Standard Method of Test
for

Notched Bar Impact Testing of Metallic Materials (CVN)

AASHTO DESIGNATION: T 266-96

AASHTO T 266-96 is identical to ASTM E 23-96 except that the Izod Method is not included.

Designation: E 23 – 96

Standard Test Methods for Notched Bar Impact Testing of Metallic Materials[1]

This standard is issued under the fixed designation E 23; 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 to replace method 221.1 of Federal Test Method Standard No. 151b. Consult the DoD Index of Specifications and Standards for the specific year of issue which has been adopted by the Department of Defense.

1. Scope

1.1 These test methods describe notched-bar impact testing of metallic materials by the Charpy (simple-beam) apparatus and the Izod (cantilever-beam) apparatus. They give: (*a*) a description of apparatus, (*b*) requirements for inspection and calibration, (*c*) safety precautions, (*d*) sampling, (*e*) dimensions and preparation of specimens, (*f*) testing procedures, (*g*) precision and bias, and (*h*) appended notes on the significance of notched-bar impact testing. These test methods will in most cases also apply to tests on unnotched specimens.

1.2 The values stated in SI units are to be regarded as the standard. Inch-pound units are provided for information only.

1.3 This standard does not address the problems associated with impact testing at temperatures below 77°K.

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 Standards:*

E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods[2]

E 399 Test Method for Plane-Strain Fracture Toughness of Metallic Materials[3]

E 604 Test Method for Dynamic Tear Testing of Metallic Materials[3]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[2]

E 1271 Practice for Qualifying Charpy Verification Specimens of Heat-Treated Steel[3]

3. Summary of Test Methods

3.1 The essential features of an impact test are: (*a*) a suitable specimen (specimens of several different types are recognized), (*b*) an anvil or support on which the test specimen is placed to receive the blow of the moving mass, (*c*) a moving mass that has been released from a sufficient height to cause the mass to break the specimen placed in its path, and (*d*) a device for measuring the energy absorbed by the broken specimen.

4. Significance and Use

4.1 These test methods of impact testing relate specifically to the behavior of metal when subjected to a single application of a load resulting in multiaxial stresses associated with a notch, coupled with high rates of loading and in some cases with high or low temperatures. For some materials and temperatures, impact tests on notched specimens have been found to predict the likelihood of brittle fracture better than tension tests or other tests used in material specifications. Further information on significance appears in Appendix X1.

5. Apparatus

5.1 *General Requirements:*

5.1.1 The testing machine shall be a pendulum type of rigid construction and of capacity more than sufficient to break the specimen in one blow.

5.1.2 The machine frame shall be equipped with a bubble level or a machined surface suitable for establishing levelness of the axis of pendulum bearings or, alternatively, the levelness of the axis of rotation of the pendulum may be measured directly. The machine shall be level to within 3:1000 and securely bolted to a concrete floor not less than 150 mm (6 in.) thick or, when this is not practical, the machine shall be bolted to a foundation having a mass not less than 40 times that of the pendulum. The bolts shall be tightened as specified by the machine manufacturer.

5.1.3 The machine shall be furnished with scales graduated either in degrees or directly in energy on which readings can be estimated in increments of 0.25 % of the energy range or less. The scales may be compensated for windage and pendulum friction. The error in the scale reading at any point shall not exceed 0.2 % of the range or 0.4 % of the reading, whichever is larger. (See 6.2.6.2 and 6.2.7.)

5.1.4 The total friction and windage losses of the machine during the swing in the striking direction shall not exceed 0.75 % of the scale range capacity, and pendulum energy loss from friction in the indicating mechanism shall not exceed 0.25 % of scale range capacity.

5.1.5 When hanging free, the pendulum shall hang so that the striking edge is within 2.5 mm (0.10 in.) of the position where it would just touch the test specimen. When the indicator has been positioned to read zero energy in a free

[1] These test methods are under the jurisdiction of ASTM Committee E-28 on Mechanical Testing and are the direct responsibility of Subcommittee E28.07 on Impact Testing.

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[2] *Annual Book of ASTM Standards*, Vol 14.02.

[3] *Annual Book of ASTM Standards*, Vol 03.01.

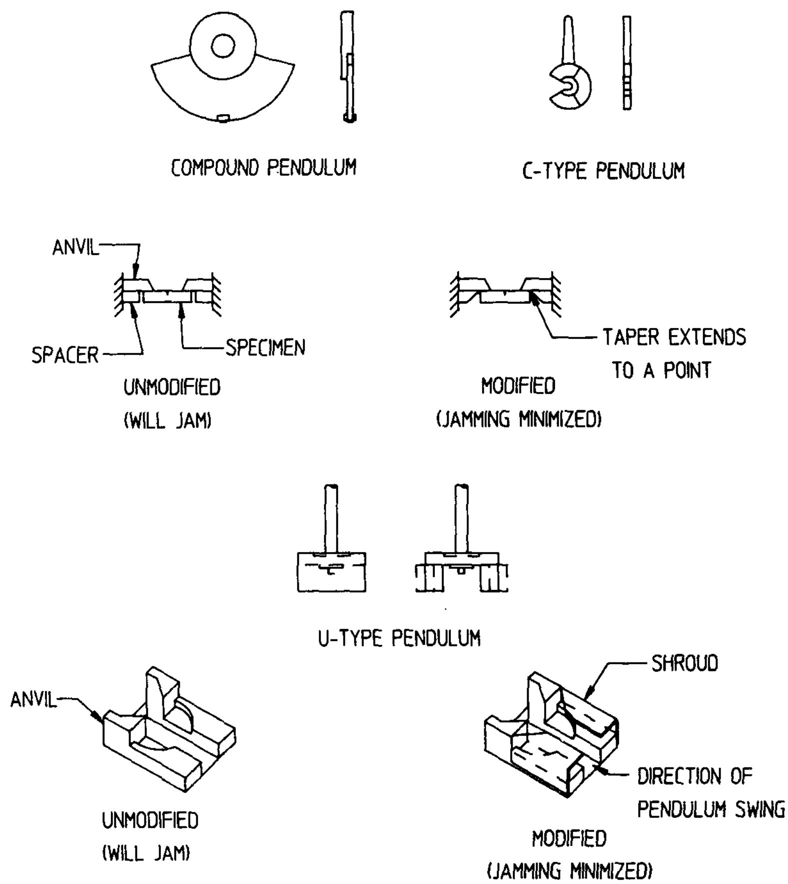

FIG. 1 Typical Pendulums and Anvils for Charpy Machines, Shown with Modifications to Minimize Jamming

swing, it shall read within 0.2 % of scale range when the striking edge of the pendulum is held against the test specimen. The plane of swing of the pendulum shall be perpendicular to the transverse axis of the Charpy specimen anvils or Izod vise within 3:1000.

5.1.6 Transverse play of the pendulum at the striker shall not exceed 0.75 mm (0.030 in.) under a transverse force of 4 % of the effective weight of the pendulum applied at the center of strike. Radial play of the pendulum bearings shall not exceed 0.075 mm (0.003 in.). The tangential velocity (the impact velocity) of the pendulum at the center of the strike shall not be less than 3 nor more than 6 m/s (not less than 10 nor more than 20 ft/s).

5.1.7 Before release, the height of the center of strike above its free hanging position shall be within 0.4 % of the range capacity divided by the supporting force, measured as described in 6.2.3.3. If windage and friction are compensated for by increasing the height of drop, the height of drop may be increased by not more than 1 %.

5.1.8 The mechanism for releasing the pendulum from its initial position shall operate freely and permit release of the pendulum without initial impulse, retardation, or side vibration. If the same lever that is used to release the pendulum is also used to engage the brake, means shall be provided for preventing the brake from being accidentally engaged.

5.2 *Specimen Clearance*—To ensure satisfactory results when testing materials of different strengths and compositions, the test specimen shall be free to leave the machine with a minimum of interference and shall not rebound into the pendulum before the pendulum completes its swing. Pendulums used on Charpy machines are of three basic designs, as shown in Fig. 1. When using a C-type pendulum or a compound pendulum, the broken specimen will not rebound into the pendulum and slow it down if the clearance at the end of the specimen is at least 13 mm (0.5 in.) or if the specimen is deflected out of the machine by some arrangement as is shown in Fig. 1. When using the U-type pendulum, means shall be provided to prevent the broken specimen from rebounding against the pendulum (Fig. 1). In most U-type pendulum machines, the shrouds should be designed and installed to the following requirements: (*a*) have a thickness of approximately 1.5 mm (0.06 in.), (*b*) have a minimum hardness of 45 HRC, (*c*) have a radius of less than 1.5 mm (0.06 in.) at the underside corners, and (*d*) be so positioned that the clearance between them and the pendulum overhang (both top and sides) does not exceed 1.5 mm (0.06 in.).

NOTE 1—In machines where the opening within the pendulum permits clearance between the ends of a specimen (resting on the anvil supports) and the shrouds, and this clearance is at least 13 mm (0.5 in.) requirements (*a*) and (*d*) need not apply.

5.3 *Charpy Apparatus:*

5.3.1 Means shall be provided (Fig. 2) to locate and support the test specimen against two anvil blocks in such a position that the center of the notch can be located within

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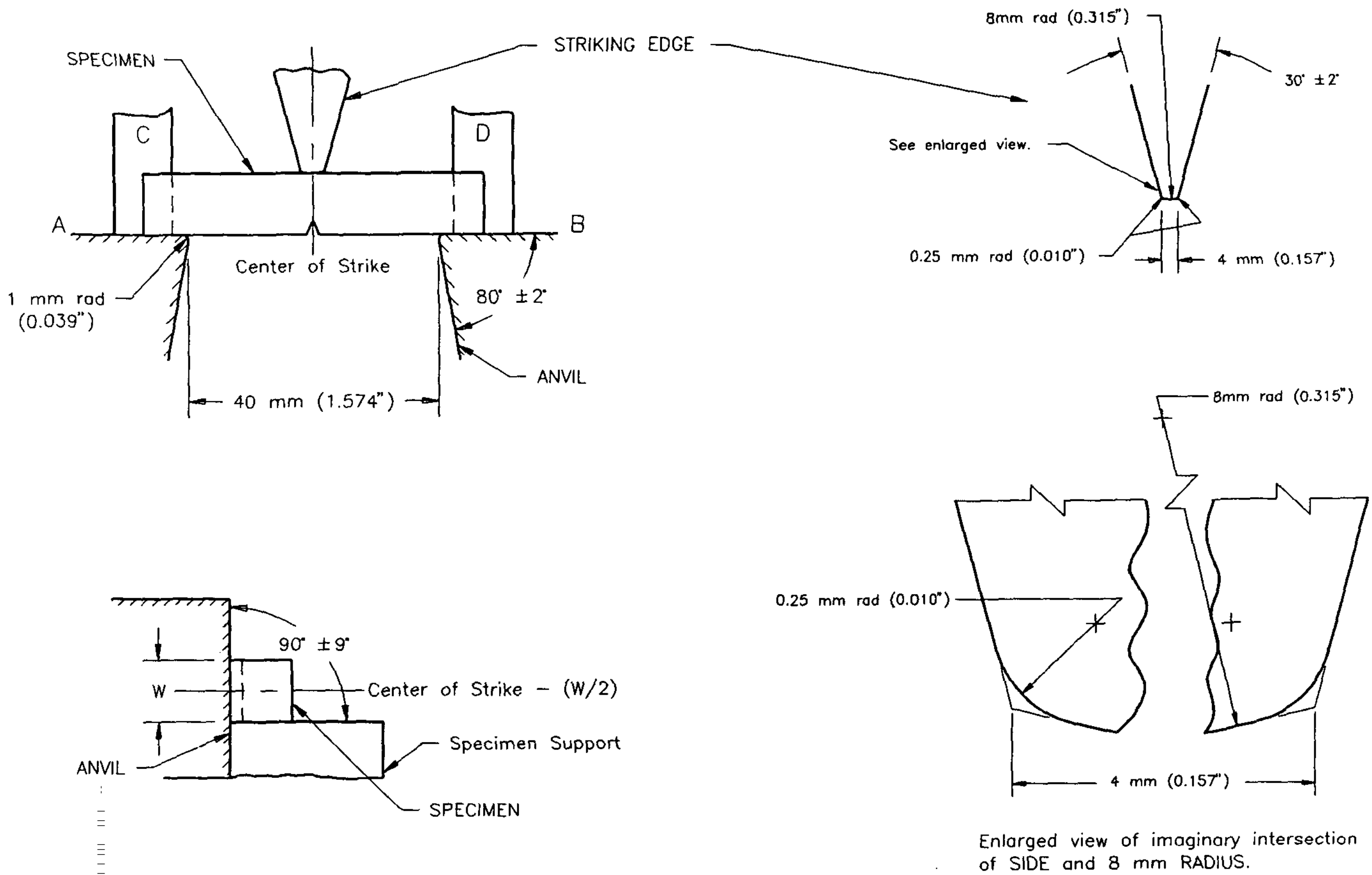


All dimensional tolerances shall be ±0.05 mm (0.002 in.) unless otherwise specified.

