This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

Designation: E23 – 23a

An American National Standard

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

This standard is issued under the fixed designation E23; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

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

## 1. Scope*

1.1 These test methods describe notched-bar impact testing of metallic materials by the Charpy (simple-beam) test and the Izod (cantilever-beam) test. They give the requirements for: test specimens, test procedures, test reports, test machines (see Annex A1) verifying Charpy impact machines (see Annex A2), optional test specimen configurations (see Annex A3), designation of test specimen orientation (see Terminology E1823), and determining the shear fracture appearance (see Annex A4). In addition, information is provided on the significance of notched-bar impact testing (see Appendix X1), and methods of measuring the center of strike (see Appendix X2).

1.2 These test methods do not address the problems associated with impact testing at temperatures below –196 °C (77 K).

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3.1 *Exception*—Section 9 and Annex A4 provide inch-pound units for information only.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 6.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

B925 Practices for Production and Preparation of Powder Metallurgy (PM) Test Specimens

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

E1823 Terminology Relating to Fatigue and Fracture Testing

E2298 Test Method for Instrumented Impact Testing of Metallic Materials

## 3. Terminology

3.1 *Definitions of Terms Common to Mechanical Testing:*

3.1.1 *drop height, h,* [L], *n*—the center of strike vertical distance between the free-hanging position and the latched position.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *absorbed energy,* [FL], *n*—work spent to fracture a specimen in a single pendulum swing, as measured by a compensated indicating device.

3.2.2 *direct verification, n*—process that ensures all parts that may affect measured absorbed energy are within specified dimensional tolerances.

3.2.3 *free-hanging position, n*—position of the pendulum after oscillation stops such that the potential and kinetic energy is zero.

3.2.4 *free swing, n*—uninterrupted (without a test specimen) pendulum swing from the latched position as recorded by the indicating device (see A2.3.8.1).

3.2.5 *indirect verification, n*—process that ensures the average absorbed energy from testing a set of verification specimens corresponds to the certified absorbed energy within a specified tolerance (see A2.4.1).

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

Current edition approved March 1, 2023. Published April 2023. Originally approved in 1933. Last previous edition approved 2023 as E23 – 23. DOI: 10.1520/E0023-23A.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

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

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3.2.6 *latched position, n*—position of the pendulum on the release mechanism prior to being released to perform a test.

3.2.7 *lateral expansion* [L], *n*—the maximum increase in the thickness of the specimen as a result of the impact test, expressed in mm.

3.2.7.1 *Discussion*—Lateral expansion is used as a measure of ductility.

3.2.8 *range capacity, n*—maximum available energy for a specific pendulum setting.

3.2.8.1 *Discussion*—On single range machines this corresponds to the machine capacity.

3.2.9 *shear fracture appearance, SFA, n*—the amount of fracture surface in the specimen that failed in a shear (stable) mode, expressed in percent.

## 4. Summary of Test Method

4.1 The essential features of an impact test are: a suitable specimen (specimens of several different types are recognized), a set of anvils, and specimen supports on which the test specimen is placed to receive the blow of the moving mass, a moving mass that has sufficient energy to break the specimen placed in its path, and an indicating device for measuring the absorbed energy of the broken specimen.

## 5. Significance and Use

5.1 These test methods of impact testing relate specifically to the behavior of metal when subjected to a single application of a force resulting in multi-axial 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 the results of impact tests on notched specimens, when correlated with service experience, have been found to predict the likelihood of brittle fracture accurately. Further information on significance appears in Appendix X1.

## 6. Precautions in Operation of Machine

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

## 7. Apparatus

7.1 *General Requirements:*

7.1.1 The testing machine shall be a pendulum type of rigid construction.

7.1.2 The testing machine shall be designed and built to conform with the requirements given in Annex A1.

7.2 *Inspection and Verification:*

7.2.1 Procedures for direct verification of impact machines are provided in A2.2 and A2.3. The items listed in A2.2 require direct verification annually.

7.2.2 Procedures for indirect verification of Charpy machines, using verification specimens, are given in A2.4. Charpy impact machines require direct and indirect verification annually.

## 8. Test Specimens

8.1 *Configuration and Orientation:*

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

8.1.2 The specimens shown in Fig. 1 and Fig. 2 are those most widely used and most generally satisfactory. They are particularly suitable for ferrous metals, excepting cast iron.[3] The Charpy specimen designations are V-notch and U-notch.

NOTE 1—Keyhole notch specimen is similar to U-notch, except the notch width is 1.6 mm or less.

8.1.3 The specimens commonly found suitable for powder metallurgy materials is shown in Fig. 3. Powder metallurgy impact test specimens shall be produced following the procedure in Practices B925. The impact test results of these materials are 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. For powder metallurgy materials the impact test results are reported as unnotched absorbed energy.

8.1.4 Sub-size and supplementary specimen recommendations are given in Annex A3.

8.2 *Specimen Machining:*

8.2.1 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 the impact properties of specimens machined before heat treatment are identical to those machined after heat treatment.

8.2.2 Notches shall be smoothly machined, but polishing has proven generally unnecessary.

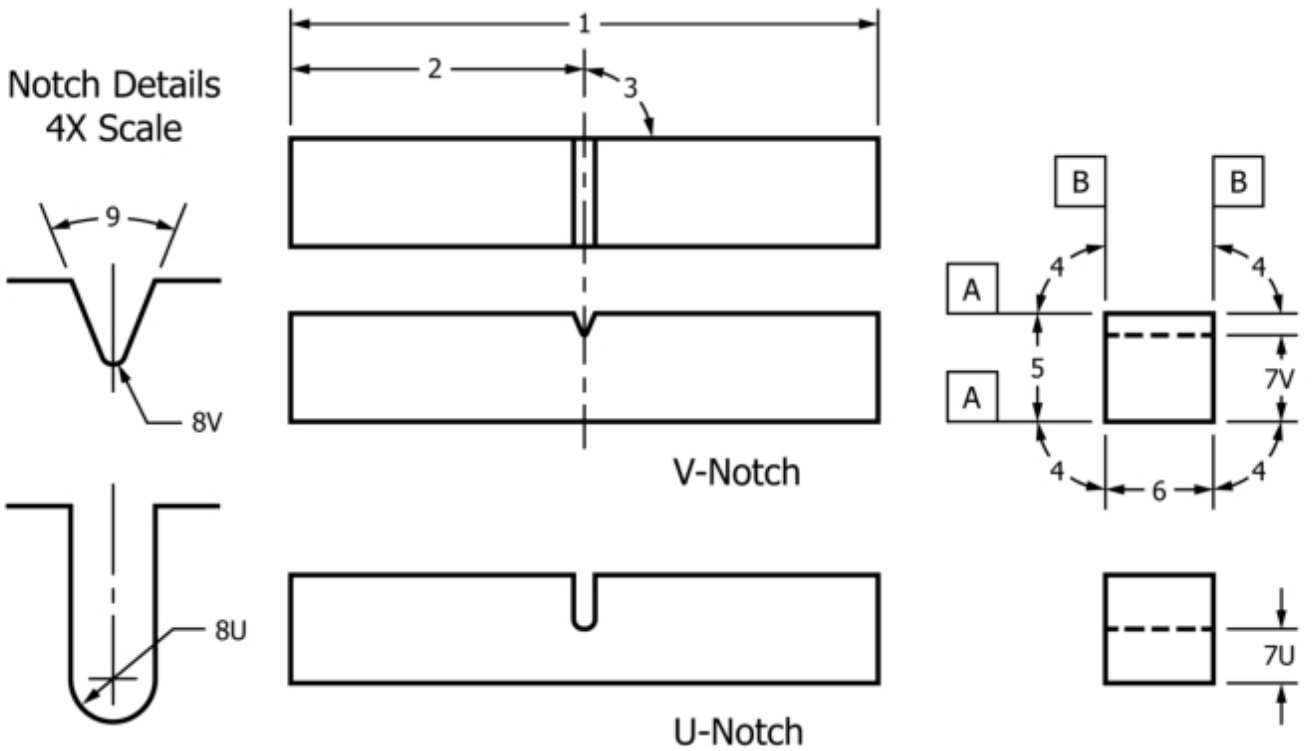
NOTE 2—Variations in notch dimensions will affect the results of the tests. Appendix X1.2 illustrates the effects from varying notch dimensions on V-notch specimens.

NOTE 3—In keyhole notch specimens, carefully drill the round hole with a slow feed rate. Exercise care in cutting the slot to ensure that the surface of the drilled hole opposite the slot is not damaged.

8.2.3 Identification marks shall only be placed in the following locations on specimens: either of the 10 mm square ends; the side of the specimen that faces up when the specimen is positioned in the anvils (see Note 4); or the side of the specimen opposite the notch. No markings, on any side of the specimen, shall be within 10 mm of the center line of the notch. Permanent markers, laser engraving, scribes, electrostatic pencils, and other reasonable marking methods may be used for identification purposes. However, some marking methods can result in damage to the specimens if not used correctly. For example, excessive heat from electrostatic pencils or deformation to the specimen from stamping can change the mechanical properties of the specimen. Therefore, care shall always be taken to avoid damage to the specimen. Stamping and other marking processes that result in deformation of the specimen should only be used on the ends of the specimens, prior to notching.

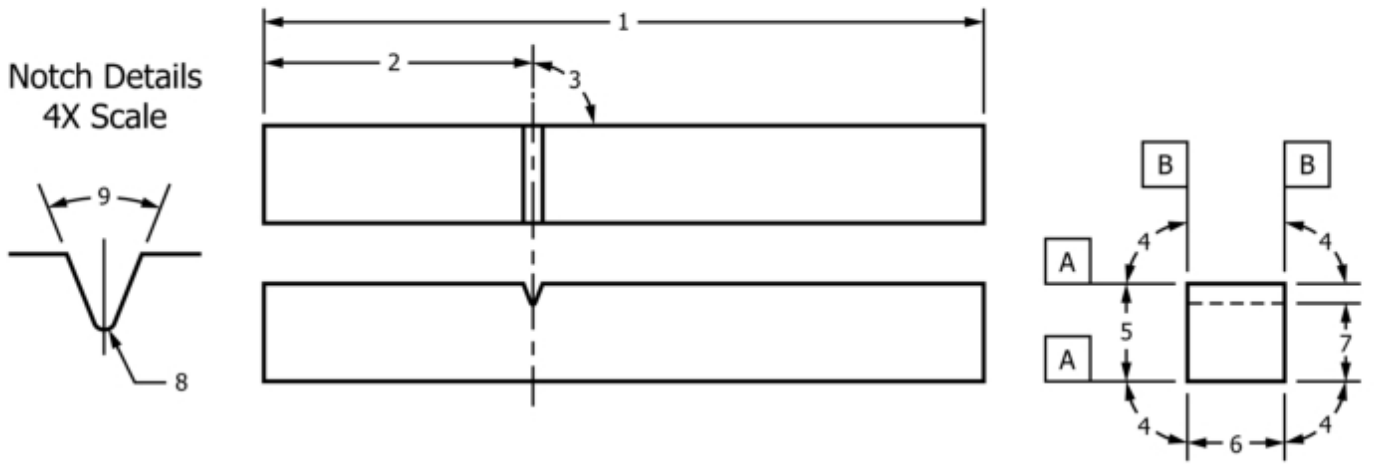
NOTE 4—Careful consideration should be given before placing identification marks on the side of the specimen to be placed up when positioned in the anvils. If the test operator is not careful, the specimen can be placed in the machine with the identification marking resting on the specimen

[3] Report of Subcommittee XV on Impact Testing of Committee A03 on Cast Iron, Proceedings, ASTM, Vol 33 Part 1, 1933.




| ID Number | Description | Dimension | Tolerance |
|---|---|---|---|
| 1 | Length of specimen | 55 mm | +0/-2.5 mm |
| 2 | Centering of notch | | ±1 mm |
| 3 | Notch length to edge | 90° | ±2° |
| 4 | Adjacent sides angle | 90° | ±0.17° |
| 5 | Width | 10 mm | ±0.075 mm |
| 6 | Thickness | 10 mm | ±0.075 mm |
| 7V | Ligament length, Type V | 8 mm | ±0.025 mm |
| 7U | Ligament length, Type U | 5 mm | ±0.075 mm |
| 8V | Radius of notch, Type V | 0.25 mm | ±0.025 mm |
| 8U | Radius of notch, Type U | 1 mm | ±0.025 mm |
| 9 | Angle of notch | 45° | ±1° |
| A | Surface finish requirements | 2 µm (Ra) | ≤ |
| B | Surface finish requirements | 4 µm (Ra) | ≤ |

**FIG. 1 Charpy (Simple-Beam) Impact Test Specimens, V-Notch and U-Notch**




| ID Number | Description | Dimension | Tolerance |
|---|---|---|---|
| 1 | Length of specimen | 75 mm | +0/-2.5 mm |
| 2 | Notch to top | 28 mm | |
| 3 | Notch length to edge | 90° | ±2° |
| 4 | Adjacent sides angle | 90° | ±0.17° |
| 5 | Width | 10 mm | ±0.025 mm |
| 6 | Thickness | 10 mm | ±0.025 mm |
| 7 | Ligament length | 8 mm | ±0.025 mm |
| 8 | Radius of notch | 0.25 mm | ±0.025 mm |
| 9 | Angle of notch | 45° | ±1° |
| A | Surface finish requirement | 2 µm (Ra) | ≤ |
| B | Surface finish requirement | 4 µm (Ra) | ≤ |

**FIG. 2 Izod (Cantilever-Beam) Impact Test Specimen**

9.2 *Test Temperature Considerations:*

9.2.1 The temperature of testing affects the impact properties of most materials. For materials with a body centered cubic structure, a transition in fracture mode occurs over a temperature range that depends on the chemical composition and microstructure of the material. Test temperatures may be chosen to characterize material behavior at fixed values, or over a range of temperatures to characterize the transition region, lower shelf, or upper shelf behavior, or all of these. The choice of test temperature is the responsibility of the user of this test method and will depend on the specific application. For tests performed at room temperature, the temperature should be 20 °C ± 5 °C.

