Designation: E2248 – 12

Standard Test Method for Impact Testing of Miniaturized Charpy V-Notch Specimens[1]

1. Scope

1.1 This test method describes notched-bar impact testing of metallic materials using Miniaturized Charpy V-Notch (MCVN) specimens and test apparatus. It provides: (*a*) a description of the apparatus, (*b*) requirements for inspection and calibration, (*c*) safety precautions, (*d*) sampling, (*e*) dimensions and preparation of specimens, (*f*) testing procedures, and (*g*) precision and bias.

1.2 This standard concerns Miniaturized Charpy V-Notch specimens, for which all linear dimensions, including length and notch depth, are reduced with respect to a type A standard impact test specimen in accordance with Test Methods E23. These are not the same as sub-size specimens, described in Annex A3 of Test Methods E23, for which length, notch angle and notch depth are the same as for the standard type A Charpy specimen. See also 1.5 below.

1.3 Comparison of the MCVN data with conventional Charpy V-Notch (CVN) data or application of the MCVN data, or both, to the evaluation of ferritic material behavior is the responsibility of the user of this test method and is not explicitly covered by this test method.

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

1.5 This standard does not address testing of sub-size specimens as discussed in Test Methods E23. The reader should understand the distinction between miniature and sub-size. Miniature specimens are shorter that sub-size specimens so that more tests can be conducted per unit volume of material. Moreover, miniature specimens are designed so that the stress fields which control fracture are similar to those of conventional Test Methods E23 specimens.

1.6 The MCVN test may be performed using a typical Test Methods E23 test machine with suitably modified anvils and striker or using a smaller capacity machine.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A370 Test Methods and Definitions for Mechanical Testing of Steel Products

E23 Test Methods for Notched Bar Impact Testing of Metallic Materials

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

E2298 Test Method for Instrumented Impact Testing of Metallic Materials

2.2 *ISO Standards:*[3]

ISO 148 Metallic materials -- Charpy pendulum impact test -- Part 1: Test method

ISO 14556 Steel -- Charpy V-notch pendulum impact test -- Instrumented test method

3. Summary of Test Method

3.1 The essential features of the MCVN impact test are: (*a*) a suitable miniature three point bend specimen, (*b*) anvils and supports on which the test specimen is placed to receive the blow of the moving mass, (*c*) a moving mass (striker) that has been released from a sufficient height to cause the mass to break the specimen placed in its path, (*d*) a device for determining the energy absorbed by the broken specimen, and optionally (*e*) instrumentation for measuring applied force as a function of time during specimen loading (refer to Test Method E2298).

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

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

[3] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.org.

3.2 The test consists of breaking the miniaturized specimen, notched in the middle, and supported at each end, with one blow from a swinging pendulum under conditions defined hereafter.

4. Significance and Use

4.1 There are cases where it is impractical or impossible to prepare conventional CVN specimens. MCVN specimens are an alternative approach for characterizing notched specimen impact behavior. Typical applications include MCVN specimens prepared from the broken halves of previously tested specimens, from thin product form material, or from material cut from in-service components.

4.2 This standard establishes the requirements for performing impact tests on MCVN specimens fabricated from metallic materials. Minimum requirements are given for measurement and recording equipment such that similar sensitivity and comparable measurements, as compared to conventional CVN tests, are achieved. The user should be aware that the transition region temperature dependence data obtained from MCVN specimens are not directly comparable to those obtained from full-size standard Charpy-V specimens and suitable correlation procedures have to be employed to obtain ductile-to-brittle transition temperature (DBTT) data equivalent to those obtained using CVN specimens. In all instances, correlations will have to be developed to relate upper shelf energy (USE) data from MCVN test to CVN comparable energy levels. Application of MCVN test data to the evaluation of ferritic material behavior is the responsibility of the user of this test method. MCVN test data should not be used directly to determine the lowest allowable operating temperature for an in-service material. The data must be interpreted within the framework of a fracture mechanics assessment.

4.3 While this Test Method treats the use of an instrumented striker as an option, the use of instrumentation in the impact test is recommended and is fully described in Test Method E2298. In order to establish the force-displacement diagram, it is necessary to measure the impact force as a function of time during contact of the striker with the specimen. The area under the force-displacement curve is a measure of absorbed energy. As an alternative, absorbed energy may be evaluated directly from machine dial reading. Whenever possible, an optical encoder shall be used in place of the machine dial because an encoder has better resolution than a dial.

