Designation: F 519 – 05

Standard Test Method for Mechanical Hydrogen Embrittlement Evaluation of Plating/Coating Processes and Service Environments[1]

This standard is issued under the fixed designation F 519; 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 test method covers mechanical tests for the evaluation of hydrogen embrittlement from plating/coating processes or subsequent service environments (including cleaning treatments, maintenance chemicals or gaseous environments), or both, that may contact the surface of steels.

1.2 This test method is intended to be used as a process control for hydrogen produced by plating/coating processes and exposure to chemicals encountered in a service environment. It is not intended to measure the relative susceptibility of different steels. The relative susceptibility of different materials to hydrogen embrittlement may be determined in accordance with Test Method F 1459.

1.3 This test method assumes that air melted AISI E4340 steel per MIL-S-5000 at 51 to 53 Rockwell C Hardness Scale (HRC) is the worst case; that is, all other heat-treated, high-hardness steels are less susceptible to hydrogen embrittlement. The sensitivity to hydrogen embrittlement shall be demonstrated for each heat of steel used in the manufacture of test specimens.

1.4 Test procedures and acceptance requirements are specified for seven specimens of different sizes, geometries, and loading configurations. For plating/coating processes, specimens must meet or exceed 200 hours at a sustained load of 75 % of the notched fracture strength (NFS) (92 % of the ultimate strength for the Type 2a O-Ring specimen) or exceed a threshold of 75 % of the NFS for a quantitative, accelerated (≤24 hours) incremental step-load (ISL) test. For service environments, loading conditions, and pass/fail requirements for each specimen are specified in Annex A5.

1.5 This test method is divided into two parts. The first part gives general information concerning requirements for hydrogen embrittlement testing. The second is composed of annexes that give specific requirements for the seven specimens covered by this test method and the details for testing service environments.

1.5.1 Annex A1 details circumferentially-notched tensile specimens. Annex A2 details self-loading notched specimens including; round tensile, round bend and C Ring specimens. Annex A3 details a notched, four-point bend specimen that combines sustained load and slow strain rate testing, using incremental loads and hold times under displacement control to measure a threshold stress in an accelerated manner. The test in Annex A3 measures the threshold for hydrogen stress cracking that is used to quantify the amount of residual hydrogen in the specimen. Annex A4 details a smooth O-Ring specimen under displacement control. Annex A5 details testing in service environments.

1.6 Specific requirements for the two types of specimens and the seven specific loading and geometrical configurations are as listed:

1.6.1 Type 1—Notched Specimens

Type 1a: Notched, Round, Tension	
Type 1a.1—Standard Size	Annex A1
Type 1a.2—Oversized	Annex A1
Type 1b: Notched, Round, Tension—Self Loading Fixture	Annex A2
Type 1c: Notched, Round, Bend—Self Loading Fixture	Annex A2
Type 1d: Notched, C-Ring, Bend—Self Loading Fixture	Annex A2
Type 1e: Notched, Square, Bend—Displacement Control	Annex A3

1.6.2 Type 2—Smooth Specimens

Type 2a: O-Ring, Bend—Self Loading Fixture	Annex A4

1.7 The values stated in the foot-pound-second (fps) system in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.8 *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.*

[1] This test method is under the jurisdiction of ASTM Committee F07 on Aerospace and Aircraft and is the direct responsibility of Subcommittee F07.04 on Hydrogen Embrittlement.

