Designation: E208 – 06

Standard Test Method for Conducting Drop-Weight Test to Determine Nil-Ductility Transition Temperature of Ferritic Steels[1]

This standard is issued under the fixed designation E208; 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 Department of Defense.

INTRODUCTION

This drop-weight test was developed at the Naval Research Laboratory in 1952 and has been used extensively to investigate the conditions required for initiation of brittle fractures in structural steels. Drop-weight test facilities have been established at several Naval activities, research institutions, and industrial organizations in this country and abroad. The method is used for specification purposes by industrial organizations and is referenced in several ASTM specifications and the ASME Boiler and Pressure Vessel Code. This procedure was prepared to ensure that tests conducted at all locations would have a common meaning. This test method was originally published as Department of the Navy document NAVSHIPS-250-634-3.

1. Scope*

1.1 This test method covers the determination of the nil-ductility transition (NDT) temperature of ferritic steels, ⅝ in. (15.9 mm) and thicker.

1.2 This test method may be used whenever the inquiry, contract, order, or specification states that the steels are subject to fracture toughness requirements as determined by the drop-weight test.

1.3 The values stated in inch-pound units are to be regarded as the 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 and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Adjuncts:*
Drop Weight Machine[2]

3. Terminology

3.1 *Definitions:*

3.1.1 *ferritic*—the word ferritic as used hereafter refers to all α-Fe steels. This includes martensitic, pearlitic, and all other nonaustenitic steels.

3.1.2 *nil-ductility transition (NDT) temperature*— the maximum temperature where a standard drop-weight specimen breaks when tested according to the provisions of this method.

4. Summary of Test Method

4.1 The drop-weight test employs simple beam specimens specially prepared to create a material crack in their tensile surfaces at an early time interval of the test. The test is conducted by subjecting each of a series (generally four to eight) of specimens of a given material to a single impact load at a sequence of selected temperatures to determine the maximum temperature at which a specimen breaks. The impact load is provided by a guided, free-falling weight with an energy of 250 to 1200 ft-lbf (340 to 1630 J) depending on the yield strength of the steel to be tested. The specimens are prevented by a stop from deflecting more than a few tenths of an inch.

4.2 The usual test sequence is as follows: After the preparation and temperature conditioning of the specimen, the initial drop-weight test is conducted at a test temperature estimated to be near the NDT temperature. Depending upon the results of the first test, tests of the other specimens are conducted at suitable temperature intervals to establish the limits within 10°F (5°C) for break and no-break performance. A duplicate test at the lowest no-break temperature of the series is conducted to confirm no-break performance at this temperature.

[1] This test method is under the jurisdiction of the ASTM Committee E28 on Mechanical Testing and is the direct responsibility of Subcommittee E28.07 on Impact Testing.

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[2] Detail drawings for the construction of this machine are available from ASTM Headquarters. Order ADJE0208. Original adjunct produced in 2002.

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

4.3 In 1984, the method of applying the crack-starter weld bead was changed from a two-pass technique to the current single-pass procedure, and the practice of repair-welding of the crack-starter weld bead was prohibited. For steels whose properties are influenced by tempering or are susceptible to temper embrittlement, the nil-ductility transition (NDT) temperature obtained using the single-pass crack-starter weld bead may not agree with that obtained using the previous two-pass crack-starter weld bead, or when the crack-starter bead was repaired.

5. Significance and Use

5.1 The fracture-strength transitions of ferritic steels used in the notched condition are markedly affected by temperature. For a given "low" temperature, the size and acuity of the flaw (notch) determines the stress level required for initiation of brittle fracture. The significance of this test method is related to establishing that temperature, defined herein as the NDT temperature, at which the "small flaw" initiation curve, Fig. 1, falls to nominal yield strength stress levels with decreasing temperature, that is, the point marked NDT in Fig. 1.[3, 4]

5.2 Interpretations to other conditions required for fracture initiation may be made by the use of the generalized flaw-size, stress-temperature diagram shown in Fig. 1. The diagram was derived from a wide variety of tests, both fracture-initiation and fracture-arrest tests, as correlated with the NDT temperature established by the drop-weight test. Validation of the NDT concept has been documented by correlations with numerous service failures encountered in ship, pressure vessel, machinery component, forged, and cast steel applications.