FIG. 2 Charpy Striking Tup

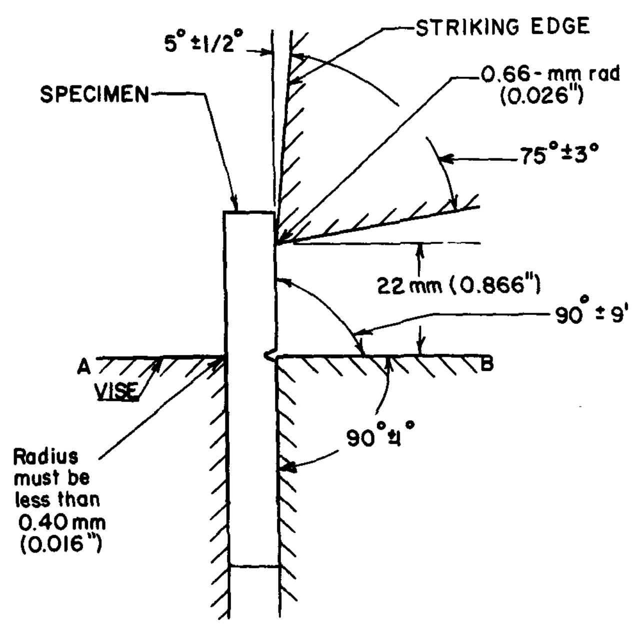
0.25 mm (0.010 in.) of the midpoint between the anvils (see 12.2.1.2).

5.3.2 The supports and striking edge shall be of the forms and dimensions shown in Fig. 2. Other dimensions of the pendulum and supports should be such as to minimize interference between the pendulum and broken specimens.

5.3.3 The center line of the striking edge shall advance in the plane that is within 0.40 mm (0.016 in.) of the midpoint between the supporting edges of the specimen anvils. The striking edge shall be perpendicular to the longitudinal axis of the specimen within 5:1000. The striking edge shall be parallel within 1:1000 to the face of a perfectly square test specimen held against the anvil.

5.4 *Izod Apparatus:*

5.4.1 Means shall be provided (Fig. 3) for clamping the specimen in such a position that the face of the specimen is parallel to the striking edge within 1:1000. The edges of the clamping surfaces shall be sharp angles of 90 ± 1° with radii less than 0.40 mm (0.016 in.). The clamping surfaces shall be smooth with a 2-μm (63-μin.) finish or better, and shall clamp the specimen firmly at the notch with the clamping force applied in the direction of impact. For rectangular specimens, the clamping surfaces shall be flat and parallel within 0.025 mm (0.001 in.). For cylindral specimens, the clamping surfaces shall be contoured to match the specimen and each surface shall contact a minimum of $\pi/2$ rad (90°) of the specimen circumference.



All dimensional tolerances shall be ±0.05 mm (0.002 in.) unless otherwise specified.

NOTE 1—The clamping surfaces of A and B shall be flat and parallel within 0.025 mm (0.001 in.).

NOTE 2—Finish on unmarked parts shall be 2 μm (63 μin.).

NOTE 3—Striker width must be greater than that of the specimen being tested.

FIG. 3 Izod (Cantilever-Beam) Impact Test

5.4.2 The dimensions of the striking edge and its position relative to the specimen clamps shall be as shown in Fig. 3.

5.5 *Energy Range*—Energy values above 80 % of the scale range are inaccurate and shall be reported as approximate. Ideally an impact test would be conducted at a constant impact velocity. In a pendulum-type test, the velocity decreases as the fracture progresses. For specimens that have impact energies approaching the capacity of the pendulum, the velocity of the pendulum decreases during fracture to the point that accurate impact energies are no longer obtained.

6. Inspection

6.1 *Critical Parts:*

6.1.1 *Specimen Anvils and Supports or Vise*—These shall conform to the dimensions shown in Fig. 2 or 3. To ensure a minimum of energy loss through absorption, bolts shall be tightened as specified by the machine manufacturer.

NOTE 2—The impact machine will be inaccurate to the extent that some energy is used in deformation or movement of its component parts or of the machine as a whole; this energy will be registered as used in fracturing the specimen.

6.1.2 *Pendulum Striking Edge*—The striking edge (tup) of the pendulum shall conform to the dimensions shown in Figs. 2 or 3. To ensure a minimum of energy loss through absorption, the striking edge bolts shall be tightened as specified by the machine manufacturer. The pendulum striking edge (tup) shall comply with 5.3.3 (for Charpy tests) or 5.4.1 (for Izod tests) by bringing it into contact with a standard Charpy or Izod specimen.

6.2 *Pendulum Operation:*

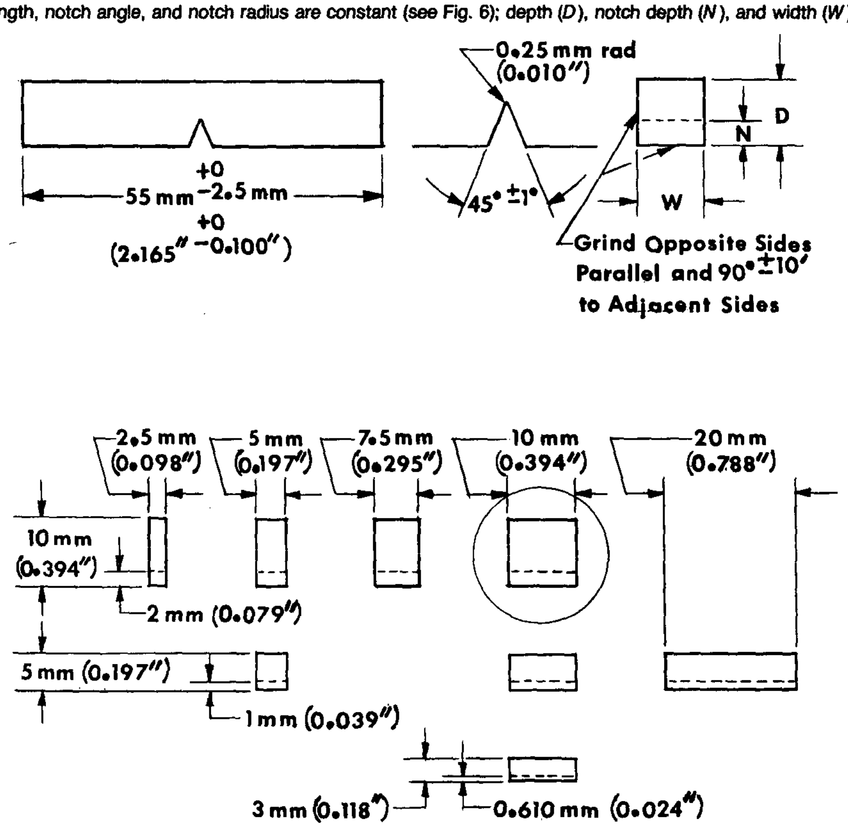
6.2.1 *Pendulum Release Mechanism*—The mechanism for releasing the pendulum from its initial position shall comply with 5.1.8.

6.2.2 *Pendulum Alignment*—The pendulum shall comply with 5.1.5 and 5.1.6. If the side play in the pendulum or the radial plays in the bearings exceeds the specified limits, adjust or replace the bearings.

6.2.3 *Potential Energy*—Determine the initial potential energy using the following procedure when the center of strike of the pendulum is coincident with a radial line from the center line of the pendulum bearings (herein called the axis of rotation) to the center of gravity. (See Appendix X2.) If the center of strike is more than 1.0 mm (0.04 in.) from this line, suitable corrections in elevation of the center of strike must be made in 6.2.3.2, 6.2.3.3, 6.2.6.1, and 6.2.7, so that elevations set or measured correspond to what they would be if the center of strike were on this line.

6.2.3.1 For Charpy machines place a half-width specimen (see Fig. 4) 10 by 5 mm (0.394 by 0.197 in.) in test position. With the striking edge in contact with the specimen, a line

On subsize specimens the length, notch angle, and notch radius are constant (see Fig. 6); depth (*D*), notch depth (*N*), and width (*W*) vary as indicated below.



NOTE 1—Circled specimen is the standard specimen (see Fig. 6).
NOTE 2—Permissible variations shall be as follows:

Cross-section dimensions	±1 % or ±0.075 mm (0.003 in.), whichever is smaller
Radius of notch	±0.025 mm (0.001 in.)
Depth of notch	±0.025 mm (0.001 in.)
Finish requirements	2 μm (63 μin.) on notched surface and opposite face; 4 μm (125 μin.) on other two surfaces

FIG. 4 Charpy (Simple-Beam) Subsize (Type A) Impact Test Specimens

scribed from the top edge of the specimen to the striking edge will indicate the center of strike on the striking edge.

6.2.3.2 For Izod machines, the center of strike may be considered to be the contact line when the pendulum is brought into contact with a specimen in the normal testing position.

6.2.3.3 Support the pendulum horizontally to within 15:1000 with two supports, one at the bearings (or center of rotation) and the other at the center of strike on the striking edge (see Fig. 5). Arrange the support at the striking edge to react upon some suitable weighing device such as a platform scale or balance, and determine the weight to within 0.4 %. Take care to minimize friction at either point of support. Make contact with the striking edge through a round rod crossing the edge at a 90° angle. The supporting force is the scale reading minus the weights of the supporting rod and any shims that may be used to maintain the pendulum in a horizontal position.

6.2.3.4 Determine the height of pendulum drop for compliance with the requirement of 5.1.7. On Charpy machines determine the height from the top edge of a half-width (or center of a full-width) specimen to the elevated position of the center of strike to 0.1 %. On Izod machines determine the height from a distance 22.66 mm (0.892 in.) above the vise to the release position of the center of strike to 0.1 %. The height may be determined by direct measurement of the elevation of the center of strike or by calculation from the change in angle of the pendulum using the following formulas: (See Fig. 5)

$$S = L\,(1 - \mathrm{Cos}\,\beta) \text{ or } h_1 = L\,(1 - \mathrm{Cos}\,\alpha)\text{''}$$

6.2.3.5 The potential energy of the system is equal to the height from which the pendulum falls, as determined in 6.2.3.4, times the supporting force, as determined in 6.2.3.3.

6.2.4 *Impact Velocity*—Determine the impact velocity, v, of the machine, neglecting friction, by means of the following equation:

$$v = \sqrt{2\,gh}$$

where:

v = velocity, m/s (or ft/s),
g = acceleration of gravity, 9.81 m/s^2 (32.2 ft/s^2), and
h = initial elevation of the striking edge, m (or ft).

6.2.5 *Center of Percussion*—To ensure that minimum force is transmitted to the point of rotation, the center of percussion shall be at a point within 1 % of the distance from the axis of rotation to the center of strike in the specimen. Determine the location of the center of percussion as follows:

6.2.5.1 Using a stop watch or some other suitable time-measuring device, capable of measuring time to within 0.2 s, swing the pendulum through a total angle not greater than 15° and record the time for 100 complete cycles (to and fro).

