# Alloy 20 - Stainless Steel: Superaustenitic

(UNS N08020)

## INTRODUCTION

Alloy 20 (UNS N08020) has been available for many years and has found applications in many environments, such as in chlorides and in sulfuric and sulfurous acids.

Although Alloy 20 was developed for improved resistance to corrosion by sulfuric acid, it finds wide use throughout the chemical industry. It is used extensively in the manufacture of solvents, explosives, plastics, synthetic fibers, organic chemicals, pharmaceuticals, and food-processing equipment. Containment of acid mixtures and chloride stress corrosion resistance are examples of successful applications for Alloy 20. Where purity must be maintained in the processing of products such as foodstuffs or dyes, Alloy 20 is used to protect end products from the danger of contamination by metallic ions through corrosion.

Alloy 20 has been applied economically in many areas where other materials may provide the necessary corrosion resistance but are either higher in initial cost or more expensive to install and maintain. Important advantages of Alloy 20 are its excellent mechanical properties and comparative ease of fabrication. The presence of columbium in the alloy minimizes the precipitation of carbides in heat-affected zones during welding so that assemblies can usually be placed in service in the as-welded condition.
Welds with matching filler metal will be slightly less corrosion resistant than the base alloy.

Alloy 20 is readily available in a wide range of product forms and is covered by a wide variety of ASTM and ASME specifications having assigned maximum design stresses to 1000°F (540°C). The alloy is familiar to many fabricators, and the weldability of this alloy contributes to its use in many engineered applications. Weld filler metal is readily available, and welding procedures are well established.

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# Alloy 20

## TYPICAL COMPOSITION

| Typical Chemical Composition in Weight Percent per ASTM B463 | |
|---|---|
| **Element** | **Weight Percent** |
| Carbon | 0.02 |
| Manganese | 0.40 |
| Phosphorus | 0.025 |
| Sulfur | 0.002 |
| Silicon | 0.40 |
| Nickel | 33.0 |
| Chromium | 19.5 |
| Molybdenum | 2.15 |
| Copper | 3.20 |
| Columbium + Tantalum | 0.15 |
| Iron | Balance |

## PRODUCT FORMS

The Alloy 20 is available in sheet, strip, plate and welded tube. All material is furnished in the annealed condition.

| Product Form | Specification | |
|---|---|---|
| | ASTM | ASME |
| Plate, Sheet and Strip | B 463 | SB-463 |
| Bar and wire | B 473 | SB-473 |
| Billets and bars for reforging | B 472 | - |
| Welded pipe | B 464 | SB-464 |
| Electric fusion welded pipe | B 474 | - |
| Welded tubes | B 468 | SB-468 |
| Weaving wire | B 475 | - |
| Round spring wire | B 471 | - |
| Forged pipe flanges, fittings, valves and parts | B 462 | SB-262 |
| Factory-made wrought nickel and nickel alloy welding fittings | B 366 | SB-366 |

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# Alloy 20

The American Society of Mechanical Engineers has approved the use of N08020 alloy in the construction of welded unfired pressure vessels in the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1; Section VIII, Division 2 and also in Section III, Class 2 and 3. Welded products are covered in American Welding Society 5.4 and 5.9 specifications. The AWS specifications for matching filler are E320-15 and 16.

## PHYSICAL CONSTANTS

| | | | |
|---|---|---|---|
| **Specific Gravity** | | 8.08 | |
| **Density** | | lb/in$^3$ | 0.292 |
| | | g/cm$^3$ | 8.08 |
| **Thermal Expansion*** <br> **Temperature Range** | | Mean Coefficient of Expansion | |
| 77°F | (25°C) to | ($10^{-6}$/°F) | ($10^{-6}$/°C) |
| 212°F | (100°C) | 8.16 | 14.7 |
| 302 | (150) | 8.27 | 14.9 |
| 392 | (200) | 8.37 | 15.1 |
| 482 | (250) | 8.53 | 15.4 |
| 572 | (300) | 8.62 | 15.5 |
| * Annealed 1725°F (941°C) 1 hour and water quenched | | | |

| Thermal Conductivity<br>Test Temperature °F(°C) | | Thermal Conductivity<br>Watts/m-°C | BTU/ft•hr•°F |
|---|---|---|---|
| 50 | (122) | 12.2 | 7.05 |
| 100 | (212) | 13.1 | 7.57 |
| 200 | (392) | 14.8 | 8.56 |
| 300 | (572) | 16.5 | 9.53 |
| **Electrical Resistivity** | | | |
| ohm-cir-mil/ft | | 651 | |
| microhm-cm | | 108 | |
| **Specific Heat** | | | |
| Btu/lb•F (32/212°F) | | 0.12 | |
| kJ/kg•K (0/100°C) | | 0.50 | |
| **Modulus of Elasticity** | | | |
| Tension, psi | | $28 \times 10^6$ | |
| Tension, MPa | | $193 \times 10^3$ | |

