



# Standard Practice for Preparation of Stress-Corrosion Test Specimens for Weldments<sup>1</sup>

This standard is issued under the fixed designation G 58; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This practice covers procedures for the making and utilization of test specimens for the evaluation of weldments in stress-corrosion cracking (SCC) environments.

1.2 Test specimens are described in which (a) stresses are developed by the welding process only, (b) stresses are developed by an externally applied load in addition to the stresses due to welding, and (c) stresses are developed by an externally applied load only with residual welding stresses removed by annealing.

1.3 This practice is concerned only with the welded test specimen and not with the environmental aspects of stress-corrosion testing. Specific practices for the bending and loading of test specimens, as well as the stress considerations involved in preparation of C-rings, U-bend, bent beam, and tension specimens are discussed elsewhere in ASTM standards.

1.4 The actual stress in test specimens removed from weldments is not precisely known because it depends upon the level of residual stress from the welding operation combined with the applied stress. A method for determining the magnitude and direction of residual stress which may be applicable to weldment is described in Test Method E 837. The reproducibility of test results is highly dependent on the preparation of the weldment, the type of test specimen tested, and the evaluation criteria used. Sufficient replication should be employed to determine the level of inherent variability in the specific test results that is consistent with the objectives of the test program.

1.5 *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 information, see Section 7.)

## 2. Referenced Documents

### 2.1 ASTM Standards:

E 8 Test Methods for Tension Testing of Metallic Materials<sup>2</sup>

<sup>1</sup> 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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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 03.01.

E 399 Test Method of Plane-Strain Fracture Toughness of Metallic Materials<sup>2</sup>

E 837 Test Method for Determining Residual Stresses by the Hole-Drilling Strain-Gage Method<sup>2</sup>

G 1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens<sup>3</sup>

G 30 Practice for Making and Using U-Bend Stress-Corrosion Test Specimens<sup>3</sup>

G 35 Practice for Determining the Susceptibility of Stainless Steels and Related Nickel-Chromium-Iron Alloys to Stress-Corrosion Cracking in Polythionic Acids<sup>3</sup>

G 36 Practice for Performing Stress-Corrosion Cracking Tests in a Boiling Magnesium Chloride Solution<sup>3</sup>

G 37 Practice for Use of Mattsson's Solution of pH 7.2 to Evaluate the Stress-Corrosion Cracking Susceptibility of Copper-Zinc Alloys<sup>3</sup>

G 38 Practice for Making and Using C-Ring Stress Corrosion Test Specimen<sup>3</sup>

G 39 Practice for Preparation and Use of Bent-Beam Stress-Corrosion Test Specimens<sup>3</sup>

G 44 Practice for Evaluating Stress Corrosion Cracking Resistance of Metals in 3.5 % Sodium Chloride Solution<sup>3</sup>

G 49 Practice for Preparation and Use of Direct Tension Stress Corrosion Test Specimens<sup>3</sup>

## 3. Summary of Practice

3.1 The following summarizes the test objectives that may be evaluated:

3.1.1 Resistance to SCC of a total weldment (weld, heat-affected zone, and parent metal) as produced by a specific welding process.

3.1.2 Resistance to SCC of deposited weld metal.

3.1.3 Determination of a stress level or stress intensity that will produce SCC in a weldment.

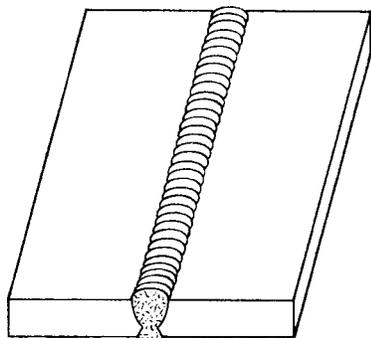
3.1.4 Evaluation of SCC failure in the specific zones of a weld (weld metal, partially melted zone, weld interface, heat-affected zone, and base metal).

3.1.5 Evaluation of the effect of notches and stress raisers in weldments.

## 4. Significance and Use

4.1 The intent of this practice is to indicate standard welded

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 03.02.



*Procedure:*

- (a) Specimen size—as required.
- (b) Note grain direction and weld longitudinally or across grain.
- (c) For multiple-pass welds, grind between passes. Use back gouging from opposite side to attain 100 % weld penetration.
- (d) Discard weld ends.
- (e) Remove test sections as required. Sections may be taken across the weld or longitudinally with the weld.

