



Standard Test Methods for Notched Bar Impact Testing of Metallic Materials¹

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 Methods²
- E 399 Test Method for Plane-Strain Fracture Toughness of Metallic Materials³
- E 604 Test Method for Dynamic Tear Testing of Metallic Materials³
- E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method²
- E 1271 Practice for Qualifying Charpy Verification Specimens of Heat-Treated Steel³

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

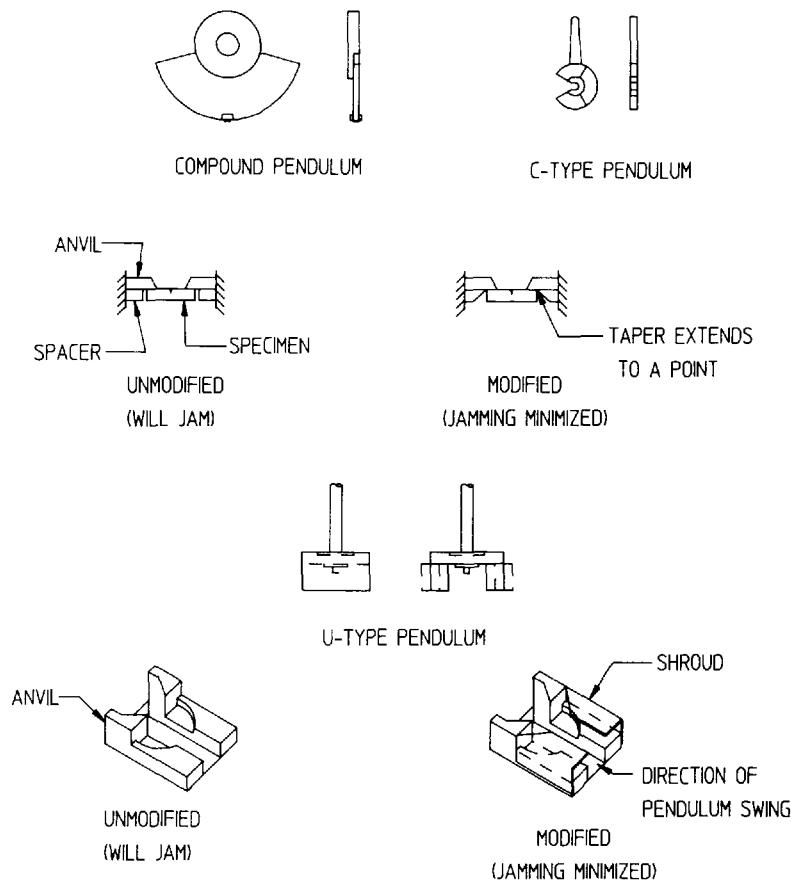


FIG. 1 Typical Pendulums and Anvils for Charpy Machines, Shown with Modifications to Minimize Jamming

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.