9.2.2 The temperature of a specimen can change significantly during the interval it is removed from the temperature conditioning environment, transferred to the impact machine, and the fracture event is completed (see Note 9). When using a heating or cooling medium near its boiling point, use data from the references in Note 9 or calibration data with thermocouples to confirm that the specimen is within the stated temperature tolerances when the striker contacts the specimen. If excessive adiabatic heating is expected, monitor the specimen temperature near the notch during fracture.

9.2.3 Verify temperature-measuring equipment at least every six months. If liquid-in-glass thermometers are used, an initial verification shall be sufficient, however, the device shall be inspected for problems, such as the separation of liquid, at least every six months.

9.2.4 Hold the specimen at the desired temperature within ±1 °C (±2 °F) in the temperature conditioning environment. Any method of heating or cooling or transferring the specimen to the anvils may be used provided the temperature of the specimen immediately prior to fracture is essentially the same as the holding temperature (see Note 9). The maximum change in the temperature of the specimen allowed for the interval between the temperature conditioning treatment and impact is not specified here, because it is dependent on the material being tested and the application. The user of nontraditional or lesser used temperature conditioning and transfer methods (or specimen sizes) shall show that the temperature change for the specimen prior to impact is comparable to or less than the temperature change for a standard size specimen of the same material that has been thermally conditioned in a commonly used medium (oil, air, nitrogen, acetone, methanol), and transferred for impact within 5 s (see Note 9). Three temperature conditioning and transfer methods used in the past are: liquid bath thermal conditioning and transfer to the specimen supports with centering tongs; furnace thermal conditioning and robotic transfer to the specimen supports; placement of the specimen on the supports followed by in situ heating and cooling.

9.2.4.1 For liquid bath cooling or heating use a suitable container, which has a grid or another type of specimen positioning fixture. Cover the specimens, when immersed, with at least 25 mm (1 in.) of the liquid, and position so that the notch area is not closer than 25 mm to the sides or bottom of the container, and no part of the specimen is in contact with the container. Place the device used to measure the temperature of the bath in the center of a group of the specimens. Agitate the bath and hold at the desired temperature within ±1 °C (±2 °F). Thermally condition the specimens for at least 5 min before testing, unless a shorter thermal conditioning time can be shown to be valid by measurements with thermocouples. Leave the device (tongs, for example) used to handle the specimens in the bath for at least 5 min before testing, and return the device to the bath between tests.

9.2.4.2 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 device used to remove the specimen from the medium in the medium except when handling the specimens.

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

NOTE 8—For testing at temperatures down to –196 °C (77 °K), standard testing procedures have been found to be adequate for most metals.

NOTE 9—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 specimen supports.[4] Other studies, using cooling media that are above their boiling points at room temperature have also shown large changes in specimen temperature during the transfer of specimens to the machine anvils. In addition, some materials change temperature dramatically during impact testing at cryogenic temperatures due to adiabatic heating.[5]

9.3 *Charpy Test Procedure:*

9.3.1 The Charpy test procedure may be summarized as follows: the test specimen is thermally conditioned and positioned on the specimen supports against the anvils; the pendulum is released without vibration, and the specimen is impacted by the striker. Information is obtained from the machine and from the broken specimen.

9.3.1.1 The 8 mm striker shall be used, unless the 2 mm striker is specified.

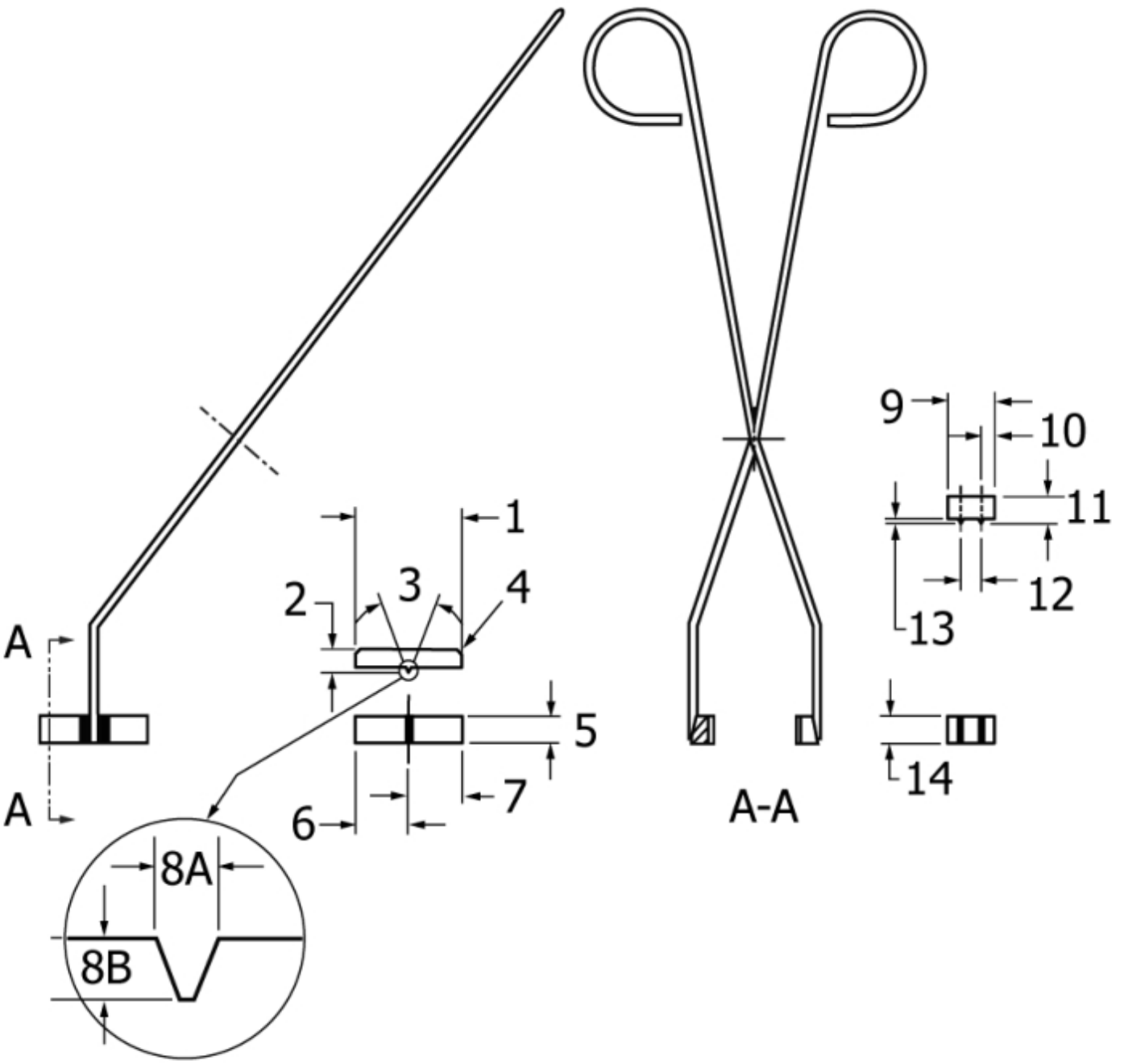
NOTE 10—For some materials, the striker radius can significantly affect the results.

9.3.2 To position a test specimen in the machine, self-centering tongs similar to those shown in Fig. 4 should be used (see A1.10.1). The tongs illustrated in Fig. 4 are for centering V-notch specimens. If non V-notch specimens are used, modification of the tong design may be necessary. If an end-centering device is used, caution shall be taken to ensure that low-energy high-strength specimens will not rebound off this device into the pendulum and cause erroneously high recorded absorbed energy values. Many such devices are permanent fixtures of machines, and if the clearance between the end of a specimen in the test position and the centering device is not approximately 13 mm, the broken specimens may rebound into the pendulum.

9.3.3 To conduct the test, prepare the machine by raising the pendulum to the latched position, prepare the indicating device (set the analog scale pointer at the range capacity, or initialize the digital display, or both), position the specimen on the specimen supports against the anvils, and release the pendulum. If a liquid bath or gas medium is being used for thermal

[4] 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*, ASTM, 1990, pp. 195-210.

[5] Tobler R. L. Et al.," Charpy Impact Tests Near Absolute Zero," *Journal of Testing and Evaluation*, Vol 19, 1 1992.




| ID Number | Designation | Dimension, mm | ID Number | Designation | Dimension, mm |
|---|---|---|---|---|---|
| 1 | Support (notch side) length | 39.93 + 0 −0.051 | 8B | 10 mm specimen width | 1.52 to 1.65 |
| | | | | 5 mm specimen width | 0.69 to 0.81 |
| | | | | 3 mm specimen width | 0.36 to 0.48 |
| 2 | Support (notch side) height | 7.94 ± 1 | 9 | Solder pad length | 17.46 ± 1 |
| 3 | Insert angle | 44.5 ± 0.5° | 10 | Solder pad extension | 4.76 ± 1 |
| 4 | Radius on support | 2 ± 1 | 11 | Solder pad height | 9.5 ± 1 |
| 5 | Support width | 9.5 ± 1 | 12 | rod | 7.94 ± 1 |
| 6 | Notch center | 19.96 | 13 | | 1.588 ± 1 |
| 7 | Notch center | 19.96 | 14 | Solder pad width | 9.5 ± 1 |
| 8A | 10 mm specimen width | 1.60 to 1.70 | | | |
| | 5 mm specimen width | 0.74 to 0.80 | | | |
| | 3 mm specimen width | 0.45 to 0.51 | | | |

**FIG. 4 Centering Tongs for V-Notch Charpy Specimens**

conditioning, perform the following sequence in less than 5 s (for 10 mm × 10 mm × 55 mm specimens, see 9.2.4). Remove the test specimen from its cooling (or heating) medium with centering tongs that have been temperature conditioned with the test specimen, place the specimen in the test position, and release the pendulum smoothly. If a test specimen has been removed from the temperature conditioning bath and it is questionable that the test can be conducted within the 5 s time frame, return the specimen to the bath for the time required in 9.2 before testing.

9.3.3.1 If a fractured impact specimen does not separate into two pieces, report it as unbroken (see 10.2.2 for separation instructions). Unbroken specimens with absorbed energies of less than 80 % of the range capacity may be averaged with

values from broken specimens. If the absorbed energy exceeds 80 % of the range capacity and the specimen passes completely between the anvils, report the value as approximate (see Note 11) and do not average it with other values. If an unbroken specimen does not pass between the machine anvils, (for example, it stops the pendulum), the result shall be reported as exceeding the range capacity. A specimen shall never be struck more than once.

NOTE 11—Absorbed energy values above 80 % of the range capacity are inaccurate. 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 absorbed energies approaching 80 % of the range capacity, the velocity of the pendulum decreases (to about 45 % of the initial velocity) during fracture to the point that accurate absorbed energies are no longer obtained.

9.3.3.2 If a specimen jams in the machine, disregard the results and check the machine thoroughly for damage or misalignment, which would affect its direct verification, indirect verification, or both.

9.3.3.3 To prevent recording an erroneous indicated value, caused by jarring the analog scale pointer when locking the pendulum in its latched position, read the value for each test from the analog scale prior to locking the pendulum for the next test.

9.4 *Izod Test Procedure:*

9.4.1 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:

9.4.2 Testing at temperatures other than room temperature is difficult because the specimen-holding fixture for Izod specimens is often part of the base of the machine and cannot be readily cooled (or heated). Consequently, Izod testing should be performed at room temperature.

9.4.3 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. Prepare the indicating device (set the analog scale pointer at the range capacity or initialize the digital display, or both) and release the pendulum smoothly. Sections 9.3.3.1 – 9.3.3.3, also apply when testing Izod specimens.

## 10. Information Obtainable from Impact Tests

10.1 *The absorbed energy* shall be taken as 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. This absorbed energy value is determined by the indicating device which has been corrected for total frictional losses.

10.2 *Lateral expansion measurement* methods shall 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. Therefore, the expansion on each side of each specimen half shall be measured relative to the plane defined by the undeformed portion on the side of the specimen, as shown in Fig. 5. For example, if $A_1$ is greater than $A_2$, and $A_3$ is less than $A_4$, then the lateral expansion is the sum of $A_1 + A_4$.