6.2.5.2 Determine the center of percussion by means of the following equation:

$$L = \frac{gp^2}{4\pi^2}$$

where:

L = distance from the axis to the center of percussion, m (ft),
g = local gravitational acceleration (accuracy of one part in one thousand), m/s^2 (ft/s^2),
π = 3.1416, and

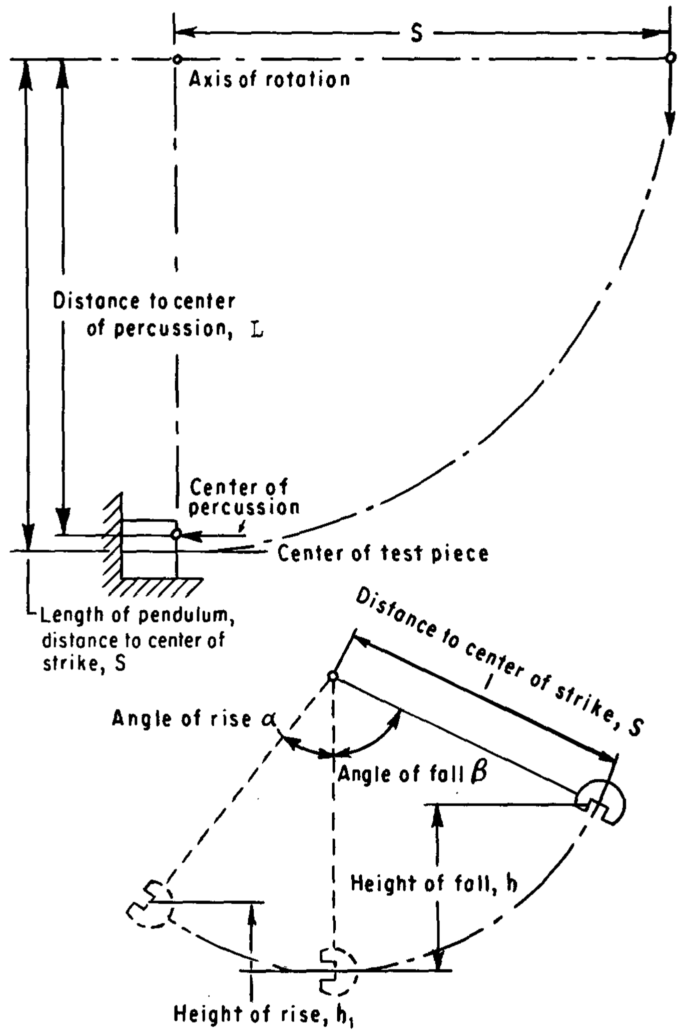


FIG. 5 Dimensions for Calculations

p = period of a complete swing (to and fro), s.

6.2.6 *Friction*—The energy loss from friction and windage of the pendulum and friction in the recording mechanism, if not corrected, will be included in the energy loss attributed to breaking the specimen and can result in erroneously high impact values. In machines recording in degrees, normal frictional losses are usually not compensated for by the machine manufacturer, whereas they are usually compensated for in machines recording directly in energy by increasing the starting height of the pendulum. Determine energy losses from friction as follows:

6.2.6.1 Without a specimen in the machine, and with the indicator at the maximum energy reading, release the pendulum from its starting position and record the energy value indicated. This value should indicate zero energy if frictional losses have been corrected by the manufacturer. Raise the pendulum so it just contacts the pointer at the value obtained in the free swing. Secure the pendulum at this height and determine the vertical distance from the center of strike to the top of a half-width specimen positioned on the specimen rests (see 6.2.3.1). Determine the supporting force as in 6.2.3.2 and multiply by this distance. The difference in this value and the initial potential energy is the total energy loss in the pendulum and indicator combined. Without resetting the pointer, repeatedly release the pendulum from its initial position until the pointer shows no further movement. The energy loss determined by the final position of the pointer is that due to the pendulum alone. The frictional loss in the indicator alone is then the difference between the combined indicator and pendulum losses and those due to the pendulum alone.

6.2.6.2 To ensure that friction and windage losses are within tolerances allowed (see 5.1.4), a simple weekly procedure may be adopted for direct-reading machines. The following steps are recommended: (*a*) release the pendulum from its upright position without a specimen in the machine, and the energy reading should be 0 J (0 ft·lbf); (*b*) without resetting the pointer, again release the pendulum and permit it to swing 11 half cycles; and after the pendulum starts its 11th cycle, move the pointer to between 5 and 10 % of scale range capacity and record the value obtained. This value, divided by 11, shall not exceed 0.4 % of scale range capacity. If this value does exceed 0.4 %, the bearings should be cleaned or replaced.

6.2.7 *Indicating Mechanism*—To ensure that the direct reading scale is recording accurately over the entire range, check it at graduation marks corresponding to approximately 0, 10, 20, 30, 50, and 70 % of each range. With the striking edge of the pendulum scribed to indicate the center of strike, lift the pendulum and set it in a position where the indicator reads, for example, 13 J (10 ft·lbf). Determine the height of center of strike to within 0.1 %. The height of center of strike multiplied by the supporting force, as determined in 6.2.3.3, is the residual energy. Increase this value by the total frictional and windage losses for a free swing (see 6.2.6.1) multiplied by the ratio of the angle of swing during a test to twice the angle of fall. Subtract the sum of the residual energy and proportional frictional and windage loss from the potential energy at the latched position. (See 6.2.3.) Make similar calculations at other points of the scale. The scale pointer shall not overshoot or drop back with the pendulum. Make test swings from various heights to check visually the operation of the pointer over several portions of the scale.

6.2.8 The impact value shall be taken as the energy absorbed in breaking the specimen and is equal to the difference between the energy in the striking member at the instant of impact with the specimen and the energy remaining after breaking the specimen.

7. Precaution in Operation of Machine

7.1 *Safety Precautions*—Precautions should be taken to protect personnel from the swinging pendulum, flying broken specimens, and hazards associated with specimen warming and cooling media.

8. Sampling

8.1 Specimens shall be taken from the material as specified by the applicable specification.

9. Test Specimens

9.1 *Material Dependence*—The choice of specimen depends to some extent upon the characteristics of the material to be tested. A given specimen may not be equally satisfactory for soft nonferrous metals and hardened steels; therefore, a number of types of specimens are recognized. In general, sharper and deeper notches are required to distinguish differences in the more ductile materials or with lower testing velocities.

9.1.1 The specimens shown in Figs. 6 and 7 are those most widely used and most generally satisfactory. They are particularly suitable for ferrous metals, excepting cast iron.[4]

9.1.2 The specimen commonly found suitable for die cast alloys is shown in Fig. 8.

9.1.3 The specimens commonly found suitable for powdered metals (P/M) are shown in Figs. 9 and 10. The specimen surface may be in the as-produced condition or smoothly machined, but polishing has proven generally unnecessary. Unnotched specimens are used with P/M materials. In P/M materials, the impact test results will be affected by specimen orientation. Therefore, unless otherwise specified, the position of the specimen in the machine shall be such that the pendulum will strike a surface that is parallel to the compacting direction.

9.2 *Sub-Size Specimen*—When the amount of material available does not permit making the standard impact test specimens shown in Figs. 6 and 7, smaller specimens may be used, but the results obtained on different sizes of specimens cannot be compared directly (X1.3). When Charpy specimens other than the standard are necessary or specified, it is recommended that they be selected from Fig. 4.

9.3 *Supplementary Specimens*—For economy in preparation of test specimens, special specimens of round or rectangular cross section are sometimes used for cantilever beam test. These are shown as Specimens X, Y, and Z in Figs. 11 and 12. Specimen Z is sometimes called the Philpot specimen after the name of the original designer. In the case of hard materials, the machining of the flat surface struck by the pendulum is sometimes omitted. Types Y and Z require a different vise from that shown in Fig. 3, each half of the vise having a semi-cylindrical recess that closely fits the clamped portion of the specimen. As previously stated, the results cannot be reliably compared to those obtained using specimens of other sizes or shapes.

9.4 *Specimen Machining:*

9.4.1 When heat-treated materials are being evaluated, the specimen shall be finish machined, including notching, after the final heat treatment, unless it can be demonstrated that there is no difference when machined prior to heat treatment.

9.4.2 Notches shall be smoothly machined but polishing has proven generally unnecessary. However, since variations in notch dimensions will seriously affect the results of the tests, it is necessary to adhere to the tolerances given in Fig. 6 (X1.2 illustrates the effects from varying notch dimensions on Type A specimens). In keyhole specimens, the round hole shall be carefully drilled with a slow feed. The slot may be cut by any feasible method. Care must be exercised in cutting the slot to see that the surface of the drilled hole opposite the slot is not marked.

9.4.3 Identification marks shall only be placed in the following locations on specimens: either of the 10-mm

[4] For testing cast iron, see 1933 Report of Subcommittee XV on Impact Testing of Committee A-3 on Cast Iron, *Proceedings*, Am. Soc. Testing Mats., Vol 33, Part 1, 1933.

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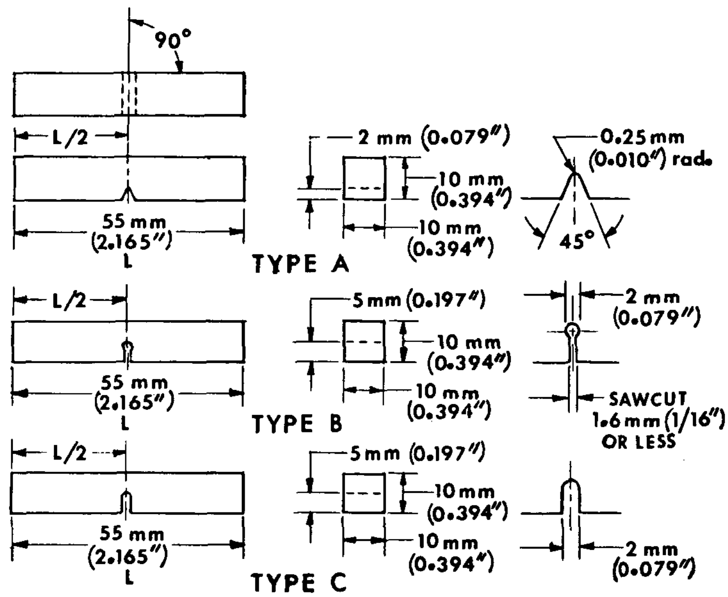
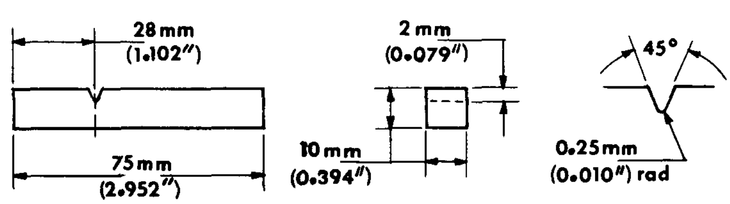


NOTE—Permissible variations shall be as follows:

Notch length to edge	90 ±2°
Adjacent sides shall be at	90° ±10 min
Cross-section dimensions	±0.075 mm (±0.003 in.)
Length of specimen (*L*)	+0, −2.5 mm (+0, −0.100 in.)
Centering of notch (*L*/2)	±1 mm (±0.039 in.)
Angle of notch	±1°
Radius of notch	±0.025 mm (±0.001 in.)
Notch depth:	
Type A specimen	±0.025 mm (±0.001 in.)
Types B and C specimen	±0.075 mm (±0.003 in.)
Finish requirements	2 μm (63 μin.) on notched surface and opposite face; 4 μm (125 μin.) on other two surfaces

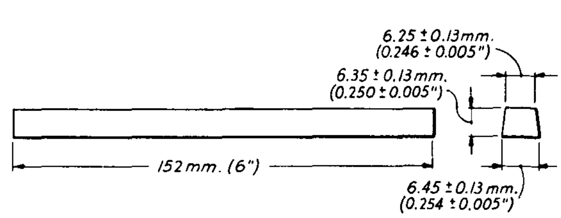
FIG. 6 Charpy (Simple-Beam) Impact Test Specimens, Types A, B, and C



NOTE—Permissible variations shall be as follows:

Notch length to edge	90 ±2°
Cross-section dimensions	±0.025 mm (±0.001 in.)
Length of specimen	+0, −2.5 mm (±0, −0.100 in.)
Angle of notch	±1°
Radius of notch	±0.025 mm (±0.001 in.)
Notch depth	±0.025 mm (±0.001 in.)
Adjacent sides shall be at	90° ± 10 min
Finish requirements	2 μm (63 μin.) on notched surface and op posite face; 4 μm (125 μin.) on other two surfaces

FIG. 7 Izod (Cantilever-Beam) Impact Test Specimen, Type D



NOTE 1—Two test specimens may be cut from this bar.
NOTE 2—Blow shall be struck on narrowest face.

