Product Forms*

C-2000 alloy is available in plate, sheet, strip, billet, bar, wire, covered electrodes, pipe, and tubing.

*Applications*

- Chemical process industry reactors, heat exchangers, columns, and piping.
- Pharmaceutical industry reactors and dryers.
- Flue gas desulfurization systems.

*Field Test Program*

Samples of C-2000 alloy are available for field trials. Furthermore, samples can be weighed prior to delivery, and then reweighed after test by the customer, and reports provided on corrosion rates and other observations.

*Specifications*

C-2000 alloy is covered by ASME, ASTM, AWS, DIN, and TÜV specifications. A listing of these is provided on page 14.

# COMPOSITION, wt. %**

| Ni | Cr | Mo | Fe | Cu | Al | Mn | Si | C |
|---|---|---|---|---|---|---|---|---|
| BAL | 23 | 16 | 3*** | 1.6 | 0.5*** | 0.5*** | 0.08*** | 0.01*** |

*Covered by U.S. Patent 6,280,540

** The undiluted deposit composition of C-2000 alloy covered electrodes contains up to 0.02% carbon and 0.2% silicon.

*** Maximum.

# PHYSICAL PROPERTIES

| Physical Property | Metric Units | | British Units | |
|---|---|---|---|---|
| Density | RT | 8.50 g/cm.$^3$ | RT | 0.307 lb/in.$^3$ |
| Electrical Resistivity | RT | 1.28 μohm.m | RT | 50.6 μohm.in |
| | 100°C | 1.29 μohm.m | 200°F | 50.8 μohm.in |
| | 200°C | 1.30 μohm.m | 400°F | 51.2 μohm.in |
| | 300°C | 1.31 μohm.m | 600°F | 51.6 μohm.in |
| | 400°C | 1.32 μohm.m | 800°F | 52.2 μohm.in |
| | 500°C | 1.34 μohm.m | 1000°F | 52.9 μohm.in |
| | 600°C | 1.35 μohm.m | 1200°F | 53.0 μohm.in |
| Thermal Conductivity | RT | 9.1 W/m.°C | RT | 63 btu.in/h.ft$^2$.°F |
| | 100°C | 10.8 W/m.°C | 200°F | 74 btu.in/h.ft$^2$.°F |
| | 200°C | 12.6 W/m.°C | 400°F | 88 btu.in/h.ft$^2$.°F |
| | 300°C | 14.1 W/m.°C | 600°F | 99 btu.in/h.ft$^2$.°F |
| | 400°C | 16.1 W/m.°C | 800°F | 114 btu.in/h.ft$^2$.°F |
| | 500°C | 18.0 W/m.°C | 1000°F | 133 btu.in/h.ft$^2$.°F |
| | 600°C | 21.6 W/m.°C | 1200°F | 162 btu.in/h.ft$^2$.°F |
| Mean Coefficient of Thermal Expansion | 25-100°C | 12.4 μm/m.°C | 77-200°F | 6.9 μin/in.°F |
| | 25-200°C | 12.4 μm/m.°C | 77-400°F | 6.9 μin/in.°F |
| | 25-300°C | 12.6 μm/m.°C | 77-600°F | 7.0 μin/in.°F |
| | 25-400°C | 12.9 μm/m.°C | 77-800°F | 7.2 μin/in.°F |
| | 25-500°C | 13.2 μm/m.°C | 77-1000°F | 7.4 μin/in.°F |
| | 25-600°C | 13.3 μm/m.°C | 77-1200°F | 7.6 μin/in.°F |
| Thermal Diffusivity | RT | 0.025 cm$^2$/s | RT | 0.10 ft$^2$/h |
| | 100°C | 0.029 cm$^2$/s | 212°F | 0.11 ft$^2$/h |
| | 200°C | 0.033 cm$^2$/s | 392°F | 0.13 ft$^2$/h |
| | 300°C | 0.036 cm$^2$/s | 572°F | 0.14 ft$^2$/h |
| | 400°C | 0.040 cm$^2$/s | 752°F | 0.16 ft$^2$/h |
| | 500°C | 0.043 cm$^2$/s | 932°F | 0.17 ft$^2$/h |
| | 600°C | 0.047 cm$^2$/s | 1112°F | 0.18 ft$^2$/h |
| Specific Heat | RT | 428 J/kg.°C | RT | 0.10 btu/lb.°F |
| | 100°C | 434 J/kg.°C | 212°F | 0.10 btu/lb.°F |
| | 200°C | 443 J/kg.°C | 392°F | 0.11 btu/lb.°F |
| | 300°C | 455 J/kg.°C | 572°F | 0.11 btu/lb.°F |
| | 400°C | 468 J/kg.°C | 752°F | 0.11 btu/lb.°F |
| | 500°C | 486 J/kg.°C | 932°F | 0.12 btu/lb.°F |
| | 600°C | 536 J/kg.°C | 1112°F | 0.13 btu/lb.°F |
| Dynamic Modulus of Elasticity | RT | 207 GPa | RT | $30.0 \times 10^6$ psi |
| | 316°C | 190 GPa | 600°F | $27.5 \times 10^6$ psi |
| | 427°C | 177 GPa | 800°F | $25.6 \times 10^6$ psi |
| | 538°C | 171 GPa | 1000°F | $24.8 \times 10^6$ psi |
| | 649°C | 162 GPa | 1200°F | $23.5 \times 10^6$ psi |
| Melting Range | 1328-1358°C | | 2422-2476°F | |