[3] Pellini, W. S., and Puzak, P. P., "Fracture Analysis Diagram Procedures for the Fracture-Safe Engineering Design of Steel Structures," *NRL Report 5920,*March 15, 1963; also *Welding Research Council Bulletin,*Series No. 88, May, 1963.

[4] Pellini, W. S., and Puzak, P. P., "Practical Considerations in Applying Laboratory Fracture Test Criteria to the Fracture-Safe Design of Pressure Vessels," *NRL Report 6030,*November 5, 1963; also *Transactions,*Am. Soc. Mechanical Engrs., Series A., *Journal of Engineering for Power,* October 1964, pp. 429–443.

6. Apparatus

6.1 The drop-weight machine is of simple design based on the use of readily available structural steel products.[2] The principal components of a drop-weight machine are a vertically guided, free-falling weight, and a rigidly supported anvil which provides for the loading of a rectangular plate specimen as a simple beam under the falling weight. Fig. 2(*a*) illustrates a typical drop-weight machine built of standard structural shapes.

6.2 A rail, or rails, rigidly held in a vertical position and in a fixed relationship to the base shall be provided to guide the weight. The weight shall be provided with suitable devices which engage the rail, or rails, and ensure that it will drop freely in a single, vertical plane. The weight may be raised by any convenient means. A weight-release mechanism, functioning similarly to that shown in Fig. 2(*b*), shall be provided to release the weight quickly without affecting its free fall. The weight shall be made in one piece, or if made of several pieces, its construction shall be rigid to ensure that it acts as a unit when it strikes the specimen. The striking tup of the weight shall be a steel cylindrical surface with a radius of 1 in. (25.4 mm) and a minimum hardness of HRC 50 throughout the section. The weight shall be between 50 and 300 lb (22.7 and 136 kg). The rails and hoisting device shall permit raising the weight various fixed distances to obtain potential energies of 250 to 1200 ft-lbf (340 to 1630 J).

6.3 A horizontal base, located under the guide rails, shall be provided to hold and position precisely the several styles of anvils required for the standard specimens. The anvil guides shall position the anvil with the center-line of the deflection stops under the center-line of the striking tup of the weight. In general, the base will also support the guide rails, but this is not a requirement. The base shall rest on the rigid foundation. The base-foundation system shall be sufficiently rigid to allow the normal drop-weight energy (Table 1) to deflect a standard specimen to the stop at temperatures above the NDT. The base