5. Test Machine

5.1 The test shall be carried out with a pendulum-type impact testing machine which is (optionally) instrumented to determine force-time curves. The test machine shall have sufficient capacity to break the specimen in one blow while losing not more than 80 % of the initial potential energy. Provided energy measurements can be obtained with a resolution better than or equal to 0.1 J, the same test machine used for CVN testing may be used to test MCVN specimens.

5.2 The MCVN specimen has to be suitably supported so that the centerline of the specimen coincides with the center of strike of the pendulum. If the same machine used for CVN testing is used for MCVN specimens, refer to Appendix X3 of E23 for changing the specimen support height by manufacturing new supports or adding shims.

5.3 The impact velocity (tangential velocity) of the pendulum at the center of the strike shall not be less than 1 nor more than 6 m/s.

NOTE 1—Impact velocities above 4 m/s are not advisable for instrumented MCVN tests, since excessive oscillations are then superimposed on the initial portion of the test diagram and errors in the evaluation of the force-displacement trace may occur. For the same reason (ease of interpretation of the instrumented curve), lower velocities are allowed for MCVN tests than required by E23 (not less than 3 m/s).

5.4 It is recommended that the scalability of the stress fields is maintained. This is accomplished by scaling the striker radius, anvil radii, and the span of the anvils with respect to a specimen size that is proportional to the CVN specimen. Fig. 1 shows the dimensions of 8 and 2 mm strikers (3.86 mm and 0.96 mm) scaled for use with the nominal ½-scale MCVN (4.83 by 4.83 by 24.13 mm) specimen shown in Fig. 2. For

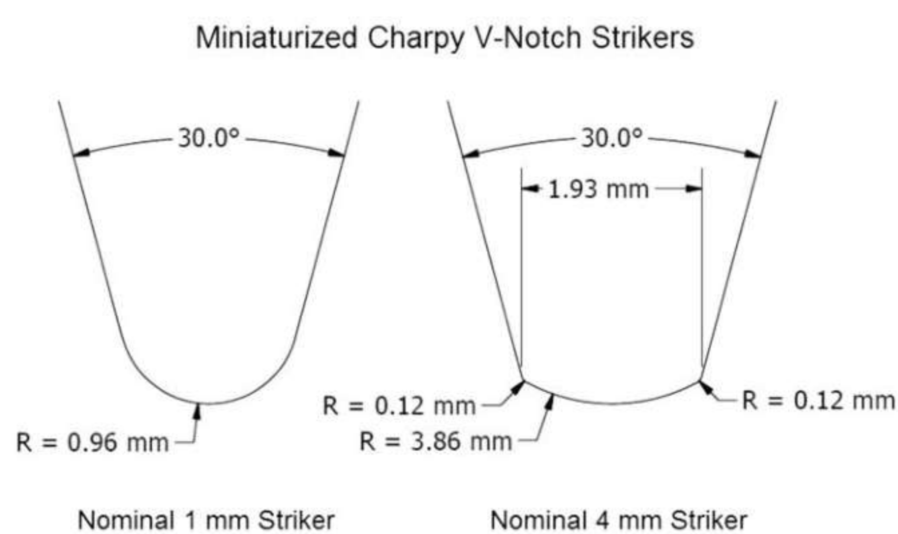
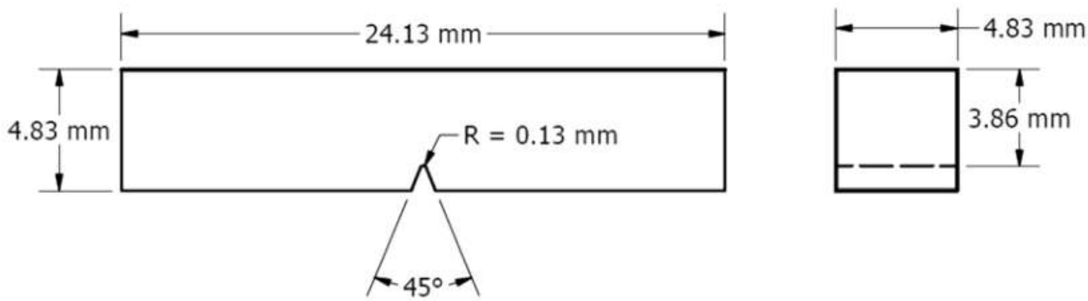


FIG. 1 Scaled 8 mm and 2 mm Strikers for Use in Miniaturized Charpy Impact Testing