# LOCALIZED CORROSION DATA

## Critical Crevice (CCT) and Critical Pitting (CPT) Temperatures in Acidified Ferric Chloride (ASTM G 48, Methods D and C)

To assess the resistance of alloys to pitting and crevice attack, it is customary to measure their Critial Crevice Temperatures and Critical Pitting Temperatures in acidified 6 wt.% ferric chloride, in accordance with the procedures defined in ASTM Standard G 48. These values represent the lowest temperatures at which crevice attack and pitting attack are encountered in acidified ferric chloride, within 72 hours.

| | Critical Crevice Temperatures | | Critical Pitting Temperatures | |
|---|---|---|---|---|
| ALLOY | °C | °F | °C | °F |
| 316L | 0 | 32 | 15 | 59 |
| 254SMO® | 30 | 86 | 60 | 140 |
| 625 | 40 | 104 | 100 | 212 |
| C-22 | 80 | 176 | >120 | >248 |
| C-276 | 55 | 131 | >120 | >248 |
| **C-2000** | **80** | **176** | **>120** | **>248** |

## Critical Pitting Temperatures in Green Death Solution

Another solution commonly used for assessing the pitting resistance of nickel alloys is 11.5% sulfuric acid + 1.2% hydrochloric acid + 1% ferric chloride + 1% cupric chloride, otherwise known as Green Death. Listed are Critical Pitting Temperatures of C-2000 and other alloys in Green Death, based on tests of 24 hours.

| | Critical Pitting Temperatures | |
|---|---|---|
| ALLOY | °C | °F |
| 316L | 25 | 77 |
| 625 | 75 | 167 |
| C-4 | 90 | 194 |
| C-22 | 120 | 248 |
| C-276 | 105 | 221 |
| **C-2000** | **110** | **230** |

## Seawater Crevice Corrosion Results

Seawater is probably the most common aqueous salt solution. Not only is it encountered in marine transportation and offshore oil rigs, but it is also used as a coolant in coastal industries. Listed are some recent data, generated as part of a U.S. Navy study at the LaQue Laboratories in Wrightsville Beach, North Carolina.* Crevice tests were performed in both still (quiescent) and flowing seawater, at 29°C, plus or minus 3°C. Two samples of each alloy were tested in still water for 180 days, and two samples of each alloy were tested in flowing water for 180 days. Each sample contained two possible crevice sites.

| ALLOY | QUIESCENT NO. OF SITES | QUIESCENT DEPTH, mm | FLOWING NO. OF SITES | FLOWING DEPTH, mm |
|---|---|---|---|---|
| 316L | 2 | 1.80 | 2 | 0.32 |
| 254SMO | 2 | 1.25 | 2 | 0.01 |
| 625 | 2 | 0.11 | 2 | <0.01 |
| C-22 | 0 | 0 | 0 | 0 |
| C-276 | 1 | 0.12 | 0 | 0 |
| **C-2000** | **0** | **0** | **0** | **0** |

*Ref. D. M. Aylor et al, Paper No. 329, CORROSION 99, NACE International, 1999.

