SAE Aerospace
An SAE International Group

AEROSPACE RECOMMENDED PRACTICE

SAE ARP1110 REV. B

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Superseding ARP1110A

Minimizing Stress Corrosion Cracking in Wrought Forms of Steels and Corrosion Resistant Steels and Alloys

RATIONALE

ARP1110B is a Five-Year Review and update of this specification.

1. SCOPE:

The purpose of this SAE Aerospace Recommended Practice (ARP) is to provide the aerospace industry with recommendations concerning the minimization of stress corrosion cracking in wrought heat-treatable carbon and low alloy steels and in austenitic, precipitation hardenable, and martensitic corrosion-resistant steels and alloys.

The detailed recommendations are based on laboratory and field experience and reflect those design practices and fabrication procedures which should avoid in-service stress corrosion cracking.

2. REFERENCES:

2.1 Applicable Documents:

The issue of the following documents in effect on the date of the purchase order forms a part of this specification to the extent specified herein. The supplier may work to a subsequent revision of a document unless a specific document issue is specified. When the referenced document has been cancelled and no superseding document has been specified, the last published issue of that document shall apply.

2.1.1 SAE Publications: Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org

AMS 2430	Shot Peening
AMS 2431	Peening Media, General Requirements
AMS 2432	Shot Peening, Computer Monitored

2.1.2 ASTM Publications: Available from ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org

ASTM G 49	Standard Recommended Practice for Preparation and Use of Direct Tension Stress-Corrosion Test Specimens
ASTM G 58	Standard Practice for the Preparation of Stress Corrosion Test Specimens for Weldments

2.1.3 Other Publications:

Damage Tolerant Design Handbook, MCIC-HB-01, Air Force Materials Lab, Air Force Flight Dynamics Laboratory

Aerospace Structural Metals Handbook (formerly AFML-TR-68-115), CINDAS/Purdue University, West Lafayette, IN 47907

Deformation and Fracture Mechanics of Engineering Materials, Richard W. Hertzberg, Materials Research Center, Lehigh University, Wiley Publishing, ISBN 0471012149

Corrosion Engineering, Fontana and Greene, McGraw-Hill Book Company, ISBN 0072939737

2.2 Definitions:

2.2.1 Stress Corrosion Cracking: The combined action of sustained tensile stresses and corrosion to cause premature failure (see 5.2).

2.2.2 The relative resistance of a material and its thermomechanical condition (heat treatment or degree of work hardening) to stress corrosion cracking is characterized by the following terms:

2.2.2.1 Low Resistance to Stress Corrosion Cracking: The material and condition are generally susceptible to stress corrosion cracking.

2.2.2.2 Moderate Resistance to Stress Corrosion Cracking: The material and condition are not generally susceptible to stress corrosion cracking, but conditions of high stress or aggressive environments have been shown to result in stress corrosion cracking.

2.2.2.3 High Resistance to Stress Corrosion Cracking: The material and condition are not likely to exhibit stress corrosion cracking under a wide range of exposure environments.

3. GENERAL:

3.1 The following three conditions must always be present for stress corrosion cracking to occur.

a. An alloy/condition which is susceptible to stress corrosion cracking.

b. A sustained or residual tensile stress that, especially if associated with geometric features such as notches or corners, generates a stress intensity which exceeds the threshold for the specific alloy/condition/environment combination.

c. A specific corrosive environment to which the alloy/condition is susceptible.

3.2 Stress corrosion cracking growth rates are accelerated by increasing stress, temperature, and concentration of the contaminating environment.

3.3 Carbon and low alloy steels with an ultimate tensile strength below 180 ksi (1241 MPa) are generally resistant to stress corrosion. At ultimate tensile strengths above 180 ksi (1241 MPa) and below 200 ksi (1379 MPa), these steels generally have moderate resistance to stress corrosion. Above 200 ksi (1379 MPa) ultimate tensile strength, these steels generally have poor resistance to stress corrosion except for AISI 1095 and music wire, both of which have high resistance to stress corrosion. Surface treatments such as carburizing, carbonitriding, and induction hardening will increase the susceptibility to stress corrosion cracking.

3.4 The relative stress corrosion resistance of various stainless steels and corrosion resistant alloys when exposed to saltwater, seacoast environment, or mild industrial environments at ambient temperature are shown in Table 1.