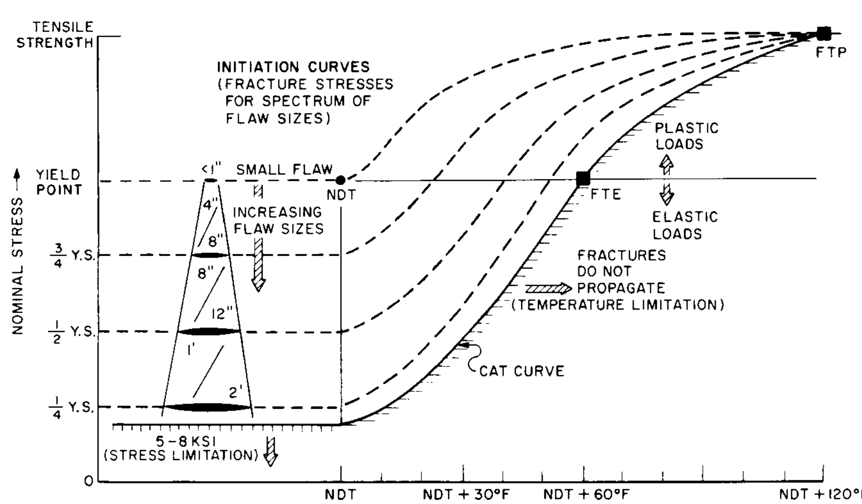
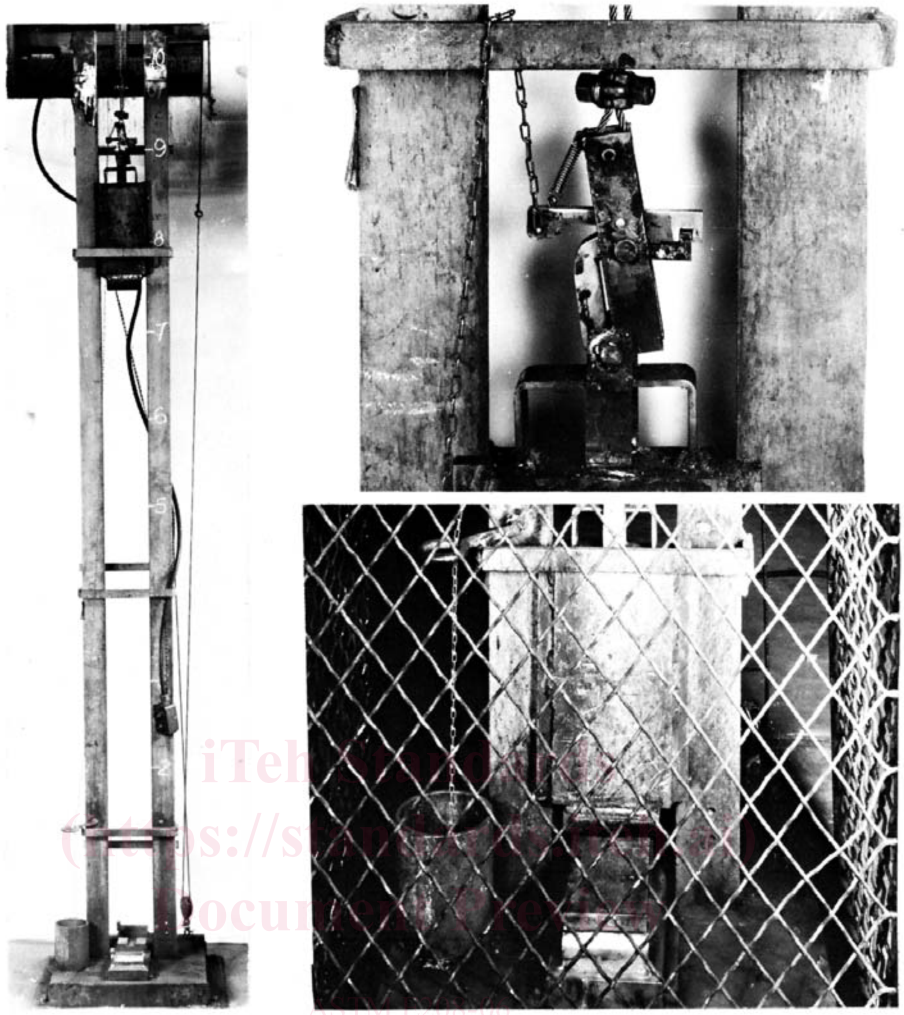


FIG. 1 Generalized Fracture Analysis Diagram Indicating the Approximate Range of Flaw Sizes Required for Fracture Initiation at Various Levels of Nominal Stress, as Referenced by the NDT Temperature



(*a*) *Left*—Complete Assembly
(*b*) *Upper Right*—Quick Release Mechanism
(*c*) *Lower Right*—Guard Screen

