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AL 2003™: A Lean Duplex Stainless Alloy for Pressure Vessel Applications - ASME Code Case 2503-1

Introduction

ASME Code Case 2503-1 allows use of an economical, high strength, lean duplex stainless steel alloy, AL 2003™ alloy (United States Patent Number 6,623,569, granted September 23, 2003) in ASME pressure vessel construction.

High strength, good weldability, formability, and ductility make this alloy a desirable choice for pressure vessel construction.

Background

The lower alloy content of AL 2003 alloy (20% Cr, 3.5% Ni, 1.7% Mo, 0.17% N, balance Fe) makes it a lower cost alternative to austenitic Type 316L and duplex 2205 alloys. When heat-treated properly, the balanced composition of AL 2003 alloy produces a microstructure that consists of nearly equal proportions of the austenite and ferrite phases. The microstructure and composition of the AL 2003 alloy provide stress-corrosion cracking resistance that is superior to that of Types 316 or 317, and a yield strength that is more than double that of conventional austenitic stainless steels.

With reduced levels of Cr and Mo, the AL 2003 alloy is more resistant than AL 2205™ material to detrimental phases such as sigma. The AL 2003 alloy was created for use in environments where resistance to general corrosion and chloride stress corrosion cracking is important.

ASME Code Case 2503 (UNS S32003)

ASME Code Case 2503 was approved by the Board on Pressure Technology Codes and Standards on January 19, 2006.

The Section VIII Division 1 Code Case has the potential to reduce the cost of equipment fabricated from AL 2003 alloy, compared to 316L or 317L austenitic stainless steel and S31803 austenitic-ferritic stainless steel.

The chemical and mechanical requirements of AL 2003 alloy are as shown in Tables 1 and 2. The Code Case includes allowable stresses for plate, sheet, strip, tube and pipe.

The maximum allowable stress values allowed in the Case are shown in Table 4A or 4B and plotted graphically along with corresponding values for S31803 duplex and S31603 austenitic stainless steels in Figure 1. Design Allowable Stresses for AL 2003 alloy per Code Case 2503 are more than 50% higher than for S31603 at most temperatures.

Code Case 2503 material was assigned to External Pressure Chart HA-5 of Section II, Part D, the same as is used for most other austenitic-ferritic stainless steels.

All other rules for Section VIII, Division 1 applicable to austenitic-ferritic stainless steels must be met.

To use the Case, Code Case 2503 must be referenced in the documentation and marking of the material and must be shown on the Manufacturer's Data Report. Thus, AL 2003 material for pressure vessel applications should be ordered to the requirements of Code Case 2503.

Higher Allowable Design Temperature

The 650°F limit on the Maximum Design Temperature is as high as or higher than other duplex stainless steels. This is based on improved resistance of AL 2003 alloy to embrittlement at elevated temperatures, compared to S31803 and other higher-alloy duplex materials. Allowable stresses for the material were based on new elevated temperature tests conducted to 1000˚F by ATI Allegheny Ludlum.

Welding Filler Metal

Code Case 2503 required separate welding qualifications. Revised Code Case 2503-1 modified this. Separate welding procedure qualifications are still required, but for welding performance qualifications, S32003 material shall has been assigned to P-No. 10H, Group 1, which is the same group to which S31803 and other widely-used austenitic-ferritic stainless steels belong.

AWS E2209 (Shielded Electrodes), and ER2209 (Bare Electrodes) over-matching filler metal, developed for use with S31803, provide a readily available filler metals for welding AL 2003 alloy. These are listed in AWS A5.5-96 and A5.9-93 (ASME SFA-5.5 and SFA-5.9), respectively. These fillers provide matching strength and over-matching corrosion resistance.

UNS Numbers and ASTM Specifications

AL 2003 alloy has been assigned. UNS Number S32003. UNS S32003 is covered by ASTM specifications for several wrought products, as listed in Table 3.

Corrosion Performance

AL 2003 alloy exhibits corrosion performance superior to Type 317L stainless steel in many environments. The Critical Pitting Temperature (CPT) of AL 2003 alloy is 20°C higher than that of type 316L stainless steel and a few degrees above type 317L as measured in the ASTM G 150 test. The high resistance of AL 2003 alloy to chloride stress-corrosion cracking (SCC) is shown in Table 5.

Other Applications for AL 2003 Alloy

S32003 alloy has been certified as an acceptable material for use in drinking water treatment and distribution systems by NSF International in Appendix C of NSF/ANSI Standard 61:2005.

Copy of Code Case 2503-1

Code Case 2503-1 was published by American Society for Mechanical Engineers, Boiler and Pressure Vessel Code, Three Park Avenue, New York, New York 10016-5990 in Supplement 4 to 2007 Code Cases.

For more information about AL 2003 alloy for pressure vessel applications, contact Dr. Dave Bergstrom at dbergstrom@alleghenyludlum.com or reach him by phone at 724-226-6417.

