# Standard Practice for Preparation and Use of Direct Tension Stress-Corrosion Test Specimens[1]

This standard is issued under the fixed designation G 49; 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 designing, preparing, and using ASTM standard tension test specimens for investigating susceptibility to stress-corrosion cracking. Axially loaded specimens may be stressed quantitatively with equipment for application of either a constant load, constant strain, or with a continuously increasing strain.

1.2 Tension test specimens are adaptable for testing a wide variety of product forms as well as parts joined by welding, riveting, or various other methods.

1.3 The exposure of specimens in a corrosive environment is treated only briefly because other standards are being prepared to deal with this aspect. Meanwhile, the investigator is referred to Practices G 35, G 36, and G 37, and G 44, and to ASTM Special Technical Publication 425 **(1).**[2]

## 2. Referenced Documents

2.1 *ASTM Standards:*

E 8 Test Methods for Tension Testing of Metallic Materials[3]

G 35 Practice for Determining the Susceptibility of Stainless Steels and Related Nickel-Chromium-Iron Alloys to Stress-Corrosion Cracking in Polythionic Acids[4]

G 36 Practice for Evaluating Stress-Corrosion Cracking Resistance of Metals and Alloys in a Boiling Magnesium Chloride Solution[4]

G 37 Practice for Use of Mattsson's Solution of pH 7.2 to Evaluate the Stress-Corrosion Cracking Susceptibility of Copper-Zinc Alloys[4]

G 44 Practice for Evaluating Stress-Corrosion Cracking Resistance of Metals and Alloys by Alternate Immersion in 3.5 % Sodium Chloride Solution[4]

## 3. Summary of Practice

3.1 This practice covers the use of axially loaded, quantitatively stressed ASTM standard tension test specimens for investigating the resistance to stress-corrosion cracking of metallic materials in all types of product forms. Consideration is given to important factors in the selection of appropriate specimens, the design of loading equipment, and the effects of these factors on the state of stress in the specimen as corrosion occurs.

## 4. Significance and Use

4.1 Axially loaded tension specimens provide one of the most versatile methods of performing a stress-corrosion test because of the flexibility permitted in the choice of type and size of test specimen, stressing procedures, and range of stress levels.

4.2 The uniaxial stress system is simple; hence, this test method is often used for studies of stress-corrosion mechanisms. This type of test is amenable to the simultaneous exposure of unstressed specimens (no applied load) with stressed specimens and subsequent tension testing to distinguish between the effects of true stress corrosion and mechanical overload **(2)**. Additional considerations in regard to the significance of the test results and their interpretation are given in Sections 6 and 10.

4.3 Wide variations in test results may be obtained for a given material and specimen orientation with different specimen sizes and stressing procedures. This consideration is significant especially in the standardization of a test procedure for interlaboratory comparisons or quality control.

## 5. Test Specimens

5.1 Whenever possible, tension test specimens used in evaluating susceptibility to stress-corrosion cracking should conform to the dimensions of standard tension test specimens specified in Test Methods E 8, which contain details for specimens machined from various product forms.

5.2 A wide range of sizes for tension test specimens is possible, depending primarily upon the dimensions of the product to be tested. Because the stress-corrosion test results can be markedly influenced by the cross section of the test specimen, this factor should be given careful consideration with regard to the object of the investigation. Although larger specimens may be more representative of most actual structures, they often cannot be machined from product forms to be evaluated; and they present more difficulties in stressing and

[1] This practice is under the jurisdiction of ASTM Committee G-1 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.06 on Stress-Corrosion Cracking and Corrosion Fatigue.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this practice.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

[4] *Annual Book of ASTM Standards*, Vol 03.02.

handling in the laboratory. Also, larger specimens of some materials may require longer exposure periods than smaller specimens.

5.3 Smaller cross-section specimens are widely used because they (*a*) have a greater sensitivity to the initiation of stress-corrosion cracking, (*b*) usually give test results more quickly, and (*c*) permit greater convenience in testing. On the other hand, the smaller specimens are more difficult to machine, and their performance is more likely to be influenced by extraneous stress concentrations resulting from non-axial loading, corrosion pits, etc. Therefore, specimens less than about 10 mm (0.4 in.) in gage length or 3.0 mm (0.12 in.) in diameter are not recommended for general use.

