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Contents

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Definitions

STANDARD, *n*	As used in ASTM International, a document that has been developed and established within the consensus principles of the Society and that meets the approval requirements of ASTM procedures and regulations. **Discussion** The term "standard" serves in ASTM International as a nominative adjective in the title of documents, such as test methods or specifications, to connote specified consensus and approval. The various types of standard documents are based on the needs and usages as prescribed by the technical committees of the Society. Definitions for the types of ASTM International standards (classification, guide, practice, specification, terminology, and test method) are quoted below from the current Regulations Governing ASTM Technical Committees. Select the link identifying each type of standard to view a sample. **Note** These documents may only be used by student members for study purposes only, and not for any other distribution, republication, or resale. No further reproduction of these documents, in full or part, without the expressed written permission of ASTM, is authorized.
CLASSIFICATION, *n*	A systematic arrangement or division of materials, products, systems, or services into groups based on similar characteristics such as origin, composition, properties, or use.
GUIDE, *n*	A systematic arrangement or division of materials, products, systems, or services into groups based on similar characteristics such as origin, composition, properties, or use.
PRACTICE, *n*	A definitive set of instructions for performing one or more specific operations that does not produce a test result. **Discussion** Examples of practices include, but are not limited to: application, assessment, cleaning, collection, decontamination, inspection, installation, preparation, sampling, screening, and training.
SPECIFICATION, *n*	An explicit set of requirements to be satisfied by a material, product, system, or service. **Discussion** Examples of specifications include, but are not limited to, requirements for; physical, mechanical, or chemical properties, and safety, quality, or performance criteria. A specification identifies the test methods for determining whether each of the requirements is satisfied.
TERMINOLOGY STANDARD, *n*	A document comprising definitions of terms; explanations of symbols, abbreviations, or acronyms.
TEST METHOD, *n*	A definitive procedure that produces a test result. **Discussion** Examples of test methods include, but are not limited to: identification, measurement, and evaluation of one or more qualities, characteristics, or properties. A precision and bias statement shall be reported

Designation: C143/C143M – 20

Standard Test Method for Slump of Hydraulic-Cement Concrete[1]

This standard is issued under the fixed designation C143/C143M; 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 This test method covers determination of slump of hydraulic-cement concrete, both in the laboratory and in the field.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. Within the text, the SI units are shown in brackets. The values stated in each system are not necessarily exact equivalents; therefore, to ensure conformance with the standard, each system shall be used independently of the other, and values from the two systems shall not be combined.

1.3 The text of this standard refers to notes and footnotes that provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of this standard.

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.* (**Warning**—Fresh hydraulic cementitious mixtures are caustic and may cause chemical burns to skin and tissue upon prolonged exposure.[2])

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:*[3]

C31/C31M Practice for Making and Curing Concrete Test Specimens in the Field

C138/C138M Test Method for Density (Unit Weight), Yield, and Air Content (Gravimetric) of Concrete

C172/C172M Practice for Sampling Freshly Mixed Concrete

C173/C173M Test Method for Air Content of Freshly Mixed Concrete by the Volumetric Method

C231/C231M Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

D638 Test Method for Tensile Properties of Plastics

3. Summary of Test Method

3.1 A sample of freshly mixed concrete is placed and compacted by rodding in a mold shaped as the frustum of a cone. The mold is raised, and the concrete allowed to subside. The vertical distance between the original and displaced position of the center of the top surface of the concrete is measured and reported as the slump of the concrete.

4. Significance and Use

4.1 This test method is intended to provide the user with a procedure to determine slump of plastic hydraulic-cement concretes.

NOTE 1—This test method was originally developed to provide a technique to monitor the consistency of unhardened concrete. Under laboratory conditions, with strict control of all concrete materials, the slump is generally found to increase proportionally with the water content of a given concrete mixture, and thus to be inversely related to concrete strength. Under field conditions, however, such a strength relationship is

[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.60 on Testing Fresh Concrete.

Current edition approved June 1, 2020. Published July 2020. Originally approved in 1922. Last previous edition approved in 2015 as C143/C143M – 15a. DOI: 10.1520/C0143_C0143M-20.

[2] Section on Safety Precautions, Manual of Aggregate and Concrete Testing, *Annual Book of ASTM Standards*, Vol 04.02.

[3] 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**

not clearly and consistently shown. Care should therefore be taken in relating slump results obtained under field conditions to strength.

4.2 This test method is considered applicable to plastic concrete having coarse aggregate up to 1½ in. [37.5 mm] in size. If the coarse aggregate is larger than 1½ in. [37.5 mm] in size, the test method is applicable when it is performed on the fraction of concrete passing a 1½-in. [37.5-mm] sieve, with the larger aggregate being removed in accordance with the section titled "Additional Procedure for Large Maximum Size Aggregate Concrete" in Practice C172/C172M.

4.3 This test method is not considered applicable to non-plastic and non-cohesive concrete.

NOTE 2—Concretes having slumps less than ½ in. [15 mm] may not be adequately plastic and concretes having slumps greater than about 9 in. [230 mm] may not be adequately cohesive for this test to have significance. Caution should be exercised in interpreting such results.