10.2.1 Before making any lateral expansion measurements, it is essential that the two specimen halves are visually examined for burrs that may have formed during impact testing; if the burrs will influence the lateral expansion measurements, they shall be removed (by rubbing on emery cloth or any other suitable method), making sure that the protrusions to be measured are not rubbed during the removal of the burr. Then, examine each fracture surface to ascertain that the protrusions have not been damaged by contacting an

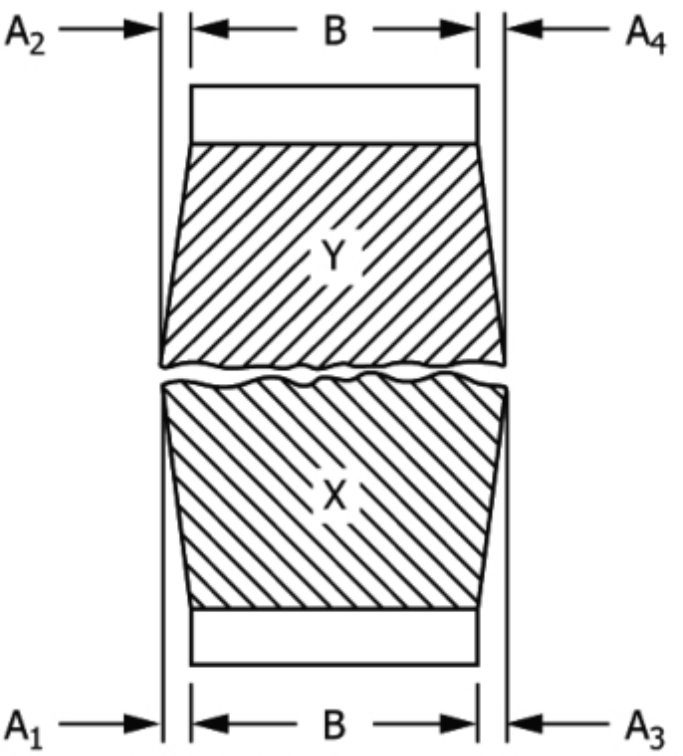



**FIG. 5 Halves of Broken Charpy V-Notch Impact Specimen Illustrating the Measurement of Lateral Expansion, Dimensions $A_1$, $A_2$, $A_3$, $A_4$ and Original Thickness, Dimension B**

anvil, a machine mounting surface, etc. Lateral expansion shall not be measured on a specimen with this type of damage.

10.2.2 Lateral expansion measurements shall be reported as follows. An unbroken specimen can be reported as broken if the specimen can be separated by pushing the hinged halves together once and then pulling them apart without further fatiguing the specimen, and the lateral expansion measured for the unbroken specimen (prior to bending) is equal to or greater than that measured for the separated halves. In the case where a specimen cannot be separated into two halves, the lateral expansion can be measured as long as the shear lips can be accessed without interference from the hinged ligament that has been deformed during testing. The specimen shall be reported as unbroken.

10.2.3 Lateral expansion may be measured easily by using a gauge like the one shown in Fig. 6 (assembly and details shown in Fig. 7). Using this type of gauge the measurement is made with the following procedure: orient the specimen halves so that the compression sides are facing each other, take one half of the fractured specimen and press it against the anvil and indicator plunger and record the reading, make a similar measurement on the other half (same side) of the fractured specimen and disregard the lower of the two values, do the same for the other side of the fractured specimen, report the sum of the maximum expansions for the 2 sides as the lateral expansion for the specimen.

10.3 *The shear fracture appearance* may be determined using a variety of methods. The approach and the acceptable methods are defined in Annex A4. For each method, the user shall distinguish between regions formed by stable crack growth mechanisms, and regions formed by unstable crack growth mechanisms. For purposes of this Test Method, the "shear area" consists of those portions of the fracture surface that form by stable crack growth (Fracture Initiation Region, Shear Lips, and Final Fracture Region), as shown in Fig. 8.

The shear fracture appearance is typically calculated as the difference between the total fractured area (Fracture Initiation Region, Shear Lips, Unstable Fracture Region, and Final Fracture Region) and the area of unstable fracture region, divided by the total fractured area, times 100. The measurement methods described in Annex A4 provide estimates for the area of the unstable fracture region (directly or indirectly), but do not consider details of the fracture mode for the unstable region. The unstable fracture region could be 100 % cleavage, a mixture of cleavage and ductile-dimple fracture morphologies, a mixture of intergranular and ductile-dimple fracture morphologies, or a mixture of other fracture morphologies.

NOTE 12—Carbon steels often exhibit a classic cleavage region that identifies the unstable fracture region with a well-defined area of shiny fracture that is easy to recognize and measure. Other steels, such as quenched and tempered SAE 4340, alloys have a region of unstable fracture that consists of an intimate mixture of cleavage facets and ductile dimples (only apparent at high magnifications). Some embrittled steels can exhibit partially intergranular fracture, as well. In these cases the area of unstable fracture may not be as easy to identify.

## 11. Test Report and Test Records

11.1 The test report shall include the following information (for each specimen tested):

11.1.1 Conformance to Test Method E23-YR (where YR is edition year),

11.1.2 Specimen type, per Fig. 1 or any other applicable figure in this test method. Any deviations shall be reported.

11.1.3 Specimen size (if sub-size specimen),

11.1.4 Test temperature (if room temperature, report actual temperature),

11.1.5 For Charpy testing specify the striker radius as 8 mm or 2 mm,

11.1.6 Absorbed energy,

11.1.7 Unbroken specimens and whether or not they were used in the average

11.1.8 Any specimens for which the absorbed energy exceeds 80% of the range capacity, report the value as approximate or exceeding the range capacity (see 9.3.3.1), and

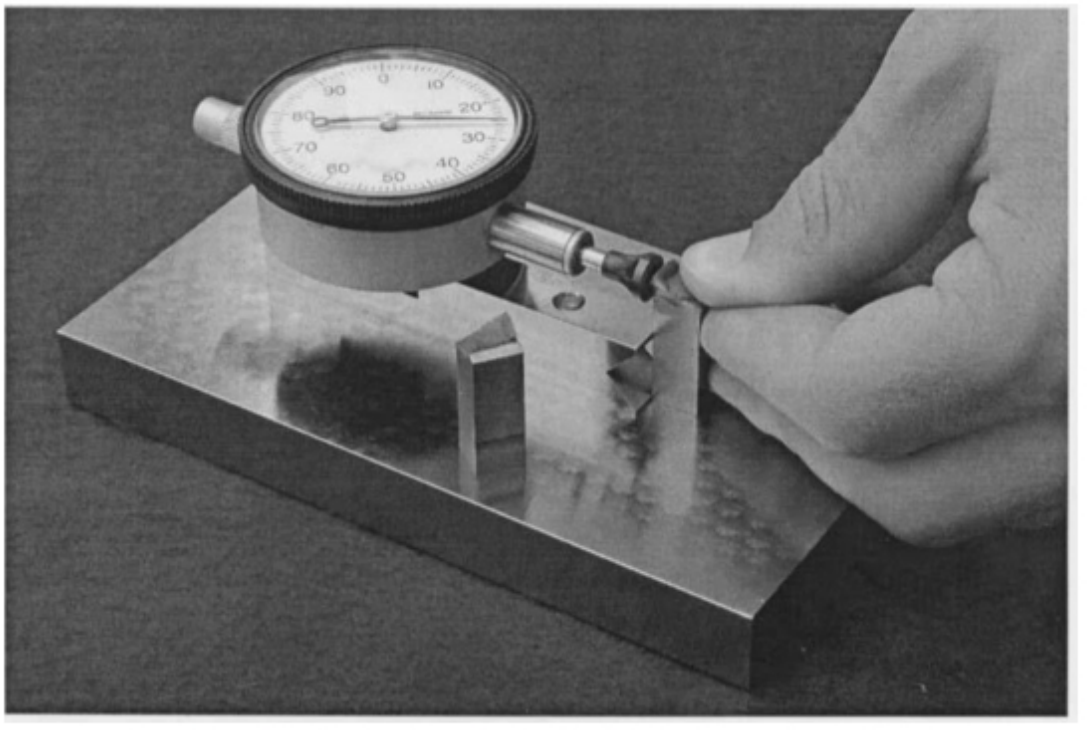
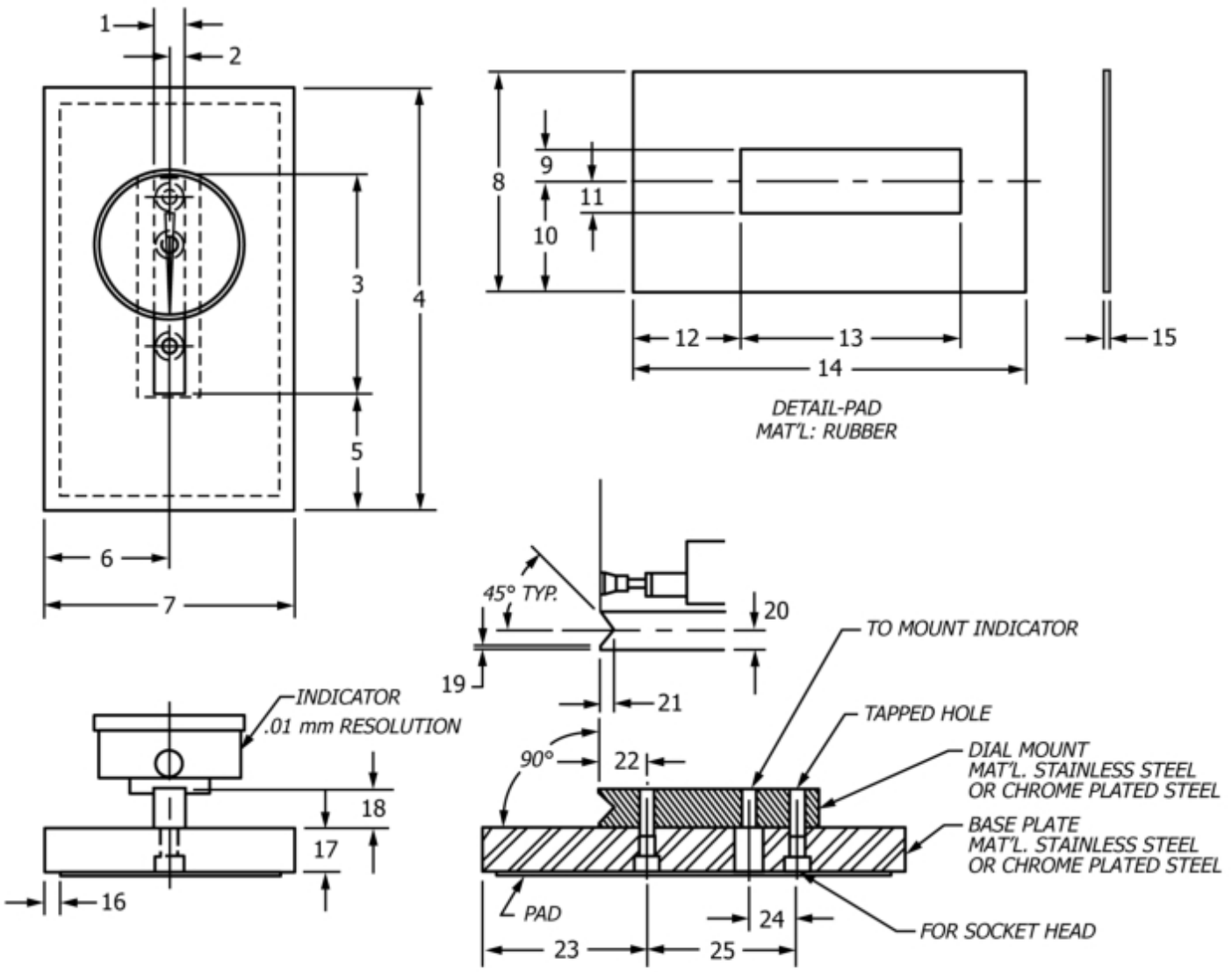


**FIG. 6 Lateral Expansion Gauge for Charpy Impact Specimens**




| ID Number | Dimension, mm | ID Number | Dimension, mm |
|---|---|---|---|
| 1 | 12.7 | 15 | 1.6 |
| 2 | 6.4 | 16 | 6.4 |
| 3 | 88.9 | 17 | 17.5 |
| 4 | 171.5 | 18 | 15.9 |
| 5 | 47.6 | 19 | 1.7 |
| 6 | 50.8 | 20 | 8.3 |
| 7 | 101.6 | 21 | 6.1 |
| 8 | 88.9 | 22 | 19.1 |
| 9 | 12.7 | 23 | 66.7 |
| 10 | 44.5 | 24 | 19.1 |
| 11 | 12.7 | 25 | 60.3 |
| 12 | 43.2 | | |
| 13 | 88.9 | | |
| 14 | 158.8 | | |

**FIG. 7 Assembly and Details for Lateral Expansion Gauge**

11.1.9 Any other contractual requirements.

11.2 The test records should include the following information in addition to the information in 11.1:

11.2.1 Impact machine manufacturer, serial number, most recent successful direct and indirect verification dates, and verified range for Charpy testing or direct verification date and range capacity for Izod testing.

11.2.2 Lateral expansion,

11.2.3 Shear fracture appearance (See Note A4.1),

11.2.4 Specimen orientation, and

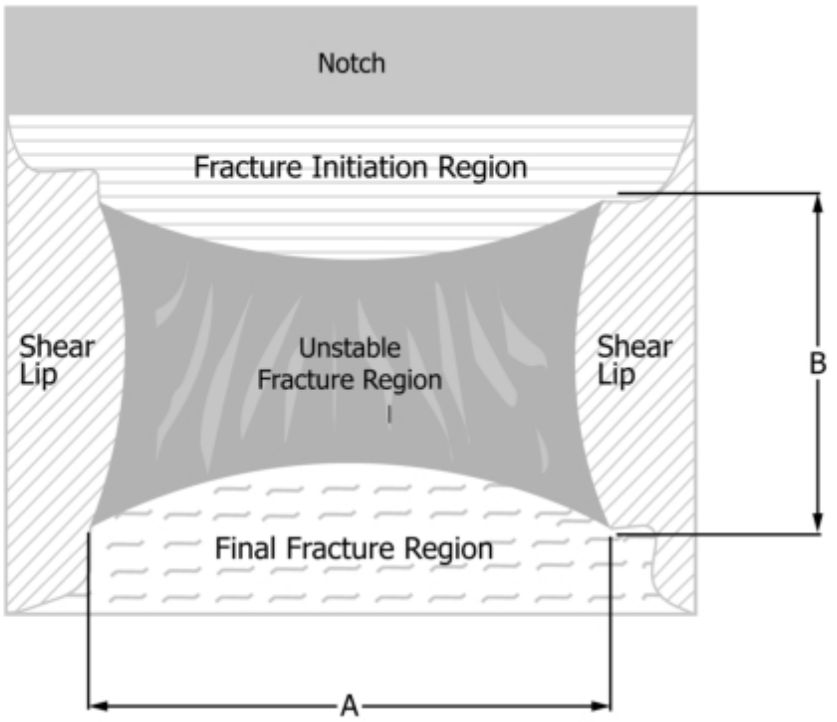
11.2.5 Specimen location.

