INTERNATIONAL

Designation: G38 − 01 (Reapproved 2021)

Standard Practice for Making and Using C-Ring Stress-Corrosion Test Specimens[1]

This standard is issued under the fixed designation G38; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope

1.1 This practice covers the essential features of the design and machining, and procedures for stressing, exposing, and inspecting C-ring type of stress-corrosion test specimens. An analysis is given of the state and distribution of stress in the C-ring.

1.2 Specific considerations relating to the sampling process and to the selection of appropriate test environments are outside the scope of this practice.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *NACE Document:*

NACE TM0177–96 Laboratory Testing of Metals for Resistance to Sulfide Stress Cracking and Stress Corrosion Cracking in H_2S Environments[2]

3. Summary of Practice

3.1 This practice involves the preparation of and the quantitative stressing of a C-ring stress-corrosion test specimen by application of a bending load. Characteristics of the stress system and the distribution of stresses are discussed. Guidance is given for methods of exposure and inspection.

4. Significance and Use

4.1 The C-ring is a versatile, economical specimen for quantitatively determining the susceptibility to stress-corrosion cracking of all types of alloys in a wide variety of product forms. It is particularly suitable for making transverse tests of tubing and rod and for making short-transverse tests of various products as illustrated for plate in Fig. 1.

5. Sampling

5.1 Test specimens shall be taken from a location and with an orientation so that they adequately represent the material to be tested.

5.2 In testing thick sections that have a directional grain structure, it is essential that the C-ring be oriented in the section so that the direction of principal stress (parallel to the stressing bolt) is in the direction of minimum resistance to stress-corrosion cracking. For example, in the case of aluminum alloys (**1**),[3] this is the short-transverse direction relative to the grain structure. If the ring is not so oriented it will tend to crack off-center at a location where the stress is unknown.

6. Specimen Design

6.1 Sizes for C-rings may be varied over a wide range, but C-rings with an outside diameter less than about 16 mm (5⁄8 in.) are not recommended because of increased difficulties in machining and decreased precision in stressing. The dimensions of the ring can affect the stress state, and these considerations are discussed in Section 7. A typical shop drawing for the manufacture of a C-ring is shown in Fig. 2.

7. Stress Considerations

7.1 The stress of principal interest in the C-ring specimen is the circumferential stress. It should be recognized that this stress is not uniform (**2, 3**). First, there is a gradient through the thickness, varying from a maximum tension on one surface to

[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.

Current edition approved Aug. 1, 2021. Published August 2021. Originally approved in 1973. Last previous edition approved in 2013 as G38–01 (2013). DOI: 10.1520/G0038-01R21.

[2] Available from NACE International (NACE), 15835 Park Ten Pl., Houston, TX 77084, http://www.nace.org.

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

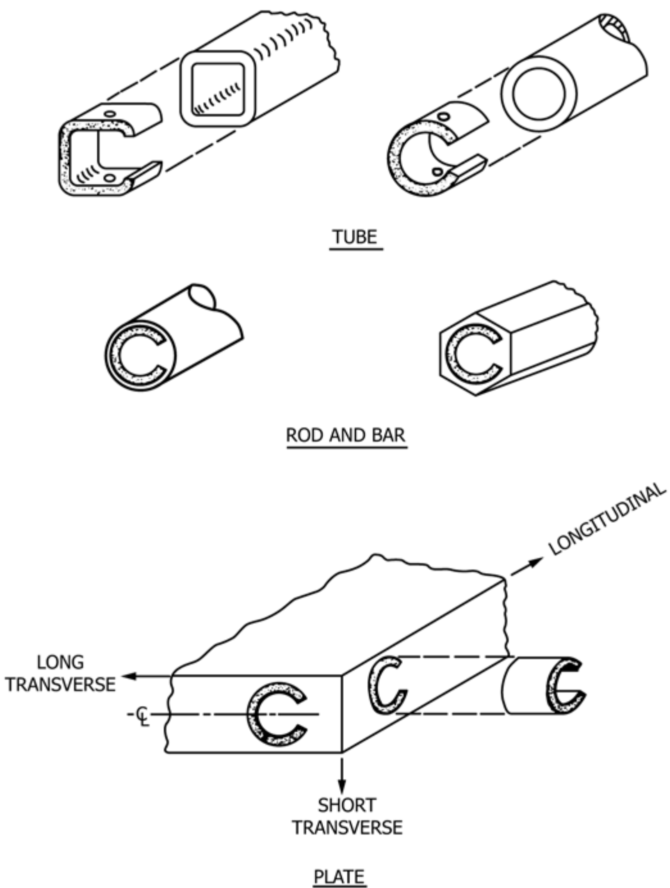
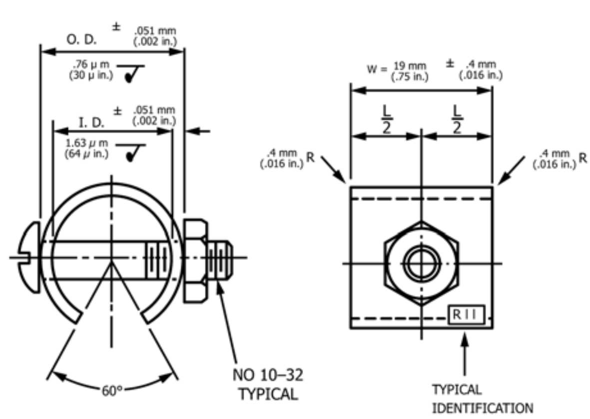


FIG. 1 Sampling Procedure for Testing Various Products



NOTE 1—If stock is undersize or tube stock is used dimensions can be varied to suit size of section from which the specimen must be cut.