## CORROSION RESISTANCE

### General Corrosion

General corrosion is defined as corrosive attack dominated by uniform thinning that proceeds without appreciable localized attack. The general corrosion of stainless steel, and alloys like Alloy 20, in many environments, is under 0.001" (0.0254mm) per year; and it is the only form of corrosion occurring. The level of chromium and molybdenum in the Alloy 20 provides good resistance to organic acids, but not to the level of high molybdenum alloys like AL-6XN® alloy (UNS N08367).
The level of nickel and copper gives the Alloy 20 useful resistance to reducing acids.

### Pitting/Crevice Corrosion

The Alloy 20 is comparable to Type 316 in resistance to chloride pitting and crevice corrosion, based on comparable chromium and molybdenum levels in both alloys. In severe chloride pitting and crevice corrosion environments, AL-6XN® alloy is a better choice. The following data illustrates crevice corrosion resistance of Alloy 20 versus other stainless steels.

| General Corrosion of Alloy 20 Compared to Type 316 in Acids, Bases & Salts* | | | | | |
|---|---|---|---|---|---|
| Solutions | Sample Condition | Avg. Corrosion Rate, MPY (mm/a) | | | |
| | | Type 316 | | Alloy 20 | |
| 20% Phosphoric Acid | Plain | 0.2 | (<0.01) | 0.2 | (<0.01) |
| | Autogenous GTAW | 0.2 | (<0.01) | 0.0 | (0.0) |
| 10% Sodium Bisulfate | Plain | 42.0 | (1.1) | 7.2 | (0.2) |
| | Autogenous GTAW | 42.0 | (1.1) | 55.2 | (1.4) |
| 50% Sodium Hydroxide | Plain | 123.6 | (3.1) | 7.2 | (0.2) |
| | Autogenous GTAW | 136.8 | (3.5) | 6.0 | (0.2) |
| 10% Sulfamic Acid | Plain | 63.6 | (1.6) | 9.6 | (0.2) |
| | Autogenous GTAW | 62.4 | (1.6) | 9.6 | (0.2) |
| 20% Acetic Acid | Plain | 0.0 | (0.0) | 0.0 | (0.0) |
| | Autogenous GTAW | 0.0 | (0.0) | 0.0 | (0.0) |
| 45% Formic Acid | Plain | 10.8 | (0.3) | 8.4 | (0.2) |
| | Autogenous GTAW | 10.8 | (0.3) | 7.2 | (0.2) |
| 10% Oxalic Acid | Plain | 39.6 | (1.1) | 31.2 | (0.8) |
| | Autogenous GTAW | 39.6 | (1.1) | 27.6 | (0.7) |
| Boiling 1% Hydrochloric Acid | Plain | 226 | (5.7) | 39.6 | (1.0) |
| | Autogenous GTAW | 300 | (7.6) | 39.6 | (1.0) |
| Boiling 10% Sulfuric Acid | Plain | 636 | (16.2) | 13.2 | (0.3) |
| | Autogenous GTAW | 641 | (16.3) | 14.4 | (0.4) |
| Boiling 20% Sulfuric Acid | Plain | | | 8.4 | (0.2) |
| | Autogenous GTAW | | | 13.2 | (0.3) |
| Boiling 40% Sulfuric Acid | Plain | | | 6.0 | (0.2) |
| | Autogenous GTAW | | | 12.0 | (0.3) |
| *Concentrations in percent by weight. Solutions boiling, five 48-hour periods except where noted. | | | | | |

**Stress Corrosion**

The high level of nickel in the Alloy 20 provides significant resistance to chloride stress-corrosion cracking. While the alloy will crack in the very severe 45% magnesium chloride test, it is resistant to most less severe laboratory SCC tests. The Alloy 20 is successfully used in many situations where chloride stress-corrosion cracking would be a problem for conventional austenitic stainless steels. Among such applications are food processing where salt is present in an aqueous solution. Alloy 20 resists both chloride stress-corrosion cracking and general corrosion.

