Designation: E290 – 22

Standard Test Methods for Bend Testing of Material for Ductility[1]

This standard is issued under the fixed designation E290; 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 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 of bend or to a specified inside radius of bend (*r*) 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 irregularities. 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 surface irregularities visible to the unaided eye occurring on the convex surface of the specimen after bending, as specified by the product specification. 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 specification.

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, 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 *ASTM Standards:*[2]

E6 Terminology Relating to Methods of Mechanical Testing

E8/E8M Test Methods for Tension Testing of Metallic Materials

E190 Test Method for Guided Bend Test for Ductility of Welds

3. Terminology

3.1 *Definitions*—Refer to Terminology E6 for the definitions of bend test, ductility and springback.

3.1.1 *guided bend, n*—the bend obtained by using a mandrel to guide and force the portion of the specimen being bent between two faces of a die.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *angle of bend, n*—the change in the angle between the two legs of the specimen during a bend test, measured before release of the bending forces, unless otherwise specified.

3.2.2 *bend-and-flatten bend, n*—the bend obtained by compressing the legs of a 180° bend between platens until the legs of the bend contact.

3.2.3 *crack, n*—a nominally two-dimensional defect caused by the bend test that extends primarily from the surface of the test specimen to its interior.

3.2.3.1 *Discussion*—Different disciplines characterize and describe cracks using different, specific terminology. The terminology of a specification that cites E290 shall always be followed instead of any crack terminology defined here.

[1] 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 Formability.

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[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.

***A Summary of Changes section appears at the end of this standard**

3.2.4 *free bend*—the bend obtained by applying forces to the ends of a specimen without the application of force at the point of maximum bending.

3.2.4.1 *Discussion*—In making a free bend, lateral forces first are applied to produce a small amount of bending at two points. The two bends, each a suitable distance from the center, are both in the same direction.

3.2.5 *mandrel, n*—In bend testing, the tool used to control the strain on the concave side of a bend in a wrap-around bend test and also to apply the bending force in a semi-guided or guided-bend test.

3.2.5.1 *Discussion*—The terms pin, plunger, and male die have been used in place of mandrel.

3.2.5.2 *Discussion*—In free bends or semi-guided bends to an angle of 180° a shim or block of the proper thickness is sometimes placed between the legs of the specimen as bending is completed. This shim or block is also referred to as a pin or mandrel.

3.2.6 *radius of bend* [L], *n*—the radius of the cylindrical surface of the pin, mandrel, plunger, roller, support, or male die that comes in contact with the inside surface of the bend during a guided or semi-guided bend test.

3.2.6.1 *Discussion*—In the case of free or semi-guided bends to 180° in which a shim or block is used, the radius of bend is one half the thickness of the shim or block.

3.2.6.2 *Discussion*—radius of bend is typically not measured in free-bend tests and bend-and-flatten bend tests.

3.2.7 *semi-guided bend, n*—the bend obtained by applying a force directly to the specimen in the portion that is to be bent.

3.2.7.1 *Discussion*—The specimen is either held at one end or forced around a pin, mandrel, roller, or support, or is supported near the ends and bent by a force applied on the side of the specimen opposite the supports and midway between them. In some instances, the bend is started in this manner and finished in the manner of the free bend.

3.2.8 *surface irregularity, n*—a nominally two-dimensional type of damage caused by the bend test that encompasses an area of the surface of a test specimen, but does not extend into its interior.

3.2.8.1 *Discussion*—Surface disturbances such as loss of coating adherence or surface roughening such as orange peel are examples of surface irregularity.

3.2.8.2 *Discussion*—Different codes and product specifications characterize surface irregularities using different, specific terminology. The terminology of a code or product specification that cites E290 shall always be followed instead of any terminology defined or used here.