FIG. 2 C-Ring Type of Stress-Corrosion Specimen

a maximum compression on the opposite surface. Secondly, the stress varies around the circumference of the C-ring from zero at each bolt hole to a maximum at the middle of the arc opposite the stressing bolt; the nominal stress is present only along a line across the ring at the middle of the arc. Thus, when the specimen is stressed by measuring the strain on the tension surface of the C-ring, the strain gage should be positioned at the middle of the arc in order to indicate the maximum strain. Thirdly, the circumferential stress may vary across the width of the ring, the extent of the variation depending on the width-to-thickness and diameter-to-thickness ratios of the C-ring. In general, when loaded as shown in Fig. 3 (*a*, *b*), the tensile stress on the outer surface will be greater at the extreme edge than at the center, while when loaded as shown in Fig. 3 (*c*), the tensile stress on the inner surface will be less at the edge than at the center **(4)**.

7.2 Another characteristic of the stress system in the C-ring is the presence of biaxial stresses; that is, transverse as well as circumferential stresses are developed on the critical test section. The transverse stress will vary from a maximum at the mid-width to zero at the edges, and will be the same sign as the circumferential stress. In general, the transverse stress may be expected to decrease with decreasing width to thickness and increasing diameter to thickness ratios. An example is shown in Fig. 4 where the transverse tensile stress at the mid-width of a 19.00 mm (0.748 in.) outside diameter by 1.537 mm (0.0605 in.) thick by 19.0 mm (0.75 in.) wide C-ring of aluminum alloy 7075-T6 was equal to about one third of the circumferential tensile stress. In this example the circumferential stress was uniform over most of the width of the C-ring; measurements were not made at the extreme edge.

7.3 In the case of the notched C-ring (Fig. 3(*d*)) a triaxial stress state is present adjacent to the root of the notch **(5)**. In addition, the circumferential stress at the root of the notch will be greater than the nominal stress and generally may be expected to be in the plastic range.

7.4 The possibility of residual stress should always be considered, especially when C-rings are machined from products that contain appreciable residual stress or when C-rings over about 6.35 mm (¼ in.) thick are heat treated after being machined. It is generally not advisable to heat treat finish-machined C-rings because of the likelihood of developing residual stresses in the ring.

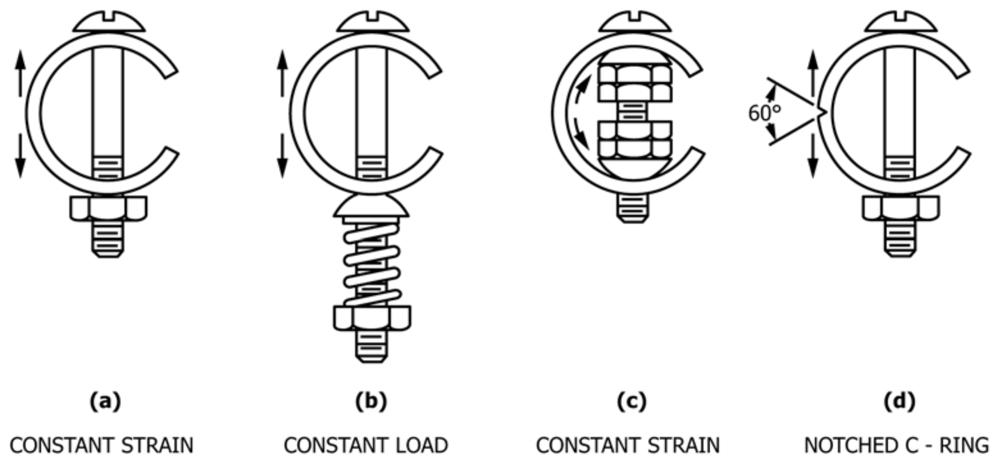
NOTE 1—When specimens are exposed to corrosive media at elevated temperatures, the possibility of relaxation of stress during the exposure period should be investigated. Relaxation can be estimated from known creep data for both the ring and the stressing bolt.

7.5 An advantage of the C-ring is that it can be stressed with high precision and bias by application of a measured deflection. The sources of error in stressing are those that are inherent with the use of measuring instruments (micrometers, strain gages, etc.) as discussed in 7.2 – 7.4 and Annex A1.