## 12. Precision and Bias

12.1 *An Interlaboratory study* used CVN verification 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 verification specimens of each energy level. Except being limited to only two energy levels (by availability of verification specimens), Practice E691 was followed for the design and analysis of the data; the details are given in ASTM Research Report No. RR:E28-1014.[6]

12.2 *Precision—The Precision* information given below is for the average CVN absorbed energy of five test determinations at each laboratory for each material.

[6] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: RR:E28-1014.




NOTE 1—Measure average dimensions A and B to the nearest 0.5 mm. Determine the shear fracture appearance using Table A4.1 or Table A4.2.

**FIG. 8 Schematic of the Fracture Surface of a Charpy V-Notch Impact Test Specimen Showing the Various Region of Fracture**

| Material | Low-Energy J | High-Energy J |
|---|---|---|
| Absorbed Energy | 15.9 | 96.2 |
| 95 % Repeatability Limits | 2.4 | 8.3 |
| 95 % Reproducibility Limits | 2.7 | 9.2 |

The terms repeatability and reproducibility limits are used as defined in Practice E177. The respective standard deviations among test results may be obtained by dividing the above limits by 2.8.

12.3 *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 absorbed energy can be compared.

## 13. Keywords

13.1 Charpy test; shear fracture appearance; impact test; Izod test; notched specimens; pendulum machine

# ANNEXES

**(Mandatory Information)**

## A1. GENERAL REQUIREMENTS FOR IMPACT MACHINES

A1.1 *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 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.

A1.2 *An analog scale and digital display*, graduated in degrees or absorbed energy, on which readings can be estimated in increments of 0.25 % of the range capacity or less shall be furnished for the machine.

A1.2.1 The analog scales and digital displays may be compensated for total frictional losses. The error in the indicating device at any point shall not exceed 0.2 % of the range capacity or 0.4 % of the reading, whichever is larger. (See A2.3.8.)

A1.3 *The total frictional losses* of the machine during the swing in the striking direction shall not exceed 0.75 % of the range capacity, and pendulum energy loss from friction in the analog scale pointer mechanism shall not exceed 0.25 % of range capacity. See A2.3.8 for total frictional losses calculations.

A1.4 *At the free-hanging position*, the striker shall be within 2.5 mm from the test specimen. The indicating device shall read within 0.2 % of the range capacity when the striker 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 anvils or Izod vise within 3:1000.

A1.5 *Transverse play of the pendulum* at the striker shall not exceed 0.75 mm 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.

A1.6 *The impact velocity* (tangential velocity) of the pendulum at the center of strike shall not be less than 3 nor more than 6 m/s.

A1.7 *The height of the center of strike* in the latched position, above its free-hanging position, shall be within 0.4 % of the range capacity divided by the supporting force, measured as described in A2.3.5.1. If total frictional losses are compensated for by increasing the drop height, the drop height may be increased by not more than 1 %.

A1.8 *The mechanism for releasing the pendulum* from its latched position shall operate freely and permit release of the pendulum without initial impulse, retardation, or side vibration. If the same lever used to release the pendulum is also used to engage the brake, means shall be provided for preventing the brake from being accidentally engaged.

A1.9 *Specimen clearance* is needed to ensure satisfactory results when testing materials of different strengths and compositions. The test specimen shall exit the machine with a minimum of interference. Pendulums used on Charpy machines are of three basic designs, as shown in Fig. A1.1.

A1.9.1 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 or if the specimen is deflected out of the machine by some arrangement such as that shown in Fig. A1.1.

A1.9.2 When using a U-type pendulum, means shall be provided to prevent the broken specimen from rebounding against the pendulum (see Fig. A1.1). In most U-type pendulum machines, steel shrouds should be designed and installed to the following requirements: (*a*) thickness of approximately 1.5 mm, (*b*) minimum hardness of 45 HRC, (*c*) radius of less than 1.5 mm at the underside corners, and (*d*) positioned so that the clearance between them and the pendulum overhang (both top and sides) does not exceed 1.5 mm. In machines where the opening within the pendulum permits clearance between the ends of a specimen (resting on the specimen supports) and the shrouds, and this clearance is at least 13 mm, the requirements (*a*) and (*d*) need not apply.

A1.10 *Charpy Apparatus*:

A1.10.1 Means shall be provided (see Fig. A1.2) to locate and support the test specimen against two anvils in such a position that the center of the notch is located within 0.25 mm of the midpoint between the anvils (see 9.3.2).

A1.10.2 The Charpy anvils and specimen supports shall conform to the dimensions and tolerances shown in Fig. A1.2. Other dimensions of the anvils and specimen supports should be such as to minimize interference between the pendulum and broken specimens.

A1.10.3 The center line of the striker shall advance in the plane that is within 0.40 mm of the midpoint between the supporting edges of the anvils shown in Fig. A1.2 Top View. The striker shall be perpendicular to the longitudinal axis of the

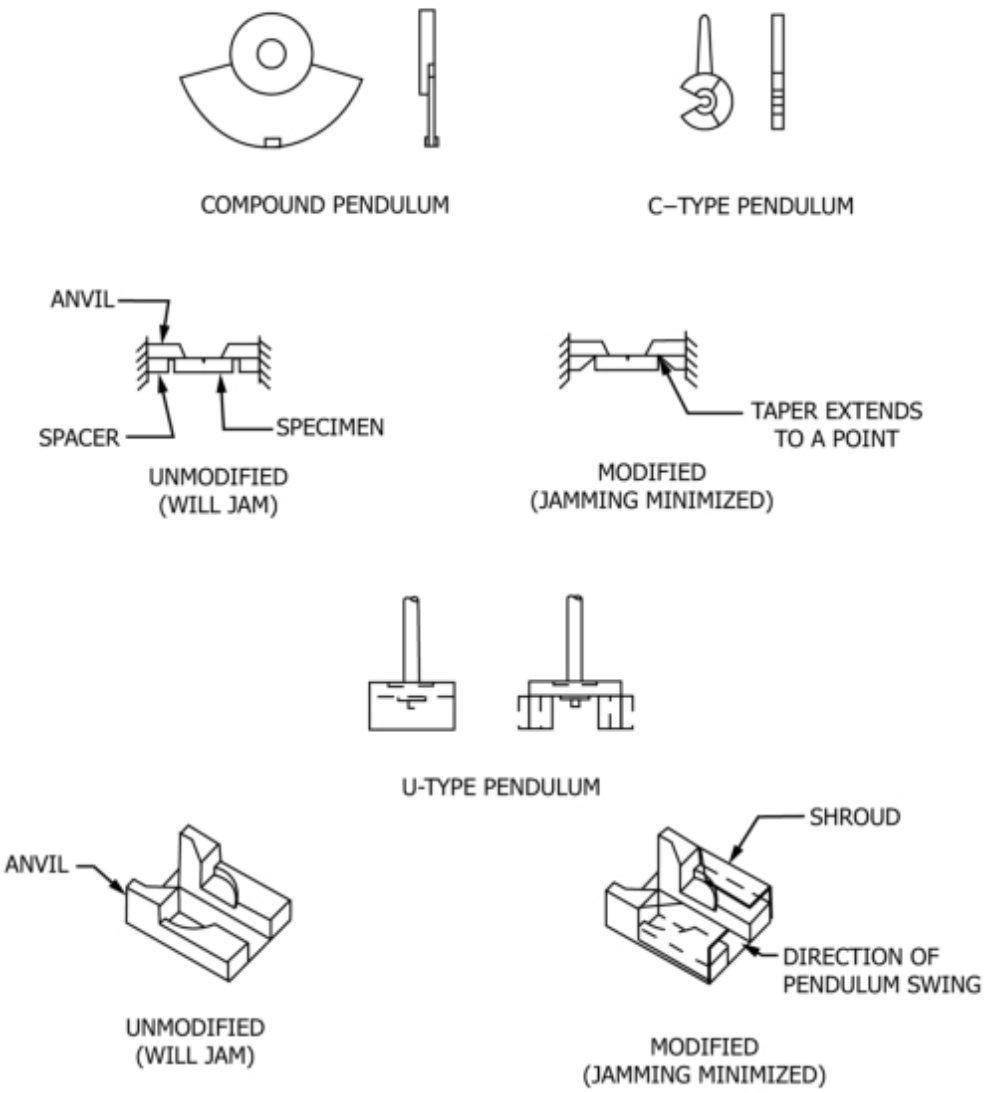
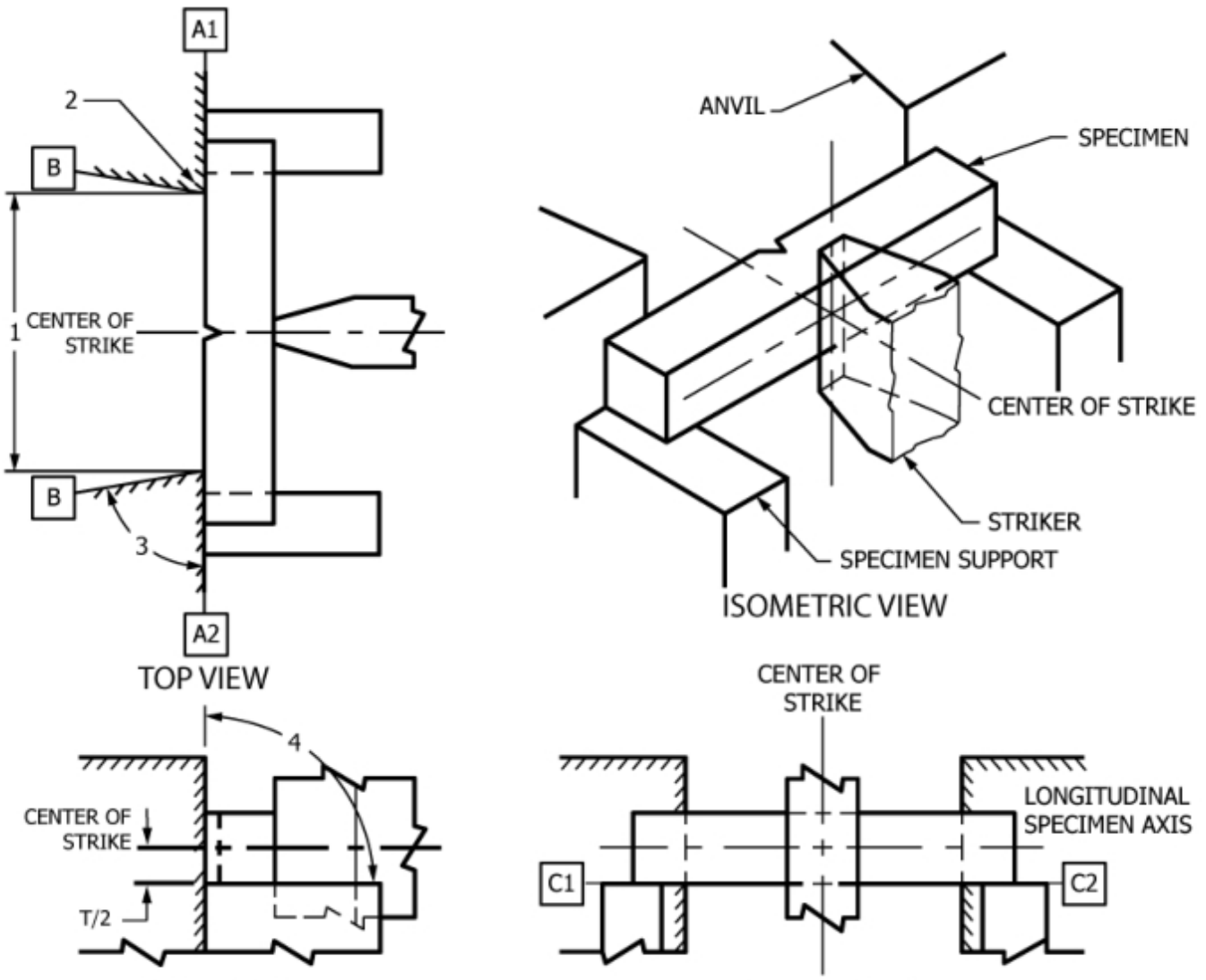



**FIG. A1.1 Typical Pendulums and Anvils for Charpy Machines, Shown with Modifications to Minimize Jamming**




| ID Num | Designation | Dimension | Tolerance |
|---|---|---|---|
| 1 | Span between anvils | 40.00 mm | ±0.05 mm |
| 2 | Anvil radius | 1.00 mm | ±0.05 mm |
| 3 | Anvil angle | 80° | ±2° |
| 4 | Anvil-Support angle | 90° | ±0.15° |
| A and B | Surface finish, Anvils | 0.1μm ($R_a$) | ≤ |
| A1 and A2 | Anvils coplanar | 0 | <0.05 mm |
| C1 and C2 | Supports coplanar | 0 | <0.12 mm |

