



Designation: E 290 – 97a (Reapproved 2004)

## Standard Test Methods for Bend Testing of Material for Ductility<sup>1</sup>

This standard is issued under the fixed designation E 290; 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.

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

### 1. Scope

1.1 These test methods cover bend testing for ductility of materials. Included in the procedures are four conditions of constraint on the bent portion of the specimen; a guided-bend test using a mandrel or plunger of defined dimensions to force the mid-length of the specimen between two supports separated by a defined space; a semi-guided-bend test in which the specimen is bent, while in contact with a mandrel, through a specified angle or to a specified inside radius ( $r$ ) of curvature, measured while under the bending force; a free-bend test in which the ends of the specimen are brought toward each other, but in which no transverse force is applied to the bend itself and there is no contact of the concave inside surface of the bend with other material; a bend and flatten test, in which a transverse force is applied to the bend such that the legs make contact with each other over the length of the specimen.

1.2 After bending, the convex surface of the bend is examined for evidence of a crack or surface irregularity. If the specimen fractures, the material has failed the test. When complete fracture does not occur, the criterion for failure is the number and size of cracks or other surface irregularity visible to the unaided eye occurring on the convex surface of the specimen after bending, as specified by the product standard. Any cracks within one thickness of the edge of the specimen are not considered a bend test failure. Cracks occurring in the corners of the bent portion shall not be considered significant unless they exceed the size specified for corner cracks in the product standard.

1.3 The values stated in SI units are to be regarded as standard. Inch-pound values given in parentheses were used in establishing test parameters and are for information only.

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

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.02 on Ductility and Flexure Testing.

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### 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

- E 6 Terminology Relating to Methods of Mechanical Testing
- E 8 Test Methods for Tension Testing of Metallic Materials
- E 8M Test Methods for Tension Testing of Metallic Materials (Metric)
- E 18 Test Methods for Rockwell Hardness and Rockwell Superficial Hardness of Metallic Materials
- E 190 Test Method for Guided Bend Test for Ductility of Welds

### 3. Summary of Test Methods

3.1 Four methods for ductility testing employing bending are included in these test methods. Two methods have subgroups with specific procedures.

3.1.1 *Guided-Bend*

3.1.2 *Semi-guided Bend:*

3.1.2.1 *Arrangement A*, specimen held at one end.

3.1.2.2 *Arrangement B*, for thin material.

3.1.2.3 *Arrangement C*, mandrel contact force in the bend.

3.1.3 *Free-Bend:*

3.1.3.1 *Type 1*, 180° bend.

3.1.3.2 *Type 2*, bend flat on itself.

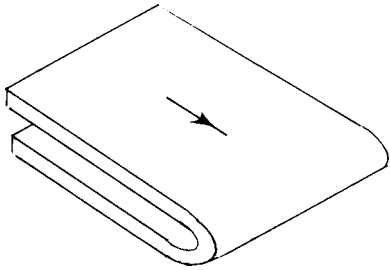
3.1.4 *Bend and Flatten:*

3.2 A guided bend test for ductility of welds is described in Method E 190 and may be used for flat-rolled materials when specified by the product standard. The essential features of this bending method are employed in Method 1 Guided-Bend (3.1.1).

3.3 Bend tests are made in one of two directions relative to the principal working direction employed in production processing of the material.

3.3.1 Longitudinal tests use a specimen with its long dimension aligned with the processing direction such that the bend is formed across the processing direction, as shown in Fig. 1.

<sup>2</sup> 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.



NOTE 1—Arrow indicates direction of processing.  
**FIG. 1 Longitudinal Bend Test**

3.3.2 Transverse tests use a specimen with the long dimension perpendicular to the processing direction so that the bend axis is aligned with the processing direction, as shown in Fig. 2. The axis of bend is the center of the bend radius.

3.3.3 Thin sheet products are generally produced by reducing the thickness of stock in rolling mills and from this the term rolling direction is used to identify the principal processing direction. Similarly, a product produced in coil form may have the processing direction referred to as the coiling direction.

3.4 The location of the force application to the specimen relative to the bend itself and the amount of bending differentiate the four methods of bending covered in these test methods. The two semi-guided-bend test procedures provide radiused surfaces over which the bend is formed. The results obtained by different test procedures may not be the same, especially for material with a tendency to crack or fracture.

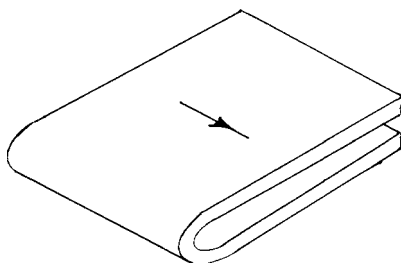
3.5 The test is completed when the designated angle of bend, or other specified condition, has been reached.