7.6 The calculated stress applies only to the state of stress *before* initiation of cracks. Once cracking has initiated the stress at the tip of the crack, as well as in uncracked areas, has changed.

8. Stressing Methods

8.1 The C-ring, as generally used, is a constant-strain specimen with tensile stress produced on the exterior of the ring by tightening a bolt centered on the diameter of the ring. However, a nearly constant load can be developed by the use of a calibrated spring placed on the loading bolt. C-rings also can be stressed in the reverse direction by spreading the ring and creating a tensile stress on the inside surface. These methods of stressing are illustrated in Fig. 3. Proper choice of a minimum



NOTE 1—For Fig 3 (d) a similar notch could be used on the tension side of (b) or (c).

FIG. 3 Methods of Stressing C-Rings

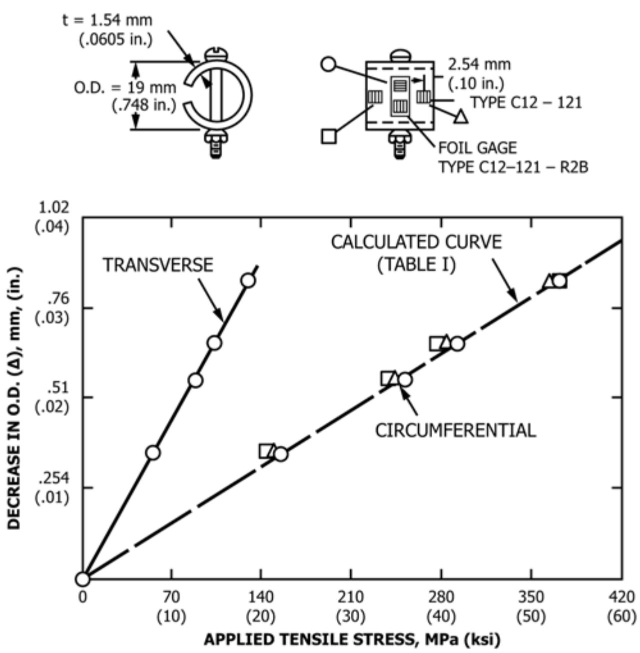


FIG. 4 Stresses in 7075-T6 Aluminum Alloy C-Ring Stress-Corrosion Specimen (4)

bolt diameter or a spring constant is, of course, required to assure achieving true constant strain or constant load stressing.

8.2 The most accurate stressing procedure is to attach circumferential and transverse electrical strain gages to the surface stressed in tension and to tighten the bolt until the strain measurements indicate the desired circumferential stress. The circumferential (σ_C) and transverse (σ_T), stresses are calculated as follows:

$$\sigma_C = E/(1-\mu^2)\cdot(\varepsilon_C+\mu\varepsilon_T), \text{ and}$$
$$\sigma_T = E/(1-\mu^2)\cdot(\varepsilon_T+\mu\varepsilon_C)$$

where:

E = Young's modulus of elasticity,
μ = Poisson's ratio,
ε_C = circumferential strain, and
ε_T = transverse strain.

NOTE 2—When using electrical strain gages with thin-walled C-rings, a correction should be allowed for the displacement of the gage from the surface of the ring. All traces of the gage and the adhesive must be removed from the C-ring before it is exposed.

NOTE 3—Stresses may be calculated from measured strains using the modulus of elasticity, *provided the stresses and strains do not exceed the proportional limit.*

8.3 When several rings of the same alloy and dimensions are to be loaded, it is convenient to determine a calibration curve of circumferential stress versus ring deflection as in Fig. 4 to avoid the inconvenience of strain gaging each ring.

8.4 The amount of compression required on the C-ring to produce elastic straining only, and the degree of elastic strains can be predicted theoretically (**2, 3**). Therefore, C-rings may be stressed by calculating the deflection required to develop a desired elastic stress by using the individual ring dimensions in a modified curved beam equation as shown in Table A1.1. The accuracy of calculated stresses is shown in Fig. 4 by the agreement of the calculated curve and the actual data points. See Annex A1 for the equation for stressing C-ring specimens.

8.5 In the case of notched specimens a nominal stress is assumed using the ring outside diameter measured at the root of the notch. Consideration then should be given to the stress concentration factor (K_T) for the specific notch when calculating the Δ required to develop the intended stress.

NOTE 4—The NACE International Standard TM0177–96 provides procedures for stressing C-Rings to the 0.2% offset yield strength of the material to be tested. Experimentation under the review and scrutiny of the ASTM subcommittee holding jurisdiction of this standard was conducted to assess the accuracy and validity of such procedures. It was found that for a wide range of alloy systems, heat treatments, and test specimen dimensions, errors in the target strain associated with the 0.2% offset yield strength occurred which would be of significance. However, it was also determined that in all cases the actual strain realized following the procedures exceeded that associated with the 0.2% offset yield stress, rendering results following such procedures conservative from an engineering analysis standpoint.

9. Machining

9.1 When rings are machined from solid stock, precautions should be taken to avoid practices that overheat, plastically