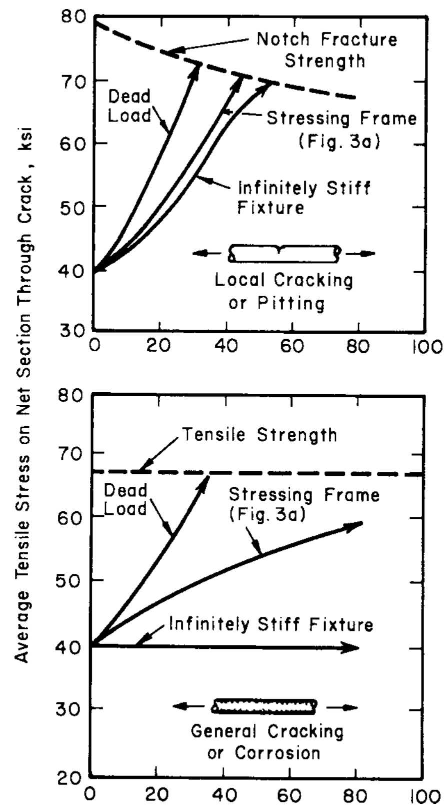
5.4 Tension specimens containing machined notches have been used in studies of stress-corrosion cracking and hydrogen embrittlement **(3)**. The presence of a notch induces a triaxial stress state at the root of the notch wherein the actual stress will be greater by a concentration factor dependent on the notch geometry. Advantages of such specimens include the probable localization of cracking to the notch region and acceleration of failure. However, unless directly related to practical conditions of usage, spurious results may ensue.

5.5 Tension specimens containing a machined notch in which a mechanical precrack (for example, a fatigue or tension crack) has been started will be the subject of another ASTM standard. Various types of precracked specimens are discussed in other publications **(2, 4)**.

## 6. Stress Considerations

6.1 There are several factors that may introduce bending moments on specimens, such as a longitudinal curvature, misalignment of threads on threaded-end round specimens, and the corners of sheet-type specimens. The significance of these factors is greater for specimens with smaller cross sections. Even though eccentricity in loading can be minimized to equal the same standards accepted for tension testing machines, inevitably, there is some variation in the tensile stress around the circumference of the test specimen which can be of such magnitude that it will introduce considerable error in the desired stress. Tests should be made on specimens with strain gages affixed to the specimen surface (around the circumference in 90° or 120° intervals) to verify strain and stress uniformity and determine if machining practices and stressing jigs are of adequate tolerance and quality.

6.2 Another consideration is the possible increase in net section stress that will occur when corrosion develops during the environmental exposure **(1, 5)**. As shown schematically in Fig. 1, there are two limiting curves: one for zero stiffness (dead weight) and the other for infinite stiffness (ideal constant strain). In actual testing with various types of stressing frames, such as those shown in Figs. 2-4, the increase in net section stress will be somewhere in between. When the net section stress becomes greater than the nominal gross section stress and increases to the point of fracture, either of two events can occur: (*a*) fracture by mechanical overload of a material that is not susceptible to stress-corrosion cracking, or (*b*) stress-corrosion cracking of a material at an unknown stress higher than the intended nominal test stress. The occurrence of either of these phenomena would interfere with a valid evaluation of materials with a relatively high resistance to stress corrosion. These considerations must be taken into account in experiments undertaken to determine "threshold" stresses. The significance of these factors is discussed further in Section 10.




NOTE 1—The behavior shown is generally representative, but the curves will vary with specific alloys and tempers.

**FIG. 1 Effect of Loading Method and Extent of Cracking or Corrosion Pattern on Average Net Section Stress**

## 7. Stressing Methods

7.1 *General Considerations*:

7.1.1 Tension specimens may be subjected to a wide range of stress levels associated with either elastic or elastic and plastic strain. Because the stress system is intended to be essentially uniaxial (except in the case of notched specimens), great care must be exercised in the construction of stressing frames so that bending stresses are avoided or minimized.