Square Cross Section Notched Bar

NOTE 1—Permissible variations shall be as follows:

Angle of striker	±1°
Radius of curvature of striking edge	Nominal 1 mm Striker: +0.25, –0 Nominal 4 mm Striker: ±0.025 mm
Radius of shoulder of nominal 4 mm striker	±0.025 mm
Width of edge of nominal 4 mm striker	±0.025 mm
Surface finish requirements	0.1μm or better
Notch length to edge	90° ± 2°
Notch root radius	± 0.025 mm
Adjacent sides at	90° ± 10 min
Ligament length	±0.025 mm
Cross section dimensions	±0.025 mm
Finish requirements	2μm notched surface/ opposite surface 4μm other surfaces
Length of specimen	+0. -12mm
Centering of notch	±0.12 mm
Angle of notch	±1°

FIG. 2 Miniaturized Charpy Impact Specimen

both of these scaled strikers, the anvil radius is scaled to 0.48 ± 0.025 mm, and the span is 19.3 ± 0.025 mm.

5.5 A non-scaled 2 mm striker can be used to test the 4 by 3 by 27 mm MCVN specimen described in Annex D of ISO 14556. The anvil radius and span, in this case are $1\ _{0}^{+0.50}$ mm and $22_{0}^{+0.10}$ mm respectively.

NOTE 2—This particular test is allowed because a substantial amount of data exists for this specimen and test geometry. This MCVN specimen is not proportional to the CVN specimen, so scaling is not appropriate.

5.6 The testing machine shall be a pendulum type of rigid construction. All general requirements for apparatus and calibration specified in Test Methods E23 shall be satisfied.

5.7 For instrumented force measurements using optional force measuring instrumentation, the requirements given in Test Method E2298 regarding striker instrumentation, data acquisition, and data analysis shall be satisfied.

6. Hazards

6.1 Safety precautions should be taken to protect personnel from electric shock, the swinging pendulum, flying broken specimens, and hazards associated with specimen warming and cooling media. See also 1.6.

7. Test Specimens

7.1 The recommended proportional specimen configuration is the square cross section notched bar shown in Fig. 2. The cross sectional dimension is slightly under 5 mm to enable machining from a previously tested CVN. Information on additional specimen geometries that have been successfully used is provided in Appendix X1.

NOTE 3—In case MCVN specimens are extracted from broken CVN specimens of highly ductile materials, the user should ensure that the severe plastic deformation occurred during fracture of the CVN specimens does not affect the impact behavior of the miniaturized samples.

7.2 Microstructural considerations dictate that only V-notch specimens with cross sectional dimensions sufficient to ensure a representative volume of material is tested may be used. In order to satisfy this requirement, the size scale and mean separation distance of inhomogeneities that exist in the material must be known. The cross sectional dimension must be at least five times greater than the largest inhomogeneity. Post-test metallography may be performed in order to confirm that the requirement has been met.

7.3 Stress field similitude dictates that if the miniaturized specimens (such as the one shown in Fig. 2) do not satisfy the microstructural considerations, specimens with a larger cross section may be used. For the square cross section specimen in Fig. 2, all the remaining specimen dimensions (length, notch depth, etc.) shall be scaled by appropriate ratio with the conventional CVN dimensions. This has the advantage of standardization of approach and scalability of previously calculated finite element solutions.

7.4 Machining the outside surfaces of the MCVN specimens using continuous wire electric discharge machining (EDM) or any other machining method which produces less than 0.005 mm of disturbed material on the surface is acceptable. The crack starter notch shall be EDM machined or precision ground.

7.5 Side grooving of the MCVN specimens (see also Appendix X2) is optional. Investigations (1) have shown that the use of side grooves on MCVN specimens provides a larger volume of material which is sampled at plane strain conditions. This results in less downward shift in temperature due to loss of constraint caused by miniaturization, and thereby reduces the need for correction factors to simulate CVN transitional fracture temperature dependence.

7.6 The choice of specimen depends on the application.

NOTE 4—Although this test method specifically addresses impact tests performed on notched specimens, the use of unnotched samples may be advantageous when testing refractory metals or materials produced by powder metallurgy methods. For such materials, machining an accurate notch without producing significant damage is extremely difficult. The use of unnotched specimens, however, is outside the scope of this test method.

7.6.1 For some materials, the use of different methods for machining specimens may increase results variability and data scatter. For this reason, the machining method used shall be reported (see 11.1.2). Performing microstructural investigations in order to determine the depth of the recast layer might be helpful.

