Designation: E 1236 – 91 (Reapproved 1997)

Standard Practice for Qualifying Charpy Impact Machines as Reference Machines[1]

This standard is issued under the fixed designation E 1236; 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.

INTRODUCTION

Some standards for impact testing require that the bias of the machines be evaluated by testing one or more sets of specimens with known impact energy. These specimens are called verification specimens. The known value is determined by tests using three machines which, by consensus, are designated as giving correct results. Such machines will be referred to as reference machines and the impact energy values determined from tests using these machines will be referred to as reference values.

In order to assure an adequate supply of verification specimens and also to assure that the reference values are not influenced by uncontrolled changes in one reference machine, it is necessary to recognize several machines as reference machines. However, when several different machines are used to test a large number of specimens from the same lot, the average impact energy from each machine is usually different from the corresponding values from tests by other machines. This practice provides procedures for minimizing these differences.

1. Scope

1.1 This practice lists the physical requirements that an impact machine shall meet in order to be registered as a reference machine.

1.2 This practice describes the procedure by which a reference machine shall be qualified to make tests to establish reference values.

1.3 These requirements and procedures are not intended to be applied to impact machines and testing procedures used for purposes other than to qualify machines for the determination of reference values of verification specimens.

1.4 This practice does not describe the procedure by which the reference value for a specified reference material is determined. The procedure varies with the material being tested and is to be found in different standards for various specified verification materials.

1.5 Values stated in inch-pound units are to be regarded as the standard. SI units are given for information only.

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

2. Referenced Documents

2.1 *ASTM Standards:*

E 23 Test Methods for Notched Bar Impact Testing of Metallic Materials[2]

E 178 Practice for Dealing with Outlying Observations[3]

E 456 Terminology Relating to Quality and Statistics[3]

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[3]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *coordinator*—the person or agency who conducts the annual interlaboratory coordination program and maintains a file on all reference machines.

3.1.2 *impact energy*—the energy required to break a specimen when tested by an impact machine. It is equal to the difference in the potential energy of the pendulum at the start and at the end of a swing during which a specimen is broken, minus the proportional amount of windage and friction loss which corresponds to the angle of swing.

3.1.3 *lot*—a definite quantity of some commodity manufactured under similar conditions of production.

3.1.3.1 *Discussion*—With the exceptions noted, the definitions of statistical terms given in Terminology E 456 shall apply.

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

Current edition approved Jan. 25, 1991. Published March 1991. Originally published as E 1236 – 88. Last previous edition E 1236 – 88.

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

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

3.1.4 *reference machines*—impact machines meeting the requirements of this practice.

3.1.5 *reference value*—the impact energy value furnished with verification specimens, determined from tests made using reference machines.

3.1.6 *set*—a group of specimens chosen at random from a lot, to be later tested successively in a single machine.

3.1.6.1 *Discussion*—With the exceptions noted, the definitions of statistical terms given in Terminology E 456 shall apply.

3.1.7 *specified verification material*—any one of several materials that meet a specification given in a standard that describes verification specimens.

3.1.8 *verification specimens*—impact specimens to be used to evaluate the suitability of a machine for material acceptance testing by comparing the impact energy measured by that machine to the reference value furnished with the specimens.

4. Summary of Practice

4.1 Any impact machine that meets the physical requirements of this practice may be a candidate reference machine. Before the machine is permitted to be used to determine reference values, it shall be qualified by participating in an interlaboratory coordination program that compares results from all candidate reference machines at low, medium, and high energy levels. The average value and variability of the test results from each machine are compared to corresponding values from all machines combined. If the differences between the value from a particular machine and the combined value is less than the amounts specified in this practice, that machine is certified as a reference machine for the next twelve months or until the next report of the interlaboratory coordination program is distributed.

5. Significance and Use

5.1 This practice is expected to increase the availability of verification specimens by permitting an increase in the number of qualified reference machines.

6. Apparatus

6.1 *Reference Machines*, used to determine the reference values for a specified verification material, shall comply with the requirements of the standard for verification specimens of that material.

