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Standard Classification of Resistance to Stress-Corrosion Cracking of Heat-Treatable Aluminum Alloys[1]

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INTRODUCTION

Stress corrosion behavior is an important characteristic to be considered when optimizing the choice of material for an engineering structure. Unfortunately, there is no generally accepted scale for measuring it, and stress corrosion tendencies are difficult to define because of the complex interdependence of the material, tensile stress, environment, and time. Conventional test-dependent types of laboratory stress corrosion data have only very limited applicability in mathematical models used for materials selection.

This standard is intended to provide a qualitative classification of the relative resistance to stress corrosion cracking (SCC) of high-strength aluminum alloys to assist in the selection of materials. The classification is based on a combination of service experience and a widely accepted laboratory corrosion test.

It is cautioned, however, that any such generalized classification of alloys can involve an oversimplification in regard to their behavior in unusual environments. Moreover, the quantitative prediction of the service performance of a material in a specific situation is outside the scope of this standard.

1. Scope

1.1 This classification covers alphabetical ratings of the relative resistance to SCC of various mill product forms of the wrought 2XXX, 6XXX, and 7XXX series heat-treated aluminum alloys and the procedure for determining the ratings.

1.2 The ratings do not apply to metal in which the metallurgical structure has been altered by welding, forming, or other fabrication processes.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

G44 Practice for Exposure of Metals and Alloys by Alternate Immersion in Neutral 3.5 % Sodium Chloride Solution[2]

G47 Test Method for Determining Susceptibility to Stress-Corrosion Cracking of 2XXX and 7XXX Aluminum Alloy Products

2.2 *Other Documents:*

MIL-HANDBOOK-5 Metallic Materials and Elements for Aerospace Vehicle Structures[3]

MIL-STD-1568 Materials and Processes for Corrosion Prevention and Control in Aerospace Systems[3]

[1] This classification is under the jurisdiction of ASTM Committee G01 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.06 on Environmentally Assisted Cracking.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098

TABLE 1 Practical Interpretation of Ratings for Resistance to SCC

NOTE 1—The stress levels mentioned below and the test stresses mentioned in 6.2 are not to be interpreted as "threshold" stresses, and are not recommended for design. Other documents, such as MIL-HANDBOOK-5, MIL-STD-1568, NASC SD-24, and MSFC-SPEC-522A, should be consulted for design recommendations.

Rating	Interpretation
A	Very high. SCC not anticipated in general applications if the total sustained tensile stress[A] is less than 75 % of the minimum specified yield strength for the alloy, heat treatment, product form, and orientation.
B	High. SCC not anticipated if the total sustained tensile stress[A] is less than 50 % of the minimum specified yield strength.
C	Intermediate. SCC not anticipated if the total sustained tensile stress[A] is less than 25 % of the minimum specified yield strength. This rating is designated for the short transverse direction in improved products used primarily for high resistance to exfoliation corrosion in relatively thin structures where appreciable short transverse stresses are unlikely.
D	Low. SCC failures have occurred in service or would be anticipated if there is any sustained tensile stress[A] in the designated test direction. This rating currently is designated only for the short transverse direction in certain materials.

[A] The sum of all stresses including those from service loads (applied), heat treatment, straightening, forming, and so forth.

MSFC-SPEC-522A Design Criteria for Controlling Stress Corrosion Cracking[4]

3. Terminology

3.1 *Definitions:*

3.1.1 *lot*—an identifiable quantity of material of the same mill form, alloy, temper, section, and size (or thickness, in the case of sheet and plate) traceable to a heat treat lot or lots, and subjected to inspection at one time.

3.1.2 *stress-corrosion cracking (SCC)*—a cracking process that requires the simultaneous action of a corrodent and sustained tensile stress. SCC in aluminum alloy products historically has been observed to follow an intergranular path leading to the ultimate fracture. Thus, for the purpose of this standard, a fractured test specimen that reveals only pitting corrosion or pitting plus transgranular cracking shall not be considered as an SCC failure (Test Method G47).

4. Significance and Use

4.1 This classification involves alphabetical ratings intended only to provide a qualitative guide for materials selection. The ratings are based primarily on the results of standard corrosion tests.

4.2 Interpretations of the SCC ratings in terms of typical problem areas including service experience are given in Table 1. Practical experience has shown that SCC problems with aluminum alloys generally have involved situations where the direction and magnitude of the tensile stresses resulting from manufacturing or use, or both, of the material were not recognized.

4.3 A list of the SCC ratings for the heat-treatable aluminum alloy products is given in Table 2. Revisions to the table will be required as new materials become available and additional test results are accumulated.