4. Summary of Test Methods

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

4.1.1 *Guided-bend Tests:*

4.1.1.1 Guided-bend, No-die Test,

4.1.1.2 Guided-bend, U-bend Test,

4.1.1.3 Guided-Bend, V-bend Test,

4.1.1.4 Guided-Bend, V-bend test for cold-rolled sheet,

4.1.2 *Semi-guided Bend Tests:*

4.1.2.1 *Arrangement A,* one-end-held semi-guided bend test.

4.1.2.2 *Arrangement B,* thin-material semi-guided bend test.

4.1.2.3 *Arrangement C,* mandrel-guided semi-guided bend test.

4.1.3 *Free-bend Tests:*

4.1.3.1 *Type 1,* 180° free-bend test.

4.1.3.2 *Type 2,* flat-on-itself free-bend test.

4.1.4 *Bend-and-flatten Test*

4.2 A guided-bend test for ductility of welds is described in Method E190 and may be used for flat-rolled materials when specified by the product specification. The essential features of this bending method are employed in 4.1.1.2, guided-bend, U-bend test.

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

4.3.1 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.

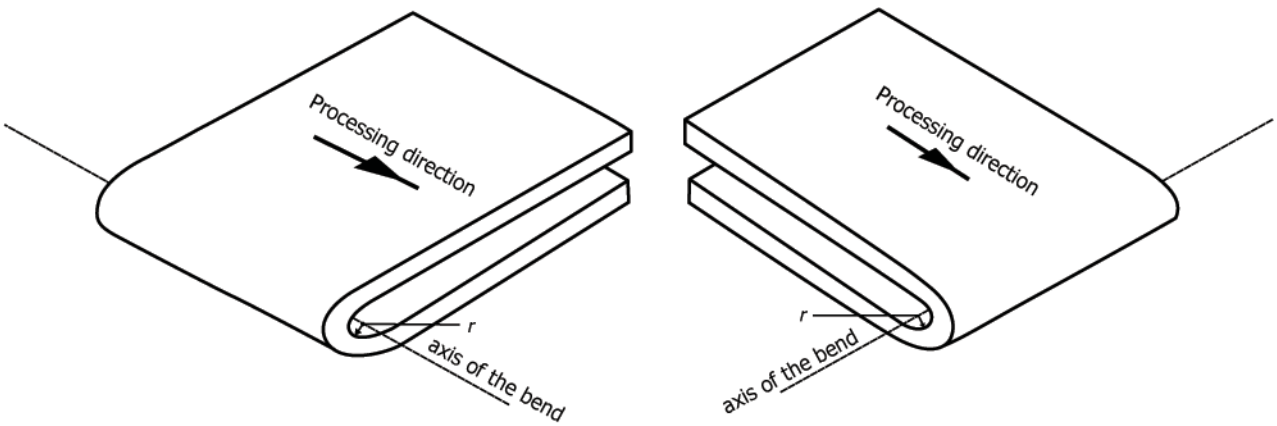


FIG. 1 Relationship Between Specimen Long Dimension and Processing Direction in Bend Tests

4.3.2 Transverse tests use a specimen with the long dimension perpendicular to the processing direction so that the axis of the bend is aligned with the processing direction, as shown in Fig. 1. The axis of bend is the center of the radius of bend.

4.3.3 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.

4.4 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 three 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.

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

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

4.5.2 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.

4.6 *Guided-bend Test:*

4.6.1 The specimen is supported near each end on pins, rollers, shoulders, or flat surfaces with appropriate end radii and a force is applied through a plunger, pin, mandrel, or male die midway between two supports, as shown schematically in Fig. 2, Fig. 3, Fig. 4, and Fig. 5 until the desired bend is formed.

NOTE 1—The testing community uses many different terms to describe the parts of the guided-bend test fixture. To make the usage consistent with Method E190, this standard uses "plunger" to describe the piece that other standards describe as a pin, punch, mandrel, or male die. It uses "supports" or "die" as appropriate to refer to the pins, rollers, shoulders, flat surfaces, or die that support the specimen as it is bent.

NOTE 2—The term "jig" is often used instead of the term "fixture" in other standards, including Method E190. The two terms are used interchangeably.