6.1.1 Unless specifically stated otherwise in the standard for verification specimens, reference machines shall comply with the requirements of Test Method E 23, except as modified in 6.1.2.

6.1.2 The requirements for reference machines shall differ from those given in Test Method E 23, as follows:

6.1.2.1 The capacity of a reference machine shall be 240 ft·lbf (330 J) or greater.

6.1.2.2 The portions of the striker and anvils that contact the specimen and apply or react to the impacting force shall have a hardness of 56HRC or greater.

6.1.2.3 The angular position of the pendulum at the extremes of the swing or the impact energy calculated therefrom shall be automatically recorded in digital or graphical form. These records shall be in permanent form suitable for evaluation at any time until 1 year after all the specimens from the same lot have been tested or sold.

6.1.2.4 If impact energy is automatically calculated and printed, the value shown shall be rounded to 0.1 ft·lbf (0.1 J) or, optionally, 0.5 % of the impact energy, if greater.

6.1.2.5 If pendulum position is recorded, the record shall be readable to an angle corresponding to the larger of 0.2 ft·lbf (0.3 J) or 1 % of the impact energy.

6.2 Environment of the reference machine shall be similar to that of the average quality control environment with specific attention to the following factors:

6.2.1 The machine shall be in an enclosed area with sufficient lighting and clearance around the equipment to permit convenient access for conducting the necessary periodic inspections and maintenance.

6.2.2 Normal room temperature and humidity is satisfactory. No concentrated heating or cooling sources shall be located near or directed toward the machine or its indicating mechanism.

6.2.3 The atmosphere shall be sufficiently clean to prevent the accumulation of dust or foreign material that could contaminate the bearings or otherwise cause damage to the equipment which would affect its performance.

6.2.4 The reference machine shall not be subjected to external (random) vibrations induced by other equipment in close proximity, such as forging hammers, presses, vehicular movements, and so forth. Vibrations discernable by placing the hand on the pendulum would be considered excessive.

NOTE 1—Excessive vibration from a machine firmly fastened to the floor indicates the need of a separate foundation or base connected to the floor by vibration isolators.

7. Selection of the Coordinator of the Interlaboratory Coordination Program

7.1 The machine owner accepting responsibility for the coordinative function has the option of assigning an employee or of contracting with a person or agency outside the owner's organization to serve as coordinator.

7.2 *Timing*—The coordinator of the next program shall be designated within 60 days of the distribution of the report of the preceding program.

7.3 For the first year of the program, the coordinative responsibility will be assigned to the owner of reference machine A.

7.4 For the second and subsequent programs, the machine owner who last accepted responsibility will request successively, in alphabetical order, the other owners to designate the coordinator for the next program.

7.4.1 If none of the owners voluntarily accept the coordinative responsibility, the responsibility shall be assigned to the owner whose machine has the first alphabetical identification letter among those who have previously accepted the responsibility the least number of times per reference machine owned. If that owner refuses to accept the assignment, that machine shall be excluded from the next program and thereby loses reference machine status.

8. Calibration and Standardization

8.1 Calibration and verification of reference machines shall conform to Test Methods E 23.

8.2 *Registration of Reference Machines*:

8.2.1 Registration shall be initiated by a letter of application from the machine owner to the coordinator. The letter shall furnish the information and make the commitments that follow:

8.2.1.1 Identify the machine and certify that the requirements of Section 6 are satisfied.

8.2.1.2 State that the owner agrees to participate in the annual interlaboratory coordination program.

8.2.1.3 State that the owner will permit suppliers and users of the verification specimens tested by this machine to see the machine and examine the permanent records required by this practice. These inspections are to be by appointment at the owner's convenience.

8.2.2 The coordinator will assign the next letter of the alphabet to that machine for identification.

8.2.3 The coordinator will acknowledge the receipt of the application by a letter addressed to the owner. An attachment will list all currently registered reference machines by identifying letter and give the name, address, and telephone number of the owner of each machine.