# UNIFORM CORROSION DATA (C-2000, C-4, C-22)

| Chemical | Conc. | Temperature | | Corrosion Rate | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | wt.% | °C | °F | C-2000 | | C-4 | | C-22 | |
| | | | | mm/y | mpy | mm/y | mpy | mm/y | mpy |
| Hydrochloric Acid | 1 | Boiling | | **0.01** | **0.2** | 0.48 | 18.8 | 0.06 | 2.2 |
| | 5 | 79 | 175 | **<0.01** | **0.1** | 0.98 | 38.6 | 1.44 | 56.6 |
| | 10 | 38 | 100 | **<0.01** | **<0.1** | 0.19 | 7.3 | 0.01 | 0.4 |
| | 20 | 38 | 100 | **0.16** | **6.3** | 0.14 | 5.4 | 0.20 | 7.7 |
| Hydrobromic Acid | 2.5 | Boiling | | **0.01** | **0.2** | 0.08 | 3.3 | 0.02 | 0.6 |
| | 5 | 93 | 200 | **0.01** | **0.2** | 0.76 | 29.9 | 0.01 | 0.3 |
| | 7.5 | 93 | 200 | **<0.01** | **0.1** | 0.76 | 29.9 | 0.45 | 17.8 |
| | 10 | 79 | 175 | **<0.01** | **<0.1** | 0.53 | 20.9 | 0.01 | 0.3 |
| | 20 | 66 | 150 | **<0.01** | **<0.1** | 0.35 | 13.7 | 0.46 | 18.2 |
| Hydrofluoric Acid | 1 | 79 | 175 | **0.18** | **7.0** | N/T | N/T | 0.21 | 8.2 |
| | 5 | 52 | 125 | **0.09** | **3.7** | N/T | N/T | 0.15 | 6.0 |
| | 10 | 52 | 125 | **0.22** | **8.7** | N/T | N/T | 0.33 | 13.1 |
| | 20 | 52 | 125 | **0.48** | **18.8** | N/T | N/T | 0.53 | 21.0 |
| Sulfuric Acid | 10 | 93 | 200 | **0.02** | **0.8** | 0.19 | 7.3 | 0.04 | 1.6 |
| | 20 | 93 | 200 | **0.03** | **1.0** | 0.38 | 15.1 | 0.28 | 11.0 |
| | 30 | 93 | 200 | **0.04** | **1.5** | 0.54 | 21.3 | 0.68 | 26.8 |
| | 40 | 79 | 175 | **0.01** | **0.5** | 0.38 | 15.0 | 0.31 | 12.3 |
| | 50 | 79 | 175 | **0.02** | **0.7** | 0.63 | 24.7 | 0.40 | 15.9 |
| | 60 | 79 | 175 | **0.02** | **0.9** | 0.67 | 26.4 | 0.67 | 26.4 |
| | 70 | 66 | 150 | **0.01** | **0.2** | 0.14 | 5.7 | 0.28 | 11.0 |
| | 80 | 66 | 150 | **0.06** | **2.2** | 0.13 | 5.1 | N/T | N/T |
| | 90 | 79 | 175 | **0.07** | **2.9** | 0.71 | 27.9 | N/T | N/T |
| Nitric Acid | 20 | Boiling | | **0.02** | **0.7** | 0.38 | 15.0 | 0.06 | 2.3 |
| | 40 | Boiling | | **0.24** | **9.5** | 1.27 | 50.0 | 0.26 | 10.4 |
| | 60 | 93 | 200 | **0.19** | **7.4** | 0.73 | 28.7 | 0.19 | 7.6 |
| | 70 | 93 | 200 | **0.29** | **11.4** | 0.95 | 37.4 | 0.33 | 13.0 |
| Phosphoric Acid | 50 | Boiling | | **0.03** | **1.1** | 0.27 | 10.7 | 0.03 | 1.3 |
| | 60 | Boiling | | **0.08** | **3.2** | 0.11 | 4.3 | 0.56 | 21.9 |
| | 70 | Boiling | | **0.15** | **6.0** | 0.13 | 5.1 | 1.04 | 41.0 |
| | 80 | Boiling | | **0.40** | **15.6** | 0.26 | 10.3 | 3.02 | 119.0 |
| Chromic Acid | 10 | 66 | 150 | **0.10** | **3.9** | N/T | N/T | 0.13 | 5.0 |
| | 20 | 66 | 150 | **0.61** | **24.1** | N/T | N/T | 0.68 | 26.7 |
| Acetic Acid | 99 | Boiling | | **<0.01** | **<0.1** | <0.01 | 0.1 | <0.01 | 0.1 |
| Formic Acid | 88 | Boiling | | **0.01** | **0.4** | 0.05 | 2.0 | 0.02 | 0.9 |
| ASTM G 28A** | | Boiling | | **0.67** | **26.3** | 3.52 | 138.6 | 1.02 | 40.0 |
| ASTM G 28B*** | | Boiling | | **0.11** | **4.2** | N/T | N/T | 0.20 | 8.0 |

*N/T = not tested

**G 28A = 50% $H_2SO_4$ + 42 g/l $Fe_2(SO_4)_3$

***G 28B = 23% $H_2SO_4$ + 1.2% HCl + 1% $FeCl_3$ + 1% $CuCl_2$

# UNIFORM CORROSION DATA (C-276, 625)

| Chemical | Conc. | Temperature | | Corrosion Rate | | | |
|---|---|---|---|---|---|---|---|
| | wt.% | °C | °F | C-276 | | 625 | |
| | | | | mm/y | mpy | mm/y | mpy |
| Hydrochloric Acid | 1 | Boiling | | 0.33 | 13.0 | 0.23 | 8.9 |
| | 5 | 79 | 175 | 0.75 | 29.4 | 4.65 | 183.0 |
| | 10 | 38 | 100 | 0.17 | 6.8 | 0.30 | 11.9 |
| | 20 | 38 | 100 | 0.14 | 5.4 | 0.36 | 14.1 |
| Hydrobromic Acid | 2.5 | Boiling | | 0.13 | 5.0 | <0.01 | 0.1 |
| | 5 | 93 | 200 | 0.15 | 5.8 | 0.60 | 23.7 |
| | 7.5 | 93 | 200 | 0.73 | 28.7 | 0.93 | 36.5 |
| | 10 | 79 | 175 | 0.51 | 20.0 | 0.82 | 32.3 |
| | 20 | 66 | 150 | 0.37 | 14.5 | 0.65 | 25.7 |
| Hydrofluoric Acid | 1 | 79 | 175 | 0.40 | 15.9 | 0.31 | 12.2 |
| | 5 | 52 | 125 | 0.34 | 13.4 | 0.70 | 27.4 |
| | 10 | 52 | 125 | 0.41 | 16.0 | 2.23 | 87.8 |
| | 20 | 52 | 125 | 0.48 | 18.8 | 4.33 | 170.5 |
| Sulfuric Acid | 10 | 93 | 200 | 0.14 | 5.5 | 0.24 | 9.5 |
| | 20 | 93 | 200 | 0.40 | 15.6 | 0.58 | 23.0 |
| | 30 | 93 | 200 | 0.42 | 16.4 | 0.68 | 26.9 |
| | 40 | 79 | 175 | 0.19 | 7.5 | 0.58 | 22.8 |
| | 50 | 79 | 175 | 0.26 | 10.3 | 0.89 | 35.2 |
| | 60 | 79 | 175 | 0.30 | 11.8 | 0.92 | 36.2 |
| | 70 | 66 | 150 | 0.05 | 1.8 | 0.63 | 24.7 |
| | 80 | 66 | 150 | 0.04 | 1.6 | 0.91 | 35.8 |
| | 90 | 79 | 175 | 0.05 | 1.9 | 6.97 | 274.5 |
| Nitric Acid | 20 | Boiling | | 0.66 | 25.9 | 0.01 | 0.3 |
| | 40 | Boiling | | 4.42 | 174.0 | 0.14 | 5.5 |
| | 60 | 93 | 200 | 2.03 | 80.0 | 0.06 | 2.4 |
| | 70 | 93 | 200 | 2.62 | 103.0 | 0.08 | 3.2 |
| Phosphoric Acid | 50 | Boiling | | 0.18 | 6.9 | 0.02 | 0.9 |
| | 60 | Boiling | | 0.28 | 11.1 | 0.16 | 6.2 |
| | 70 | Boiling | | 0.13 | 5.2 | 0.89 | 35.2 |
| | 80 | Boiling | | 0.31 | 12.3 | 4.90 | 193.0 |
| Chromic Acid | 10 | 66 | 150 | 0.13 | 5.0 | 0.13 | 5.2 |
| | 20 | 66 | 150 | 0.53 | 21.0 | 1.00 | 39.3 |
| Acetic Acid | 99 | Boiling | | <0.01 | 0.1 | <0.01 | 0.1 |
| Formic Acid | 88 | Boiling | | 0.04 | 1.4 | 0.24 | 9.3 |
| ASTM G 28A** | | Boiling | | 5.97 | 235.0 | 0.48 | 18.8 |
| ASTM G 28B*** | | Boiling | | 1.23 | 48.3 | N/T | N/T |