**FIG. 1 Flat Weldment**

specimens and welding procedures for evaluating the SCC characteristics of weldments in corrosive environments. The practice does not recommend the specific corrosive media that may be selected by the user depending upon the intent of his investigation. Specific corrosive media are included in Practices G 35, G 36, G 37, and G 44. Other environments can be used as required.

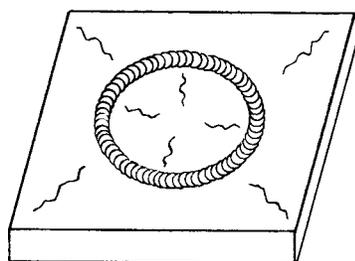
**5. Types of Specimens and Specific Applications**

5.1 This practice covers the following procedures for the preparation of test weldments. The form of the material to be evaluated (plate, bar, tubing, casting, or forging) may determine whether its usage is applicable in a given test. Residual welding stresses may be left intact or they may be fully or partially removed by an appropriate heat treatment.

5.1.1 *Flat Welding* (Fig. 1)—This weldment (1)<sup>4</sup> is applicable for all tension and bend specimens. The size of the weldment may be varied according to the needs of the user or the demands of welding practice being evaluated. It is applicable to any welding procedure and can involve single- or multiple-pass welds.

5.1.2 *Circular Bead Weldment* (Fig. 2)—This weldment (2, 3, 4, 5) measures the tendency for SCC in the base metal, heat-affected zone, and deposited weld metal. The circular weld develops residual stresses. It is applicable to any material form (plate, bar, castings) that can be machined to the recommended size. The welding procedure involves one circular stringer bead deposit of weld metal.

<sup>4</sup> The boldface numbers in parentheses refer to the list of references at the end of this practice.



*Procedure:*

- (a) Specimen size: 100 by 100 by 3 to 12 mm (4 by 4 by 1/8 to 1/2 in.)
- (b) Clamp or tack weld the edges of the test specimen to a base plate to obtain restraint.
- (c) Weld a 50-mm or 2-in. diameter circular bead using the selected weld process (Table 1).
- (d) Examine both sides of specimen after exposure.

**FIG. 2 Circular Bead Weldment**

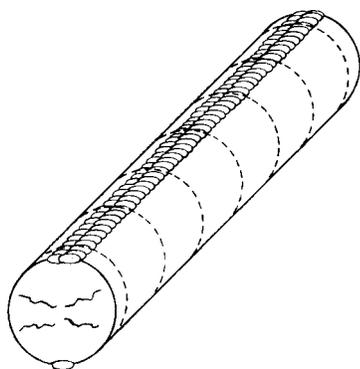
5.1.3 *Bead-on-Bar Weldment* (Fig. 3)—This weldment, (2) measures the tendency for SCC of the base metal. The longitudinal fusion welds develop residual stresses on the bar. It is applicable to materials that can be machined to approximately a 25-mm or 1-in. round.

5.1.4 *Direct Tension Weldments* (Fig. 4)—These weldments (3, 4, 5) measure the cracking tendency in weld metal, base metal, or heat-affected zone. The applied stress is developed in uniaxially loaded tension specimens. Notches may be introduced into the weld metal, base metal, or heat-affected zone. The tension specimens are machined from welded plate or cast sections (Fig. 1) and may be made exclusively from weld metal.

5.1.5 *U-Bend Weldment* (Fig. 5)—This weldment (5, 6) measures crack tendency in the weld, base metal, and heataffected zone. The bending operation after welding creates high levels of elastic and plastic strain resulting in a wide range of stresses in a single specimen. The presence of residual welding stresses make this a most severe test procedure. It is applicable to any material that can be formed into a U-shape without mechanical cracking or localized bending in the heataffected zone.

5.1.6 *Bent-Beam Weldment* (Fig. 6)—This weldment (4, 5, 6) measures cracking tendency in the weld bead, the weldbase metal interface, and heat-affected zone due to stress concentration. The specimen will contain residual welding stresses and stresses due to elastic strain produced by bending. This specimen is particularly applicable to materials that cannot be bent into a U-shape.