8.3 The interlaboratory coordination program will consist of specimen procurement and testing, and the comparison of test results to determine whether the deviation and variability of each machine is within the limits specified in 8.3.6 and 8.3.7.

8.3.1 The specimen shall meet the dimensional requirements given in Test Methods E 23 for Charpy Impact Specimens-Type A, and any additional requirements imposed by the standard for verification specimens.

8.3.2 If all of the candidate machines are under the control of one person or organization, that owner shall be responsible for conducting the interlaboratory coordination program and for keeping a summary report on file.

8.3.3 If the candidate reference machines are under the control of two or more owners, the coordinator shall conduct the interlaboratory coordination program as described in 8.3.3.1-8.3.8.2.

8.3.3.1 During January of each year, the coordinator shall request quotations of price and delivery for the specimens needed for the interlaboratory coordination programs.

(a) Requests shall be addressed to each known supplier of verification specimens and to all other manufacturers who have had experience in producing Charpy specimens and who have asked to be considered.

(b) The request shall be for separate quotations for verification specimens in one or more of the following energy ranges: low, 10 to 15 ft·lbf (13 to 20 J); medium, 65 to 90 ft·lbf (88 to 122 J); high, 130 to 180 ft·lbf (176 to 244 J), whose specifications are shown in standards for verification specimens.

(c) The request shall stipulate that the quotation shall include the material specification from the manufacturer and a certificate stating that all material furnished to that specification was taken from a single billet or melt.

(d) The request shall require that the quotation include the results of tests on specimens randomly selected from the lot being offered. These results shall include average impact energy, the standard deviation, the test temperature, the number of specimens tested, and all other information needed to show that the offered lot meets the specifications of the standard for verification specimens of that material.

(e) The request shall state that the minimum number of specimens required to be in each lot shall be equal to the product of 1.5 times the number of registered reference machines and the number of specimens in each set. Unless otherwise required by the standard for the verification specimens, each set shall consist of 25 specimens. The inquiry shall state that the quoted lot size shall be reserved for use in the interlaboratory coordination program for at least twelve months after the first specimens are delivered.

(f) The request shall require that the specimen be permanently marked with coded letters to identify the lot from which it was drawn and also with a number to uniquely identify that specimen from all others within the lot and that the specimens for each set shall be drawn at random from the lot. The specimen numbers for each set shall be retained in a permanent record.

(g) The request shall state that only quotations submitted before the end of February will be considered.

8.3.3.2 The coordinator shall then send copies of all quotations for specimens to participating machine owners. Each owner shall be requested to vote during April for a specimen supplier at each energy level. Each owner shall have one vote for each of the owner's machines that is to be qualified.

8.3.3.3 During May, the coordinator shall notify the supplier whose proposal received the most votes at an energy level to expect orders for specimens at that level. The coordinator shall notify all others who quoted that their proposal did not receive the most votes. In the case of a tie, the coordinator shall cast the deciding vote.

8.3.3.4 During May, the coordinator shall send a letter to each voter stating that a set of specimens for each candidate reference machine at each level shall be obtained by sending a purchase order to the chosen supplier(s). The letter shall also give a schedule for reporting the results of the tests and a blank form for recording the data and all other information required for the summary report.

8.3.4 Each owner shall test a set of specimens at each energy level and report the results on the forms furnished by the coordinator.

8.3.4.1 Before testing any specimen from the set, all specimens shall be inspected for dimensional accuracy. If any are found to be out of tolerance, the whole set shall be returned to the supplier with a note listing the defects. A replacement set shall be requested.

8.3.4.2 The testing procedure shall be in accordance with 9.1.

8.3.4.3 If a testing error involving more than two specimens is known to have occurred, a replacement set shall be ordered and tested. No substitution of specimens from outside the original set is permitted. If the testing error involved only one or two specimens, the original set of specimens need not be

replaced. If there is physical evidence to support the occurrence of the testing error, the results for the one or two specimens involved may be deleted from the calculations, but the reading obtained, type of error, and the evidence of error must be included in the report. Examples of such evidence are:

(a) Atypical fracture appearance,

(b) Off-center anvil marks, and

(c) An exceptionally high or low reading of impact energy for a specimen that has lateral expansion typical of the other specimens.

