# RADATA SHEET

# RA2205
## DUPLEX STAINLESS

### Features
- High resistance to chloride stress corrosion cracking
- Chloride pitting and crevice corrosion resistance superior to 317L stainless
- Good general corrosion resistance
- High strength
- Good sulfide stress corrosion resistance

### Applications
- Chemical process vessels, piping, and heat exchangers
- Pulp mill digesters, bleach washers, chip presteaming vessels
- Food processing equipment
- Oil field piping and heat exchangers

### Chemical Composition, %

| | |
|---|---|
| Chromium | 22.0-23.0 |
| Nickel | 4.50-6.50 |
| Molybdenum | 3.00-3.50 |
| Carbon | 0.030 max |
| Nitrogen | 0.14-0.20 |
| Manganese | 2.00 max |
| Silicon | 1.00 max |
| Phosphorus | 0.030 max |
| Sulfur | 0.020 max |
| Iron | Balance |

### Specifications

UNS S31803 / UNS S32205 W. Nr. 1.4462

ASTM/ASME

| | |
|---|---|
| A 182 / SA 182 | Flanges, Fittings, and Valves |
| A 240 / SA 240 | Plate, Sheet, Strip |
| A 276 / SA 479 | Bars and Shapes |
| A 789 / SA 789 | Seamless and Welded Tube |
| A 790 / SA 790 | Seamless and Welded Pipe |
| A 815 / SA 815 | Wrought Piping Fittings |
| ASTM A 928 | Fusion Welded Pipe |

ASTM A 923 Detection of Intermetallic Phases

Section VIII Division 2 Code Case 2067-2

ASME Code Case 2186 (Plates in Dimpled or Embossed Assemblies)

ASME Section IX P No. 10H, Group 1

ASME B31.1 Code Case 153

NACE MR0175 DIN Std. No. 1.4462
EN 1.4462

### Introduction

RA2205 is a duplex stainless steel that was developed as a cost effective solution to common corrosion problems encountered with 300 series stainless steels. "Duplex" describes a family of stainless steels that are neither fully austenitic, like 304 stainless, nor purely ferritic, like type 430 stainless. The structure of RA2205 consists of austenite pools surrounded by a continuous ferrite phase. In the annealed condition, RA2205 contains approximately 40-50% ferrite.

The advantage of a duplex structure is that it combines the favorable qualities of a ferritic alloy (stress corrosion cracking resistance and high strength) with those of an austenitic alloy (ease of fabrication and corrosion resistance).

### Mechanical Properties

The duplex structure of RA2205 gives it significantly higher strength than 316L stainless. As a result, lighter gages of RA2205 can often be utilized creating weight savings without sacrificing structural strength. For this reason, RA2205 has become a common material of construction for components of offshore oil platforms and chemical transport tankers. Table 1 compares the mechanical properties of RA2205 versus other common corrosion resistant materials.

**Table 1 - Specified Tensile Properties**
**ASTM A 240, ASME SA 240**

| Alloy | Ultimate Tensile Strength UTS, ksi, (minimum) | 0.2% Yield Strength YS, ksi, (minimum) | Hardness (maximum) |
|---|---|---|---|
| **RA2205** | **90** | **65** | **31 Rc** |
| 304L | 70 | 25 | 92 Rb |
| 316L | 70 | 25 | 95 Rb |
| 317L | 75 | 30 | 95 Rb |
| 904L | 71 | 31 | 90 Rb |
| 20Cb-3® | 80 | 35 | 95 Rb |
| AL-6XN® | 95 | 45 | 100 Rb |

20Cb-3 is a Registered Trademark of Carpenter Technology Corp.

AL-6XN is a Registered Trademark of ATI Properties, Inc.

**Table 2 - ASME Boiler & Pressure Vessel Code, Section VIII Division 1, Allowable Stress Values, ksi**

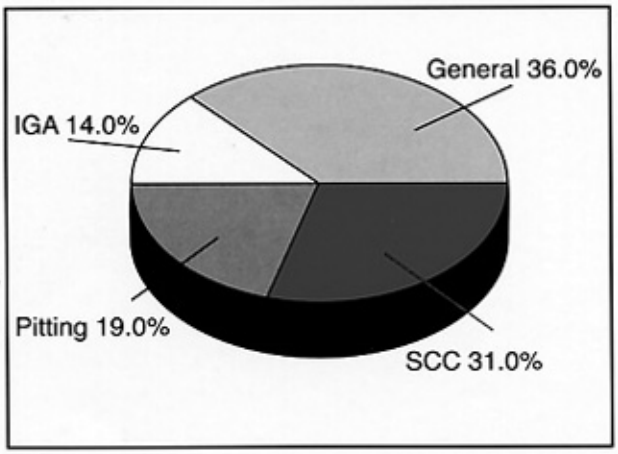
*For external pressure design of RA2205 use Chart No. HA-5 in Section II D.*

| Alloy | 200°F | 300°F | 400°F | 500°F | 600°F |
|---|---|---|---|---|---|
| **RA2205** | **25.7** | **24.8** | **23.9** | **23.3** | **23.1** |
| 304L | 14.3 | 12.8 | 11.7 | 10.9 | 10.4 |
| 316L | 14.2 | 12.7 | 11.7 | 10.9 | 10.4 |
| 317L | 17.0 | 15.2 | 14.0 | 13.1 | 12.5 |
| 904L | 16.7 | 15.1 | 13.8 | 12.7 | 11.9 |
| 20Cb-3® | 20.6 | 19.7 | 18.9 | 18.2 | 17.7 |
| AL-6XN® | 26.2 | 23.8 | 21.9 | 20.5 | 19.4 |