FIG. 8 Simple Beam Impact Test Bar for Die Castings Alloys

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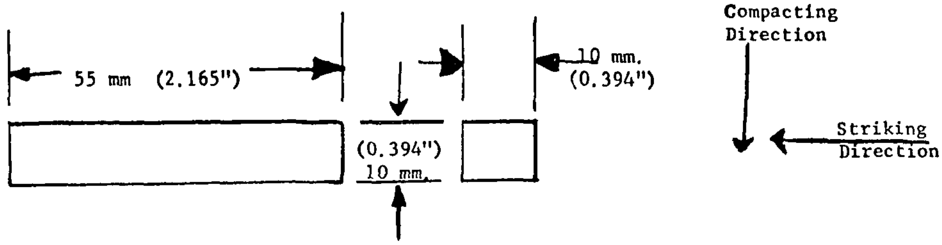
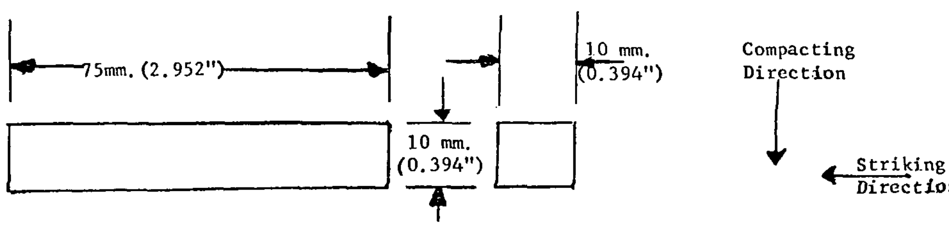


NOTE—Permissible variations shall be as follows:

Adjacent sides shall be at	90° ± 10 min
Cross section dimensions	±0.125 mm (0.005 in.)
Length of specimen	+0, −2.5 mm (+0, −0.100 in.)

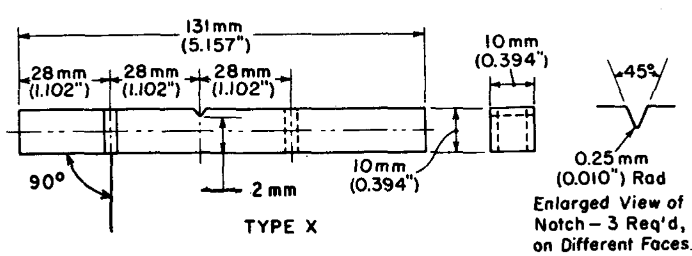
FIG. 9 Charpy (Simple Beam) Impact Test Specimens for Metal Powder Structural Parts



NOTE—Permissible variations shall be as follows:

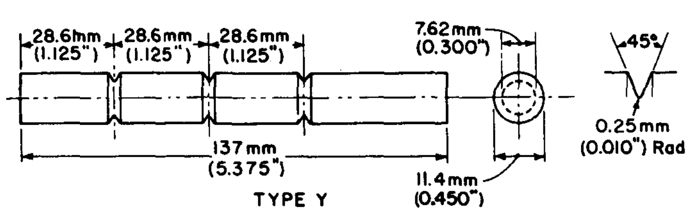
Adjacent sides shall be at	90° ± 10 min.
Cross section dimensions	±0.125 mm (0.005 in.)
Length of specimens	+0, −2.5 mm (+0, −0.100 in.)

FIG. 10 Izod (Cantilever-Beam) Impact Test Specimen for Metal Powder Structural Parts



NOTE—Permissible variations for type X specimens shall be as follows:

Notch length to edge	90 ±2°
Adjacent sides shall be at	90° ±10 min
Notch depth of Type X specimen	±0.025 mm (±0.001 in.)

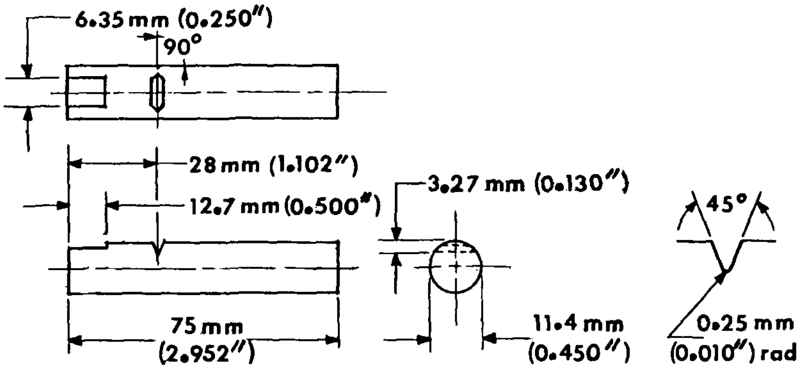


NOTE—Permissible variations for both specimens shall be as follows:

Cross-section dimensions	±0.025 mm (±0.001 in.)
Lengthwise dimensions	+0, −2.5 mm (+0, −0.100 in.)
Angle of notch	±1°
Radius of notch	±0.025 mm (±0.001 in.)
Notch diameter of Type Y specimen	±0.025 mm (±0.001 in.)

FIG. 11 Izod (Cantilever-Beam) Impact Test Specimens, Types X and Y

The flat shall be parallel to the longitudinal centerline of the specimen and shall be parallel to the bottom of the notch within 2:1000.



NOTE—Permissible variations shall be as follows:

Notch length to longitudinal centerline	90 ±2°
Cross-section dimensions	±0.025 mm (±0.001 in.)
Length of specimen	+0, −2.5 mm (+0 −0.100 in.)
Angle of notch	±1°
Radius of notch	±0.025 mm (±0.001 in.)
Notch depth	±0.025 mm (.130 ±0.001 in.)

FIG. 12 Izod (Cantilever-Beam) Impact Test Specimen (Philpot), Type Z

square ends; the side of the specimen which faces up when the specimen is positioned in the anvils (see Note 3); or the portion of the side opposite the notch which is at least 10 mm away from the center line of the notch. No marking shall be done on any portion of the specimen that is visibly deformed during fracture. An electrostatic pencil may be used for identification purposes, but caution must be taken to avoid excessive heat.

NOTE 3—Careful consideration must be given before placing identification marks on the side of the specimen to be placed up when positioned in the anvils. If the test operator is not careful, the specimen may be placed in the machine with the identification marking resting on the specimen supports. Under these circumstances, the energy value obtained will be unreliable.

10. Preparation of Apparatus

10.1 *Daily Checking Procedure*—After the testing machine has been ascertained to comply with Sections 5 and 6, the routine daily checking procedures shall be as follows:

10.1.1 Prior to testing a group of specimens and before a specimen is placed in position to be tested, check the machine by a free swing of the pendulum. With the indicator at the maximum energy position, a free swing of the pendulum shall indicate zero energy on machines reading directly in energy, which are compensated for frictional losses. On machines recording in degrees, the indicated values when converted to energy shall be compensated for frictional losses that are assumed to be proportional to the arc of swing.

11. Verification of Charpy Machines

11.1 Verification consists of inspecting those parts subjected to wear to ensure that the requirements of Sections 5 and 6 are met and the testing of standardized specimens (Notes 4 to 6). It is not intended that parts not subjected to wear (such as pendulum and scale linearity) need to be remeasured during verification unless a problem is evident. The average value at each energy level determined for the standardized specimens shall correspond to the nominal values of the standardized specimens within 1.4 J (1.0 ft·lbf) or 5.0 %, whichever is greater.

11.2 Verification specimens are available directly from the National Institute of Standards and Technology (NIST) through the Standard Reference Materials program. Other sources of verification specimens may be used provided they conform to Practice E 1271 and their reference value has been established on the three reference machines owned, maintained, and operated by NIST in Boulder, CO.

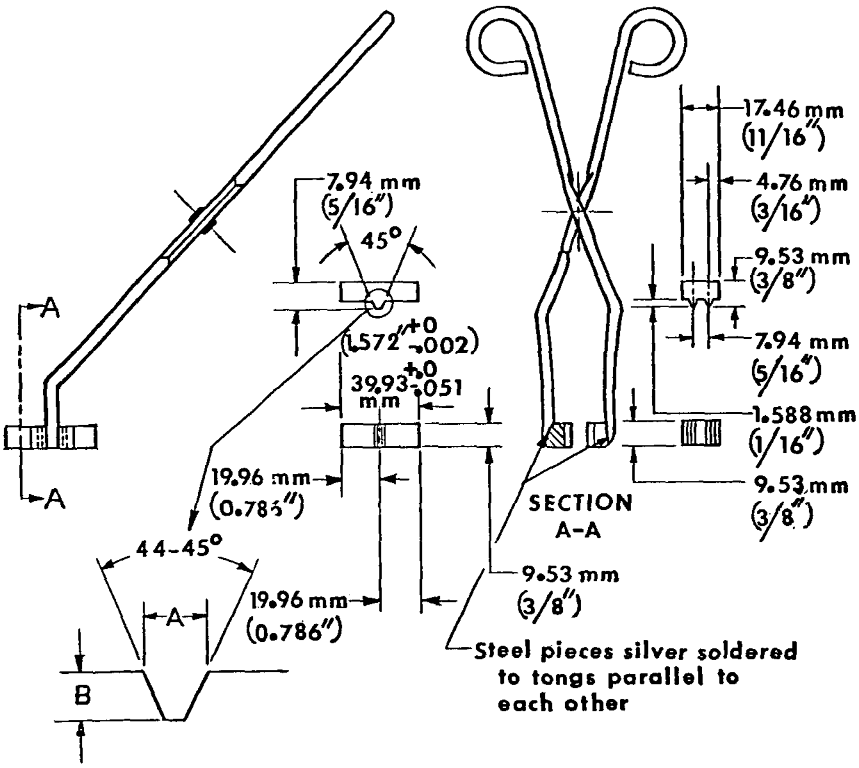
NOTE 4—Standardized specimens are available for Charpy machines only.

NOTE 5—Information pertaining to the availability of standardized specimens may be obtained by addressing: National Institute of Standards and Technology, Office of Standard Reference Materials, B311 Chemistry Building, Gaithersburg, MD 20899. Telephone inquires may be made to the following number: (301) 975-6776.

NOTE 6—The National Institute for Standards and Technology conducts a Charpy machine qualification program originally developed by the Army.[5] Under this program standardized specimens are used to certify the machines of laboratories using the test as an inspection requirement on contracts. If the user desires, the results of tests with the standardized specimens will be evaluated. Participants desirous of the evaluation should complete the questionnaire provided with the standardized specimens. The questionnaire provides for information such as testing temperature, the dimensions of certain critical parts, the cooling and testing techniques, and the results of the test. The broken standardized specimens are to be returned along with the completed questionnaire for evaluation to Charpy Program Coordinator, NIST Code 853, 325 Broadway, Boulder, CO 80303. Upon completion of the evaluation, NIST will return a report. If a machine is producing values outside the standardized specimen tolerances, the report may suggest changes in machine design, repair or replacement of certain machine parts, a change in testing techniques, etc.

11.3 The verified-range of a Charpy impact machine shall be described by a lower value and a higher value. Both these values are determined from tests on sets of standardized specimens at two or more levels of absorbed energy.

[5] Driscoll, D. E., "Reproducibility of Charpy Impact Test," *Symposium on Impact Testing, ASTM STP 176*, ASTM, 1955, p. 170.



NOTE—Unless otherwise shown, permmissible variation shall be ±1 mm (0.04 in.).

Specimen Depth, mm (in.)	Base Width (A), mm (in.)	Height (B), mm (in.)
10 (0.394)	1.60 to 1.70 (0.063 to 0.067)	1.52 to 1.65 (0.060 to 0.065)
5 (0.197)	0.74 to 0.80 (0.029 to 0.033)	0.69 to 0.81 (0.027 to 0.032)
3 (0.118)	0.45 to 0.51 (0.016 to 0.020)	0.36 to 0.48 (0.014 to 0.019)

FIG. 13 Centering Tongs for V-Notch Charpy Specimens

11.3.1 Values of impact energy outside the verified range shall be reported as approximate.

11.3.2 With the exception stated in 11.3.2.4, the lower limit of the verified range shall be the greater of:

11.3.2.1 One half the certified value of the lowest-value standardized specimen set tested, or,

11.3.2.2 On an analogue scale, five times the difference between the energy values represented by the graduation marks on either side of the pointer position when the lowest value from the standardized specimens is read, or,

11.3.2.3 On a digital scale, 25 times the least count of the digital display or printout when the lowest value from the standardized specimens is read.

