# 904L - Stainless Steel: Superaustenitic

(UNS N08904)

## INTRODUCTION

904L alloy (UNS N08904) is an austenitic stainless steel designed for a middle to high level of corrosion resistance. The alloy contains high levels of chromium and nickel with additions of molybdenum and copper to provide added corrosion resistance in certain media. The alloy is produced to low carbon levels for use in the welded condition as in welded vessels and other large and complex fabrications.

The high nickel (25%) and molybdenum (4.5%) contents of the 904L alloy provide good resistance to chloride stress corrosion cracking, although not total resistance as judged by the extremely severe laboratory test, boiling magnesium chloride. The Chromium, molybdenum and nickel levels provide general and chloride pitting corrosion resistance above the level of Types 316 and 317 in many media. The copper addition provides added resistance to reducing media such as hot phosphoric acid and dilute sulfuric acid.

The N08904 alloy has been incorporated in ASTM and ASME specifications and is widely and readily available in a variety of product forms, welding electrodes, and fittings. The 904L alloy has performed well in a variety of service environments such as utility scrubbers, acid and fertilizer production. Representative corrosion data follows.

## COMPOSITION

| Element | Typical | ASTM Specification (Alloy N08904) |
|---|---|---|
| Carbon | 0.015 | 0.020 maximum |
| Manganese | 1.60 | 2.00 maximum |
| Phosphorus | 0.035 | 0.045 maximum |
| Sulfur | 0.003 | 0.035 maximum |
| Silicon | 0.50 | 1.00 maximum |
| Chromium | 20.50 | 19.00-23.00 |
| Nickel | 24.5 | 23.00-28.00 |
| Molybdenum | 4.50 | 4.00-5.00 |
| Copper | 1.50 | 1.00-2.00 |
| Iron | Remainder* | Remainder* |

*By difference.

## CORROSION RESISTANCE

### General Corrosion

The alloy content of the 904L alloy provides a level of general corrosion resistance that is generally higher than familiar Type 316 stainless steel. Illustrative laboratory corrosion data from boiling solutions are listed below.

| Boiling Solution | | Corrosion Rate in MPY (mm/a) | |
|---|---|---|---|
| | | 316 | 904L |
| 20% | Acetic Acid | 0.1 (<0.01) | 0.6 (0.02) |
| 45% | Formic Acid | 10.9 (0.28) | 7.7 (0.20) |
| 1% | Hydrochloric Acid | **226 (5.74)** | 21.6 (0.55) |
| 10% | Oxalic Acid | 40.1 (1.02) | 27.1 (0.69) |
| 20% | Phosphoric Acid | **0.20 (<.01)** | 0.5 (0.01) |
| 10% | Sodium Bisulfate | 41.5 (1.06) | 8.9 (0.23) |
| 50% | Sodium Hydroxide | >100 (>2.5) | 9.6 (0.24) |
| 10% | Sulfamic Acid | 63.6 (1.62) | 9.1 (0.23) |
| 10% | Sulfuric Acid | **636 (16.2)** | 101 (2.57) |

### Pitting Corrosion

The 904L alloy contains a combination of chromium and molybdenum which produces an improved level of resistance to pitting and crevice corrosion by chlorides compared to 316 stainless steel. The alloy may by considered for such end uses as tubesheets in seawater heat exchangers or pulp and paper bleach plant equipment where a level of resistance above that of 316 is desired but some degree of attack can be tolerated. The ATI 904L alloy is not totally resistant to environments such as aerated seawater.

Resistance to chloride ion pitting or crevice corrosion can be ranked in laboratory tests such as 10% Ferric Chloride (ASTM Procedure G-48). In this test, the material is tested with artificial crevices attached, and test temperature is raised after each test period in which no attack is observed. Failure is noted as that temperature at which attack is first observed, called the onset temperature for crevice corrosion attack. In this manner, a series of alloys may be ranked as follows:

| | Temperature of Onset of Crevice Corrosion Attack* | |
|---|---|---|
| **Alloy** | **°F** | **(° C)** |
| **316** | 27 | (-3) |
| **317** | 35 | (2) |
| **904L** | 65 | (18) |
| **625** | 113 | (45) |

*ASTM Procedure G-48, 10% Ferric Chloride Solution.

**Chloride Stress Corrosion Cracking**

Resistance to chloride stress corrosion cracking is correlated with nickel content, with the 25% nickel 904L alloy, showing improved resistance compared to an 8% nickel alloy like Type 304 stainless steel. Resistance of the 904L alloy is further aided by presence of 4.5% molybdenum. However, the alloy is not completely resistant to the extremely severe laboratory test, such as boiling magnesium or lithium chlorides, as shown by the following comparative data.

| | Performance Using U-Bend Samples and Test Times to 1000 Hours | | |
|---|---|---|---|
| **Boiling Solution** | **316** | **904L** | **A20** |
| 42% Magnesium Chloride | Fail | Fail | Fail |
| 33% Lithium Chloride | Fail | Fail | Pass |
| 26% Sodium Chloride | Fail | Pass | Pass |

Fail = Chloride stress corrosion cracks observed.

Pass = No cracking observed in testing.

**Galvanic Compatibility**

The 904L alloy may influence corrosion when galvanically coupled to less corrosion resistant materials in relatively high conductivity waters such as seawater. In such a case, the 904L alloy, the noble metal, will cause galvanic corrosion of the less noble material. The 904L alloy is sufficiently resistant that it may be considered as the tubesheet material for highly corrosion resistant tubing alloys in seawater.