## Corrosion Resistance

A recent study conducted at a U. S. chemical producer analyzed the causes of failures in metallic process equipment and piping. It was determined that 55% of failures were due to corrosion, while 45% were mechanical in nature. The cost of the corrosion failures was compiled and divided into four categories as follows.

**Cost of Corrosion Failures (Percent)**




The high chromium, molybdenum, and nitrogen contents of RA2205 provide corrosion resistance superior to common stainlesses such as 316L and 317L in most environments.

## Chloride Stress Corrosion Cracking

RA2205 is a cost effective solution for many applications where 300 series stainless steels are susceptible to chloride stress corrosion cracking (SCC).

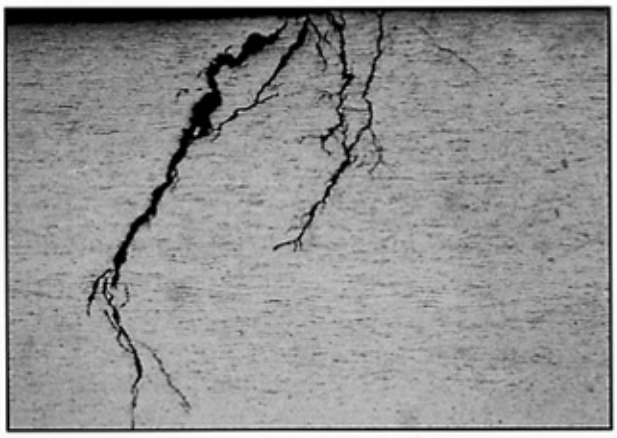


*Figure 1. Stress corrosion cracking of a 316L welded tube used in the steam inlet of a boiler feed water deaerator. Steam temperature was 193° F and the water temperature was 70-90° F with 106 ppm Cl. Feedwater was buffered to a pH of 9-10 with NaOH and heated to 230° F. This tube was replaced by duplex stainless.*

SCC will occur when stainless steels are subjected to tensile stress, while in contact with solutions containing chlorides. Increasing temperatures also increase the susceptibility of stainless steels to SCC.

**Table 3 - Stress Corrosion Cracking Resistance**

| Alloy | Boiling 42% $MgCl_2$ | Wick Test | Boiling 25% NaCl |
|---|---|---|---|
| **RA2205** | **F** | **P** | **P** |
| 316L | F | F | F |
| 304L | F | F | F |
| 904L | F | P/F | P/F |
| 20Cb-3® | F | P | P |
| 317L | F | F | F |

*P = Passed F = Failed*

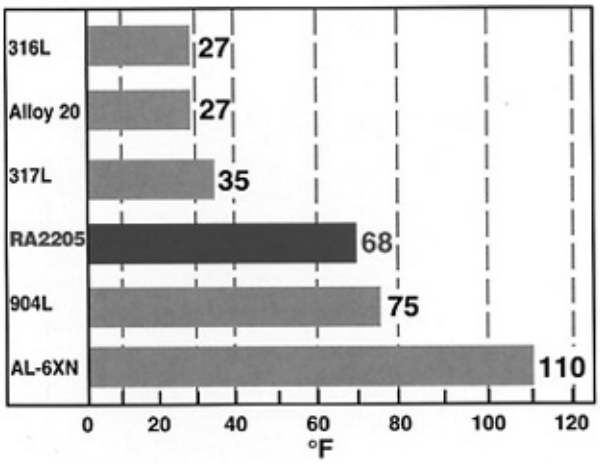
## Pitting and Crevice Corrosion

The combination of chromium, molybdenum, and nitrogen impart the good resistance of RA2205 to chloride pitting and crevice corrosion. This resistance is extremely important for services such as marine environments, brackish water, bleaching operations, closed loop water systems, and some food processing applications.

ASTM G 48 Practice B is a common method for

evaluating the crevice corrosion resistance of an alloy. Testing is performed in a 10% $FeCl_3 \cdot 6H_2O$ solution. Using this test, the critical crevice temperature (CCCT) of an alloy can be determined. Alloys with higher CCCTs are considered more resistant to crevice attack.