3.5.1 If a defined amount of cracking is permitted by the product standard, the convex surface of the bend region is examined for cracks and surface irregularities.

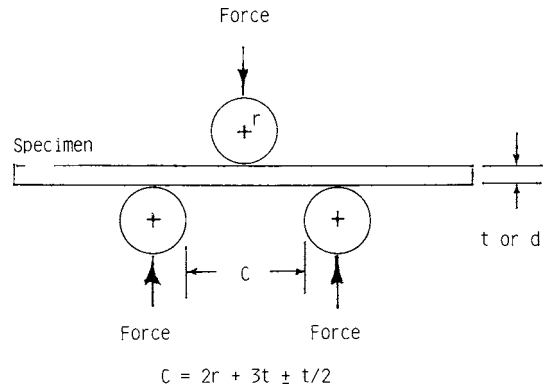
3.5.2 Surface irregularities, such as orange peel, loss of coating adherence, or imperfections resulting from the bend, shall be noted as required by the product specification.

3.6 *Guided-Bend*—The guided-bend test is made by supporting the specimen on pins, rollers, or radiused flats near each end and applying a force through a pin, mandrel, or plunger midway between two supports, as shown schematically in Fig. 3, until the desired bend is formed. No force is applied directly to the outer face of the bend.

3.6.1 The radii of the plunger and of the two supports shall be defined in the product specification as related to the thickness ( $t$ ) of the specimen being tested. A clearance of three



NOTE 1—Arrow indicates direction of processing.  
**FIG. 2 Transverse Bend Test**



NOTE 1— $C$  = distance between lower supports,  
 $r$  = radius of the end of the mandrel or plunger,  
 $t$  = sheet specimen thickness,  
 $d$  = round specimen diameter, and  
 $w$  = sheet specimen width.  
**FIG. 3 Schematic Fixture for the Guided-Bend Test**

thickness with a tolerance of one half thickness shall be provided between the pins, plunger, and specimen in the initial bend fixture.

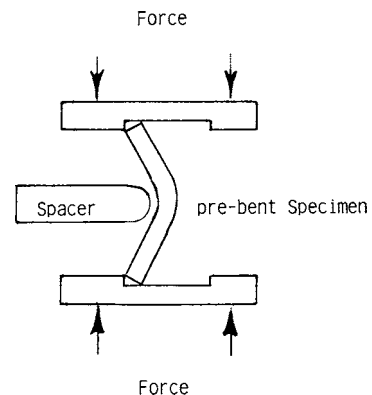
3.6.1.1 The distance between supports ( $C$ ) shall be three thicknesses plus twice the plunger radius, with a tolerance of one-half thickness, as shown in Fig. 3.

3.6.2 The surfaces of the supports and plunger shall be hardened to between 20 and 30 HRC. Refer to Method E 18.

3.6.3 The supports can be fixed or free to rotate. A lubricant may be applied to the supports and plunger.

3.6.4 The width of the guided-bend fixture, including the supports and plunger, shall be such that the specimen is subject to the bending force across its width ( $w$ ) during bending.

3.6.5 When the thickness or strength of the specimen, or capacity of the guided-bend test fixture (shown in Fig. 3) does not produce the required amount of bending, the specimen can be removed from the fixture and the bend completed by applying force against the ends of the specimen, as shown schematically in Fig. 4. A spacer with a thickness equal to twice the required bend radius is inserted at the location of the bend. The edges at the ends shall be constrained so the specimen cannot eject from the fixture under the bending force.



**FIG. 4 Schematic Fixture for Completing the Guided-Bend Test Started as Shown in Fig. 3**

3.6.6 Surface cracks and imperfections resulting from the bend shall be evaluated and reported.

3.7 *Semi-guided Bend*—The semi-guided-bend test employs a constraining force on the inside of the bend during the initiation of the bending and continuing until the final bend condition is achieved.

3.7.1 The semi-guided bend test is made by applying a force transversely to the specimen's long axis in the portion that is being bent.

3.7.2 The angle of bend in the semi-guided-bend test is measured while the specimen is held stationary under the force forming the bend.

3.7.3 The location of the bend along the length of the specimen is unimportant. The specimen is clamped or supported by one of the methods shown schematically in Figs. 5-7. It is possible that different results will be obtained with the use of different devices. The method used shall be described in the test report on the ductility of the material being evaluated.

3.7.4 *Arrangement A—One End Held*—Arrangement A involves holding one end of the semi-guided bend specimen and applying a force transversely near the free end as in Fig. 5. The bend is formed around a stationary pin, mandrel, or roller of a specified radius. Bending is continued until failure occurs or the specified angle of bend has been achieved.