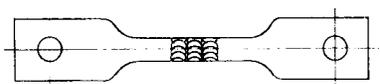
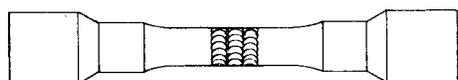
5.1.7 *Precracked Cantilever Beam Weldment* (Fig. 7)—This weldment (5) measures the level of stress intensity to produce



*Procedure:*

- (a) Specimen size: 25-mm (1 in.) diameter by 150 mm (6 in.) long.
- (b) Fusion weld (GTAW) entire length on opposite sides.
- (c) Discard 6 mm or ¼ in. from ends and remove 20-mm or ¾-in. test specimens.
- (d) Examine cross section for radial cracking.

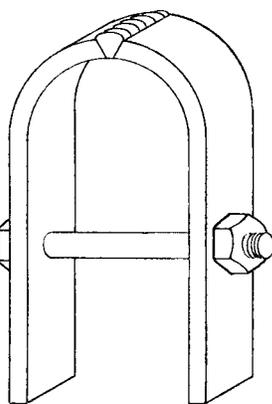
**FIG. 3 Bead-on-Bar Weldment**



*Procedure:*

- (a) Direct tension specimens to be machined directly from flat plate weldment (Fig. 1).
- (b) See Practice G 49 and Test Methods E 8 for recommended dimensions.

**FIG. 4 Direct Tension Weldments**



*Procedure:*

- (a) U-bend specimens to be machined directly from flat plate weldment (Fig. 1)
- (b) See Practice G 30 for bending method.

NOTE 1—The welds may be oriented 90° to the direction shown.

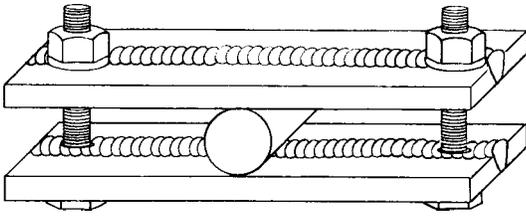
**FIG. 5 U-Bend Weldment**

crack initiation or propagation in various areas of a weldment. Notches or cracks may be introduced into the weld metal, base metal, or heat-affected zone. The specimen will contain residual welding stresses and applied stresses. Weldments may be prepared in accordance with Fig. 1 or by means of the K-preparation for multiple-pass welds (Fig. 11 and Ref (7)).

5.1.8 *Tuning Fork Weldment* (Fig. 8)—This weldment (5, 8) measures cracking tendency in the base metal, heat-affected zone, or weld-base metal interface if the weld reinforcement is not removed. When the reinforcement is removed, cracking may also occur in the weld metal, depending on the susceptibility of the three zones of the weldment and the coincidence of maximum stress with the base metal, heat-affected zone, or

weld metal. Stresses are applied by closing the tines of the fork, and the toe of the weld acts as a metallurgical notch. Tuning-fork specimens may also be machined exclusively from weld metal.

5.1.9 *Cruciform Weldment* (Fig. 9)—This weldment (9) will develop the highest degree of weld restraint and residual weld stresses. It has been used for evaluating the susceptibility of high-strength steel and armor plate to underbead cracking in the heat-affected zone of the weld. The welding sequence will produce an increasing degree of restraint with each successive weld pass. The number of passes may be varied. Sections are taken from the weldment and if not already cracked may be exposed to SCC environments.

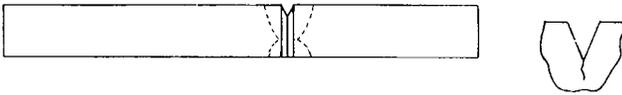


*Procedure:*

- (a) Bent-beam specimens to be machined directly from flat plate weldment. (Fig. 1). Fulcrum should be notched so as not to contact weld bead.
- (b) Dimensions: as required.
- (c) See Practice G 39 for stress calculations.

NOTE 1—The welds may be oriented 90° to the direction shown.

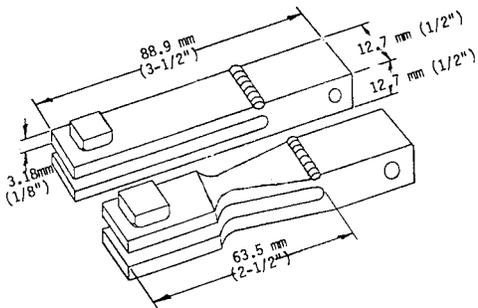
**FIG. 6 Bent-Beam Weldment**



*Procedure:*

- (a) Specimens may be machined from flat plate weldment (Fig. 1) or K-weld preparation (Fig. 11).
- (b) See Test Method E 399 and Ref (13).