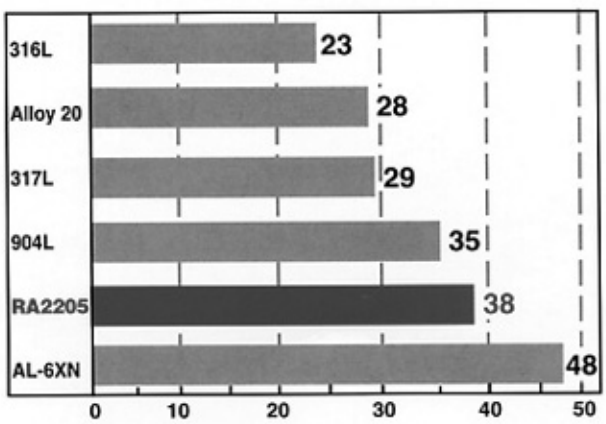
**Critical Crevice Corrosion Temperature (CCCT) in 10% $FeCl_3 \cdot 6H_2O$**




As mentioned previously, pitting resistance relates heavily to the Cr, Mo, and N content of a stainless steel. A numerical relationship has been developed for comparing the pitting resistance of stainlesses based on these three elements. This method is known as the Pitting Resistance Equivalent, (PRE)N.

The following figure compares the (PRE)N of RA2205 to other common corrosion resistant alloys.

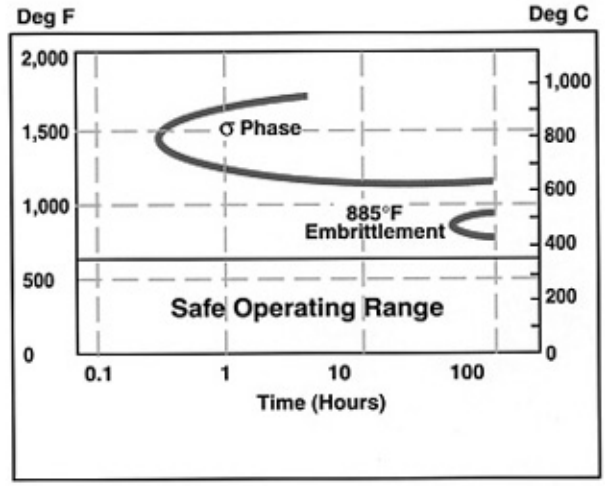
**Pitting Resistance Equivalent (PRE) N**
**PRE (N) = Cr + 3.3Mo + 30N**




## Structural Stability

Usage of RA2205 should be limited to temperatures below 600°F. Extended elevated temperature exposure can embrittle RA2205 stainless. The following figure shows the temperatures and lengths of time required for secondary phases to precipitate in RA2205 stainless.

**RA2205 Time Temperature Precipitation Diagram**




Sigma phase will precipitate upon exposure to temperatures within the 1300-1800°F range. Precipitation occurs most rapidly at 1600°F. The presence of sigma phase will cause both a loss in room temperature ductility and a reduction in corrosion resistance. RA2205 mill products are evaluated in accordance with ASTM A 923 and are free of harmful levels of intermetallic phases.

The welding of RA2205 does subject the heat affected zone (HAZ) of the joint to the sigma formation temperature range. The high nitrogen content of RA2205 slows the precipitation of intermetallic phases so that welding can be performed without the formation of harmful levels of sigma phase formation.

Exposure to temperatures in the 650-980°F range causes the precipitation of alpha prime in the ferritic portion of the material. This phenomenon is also referred to as 885°F embrittlement. The time required for this phenomenon to occur is sufficiently long that in most cases it is not a concern during fabrication. It does, however, limit the use of RA2205 to temperatures below 600°F.

**Table 4 - Physical Properties (RoomTemperature unless otherwise specified)**

| | Units | RA2205 | 316L |
|---|---|---|---|
| Density | lb/in$^3$ | **0.278** | 0.29 |
| Modulus of Elasticity (E) | psi x $10^6$ | **29.0** | 28.0 |
| Coefficient of Thermal Expansion ($\alpha$) (68-212°F) | in/in °F X $10^{-6}$ | **7.2** | 8.9 |
| Thermal Conductivity (k) (212°F) | BTU/ft • h • °F | **11.8** | 9.4 |
| Specific Heat (c) | BTU/lb/°F | **0.112** | 0.12 |
| Electrical Resistivity ($\rho$) | $\Omega$in x $10^{-6}$ | **33.5** | 31.1 |
| Magnetic Permeability ($\mu$) | H/m (Annealed) | **<100** | 1.02 Max |

## Physical Properties

The higher thermal conductivity gives it a distinct advantage over 316L series stainless steels in heat transfer applications such as process heat exchangers. The lower coefficient of expansion of RA2205 more closely matches that of carbon steel. This is a significant advantage for RA2205 over 316L for heat exchangers where carbon steel shells and stainless steel tube bundles are used.

## Economy

**Table 5 - Relative pricing of various alloys versus 1/4 inch 316L plate, Spring, 2000**

| | | | |
|---|---|---|---|
| 304L | 0.80 | 317L | 1.25 |
| 316L | 1.00 | 20Cb-3® | 2.95 |
| **RA2205** | **1.15** | AL-6XN® | 3.50 |

The combined resistance of RA2205 to chloride stress corrosion cracking and pitting, its mechanical and physical properties, and its fabricability demonstrate the cost effectiveness of this material.

## Fabrication

Information on the fabrication of RA2205 duplex stainless steel is available from Rolled Alloys. This information can be obtained through one of our sales offices listed.