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2. Referenced Documents

2.1 *ASTM Standards:* [2]

B 374 Terminology Relating to Electroplating

B 851 Specification for Automated Controlled Shot Peening of Metallic Articles Prior to Nickel, Autocatalytic Nickel, or Chromium Plating, or as Final Finish

D 1193 Specification for Reagent Water

E 4 Practices for Force Verification of Testing Machines

E 8 Test Methods for Tension Testing of Metallic Materials

E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials

E 29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

E 616 Terminology Relating to Fracture Testing[3]

E 709 Guide for Magnetic Particle Examination

F 1459 Test Method for Determination of the Susceptibility of Metallic Materials to Gaseous Hydrogen Embrittlement

F 1624 Test Method for Measurement of Hydrogen Embrittlement Threshold in Steel by the Incremental Step Loading Technique

F 2078 Terminology Relating to Hydrogen Embrittlement Testing

G 5 Reference Test Method for Making Potentiostatic and Potentiodynamic Anodic Polarization Measurements

2.2 *SAE AMS Standard:*[4]

AMS 2430 (R) Shot Peening, Automatic

2.3 *Military and Federal Standards:*[5]

MIL-S-5000 Steel, Chrome-Nickel-Molybdenum (E4340) Bars and Forging Stock [Refer to: SAE AMS-S-5000]

MIL-H-6875 Heat Treatment of Steel Raw Materials [Refer to: SAE AMS-H-6875]

MIL-PRF-16173 Corrosion Preventive Compound, Solvent Cutback, Cold-Application

Federal Specification QQ-P-416 Plating, Cadmium (Electrodeposited) [Refer to: SAE AMS QQ P 416]

Federal Specification A-A-55827 Chromium Trioxide, Technical

3. Terminology

3.1 *Definitions*—Definitions of terms used in this test method may be found in Terminology B 374, Terminology E 616 and Terminology F 2078.

3.2 *Acronyms and Abbreviations*:

AISI = American Iron and Steel Institute

a/W = notch depth-to-width ratio

d/D = ratio of minor to major diameters at the notch

ESH = Environmental, Safety and Health

fps = foot pound second

HRC = Rockwell Hardness Scale C

ID = inside diameter

ISL = incremental step load

kip = pounds load multiplied by 1000

ksi = pounds-force per square inch multiplied by 1000

K_t = stress concentration factor

LS = longitudinal short transverse

NFS = notched fracture strength

OD = outside diameter

psi = pounds-force per square inch

RMS = root mean square

SAE AMS = Society of Automotive Engineers Aerospace Material Specification

SCE = saturated calomel electrode

SLT = sustained load test

T.I.R. = total indicated runout

4. Summary of Test Methods

4.1 *Plating/coating Processes*—Unstressed test specimens are cleaned, plated/coated, and baked in accordance with the specification to which the process is to be qualified. Specimens are then maintained under a sustained load in air to measure the time to rupture/completion of the test period or they are tested by ISL to measure the threshold stress.

4.2 *Service Environments*—Plating/coating applied to the test specimens must first be certified by the requirements stated herein for the plating/coating process. They are then tested under load in the service environment. The sequence of exposure to the environment and loading shall be as defined in Annex A5.

5. Significance and Use

5.1 *Plating/coating Processes*—This test method provides a means by which to prevent hydrogen embrittlement of steel parts during manufacture by maintaining strict controls during production operations such as surface preparation, pretreatments, and plating/coating. It is intended to be used as a qualification test for new plating/coating processes and as a periodic inspection audit for the control of a plating/coating process.

5.2 *Service Environment*—This test method provides a means by which to determine the hydrogen embrittlement potential of chemicals that may contact plated/coated or bare steel, or both, parts during manufacturing, overhaul and service life. The details of testing in a service environment are found in Annex A5.

6. Apparatus

6.1 *Testing Machine*—Testing machines shall be within the guidelines of calibration, force range, resolution, and verification of Practices E 4.

6.2 *Gripping Devices*—Various types of gripping devices may be used in either tension or bending to transmit the load applied by the testing machine or self-loading frame to the test specimen.

6.3 *Service Environment Testing*—For testing in service environments, an inert container and fixture arrangement that is suitably electrically isolated from the specimen or compensated to prevent galvanic coupling shall be used for testing in

[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] Withdrawn.

[4] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

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

aqueous environments. The corrosion potential of the specimen may be controlled with a reference Saturated Calomel Electrode (SCE) or equivalent reference electrode such as with Ag/AgCl in accordance with Reference Test Method G 5.