**FIG. A1.2 Charpy Anvils and Specimen Supports**

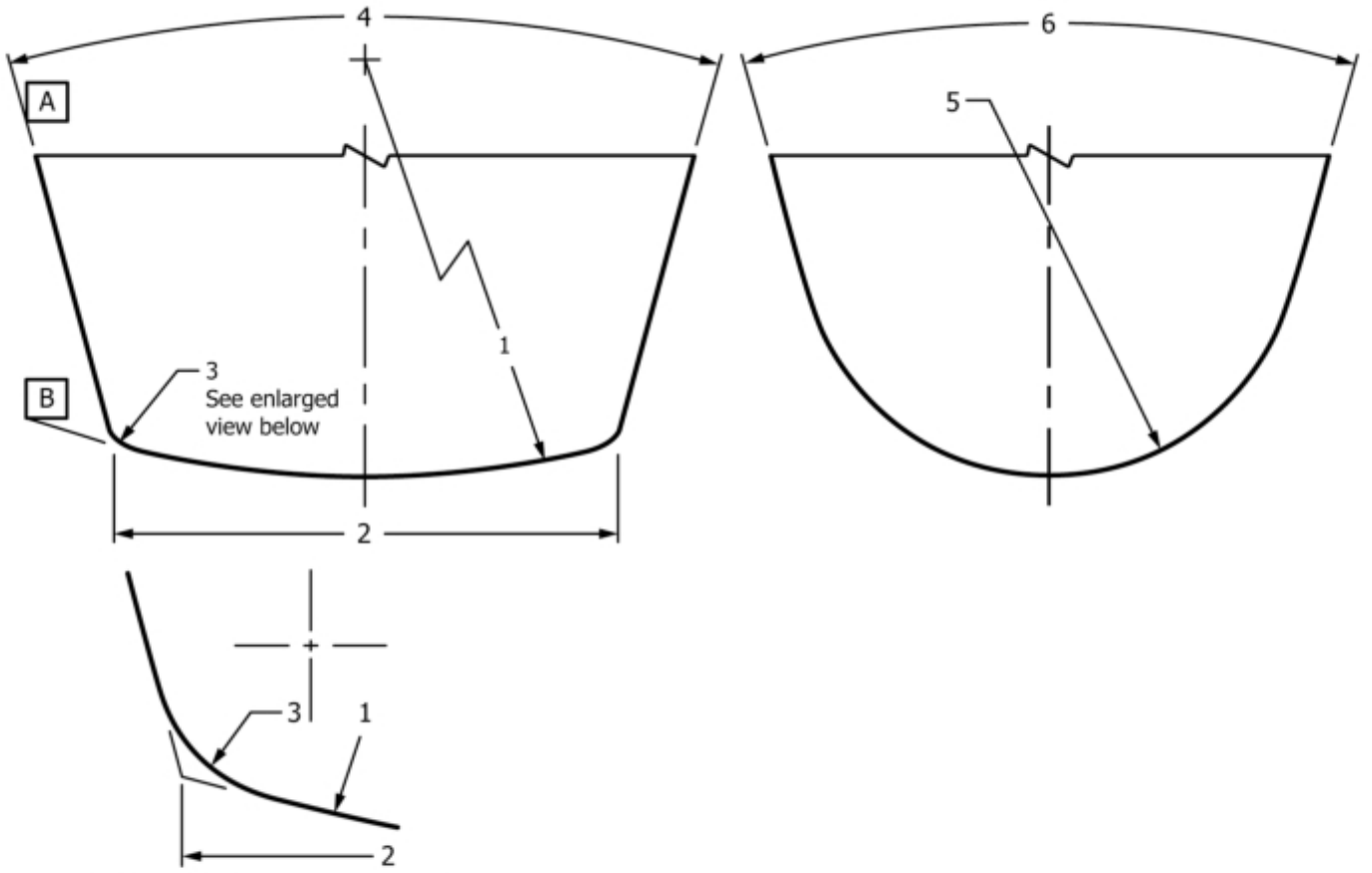
specimen within 5:1000 shown in Fig. A1.2 Right View. The striker shall be parallel within 1:1000 to the face of a perfectly square test specimen held against the anvils shown in Fig. A1.2 Front View.

A1.10.4 The striker shall conform to dimensions and tolerances shown in Fig. A1.3. The standard 8 mm striker is shown in Fig. A1.3(a) and optional 2 mm striker is shown in Fig. A1.3(b).

A1.11 *Izod Apparatus*:

A1.11.1 Means shall be provided (see Fig. A1.4) for clamping the specimen in such a position that the face of the specimen is parallel to the striker within 1:1000. The edges of the clamping surfaces shall be sharp angles of 90° ± 1° with radii less than 0.40 mm. The clamping surfaces shall be smooth with a 2 μm ($R_a$) 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. For cylindrical specimens, the clamping surfaces shall be contoured to match the specimen and each surface shall contact a minimum of π/2 rad (90°) of the specimen circumference.

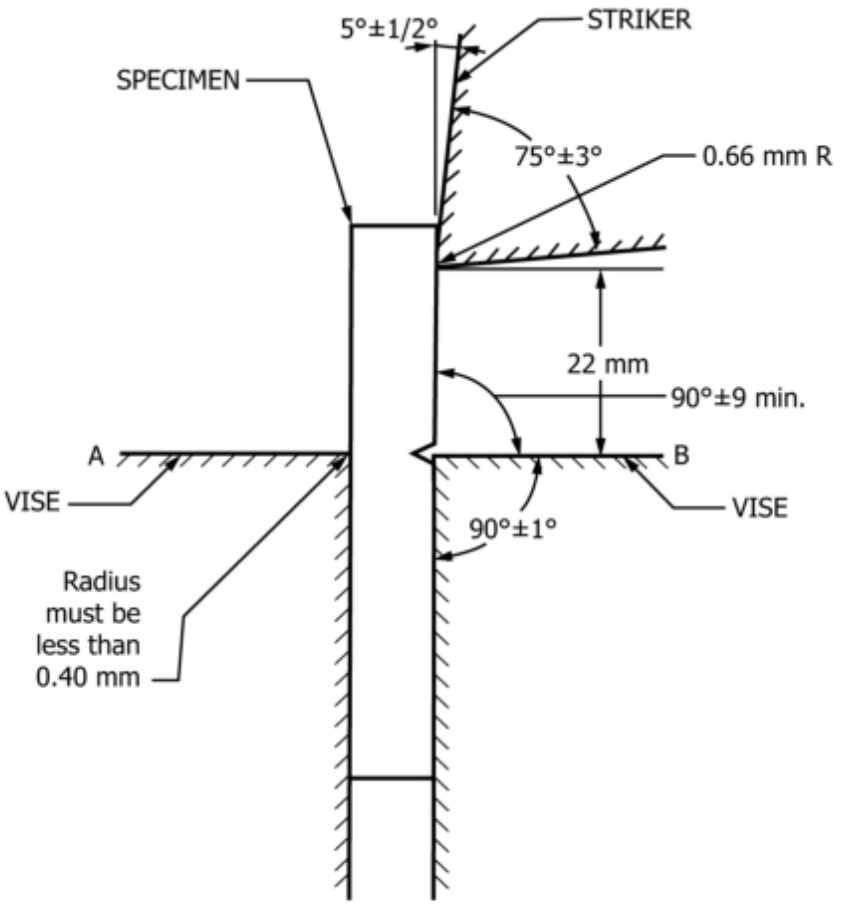
A1.11.2 The dimensions of the striker and its position relative to the specimen clamps shall be as shown in Fig. A1.4.




Enlarged view of imaginary intersection
of SIDE and 8 mm RADIUS.

| ID Num | Designation | Dimension | Tolerance |
|---|---|---|---|
| 1 | Striker radius, 8 mm Striker | 8.00 mm | ±0.05 mm |
| 2 | Striker width, 8 mm Striker | 4.00 mm | ±0.05 mm |
| 3 | Striker corner radii, 8 mm Striker | 0.25 mm | +0.50/-0.05 mm |
| 4 | Striker angle, 8 mm Striker | 30° | ±2° |
| A and B | Striker Finish, 8 mm Striker | 0.1μm ($R_a$) | ≤ |
| 5 | Striker radius, 2 mm Striker | 2.00 mm | +0.50/-0 mm |
| 6 | Striker angle, 2 mm Striker | 30° | ±1° |

**FIG. A1.3 Charpy Strikers**




NOTE 1—All dimensional tolerances shall be ±0.05 mm unless otherwise specified.
NOTE 2—The clamping surfaces of A and B shall be flat and parallel within 0.025 mm.
NOTE 3— Surface finish on striker and vise shall be 2 μm ($R_a$).
NOTE 4—Striker width shall be greater than that of the specimen being tested.

**FIG. A1.4 Izod (Cantilever-Beam) Impact Test**

## A2. VERIFICATION OF PENDULUM IMPACT MACHINES

A2.1 *The verification of impact machines has two parts:* direct verification, which consists of inspecting the machine to ensure that the requirements of this annex and Annex A1 are met, and indirect verification, which entails the testing of verification specimens.

A2.1.1 Izod machines require direct verification annually.

A2.1.2 Charpy machines require direct and indirect verification annually. Data is valid only when produced within 365 days following the date of the most recent successful indirect verification test. Charpy machines shall also be verified immediately after replacing parts that may affect the measured absorbed 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. These restrictions include cases where parts, which may affect the measured absorbed energy, are removed from the machine and then reinstalled without modification (with the exception of when the striker or anvils are removed to permit use of a different striker or set of anvils, or both and then are reinstalled, see A2.1.3). It is not intended that parts not subjected to wear (such as pendulum and indicating device linearity) require direct verification each year unless a problem is evident. Only the items cited in A2.2 require direct verification annually. Other parts of the machine require direct verification at least once, when the machine is new, or when parts are replaced.

A2.1.3 Charpy machines do not require immediate indirect verification after removal and replacement of the striker or anvils, or both, that were on the machine when it was verified provided the following safeguards are implemented: *(1)* an organizational procedure for the change is developed and followed, *(2)* high-strength low-energy quality control specimens (see A2.4.1.1 for guidance in absorbed energy range for these low-energy level specimens) are tested prior to removal and immediately after installation of the previously verified striker or anvils, or both within the 365 day indirect verification period, *(3)* the results of the before and after tests of the quality control specimens are within 1.4 J of each other, *(4)* the results of the comparisons are kept in a log book, and *(5)* before reattachment, the striker and anvils are visually inspected for wear and dimensionally verified to assure that they meet the

required tolerances of Fig. A1.2 and Fig. A1.3. The use of verification specimens with certified absorbed energy values is not required and internal quality control specimens are permitted.

A2.2 *Direct Verification of Parts Requiring Annual Inspection*:

A2.2.1 Inspect the anvils and striker, and replace any parts that do not conform to the dimensions and tolerances shown either in Fig. A1.2 and Fig. A1.3 or in Fig. A1.4.

NOTE A2.1—A straight edge or radius gauge can be used to discern differences between the used and unused portions of these parts to help identify a worn condition. To measure the anvil or striker radii, the user may make a replica (casting) of the region of interest and measure cross sections of the replica. This can be done with the anvils and striker in place on the machine or removed from the machine. Make a dam with cardboard and tape surrounding the region of interest, then pour a low-shrinkage casting compound into the dam (silicone rubber casting compounds work well). Allow the casting to cure, remove the dam, and slice cross sections through the region of interest with a razor. Use these cross sections to make radii measurements on optical comparators or other instruments.

A2.2.2 Ensure the bolts that attach the anvils and striker to the machine are tightened to the manufacturer's specifications.

A2.2.3 Verify that the shrouds, if applicable, are properly installed (see A1.9.2).

A2.2.4 The pendulum release mechanism, which releases the pendulum from its latched position, shall comply with A1.8.

A2.2.5 Check the level of the machine in both directions (see A1.1).

A2.2.6 Check that the foundation bolts are tightened to the manufacturer's specifications. Expansion bolts or fasteners with driven-in inserts shall not be used for foundations.

NOTE A2.2—Expansion bolts or fasteners with driven-in inserts will work loose or will tighten up against the bottom of the machine indicating a false high torque value when the bolts are tightened.

A2.2.7 Check the indicating device zero and the percent friction and windage loss of the machine as described in 9.1.

A2.3 *Direct Verification of Parts to be Verified at Least Once*:

A2.3.1 Charpy specimen supports or Izod vises shall conform to the dimensions and tolerances shown in Fig. A1.2 or Fig. A1.4.

NOTE A2.3—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 and can result in erroneously high measurements of absorbed energy.

A2.3.2 The striker mounting surfaces shall be clean and free of defects that would prevent a good fit. Check that the striker position conforms to A1.10.3 (for Charpy tests) or A1.11.1 (for Izod tests).

A2.3.3 The pendulum alignment shall comply with A1.4 and A1.5. If the side play in the pendulum or the radial play in the bearings exceed the specified limits, adjust or replace the bearings, or both.

A2.3.4 *Determine the Center of Strike*—For Charpy machines the center of strike of the pendulum is determined using a half-thick specimen (10 mm × 5 mm × 55 mm) in the test position. With the striker in contact with the half-thick specimen, a line marked along the top edge of the half-thick specimen on the striker will indicate the center of strike. For Izod machines, the center of strike may be considered to be the contact line when the striker is brought into contact with a specimen in the normal testing position.

A2.3.5 *Determine the Potential Energy*—The following procedure shall be used when the center of strike of the pendulum is coincident with the radial line from the centerline 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 from this line, suitable corrections in elevation of the center of strike shall be made in A2.3.8.1 and A2.3.9, so that elevations set or measured correspond to what they would be if the center of strike were on this line. The potential energy of the system is equal to the drop height, as determined in A2.3.5.2, times the supporting force, as determined in A2.3.5.1.