FIG. 2 Drop-Weight Test Apparatus

TABLE 1 Standard Drop-Weight Test Conditions

Type of Specimen	Specimen Size, in. (mm)	Span, in. (mm)	Deflection Stop, in. (mm)	Yield Strength Level, ksi (MPa)	Drop-Weight Energy for Given Yield Strength Level[A]	
					ft-lbf	J
P-1	1 by 3½ by 14 (25.4 by 89 by 356)	12.0 (305)	0.3 (7.6)	30 to 50 (210 to 340)	600	800
				50 to 70 (340 to 480)	800	1100
				70 to 90 (480 to 620)	1000	1350
				90 to 110 (620 to 760)	1200	1650
P-2	¾ by 2 by 5 (19 by 51 by 127)	4.0 (102)	0.06 (1.5)	30 to 60 (210 to 410)	250	350
				60 to 90 (410 to 620)	300	400
				90 to 120 (620 to 830)	350	450
				120 to 150 (830 to 1030)	400	550
P-3	⅝ by 2 by 5 (15.9 by 51 by 127)	4.0 (102)	0.075 (1.9)	30 to 60 (210 to 410)	250	350
				60 to 90 (410 to 620)	300	400
				90 to 120 (620 to 830)	350	450
				120 to 150 (830 to 1030)	400	550

[A] Initial tests of a given strength level steel shall be conducted with the drop-weight energy stated in this column. In the event that insufficient deflection is developed (no-test performance) an increased drop-weight energy shall be employed for other specimens of the given steel.

shall not jump or shift during the test, and shall be secured to the foundation if necessary to prevent motion.

6.4 A guard screen, similar to that shown in Fig. 2(*c*), is recommended to stop broken specimen halves of the very brittle steels which break into two pieces with both halves being ejected forcefully from the machine.

6.5 The general characteristics of two of the anvils required are illustrated in Fig. 3. The anvils shall be made in accordance with the dimensions shown in Fig. 4. The anvil supports and deflection stops shall be steel-hardened to a minimum hardness of HRC 50 throughout their cross section. The space between the two stops is provided as clearance for the crack-starter weld on the specimen. The deflection stops may be made in two separate pieces, if desired. The anvil-base system shall be sufficiently rigid to allow the normal drop-weight energy (Table 1) to deflect the specimen to the stop at temperatures well above the NDT.

6.6 A measuring system shall be provided to assure that the weight is released from the desired height for each test, within the limits of +10, −0 %.

6.7 Modifications of the equipment or assembly details of the drop-weight machine shown in Fig. 2 are permitted provided that the modified machine is functionally equivalent. Fig. 5 illustrates a portable machine design used by an industrial concern for drop-weight tests of materials used for pressure vessel components at different fabrication sites.

7. Precautions

7.1 The drop-weight test was devised for measuring fracture initiation characteristics of ⅝-in. (15.9-mm) and thicker structural materials. This test is not recommended for steels less than ⅝-in. thick.

7.2 This test method establishes standard specimens and conditions to determine the NDT temperature of a given steel. The use of standard specimens with nonstandard test conditions or the use of nonstandard specimens shall not be allowed for specification purposes.

7.3 This test method employs a small weld bead deposited on the specimen surface, whose sole purpose is to provide a brittle material for the initiation of a small, cleavage crack-flaw in the specimen base material during the test. Anomalous behavior may be expected for materials where the heat-affected zone created by deposition of the crack-starter weld is made more fracture resistant than the unaffected plate. This condition is developed for quenched and tempered steels of high hardness obtained by tempering at low temperatures. The problem may be avoided by placing the crack-starter weld on these steels before conducting the quenching and tempering heat treatment. Except for other cases which may be readily rationalized in metallurgical terms (for example, it is possible to recrystallize heavily cold-worked steels in the heat-affected zone and to develop a region of improved ductility), the heat-affected zone problem is not encountered with conventional structural grade steels of a pearlitic microstructure or

