



Designation: G41 – 90 (Reapproved 2013)

Standard Practice for Determining Cracking Susceptibility of Metals Exposed Under Stress to a Hot Salt Environment¹

This standard is issued under the fixed designation G41; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice covers procedures for testing metals for embrittlement and cracking susceptibility when exposed under stress to a hot salt environment. This practice can be used for testing all metals for which service conditions dictate the need for such information. The test procedures described herein are generally applicable to all metal alloys; required adjustments in environmental variables (temperature, stress) to characterize a given materials system should be made. This practice describes the environmental conditions and degree of control required, and suggests means for obtaining this desired control.

1.2 This practice can be used both for alloy screening for determination of relative susceptibility to embrittlement and cracking, and for the determination of time-temperature-stress threshold levels for onset of embrittlement and cracking. However, certain specimen types are more suitable for each of these two types of characterizations.

NOTE 1—This practice relates solely to the performance of the exposure test. No detailed description concerning preparation and analysis of specimen types is offered. However, the optimum sample design may be one that uses the same type of stress encountered in service loading situations. Standards describing principal types of stress corrosion specimens, their preparation, and analysis, include Practices G30, G38, and G39.

1.3 *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.* (For more specific safety hazard statements see Section 8.)

2. Referenced Documents

2.1 ASTM Standards:²

¹ This practice 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.

- D1141 Practice for the Preparation of Substitute Ocean Water
- D1193 Specification for Reagent Water
- G1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens
- G30 Practice for Making and Using U-Bend Stress-Corrosion Test Specimens
- G38 Practice for Making and Using C-Ring Stress-Corrosion Test Specimens
- G39 Practice for Preparation and Use of Bent-Beam Stress-Corrosion Test Specimens
- G49 Practice for Preparation and Use of Direct Tension Stress-Corrosion Test Specimens

3. Summary of Practice

3.1 The hot salt test consists of exposing a stressed, salt-coated test specimen to elevated temperature for various predetermined lengths of time, depending on the alloy, stress level, temperature, and selected damage criterion (that is, embrittlement, cracking, or rupture, or a combination thereof). Exposures are normally carried out in laboratory ovens or furnaces with associated loading equipment for stressing of specimens.

3.2 The ovens are provided with facilities to circulate air at various flow rates and ambient pressure. However, for certain specific applications, airflow and pressure may be adjusted to obtain information on material behavior in simulated service environments. Exposure temperatures and stress levels are generally selected on the basis of mechanical property data for a given alloy, or of expected service conditions, or both.

4. Significance and Use

4.1 The hot salt test as applied to metals is utilized as a secondary design consideration indicator, as cracking has been shown to occur in laboratory tests simulating possible service conditions. Although limited evidence exists linking this phenomenon to actual service failures, cracking under stress in a hot salt environment should be recognized as a potential design controlling factor.

4.2 The hot salt test is not to be misconstrued as being related to the stress corrosion cracking of materials in other

environments. It is considered solely as a test in an environment that might be encountered in service.

4.3 Because hot salt cracking under stress is considered a secondary design consideration and service failures have not been attributed solely to this phenomenon, manufacturing processes will be optimized or alloying changes will be made only after consideration is given to primary design factors such as creep resistance of a given high temperature alloy. The usefulness of the test lies rather in limiting maximum operating temperatures and stress levels or categorizing different alloys as to susceptibility, or both, if it is found that hot salt damage may accelerate failure by creep, fatigue, or rupture.

4.4 Finally, the test does not lend itself to the utilization of pre-cracked specimens because cracking reinitiates at any salt-metal-air interface, resulting generally in many small cracks which extend independently. For this reason, specimens that are recommended for utilization in routine testing are of the smooth specimen category.

5. Interferences

5.1 Hot salt cracking under stress is often considered a hydrogen-related phenomenon, and the source of hydrogen is a corrosion reaction involving moisture, available either from the hydrated salt, trapped as fluid inclusions in nonhydrated salt, or from humidity in the test atmosphere if absent in the salt crystals. Because of this fact, considerable variation in test results can be obtained, simply from the method of salt deposition on the test specimen, even when effective controls on other test variables are realized. Efforts should be made to standardize the salt deposition techniques and to control or monitor humidity in order to achieve desired test validity.