4.6.2 No force is applied directly to the outer face of the bend when no die is used (4.1.1.1). Some force may be applied by the die to the outer face of the bend in the case of U-bend (4.1.1.2) and V-bends (4.1.1.3 and 4.1.1.4). In some cases, for U-bend and V-bends it may be necessary for the specimen to bottom out in the die to ensure the correct amount of bending.

4.6.3 The radii of the plunger and the two supports or shoulders of the die shall be defined in the product specification as related to the thickness (t) of the specimen being tested.

4.6.4 *Clearance*—The distance between supports (C), or clearance, shall be three thicknesses plus twice the plunger radius, with a tolerance of one-half thickness, as shown in Fig. 2.

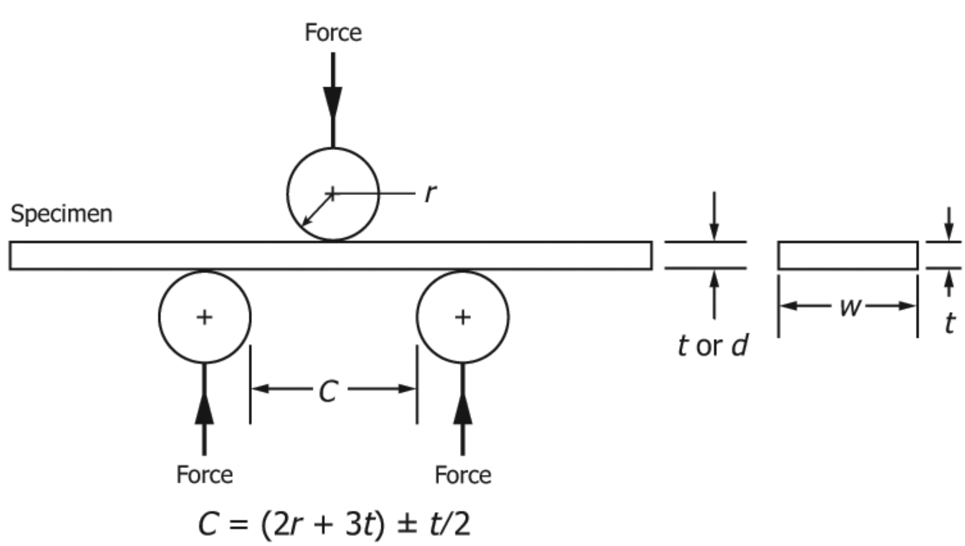
$$C = (2r + 3t) \pm t/2 \tag{1}$$

4.6.5 When dies are used for U-bend and V-bend, they shall conform approximately to the geometries shown in Fig. 3, Fig. 4, and Fig. 5.

4.6.6 The surfaces of the supports and plunger shall be hard enough to resist plastic deformation and wear that can be observed after the test. If visible flattening, wear, or other permanent deformation of the test fixtures does occur, the test is invalid.

NOTE 3—Supports and plungers hardened to at least 20 HRC have been found to be generally suitable for this test. It is recommended that checking by the unaided eye for flattening, wear, or other deformation of the test fixtures take place after testing different and potentially harder materials than usual.

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



C = distance between lower supports,
r = radius of the end of the pin, mandrel, plunger, or male die,
t = sheet specimen thickness,
d = round specimen diameter, and
w = sheet specimen width.