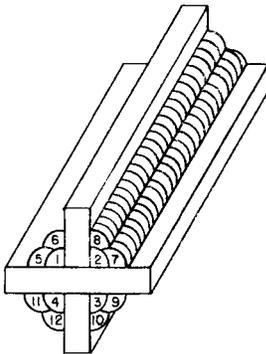
**FIG. 7 Precracked Cantilever Beam Weldment**



*Procedure:*

- (a) Specimens are machined from parent metal and machined to shape.
- (b) Weld bead is applied across the test specimen at the base of one tine.
- (c) Either style specimen is appropriate for this test.

**FIG. 8 Tuning Fork Weldment**



*Procedure:*

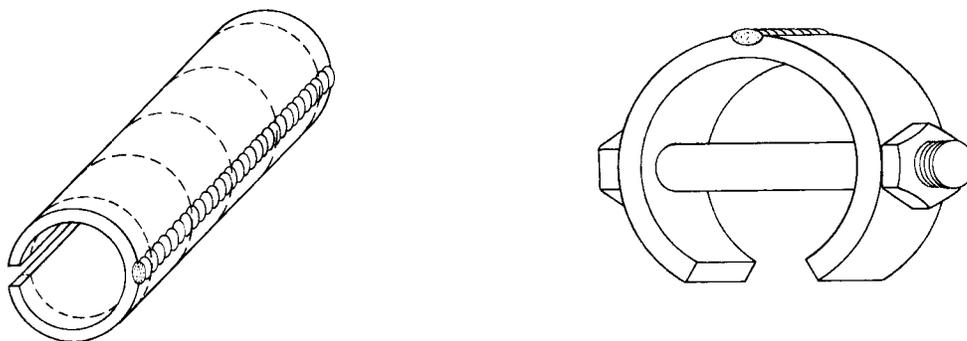
- (a) The dimensions of the plate sections may be varied to suit the needs of the material under study.
- (b) To obtain maximum and uniform weld restraint it is essential to grind all mating surfaces flat. The ground area should be extended to cover the test weld area.
- (c) Weld in sequence shown. The number of passes may be varied to suit the needs of the test.
- (d) Remove and discard 6.4 mm (1/2 in.) on both ends and section tests specimens as required.

**FIG. 9 Cruciform Weldment**

5.1.10 *C-Ring and Slit Tubing Weldments* (Fig. 10)—These weldments (2, 4, 5) measure the cracking tendency in the weld, base metal, and heat-affected zone. In the C-ring test (Practice G 38), the stress is applied externally. In the slit tubing test, the stress is applied by a wedge that is forced into the slit section.

While any material form can be machined into a ring section, this test is specifically designed for tubing.

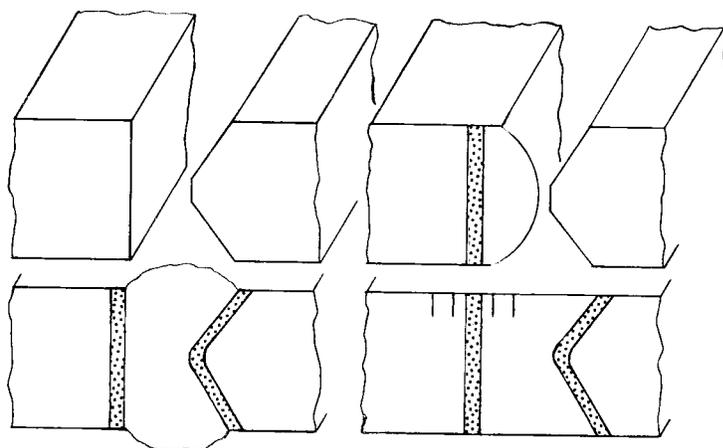
5.1.11 *K-Weld Preparation* (Fig. 11)—This weldment (7) was specifically designed to test the stress-corrosion cracking tendency in various zones of a multiple-pass weld. Notches are



*Procedure:*

- (a) Use plate, bar, tube, or pipe of suitable size from which C-ring specimens can be machined.
- (b) Weld one side for the entire length before cutting slot. The weld bead may be applied in a 60° groove to obtain 100 % weld penetration or it may be applied on the surface only. Cut slot after machining plate or bar to form tube.
- (c) Discard 6.4 mm (¼ in.) on both ends and remove 25-mm (1-in.) long test specimens.
- (d) For slit tubing test, machine a thin slit in the side opposite weld. Stress may be applied by forcing a wedge or block in the slit.
- (e) For C-ring dimension and loading see Practice G 38.