5.2 The effects of cycling time at temperature to achieve a given total cumulative exposure have been shown to have a significant effect on test results, with shorter cycle duration and greater cycle frequency generally resulting in less damage for the same cumulative exposure time. For this reason, selection between continuous and cyclic exposure, duration, and frequency of cycling, and heating and cooling rates must be made with the end purpose of the test in mind.

5.3 Variations in heat to heat or product forms, or both, have been shown to have a significant effect on damage thresholds determined from experimental testing. This effect may be more pronounced than is observed in more conventional stress corrosion testing of the aqueous type. For this reason, it is important to obtain and document to the fullest extent possible all certified analyses and tests associated with the material to be tested and associated fabrication and treatment histories. Interstitial concentration levels, chemical contaminants, and thermomechanical processing should be included in the documentation (see Section 12).

5.4 Details regarding general surface preparation and use of bent-beam stress-corrosion specimens are outlined in Practice G39. Procedures for making and using direct tension stress-corrosion specimens is described in Practice G49. However, because of the highly localized nature of onset of attack at the surface in hot salt exposure testing, it is desirable to characterize as fully as possible the surface condition of the material.

If an as-received surface condition is to be investigated, efforts should be made to ascertain the state of residual stress as regards the material surface. Both magnitude and algebraic sign (tension or compression) of residual stress should be determined and reported if possible. Chemical milling can be employed in final surface preparation in order to avoid extraneous surface effects. However, care should be taken to ensure that proper chemical milling techniques are employed, and that hydrogen uptake does not occur during the surface preparation.

6. Apparatus

6.1 *Apparatus for Salt Coating*—A conventional air brush should be used for spraying the specimens to accomplish the salt-coating procedure. This will generally provide a thin uniform salt deposition of the desired density.

6.2 *Apparatus for Conducting Exposure Test:*

6.2.1 Apparatus required for conducting the exposure test depends on the selection of the specimen type to be used. If a constant-deflection type specimen is utilized for which no external loading requirement exists, conventional laboratory ovens are suitable for conducting the exposure test. Provision for controlling or monitoring inlet air humidity is recommended.

6.2.1.1 *Specimen Holders*, suitable for applying stress to constant-deflection type specimens should be made of the same or a similar alloy as the material to be tested in order to avoid galvanic effects. The requirement for the use of a fixture to apply stress can be avoided when testing sheet materials by utilizing a self-stressed specimen design.³

6.2.1.2 *Racks*, suitable for supporting specimens in the oven and for transferring specimens should be made of the same or a similar alloy as the material to be tested. Open circuit conditions should be maintained, although galvanic effects are considered to be highly localized on the surface.

6.2.2 If a constant-deflection type specimen is utilized, care must be taken to either avoid or take into account differences in thermal expansion between test specimen and test fixture. Thermal expansion differences can substantially change the stress level applied at ambient temperature when specimens are heated to the test temperature.

6.2.3 If a constant-load type specimen is to be utilized, provision must be made to combine both heating and loading equipment. Vertical-tube resistance-wound furnaces can be utilized with dead-weight loading or conventional creep frame equipment for low and high loading conditions, respectively (Note 2). Direct induction or resistance heating of the specimen itself is not recommended.

NOTE 2—When using vertical-tube furnaces care must be taken to avoid a chimney effect through the furnace, which could result in excessive airflow and uneven temperature distribution along the specimen length. Sealing at both ends will allow control of air flow and improve temperature distribution within the furnace.

7. Reagents and Materials

7.1 Reagent grade salts shall be used when preparing solutions from which the salt coating is derived. Sodium

³ See “A Stress Corrosion Test for Structural Sheet Materials,” *Materials Research and Standards*, Vol 5, No. 1, January 1965, pp. 18–22.