4.4 These alphabetical ratings are not suitable for direct use in mathematical models for material selection, but numerical weights and confidence factors can be devised on the basis of experience and judgment of the materials engineer.[5]

5. Basis of Classification

5.1 The stress corrosion ratings for new or additional materials shall be based on laboratory tests of standard smooth specimens for susceptibility at specified stress levels. The 3.5 % NaCl alternate immersion test (Practice G44) was chosen for the laboratory test because it is widely used for aluminum alloys and is capable of detecting materials that would be likely to be susceptible to SCC in natural environments.[6]

5.2 Other types of tests using precracked specimens or dynamic loading have promise[7] as alternative or supplementary methods, but they presently require better understanding and standardization.

6. Test Method

6.1 To rate a new material and test direction, stress-corrosion tests shall be performed on at least ten random lots. The highest rating assigned shall be that for which the test results show 90 % conformance at the 95 % confidence level when tested at the following stresses:

A—Equal to or greater than 75 % of the specified minimum yield strength.

B—Equal to or greater than 50 % of the specified minimum yield strength.

C—Equal to or greater than 25 % of the specified minimum yield strength or 100 MPa (14.5 ksi), whichever is higher.

D—Fails to meet the criterion for rating C.

[4] Available from National Aeronautics and Space Administration (NASA), 300 E St. SW, Washington, D.C.

[5] Cook, O. H., Shaffer, I. S., Hoffner, J., and Devitt, D. F., "A Method for Predicting Stress Corrosion Cracking," Paper No. 224 Presented at the NACE Corrosion/78 International Corrosion Conference in Houston, TX, March 6–10, 1978.

[6] Sprowls, D. O., Summerson, T. J., Ugiansky, G. M., Epstein, S. G., and Craig, H. L., Jr., "Evaluation of a Proposed Standard Method of Testing for Susceptibility to Stress-Corrosion Cracking of High-Strength 7XXX Series Aluminum Alloy Products," *Stress Corrosion-New Approaches, ASTM STP 610*, ASTM, 1976, pp. 3–31.

[7] Brown, B. F., "*Stress Corrosion Cracking Control Measures,*" *NBS Monograph 156*, published by the U.S. Department of Commerce, National Bureau of Standards, June 1977.

TABLE 2 Resistance to Stress-Corrosion Ratings for Heat-Treatable Commercial Aluminum Alloy Products

Alloy and Temper[A]	Test Direction[B]	Rolled Plate	Rod and Bar[C]	Extruded Shapes	Forgings	Alloy and Temper[A]	Test Direction[B]	Rolled Plate	Rod and Bar[C]	Extruded Shapes	Forgings
2011-T3, T4	L	[D]	B	[D]	[D]	7049-T76	L	[D]	[D]	A	[D]
	LT	[D]	D	[D]	[D]		LT	[D]	[D]	A	[D]
	ST	[D]	D	[D]	[D]		ST	[D]	[D]	C	[D]
2011-T8	L	[D]	A	[D]	[D]	7149-T73	L	[D]	[D]	A	A
	LT	[D]	A	[D]	[D]		LT	[D]	[D]	A	A
	ST	[D]	A	[D]	[D]		ST	[D]	[D]	B	A
2014-T6	L	A	A	A	B	7050-T74	L	A	[D]	A	A
	LT	B[E]	D	B[E]	B[E]		LT	A	[D]	A	A
	ST	D	D	D	D		ST	B	[D]	B	B
2024-T3, T4	L	A	A	A	[D]	7050-T76	L	A	A	A	[D]
	LT	B[E]	D	B[E]	[D]		LT	A	B	A	[D]
	ST	D	D	D	[D]		ST	C	B	C	[D]
2024-T6	L	[D]	A	[D]	A	7075-T6	L	A	A	A	A
	LT	[D]	B	[D]	A[E]		LT	B[E]	D	B[E]	B[E]
	ST	[D]	B	[D]	D		ST	D	D	D	D
2024-T8	L	A	A	A	A	7075-T73	L	A	A	A	A
	LT	A	A	A	A		LT	A	A	A	A
	ST	B	A	B	C		ST	A	A	A	A
						7075-T74	L	[D]	[D]	[D]	A
							LT	[D]	[D]	[D]	A
							ST	[D]	[D]	[D]	B
2124-T8	L	A	[D]	[D]	[D]	7075-T76	L	A	[D]	A	[D]
	LT	A	[D]	[D]	[D]		LT	A	[D]	A	[D]
	ST	B	[D]	[D]	[D]		ST	C	[D]	C	[D]
2219-T3, T37	L	A	[D]	A	[D]	7175-T74	L	[D]	[D]	[D]	A
	LT	B	[D]	B	[D]		LT	[D]	[D]	[D]	A
	ST	D	[D]	D	[D]		ST	[D]	[D]	[D]	B
2219-T6	L	[D]	[D]	[D]	A	7475-T6	L	A	[D]	[D]	[D]
	LT	[D]	[D]	[D]	A		LT	B[E]	[D]	[D]	[D]
	ST	[E]	[E]	[E]	A	ST	D	[D]	[D]	[D]	
2219-T8, T87	L	A	A	A	A	7475-T73	L	A	[D]	[D]	[D]
	LT	A	A	A	A		LT	A	[D]	[D]	[D]
	ST	A	A	A	A		ST	A	[D]	[D]	[D]
6061-T6	L	A	A	A	A	7475-T76	L	A	[D]	[D]	[D]
	LT	A	A	A	A		LT	A	[D]	[D]	[D]
	ST	A	A	A	A		ST	C	[D]	[D]	[D]
7005-T53, T63	L	[D]	[D]	A	A	7178-T6	L	A	[D]	A	[D]
	LT	[D]	[D]	A[E]	A[E]		LT	B[E]	[D]	B[E]	[D]
	ST	[D]	[D]	D	D		ST	D	[D]	D	[D]
7039-T64	L	A	[D]	A	[D]	7178-T76	L	A	[D]	A	[D]
	LT	A[E]	[D]	A[E]	[D]		LT	A	[D]	A	[D]
	ST	D	[D]	D	[D]		ST	C	[D]	C	[D]
7049-T73	L	A	[D]	A	A	7079-T6	L	A	[D]	A	A
	LT	A	[D]	A	A		LT	B[E]	[D]	B[E]	B[E]
	ST	A	[D]	B	A		ST	D	[D]	D	D