Table 1. Chemical Requirements

Element	**Composition %**
Carbon	0.030 max.
Manganese	2.00 max.
Phosphorus	0.030 max.
Sulfur	0.020 max.
Silicon	1.00 max.
Chromium	19.5 - 22.5
Nickel	3.0 - 4.0
Molybdenum	1.50 - 2.00
Nitrogen	0.14 - 0.20
Iron	Balance

Table 2. Mechanical Requirements

	Sheet, strip ≤3/16" (≤4.8 mm)	Plate >3/16" (>4.8 mm)	Tube	Pipe
Tensile Strength (min.)	100 ksi (690 MPa)	95 ksi (655 MPa)	100 ksi (690 MPa)	90 ksi (620 MPa)
Yield Strength (min.)	70 ksi (485 MPa)	65 ksi (450 MPa)	70 ksi (485 MPa)	65 ksi (450 MPa)
Elongation (min.)	25%	25%	25%	25%

Table 3. Product Specifications

Product	Spec.
Plate, Sheet, Strip	A 240
Sanitary Tube	A 270
Tubing	A 789
Pipe	A 790
Welded Pipe w/ filler	A 928

FIGURE 1. Allowable Stresses for Stainless Steels from Code Case 2503-1 and ASME Table 1A. (US Customary Values)

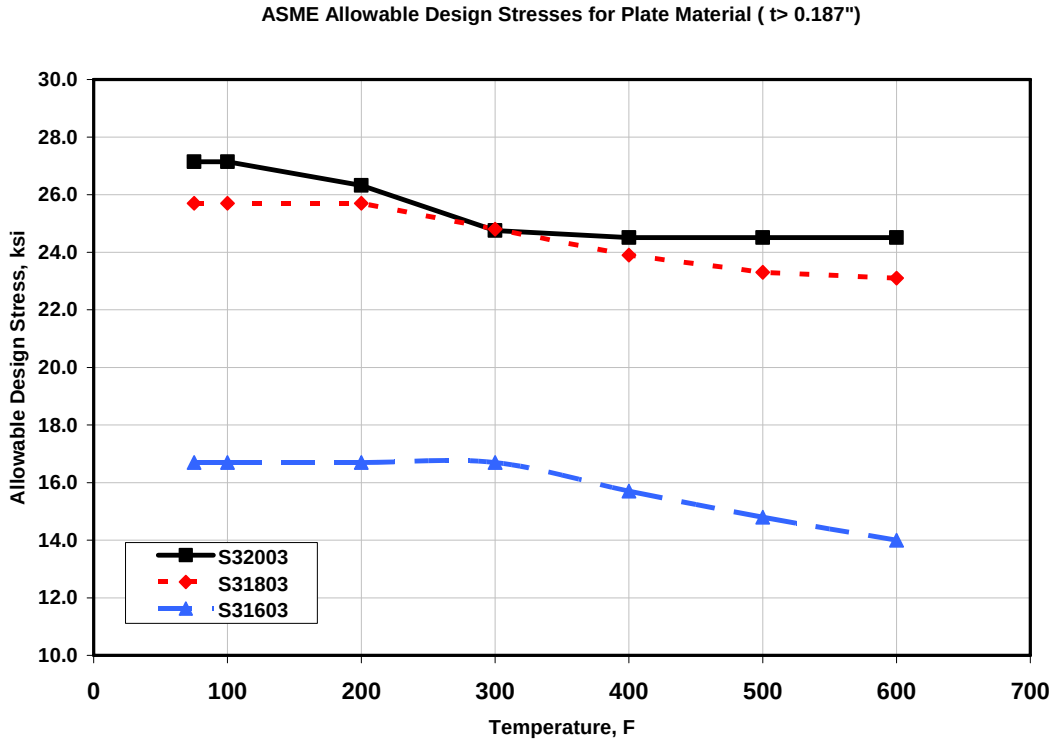

Table 4a. Maximum Allowable Stress Values (US Customary Values)[1]

For Metal Temp. Not Exceeding (°F)	Allowable Stress Values (ksi)			
	Sheet, Strip	Plate	Tube[2]	Pipe[2]
100	28.6	27.1	28.6	25.7
200	27.7	26.3	27.7	24.9
300	26.1	24.8	26.1	23.5
400	25.8	24.5	25.8	23.2
500	25.8	24.5	25.8	23.2
600	25.8	24.5	25.8	23.2
650	25.8	24.5	25.8	23.2

NOTES:
(1) The revised criterion of 3.5 on tensile strength was used in establishing these values.
(2) For welded pipe, tube and fittings a joint efficiency of 0.85 shall be used.

Table 4b.Maximum Allowable Stress Values (SI Units)[1]

For Metal Temp. Not Exceeding (°C)	Allowable Stress Values (MPa)			
	Sheet, Strip	Plate	Tube[2]	Pipe[2]
40	197	187	197	177
65	197	187	197	177
100	189	180	189	170
150	180	171	180	162
200	178	169	178	160
250	178	169	178	160
300	178	169	178	160
325	178	169	178	160
350 [3]	178	169	178	160

NOTES:
(1) The revised criterion of 3.5 on tensile strength was used in establishing these values.
(2) For welded pipe, tube and fittings a joint efficiency of 0.85 shall be used.
(3) The maximum use temperature is 343°C; the 350°C value is for interpolation only.

Table 5. Stress Corrosion Cracking Performance in Boiling 26% NaCl

Austenitic Type 304L (8% Ni)	Failed (850 Hours)
Austenitic Type 316 (12% Ni, 2.5% Mo)	Failed (530-940 Hours)
Austenitic Type 317L (13% Ni, 3.5% Mo)	Failed (1000 Hours)
Duplex AL 2003™ (3% Ni, 1.7% Mo)	Passed (1000 Hours)
Duplex AL 2205™ (5% Ni, 3% Mo)	Passed (1000 Hours)