*N/T = not tested

**G 28A = 50% $H_2SO_4$ + 42 g/l $Fe_2(SO_4)_3$

***G 28B = 23% $H_2SO_4$ + 1.2% HCl + 1% $FeCl_3$ + 1% $CuCl_2$

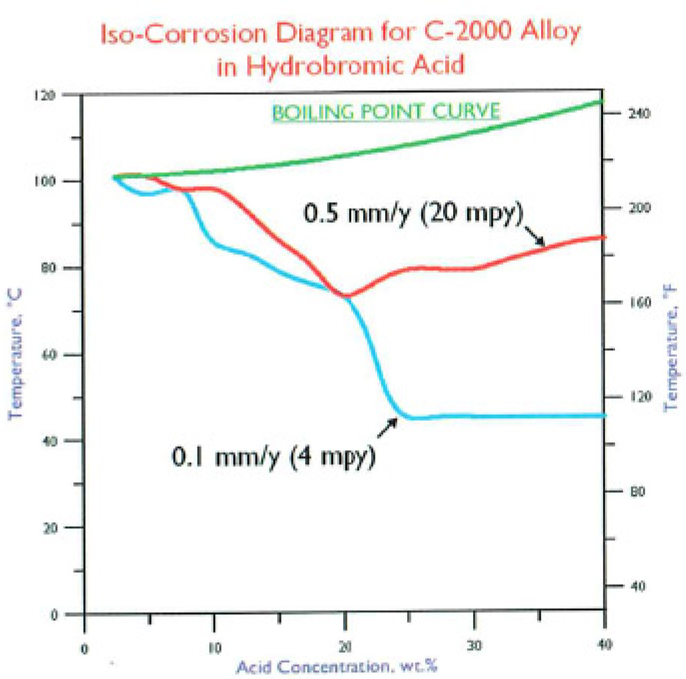
# STRESS CORROSION CRACKING

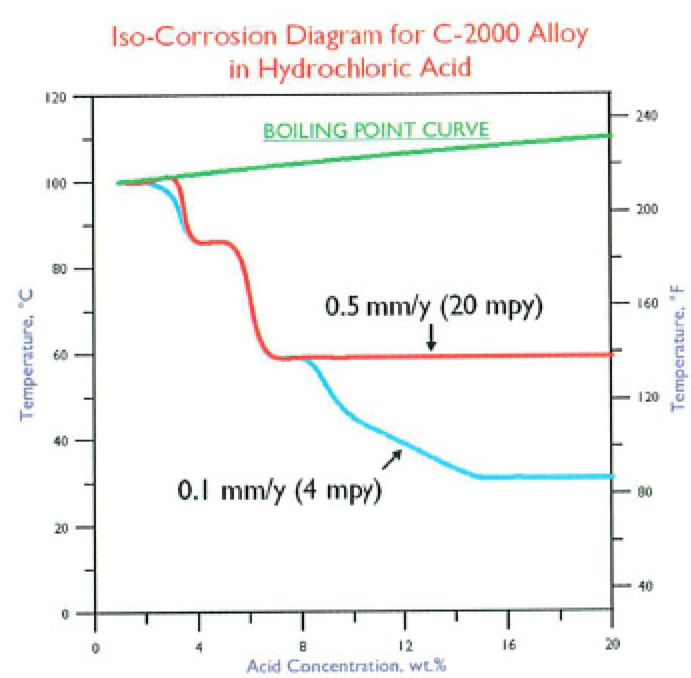
A common solution for assessing the resistance to chloride-induced stress corrosion cracking of a material is boiling 45% magnesium chloride. This table indicates the times required to induce cracking in U-bend samples of several materials. The tests were stopped after six weeks (1008 hours).

| ALLOY | TIME TO CRACKING |
|---|---|
| 316L | 2 h |
| 254SMO | 24 h |
| 625 | No cracking in 1008 h |
| C-22 | No cracking in 1008 h |
| C-276 | No cracking in 1008 h |
| **C-2000** | **No cracking in 1008 h** |