7. Materials and Reagents

7.1 *Materials*:

7.1.1 AISI E4340 per MIL-S-5000.

7.1.2 Aluminum oxide (150 grit or finer), and 180-grit silicon-carbide paper.

7.1.3 Clean shot, size in accordance with Specification B 851.

7.2 *Reagents*:

7.2.1 Corrosion preventive compound, meeting the requirements of MIL-PRF-16173, Grade 2.

7.2.2 Cadmium cyanide electroplating bath (Federal Specification QQ-P-416). (Table 2).

7.2.3 Maintenance chemicals, cleaners, paint strippers, and aqueous environments.

7.2.4 Chromic acid (Federal Specification A-A-55827).

7.2.5 Water (Specification D 1193 Type IV).

8. Hazards

8.1 *Environmental, Safety and Health (ESH)*:

8.1.1 Equipment, materials, solutions, and emissions (if applicable) shall be controlled, handled, used, and disposed of in accordance with the applicable governing ESH regulations.

9. Test Specimens

9.1 *Configuration*—

9.1.1 Seven specific dimensional drawings with tolerances are given for the two types of specimens in the following annexes:

9.1.1.1 Type 1—Notched Specimens

Type 1a: Notched, Round, Tension	
Type 1a.1—Standard Size—per Fig. A1.1	Annex A1
Type 1a.2—Oversized—per Fig. A1.2	Annex A1
Type 1b: Notched, Round, Tension Self Loading Fixture—per Fig. A2.1, Fig. A2.2, Fig. A2.3	Annex A2
Type 1c: Notched, Round, Bend Self Loading Fixture—per Fig. A2.4, Fig. A2.5	Annex A2
Type 1d: Notched, C-Ring, Bend Self Loading Fixture—per Fig. A2.6, Fig. A2.7	Annex A2
Type 1e: Notched, Square, Bend—per Fig. A3.1	Annex A3

9.1.1.2 Type 2—Smooth Specimens

Type 2a: O-Ring, Bend Self Loading Fixture—per Fig. A4.1, Fig. A4.2	Annex A4

9.1.2 The notched round tension, round bend and square bend specimens shall be loaded in the longitudinal grain direction, but the C-Ring and O-Ring can only be loaded normal to the longitudinal grain direction.

9.2 *Manufacture*:

9.2.1 For all notched round specimens, a stress concentration factor (K_t) of 3.1 ± 0.2 shall be maintained[6].

9.2.2 If the 60° notch angle does not permit plating/coating to the root of the notch, then an angle of 90° ± 1° shall be used. For the Type 1a.1 specimen shown in Fig. A1.1, the K_t of 3.1 ± 0.2 shall be maintained by reducing the root radius of the notch to 0.008 ± 0.001 in. for the 90° notch.

9.2.3 The test specimens may be produced from normalized and tempered, hot or cold drawn bar stock, AISI E4340 steel per MIL-S-5000 and heat treated per MIL-H-6875 so as to meet the hardness requirement of 51 to 53 HRC per Test Methods E 18. Rounding per Practice E 29 permits an absolute hardness range of 50.6 to 53.4 HRC of the average of three measurements.

9.2.4 Tolerances unless otherwise specified are:

X.X	±0.1 inches
X.XX	±0.01 inches
X.XXX	±0.001 inches

9.2.5 The surface finish of all notches shall be 32 root mean square (RMS) or better. The other surfaces shall have a finish of 63 RMS or better.

9.2.6 After quenching and tempering to final hardness, the entire notch shall be ground to size before plating/coating. Single-point machining of the notch configuration is not permitted. Burnishing of the notch is not permitted. The notch shall not be shot peened or receive any blasting/mechanical cleaning operation after the notch is ground to size.

9.2.7 After grinding, all specimens shall receive a stress relief bake at 375 ± 25°F (190 ± 14°C) for 4 hours. A suitable protection from heat treating discoloration should be used.