11.3.2.4 If the lowest value of standardized specimens commercially available has been tested, then 11.3.2.1 does not apply.

11.3.3 With the exception stated in 11.3.3.2, the upper value of the verified range shall be the lesser of:

11.3.3.1 Eighty percent of the maximum value of the scale being tested, or,

11.3.3.2 1.5 times the certified value of the highest level standardized specimens tested.

11.3.3.3 If the highest value of standardized specimens commercially available has been tested, then 11.2.3.2 does not apply.

11.3.3.4 Standardized specimens whose certified value is greater than 80 % of the maximum value on the scale being used shall not be tested.

11.3.4 If the ratio of the higher certified value to the lower certified value of the two levels of standardized specimens is greater than four, testing of a third set of intermediate energy level specimens, if commercially available, is required.

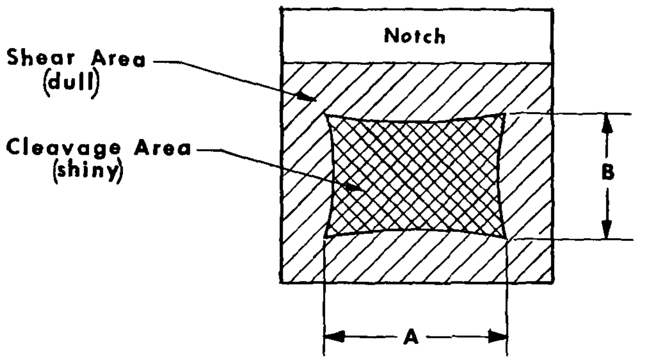
11.4 *Frequency of Verification*—Charpy machines shall be verified within one year prior to the time of testing. Charpy machines shall also be verified immediately after replacing parts that may affect the measured energy, after making repairs or adjustments, after they have been moved, or whenever there is reason to doubt the accuracy of the results, without regard to the time interval.

11.4.1 The accuracy of a Charpy machine shall be rechecked using standardization specimens (see 11.1) when parts that may affect the measured energy are removed from the machine and then reinstalled without modification (for example, when the tup or anvils are removed to permit use of a different tup or set of anvils and then are reinstalled).

12. Procedure

12.1 The Daily Checking Procedure (Section 10) shall be performed at the beginning of each day or each shift.

12.2 *Charpy Test Procedure*—The Charpy test procedure may be summarized as follows: the test specimen is removed from its cooling (or heating) medium, if used, and positioned on the specimen supports; the pendulum is released without



NOTE 1—Measure average dimensions *A* and *B* to the nearest 0.5 mm or 0.02 in.

NOTE 2—Determine the percent shear fracture using Table 1 or Table 2.

FIG. 14 Determination of Percent Shear Fracture

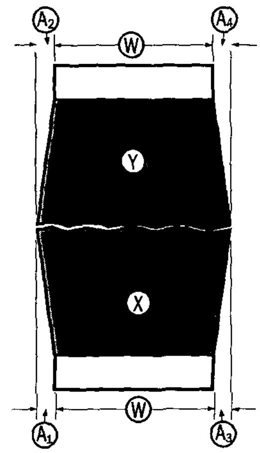
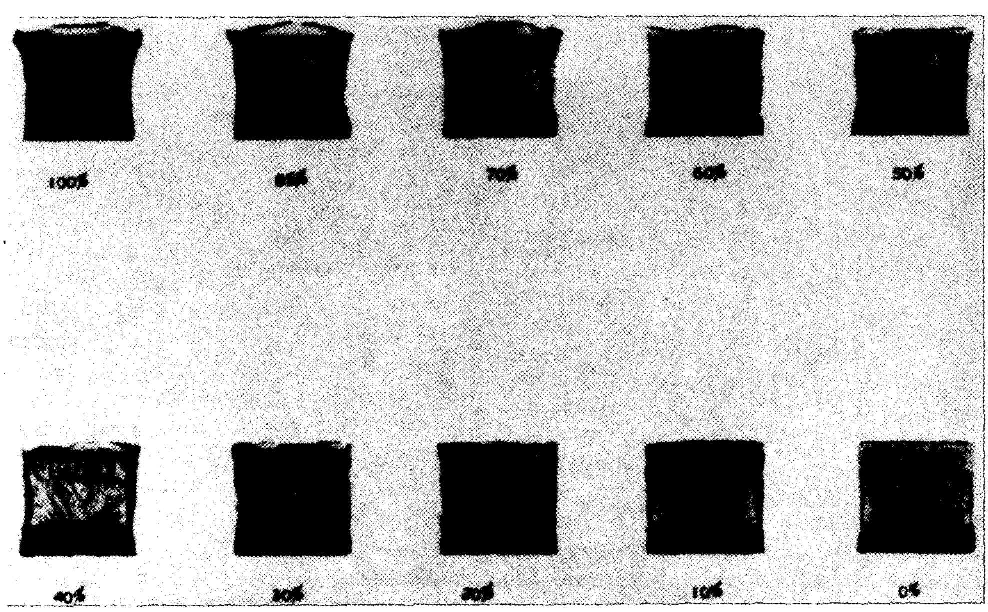


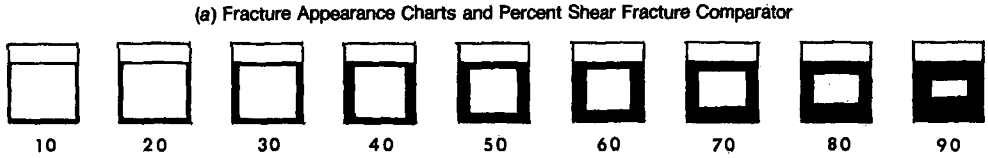
FIG. 16 Halves of Broken Charpy V-Notch Impact Specimen Illustrating the Measurement of Lateral Expansion, Dimensions A_1, A_2, A_3, A_4 and Original Width, Dimension W

vibration, and the specimen is broken within 5 s after removal from the medium. Information is obtained from the machine and from the broken specimen. The details are described as follows:

12.2.1 *Temperature of Testing*—In most materials, impact values vary with temperature. Unless otherwise specified, tests shall be made at 15 to 32°C (60 to 90°F). Accuracy of results when testing at other temperatures requires the following procedure: For liquid cooling or heating fill a suitable container, which has a grid raised at least 25 mm (1 in.) from the bottom, with liquid so that the specimen when immersed will be covered with at least 25 mm (1 in.) of the liquid. Bring the liquid to the desired temperature by any convenient method. The device used to measure the temperature of the bath should be placed in the center of a group of the specimens. Verify all temperature-measuring equipment at least twice annually. When using a liquid medium, hold



(*a*) Fracture Appearance Charts and Percent Shear Fracture Comparator



(*b*) Guide for Estimating Fracture Appearance

FIG. 15 Fracture Appearance

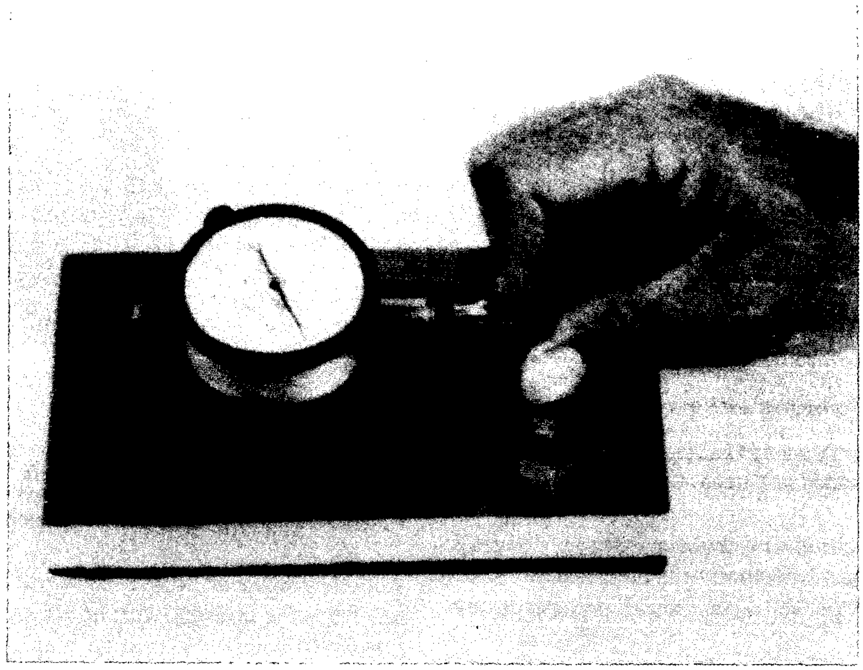
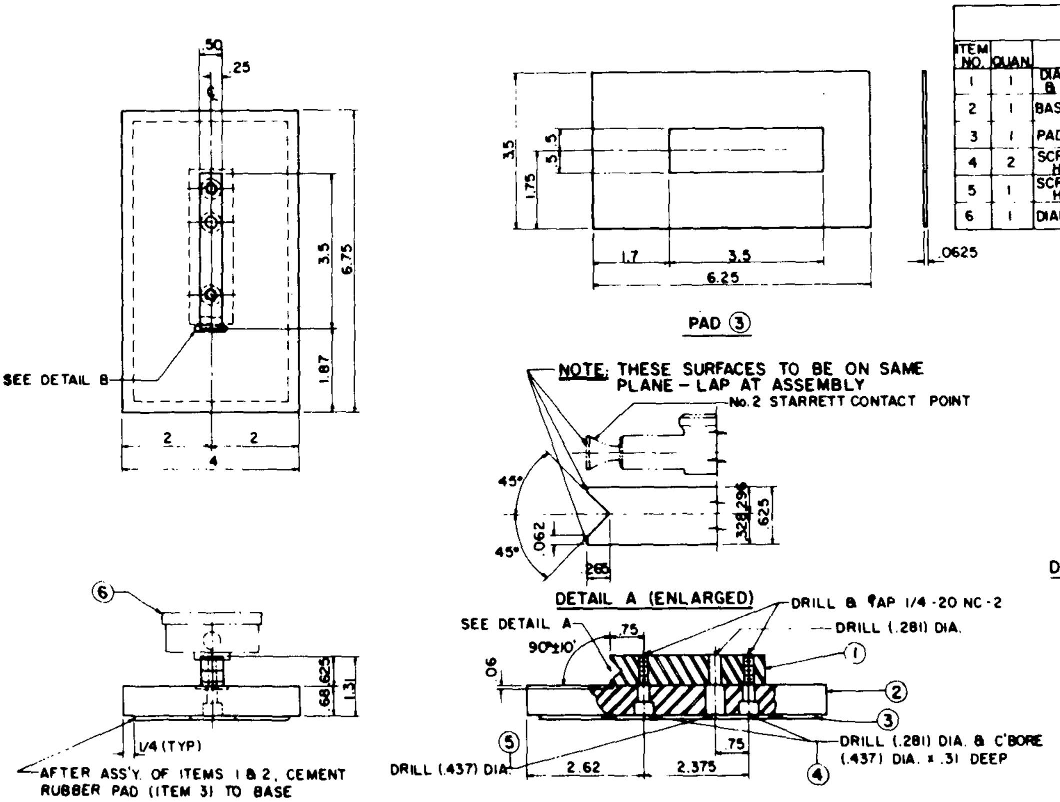


FIG. 17 Lateral Expansion Gage for Charpy Impact Specimens



BILL OF MATERIAL			
ITEM NO.	QUAN.	DESCRIPTION	MATERIAL AND SIZE
1	1	DIAL MOUNT & STOP 4 x 5/8 x 1/2	STEEL SAE 1015-1020
2	1	BASE PLATE 7 x 4 x 3/4	STEEL SAE 1015-1020
3	1	PAD 6-1/4 x 3-1/2 x 1/16	RUBBER
4	2	SCREW-SOCKET HEAD CAP	STEEL 1/4-20 x 1" LG.
5	1	SCREW-SOCKET HEAD CAP	STEEL 1/4-20 x 3/4" LG.
6	1	DIAL INDICATOR	(SEE NOTE 2)

NOTES:

1.) FLASH CHROME PLATE ITEMS 1 & 2

2) DIAL INDICATOR- STARRETT NO. 25-241
RANGE .001 - .250
BACK-ADJUSTABLE BRACKET
CONTACT POINT NO. 2

FIG. 18 Assembly and Details for Lateral Expansion Gage

TABLE 1 Percent Shear for Measurements Made in Millimetres

NOTE—100 % shear is to be reported when either *A* or *B* is zero.