FIG. 2 Schematic Fixture for the Guided-bend, No-die Test

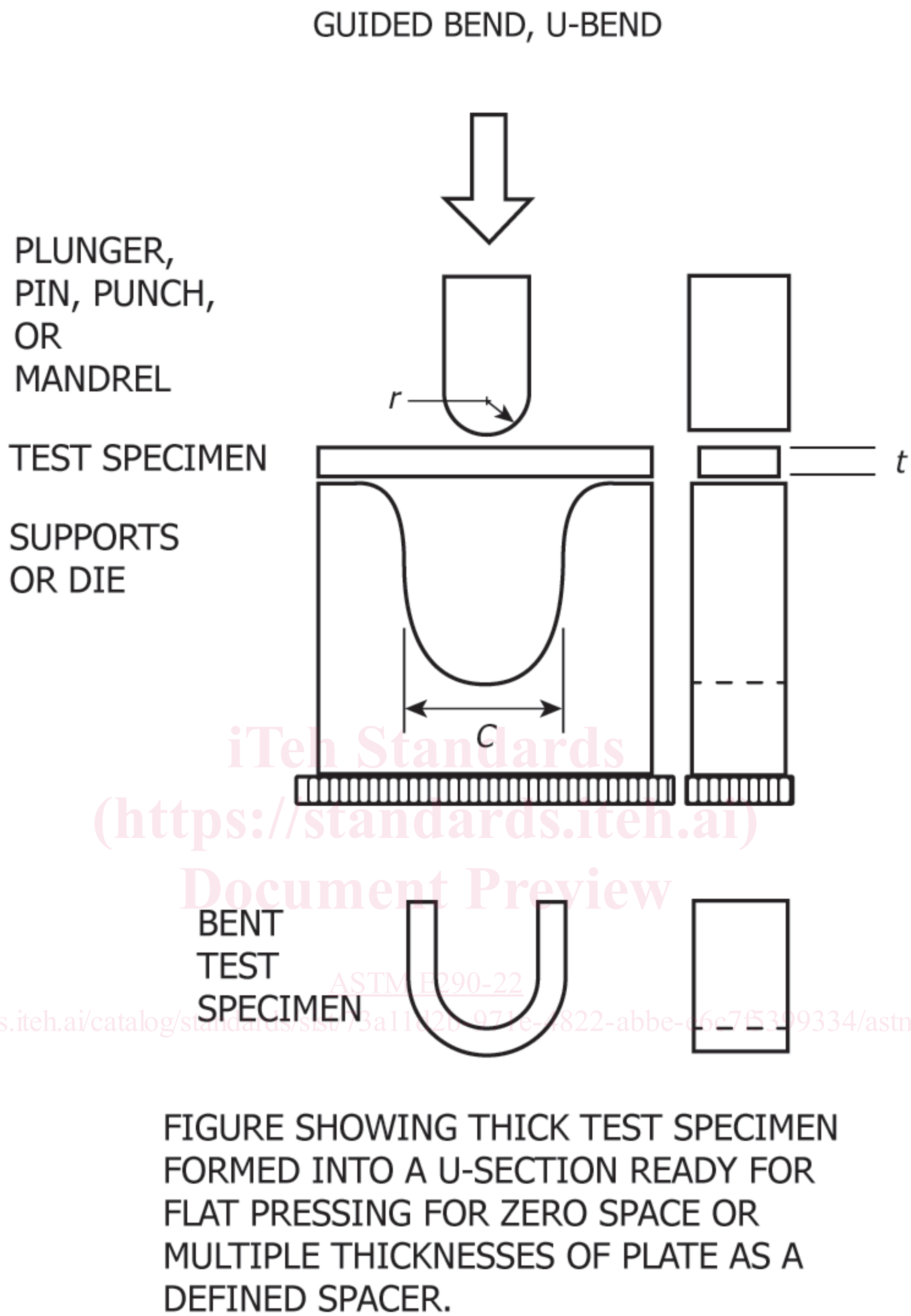


FIG. 3 Schematic Fixture for the Guided-bend, U-bend Test

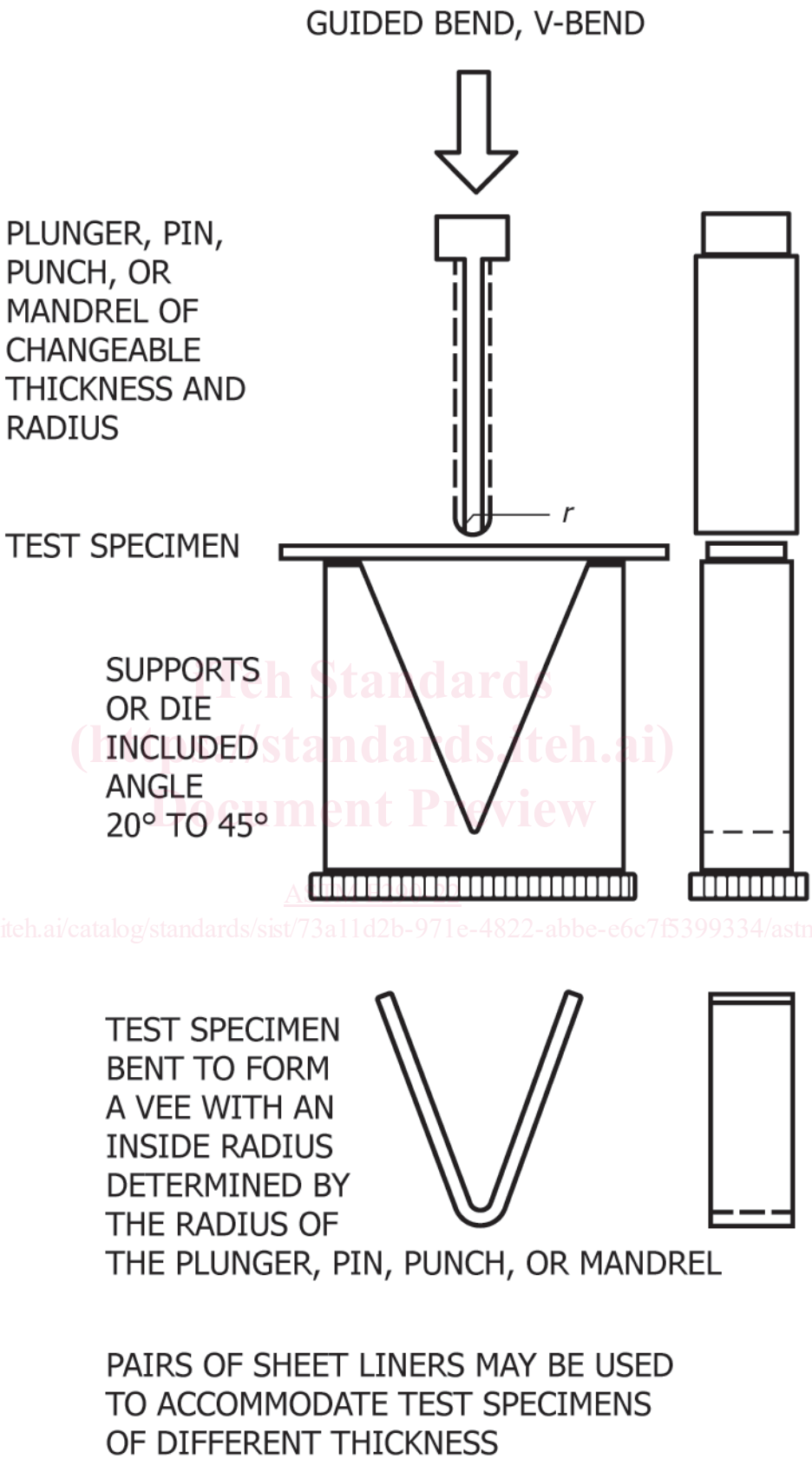


FIG. 4 Schematic Fixture for the Guided-bend, V-bend Test

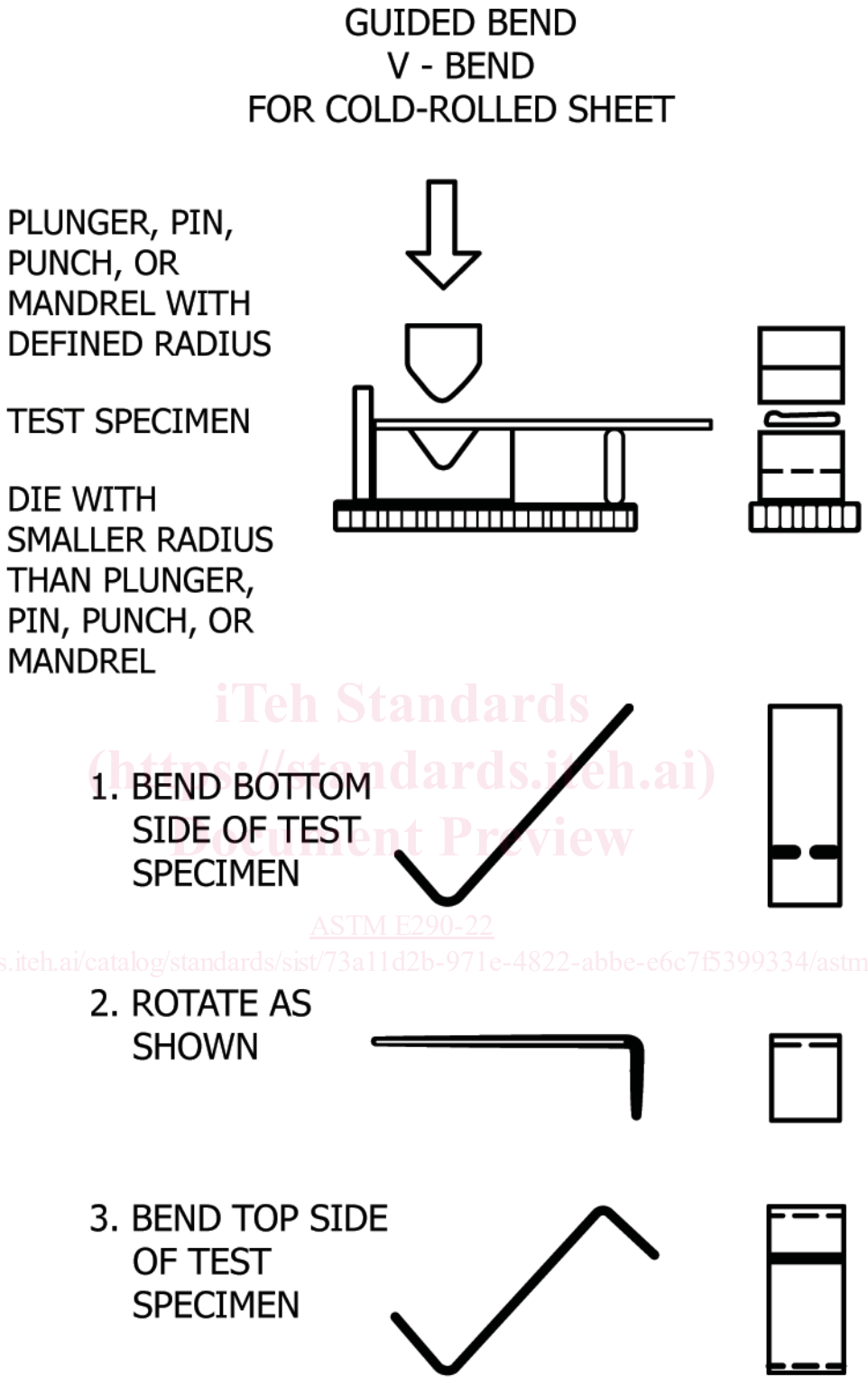


FIG. 5 Schematic Fixture for the Guided-bend, V-bend Test for Cold-rolled Sheet

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

4.6.9 When the thickness or strength of the specimen, or capacity of the guided-bend test fixture (shown in Fig. 2) 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. 6. A spacer with a thickness equal to twice the required radius of bend 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.

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

4.7 *Semi-guided Bend Test*—A constraining force is applied on the inside of the bend during the initiation of the bending and continues until the final bend condition is achieved.

4.7.1 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.