A2.3.5.1 To measure the supporting force, support the pendulum horizontally to within 15:1000 with two supports, one at the bearings (or axis of rotation) and the other at the center of strike on the striker (see Fig. A2.1). Then arrange the support at the striker 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 striker through a round rod crossing the center of strike. 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.

A2.3.5.2 Determine the drop height compliance with the requirement of A1.7. On Charpy machines determine the drop height as the vertical distance from the top edge of a half-thick (or center of a 10 mm × 10 mm × 55 mm) specimen to the latched position of the center of strike within 0.1 %. On Izod machines determine the drop height as the vertical distance from 22.66 mm above the vise to the latched position of the center of strike within 0.1 %. The drop height may be determined by direct measurement of the change in vertical distance of the center of strike or by calculation from the change in angle from free-hanging position to latched position using the following formulas (see Fig. A2.1):

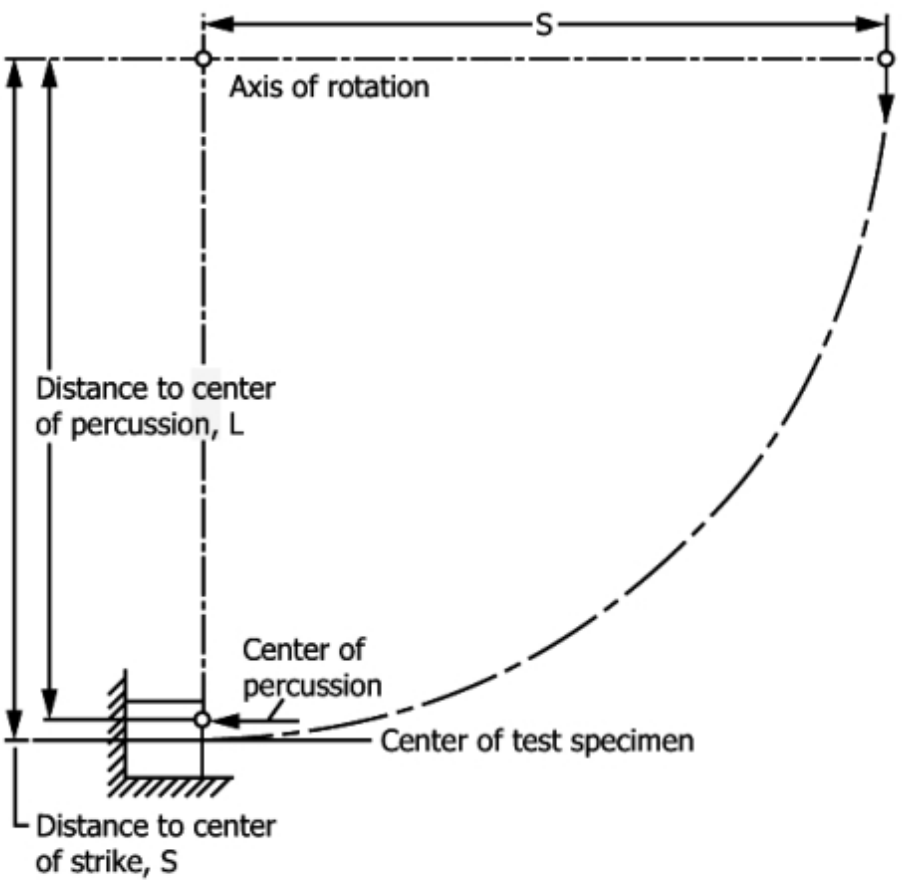
$$h = S\,(1 - \cos\beta) \qquad \text{(A2.1)}$$

$$h_1 = S\,(1 - \cos\alpha) \qquad \text{(A2.2)}$$

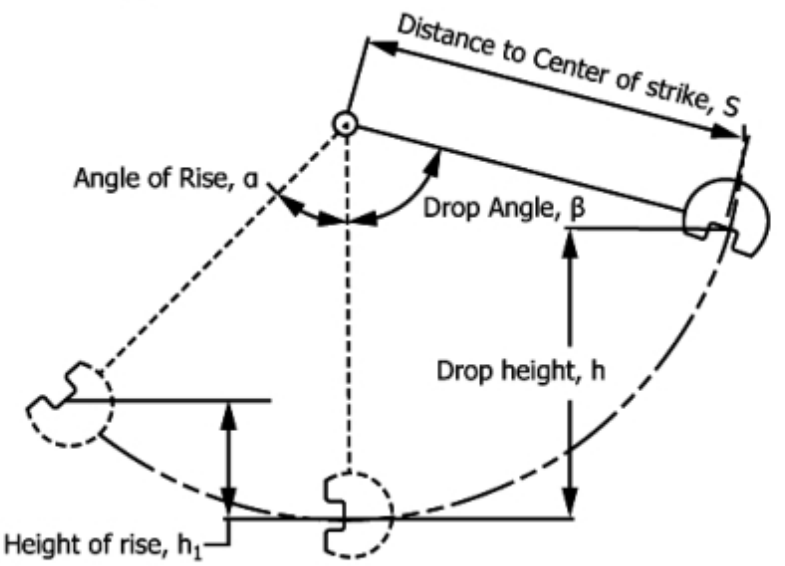
where:

$h$ = drop height, m,
$S$ = distance between axis of rotation and the center of strike, m,
$\beta$ = drop angle,
$h_1$ = height of rise, m, and
$\alpha$ = angle of rise.

A2.3.6 Determine the impact velocity, $v$, of the machine, neglecting friction, by means of the following equation:




(a) Center of Percussion and Center of Strike




(b) Drop Height

**FIG. A2.1 Dimensions for Calculations**

$$v = \sqrt{2\,gh} \qquad \text{(A2.3)}$$

where:

$v$ = velocity, m/s,
$g$ = acceleration of gravity, 9.81 m/s$^2$ , and
$h$ = drop height, m.

A2.3.7 The center of percussion shall be at a point within 1 % of the distance from the axis of rotation to the center of strike, to ensure that minimum force is transmitted to the point of rotation. Determine the location of the center of percussion as follows:

A2.3.7.1 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 (a forward and backward swing together). The period of the pendulum then, is the time for 100 cycles divided by 100.

A2.3.7.2 Determine the center of percussion by means of the following equation:

$$L = \frac{gp^2}{4\pi^2} \qquad \text{(A2.4)}$$

where:

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

$\pi$ = 3.1416, and
$p$ = period of the pendulum, a complete cycle, s.

A2.3.8 *Determination of the Total Frictional Losses*—The friction and windage losses of the pendulum and friction in the indicating device, if not corrected, will be included in the energy loss attributed to breaking the specimen and can result in erroneously high measurements of absorbed energy. For machines recording in degrees, total frictional losses are usually not compensated for by the machine manufacturer, whereas in machines recording directly in energy, they are usually compensated for by increasing the drop height of the pendulum. Determine total frictional losses as follows.

A2.3.8.1 Perform a free swing; without a specimen in the machine, and prepare the indicating device (set the analog scale pointer at range capacity or initialize the digital display, or both) release the pendulum from its latched position and record the energy value indicated. This value shall indicate zero absorbed energy if total frictional losses have been corrected by the manufacturer. Now raise the pendulum slowly until the indicating device is at the value obtained in the free swing. Secure the pendulum at this height and within 0.1 % determine the vertical distance from the center of strike to the top of a half-thick specimen positioned on the specimen supports (see A2.3.5). Determine the supporting force as in A2.3.5.1 and multiply by this vertical distance. The difference between the potential energy and this value at the latched position is the total frictional losses. For analog scale, without resetting the analog scale pointer, repeatedly release the pendulum from its latched position until the pointer shows no further movement. The energy loss determined by the final position of the analog scale pointer is friction and windage losses of the pendulum alone. The friction in the analog scale pointer mechanism alone is then the difference between the total frictional losses and the friction and windage losses of the pendulum alone.

A2.3.9 The indicating device accuracy shall be checked to ensure that it is recording accurately over the entire range capacity (see A1.2.1). Check it at approximately 0, 10, 20, 30, 50, and 70 % of each range capacity. With the striker marked to indicate the center of strike, lift the pendulum and set it in a position where the indicating device reads, for example, 13 J. Secure the pendulum at this height and within 0.1 % determine the vertical distance from the center of strike to the top of a half-thick specimen positioned on the specimen supports (see A2.3.5). Determine the residual energy by multiplying the height of the center of strike by the supporting force, as described in A2.3.5.1. Increase this value by the total frictional losses for a free swing (see A2.3.8.1) multiplied by the ratio of the angle of swing of the pendulum from the latched position to the energy value being evaluated to the angle of swing of the pendulum from the latched position to the free swing reading. Subtract the sum of the residual energy and proportional total frictional losses from the potential energy at the latched position (see A2.3.5). The indicating device shall agree with the energy calculated within the limits of A1.2.1. Make similar calculations at other points of the indicating device. Analog scales that indicate in degrees shall be checked using the above procedure. Degree readings from the analog scale shall be converted to absorbed energy using the conversion formula or table normally used in testing. The analog scale pointer mechanism shall not overshoot or drop back with the pendulum. Make test swings from various heights to check visually the operation of the analog scale pointer over several portions of the analog scale.

NOTE A2.4—In this way the analog scale degree reading formula or table can also be checked for total frictional losses corrections.

A2.4 *Indirect Verification*:

A2.4.1 Indirect verification requires the testing of verification specimens with certified absorbed energy values to verify the accuracy of Charpy impact machines.

A2.4.1.1 Verification specimens with certified absorbed energy values are produced at low (typically 13 J to 20 J), high (typically 90 J to 140 J), and super-high (typically 175 J to 240 J) energy levels. To meet the indirect verification requirements, the average absorbed energy value determined for a set of verification specimens at each energy level tested shall correspond to the certified absorbed energy values of the verification specimens within 1.4 J (1.0 ft lbf) or 5.0 %, whichever is greater.

A2.4.1.2 The certified absorbed energy values for the verification specimens shall be established on the three reference machines owned, maintained, and operated by NIST in Boulder, CO.

A2.4.2 The verified range of a Charpy range capacity is defined with reference to the lowest and highest energy level verification specimens tested. These values are determined from tests on sets of verification specimens at two or more energy levels, except in the case where a Charpy range capacity is too low for two energy levels to be tested. In this case, one energy level can be used for indirect verification.

A2.4.3 Determine the usable range of the range capacity prior to testing verification specimens. The usable range of an impact machine is dependent upon the resolution of the indicating device at the low end and the range capacity at the high end.

A2.4.3.1 The resolution of the indicating device establishes the lower limit of the usable range. The lower limit is equal to 25 times the resolution of the indicating device at 15 J.

NOTE A2.5—On analog scales, the resolution is the smallest change in energy that can be discerned on the analog scale. This is usually ¼ to ⅕ of the difference between two adjacent marks on the scale at the 15 J energy level.

**TABLE A2.1 Verified Ranges for Various Range Capacities and Verification Specimens Tested[A]**

| Range Capacity J | Resolution J | Usable Range J | Verification Specimens Tested | | | Verified Range J |
|---|---|---|---|---|---|---|
| | | | Low | High | Super-high | |
| 80 | 0.10 | 2.5 to 64 | X | . . . | . . . | 2.5 to 64 |
| 160 | 0.20 | 5.0 to 128 | X | X | . . . | 5.0 to 128 |
| 325 | 0.25 | 6.25 to 260 | X | X | X | 6.25 to 260 |
| 400 | 0.30 | 7.5 to 320 | . . . | X | X | 50 to 320 |
| 400 | 0.15 | 3.75 to 320 | X | X | . . . | 3.75 to 150 |
| 400 | 0.15 | 3.75 to 320 | X | X | X | 3.75 to 320 |

[A] In these examples, the high-energy verification specimens are assumed to have a certified absorbed energy value of 100 J.

NOTE A2.6—Digital displays usually incorporate devices, such as digital encoders, with a fixed discrete angular resolution. The resolution of these types of indicating devices is the smallest change in absorbed energy that can be consistently measured at 15 J. The resolution of these types of indicating devices is usually not a change in the last digit shown on the digital display because resolution is a function of the angular position of the pendulum and changes throughout the swing. One method for determining resolution of indicating devices that incorporate a verification mode, in which live absorbed energy is available, is to move the pendulum slowly in the area of 15 J. The smallest observable change in the indicating device is the resolution.

A2.4.3.2 The upper limit of the usable range is equal to 80 % of the range capacity.

A2.4.4 Only verification specimens that are within the usable range of the range capacity shall be tested. To verify the range capacity over its full usable range, test the lowest and highest energy levels of verification specimens commercially available that are within the range capacity's usable range. If the ratio between the highest and lowest verification specimens' certified absorbed energy values tested is greater than four, testing of a third set of intermediate energy level verification specimens is required (if the specimens are commercially available).

NOTE A2.7—Use the typical upper bound of the energy range given for the low, high, and super-high energy verification specimens (20 J, 140 J, and 240 J respectively) to determine the highest energy level verification specimens that can be tested. Alternately, use the typical lower bound of the energy range given for the verification specimens to determine the minimum energy level for testing.

A2.4.4.1 If the low energy verification specimens were not tested (only high and super-high verification specimens were tested), the lower limit of the verified range shall be one half the certified absorbed energy value of the lowest energy verification specimens set tested.

NOTE A2.8—For example, if the certified absorbed energy value of the high-energy verification specimens tested was 100 J, the lower limit would be 50 J.