# ISO-CORROSION DIAGRAMS

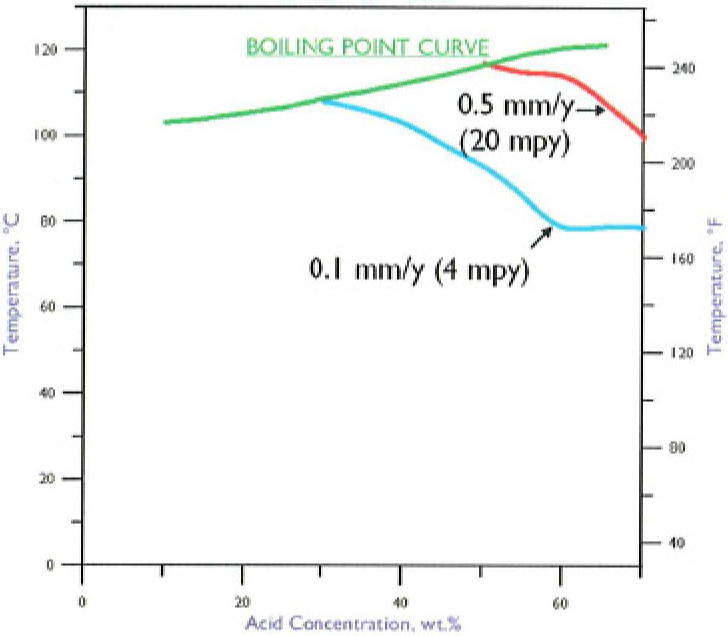
Each of these iso-corrosion diagrams was constructed using numerous corrosion rate values, generated at different acid concentrations and temperatures. The blue line represents those combinations of acid concentration and temperature at which a corrosion rate of 0.1 mm/y (4 mils per year) is expected, based on laboratory tests. Below the line, rates under 0.1 mm/y are expected. Similarly, the red line indicates the combinations of acid concentration and temperature at which a corrosion rate of 0.5 mm/y (20 mils per year) is expected. Above the red line, rates of over 0.5 mm/y are expected. Between the blue and red lines, corrosion rates are expected to fall between 0.1 and 0.5 mm/y.



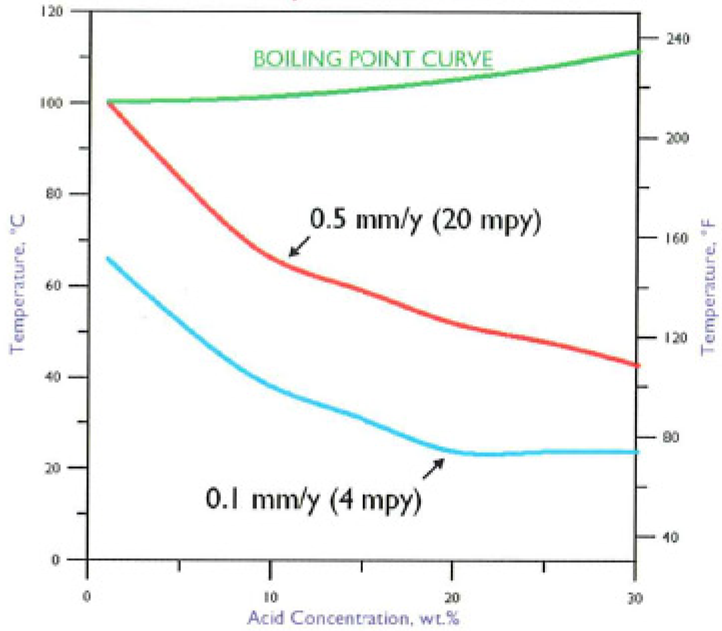



# ISOCORROSION DIAGRAMS

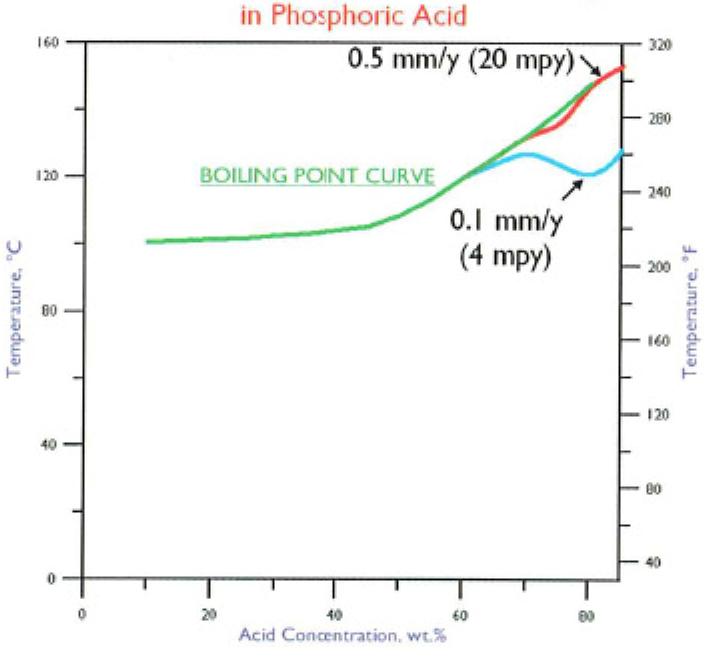
Iso-Corrosion Diagram for C-2000 Alloy
in Nitric Acid