9.2.8 Acid or cathodic electrolytic cleaning is prohibited.

9.2.9 Straightening after final heat treatment is prohibited.

9.3 *Storage*:

9.3.1 Before plating/coating, all specimens shall be protected during storage to prevent corrosion. A suitable means of protection is to coat the specimen with a corrosion preventive compound meeting the requirements of MIL-PRF-16173, Grade 2.

9.4 *Inspection*:

9.4.1 A lot shall consist of only those specimens cut from the same heat of steel in the same orientation, heat treated together in the same furnace, quenched and tempered together and subjected to the same manufacturing processes together.

9.4.2 All notched specimens shall be suitable for test purposes if the sampling and inspection results conform to the requirements of Table 1 .

9.5 *Sensitivity Test*:

9.5.1 The sensitivity to hydrogen embrittlement must be demonstrated for each heat of AISI E4340 steel by exposing six trial specimens to two different embrittling environments after manufacture and inspection in accordance with Section 9.

9.5.1.1 Three specimens shall be electroplated under the highly embrittling conditions produced in a bright cadmium cyanide bath by Treatment A (Table 2) and the remaining three specimens shall be electroplated under the less embrittling conditions of Treatment B (Table 2). An equivalent plating/coating or imposed potential may be used if its sensitivity is demonstrated to be equivalent to that found in Table 2.

9.5.2 Each heat of steel shall be of suitable sensitivity only if all three specimens plated by Treatment A fracture within 24 hours and none of the three specimens plated by Treatment B fracture within 200 hours after applying the sustained loads specified in Table 3 .

[6] See Peterson, R. E., *Stress Concentration Factors*, John Wiley and Sons, 1974.

TABLE 1 Lot Acceptance Criteria for Notched Specimens

Type	Item	Sampling of Each Lot	Requirement/Method
1	Hardness[A]	5 %	51 to 53 HRC per Test Methods E 18. Round the average of three readings per specimen per Practice E 29.
1	Dimensions	100 %	Meet tolerances of corresponding drawings. Notch dimension verified with shadow graphic projection at 50 to 100×.
1	NFS	10 ea	NFS of each specimen must be within 10 ksi (pounds per square inch × 1000) of the average.
1c	Self-loading notched round specimen bend fixture, Fig. A2.5	10 ea	Alternate: The number of turns of the loading bolt, which is required to produce fracture in each specimen, must be within 5 % of the average.
1d	Self-loading notched C-Ring bend fixture, Fig. A2.6	10 ea	Alternate: The change in diameter at fracture load for each specimen must be within 0.005 inches of the average.

[A] If the hardness requirements of any of the sampled specimens are not satisfied, only those specimens of the lot that are individually inspected for conformance to these requirements shall be used for testing.

TABLE 2 Electroplating Bath Compositions and Operating Conditions for Sensitivity Test of Heats of AISI E4340 Steel

Item	Treatment A	Treatment B
Bath composition:		
Cadmium (as CdO)	4.5 oz/gal (33.7 g/L)	4.5 oz/gal (33.7 g/L)
Sodium cyanide (NaCN)	14 oz/gal (104 g/L)	14 oz/gal (104 g/L)
Ratio NaCN to CdO	3.0	3.0
pH	12.0	12.0
Temperature	70–90°F (21–32°C)	70–90°F (21–32°C)
Sodium hydroxide (NaOH)	2.5 oz/gal (18.7 g/L)	2.5 oz/gal (18.7 g/L)
Brightener such as ROHCO 20 X L or equivalent	2.0 oz/gal (15.0 g/L)	...
Electroplating current	10 A/ft^2 (108 A/m^2)	60 A/ft^2 (645 A/m^2)
Electroplating time	30 minutes	6 minutes
Baking:		
Baking temperature	375 ± 25°F (190 ± 14°C)	375 ± 25°F (190 ± 14°C)
Baking time: Type 1 Specimen	Do Not Bake	23 hours
Baking time: Type 2a Specimen	8 hours	23 hours

TABLE 3 Pass/Fail Loading Requirements of Test Specimens

Type 1a, 1b, 1c, 1d	75 % of the tensile or bend NFS (Table 1).
Type 2a	92 % of the Test Methods E 8 ultimate strength, obtained by deflecting a 2.300-inch diameter O-Ring specimen with a 2.525-inch stressing bar.