3.7.5 *Arrangement B—Thin Materials*—Arrangement B is for semi-guided bend tests of thin specimens, and includes a support between the clamp and the bend radius, as shown schematically in Fig. 6. No tension force is applied to the specimen during the bending. The results should be the same for tests using either Arrangement A, or Arrangement B.

3.7.6 *Arrangement C—Mandrel Contact on Outer Surface*—Arrangement C employs a stationary pin, or mandrel, over which the semi-guided-bend specimen is bent by the force of a roller, or mandrel, in contact with the outer surface of the bend (as shown schematically in Fig. 7). This may exert a small tension force in the bend. The test is sometimes referred to as a *wrap*, but it is distinct from the *wrap around* wire test described in Method E 6.

3.7.7 Surface cracks and irregularities resulting from the bend shall be evaluated and reported.

3.8 *Free-Bend*—The free-bend test is made with no external force applied to the specimen in the immediate area of the bend.

3.8.1 The force to initiate bending for a free-bend test shall be applied at, or within one width distance from, the ends of the specimen. This may be done by gripping the specimen. If the material is too stiff to respond to such force it shall be

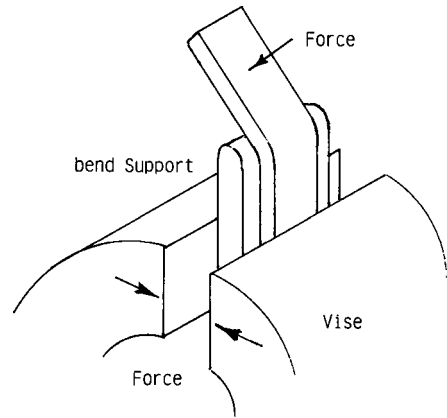


FIG. 6 Arrangement B for Semi-Guided-Bend Test of Thin Specimens—One End Held

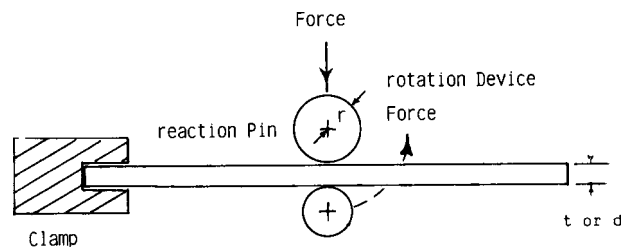


FIG. 7 Schematic Fixture for Semi-Guided-Bend Test Arrangement C—One End Held—Force Applied Near Mandrel

supported at the mid-length (as shown schematically in Fig. 8) over a span of at least the specimen width while the initial force is applied near the two ends of the specimen.

3.8.2 The angle of a free-bend is measured once the specimen has been removed from the bending fixture and is under no constraining force. There is no radius of bend measurement required for a free-bend test.

3.8.3 *Type 1-Free-Bend—180° Bend*—The bending is initiated as described in 3.8.1 and is then continued until a 180° bend is developed by applying force to bring the legs of the specimen to a parallel position (as shown schematically in Fig. 9).

3.8.4 *Type 2-Free Bend (Flat on Itself Bend)*—The legs of the specimen are placed under flat platens and compressed to contact no closer than one width of specimen distance from the outer extension of the bend (as shown schematically in Fig. 10).

3.8.5 The bending force is more severe in a Type 2-Free-Bend test than in a Type 1-Free-Bend test. For this reason, the type of bending used shall be described in the report.

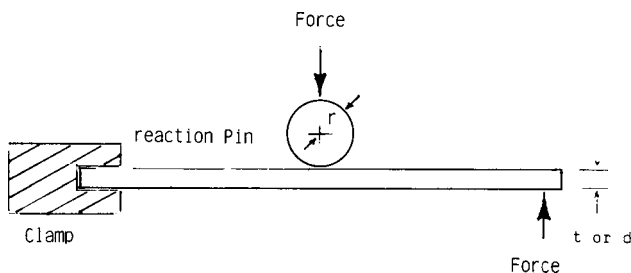


FIG. 5 Schematic Fixture for Semi-Guided-Bend Test Arrangement A—One End Held—Force Applied Near Free End