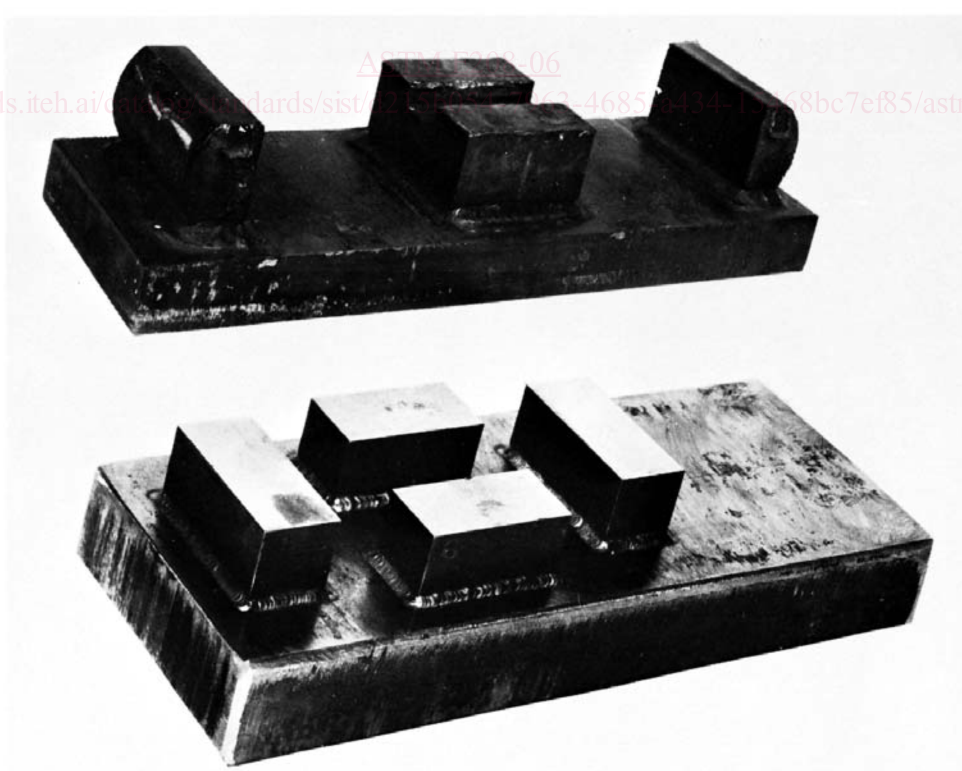
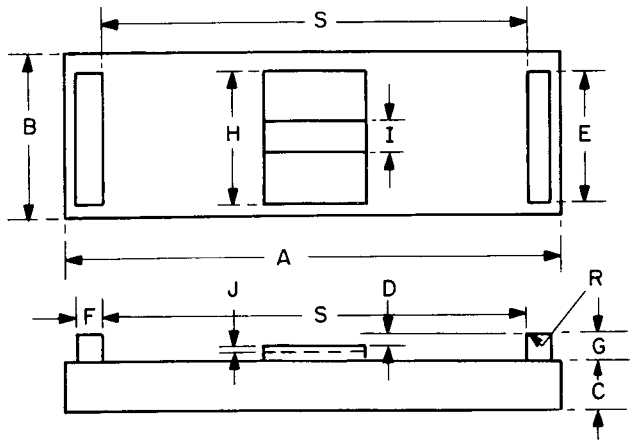


FIG. 3 General Appearance of the Anvils Required for Drop-Weight NDT Tests



Anvil Dimension	Units	Specimen Type			Tolerance
		P-1	P-2	P-3	
S, Span	in.	12.0	4.0	4.0	±0.05
	mm	305	100	100	±1.5
D, Deflection stop	in.	0.30	0.060	0.075	±0.002
	mm	7.60	1.50	1.90	±0.05
A, Anvil length	←——not critical——→				
B, Anvil width	←——not critical——→				
C, Anvil thickness	in.	1.5 min	1.5 min	1.5 min	
	mm	38 min	38 min	38 min	
E, Support length	in.	3.5 min	2.0 min	2.0 min	
	mm	90 min	50 min	50 min	
F, Support width	←——not less than *G*——→				
G, Support height	in.	2.0	2.0	2.0	±1
	mm	50	50	50	±25
R, Support radius	in.	0.075	0.075	0.075	±0.025
	mm	1.0	1.0	1.0	±0.1
H, Stop width	in.	3.5 min	2.0 min	2.0 min	±2
	mm	90 min	50 min	50 min	±50
I, Weld clearance	in.	0.9	0.9	0.9	±0.1
	mm	22	22	22	±3
J, Weld clearance depth	in.	0.4 min	0.4 min	0.4 min	
	mm	10 min	10 min	10 min	

FIG. 4 Anvil Dimensions

quenched and tempered steels tempered at high temperatures to develop maximum fracture toughness.