9.5.3 To further verify the quality of the manufactured lot of specimens, a minimum of five specimens plated per Treatment B shall be tensile tested per Test Methods E 8 as in Table 1 and all of the tensile test results shall be within ±10 ksi (pounds per square inch × 1000) of the mean of the ten unplated specimens. The dimensions of the bare metal specimen shall be used in the stress calculations.

9.6 *Certification*:

9.6.1 Each lot of specimens manufactured and sold shall be certified in writing to indicate that it meets the conditions found in this section, including the following information:

9.6.1.1 Manufacturer of specimen lot.

9.6.1.2 Steel supplier, heat number, and certificate for chemical composition and heat treatment response.

9.6.1.3 Test results for requirements in Table 1, 9.5.2 and 9.5.3, including the corresponding average rupture load in units of X.XX kips (1 kip = 1000 pounds load).

10. Procedure

10.1 *Plating/coating Processes*:

10.1.1 *Number of Specimens*—A minimum of four specimens shall be used per test.

10.1.2 *Re-Use of Specimens*—Test specimens produced and tested per this test method shall only be used once. Stripping and reuse of specimens are prohibited.

10.1.3 Sometimes it is necessary to plate only the notched area of the specimen to provide an escape path for hydrogen during bake.

10.1.4 *Dimensions for Stress Calculations*—The dimensions of the bare metal specimen shall be used in stress calculations.

10.1.5 *Load*—Sustained load specimens shall be loaded in accordance with Table 3.

10.1.6 *Time*—Sustained loads shall be maintained for a minimum of 200 hours. Actual fracture times may be electronically monitored with a relay switch system.

10.1.6.1 An alternate, ISL accelerated test (≤24 hours) as described in Annex A3 of this document and as further defined in Test Method F 1624 may be used only if specified by the purchaser.

10.2 *Service Environments*:

10.2.1 The testing protocol (number, load, and time) are specified in Annex A5.

11. Interpretation of Results

11.1 A plating/coating process shall be considered non-embrittling if none of the plated/coated specimens fracture within 200 hours after loading as specified in Table 3.

11.1.1 If only one of a minimum of four specimens fractures within the 200-hour sustained load exposure time, step load the remaining three specimens every hour in 5 % increments to 90 % of the NFS after completion of the 200-hour sustained load. After 1 hour at 90 %, the process shall be considered non-embrittling if no fracture occurs in the three remaining specimens.

11.2 If two or more specimens fracture within the sustained load exposure time, the plating/coating process shall be considered embrittling.

11.3 The root cause of any failure shall be determined and corrected before a replacement test is carried out.

11.3.1 A failure can be ruled anomalous if it is determined that an error was made in the plating/coating of the specimen or if a metallurgical examination of the fractured specimen indicates some defect in the manufacture of the specimen.

11.3.1.1 Pre-existing specimen defects such as cracks, grinding burns, or nonmetallic inclusions can be considered as a basis for invalidation of test results and replacement testing.

11.4 A replacement test can be conducted if it is determined that the failures were anomalous. This test shall use four specimens. If no fracture occurs within the sustained load exposure time, the plating/coating process shall be considered non-embrittling. If any specimen fractures during the replacement test, the plating/coating process shall be considered embrittling.

12. Report

12.1 A test report shall be produced upon completion of testing that bears the minimum information specified in 12.1.1 through 12.1.5.

12.1.1 A lot acceptance and sensitivity certification report.

NOTE 1—The lot acceptance and sensitivity report may be provided by the specimen manufacturer.

12.1.2 The type and number of specimens tested including deviations from standard geometry or K_t, or both.

12.1.3 A description of the plating/coating process and test environment (concentration, temperature, and so forth) if other than ambient air.