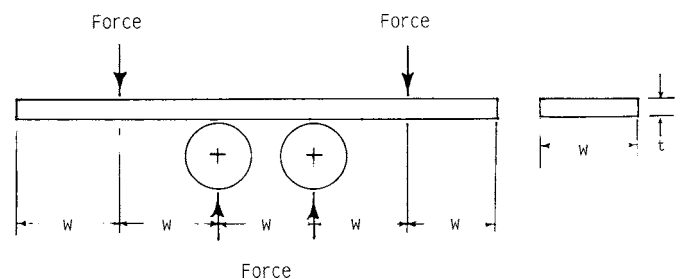


FIG. 8 Free-Bend Support and Force

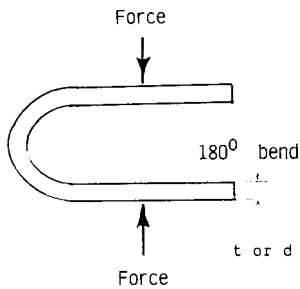


FIG. 9 Type 1 180° Free-Bend

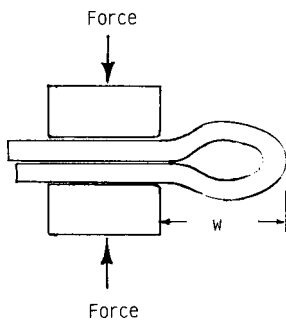


FIG. 10 Type 2 Flat-on-Itself Free-Bend

NOTE 1—The distance from the clamping platens to the outer bend shall not be less than the width ( $w$ ) of the bend specimen.

3.8.6 Materials that age harden at room temperature shall be tested within the allowed period of time, as defined in the product standard.

3.8.7 After completing the free-bend, the surface is examined for cracks and imperfections.

3.9 *Bend and Flatten*—For the bend and flatten test for ductility, an initial 180° bend is made as described in 3.8.1 and 3.8.3. The specimen is then placed between two parallel platens extending beyond the bent portion of the specimen and wider than the specimen width.

3.9.1 Force is exerted to clamp the specimen and cause the two legs to contact at the bend, exclusive of the eye of the bend (as shown schematically in Fig. 11).

3.9.2 Examination for cracks in the outer surface of the bend is done after removing the specimen from the bending force and allowing springback. The allowed number and size of cracks on the outer surface of the bend shall be as specified in the product standard.

3.9.3 Any surface imperfections resulting from the bend test shall be noted and reported.

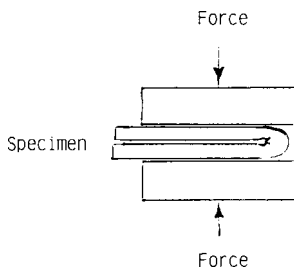


FIG. 11 Bend and Flatten

#### 4. Significance and Use

4.1 Bend tests for ductility provide a simple way to evaluate the quality of materials by their ability to resist cracking or other surface irregularities during one continuous bend. No reversal of the bend force shall be employed when conducting these tests.

4.2 The type of bend test used determines the location of the forces and constraints on the bent portion of the specimen, ranging from no direct contact to continuous contact.

4.3 The test can terminate at a given angle of bend over a specified radius or continue until the specimen legs are in contact. The bend angle can be measured while the specimen is under the bending force (usually when the semi-guided bend test is employed), or after removal of the force as when performing a free-bend test. Product requirements for the material being tested determine the method used.

4.4 Materials with an as-fabricated cross section of rectangular, round, hexagonal, or similar defined shape can be tested in full section to evaluate their bend properties by using the procedures outlined in these test methods, in which case relative width and thickness requirements do not apply.

#### 5. Apparatus

5.1 To prevent the introduction of uncontrolled forces while accomplishing the bend, the following clamping and force application devices shall be used.

5.2 *Guided-Bend Test*—The shape of the material during bending is controlled by employing a pair of pins, rollers, or surfaces with end radiused flat to support the specimen while a guided plunger bends the material at its mid-length, as shown schematically in Fig. 3. A more detailed description of a fixture used for this test is given in Method E 190.

5.2.1 When the guided-bend test is to be finished by bending through a 180° bend that cannot be achieved using the fixture shown in Fig. 3, a fixture shown schematically in Fig. 4 can be used to position the ends of the specimen and prevent it from being ejected while a compression force is applied to bring the legs of the specimen together until they are parallel to each other. A spacer with a thickness equal to twice the required radius is inserted at the bend to stop the force at the specified spacing.

5.3 *Semi-guided-Bend Tests*—For a semi-guided-bend, the inside of the bend is controlled by contact with a pin or mandrel having a defined radius.

5.3.1 *Semi-guided-Bend—Arrangement A*—This arrangement involves holding one end of the specimen while a reaction pin, or mandrel, bears against the specimen at an intermediate location, usually the mid-length. A device (as shown schematically in Fig. 5) is used to apply the bending force near the free end of the specimen.

5.3.2 *Semi-guided-Bend—Arrangement B for thin material*—The specimen is placed against a support with a suitable end radius and clamped in a bench vise, as shown schematically in Fig. 6. This controls the location of the bend away from the clamping force.

5.3.3 *Semi-guided-Bend—Arrangement C*—The specimen is held at one end while a reaction pin, or mandrel, contacts the inside surface of the specimen at the location of the bend. A