[A] The ratings apply to standard mill products in the types of tempers indicated, including stress-relieved tempers, and could be invalidated in some cases by application of nonstandard thermal treatments or mechanical deformation at room temperature by the user.

[B] Test direction refers to orientation of the stressing direction relative to the directional grain structure typical of wrought materials, which in the case of extrusions and forgings may not be predictable from the geometrical cross section of the product.

L — Longitudinal: parallel to direction of principal metal extension during manufacture of the product.

LT—Long Transverse: perpendicular to direction of principal metal extension. In products whose grain structure clearly shows directionality (width-to-thickness ratio greater than two) it is that perpendicular direction parallel to the major grain dimension.

ST—Short Transverse: perpendicular to direction of principal metal extension and parallel to minor dimension of grains in products with significant grain directionality.

[C] Sections with width-to-thickness ratio equal to or less than two, for which there is no distinction between LT and ST.

[D] Rating not established because the product is not offered commercially.

[E] Rating is one class lower for thicker sections: extrusions, 25 mm (1 in.) and over; plate and forgings 40 mm (1.5 in.) and over.

6.2 Specimens shall be exposed by alternate immersion in 3.5 % sodium chloride solution in accordance with Practice G44.

6.3 The length of exposure shall be selected according to alloy type and specimen orientation as follows:

	Test Direction[A]	
Alloy Type	ST	L and LT
2XXX	10 days	40 days
6XXX	90 days	90 days
7XXX	20 days	40 days

[A] See Footnote *B*, Table 2.

These exposure periods are believed to be long enough to detect susceptibility to intergranular SCC in each instance, yet short enough to avoid excessive pitting that can lead to failure by another mechanism, as discussed in Test Method G47.

7. Sampling and Number of Tests

7.1 The method of sampling various mill product forms, the selection of test specimens, and the minimum number of tests per lot shall be in accordance with Test Method G47. The 90 % conformance at a 95 % confidence level specified in 6.1 will be satisfied if 30 specimens (3 from each of 10 lots) are tested and all pass the test.

7.2 If one of the 30 specimens should fail, tests of 18 additional specimens, all passing, would be required to achieve 90 % conformance (that is, 47 passing out of 48 total tests). If two of the original 30 specimens should fail, tests of 33 additional specimens, all passing, would be required (that is, 61 passing out of 63 total tests); if three should fail, tests of 48 additional specimens, all passing, would be required (that is, 75 passing out of 78 total tests), and so forth. (These calculations were based on the exact binomial distribution for a population proportion.)

7.2.1 The additional specimens shall be selected from other nonfailing lots or from additional lots (3 specimens per lot).

7.3 The results of all tests shall be reported.

NOTE 1—The amount of testing specified in 7.1 and 7.2 was selected as a basis for classifying different materials. However, this amount of testing is not sufficient to ensure that every production lot of a material will have a specified capability for resistance to SCC. Nor should it be construed as being appropriate for acceptance tests of production materials.

8. Keywords

8.1 alphabetical stress–corrosion ratings; heat–treatable aluminum alloys; laboratory corrosion tests; practical interpretation of ratings; service experience; stress-corrosion tracking