8. Test Specimens

8.1 *Identification of Material*—All sample material and specimens removed from a given plate, shape, forging, or casting product shall be marked to identify their particular source (heat number, slab number, etc.). A simple identification system shall be used which can be employed in conjunction with an itemized table to obtain all the pertinent information.

8.2 *Orientation*—The drop-weight test is insensitive to specimen orientation with respect to rolling or forging direction. However, unless otherwise agreed to, all specimens specified by the purchaser shall be of the same orientation and it shall be noted in the test report.

8.3 *Relation to Other Specimens*—Unless otherwise specified by the purchaser, the specimens shall be removed from the material at positions adjacent to the location of other type test specimens (for example, mechanical test specimens) required for evaluation of other material properties.

8.4 *Special Conditions for Forgings and Castings*—Where drop-weight testing of cast or forged material is specified, the size and location of integrally attached pad projections or prolongations to be used for specimen fabrication shall be agreed to in advance by the purchaser. If the design of the casting or forging does not allow an attached test-material coupon, the following requirements shall apply:

8.4.1 Drop-weight specimens cast or forged separately to the dimensions required for testing shall be allowed only where the product dimensions are equivalent and the purchaser agrees.

8.4.2 Specimens may be taken from a separately produced test-material coupon if the supplier can demonstrate that it is equivalent to the product with respect to chemical composition, soundness, and metallurgical conditions. The material shall be from the same heat and shall have been fabricated under identical conditions as the product. The specimens shall be machine-cut from locations agreed to in advance by the purchaser.

8.4.3 Specifically, in the case of casting requiring X-ray quality standard, the separate test-material coupon shall be cast separately but simultaneously with the product. Chills shall not be used. The test-material coupon shall be in proportion to the thickness, *T,* in the cast product, where *T* is diameter of the largest circle that can be inscribed in any cross section of the

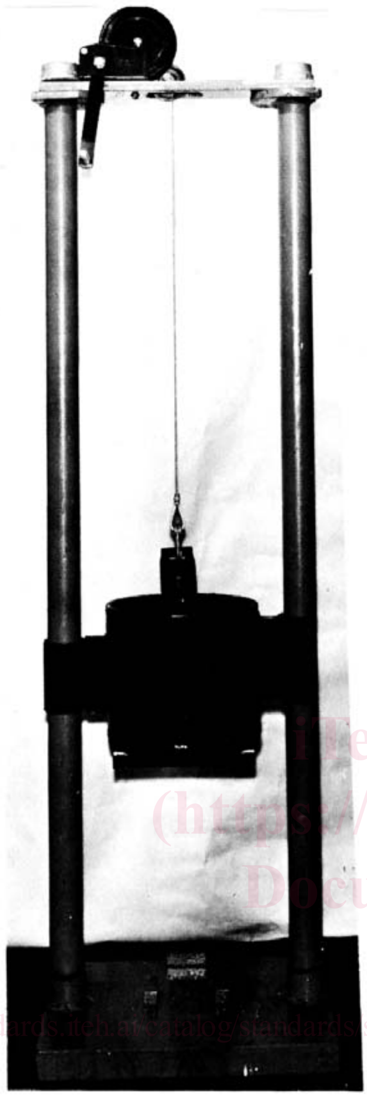


FIG. 5 Portable Drop-Weight Test Machine Used for Tests at Different Fabrication Sites

casting, or where T is defined in advance by the purchaser as the nominal design thickness, as follows:

Thickness, T, in. (mm)	Separately Cast, Nonchilled, Test-Coupon Size
½ (12.7) and less	None required
⅝ to 2 (15.9 to 50.8)	When several small castings are poured from one heat, one casting shall be used to provide test specimens, if adaptable
⅝ to 1 (15.9 to 25.4)	T by 2 by 5 in. (127 mm) for irregularly shaped castings
>1 to 3 (25.4 to 76.2)	T by 4.5T by 4.5T
>3 to 5 (76.2 to 127)	T by 3T by 3 T
Over 5 (127)	T by 3T by 3T for castings that are representative of cast plates
Over 5 (127)	T by T by 6 $\sqrt{T}$ for castings that are representative of cast plates

8.4.4 Specimens showing casting or metallurgical faults on broken fracture surfaces shall be "No-Test."

8.5 *Size of Blank*—Dimensions of the blank size required for standard test specimens are shown in Fig. 6. Equally significant NDT temperatures, within ±10°F (±5°C), are determined for a given steel with tests using any of the standard specimens. As may be convenient for the particular thickness of material, any of the standard specimens shown in Fig. 6 and prepared as described in Section 8 may be chosen for this method. The results obtained with standard test conditions shall comply with the requirements of this method for determining the NDT temperature.

8.6 *Specimen Cutting*—The specimen sample material and the specimen ends may be flame-cut. The specimen sides shall be saw-cut or machined, using adequate coolant to prevent specimen overheating, and shall be a minimum of 1 in. from any flame-cut surface. Products thicker than the standard specimen thickness shall be machine-cut to standard thickness from one side, preserving an as-fabricated surface unless otherwise specified, or agreed to, in advance by the purchaser. The as-fabricated surface so preserved shall be the welded (tension) surface of the specimen during testing.

8.7 *Crack-Starter Weld*—The crack-starter weld, which is a centrally located weld bead, approximately 2 in. (50 mm) long (WL of Fig. 6) and ½ in. (12.7 mm) wide, shall be deposited on the as-fabricated tension surface of the drop-weight specimen in a single pass. To assist the welding operator in centering the weld deposit properly on the test piece, two punch marks spaced to the appropriate WL dimension of Fig. 6 shall be positioned as *A* and *D* as shown in Fig. 7*(a)*. As an alternative to the punch marks, a copper template containing a centrally positioned slot, 1 in by WL + ½ in. (25 mm by WL + 13 mm) Fig. 7 *(b)*, may be used. See Note 1 and Fig. 7 *(b)*. The weld shall start from either Point *A* or *D* and shall proceed without interruption as a stringer bead (no weaving) to the other point. The bead appearance is determined by the amperage, arc voltage, and speed of travel used. A current of 180 to 200 A, a medium arc length, and a travel speed that will result in a moderately high-crowned bead have been found to be suitable conditions. An enlarged view of an as-deposited crack-starter weld is shown in Fig. 7(*c*). "Each lot of electrodes shall be checked by the user in accordance with the requirements of 8.10 for suitability with the material the user is testing. Providing a heat sink under P-2 and P-3 specimens during welding is recommended but not required in order to minimize microstructural changes to these smaller specimens. Both metallic and water-box heat sinks have been used for this purpose.

NOTE 1—The copper template is especially recommended for the Type P-2 and P-3 specimens since in addition to heat sink advantages it eliminates weld spatter which may interfere with proper seating of the specimen during test.

8.7.1 *Microstructure of Base Metal*—Data presented show that the method of depositing the weld bead can influence the microstructure of the heat-affected zone under the weld notch which in turn can influence the NDT determined especially in heat-treated steels.[5]

8.8 *Weld Notch*—The final preparation of the specimen consists of notching the deposited weld at the center of the

[5] Tsukada, H., Suzuki, I. I., and Tanaka, Y., "A Study on Drop-Weight Test Using A508 Class 2 Steel," *Japan Steel Works, Ltd.*, December 1, 1981.