Dimension *B*, mm	Dimension *A*, mm																		
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10
1.0	99	98	98	97	96	96	95	94	94	93	92	92	91	91	90	89	89	88	88
1.5	98	97	96	95	94	93	92	92	91	90	89	88	87	86	85	84	83	82	81
2.0	98	96	95	94	92	91	90	89	88	86	85	84	82	81	80	79	77	76	75
2.5	97	95	94	92	91	89	88	86	84	83	81	80	78	77	75	73	72	70	69
3.0	96	94	92	91	89	87	85	83	81	79	77	76	74	72	70	68	66	64	62
3.5	96	93	91	89	87	85	82	80	78	76	74	72	69	67	65	63	61	58	56
4.0	95	92	90	88	85	82	80	77	75	72	70	67	65	62	60	57	55	52	50
4.5	94	92	89	86	83	80	77	75	72	69	66	63	61	58	55	52	49	46	44
5.0	94	91	88	85	81	78	75	72	69	66	62	59	56	53	50	47	44	41	37
5.5	93	90	86	83	79	76	72	69	66	62	59	55	52	48	45	42	38	35	31
6.0	92	89	85	81	77	74	70	66	62	59	55	51	47	44	40	36	33	29	25
6.5	92	88	84	80	76	72	67	63	59	55	51	47	43	39	35	31	27	23	19
7.0	91	87	82	78	74	69	65	61	56	52	47	43	39	34	30	26	21	17	12
7.5	91	86	81	77	72	67	62	58	53	48	44	39	34	30	25	20	16	11	6
8.0	90	85	80	75	70	65	60	55	50	45	40	35	30	25	20	15	10	5	0

TABLE 2 Percent Shear for Measurements Made in Inches

NOTE—100 % shear is to be reported when either *A* or *B* is zero.

Dimension *B*, in.	Dimension *A*, in.																
	0.05	0.10	0.12	0.14	0.16	0.18	0.20	0.22	0.24	0.26	0.28	0.30	0.32	0.34	0.36	0.38	0.40
0.05	98	96	95	94	94	93	92	91	90	90	89	88	87	86	85	85	84
0.10	96	92	90	89	87	85	84	82	81	79	77	76	74	73	71	69	68
0.12	95	90	88	86	85	83	81	79	77	75	73	71	69	67	65	63	61
0.14	94	89	86	84	82	80	77	75	73	71	68	66	64	62	59	57	55
0.16	94	87	85	82	79	77	74	72	69	67	64	61	59	56	53	51	48
0.18	93	85	83	80	77	74	72	68	65	62	59	56	54	51	48	45	42
0.20	92	84	81	77	74	72	68	65	61	58	55	52	48	45	42	39	36
0.22	91	82	79	75	72	68	65	61	57	54	50	47	43	40	36	33	29
0.24	90	81	77	73	69	65	61	57	54	50	46	42	38	34	30	27	23
0.26	90	79	75	71	67	62	58	54	50	46	41	37	33	29	25	20	16
0.28	89	77	73	68	64	59	55	50	46	41	37	32	28	23	18	14	10
0.30	88	76	71	66	61	56	52	47	42	37	32	27	23	18	13	9	3
0.31	88	75	70	65	60	55	50	45	40	35	30	25	20	18	10	5	0

the specimens in an agitated bath at the desired temperature within ±1°C (±2°F) for at least 5 min. When using a gas medium, position the specimens so that the gas circulates around them and hold the gas at the desired temperature within ±1°C (±2°F) for at least 30 min. Leave the mechanism used to remove the specimen from the medium in the medium except when handling the specimens.

NOTE 7—Temperatures up to +260°C (+500°F) may be obtained with certain oils, but "flash-point" temperatures must be carefully observed.

12.2.1.1 When the bath is near its boiling point, evaporative cooling can dramatically lower the specimen temperature during the interval between removal from the bath and fracture. A study has shown that a specimen heated to 100°C in water can cool 10°C in the 5 s allowed for transfer to the machine anvils.[6] When using a heating medium near its boiling point, use the data in this reference or calibration data with thermocouples to confirm that the specimen is within the stated tolerance from the desired temperature when the striker fractures the specimen.

12.2.2 *Placement of Test Specimen in Machine*—It is recommended that self-centering tongs similar to those shown in Fig. 13 be used in placing the specimen in the machine (see 5.3.1). The tongs illustrated in Fig. 13 are for centering V-notch specimens. If keyhole specimens are used, modification of the tong design may be necessary. If an end-centering device is used, caution must be taken to ensure that low-energy high-strength specimens will not rebound off this device into the pendulum and cause erroneously high recorded values. Many such devices are permanent fixtures of machines, and if the clearance between the end of a specimen in test position and the centering device is not approximately 13 mm (0.5 in.), the broken specimens may rebound into the pendulum.

12.2.3 *Operation of the Machine:*

12.2.3.1 Set the energy indicator at the maximum scale reading; take the test specimen from its cooling (or heating) medium, if used; place it in proper position on the specimen anvils; and release the pendulum smoothly. This entire sequence shall take less than 5 s if a cooling or heating medium is used.

12.2.3.2 With the exception described as follows, any specimen, which when struck by a single blow does not separate into two pieces, shall be reported as unbroken. If the specimen can be separated by force applied by bare hands, the specimen may be considered as having been separated by the blow. Impact values from unbroken specimens with absorbed energy less than 80 % of the machine capacity may be averaged with values from broken specimens. If the

[6] Nanstad, R. K., Swain, R. L. and Berggren, R. G., 'Influence of Thermal Conditioning Media on Charpy Specimen Test Temperature,' *Charpy Impact Test: Factors and Variables, ASTM STP 1072*, Am. Soc. Testing Mats., 1990, p. 195.

individual values are not listed, the percent of unbroken specimens shall be reported with the average. If the absorbed energy exceeds 80 % of the machine capacity and the specimen passes completely between the anvils, the value shall be reported as approximate (see 5.5) and not averaged with others. If an unbroken specimen does not pass between the machine anvils, the result will be reported as exceeding the stated machine capacity. In no case shall the specimen be struck more than once.

12.2.3.3 If any specimen jams in the machine, disregard the results and check the machine thoroughly for damage or maladjustment, which would affect its calibration.

12.2.3.4 To prevent recording an erroneous value caused by jarring the indicator when locking the pendulum in its upright position, read the value from the indicator prior to locking the pendulum for the next test.

12.2.4 *Information Obtainable from the Test*:

12.2.4.1 *Absorbed Energy*—The amount of energy required to fracture the specimen is determined from the machine reading.

12.2.4.2 *Lateral Expansion*—The method for measuring lateral expansion must take into account the fact that the fracture path seldom bisects the point of maximum expansion on both sides of a specimen. One half of a broken specimen may include the maximum expansion for both sides, one side only, or neither. The technique used must therefore provide an expansion value equal to the sum of the higher of the two values obtained for each side by measuring the two halves separately. The amount of expansion on each side of each half must be measured relative to the plane defined by the undeformed portion of the side of the specimen, Fig. 16. Expansion may be measured by using a gage similar to that shown in Figs. 17 and 18. Measure the two broken halves individually. First, though, check the sides perpendicular to the notch to ensure that no burrs were formed on these sides during impact testing; if such burrs exist, they must be removed, for example, by rubbing on emery cloth, making sure that the protrusions to be measured are not rubbed during the removal of the burr. Next, place the halves together so that the compression sides are facing one another. Take one half (X in Fig.16) and press it firmly against the reference supports, with the protrusions against the gage anvil. Note the reading, then repeat this step with the other broken half (Y in Fig. 16), ensuring that the same side of the specimen is measured. The larger of the two values is the expansion of that side of the specimen. Next, repeat this procedure to measure the protrusions on the opposite side, then add the larger values obtained for each side. Measure each specimen. (See Note 8.)

NOTE 8—Examine each fracture surface to ascertain that the protrusions have not been damaged by contacting the anvil, machine mounting surface, etc. Such specimens should be discarded since this may cause erroneous readings. For example, if $A_1 > A_2$ and $A_3 = A_4$, then $LE = A_1 + (A_3 \text{ or } A_4)$. If $A_1 > A_2$ and $A_3 > A_4$, then $LE = A_1 + A_3$.

12.2.4.3 *Fracture Appearance*—The percentage of shear fracture may be determined by any of the following methods: (*1*) measure the length and width of the cleavage portion of the fracture surface, as shown in Fig. 14, and determine the percent shear from either Table 1 or Table 2 depending on the units of measurement; (*2*) compare the appearance of the fracture of the specimen with a fracture appearance chart such as that shown in Fig. 15; (*3*) magnify the fracture surface and compare it to a precalibrated overlay chart or measure the percent shear fracture by means of a planimeter; or (*4*) photograph the fracture surface at a suitable magnification and measure the percent shear fracture by means of a planimeter.

NOTE 9—Because of the subjective nature of the evaluation of fracture appearance, it is not recommended that it be used in specifications.

12.3 *Izod Test Procedure*—The Izod test procedure may be summarized as follows: the test specimen is positioned in the specimen-holding fixture and the pendulum is released without vibration. Information is obtained from the machine and from the broken specimen. The details are described as follows:

12.3.1 *Temperature of Testing*—The specimen-holding fixture for Izod specimens is in most cases part of the base of the machine and cannot be readily cooled (or heated). For this reason, Izod testing is not recommended at other than room temperature.

12.3.2 Clamp the specimen firmly in the support vise so that the centerline of the notch is in the plane of the top of the vise within 0.125 mm (0.005 in.). Set the energy indicator at the maximum scale reading, and release the pendulum smoothly. Sections 12.2.3.2 to 12.2.3.4 inclusively, also apply when testing Izod specimens.

12.3.3 *Information Obtainable from the Test*—The impact energy, lateral expansion, and fracture appearance, may be determined as described in 12.2.4.

13. Report

13.1 For commercial acceptance testing, report the following information:

13.1.1 Specimen type (and size if not the full size specimen),

13.1.2 Test temperature of specimen, and

13.1.3 Energy absorbed.

13.2 For other than commercial acceptance testing, report the following information, when required, in addition to the information in 13.1:

13.2.1 Lateral expansion,

13.2.2 Fracture appearance, % shear (See Note 9),

13.2.3 Specimen orientation,

13.2.4 Specimen location,

13.2.5 Original specimen width, (*W* in Fig. 4), and

13.2.6 Original specimen depth, (*D* in Fig. 4).

14. Precision and Bias

14.1 *Interlaboratory Test Program*—An interlaboratory study used CVN specimens of low energy and of high energy to find sources of variation in the CVN absorbed energy. Data from 29 laboratories were included with each laboratory testing one set of five specimens of each energy level. Except for being limited to only two energy levels (by availability of reference specimens), Practice E 691 was followed for the design and analysis of the data, the details are given in ASTM Research Report No. RR:E28-1014.

14.2 *Precision*—The precision information given below (in units of J and ft·lb) is for the average CVN impact energy of five test determinations at each laboratory for each material.

Material	Low Energy J	Low Energy ft·lb	High Energy J	High Energy ft·lb
Absorbed Energy	15.9	11.7	96.2	71.0
95 % Repeatability Limit	2.4	1.7	8.3	6.1
95 % Reproducibility Limits	2.7	2.0	9.2	6.8

The terms repeatability and reproducibility limit are used as defined in Practice E 177. The respective standard deviations among test results may be obtained by dividing the above limits by 2.8.

14.3 *Bias*—Bias cannot be defined for CVN absorbed energy. The physical simplicity of the pendulum design is complicated by complex energy loss mechanisms within the machine and the specimen. Therefore, there is no absolute standard to which the measured values can be compared.

15. Keywords

15.1 charpy test; fracture appearance; Izod test; impact test; notched specimens; pendulum machine

ANNEX

(Mandatory Information)

A1. PRECRACKING CHARPY V-NOTCH IMPACT SPECIMENS

A1.1 Scope

A1.1.1 This annex describes the procedure for the fatigue precracking of standard Charpy V-notch (CVN) impact specimens. The annex provides information on applications of precracked Charpy impact testing and fatigue-precracking procedures.