7.1.2 Although a number of different stressing frames have been used with tension specimens, three basic types are considered herein: constant (sustained) load, constant strain (deformation), and continuously increasing strain. A constant load can be obtained with dead weight, but truly constant strain loading is seldom achieved because a stressing frame with infinite stiffness would be required. Stress-corrosion test results can be influenced by the type of loading in combination with the design of the test specimen; therefore, the investigator should select loading conditions most applicable to the purpose of the investigation. Further information in regard to the type of loading most applicable to various types of structures is given in Ref **(2)**.

7.2 *Stressing Frames*:

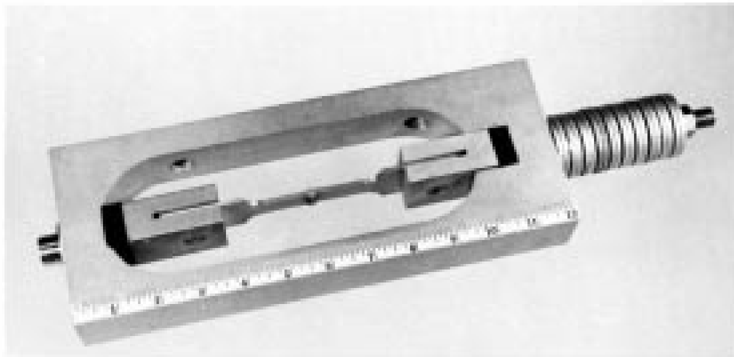


FIG. 2 Spring-Loaded Stressing Frame (7)


FIG. 3 Sustained Load Devices Using Ring Frames (8)

7.2.1 *Constant Load*:

7.2.1.1 The simplest method is a dead weight hung on one end of the specimen, and it is particularly useful for wire specimens **(6)**. For specimens of larger cross section, however, lever systems such as are used in creep testing machines are more practical. The advantage of any dead-weight loading device is the constancy of the applied load.

7.2.1.2 An approximation of a constant-load system can be attained by the use of springs with a ring such as that shown in Fig. 2 **(7)**. The principle of the proving ring, as used in the calibration of tension testing machines, has also been adapted to stress-corrosion testing to provide a simple, compact, and easily operated device to apply axial load **(8)**; see Fig. 3(*a*). The load is applied by tightening a nut on one of the bolts and is determined by carefully measuring the change in ring diameter. Another similar but less sophisticated ring device can also be used, the difference being that the load is applied with a hydraulic jig **(8)** as shown in Fig. 3(*b*). In either ring device, the bolt contains a keyway to prevent a torsional stress from being applied to the specimen while tightening the nut.

7.2.2 *Constant Strain*—Stress-corrosion tests performed in low-compliance tension testing machines are of the constant-strain type. The specimen is loaded to the required stress level and the moving beam then locked in position. Other laboratory stressing frames have also been used, generally in testing specimens of lower strength of smaller cross section **(9)**. Fig. 4(*a*) shows an exploded view of such a stressing frame, and Fig. 4(*b*) shows a special loading device developed to ensure axial loading with a minimum of torsion and bending of the specimen.

7.2.2.1 For stressing frames that do not contain any mechanism for the measurement of load, it is desirable to determine the stress levels from measurement of the strain. It must be noted, however, that only when the intended stress is below the elastic limit of the test material is the average linear stress ($\sigma$) proportional to the average linear strain ($e$), $\sigma/e = E$, where the constant $E$ is the modulus of elasticity.

7.2.2.2 When tests are conducted at elevated temperatures with constant-strain loaded specimens, consideration should be given to the possibility of stress relaxation.

7.2.3 *Continuously Increasing Strain*— A tension testing machine may be used to load the test specimen at a constant rate to failure **(10)**. If the specimen is surrounded by a test environment and strain rate is slow enough, stress-corrosion cracking may occur during the test. This can result in shorter times to fracture or in lower values of elongation or reduction of area, or both, than obtained for a specimen strained at the same rate in air or in an inert environment at the same temperature as the corrodent. Appropriate combinations of specimen cross section and corrosive environment must be determined, as well as the range of critical strain rate for specific alloy systems.