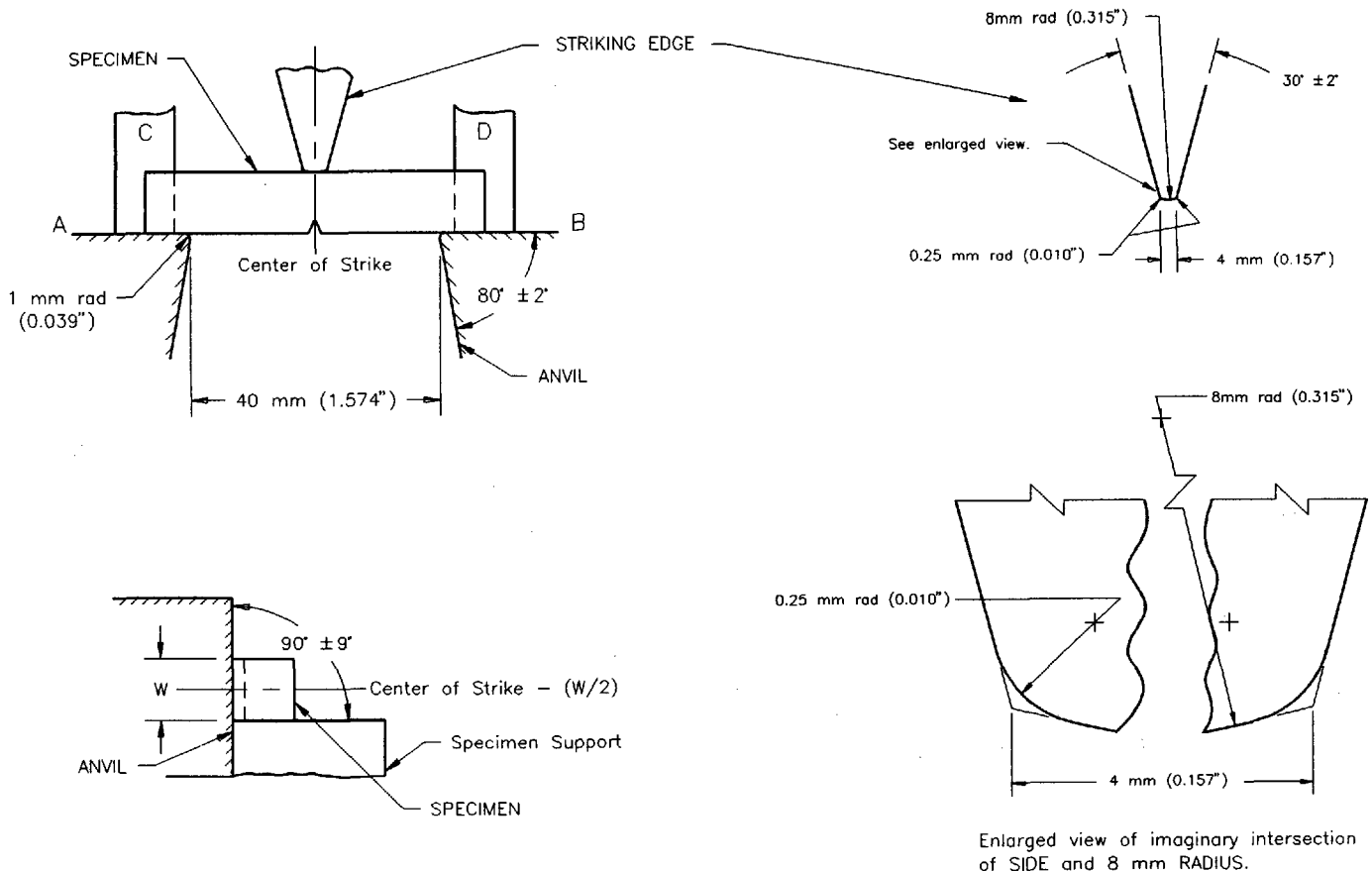
5.2 Specimen Clearance—To ensure satisfactory results when testing materials of different strengths and compositions, the test specimen shall be free to leave the machine

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



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

FIG. 2 Charpy Striking Tup

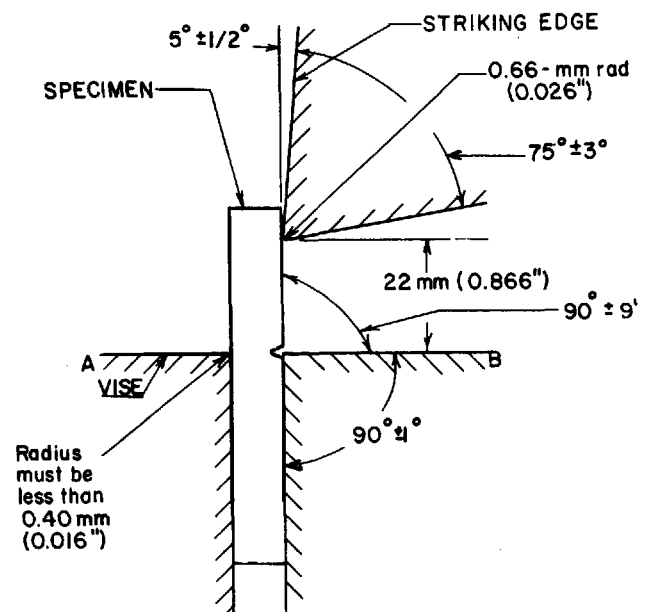
0.25 mm (0.010 in.) of the midpoint between the anvils (see 12.2.1.2).

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 $90 \pm 1^\circ$ with radii less than 0.40 mm (0.016 in.). The clamping surfaces shall be smooth with a 2- μ m (63- μ in.) 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 cylindrical 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 μ m (63 μ in.).