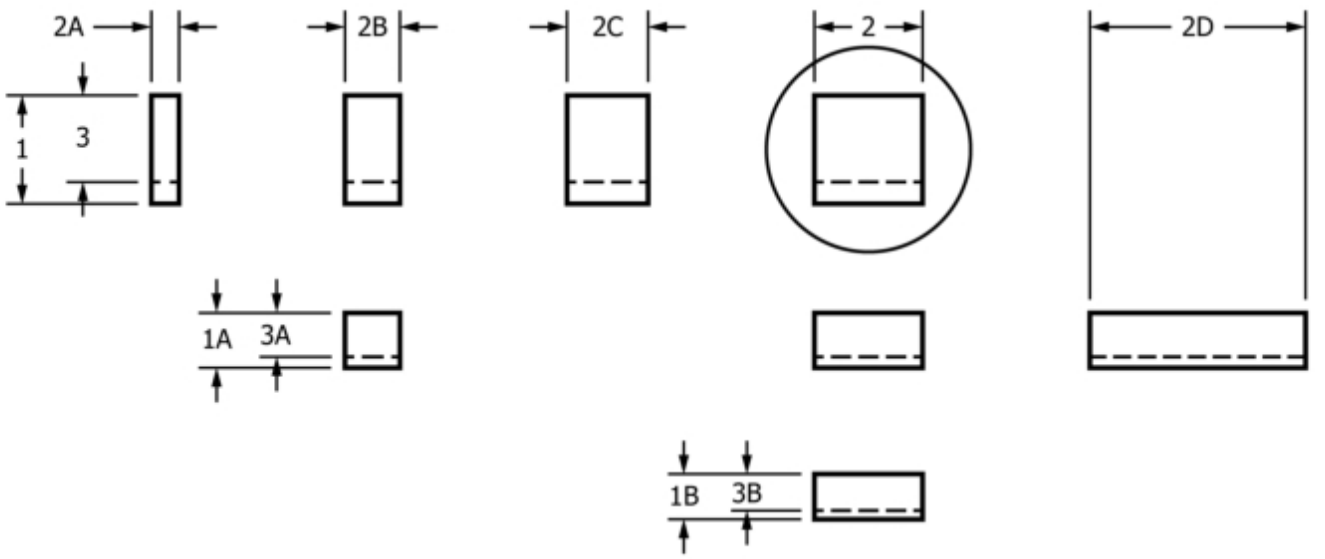
A2.4.4.2 If the highest energy verification specimens commercially available for a given Charpy range capacity were not tested, the upper limit of the verified range shall be 1.5 times the certified absorbed energy value of the highest energy verification specimens tested.

NOTE A2.9—For example, if the machine being tested has a range capacity of 325 J and only low and high-energy verification specimens were tested, the upper limit of the verified range would be 150 J (100 J × 1.5 = 150 J), assuming that the high-energy verification specimens tested had a certified absorbed energy value of 100 J. To verify this range capacity over its full usable range, low-, high-, and super-high energy verification specimens would have to be tested, because super-high energy verification specimens can be tested on a 325 J range capacity (80 % of 325 J is 260 J, and the certified absorbed energy value of super-high energy verification specimens never exceeds 260 J). See Table A2.1.

## A3. ADDITIONAL IMPACT TEST SPECIMEN CONFIGURATIONS

A3.1 *Sub-Size Specimen*—When the amount of material available does not permit making the standard impact test specimens shown in Fig. 1 and Fig. 2, 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, they should be selected from Fig. A3.1. When reporting sub-size specimen dimensions, list the width, thickness, and length (for example, the upper left specimen in Fig. A3.1 would be 10 mm × 2.5 mm × 55 mm).

A3.2 *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 Fig. A3.2 and Fig. A3.3. Specimen Z is sometimes called the Philpot specimen, after the name of the original designer. For 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. A1.4, 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 with those obtained using specimens of other sizes or shapes.

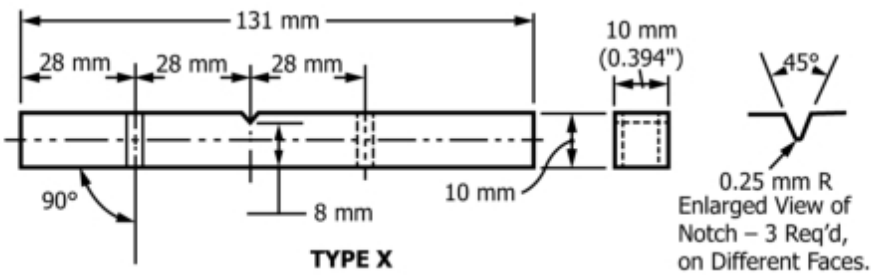



| ID Number | Description | Dimension | Tolerance |
|---|---|---|---|
| 1 | Width, Standard | 10.0 mm | ±0.075 mm |
| 1A | Width, Half | 5.0 mm | ±0.050 mm |
| 1B | Width, Third | 3.0 mm | ±0.030 mm |
| 2 | Thickness, Standard | 10.0 mm | ±0.075 mm |
| 2A | Thickness, Quarter | 2.5 mm | ±0.025 mm |
| 2B | Thickness, Half | 5.0 mm | ±0.050 mm |
| 2C | Thickness, Three-Quarters | 7.5 mm | ±0.075 mm |
| 2D | Thickness, Double | 20.0 mm | ±0.075 mm |
| 3 | Ligament Length, Standard | 8.0 mm | ±0.025 mm |
| 3A | Ligament Length, Half | 4.0 mm | ±0.025 mm |
| 3B | Ligament Length, Third | 2.4 mm | ±0.025 mm |

NOTE 1—The circled specimen is the standard V-notch specimen (see Fig. 1).

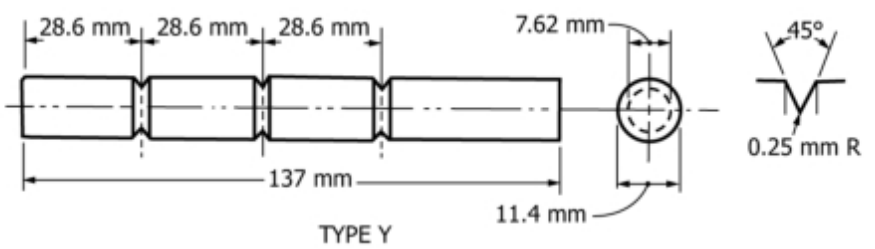
NOTE 2—On sub-size specimens the length, notch angle, notch radius, surface finish are constant with V-notch specimens (see Fig. 1); width, thickness, and ligament length vary as indicated above.

**FIG. A3.1 Sub-Size Charpy (Simple-Beam) V-Notch Impact Test Specimens**




NOTE 1—Permissible variations for type X specimens shall be as follows:

| | |
|---|---|
| Perpendicularity of notch axis | ± 2° |
| Adjacent ( 90°sides) shall be at | ± 10 min |
| Ligament length | ±0.025 mm |

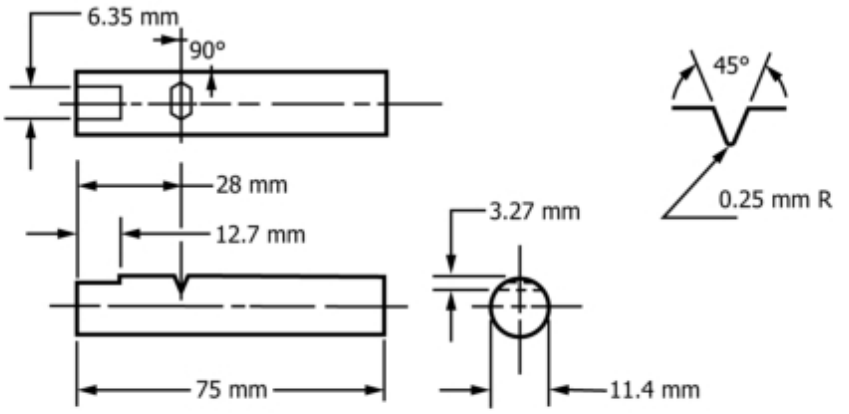



NOTE 2—Permissible variations for both specimens shall be as follows:

| | |
|---|---|
| Cross-section dimensions | ±0.025 mm |
| Lengthwise dimensions | +0, –2.5 mm |
| Angle of notch | ±1° |
| Radius of notch | ±0.025 mm |
| Notch diameter of Type Y specimen | ±0.025 mm |

**FIG. A3.2 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 1—Permissible variations shall be as follows:

| | |
|---|---|
| Perpendicularity between notch length and longitudinal centerline | ± 2° |
| Cross-section dimensions | ±0.025 mm |
| Length of specimen | +0, –2.5 mm |
| Angle of notch | ±1° |
| Radius of notch | ±0.025 mm |
| Notch depth | ±0.025 mm |

**FIG. A3.3 Izod (Cantilever-Beam) Impact Test Specimen (Philpot), Type Z**

## A4. DETERMINATION OF THE SHEAR FRACTURE APPEARANCE

A4.1 These shear fracture appearance methods are based on the concept that 100 % shear (stable) fracture occurs above the transition-temperature range and brittle unstable fracture occurs below the range, as shown by the instrumented Charpy data in Fig. A4.1 (see also Test Method E2298). This shear measurement process was developed for carbon steels that undergo a distinct ductile to brittle transition that results in a clearly defined region of cleavage fracture (unstable) on the

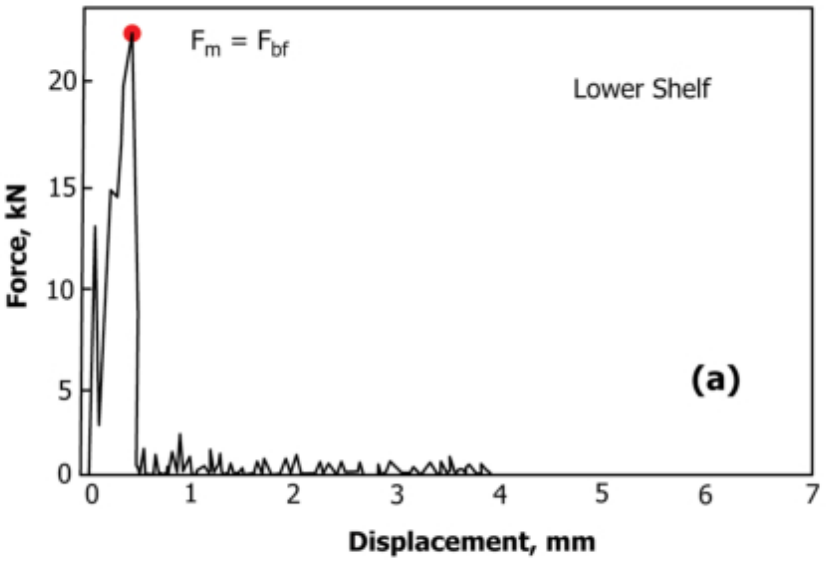



**FIG. A4.1 Instrumented Charpy impact data showing behavior of steels in the (a) lower shelf, (b) transition, and (c) upper shelf regions. The symbols are defined as: *(1)* $F_{gy}$, general yield force, *(2)* $F_m$, maximum force, *(3)* $F_{bf}$, force at initiation of unstable crack propagation, and *(4)* $F_a$, force at end of unstable crack propagation (arrest force).**

surface of the specimen. Fracture surface interpretation is complicated in materials that exhibit mixed-mode fracture during unstable crack extension.

In the transition-temperature range, fracture is initiated at the root of the notch by fibrous tearing. A short distance from the notch, unstable crack extension occurs ($F_{bf}$) as the fracture mechanism changes to cleavage, mixed mode, or another low energy fracture mode, which often results in distinct radial markings in the central portion of the specimen (indicative of fast, unstable fracture). After several microseconds the unstable crack extension arrests ($F_a$). Final fracture occurs at the remaining ligament and at the sides of the specimen in a stable manner. As shear-lips are formed at the sides of the specimen, the plastic hinge at the remaining ligament ruptures. In the ideal case, a "picture frame" of fibrous "shear" (stable) fracture surrounds a relatively flat area of unstable fracture.

The five methods used below may be used to determine the shear fracture appearance. The user should qualitatively characterize the fracture mode of the unstable fracture zone, and provide a description of how the shear measurements were made. The methods are grouped in order of increasing precision. In the case where a specimen does not separate into two halves during the impact test and the fracture occurs without any evidence of unstable crack extension, the shear fracture appearance can be considered to be 100 % and the specimen should be reported as unbroken.

NOTE A4.1—Round robin data (five U.S. companies, 1990) estimates of the shear fracture appearance for five quenched and tempered 8219 steels and four microalloyed 1040 steels indicated the following: (1) results using method A4.1.1 systematically underestimated the percent shear (compared with method A4.1.4), (2) the error using method A4.1.2 was random and, (3) the typical variation in independent measurements using method A4.1.4 was on the order of 5 % to 10 % for microalloyed 1040 steels.

A4.1.1 Measure the length and width of the unstable fracture region of the fracture surface, as shown in Fig. 8, and determine the shear fracture appearance from Table A4.1 and Table A4.2 depending on the units of measurement.

A4.1.2 Compare the appearance of the fracture of the specimen with a shear fracture appearance chart such as that shown in Fig. A4.2.

A4.1.3 Magnify the fracture surface and compare it to a precalibrated overlay chart or measure the shear fracture appearance by means of a planimeter.

A4.1.4 Photograph the fracture surface at a suitable magnification and measure the shear fracture appearance by means of a planimeter.

A4.1.5 Capture a digital image of the fracture surface and measure the shear fracture appearance using image analysis software.