8. Test Procedure

8.1 The test procedure may be summarized as follows: the test specimen is heated/cooled in situ (that is, at the impact location) or it is removed from its cooling (or heating) medium, and positioned on the specimen supports; the pendulum is released with minimum vibration; and the absorbed energy is recorded from the machine dial or, preferably, from the optical encoder. For instrumented tests, the force-time curve is measured and evaluated to give the total absorbed energy.

8.2 The temperature of the specimen at impact must be within ±2°C of the nominal test temperature. Due to the small size of the specimen, in tests below or above room temperature (RT), special attention must be devoted to temperature control within the above mentioned tolerance. It is recommended that in-situ heating/cooling be used. If a bath transfer system is used, it will be necessary to transfer the specimen to the supports and strike the specimen within a very short period of time (~ 1 s or less). If a thermal bath transfer system is not used, dummy specimens (with internal thermocouples) or test specimens (with surface thermocouples) shall be used to demonstrate that the ±2°C requirement has been met. If in-situ heating/cooling is used, dummy specimens (with internal thermocouples) or test specimens (with surface thermocouples) shall be used to calibrate the system and to demonstrate that the ±2°C requirement has been met.

8.3 The specimen shall be placed on the supports against the anvils to ensure that the notch is centered to within 0.25 mm.

9. Lateral Expansion and Percent Shear Determination

9.1 The measurement of lateral expansion shall satisfy the requirements of Test Methods E23. The uncertainty of the measurement shall be determined by using precision machined reference blocks.

9.2 The fracture appearance, characterized as percent shear area, may be measured directly or determined using a correlation of characteristic values (see 9.2.2).

9.2.1 Direct measurement of fracture appearance shall satisfy the requirements of Test Methods E23.

9.2.2 *Fracture Appearance Correlation*—The equations described in Test Method E2298 may be used to estimate the shear fracture area. These equations relate characteristic force measurements with the percentage of shear fracture area. The applicability and accuracy of the correlation for a particular material shall be demonstrated.

10. Inspection, Verification, and Preparation of Apparatus

10.1 Machine inspection and verification shall be performed in accordance with the requirements of this test method, Test Methods E23, and Test Method E2298 as appropriate.

10.2 In cases where the MCVN specimens are tested on a large capacity Test Methods E23 test machine, the test machine shall be indirectly verified using CVN verification specimens in accordance with the requirements of Test Methods E23. In particular, the anvils and striker for CVN specimens shall be used to verify the test machine. MCVN anvils and striker shall then be put on the machine and the machine shall be further checked by testing MCVN specimens which are prepared from a material with a microstructure that produces small scatter in the fracture test results and/or for which a large experimental database is available (such as round-robin results, see for example references (**1**, **2**, **3**).

10.3 MCVN test machines of small capacity, which are not capable of testing CVN verification specimens, shall be checked by testing MCVN specimens which are prepared from a material with a microstructure that produces small scatter in the fracture test results and/or for which a large experimental database is available (such as round-robin results, see for example references (**1**, **2**, **3**)). In the case of materials with a microstructure that produces small scatter in the fracture test results, it is not possible to compare MVCN results with known certified values. In such cases, it is recommended that a large batch of test specimens be prepared and used to establish the mean and standard deviation at various energy levels. The batch of test specimens can be used in the future to perform yearly test machine verification and to verify the performance of other MCVN test machines.

10.4 Prior to testing a group of specimens, and before a specimen is placed in position to be tested, check the machine by a free swing of the pendulum. With the dial indicator (if used) at the maximum energy position, a free swing of the pendulum shall indicate zero energy within at least 0.1 J on machines reading directly in energy, and which are compensated for frictional losses. On machines using optical encoders, the indicated values, when converted to energy, shall be compensated for frictional losses and the free swing of the pendulum shall indicate zero energy within ±0.1 J.

10.5 For instrumented testing, the calibration and verification procedures of Test Method E2298 shall be satisfied.

11. Report

11.1 For all tests, report the following information:

11.1.1 Specimen type and dimensions,

11.1.2 Method used for machining the specimens and specifically for cutting the notches (for example, EDM, grinding, broaching etc.),

11.1.3 Test machine characteristics including anvil spacing, anvil radius, span, and striker geometry,

11.1.4 Test temperature of specimen and method of heating or cooling, and

11.1.5 Energy absorbed as measured by dial or optical encoder.

11.2 Optional variables which may be reported include:

11.2.1 Lateral expansion,

11.2.2 Fracture appearance (shear),

11.2.3 Specimen orientation, and

11.2.4 Specimen location within the plate or weld.

11.3 For instrumented tests, additional information in accordance with Test Method E2298 shall be reported.

12. Precision and Bias

12.1 *Precision*—MCVN impact data from two interlaboratory studies have been analyzed in accordance with Practice E691 in order to establish the precision of this Test Method. The terms repeatability limit and reproducibility limit are used as specified in Practice E177.