12.1.4 The sustained or threshold load, or percent of NFS or notch bend strength of unplated specimens, or displacement as appropriate for the type of specimen tested.

12.1.5 The time under load in the test environments.

13. Precision and Bias

13.1 No information is presented about either the precision or bias of Test Method F 519 for measuring the time to failure, since the test results are nonquantitative pass/fail measurements.

13.2 The precision and bias of this test method for measuring the threshold are essentially as specified in Test Method F 1624.

14. Keywords

14.1 cleaner; coating; delayed failure; fluids; hydrogen embrittlement; maintenance chemicals; plating/coating; steel; stress cracking; threshold

ANNEXES

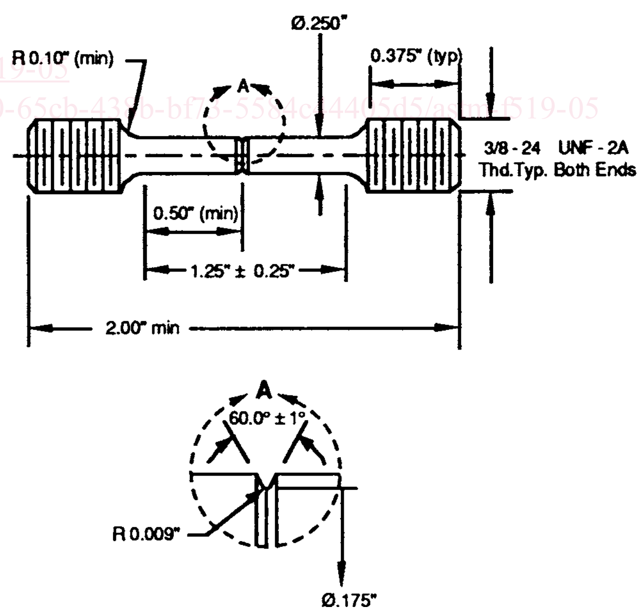
(Mandatory Information)

A1. SPECIAL REQUIREMENTS FOR THE TESTING OF NOTCHED ROUND TENSION SPECIMENS

A1.1 *Type 1a*—The notched round tension specimen is given in two sizes. If the specimen geometry is not called out, the Type 1a.1, standard notched round specimen under load control, shall be used.

A1.1.1 *Type 1a.1 Standard*—The dimensions for the standard sized specimen for the sustained load test (SLT) are shown in Fig. A1.1. The test machine shall have a minimum load capacity of 10 kips to measure the NFS in accordance with Table 1. Correspondingly, a test machine with a minimum load capacity of 7.5 kips is required to maintain a sustained load of 75 % of the NFS in accordance with Table 3.

A1.1.2 *Type 1a.2*—The dimensions for the oversized specimen for SLT are shown in Fig. A1.2. The test machine must have a minimum capacity of 16 kips to measure the NFS in accordance with Table 1. Correspondingly, a minimum 12-kip test machine is required to maintain a sustained load of 75 % of the NFS in accordance with Table 3.

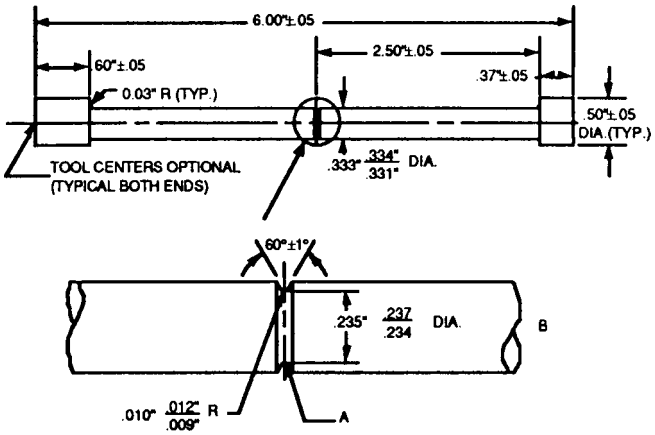


NOTE 1—Specimen preparation must comply with section 9.2.