**Intergranular Corrosion Resistance**

In the annealed and annealed plus sensitized (1250°F {677°C}, one hour) conditions, Alloy 20 has shown a corrosion rate of  less than 24 MPY (0.6 mm/a) in both the nitric acid test (240 hours in boiling

65% nitric acid), and the ferric sulfate-sulfuric acid test (120 hours in boiling 50% sulfuric acid solution containing ferric sulfate). The nitric acid test is described in ASTM A262, Practice C; the ferric sulfate-sulfuric acid test is described in ASTM A262, Practice B and ASTM G28.

The nitric acid-hydrofluoric acid test of A262, Practice D, the acidified copper sulfate test of A708, and the 24-hour copper accelerated, acidified copper sulfate test in A262, Practice E, are also applicable to Alloy 20 in the annealed and annealed plus sensitized condition.

| Crevice Corrosion of Alloy 20 in 6% $FeCl^3$ at Room Temperature | | |
|---|---|---|
| **Alloy** | **Sample Condition** | **Weight Loss ($grams/cm^2$)** |
| 316 | Plain | 0.2 |
| 316 | Welded | 0.2 |
| Alloy 20 | Plain | 0.15 |
| Alloy 20 | Welded | 0.15 |
| AL-6XN® | Plain | 0.00 |
| AL-6XN® | Welded | 0.00 |

| Intergranular Corrosion of Alloy 20 in Acids | | |
|---|---|---|
| **ASTM Test Sample Solution** | **Total Avg. Condition** | **MPY (mm/a)** |
| G28 Practice A<br>Ferric Sulfate-Sulfuric Acid | Plain<br>Welded<br>Sensitized | 10.80 (0.27)<br>9.60 (0.24)<br>19.20 (0.49) |
| A262 Practice. C<br>65% Nitric Acid | Plain<br>Welded<br>Sensitized | 9.60 (0.24)<br>8.40 (0.21)<br>18.00 (0.46) |
| A 262 Practice. E<br>Copper-Copper Sulfate-Sulfuric Acid | Plain<br>Welded | none<br>none |

| Stress-Corrosion Cracking of Alloy 20 in Various Boiling Solutions | | | |
|---|---|---|---|
| **Boiling Solution** | **Sample Condition** | **Time of Exposure** | **Results** |
| 42% Magnesium Chloride | Plain<br>Autogenous GTAW | 200 Hrs.<br>80 Hrs. | Cracked<br>Cracked |
| 33% Lithium Chloride | Plain<br>Autogenous GTAW | 1,000 Hrs.<br>1,000 Hrs. | OK<br>OK |
| 26% Soduum Chloride | Plain<br>Autogenous GTAW | 1,000 Hrs.<br>1,000 Hrs. | OK<br>OK |
| 50% Sodium Hydroxide | Plain<br>Autogenous GTAW | 1,000 Hrs.<br>1,000 Hrs. | OK<br>OK |

## WELDABILITY

Alloy 20, like many other fully austenitic alloys, is somewhat prone to weld hot cracking and/or microfissuring. Cracking is particularly prevalent under conditions of high restraint and when using high heat input welding processes. The use of the higher heat input range within any given welding process can also contribute to cracking problems.

Cleanliness is important to all welding procedures. Avoid marking crayons, etc., which can promote cracks. Avoid using tools and grinding materials that may have been used elsewhere and can transfer contamination.

### Shielded Metal Arc Welding (SMA)

The following guidelines apply to SMA welding of Alloy 20 when using E320-15* or E320-16 electrodes.