**Intergranular Corrosion**

The low carbon level of the 904L alloy provides resistance to intergranular corrosion in the welded condition as judged by laboratory intergranular corrosion rates. ASTM Procedure A708 or A262 Practice E are most commonly applied to the N08904 alloy. The following laboratory tests are illustrative. Corrosion rates are given in mils per year (MPY) and, in parentheses, millimeters per annum (mm/a):

| Intergranular Corrosion Resistance Test Procedure | Corrosion, Rates Mils per Year, (mm/a) | |
|---|---|---|
| | 316 | 904L |
| Copper-Copper Sulfate-<br>16% Sulfuric Acid<br>(ASTM A262 Practice E)<br>Evaluated by Bend Test | No Fissures | No Fissures |
| Ferric Sulfate- Sulfuric Acid<br>(ASTM A262 Practice B) | 35.5<br>(0.90) | 14.2<br>(0.36) |
| 65% Nitric Acid<br>(ASTM A262 Practice C) | 34.3<br>(0.87) | 15.4<br>(0.39) |

## PHYSICAL PROPERTIES

**Density**

0.287 lb/in$^3$

7.95 g/m$^3$

**Specific Gravity**

7.95

**Specific Heat at 68°F (20°C)**

0.11 BTU/lb-°F

**Average Coefficient of Thermal Expansion**

| | |
|---|---|
| 8.5 x 10-6/°F (68- 212°F) | 15.3 x 10-6/°C (20-100°C) |
| 9.2 x 10-6/°F (68- 750°F) | 16.5 x 10-6/°C (20-400°C) |
| 10.1 x 10-6/°F (68-1475°F) | 18.2 x 10-6/°C (20-800°C) |

**Thermal Conductivity**

| | BTU/Ft-hr-°F | W/m•K |
|---|---|---|
| 68°F (20°C) | 6.6 | 11.5 |
| 212°F (100°C) | 6.8 | 12.9 |
| 392°F (200°C) | 8.8 | 15.2 |

**Electrical Resistivity**
95.2 microhm-cm at 68°F
99.0 microhm-cm at 200°F

**Magnetic Permeability**
<1.02

**Modulus of Elasticity**
28 x 106 psi
190 GPa

The thermal conductivity of the 904L alloy is typical of the more highly alloyed austenitic stainless steels. Because of the high nickel content, no ferrite is expected in 904L alloy and magnetic permeability is low, even for heavily cold deformed material.

## MECHANICAL PROPERTIES

**ASTM and ASME B&PVC Coverage**

The alloy is covered by ASTM and ASME Boiler and Pressure Vessel Code Specifications as indicated here. Within those specifications, the alloy is designated UNS (Unified Numbering System) N08904.

| Product Form | ASTM Specification | ASME Specification |
|---|---|---|
| Plate, Sheet and Strip | B625 | SB 625 |
| Welded Pipe | B 673 | SB 673 |
| Welded Tube | B 674 | SB 674 |
| Seamless Pipe and Tube | B 677 | SB 677 |
| Bar and Wire | B 649 | SB 649 |

Typical (and minimum) Mechanical Properties for annealed material are listed:

| Property | Typical Value | ASTM and ASME Specified Properties |
|---|---|---|
| Yield Strength | 39,500 psi | 31,000 psi |
| | 270 MPa | 220 MPa minimum |
| Tensile Strength | 88,000 psi | 71,000 psi |
| | 605 MPa | 490 MPa minimum |
| Elongation (% in 2") | 50 | 36 minimum |
| Reduction of Area (%) | 55 | None Specified |
| Hardness (Brinell) | 150 | |
| Rockwell B | 79 | 70-90* |

*Hardness values are shown for information only.

The 904L alloy is covered in Section VIII of the ASME Boiler and Pressure Vessel Code with allowable stresses assigned as follows:

| Maximum Metal Temperatures | | Maximum Allowable Stress per ASME | |
|---|---|---|---|
| °F | °C | ksi | MPa |
| 100 | 38 | 17.8 | 123 |
| 200 | 93 | 16.7 | 115 |
| 300 | 149 | 15.1 | 104 |
| 400 | 204 | 13.8 | 95 |
| 500 | 260 | 12.7 | 88 |
| 600 | 316 | 12.0 | 83 |
| 700 | 371 | 11.4 | 79 |

*Alloy UNS N08904

For welded pipe and tubing, a factor of 0.85 is applied.

**Impact Resistance**

Annealed 904L alloy shows impact behavior typical of an austenitic stainless steel, that is, excellent toughness even at sub- zero temperatures.

JACQUET

# 904L

## PRODUCT FORMS

### Plate, Sheet and Strip

- Plate width to 96"
- Plate thickness 3/16" to 1"
- Sheet width to 48"
- Sheet thickness .025" to .133"
- Strip width to 24"
- Strip thickness .025" to .133"
- Other sizes on application

## FORMABILITY

The 904L alloy is capable of being formed like the standard austenitic stainless steels. The material is somewhat stronger than familiar 304 and 316 stainless and consequently requires higher loads to cause the material to deform.

## WELDABILITY

An overmatched, that is, more highly alloyed austenitic filler is suggested, for the best corrosion properties in welds, as in the joint between two plates of 904L alloy. However, a matching composition is commercially available. Overmatched fillers are customarily used in such corrosion resisting applications as fabricated utility scrubber components. The welds are ductile as expected when austenitic stainless steels are welded using highly alloyed fillers.

For environments which are mildly corrosive to the 904L alloy, matching filler may be used satisfactorily.

For welds which are not subjected to corrosive environments, standard austenitic filler materials are used satisfactorily.

## HEAT TREATMENT

The 904L alloy should be annealed (solution treated) between 2000 and 2100°F (1095 and 1150°C) and quickly cooled.