8.3.4.4 After all the specimens of a set have been tested, the owner shall identify outliers as described in 10.4. All specimens identified as outliers shall be examined for physical evidence of a difference between the outliers and the other specimens. Examples of such evidence are:

(a) Difference in hardness,

(b) Misplaced anvil marks,

(c) Unusual fracture appearance, and

(d) Defects exposed by the fracture surface such as voids, segregations, or inclusions.

8.3.4.5 If such physical evidence of a difference between the outlier and the other specimens is found, the value of impact energy for that specimen shall be deleted from the subsequent calculations for average and standard deviation. The deletion shall be noted and the physical evidence described in the report. If no physical evidence of specimen defect or testing error is found, the outlier shall be included in subsequent calculations. The search for physical evidence shall be described in the report.

8.3.4.6 The test results and broken specimens shall be sent by the owner of each candidate reference machine to the coordinator. After the summary report has been issued, the coordinator shall return the broken specimens to the owner who tested them, if the owner so desires.

8.3.5 After test results for each candidate reference machine have been received, the coordinator shall tabulate the combined data in accordance with the section in Practice E 691 on preparing Data for Evaluation.

8.3.6 The coordinator shall compare at each energy level the variability of each machine to all the others, as described in 10.5. If this comparison identifies one or more machines as producing results with excessive variability, the coordinator shall notify the owner and suggest that the owner inspect the machine for abnormal conditions such as worn parts, misalignment, excessive friction, or loose foundation bolts. The coordinator shall also invite the owner to compare the specimens broken by the machine in question to the specimens broken by other machines. The owner shall have options of withdrawing the first results and replacing them with data from another set from the same lot or withdrawing from the present annual coordination program. In order to be included in the grand average and standard deviation, any replacement data must be received by the coordinator within 21 days after notification.

8.3.7 The coordinator shall calculate the deviation for each qualified reference machine. This is equal to the grand average of the results of all machines that did not show excessive variability minus the average for the machine whose deviation is being calculated. If magnitude of the deviation for one or more machines exceeds the specified limit of the larger of 1 ft·lbf (1.36 J) or 5 % of the grand average, the grand average shall be recalculated after deleting the data from the machine with the largest deviation. The deviation shall then be recalculated for the remaining machines and the machine with the largest deviation again eliminated if the deviation exceeds the specified limit. This process of recalculation shall be continued until all the deviations are less than the specified limit. The deviation for the machine previously deleted shall then be calculated using the grand average last calculated. If the deviations last calculated exceed the specified limit, the coordinator shall follow the notification and retest procedure described in 8.3.6 except that the retest results shall not be included in the grand average.

8.3.8 The coordinator shall write a summary report for each energy level and distribute copies to all participants in the interlaboratory coordination program.

8.3.8.1 The data summary shall be in the tabular form described in Practice E 691.

8.3.8.2 The summary report shall contain all the information furnished by the manufacturer(s) concerning the specimens tested and also the test data from the quotation submitted by the supplier of those specimens.

8.3.9 For a period of twelve months following the date of issue of the report or until the next report is distributed, the reference machine status shall be in force.

8.3.10 Additional candidate reference machines may be qualified or a repaired machine may be requalified at any time when interlaboratory test specimens are available. The owner shall register the machine in accordance with 8.2 and purchase a set of specimens from the same lot used during the latest interlaboratory coordination program. These specimens shall be tested in accordance with 8.3.4 and the data and specimens sent to the coordinator. The test for excessive variability shall be based on the pooled standard deviation from the latest report of an interlaboratory test program on the same lot. Similarly, the deviation shall be calculated using the previously determined last grand average. If neither the variability nor the deviation are excessive, the coordinator shall inform the owner that the machine has qualified for reference machine status until the next regularly scheduled interlaboratory test program. If excessive variability or deviations are found, 8.3.6 and 8.3.7 shall apply.