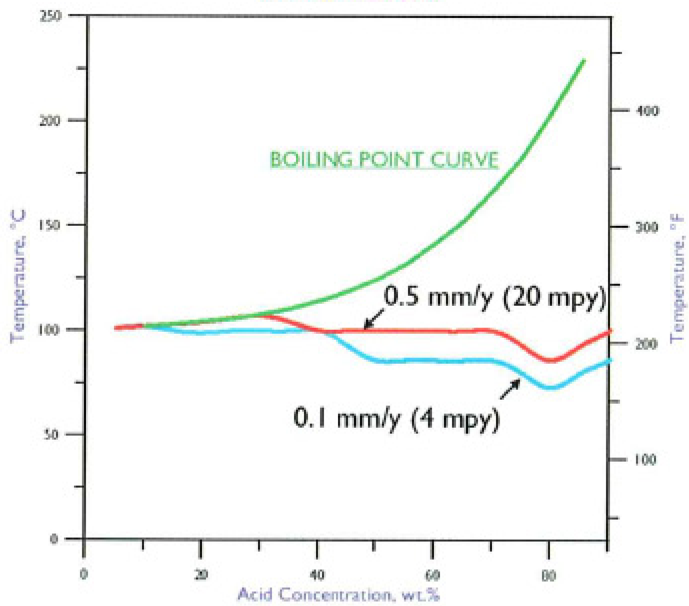

Iso-Corrosion Diagram for C-2000 Alloy
in Hydrofluoric Acid




Iso-Corrosion Diagram for C-2000 Alloy
in Phosphoric Acid




Iso-Corrosion Diagram for C-2000 Alloy
in Sulfuric Acid



# MECHANICAL PROPERTIES

## Room Temperature Tensile Data

| Form | Annealing Temperature | | Thickness/ Diameter | | 0.2% Offset Yield Strength | | Ultimate Tensile Strength | | Elongation |
|---|---|---|---|---|---|---|---|---|---|
| | °C | °F | mm | in | MPa | ksi | MPa | ksi | % |
| Sheet | 1163 | 2125 | 0.6 | 0.025 | 372 | 54.0 | 752 | 109.0 | 61.0 |
| Sheet | 1163 | 2125 | 2.0 | 0.079 | 400 | 58.0 | 786 | 114.0 | 62.0 |
| Sheet | 1163 | 2125 | 3.2 | 0.125 | 359 | 52.0 | 758 | 110.0 | 64.0 |
| Plate | 1149 | 2100 | 4.8 | 0.188 | 407 | 59.0 | 745 | 108.0 | 63.0 |
| Plate | 1149 | 2100 | 6.4 | 0.25 | 393 | 57.0 | 731 | 106.0 | 63.0 |
| Plate | 1149 | 2100 | 12.7 | 0.5 | 365 | 53.0 | 731 | 106.0 | 69.0 |
| Plate | 1149 | 2100 | 25.4 | 1.0 | 359 | 52.0 | 717 | 104.0 | 71.0 |
| Plate | 1149 | 2100 | 38.1 | 1.5 | 331 | 48.0 | 696 | 101.0 | 76.0 |
| Bar | 1149 | 2100 | 9.7 | 0.38 | 331 | 48.0 | 745 | 108.0 | 67.0 |
| Bar | 1149 | 2100 | 19.1 | 0.75 | 345 | 50.0 | 738 | 107.0 | 69.0 |
| Bar | 1149 | 2100 | 25.4 | 1.0 | 379 | 55.0 | 758 | 110.0 | 68.0 |
| Bar | 1149 | 2100 | 50.8 | 2.0 | 379 | 55.0 | 724 | 105.0 | 71.0 |
| Bar | 1149 | 2100 | 88.9 | 3.5 | 386 | 56.0 | 738 | 107.0 | 71.0 |

## Elevated Temperature Tensile Data (Averaged for Plates and Bars)

| Temperature | | 0.2% Offset Yield Strength | | Ultimate Tensile Strength | | Elongation |
|---|---|---|---|---|---|---|
| °C | °F | MPa | ksi | MPa | ksi | % |
| 93 | 200 | 319 | 46.3 | 724 | 105.0 | 70.3 |
| 149 | 300 | 308 | 44.7 | 684 | 99.2 | 68.8 |
| 204 | 400 | 283 | 41.0 | 676 | 98.0 | 69.3 |
| 260 | 500 | 260 | 37.7 | 641 | 93.0 | 67.9 |
| 316 | 600 | 243 | 35.3 | 616 | 89.3 | 72.7 |
| 371 | 700 | 234 | 33.9 | 605 | 87.8 | 69.8 |
| 427 | 800 | 216 | 31.3 | 609 | 88.3 | 73.0 |
| 482 | 900 | 223 | 32.4 | 585 | 84.9 | 72.6 |
| 538 | 1000 | 214 | 31.0 | 586 | 85.0 | 75.3 |
| 649 | 1200 | 209 | 30.3 | 554 | 80.3 | 70.7 |

## Charpy V-Notch Impact Data (Plate)

| Test Temperature | | Condition | Impact Strength | |
|---|---|---|---|---|
| °C | °F | | J | ft.lbf |
| RT | RT | Annealed | >358 | >264 |
| -196 | -320 | Annealed | >358 | >264 |
| RT | RT | Annealed then Aged for 100 h at 260°C/500°F | >358 | >264 |
| -196 | -320 | Annealed then Aged for 100 h at 260°C/500°F | 342 | 252 |
| RT | RT | Annealed then Aged for 100 h at 538°C/1000°F | 224 | 165 |
| -196 | -320 | Annealed then Aged for 100 h at 538°C/1000°F | 174 | 128 |

# WELDING AND FABRICATION

## Welding

The weldability of C-2000 alloy is similar to that of C-276 alloy. To weld the C-type alloys, three processes are commonly used. For sheet welds and plate root passes, gas tungsten arc (GTAW) welding is favored. For plate welds, the gas metal arc (GMAW) process is preferred. For field welding, the shielded metal arc process, using coated electrodes, is favored. Submerged arc welding is not recommended as this process is characterized by high heat input to the base metal and slow cooling of the weld.