**FIG. 10 Slit Tubing and C-Ring Weldments**



*Procedure:*

- (a) Double bevel groove butt-weld preparation.
- (b) Vertical face buttered with filler metal.
- (c) Weld joint completed with multiple passes of filler metal.
- (d) Joint machined and notched as required.
- (e) See Ref (7).

**FIG. 11 K-Weld Preparation**

made in the weld metal, weld interface, heat-affected zone, or parent metal of cantilever beam-type specimens (Fig. 7). The notches serve as stress concentrators.

NOTE 1—Calculated stresses developed in beam specimens, C-rings, etc. with weld beads intact will not accurately represent stresses generated in fillets at the edge of the weld beads and in relatively thick beads, and strain gages will be needed if precise values of the applied stress are required. The effective stress of course will be the algebraic sum of the applied stress and residual welding stresses.

NOTE 2—Calculated stresses also may be erroneous for bead-off specimens of weldments of dissimilar alloys or in the case of relatively soft heat-affected zones.

**6. Welding Considerations**

6.1 The choice of a welding method and the application of proper welding techniques are major factors influencing the overall corrosion resistance of a weldment. Each welding method as described in Refs (10, 11) has its own inherent

characteristics which will govern the overall quality of the weld. The welding method must therefore be carefully selected and monitored since it will be the governing parameter in the procedure and may introduce a number of variables that will affect test results.

6.2 Typical welding methods that are applicable to this practice are listed in Table 1.

6.3 Variables introduced by the welding method are (a) the amount of heat input introduced by the specific welding process and its effect on microstructure of the weld nugget, weld interface, and heat-affected zone of the parent metal, (b) localized variations in chemical composition developed during melting and solidification, (c) the possible pick-up of nitrogen, carbon, silicon, fluorine, or other impurities from surface contamination, slag, electrode coatings, fluxes, or directly from the atmosphere, (d) loss of elements across the welding arc (for example, chromium), (e) secondary precipitation and other

**TABLE 1 Welding Methods**

Method	AWS Designation	Common Terminology
Shielded metal-arc welding	SMAW	manual-stick electrode
Gas metal-arc welding	GMAW	MIG—short arc
Gas metal-arc welding	GMAW	MIG—spray arc
Gas metal-arc welding	GMAW	MIG—pulsed arc
Gas tungsten-arc welding	GTAW	TIG—fusion weld
Gas tungsten-arc welding	GTAW	TIG—cold wire feed
Gas tungsten-arc welding	GTAW	TIG—hot wire feed
Submerged-arc welding	SAW	sub—arc
Plasma-arc welding	PAW	plasma welding
Electron beam welding	EBW	electron beam welding
Electroslag welding	EW	electroslag welding
Resistance welding	RSW	spot, seam, projection, flash, etc.
Flux-cored arc welding	FCAW	flux core

possible reactions occurring at areas of extremely high heat input, and (f) porosity, shrinkage cracks, or other weld discontinuities introduced by the welding technique (12).

## 7. Hazards

7.1 Certain of the specimen types when made from high strength materials, especially in thick sections with high applied bonds, may exhibit high rates of crack propagation, and a specimen may splinter into several pieces. Due to high stresses in a specimen, these pieces may fly off at high velocity and can be dangerous. Personnel installing and examining specimens should be cognizant of this possibility and be protected against injury.

## 8. Weldment and Test Specimen Preparation

8.1 *Material Parameters*—The test material should be identified as to method of manufacture (plate, sheet, bar, forging, static casting, centrifugal casting, precision casting, powder metal, etc.) Wrought materials (sheet, plate, etc.) should be identified as to direction of rolling. Tubing and pipe should be identified as welded or seamless. In all cases the prior thermal history of the parent metal (as-rolled, annealed, stress-relieved, aged, etc.) should be noted.

8.2 *Weldment Dimensions*—The size and shape of the weldment from which test specimens will eventually be removed will be governed by the intent of the test procedure. Insofar as possible, the thickness, the size of the test material, and the welding process should be chosen to represent the actual structural member and the condition under which it will be welded. Figs. 1-11 illustrate typical combinations of weld location, parent metal, and welding method for the indicated test procedures.