1. Keep the heat input to an absolute minimum. Typical welding currents used for E-320 electrodes should be only approximately 70% of that used for carbon steels.
2. Maintain a short arc length. This also reduces the heat input to the weld. A slight weaving of the electrode, less than 1-1/2 x the electrode diameter, may assist fusion.
3. The work temperature should be kept as low as possible. This is accomplished by using stringer beads, and, where possible, a progression of staggered beads (skip welding).
4. Maintain an inter-pass temperature of less than 200°F (93°C).
5. Avoid crater cracks by filling the crater at termination of welding and washing back across previously deposited weld metal. Trial observation will show the maximum size weld pool which will be free from craters.
6. Should crater cracks occur, they must be removed by grinding before proceeding further. Aluminum oxide wheels should be used for this purpose and are preferred over the silicon carbide variety. Take care that cracks are ground out not buffed over.
7. Where possible, keep the base metal restraint to a minimum.

**Gas Tungsten Arc Welding (GTA)**

1. **Shielding Gas**

   Pure argon is the preferred shielding medium for GTA welding of Alloy 20. Flow rates on the order of 10-20 CFH are suggested. Larger cup sizes provide better weld shielding in general.
   Avoid welding in drafts. Use a large-diameter gas cup and keep it close to the work. Maintain gas hoses, fittings, O-rings, etc. to ensure that no entrainment of moisture or air will occur in the torch.
2. **Electrodes**

   The use of thoriated tungsten electrodes reduces the likelihood of tungsten inclusions in the weld and enhances arc starting. Electrodes should be ground to a sharp point (approximately 20° taper) on a fine grinding wheel.
   Use direct current-straight polarity (DCSP-electrode negative). AC with high frequency (ACHF) may be used for the thinner gauges.
3. **Filler Metals**

   Suggested filler metals for use in joining Alloy 20 to itself, are ER320* or preferably ER320LR*, ER 320 and ER320LR. The ER320LR composition has controlled residual elements to provide weld metal which is highly resistant to longitudinal weld centerline cracking (hot cracking) and micro-fissuring.
4. **Suggestions for GTA Welding**
   1. Adjust welding current to achieve proper penetration at a travel speed of approximately 6 to 12 in/min (15 to 30 cm/min).

2. On thin material, strike the arc on a carbon block or weld fixture and jump the arc to the start of the joint. On thick material, start the arc in the groove on the side wall. Do not start the arc on the material outside of the weld zone.
3. Avoid crater cracks by reducing the size of the weld pool before breaking the arc, either by increasing travel speed or by reducing weld current to very low levels.
4. Use filler metal when weld reinforcement is required, where fit-up is poor and at the ends of joints.
5. Never use core material from a covered electrode as filler metal for GTA welding. This core material may not conform to the composition requirements of ER320.
6. Keep the arc length short to help maintain a low heat input and prevent atmospheric contamination of the shielding gas. Do not hold the torch at an angle which is too acute because this can aspirate air into the shielding gas stream.
7. Use gas backup wherever possible. This prevents oxidation of the root side of the weld which can cause loss of corrosion resistance.

***** Classified in AWS specification No. AS.9, "Corrosion Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes."

## MECHANICAL PROPERTIES

To soften Alloy 20 after forming operations, heat the alloy to 1700/1850°F (927/1010°C) for 1/2 hour per inch (0.019 hour per mm) of thickness and use a water quench. Do not overheat. In this condition, Alloy 20 has a hardness of 187-240 Brinell and is stabilized against possible intergranular corrosion. Lower hardness for improved formability may be obtained by annealing to higher temperatures up to 2100°F (1149°C). This may result in a sacrifice of stabilization. The higher temperatures are permissible if Alloy 20 in the final product forms will not be subject to welding or heating over 1000°F (538°C).

**Hardening**

Alloy 20 is a fully stable austenitic alloy and cannot be hardened by heat treatment. The alloy can be hardened only by cold- working.

| Typical Room Temperature Mechanical Properties | | |
|---|---|---|
| **Property** | **Sheet & Strip** | **Plate** |
| Yield Strength, 0.2%, ksi (MPa) | 47-56<br>(324-386) | 50-60<br>(345-414) |
| Tensile Strength, ksi (MPa) | 90-96<br>(620-661) | 85-95<br>(586-655) |
| Elongation in 2" (50.8mm), % | 35-40 | 35-45 |
| Hardness, Rockwell B<br>Hardness, Brinell | 84.5-86.5<br>- | -<br>200-220 |

**Common Applications**

- Processing equipment for the manufacture of sulphuric acid and for processes based on sulphuric acid
- Extraction columns in the production of amino acid and the processing of pharmaceuticals
- Equipment for production of synthetic polymers
- Equipment for food processing to protect against contamination