12.1.1 An interlaboratory study (**1**) was conducted using miniaturized Charpy V-notch specimens with square cross section (Fig. 2) of A533B Cl.1 (tested at room temperature and 150°C) and of two reference materials produced by the National Institute of Standards and Technology, Boulder CO (low energy and high energy). The ILS was conducted in accordance with Practice E691 in six laboratories, each one obtaining up to six test results for the absorbed energy measured by the machine dial or encoder (Table 1). See ASTM Research Report No.E28-1039.[4]

12.1.2 Another interlaboratory study (**2, 3**) of characteristic instrumented impact forces, displacements an d energies was conducted using KLST miniaturized Charpy V-notch specimens with 3×4mm rectangular cross section (see Appendix X1) of A533B Cl.1. The ILS was conducted in accordance with Practice E691 in thirteen laboratories with fourteen test machines, each one obtaining up to five test results for the absorbed energy (Table 2). See ASTM Research Report No. E28-1037.[5]

TABLE 1 Absorbed energy (J) from MCVN specimens (2)

Material	Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
A553B RT	11.09	0.40	0.40	1.13	1.13
A533B 150°C	10.94	0.36	0.40	1.00	1.11
4340 (low en)	10.92	0.36	0.38	1.00	1.07
4340 (high en)	10.93	0.23	0.34	0.64	0.95

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

TABLE 2 Absorbed energy (J) from MCVN specimens of A533B cl. 1 (2, 3)

Average	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit	Reproducibility Limit
8.22	0.43	0.71	1.19	1.98

13. Keywords

13.1 fracture appearance; impact test; instrumented impact test; lateral expansion; miniaturized Charpy test; notched specimens; pendulum machine

[4] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:E28-1039.

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:E28-1037.

APPENDIXES

(Nonmandatory Information)

X1. ALTERNATIVE MCVN SPECIMEN CONFIGURATIONS

X1.1 *MCVN specimen described in Annex D of ISO 14556*—This $4 \times 3 \times 27$ mm^3 specimen has been used extensively in Europe (2, 3). We refer the user to Annex D of ISO 14556 for details of the specimen geometry.

X2. SIDE GROOVED MINIATURE CHARPY V-NOTCH SPECIMENS

X2.1 *Side Grooved Miniature Charpy V-notch Specimens:*

X2.1.1 This test method recommends the use of a proportional specimen with a square cross section, like that shown in Fig. 2. A square cross section side grooved specimen can also be used.

X2.1.2 The use of the side grooves on MCVN specimens will provide a larger volume of material which is sampled in plane strain conditions. This results in less downward shift in temperature due to loss of constraint as a result of miniaturization, and thereby reduces the need for correction factors to simulate CVN transitional fracture temperature dependence. The choice of specimen depends on the application and it is important to note that some side grooved specimens and test procedures associated with them are patented technologies (4).

REFERENCES

(1) Manahan, M. P., Sr., Martin F. J., and Stonesifer, R. B., "Results of the ASTM Instrumented/Miniaturized Round Robin Test Program", *Pendulum Impact Testing: A Century of Progress*, ASTM STP 1380, T. A. Siewert and M. P. Manahan, Sr.,Eds., American Society for Testing and Materials, West Conshohocken, PA, 1999.

(2) Lucon, E., ″ Round-Robin on Instrumented Impact Testing of Sub Size Charpy-V Specimens: Results of Phase 1″, ESIS TC5, Final Report, 2 April 1998.

(3) Lucon, E., ″ European Activity on Instrumented Impact Testing of Subsize Charpy V-Notch Specimens (ESIS TC5)″, *Pendulum Impact Testing: A Century of Progress*, ASTM STP 1380, T. A. Siewert, and M. P. Manahan, Sr., Eds., American Society for Testing and Materials, West Conshohocken, PA, 1999, p. 242-252.

(4) United States Patent numbers 4,864,867 and 5,165,287, M.P. Manahan inventor Battelle Development Corporation assignee, filed 1988.