8.3 *Weld Procedure*—The following welding procedure data should be recorded when applicable (see Figs. 1-11):

- Test number
- Base metal (type and manufacturer and heat number)
- Filler metal (type, size, manufacturer, and heat number)
- Preheat or postheat
- Welding process (GSAW, GTAW, EB, etc.)
- Gas shielding (type and flow rate)
- Calculated heat input
- Test specimen preparation
- Weld joint dimension
- Weld sequence

- Welding speed
- Current and voltage
- Polarity
- Number of passes
- Interpass temperature-maximum
- Interpass delay
- Mode and pulse form (MIG welding)

8.4 *Removal of Test Specimens from the Weldment*—With the exception of the circular bead test and the tuning fork test, the test sections are removed from the weldment by milling or saw-cutting. The ends of the weldment must be discarded unless the evaluation of the endweld effect is desired in the test procedure. In the sectioning of specimens from the weldment, care must be taken to maintain adequate section size to ensure that residual stresses are not removed by the sectioning procedure. In specimens that are to be completely machined or ground, the location of the weld nugget and heat-affected zone should be carefully identified by inspection or chemical etching prior to final machining. If applicable, the grain direction due to rolling of bar, plate, and sheet should also be identified.

8.5 *Specimen Preparation* (see Practice G 1):

8.5.1 The type and degree of final surface preparation will depend upon the intent of the test. Weld slag, scale, undercutting, and weld surface discontinuities will influence test results. The weldment should be left in the “as-welded” condition only if the effect of these surface conditions are being evaluated.

8.5.2 When it is desired to leave the weld bead on the test specimen, the surface may be cleaned by light grit or wet vapor blasting provided that care is taken to prevent residual compressive stresses being introduced by the blasting technique. Chemical descaling or pickling should be used with caution since austenitic stainless and high-nickel alloys may be made more susceptible to SCC. Hydrogen embrittlement in high-strength steels may also result from some pickling solutions.

8.5.3 Removal of the weld bead by grinding or machining is recommended where close surface evaluation is to be made in the inspection stage. The weld bead should be ground flush with the parent metal, but only a minimum amount of metal should be removed to achieve this. Residual stresses developed by overheating the metal surface during grinding, machining, and final polishing must be avoided. All sharp machined edges should be broken by light draw filing. Any final machining grinding or polishing should be parallel to the major stress direction.

8.5.4 *Polishing*—Bend test specimens may be given a final polish prior to bending. Machined or ground specimens must also be given a final polish. In all cases a 120-grit finish or better is recommended.

8.5.5 Prior to exposure, the test specimen must be thoroughly cleaned. It should be examined for presence of cracks, weld undercutting, and weld surface defects, and corrective action taken if necessary. This examination should be at the same magnification to be used for inspection after exposure.

## 9. Exposure

9.1 The test media and exposure times for the stress-corrosion testing of weldments may vary from long-term tests in plant equipment under operating conditions or in outdoor environments to various laboratory test media.

## 10. Inspection After Exposure

10.1 Depending upon the intent of the test procedure, the specimens may be inspected for one or more of the following conditions: (a) time for visible crack initiation at a stated magnification, (b) presence or absence of cracks over a given time interval, (c) location of crack (weld bead, weld interface, heat-affected zone, or parent metal, (d) intensity of applied load and time required for complete rupture (direct tension, cantilever beam), (e) microstructure of the cracked area, and (f) depth and degree of cracking.

10.2 *Macroscopic Examination*—Low-magnification examination (1 to 20×) of the test specimen is generally adequate to determine the existence of stress cracking. Higher magnification (100×) may be used to determine presence of very small cracks provided the surface finish of the original specimen is adequate.

10.3 *Examination of Microstructure* (100 to 1000×)—When it is desired to examine the cross section of a weldment, it is recommended that a sketch be made to show the orientation of the surface being examined with the overall weldment. When preparing polished cross sections, the end of the weld (edges of flat specimen) should be cut away to avoid edge effects and end grain corrosion unless an evaluation of the end weld effect is desired.

## 11. Keywords

11.1 elastic; precracked specimens; plastic strain; residual stresses; smooth specimens; stress-corrosion cracking; weld heat-affected zone; welding considerations

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