To minimize the precipitation of second phases in regions affected by the heat of welding, a maximum interpass temperature of 93°C (200°F) is recommended for the C-type alloys. Also, welding of cold-worked materials is strongly discouraged, since they sensitize more quickly and induce residual stresses. A full solution anneal, followed by water quenching, is recommended for cold-worked structures prior to welding.

**Base Metal Preparation**

The joint surface and adjacent area should be thoroughly cleaned before welding. All grease, oil, crayon marks, sulfur compounds, and other foreign matter should be removed.

**Filler Metal Selections**

For gas tungsten arc and gas metal arc welding, C-2000 filler wire (ERNiCrMo-17) is suggested. For shielded metal arc welding, C-2000 covered electrodes (ENiCrMo-17) are suggested.

## Tensile Data for Weldments

| Welding Process | Form | Test Temperature °C | Test Temperature °F | 0.2% Offset Yield Strength MPa | 0.2% Offset Yield Strength ksi | Ultimate Tensile Strength MPa | Ultimate Tensile Strength ksi | Elongation % |
|---|---|---|---|---|---|---|---|---|
| Gas Tungsten Arc Welding (GTAW) | Transverse Sample from Welded Plate of Thicknessof 12.7 mm/0.5 in | RT | RT | 465 | 67.4 | 778 | 112.8 | 36.4 |
| | | 260 | 500 | 326 | 47.3 | 642 | 93.1 | 42.1 |
| | | 538 | 1000 | 299 | 43.3 | 558 | 80.6 | 38.9 |
| | All Weld Metal Sample of Diameter 12.7 mm/0.5 in from Cruciform | RT | RT | 493 | 71.5 | 733 | 106.3 | 44.0 |
| | | 260 | 500 | 391 | 56.7 | 614 | 89.0 | 47.4 |
| | | 538 | 1000 | 365 | 52.9 | 528 | 76.6 | 46.6 |
| Synergic Gas Metal Arc Welding (GMAW) | Transverse Sample from Welded Plate of Thickness 12.7 mm/0.5 in | RT | RT | 456 | 66.2 | 783 | 113.5 | 42.1 |
| | | 260 | 500 | 352 | 51.1 | 654 | 94.8 | 43.1 |
| | | 538 | 1000 | 301 | 43.7 | 582 | 84.4 | 45.6 |
| | All Weld Metal Sample of Diameter 12.7 mm/0.5 in from Cruciform | RT | RT | 495 | 71.8 | 740 | 107.4 | 46.5 |
| | | 260 | 500 | 394 | 57.2 | 620 | 89.9 | 46.4 |
| | | 538 | 1000 | 377 | 54.7 | 552 | 80.1 | 50.5 |
| Shielded Metal Arc Welding | Transverse Sample from Welded Plate of Thickness 25.4 mm/1.0 in (Flat Position) | RT | RT | 364 | 52.8 | 718 | 104.1 | 58.1 |
| | All Weld Metal Sample of Diameter 12.7 mm/0.5 in taken from Plate Weld | RT | RT | 510 | 74.0 | 744 | 107.9 | 40.4 |
| | | 450 | 842 | 386 | 56.0 | 565 | 81.9 | 43.9 |

# WELDING AND FABRICATION

## Charpy V-Notch Impact Data for Weldments

| Welding Process | Form | Notch Position | Test Temperature °C | Test Temperature °F | Impact Strength J | Impact Strength ft.lbf |
|---|---|---|---|---|---|---|
| Synergic Gas Metal Arc Welding (GMAW) | Transverse Sample from Welded Plate of Thickness 12.7 mm./0.5 in | Mid-Weld | RT | RT | 142 | 105 |
| | | | -196 | -320 | 106 | 78 |
| | | Heat Affected Zone | RT | RT | 240 | 177 |
| | | | -196 | -320 | 203 | 150 |
| Shielded Metal Arc Welding (Stick) | All Weld Metal Sample taken from Plate Weld | In Weld | RT | RT | 71 | 52 |
| | | | -196 | -320 | 45 | 33 |

## Fabrication

### Heat Treatment

Wrought forms of Soonv C-2000 alloy are furnished in the solution annealed condition, unless otherwise specified. The standard solution annealing treatment consists of heating to 1135°C (2075°F) followed by rapid air-cooling or water quenching. Parts which have been hot formed should be solution annealed prior to final fabrication or installation.

### Forming

C-2000 alloy has excellent forming characteristics, and cold forming is the preferred method of shaping. The alloy can be easily cold worked due to its good ductility. The alloy is generally stiffer than the austenitic stainless steels; therefore, more energy is required during cold forming. For further information, please consult publication H-2010.

## Health and Safety

Welding can be a safe occupation. Those in the welding industry, however, should be aware of the potential hazards associated with welding fumes, gases, radiation, electric shock, heat, eye injuries, burns, etc. Also, local, municipal, state, and federal regulations (such as those issued by OSHA) relative to welding and cutting processes should be considered.

Nickel-, cobalt-, and iron-base alloy products may contain, in varying concentration, the following elemental constituents: aluminum, cobalt, chromium, copper, iron, manganese, molybdenum, nickel and tungsten.