## 8. Preparation of Specimens

8.1 The pronounced effect of surface conditions on the time required to initiate stress-corrosion cracking in test specimens is well-known. Unless it is desired to evaluate the as-fabricated surface, the final surface preparation generally preferred is a

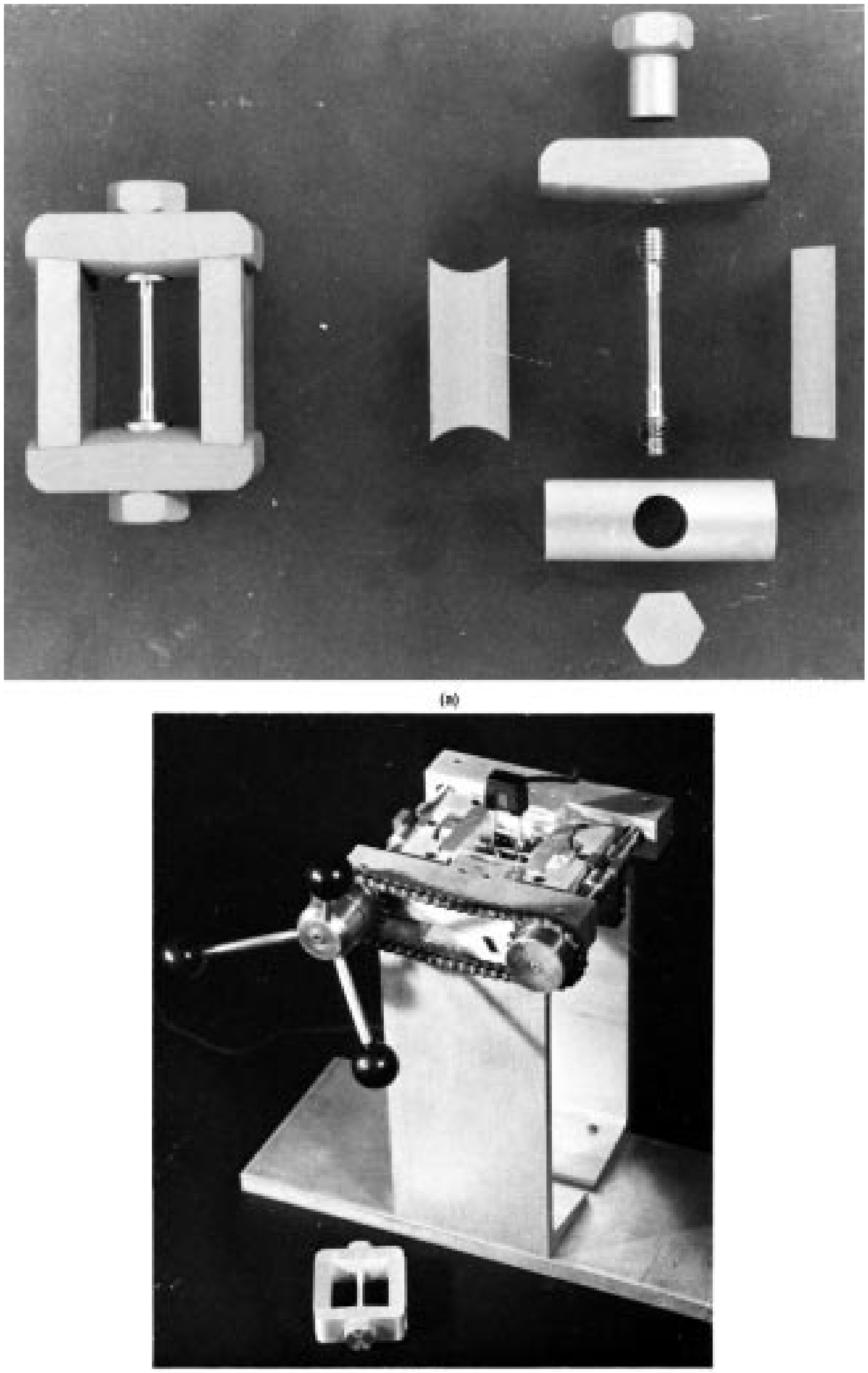



FIG. 4 Constant-Strain Type of Stressing Frame (9)

mechanical process followed by simple degreasing. Suitable mechanical finishes include a machined or machine-ground surface with a quality of about 32 µin. rms or better.