**TABLE A4.1 Shear Fracture Appearance for Measurements Made in Millimetres**

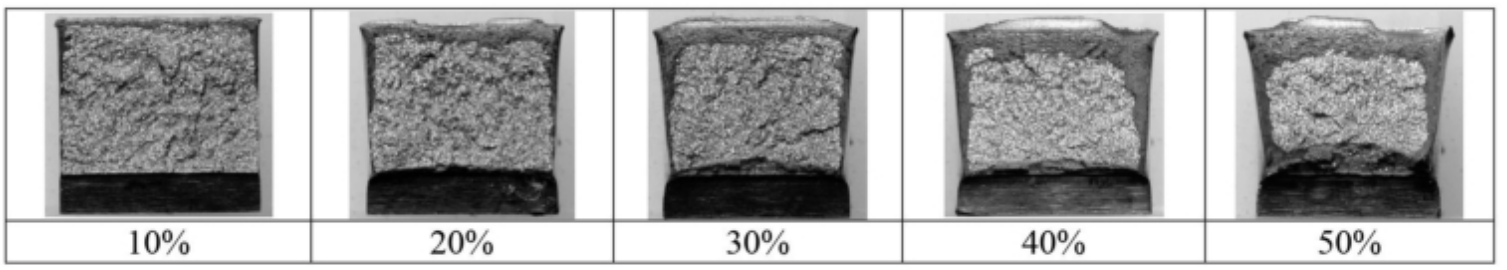
NOTE 1—100 % shear fracture appearance is to be reported when either *A* or *B* is zero.

| 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 |

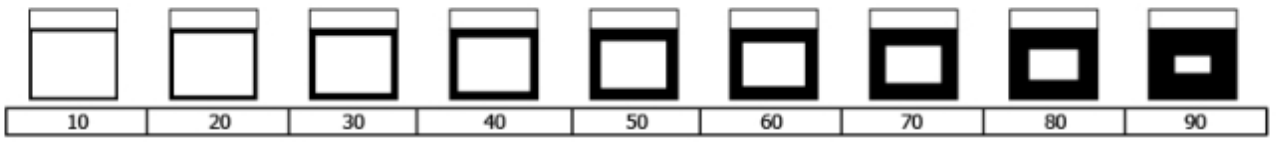
**TABLE A4.2 Shear Fracture Appearance for Measurements Made in Inches**

NOTE 1—100 % shear fracture appearance 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 |




(a) Shear Fracture Appearance Charts




(*b*) Guide for Estimating Shear Fracture Appearance

**FIG. A4.2 Shear Fracture Appearance**

## APPENDIXES

**(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 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 face-centered cubic metals and alloys, a large group of nonferrous materials and 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 V-notch Charpy or Izod specimens). Even low temperatures do not alter this characteristic of these materials. In contrast, the behavior of 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 notched condition. Notched conditions include constraints to deformation in directions perpendicular to the major stress, or multi axial 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 multi-axial 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 brittle type. Some metals can be deformed in a ductile manner even down to very low temperatures, 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 ductile or shear type of failure, considerable deformation precedes the final fracture and the broken surface appears fibrous instead of crystalline. 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 size effects, it happens more commonly that plastic deformation precedes fracture. In addition to the normal stress, the applied force 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.

X1.2.4 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 affect the results of the tests. Tests on E4340 steel specimens[7] have shown the effect of dimensional variations on Charpy results (see Table X1.1).

X1.3 *Size Effect*:

X1.3.1 Increasing either the thickness or the width of the specimen tends to increase the volume of metal subject to distortion, and by this factor tends to increase the absorbed energy. However, any increase in size, particularly in thickness, also tends to increase the degree of constraint and by tending to induce brittle fracture, may decrease the absorbed energy. Where a standard V-notch specimen is on the verge of brittle fracture, this is particularly true, and a double-thick specimen may actually require less absorbed energy to rupture than one of standard thickness.

X1.3.2 In studies of such effects where the size of the material precludes the use of the standard specimen, for example when the material is a 6.35 mm plate, sub-size specimens are used. Such specimens (Fig. A3.1) are based on the V-notch specimen of Fig. 1.

X1.3.3 A general correlation between the absorbed 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.

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

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

| | High-Energy Specimens, J | Medium-Energy Specimens, J | Low-Energy Specimens, J |
|---|---|---|---|
| Specimen with standard dimensions | 103.0 ± 5.2 | 60.3 ± 3.0 | 16.9 ± 1.4 |
| Depth of notch, 2.13 mm[A] | 97.9 | 56.0 | 15.5 |
| Depth of notch, 2.04 mm[A] | 101.8 | 57.2 | 16.8 |
| Depth of notch, 1.97 mm[A] | 104.1 | 61.4 | 17.2 |
| Depth of notch, 1.88 mm[A] | 107.9 | 62.4 | 17.4 |
| Radius at base of notch 0.13 mm[B] | 98.0 | 56.5 | 14.6 |
| Radius at base of notch 0.38 mm[B] | 108.5 | 64.3 | 21.4 |

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

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 absorbed energy values and shear 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 absorbed energy 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 striker, or the machine foundation bolts are not securely fastened, tests on ductile materials in the range of 108 J may actually indicate values in excess of 122 J to 136 J.

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 although they were struck by a pendulum traveling at speeds approximately 5.2 m/s. If the force exerted on the pendulum by the broken specimens is sufficient, the pendulum will slow down and erroneously high absorbed energy values will result. This problem accounts for many of the inconsistencies in Charpy results reported by various investigators within the 14 J to 34 J range. Fig. A1.1 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 absorbed energy 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 perform 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.

## X2. SUGGESTED METHODS FOR MEASURING THE POSITION OF THE CENTER OF STRIKE

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. Section A1.3 limits the total frictional losses in impact machines to a negligible value. The required measurements may be made using specialized instruments such as transits, clinometers, or cathetometer. 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 pendulum. Adjust the position of this object so that when back lighted, a minimal gap is visible between it and the pendulum. (See Fig. X2.1.)

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. (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.)

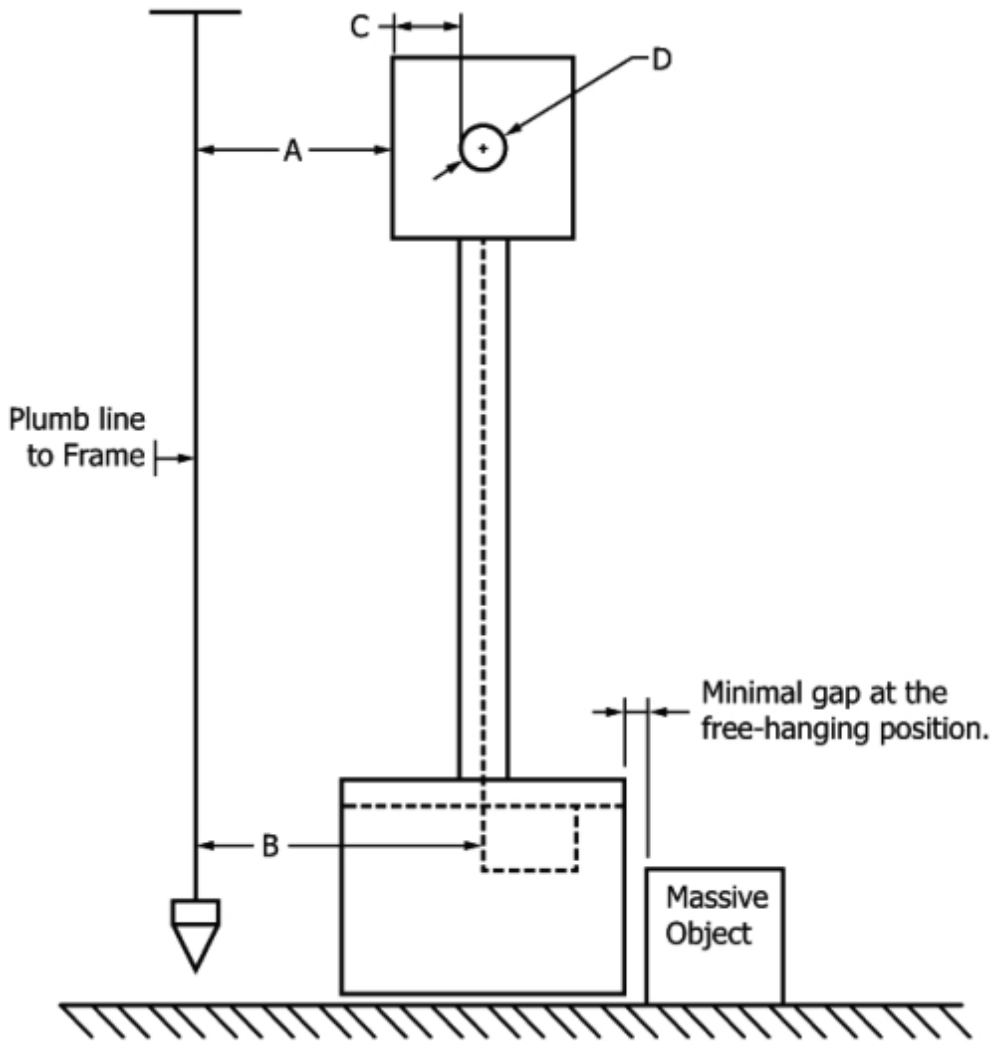



FIG. X2.1 Measurement of Deviation of Center of Strike from Vertical Plane through Axis of Rotation when Pendulum is at Free-hanging Position

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.)

X2.1.1.8 Substitute the measured dimensions in the equation

$$X = A + C + D/2 - B \quad \text{(X2.1)}$$

where:

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

## X3. INSTRUCTIONS FOR TESTING SUB-SIZE CHARPY SPECIMENS

X3.1 When testing sub-size specimens (see Fig. A3.1), the specimen support height should be changed to ensure that the center of strike is maintained (see A2.3.4 and A2.3.7 for instructions). To comply with this change, new specimen supports can be manufactured or shims may be added to the specimen supports in a secure manner so that they do not interfere with the test.

X3.2 In order to maintain the center of strike requirements, the following procedure should be used when testing a sub-size specimen. The height of the specimen supports should be changed to ensure that the centerline of the sub-size specimen will coincide with the centerline of the standard specimen. Higher specimen supports should be used when testing a smaller thickness specimen and lower specimen supports should be used when testing a larger thickness specimen.

X3.3 Determine the nominal thickness of the sub-size specimen. When testing smaller thickness specimens, subtract this value from the standard thickness specimens (10 mm). Divide this value by two. This amount shall be added to the standard specimen support height. For larger thickness specimens, the result of the subtraction is a negative number. Therefore, the thickness of the supports shall be reduced by the amount calculated.

## SUMMARY OF CHANGES

Committee E28 has identified the location of selected changes to this standard since the last issue (E23 – 23) that may impact the use of this standard. (Approved March 1, 2023.)

*(1)* 9.1.1.2, 9.2.3, and 9.3.3 were revised.
*(2)* A1.2 and A1.4 were revised.
*(3)* A1.10.1 and A1.10.2 were revised.
*(4)* A2.2.1 and Note A2.1 were revised.
*(5)* A2.3.1, A2.3.2, A2.3.3, and A2.3.4 were revised.
*(6)* A2.3.5.1 was revised.
*(7)* A2.3.7 and A2.3.7.1 were revised.
*(8)* Eq A2.4 was revised.
*(9)* A2.3.8.1 was revised.
*(10)* X2.1.1.8 was revised.

Committee E28 has identified the location of selected changes to this standard since the last issue (E23 – 22) that may impact the use of this standard. (Approved January 1, 2023.)

*(1)* 3.1 and 3.1.1 were added and subsequent sections renumbered.
*(2)* 3.2.3, 3.2.4, and 3.2.6 were added and subsequent sections renumbered.
*(3)* 9.1.1.3 was revised with release mechanism.
*(4)* 9.3.3.3, A1.8, A2.2.4, A2.3.5.2, A2.3.8.1 and A2.3.9 were revised with latched position.
*(5)* Note 10 was added (like previous 11.1) and subsequent Notes were renumbered.
*(6)* 9.3.1.1 was revised with required individual specimens absorbed energy values.
*(7)* 10.2.2 and 11.1 were revised with shall.
*(8)* Section 11 was revised.
*(9)* 11.1.1, 11.1.7 (like previous 11.3.2), and 11.1.8 were added and subsequent sections renumbered.
*(10)* 11.1.4 was revised (with previous Note 11).
*(11)* 11.2 was revised with test records should include.
*(12)* 11.2.1 was added.
*(13)* Fig. 3 was redrawn with both Charpy and Izod specimens added.
*(14)* Previous Fig. 4 with 8.1.4 was deleted with subsequent figures renumbered.
*(15)* Fig. 5 was redrawn with B (thickness dimension) and in title.
*(16)* A1.4 and Fig. X2.1 were revised with free-hanging position.
*(17)* A1.7, A2.3.5, Fig. A2.1, A2.3.5.2, A2.3.6 and A2.3.8 were revised with drop height.
*(18)* A1.10.3 was revised with Fig. A1.2 views.
*(19)* A2.3.8.1 was revised with free swing.
*(20)* Fig. A1.2 revised with labeled views and surfaces. Added tabled coplanar tolerances.
*(21)* Fig. A2.1, and A2.3.5.2 were revised with drop angle and clarified S.

Committee E28 has identified the location of selected changes to this standard since the last issue (E23 – 18) that may impact the use of this standard. (Approved December 15, 2022.)

*(1)* Previous 8.1.2 was added with side-groove variation as Note 5 and subsequent sections and notes renumbered.
*(2)* 8.2.4 was revised with "unless otherwise specified."
*(3)* 11.1.2 was revised with applicable figure specimens.
*(4)* A2.4.1.1 and Note A2.7 were revised with the typical verification specimen energy levels.

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