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:

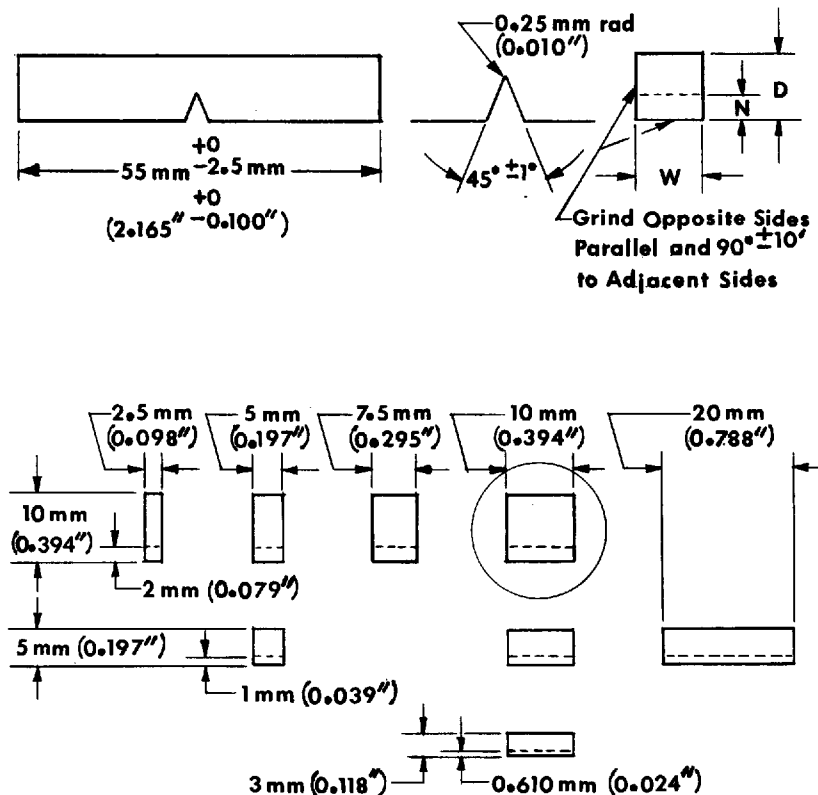
6.2.1 *Pendulum Release Mechanism*—The mechanism for releasing the pendulum from its initial position shall comply with 5.1.8.

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)

$$S = L(1 - \cos \beta) \text{ or } h_1 = L(1 - \cos \alpha)$$

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:

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

where:

v = velocity, m/s (or ft/s),

g = acceleration of gravity, 9.81 m/s² (32.2 ft/s²), 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/s² (ft/s²),
 π = 3.1416, and

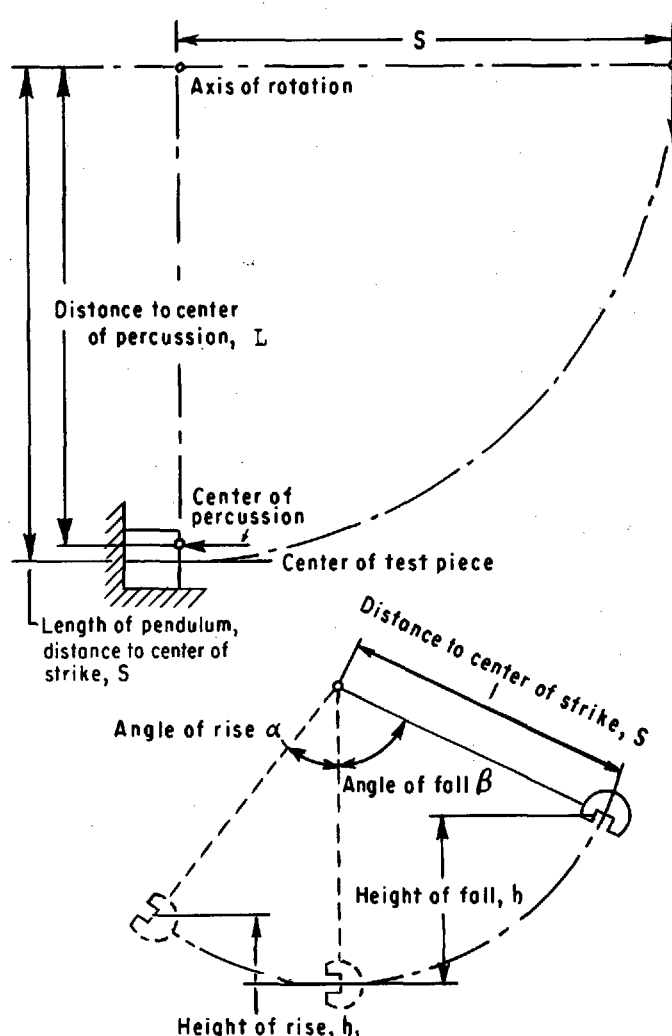


FIG. 5 Dimensions for Calculations

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 friction 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; there-

fore, 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.