A1.2 Significance and Use

A1.2.1 Section 4 also applies to precracked Charpy V-notch impact specimens.

A1.2.2 It has been found that fatigue-precracked CVN specimens generally result in better correlations with other impact toughness tests such as Test Method E 604 and with fracture toughness tests such as Test Method E 399 than the standard V-notch specimens **(1–6)**.[7] Also, the sharper notch yields more conservative estimations of the notched impact toughness and the transition temperature of the material **(7–8)**.

A1.3 Apparatus

A1.3.1 The equipment for fatigue cracking shall be such that the stress distribution is uniform through the specimen thickness; otherwise the crack will not grow uniformly. The stress distribution shall also be symmetrical about the plane of the prospective crack; otherwise the crack will deviate unduly from that plane and the test result will be significantly affected.

A1.3.2 The recommended fixture to be used is shown in Fig. A1.1. The nominal span between support rollers shall be $4D \pm 0.2D$, where D is the depth of the specimen. The diameter of the rollers shall be between $D/2$ and D. The radius of the ram shall be between $D/8$ and D. This fixture is designed to minimize frictional effects by allowing the support rollers to rotate and move apart slightly as the specimen is loaded, thus permitting rolling contact. The rollers are initially positioned against stops that set the span length and are held in place by low-tension springs (such as rubber bands). Fixtures, rolls, and ram should be made of high hardness (greater than 40 HRC) steels.

A1.4 Test Specimens

A1.4.1 The dimensions of the precracked Charpy specimen are essentially those of type-A shown in Figs. 4 and A1.2. The notch depth plus the fatigue crack extension diameter shall be designated as N. When the amount of material available does not permit making the standard impact test specimen, smaller specimens may be made by reducing the width; but the results obtained on different sizes of specimens cannot be compared directly (see X1.3).

A1.4.2 The fatigue precracking is to be done with the material in the same heat-treated condition as that in which it will be impact tested. No intermediate treatments between fatigue precracking and testing are allowed.

A1.4.3 Because of the relatively blunt machined V-notch in the Charpy impact specimen, fatigue crack initiation can be difficult. Early crack initiation can be promoted by pressing or milling a sharper radius into the V-notch. Care must be taken to ensure that excessive deformation at the crack tip is avoided.

A1.4.4 It is advisable to mark two pencil lines on each side of the specimen normal to the anticipated paths of the surface traces of the fatigue crack. The first line should indicate the point at which approximately two-thirds of the crack extension has been accomplished. At this point, the stress intensity applied to the specimen should be reduced. The second line should indicate the point of maximum crack extension. At this point, fatigue precracking should be terminated.

A1.5 Fatigue Precracking Procedure

A1.5.1 Set up the test fixture so that the line of action of the applied load shall pass midway between the support roll center within 1 mm. Measure the span to within 1 % of the

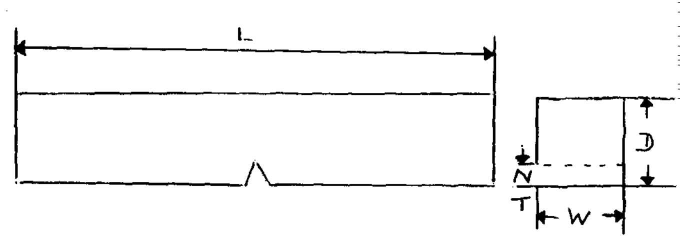
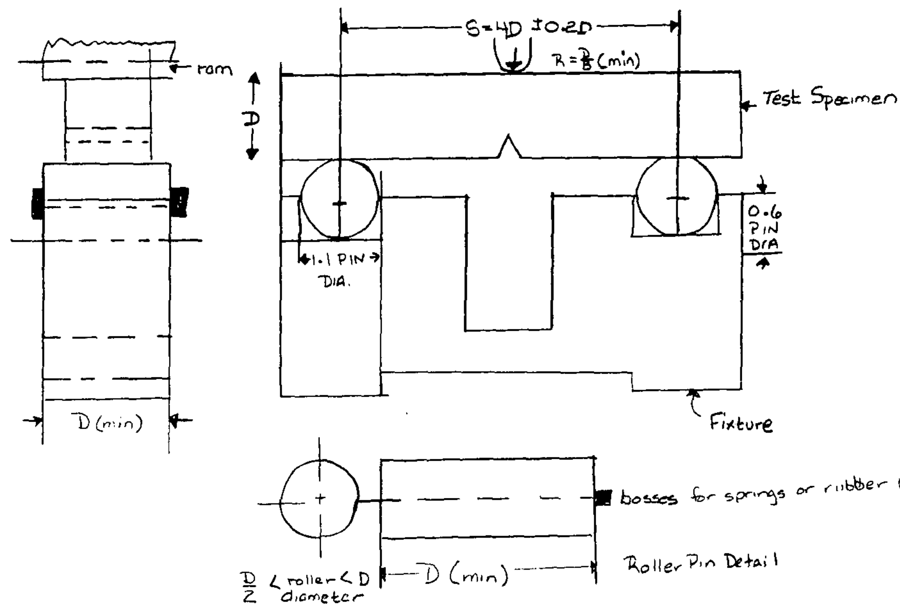


FIG. A1.1 Fatigue Precracking Fixture Design

[7] The boldface numbers in parentheses refer to the list of references at the end of this test method.

E 23



L = length = 55 mm +0, −2.5 mm,
D = depth = 10 mm ± 0.075 mm,
W = variable width (see Fig. 4),
N = notch depth = 2 mm ± 0.025 mm, included angle of notch = 45° ± 1°, and radius of notch = 0.25 mm ± 0.025 mm.

FIG. A1.2 Charpy (Simple-Beam, type A) Impact Test Specimen

nominal length. Locate the specimen with the crack tip midway between the rolls within 1 mm of the span, and square to the roll axes within 2°.

A1.5.2 Select the initial loads used during precracking so that the remaining ligament remains undamaged by excessive plasticity. If the load cycle is maintained constant, the maximum K (stress intensity) and the K range will increase with crack length; care must be taken to ensure that the maximum K value is not exceeded in order to prevent excessive plastic deformation at the crack tip. This is done by continually shedding the load as the fatigue crack extends. The maximum load to be used at any instant can be calculated from Eqs A1.1 and A1.2 while the minimum load should be kept at 10 % of the maximum. Equation A1.1 relates the maximum load to a stress intensity (K) value for the material that will ensure an acceptable plastic-zone size at the crack tip. It is also advisable to check this maximum load to ensure that it is below the limit load for the material using Eq A1.2. When the most advanced crack trace has almost reached the first scribed line corresponding to approximately two-thirds of the final crack length, reduce the maximum load so that 0.6 K_{max} is not exceeded.

A1.5.3 Fatigue cycling is begun, usually with a sinusoidal waveform and near to the highest practical frequency. There is no known marked frequency effect on fatigue precrack formation up to at least 100 Hz in the absence of adverse environments; however, frequencies of 15 to 30 Hz are typically used. Carefully monitor the crack growth optically. A low-power magnifying glass is useful in this regard. If crack growth is not observed on one side when appreciable growth is observed on the first, stop fatigue cycling to determine the cause and remedy for the behavior. Simply turning the specimen around in relation to the fixture will often solve the problem. When the most advanced crack trace has reached the half-way mark, turn the specimen around in relation to the fixture and complete the fatigue cycling. Continue fatigue cycling until the surface traces on both sides of the specimen indicate that the desired overall length of notch plus crack is

TABLE A1.1 Calculations of f(N/D)

N (mm)	D (mm)	N/D	f(N/D)
2.00	10.00	0.20	1.17
2.10	10.00	0.21	1.21
2.20	10.00	0.22	1.24
2.30	10.00	0.23	1.27
2.40	10.00	0.24	1.31
2.50	10.00	0.25	1.34
2.60	10.00	0.26	1.37
2.70	10.00	0.27	1.41
2.80	10.00	0.28	1.45
2.90	10.00	0.29	1.48
3.00	10.00	0.30	1.52
3.10	10.00	0.31	1.56
3.20	10.00	0.32	1.60
3.30	10.00	0.33	1.64
3.40	10.00	0.34	1.69
3.50	10.00	0.35	1.73
3.60	10.00	0.36	1.78
3.70	10.00	0.37	1.83
3.80	10.00	0.38	1.88
3.90	10.00	0.39	1.93
4.00	10.00	0.40	1.98
4.10	10.00	0.41	2.04
4.20	10.00	0.42	2.10
4.30	10.00	0.43	2.16
4.40	10.00	0.44	2.22
4.50	10.00	0.45	2.29
4.60	10.00	0.46	2.35
4.70	10.00	0.47	2.43
4.80	10.00	0.48	2.50
4.90	10.00	0.49	2.58
5.00	10.00	0.50	2.66

reached. The fatigue crack should extend at least 1 mm beyond the tip of the V-notch but no more than 3 mm. A fatigue crack extension of approximately 2 mm is recommended.

A1.5.4 When fatigue cracking is conducted at a temperature T_1 and testing will be conducted at a different temperature T_2, and $T_1 > T_2$, the maximum stress intensity must not exceed 60 % of the K_{max} of the material at temperature T_1 multiplied by the ratio of the yield stresses of the material at the temperatures T_1 and T_2, respectively. Control of the plastic-zone size during fatigue cracking is important when the fatigue cracking is done at room temperature and the test is conducted at lower temperatures. In this case, the maximum stress intensity at room temperature must be kept to low values so that the plastic-zone size corresponding to the maximum stress intensity at low temperatures is smaller.

A1.6 Calculation

A1.6.1 Specimens shall be precracked in fatigue at load values that will not exceed a maximum stress intensity, K_{max}. For three-point bend specimens use:

$$P_{max} = [K_{max} * W * D^{3/2}]/[\ S * f(N/D)] \tag{A1.1}$$

where:

P_{max} = maximum load to be applied during precracking,
K_{max} = maximum stress intensity = $\sigma_{ys} * (2 * PI * r_y)^{1/2}$, where r_y = is the radius of the induced plastic zone size which should be less than or equal to 0.5 mm,
D = specimen depth,
W = specimen width,
S = span, and
$f(N/D)$ = geometrical factor (see Table A1).

A1.6.2 See the appropriate section of Test Method E 399 for the f(N/D) calculation. Table A1.1 contains calculated values for f(N/D) for CVN precracking. Equation A1.2 should be used to ensure that the loads used in fatigue cracking are well below the calculated limit load for the material.

$$P_L = (4/3) * [D * (D - N)^2 * \sigma_{ys}]/S \tag{A1.2}$$

where P_L = limit load for the material.

A1.7 Crack Length Measurement

A1.7.1 After fracture, measure the initial notch plus fatigue crack length, N, to the nearest 1 % at the following three positions: at the center of the crack front and midway between the center and the intersection of the crack front with the specimen surfaces. Use the average of these three measurements as the crack length.

A1.7.2 If the difference between any two of the crack length measurements exceeds 10 % of the average, or if part of the crack front is closer to the machine notch root than 5 % of the average, the specimen should be discarded. Also, if the length of either surface trace of the crack is less than 80 % of the average crack length, the specimen should be discarded.

A1.8 Report

A1.8.1 Report the following information for each specimen tested: type of specimen used (and size if not the standard size), test temperatures, and energy absorption. Report the average precrack length in addition to these Test Method E 23 requirements.

A1.8.2 The following information may be provided as supplementary information: lateral expansion, fracture appearance, and also, it would probably be useful to report energy absorption normalized in some manner.

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APPENDIX

(Nonmandatory Information)

X1. NOTES ON SIGNIFICANCE OF NOTCHED-BAR IMPACT TESTING

X1.1 Notch Behavior

X1.1.1 The Charpy V-notch (CVN) impact test has been used extensively in mechanical testing of steel products, in research, and in procurement specifications for over three decades. Where correlations with fracture mechanics parameters are available, it is possible to specify CVN toughness values that would ensure elastic-plastic or plastic behavior for fracture of fatigue cracked specimens subjected to minimum operating temperatures and maximum in service rates of loading.