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

4.7.3 The location of the bend along the length of the specimen is unimportant. The specimen is clamped or supported by one of the arrangements shown schematically in Figs. 7-9. It is possible that different results will be obtained with the use of different arrangements. The arrangement used shall be described in the test report on the ductility of the material being evaluated.

4.7.4 *Arrangement A, One End-held Semi-guided Bend Test*—Arrangement A involves holding one end of the semi-guided bend test specimen and applying a force transversely near the free end as in Fig. 7. The bend is formed around a stationary pin, mandrel, or roller of a specified radius of bend. Bending is continued until failure occurs or the specified angle of bend has been achieved.

4.7.5 *Arrangement B, Thin-material Semi-guided Bend Test*—Arrangement B is for semi-guided bend tests of thin specimens, and includes a support between the clamp and the radius of bend, as shown schematically in Fig. 8. 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.

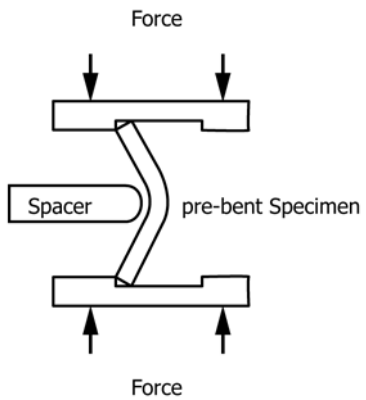


FIG. 6 Schematic Fixture for Completing the Guided-bend Test Started as Shown in Fig. 2

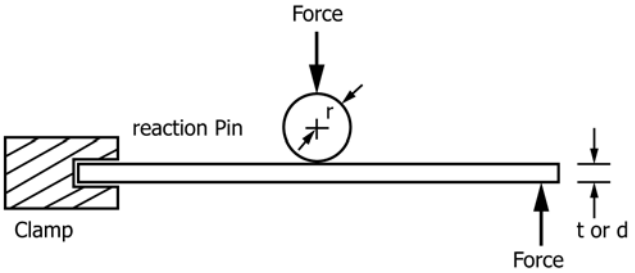


FIG. 7 Schematic Fixture for Arrangement A, One-end-held Semi-guided Bend Test

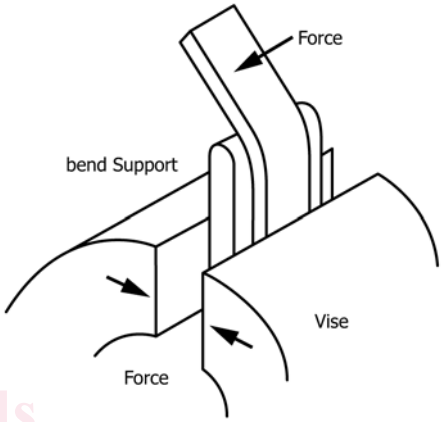


FIG. 8 Schematic Fixture for Arrangement B, Thin-material Semi-guided Bend Test

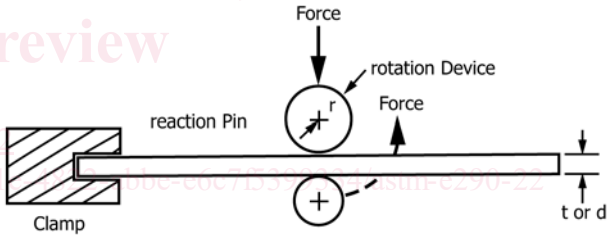


FIG. 9 Schematic Fixture for Arrangement C, Mandrel-guided Semi-guided Bend Test

4.7.6 *Arrangement C, Mandrel-guided Semi-guided Bend Test*—Arrangement C employs a stationary pin, or mandrel, over which the semi-guided bend test 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. 9). 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.

4.7.7 Cracks and surface irregularities resulting from the bend shall be evaluated and reported.

4.8 *Free-bend Test*—No external force is applied to the specimen in the immediate area of the bend.

4.8.1 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