Inhalation of metal dust or fumes generated from welding, cutting, grinding, melting, or dross handling of these alloys may cause adverse health effects such as reduced lung function, nasal and mucous membrane irritation. Exposure to dust or fumes which may be generated in working with these alloys may also cause eye irritation, skin rash and effects on other organ systems The operation and maintenance of welding and cutting equipment should conform to the provision of American National Standard ANSI/AWS Z49.1, "Safety in Welding and Cutting". Attention is especially called to Section 4 (Protection of Personnel) and 5 (Health Protection and Ventilation) of ANSI/AWS Z49.1. Mechanical ventilation is advisable and, under certain conditions such as a very confined space, is necessary during welding or cutting operations, or both, to prevent possible exposure to hazardous fumes, gases, or dust that may occur.

# MACHINING

The following are guidelines for performing typical machining operations upon C-2000 alloy wrought stock. Exact details for specific machining jobs will vary with circumstances of the particular job. Other tool materials not listed here may be suitable for machining C-2000 alloy under various conditions.

## Recommended Tool Types and Machining Conditions

| Operations | Carbide Tools | High Speed Steel Tools |
|---|---|---|
| Drilling | C-2 grade not recommended, but tipped drills may be successful on rigid setup of no great depth. The web must be thinned to reduce thrust Use 135° included angle on point, Gun drill can be used.<br>Speed: 50 sfm.<br>Oil[2] or water-base[3] coolant. Coolant-feed carbide tipped drills may be economical in some setups. | M-33, M-40 series[1] or T-15: Use short drills, heavy web, 135° crank-shaft, grind points wherever possible.<br>Speed: 10-15 sfm.<br>Feed: 0.001 in. rev. 1/8 in. dia.<br>0.002 in. rev. 1/4 in. dia.<br>0.003 in. rev. 1/2 in. dia.<br>0.005 in. rev. 3/4 in. dia.<br>0.007 in. rev. 1 in. dia.<br>Oil or water-base coolant. Use coolant feed drills if possible. |
| Normal Roughing; Turning or Facing | C-2 or C-3 grade: Negative rake square insert, 45° SCEA[4], 1/32 in. nose radius.<br>Tool holder: 5° neg. back rake, 5° neg. side rake.<br>Speed: 90 sfm depending on rigidity of set up, 0.010 in. feed, 0.150 in. depth of cut.<br>Dry[5], oil, or water-base coolant. | |
| Finishing; Turning or Facing | C-2 or C-3 grade: Positive rake square insert, if possible, 45° SCEA, 1/32 in. nose radius.<br>Tool holder: 5° pos. back rake, 5° pos. side rake.<br>Speed: 95-110 sfm, 0.005-0.007 in. feed, 0.040 in. depth of cut.<br>Dry or water-base coolant. | |

NOTES:
1. M-40 series High Speed Steels include M-41, M-42, M-43, M-44, M-45 and M-46 at the time of writing. Others may be added and should be equally suitable.
2. Oil coolant should be a premium quality, sulfochlorinated oil with extreme pressure additives. A viscosity at 100°F from 50 to 125 SSU.
3. Water-base coolant should be premium quality, sulfochlorinated water soluble oil or chemical emulsion with extreme pressure additives. Dilute with water to make 15:1 mix. Water-base coolant may cause chipping and rapid failure of carbide tools in interrupted cuts.
4. SCEA - Side cutting edge angle or lead angle of the tool.
5. At any point where dry cutting is recommended, an air jet directed on the tool may provide substantial tool life increase. A water-base coolant mist may also be effective.

# SPECIFICATIONS

| SOONV C-2000 alloy (UNS N06200) | | Metal No. 2316 |
|---|---|---|
| ASME/ASTM | SB 564/B 564 | Forgings |
| ASME/ASTM | SB 574/B 574 | Rod |
| ASME/ASTM | SB 575/B 575 | Plate, Sheet, and Strip |
| ASME/ASTM | SB 619/B 619 | Welded Pipe |
| ASME/ASTM | SB 622/B 622 | Seamless Pipe and Tubing |
| ASME/ASTM | SB 626/B 626 | Welded Tube |
| ASME/ASTM | SB 366/B 366 | Fittings |
| ASME/ASTM | SB 462/B 462 | Pipe Flanges, Forged Fittings |
| ASTM | B 472 | Billets and Bars for Reforging |
| ASME | Section VIII, Div. 1 (P=43) | All Forms |
| ASME | Code Case 2337 (F=43) | Bare Welding Rods |
| ASME | Code Case 2338 (F=43) | Covered Welding Electrodes |
| ASME | B16.5 | Pipe Flanges and Flanged Fittings |
| ASME | B16.34 | Valves-Flanged, Threaded, and Welding Ends |
| AWS | A5.14 (ERNiCrMo-17) | Bare Welding Rods |
| AWS | A5.11 (ENiCrMo-17) | Covered Welding Electrodes |
| DIN | 17744 No. 2.4675 | All Forms |
| DIN | NiCr23Mo16Cu | All Forms |
| DIN | 2.4699 (EL-NiCr23Mo16Cu) | Covered Welding Electrodes |
| DIN | 2.4698 (SG-NiCr23Mo16Cu) | Bare Welding Rods |
| TÜV | Werkstoffblatt 539 | All Forms |
| TÜV | Kennblatt 9679.00 | Welding Wire |
| TÜV | Kennblatt 9678.00 | Welding Rod |
| TÜV | Kennblatt 9677.00 | Covered Welding Electrodes |

Material Safety Data Sheets H-2071 and H-1072