X1.1.2 The notch behavior of the face-centered cubic metals and alloys, a large group of nonferrous materials and the austenitic steels can be judged from their common tensile properties. If they are brittle in tension they will be brittle when notched, while if they are ductile in tension they will be ductile when notched, except for unusually sharp or deep notches (much more severe than the standard Charpy or Izod specimens). Even low temperatures do not alter this characteristic of these materials. In contrast, the behavior of the ferritic steels under notch conditions cannot be predicted from their properties as revealed by the tension test. For the study of these materials the Charpy and Izod type tests are accordingly very useful. Some metals that display normal ductility in the tension test may nevertheless break in brittle fashion when tested or when used in the notched condition. Notched conditions include restraints to deformation in directions perpendicular to the major stress, or multiaxial stresses, and stress concentrations. It is in this field that the Charpy and Izod tests prove useful for determining the susceptibility of a steel to notch-brittle behavior though they cannot be directly used to appraise the serviceability of a structure.

X1.2 Notch Effect

X1.2.1 The notch results in a combination of multiaxial stresses associated with restraints to deformation in directions perpendicular to the major stress, and a stress concentration at the base of the notch. A severely notched condition is generally not desirable, and it becomes of real concern in those cases in which it initiates a sudden and complete failure of the brittle type. Some metals can be deformed in a ductile manner even down to the low temperatures of liquid air, while others may crack. This difference in behavior can be best understood by considering the cohesive strength of a material (or the property that holds it together) and its relation to the yield point. In cases of brittle fracture, the cohesive strength is exceeded before significant plastic deformation occurs and the fracture appears crystalline. In cases of the ductile or shear type of failure, considerable deformation precedes the final fracture and the broken surface appears fibrous instead of crytalline. In intermediate cases, the fracture comes after a moderate amount of deformation and is part crystalline and part fibrous in appearance.

X1.2.2 When a notched bar is loaded, there is a normal stress across the base of the notch which tends to initiate fracture. The property that keeps it from cleaving, or holds it together, is the "cohesive strength." The bar fractures when the normal stress exceeds the cohesive strength. When this occurs without the bar deforming it is the condition for brittle fracture.

X1.2.3 In testing, though not in service because of side effects, it happens more commonly that plastic deformation precedes fracture. In addition to the normal stress, the applied load also sets up shear stresses which are about 45° to the normal stress. The elastic behavior terminates as soon as the shear stress exceeds the shear strength of the material and deformation or plastic yielding sets in. This is the condition for ductile failure.

X.1.2.4 This behavior, whether brittle or ductile, depends on whether the normal stress exceeds the cohesive strength before the shear stress exceeds the shear strength. Several important facts of notch behavior follow from this. If the notch is made sharper or more drastic, the normal stress at the root of the notch will be increased in relation to the shear stress and the bar will be more prone to brittle fracture (see Table X1.1). Also, as the speed of deformation increases, the shear strength increases and the likelihood of brittle fracture increases. On the other hand, by raising the temperature, leaving the notch and the speed of deformation the same, the shear strength is lowered and ductile behavior is promoted, leading to shear failure.

X1.2.5 Variations in notch dimensions will seriously affect the results of the tests. Tests on E 4340 steel

TABLE X1.1 Effect of Varying Notch Dimensions on Standard Specimens

	High-Energy Specimens, J (ft·lbf)	Medium-Energy Specimens, J (ft·lbf)	Low-Energy Specimens, J (ft·lbf)
Specimen with standard dimensions	103.0 ± 5.2 (76.0 ± 3.8)	60.3 ± 3.0 (44.5 ± 2.2)	16.9 ± 1.4 (12.5 ± 1.0)
Depth of notch, 2.13 mm (0.084 in.)[A]	97.9 (72.2)	56.0 (41.3)	15.5 (11.4)
Depth of notch, 2.04 mm (0.0805 in.)[A]	101.8 (75.1)	57.2 (42.2)	16.8 (12.4)
Depth of notch, 1.97 mm (0.0775 in.)[A]	104.1 (76.8)	61.4 (45.3)	17.2 (12.7)
Depth of notch, 1.88 mm (0.074 in.)[A]	107.9 (79.6)	62.4 (46.0)	17.4 (12.8)
Radius at base of notch 0.13 mm (0.005 in.)[B]	98.0 (72.3)	56.5 (41.7)	14.6 (10.8)
Radius at base of notch 0.38 mm (0.015 in.)[B]	108.5 (80.0)	64.3 (47.4)	21.4 (15.8)

[A] Standard 2.0 ± 0.025 mm (0.079 ± 0.001 in.).
[B] Standard 0.25 ± 0.025 mm (0.010 ± 0.001 in.).

specimens[8] have shown the effect of dimensional variations on Charpy results (see Table X1.1).

X1.3 Size Effect

X1.3.1 Increasing either the width or the depth of the specimen tends to increase the volume of metal subject to distortion, and by this factor tends to increase the energy absorption when breaking the specimen. However, any increase in size, particularly in width, also tends to increase the degree of restraint and by tending to induce brittle fracture, may decrease the amount of energy absorbed. Where a standard-size specimen is on the verge of brittle fracture, this is particularly true, and a doublewidth specimen may actually require less energy for rupture than one of standard width.

X1.3.2 In studies of such effects where the size of the material precludes the use of the standard specimen, as for example when the material is 6.35-mm (0.25-in.) plate, subsize specimens are necessarily used. Such specimens (Fig. 4) are based on the Type A specimen of Fig. 6.

X1.3.3 General correlation between the energy values obtained with specimens of different size or shape is not feasible, but limited correlations may be established for specification purposes on the basis of special studies of particular materials and particular specimens. On the other hand, in a study of the relative effect of process variations, evaluation by use of some arbitrarily selected specimen with some chosen notch will in most instances place the methods in their proper order.

X1.4 Temperature Effect

X1.4.1 The testing conditions also affect the notch behavior. So pronounced is the effect of temperature on the behavior of steel when notched that comparisons are frequently made by examining specimen fractures and by plotting energy value and fracture appearance versus temperature from tests of notched bars at a series of temperatures. When the test temperature has been carried low enough to start cleavage fracture, there may be an extremely sharp drop in impact value or there may be a relatively gradual falling off toward the lower temperatures. This drop in energy value starts when a specimen begins to exhibit some crystalline appearance in the fracture. The transition temperature at which this embrittling effect takes place varies considerably with the size of the part or test specimen and with the notch geometry.

X1.5 Testing Machine

X1.5.1 The testing machine itself must be sufficiently rigid or tests on high-strength low-energy materials will result in excessive elastic energy losses either upward through the pendulum shaft or downward through the base of the machine. If the anvil supports, the pendulum striking edge, or the machine foundation bolts are not securely fastened, tests on ductile materials in the range from 108 J (80 ft·lbf) may actually indicate values in excess of 122 to 136 J (90 to 100 ft·lbf)

X1.5.2 A problem peculiar to Charpy-type tests occurs when high-strength, low-energy specimens are tested at low temperatures. These specimens may not leave the machine in the direction of the pendulum swing but rather in a sidewise direction. To ensure that the broken halves of the specimens do not rebound off some component of the machine and contact the pendulum before it completes its swing, modifications may be necessary in older model machines. These modifications differ with machine design. Nevertheless the basic problem is the same in that provisions must be made to prevent rebounding of the fractured specimens into any part of the swinging pendulum. Where design permits, the broken specimens may be deflected out of the sides of the machine and yet in other designs it may be necessary to contain the broken specimens within a certain area until the pendulum passes through the anvils. Some low-energy high-strength steel specimens leave impact machines at speeds in excess of 15.2 m/s (50 ft/s) although they were struck by a pendulum traveling at speeds approximately 5.2 m/s (17 ft/s). If the force exerted on the pendulum by the broken specimens is sufficient, the pendulum will slow down and erroneously high energy values will be recorded. This problem accounts for many of the inconsistencies in Charpy results reported by various investigators within the 14 to 34-J (10 to 25-ft·lb) range. Figure 1 illustrates a modification found to be satisfactory in minimizing jamming.

X1.6 Velocity of Straining

X1.6.1 Velocity of straining is likewise a variable that affects the notch behavior of steel. The impact test shows somewhat higher energy absorption values than the static tests above the transition temperature and yet, in some instances, the reverse is true below the transition temperature.

X1.7 Correlation with Service

X1.7.1 While Charpy or Izod tests may not directly predict the ductile or brittle behavior of steel as commonly used in large masses or as components of large structures, these tests can be used as acceptance tests or tests of identity for different lots of the same steel or in choosing between different steels, when correlation with reliable service behavior has been established. It may be necessary to make the tests at properly chosen temperatures other than room temperature. In this, the service temperature or the transition temperature of full-scale specimens does not give the desired transition temperatures for Charpy or Izod tests since the size and notch geometry may be so different. Chemical analysis, tension, and hardness tests may not indicate the influence of some of the important processing factors that affect susceptibility to brittle fracture nor do they comprehend the effect of low temperatures in inducing brittle behavior.

[8] N. H. Fahey, "Effects of Variables in Charpy Impact Testing," *Materials Research & Standards*, Vol 1, No. 11, November 1961, p. 872.

X2. SUGGESTED METHODS OF MEASUREMENT

X2.1 *Position of the Center of Strike Relative to the Center of Gravity:*

X2.1.1 Since the center of strike can only be marked on an assembled machine, only the methods applicable to an assembled machine are described as follows:

X2.1.1.1 The fundamental fact on which all the methods are based is that when the friction forces are negligible, the center of gravity is vertically below the axis of rotation of a pendulum supported by the bearings only, (herein referred to as a free hanging pendulum). Paragraph 5.1.4 limits the friction forces in impact machines to a negligible value. The required measurements may be made using specialized instruments such as transits, clinometers, or cathometers. However, simple instruments have been used as described in the following to make measurements of sufficient accuracy.

X2.1.1.2 Suspend a plumb bob from the frame. The plumb line should appear visually to be in the plane of swing of the striking edge.

X2.1.1.3 Place a massive object on the base close to the latch side of the tup. Adjust the position of this object so that when back lighted, a minimal gap is visable between it and the tup when the pendulum is free hanging.

X2.1.1.4 With a scale or depth gage pressed lightly against the striking edge at the center of strike, measure the horizontal distance between the plumb line and striking edge. (The dimension B in Fig. X2.1.)

X2.1.1.5 Similarly, measure the distance in a horizontal plane through the axis of rotation from the plumb line to the clamp block or enlarged end of the pendulum stem. (Dimension A in Fig. X2.1.)

X2.1.1.6 Use a depth gage to measure the radial distance from the surface contacted in measuring A to a machined surface of the shaft which connects the pendulum to the bearings in the machine frame. (Dimension C in Fig. X2.1.)

X2.1.1.7 Use an outside caliper or micrometer to measure the diameter of the shaft at the same location contacted in measuring C. (Dimension D in Fig. X2.1.)

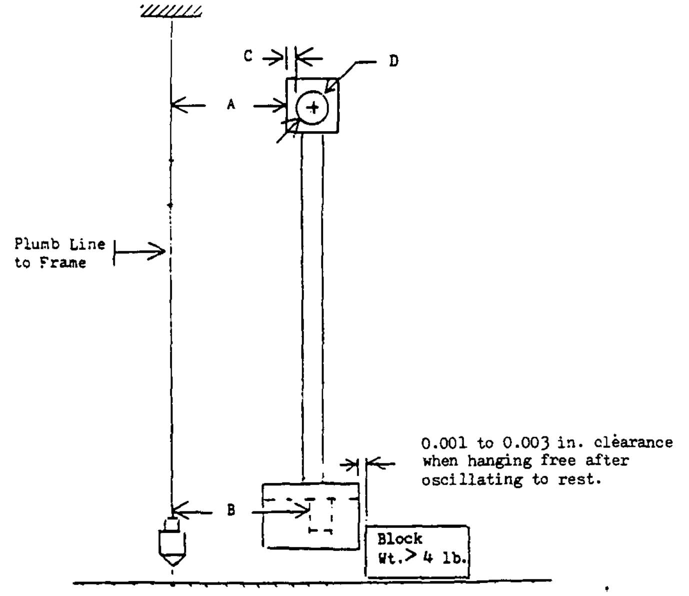

FIG. X2.1 Measurement of Deviation of Center of Strike from Vertical Plane through Axis of Rotation when Pendulum is Hanging Free

X2.1.1.8 Substitute the measured dimensions in the equation

$$X = A + C + D/2 - B$$

where:

X = deviation of the center of strike from a line from the center of rotation through the center of gravity.

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