NOTE 2—End configuration is optional, except that external threaded ends must have the minor diameter greater than 0.25 inches.

NOTE 3—Root radii, reduced section, and notch root radius must be concentric with centerline of specimen within 0.002 T.I.R. (total indicated runout).

FIG. A1.1 Dimensional Requirements for the Type 1a.1 Specimen



NOTE 1—Specimen preparation must comply with section 9.2.
NOTE 2—End configuration is optional, such as the use of external threaded ends, where the minor diameter must be greater than 0.35 inches.
NOTE 3—Root radii, reduced section, and notch root radius must be concentric with centerline of specimen within 0.002 T.I.R.

FIG. A1.2 Dimensional Requirements for the Type 1a.2 Specimen

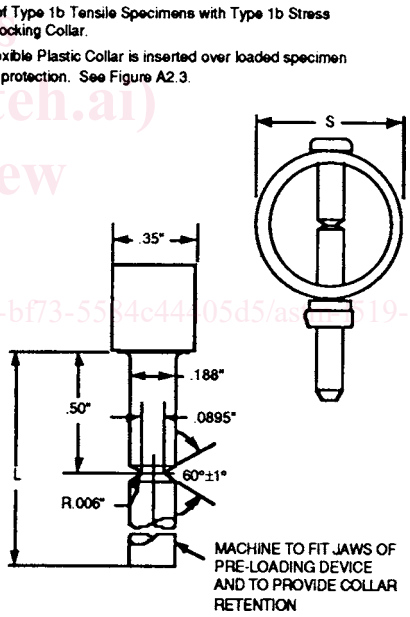
A2. SPECIAL REQUIREMENTS FOR THE TESTING OF NOTCHED SPECIMENS IN SELF-LOADING FIXTURE

A2.1 *Type 1b—Notched Tension Specimen*—Type 1b is a subsized specimen (*d*/*D* (ratio of minor to major diameters at the notch) = 0.0895/0.188) under a constant displacement requiring a special sustained loading device for loading to 75 % of the NFS. The capacity of the testing machine for determination of the NFS in accordance with Table 1 must exceed 2.5 kips. Consideration should also be given to Test Methods E 8 – 04, Note 5, Figure 8 concerning the use of subsize specimens.

A2.1.1 The method of spring-loading notched round specimens in tension uses a pre-calibrated ring as detailed in Fig. A2.1. The ring manufacturer calibrates each ring by determining the change in diameter of the ring when subjected to a load equivalent to that required to stress a test specimen to 75 % NFS.

A2.1.2 Mechanisms used to load a test specimen in a stressed ring must be able to hold the test specimen at a stress level of 90 % of the maximum load applied to the specimen. A method that allows loading and locking test specimens at stress levels as high as 75 % NFS is described as follows.

A2.1.3 Insert the test specimen in a calibrated ring. Fit the end of the specimen extending through the ring with a stainless steel retaining collar and insert it into the jaws of a hydraulic loading device. As the load is applied, the collar is swaged to the shaft of the specimen. No torsional loads shall be introduced during loading. The change in ring diameter after removal from the hydraulic loading device indicates the actual stress level obtained (test load) and this must be at least 90 % of the change in ring diameter produced during initial loading. If the specimen has not failed by the end of the test period, the measured ring diameter must be within 0.001 in. of that measured after initiating the test.



NOTE 1—"L" to be 1.5 inches (38.1 mm) or greater.
NOTE 2—Tolerance (unless otherwise specified):
X.XX ± 0.05 in. (127 mm)
X.XXX ± 0.001 in. (0.025 mm)
X.XXXX ± 0.0002 in. (0.005 mm)

FIG. A2.1 Dimensional Requirements for Type 1b Specimens

A2.1.4 **Warning**—To prevent possible injury from a failure of a loaded specimen, mount a protective collar over the specimen and ring immediately after loading as shown in Fig. A2.2 and Fig. A2.3.