TABLE 1 - Relative Resistance of Wrought Austenitic, Precipitation Hardenable, and Martensitic Corrosion-Resistant Steels to Stress Corrosion Cracking (4)

Alloy	UNS	Condition for High Resistance	Condition for Moderate Resistance	Condition for Low Resistance
300 Series Stainless Steel (2)	----------	All	--	--
A286 Stainless Steel	S66286	All	--	--
Almar® 362 Stainless Steel	S36200	H1000 and above	--	--
Custom 450®, 455® Stainless Steel	S4500, S45500	H1000 and above	Below H1000	--
15-5PH® Stainless Steel	S15500	H1000 and above	Below H1000	--
PH15-7Mo® Stainless Steel	S15700	CH900	--	All Except CH900
403, 410, 431 Stainless Steel	S40300, S41000, S43100	--	(1)	--
PH13-8Mo® Stainless Steel	S13800	--	All	--
17-4PH® Stainless Steel	S17400	--	All	--
Nitronic® 32	S24100	Annealed	--	--
440C Stainless Steel	S44004	--	--	All
Nitronic® 60	S21800	--	Annealed	--
17-7PH® Stainless Steel	S17700	CH900	--	All Except CH900
AM350, AM355 Stainless Steel	S35000, S35500	SCT1000 & above	--	Below SCT1000
21-6-9 Stainless Steel	S21904	Annealed	--	--
20Cb-3® Stainless Steel	N08020	All	--	--
Nitronic® 33 (3)	S24000	All	--	--

(1) Tempering between 700 and 1100 °F (371 and 593 °C) reduces general corrosion and stress corrosion resistance.
(2) Nonfree machining grades which are unsensitized, including weldments of 304L, 316L, 321, and 347.
(3) Including weldments.
(4) These ratings presume a typical microstructure. Certain orientations of crystallography or grain structure may enhance or may inhibit stress corrosion cracking.
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Nitronic,15-5PH, PH15-7 Mo, PH13-8 Mo, and 17-4PH are registered trademarks of Armco.
Almar is a registered trademark of Allegheny Ludlum.

3.5 The levels of stress intensity necessary to produce stress corrosion crack growth in susceptible alloys/conditions (see 5.3 and 5.4) can be found in a number of references (see 2.3) including:

- Damage Tolerant Handbook, MCIC-HB-01
- Aerospace Structural Metals Handbook (formerly AFML-TR-68-115)
- Deformation and Fracture Mechanics of Engineering Materials, Richard W. Hertzberg
- Corrosion Engineering, Fontana and Greene

4. PREVENTION:

Prevention of stress corrosion cracking is best achieved by eliminating one or more of the necessary conditions specified in 3.1. This can be accomplished by applying practices such as the following for selecting and processing materials for aerospace applications:

4.1 Alloy/Condition/Optimization (see 5.8):

4.1.1 Use alloys/conditions with inherently high stress corrosion cracking resistance as shown in 3.3 or Table 1.

4.1.2 Steels that include elements such as titanium, columbium, vanadium, molybdenum, and tungsten, permitting tempering or precipitation hardening at relatively high temperatures without losing strength, tend to display improved stress corrosion resistance.

4.1.3 Vacuum melted high purity steels appear to be more resistant to stress corrosion than air melted steels and those where nonessential residual elements are not restricted. A general correlation exists between improved fracture toughness, improved impact strength, and improved stress corrosion resistance.

4.1.4 Avoid exposure of austenitic stainless steels to the range of 900 to 1500 °F (482 to 816 °C) to prevent formation of grain boundary carbide precipitation.

4.2 Sustained Tensile Stress Minimization (see 5.9):

4.2.1 Exercise care in quenching, machining, welding, and assembly to avoid generating residual tensile stresses (see 5.1).

4.2.2 Relieve any residual tensile stresses generated during manufacture. Stress relieving, tempering, and precipitation hardening should follow machining and welding operations wherever practical.

4.2.3 Avoid sharp notches, crevices, and rough finishes.

4.2.4 Avoid situations in which tensile stresses due to assembly have been applied in the short transverse direction.

4.2.5 Shot peen or surface burnish to produce surface compressive stresses to assist in preventing stress corrosion (see AMS 2430 or AMS 2432). Do not straighten or thermally stress relieve after peening.

4.2.6 Use glass beads, ceramic beads, or corrosion resistant stainless steel shot when peening stainless steel to avoid anodic corrosion of the surface from shot residue. Where it is necessary to peen using cast steel or cut carbon steel wire shot, passivate after peening to avoid anodic corrosion (see AMS 2431).