8.2 Care should be taken to avoid overheating or excessive pressure during the final preparation; otherwise, residual stresses or metallurgical changes may be induced in the surface.

8.3 When the final surface preparation involves a chemical treatment, care must be taken to ensure that the solution does not selectively attack alloy constituents in the metal or leave undesirable residues on the surface.

8.4 Chemical or electrochemical treatments that produce hydrogen on the specimen surface must not be used on materials that are subject to hydrogen embrittlement or that react with hydrogen to form a hydride.

## 9. Exposure of Specimens

9.1 The environmental testing conditions will depend upon the intent of the test but, ideally, should be the same as those prevailing for the intended use of the alloy or relatable to the anticipated service conditions.

9.2 The stressed specimens should be exposed to the test environment, either gaseous or liquid, as soon as possible after stressing. When practicable, it is recommended that the specimens be stressed with the corrodent already present.

9.3 In the experimental setup for exposure of the specimen to the test environment (for example, total immersion, alternate immersion, atmospheric exposure, etc.), appropriate precautions must be taken to avoid galvanic action or crevice corrosion between the specimen, the stressing frame, and exposure racks. If necessary, protective coatings can be used to protect the stressing rig and areas of the specimen not critically stressed. Care must be taken that the environment does not deteriorate or become contaminated by the coating or that crevice corrosion is not generated under coating edges.

## 10. Inspection

10.1 One of the advantages of the direct-tension type of specimen is that when stress-corrosion cracking occurs, it generally results in complete fracture of the specimen, which is easy to detect. However, when there is some uncertainty as to the presence of cracks due, for example, to the presence of corrosion products on the specimen surface, it may be necessary, at the conclusion of the test, to chemically clean the specimen to facilitate adequate inspection.

10.2 It must be emphasized that fracture of the test specimen does not necessarily signify that stress-corrosion cracking has occurred. With specimens stressed by constant load, severe localized or generalized corrosion can lead to mechanical fracture by simple reduction of the cross-section area, as illustrated in Fig. 1. While this can also happen with constant-strain loaded specimens as a result of severe localized pitting corrosion, it is not likely to happen as a result of severe uniform corrosion.

10.3 It must be cautioned that constant-strain loaded specimens not having fractured may contain stress-corrosion cracks. Numerous small cracks developing in close proximity may cause relaxation of the stress. In such cases, metallographic examination can be used to establish whether or not there is stress-corrosion cracking present.

10.4 Tension tests of replicate specimens exposed with no applied stress, in conjunction with stressed specimens, can provide useful assistance in evaluating stress-corrosion effects, especially when stressed specimens do not fracture **(2)**.

10.5 In continuously increasing strain tests, the ultimate tensile strength, elongation, or reduction of area, or all three, should be measured. Also, because complete fracture occurs with or without stress-corrosion cracking, a metallographic examination or other test should be performed to establish whether or not there is stress-corrosion cracking present.

## 11. Report

11.1 In addition to an account of the results of each test, the following essential information should be recorded:

11.1.1 Full description of the test material(s), including composition and temper, type of manufactured product, section thickness, and sampling procedure (location of test specimens),

11.1.2 Orientation, type, size, and number of test specimens, and their surface preparation,

11.1.3 Stressing procedure,

11.1.4 Test environment and period of exposure, and

11.1.5 Criterion of specimen failure.

## 12. Keywords

12.1 constant load; constant strain; quantitative stress; stress-corrosion cracking; stress-corrosion test specimen; tension specimens

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