9. Procedure

9.1 The procedure for the operation and inspection of a reference machine shall conform to the requirements of Test Methods E 23 and to the following additional requirements.

9.1.1 Impact energy or pendulum position shall be automatically recorded rather than observed and recorded by an operator. This automatic record shall be retained until one year after all the specimens of the same lot have been tested or sold.

9.1.2 The combined windage and friction loss during 11 successive half-cycles shall be measured before and after each daily use, and the values recorded in a permanently retained log book.

9.1.3 The reported value of impact energy shall be compensated for windage and friction loss as shown in 10.3. Other corrections or calibration terms shall not be used.

9.1.4 If cemented carbide anvils or strikers are used, exposed carbide surfaces and bond lines shall be inspected with fluorescent penetrant quarterly. The anvils and striker shall be removed from the machine annually for a complete inspection. Any cracked parts shall be replaced and the interlaboratory test program repeated. The dates and pertinent details of all inspections shall be documented in a log book.

9.1.5 During the annual inspection of the reference machines, the flatness of the anvil surfaces that absorb force from the striker and the adjacent radii shall be measured from contact impressions using low melting point metals, plaster of Paris, or other suitable substances that harden while in contact with the anvils. A slice of these castings at the mid-plane of the specimen, perpendicular to the notch root, shall be photographed or examined with an optional comparator to determine the minimum and maximum values of radii at the noses of both anvils and the deviation of the adjacent supporting surface from the plane of the unworn portions of that surface. The photograph or slices made during successive inspections shall be retained until the anvils are replaced or remachined. The radius at the striking edge of the striker shall be measured in the same manner.

9.1.6 If it becomes necessary to repair the recording system, it shall be recalibrated by setting the pendulum at known elevations before additional tests are made.

9.1.7 If it becomes necessary to replace, repair or adjust any part of the machine other than the recording system, the interlaboratory coordination program for this machine shall be repeated before any further tests to determine reference values are made.

10. Calculation of Results

10.1 Impact energy uncorrected for friction and windage is equal to the difference between the potential energy of the pendulum at the start of the down swing, before the specimen is struck, and that at the end of the up swing, after the specimen is broken.

10.1.1 The pendulum elevation shall be measured by the angle, from the horizontal, of a line from the center of rotation to the center of gravity of the pendulum. Consider positions above the horizontal to have a plus value of angle and position below the horizontal to have a minus value. Therefore:

$$UI = W\,L\,(\mathrm{Sin}\,a - \mathrm{Sin}\,b) \tag{1}$$

where:
- UI = uncorrected impact energy,
- W = weight of pendulum,
- L = distance from center of rotation to the center of gravity of the pendulum,
- a = angle at the start of the down swing, and
- b = angle at the end of the up swing.

10.2 The friction and windage loss per swing is calculated by the formula above using angles measured before and after 11 half-cycles with no specimen in place or:

$$\mathrm{Loss} = W\,L\,(\mathrm{Sin}\,a - \mathrm{Sin}\,b')/11 \tag{2}$$

where:
a is measured before the first down swing and b' after the last upswing, and
Loss = friction and windage loss per half-cycle.
Primes indicate angles during a swing without the specimens in place.

10.3 Impact energy, as used in this practice, is the value calculated by the formula of 10.1.1, minus an amount of the friction and windage loss proportional to the angle of the swing that breaks the specimen, or:

$$I = UI - \mathrm{Loss}\,(180 + a + b)/(180 + a + b') \tag{3}$$

where:
I = impact energy of specimen broken.

All angles are measured in degrees.

10.4 The treatment of outliers among the values of impact energy for a set is in accordance with Practice E 178 using the upper 5 % significance level. The steps in the calculation are summarized as follows.

10.4.1 *Step 1*—List in order of increasing values the impact energy for all specimens in a set, tested in a single machine.

10.4.2 *Step 2*—Calculate the average, $\bar{x}$, which is equal to the sum of all the values in the set divided by the number of specimens tested. The algebraic form is:

$$\bar{x} = (x_1 + x_2 + x_3 + \ldots x_n)/n \tag{4}$$

where:
- x_1 = first value in the set,
- x_2 = second value, etc, and
- n = total number of values in the set.

10.4.3 *Step 3*—Calculate the standard deviation, s, by:

$$s = \sqrt{((x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \ldots + (x_n - \bar{x})^2)/(n-1)} \tag{5}$$

10.4.4 *Step 4*—Calculate the discriminating ratio, T, for the values of impact energy at or near the top and bottom of the list. Continue in the list until the calculated values are less than the allowable value in accordance with Practice E 178, Table on Critical Values for T, for example 2.663 for a set of 25: where:

$$T_1 = |x_1 - \bar{x}|/s,\ T_2 = |x_1 - \bar{x}|/s \ldots \qquad T_n = |x_n - \bar{x}|/s,\ T_{n-1} = |x_{n-1} - \bar{x}|/s \ldots \tag{6}$$

10.4.5 *Step 5*—Examine the broken specimens corresponding to the values of impact energy giving a value of T greater than the allowable value. If physical evidence indicates that any of these specimens are not typical of the majority of the set, the values of those specimens shall be deleted from the list.

10.4.6 *Step 6*—Using the reduced list, recalculate the average and standard deviation and use these values for all subsequent calculations.

10.5 The comparison of machines for significant differences in variability shall be made using the formula given in Practice E 691. These formulas are shown as follows with the simplified notation resulting from considering each material separately. The subscript letters shall now refer to the reference machines; that is, subscript a indicates that the value was calculated from the results of tests made using reference machine A, similarly for b and B, etc.

10.5.1 *Step 1*—Tabulate in columns the machine designation (A, B, etc.), the average of the values of the impact energy, and the standard deviations for tests made on the corresponding

machines. These numbers shall be copied directly from the last iteration of Step 6 in 10.4.6 for each reference machine used.

10.5.2 *Step 2*—Calculate the estimated pooled standard deviation within laboratories, $\bar{s}$, by using the formula:

$$\bar{s} = \sqrt{(s^2\ a + s^2\ b \ldots)/P} \quad (7)$$

where:

P = number of machines being compared.

(Eq 7) shall be used in the typical cases where the number of results utilized is the same for each machine. If this condition is not met, then (Eq 8) shall be used instead:

$$\bar{s} = \sqrt{s^2{}_a(n_a - 1) + s^2{}_b(n_b - 1) + .../(n_a - 1) + (n_b - 1) + \ldots} \quad (8)$$

10.5.3 *Step 3*—Add another column to the table used in 10.5.1 and insert the ratio, k, for each machine. This is equal to the standard deviation for the corresponding machine (already tabulated) divided by the estimated pooled standard deviation between laboratories, or algebraically:

$$k_a = s_a/s,\ k_b = s_b/s, \text{ etc.} \quad (9)$$

10.5.4 *Step 4*—These values of k shall be compared to the critical values in Table 1. The critical values are such that the value for a machine of average variability will show a k value in excess of the critical value only once in 100 trials. Therefore, a k value in excess of the critical value indicates that the machine used may not be a suitable reference machine.

TABLE 1 Critical Values of k_a

Machines, P	Number of Specimens in a Set, n				
	10[A]	15	20	25	30
3	1.38	1.32	1.28	1.25	1.23
6	1.47	1.39	1.33	1.30	1.27
9	1.49	1.41	1.35	1.31	1.28
12	1.51	1.42	1.36	1.32	1.29
15	1.52	1.42	1.37	1.32	1.29

[A] This column is taken directly from the table in Practice E 691. The other columns were obtained by extrapolation of the values in that table.

11. Keywords

11.1 CVN verification program; impact machine; impact reference machine; impact verification