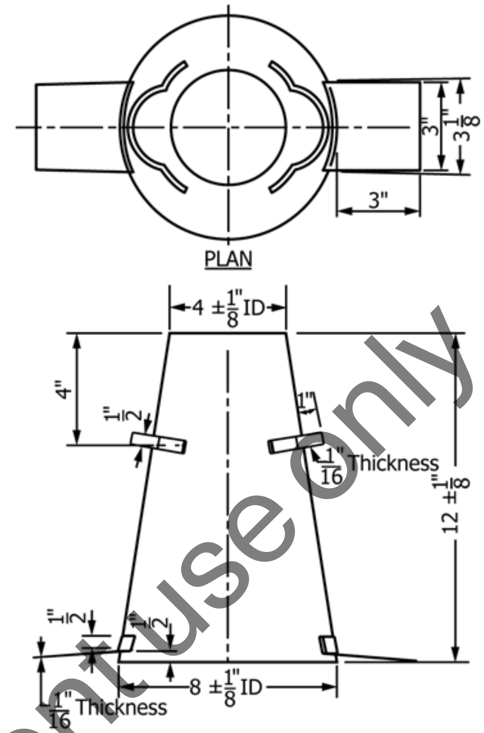
5. Apparatus

5.1 *Mold*—The test specimen shall be formed in a mold made of metal or plastic not readily attacked by the cement paste. The mold shall be sufficiently rigid to maintain the specified dimensions and tolerances during use, resistant to impact forces, and shall be non-absorbent. Metal molds shall have an average thickness of not less than 0.060 in. [1.5 mm] with no individual thickness measurement less than 0.045 in. [1.15 mm]. Plastic molds shall be ABS plastic or equivalent (Note 3) with a minimum average wall thickness of 0.125 in. [3 mm], with no individual thickness measurement less than 0.100 in. [2.5 mm]. The manufacturer or supplier shall certify the materials used in mold construction are in compliance with the requirements of this test method. The mold shall be in the form of the lateral surface of the frustum of a cone with the base 8 in. [200 mm] in diameter, the top 4 in. [100 mm] in diameter, and the height 12 in. [300 mm]. Individual diameters and heights shall be within ±⅛ in. [3 mm] of the prescribed dimensions. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mold shall be provided with foot pieces and handles similar to those shown in Fig. 1. The mold shall be constructed without a seam. The interior of the mold shall be relatively smooth and free from projections. The mold shall be free from dents, deformation, or adhered mortar. A mold which clamps to a nonabsorbent base plate is acceptable instead of the one illustrated, provided the clamping arrangement is such that it can be fully released without movement of the mold and the base is large enough to contain all of the slumped concrete in an acceptable test.

NOTE 3—ABS (Acrylonitrile Butadiene Styrene) plastic exhibits the following minimum mechanical properties:

Tensile modulus of elasticity, at 73 °F [23 °C]	320 000 psi	[2206 MPa]
Tensile strength (Test Method D638)	5670 psi	[39 MPa]
Percent Elongation at Break, at 73 °F [23 °C]	40 %	

5.1.1 Check and record conformance to the mold's specified dimensions when it is purchased or first placed in service and at least annually thereafter. To measure the top diameter, bottom diameter, and height, perform two measurements for each, approximately 90° apart, and record the results of each measurement. To verify mold thickness, perform two measurements approximately 180° apart at 1 ± ½ in. [25 ± 10 mm] from the top of the mold, two measurements approximately 180° apart at 1 ± ½ in. [25 ± 10 mm] from the bottom of the mold, and calculate the average of the four measurements.



Dimensional Units

in.	1⁄16	⅛	½	1	3	3⅛	4	8	12
mm	[2]	[3]	[15]	[25]	[75]	[80]	[100]	[200]	[300]

FIG. 1 Mold for Slump Test

5.2 *Tamping Rod*—A round, smooth, straight steel rod, with a ⅝ in. [16 mm] ± 1⁄16 in. [2 mm] diameter. The length of the tamping rod shall be at least 4 in. [100 mm] greater than the depth of the mold in which rodding is being performed, but not greater than 24 in. [600 mm] in overall length (Note 4). The rod shall have the tamping end or both ends rounded to a hemispherical tip of the same diameter as the rod.

NOTE 4—A rod length of 16 in. [400 mm] to 24 in. [600 mm] meets the requirements of the following: Practice C31/C31M, Test Method C138/C138M, Test Method C143/C143M, Test Method C173/C173M, and Test Method C231/C231M.

5.3 *Measuring Device*—A ruler, metal roll-up measuring tape, or similar rigid or semi-rigid length measuring instrument marked in increments of ¼ in. [5 mm] or smaller. The instrument length shall be at least 12 in. [300 mm].

5.4 *Scoop*—of a size large enough so each amount of concrete obtained from the sampling receptacle is representative and small enough so it is not spilled during placement in the mold.

6. Sample

6.1 The sample of concrete from which test specimens are made shall be representative of the entire batch. It shall be obtained in accordance with Practice C172/C172M.

7. Procedure

7.1 Dampen the mold and place it on a rigid, flat, level, moist, nonabsorbent surface, free of vibration, and that is large enough to contain all of the slumped concrete. It shall be held firmly in place during filling and perimeter cleaning by the operator standing on the two foot pieces or by a clamping arrangement to a base plate as described in 5.1. From the sample of concrete obtained in accordance with Section 6, immediately fill the mold in three layers, each approximately one third the volume of the mold (See Note 5). Place the concrete in the mold using the scoop described in 5.4. Move the scoop around the perimeter of the mold opening to ensure an even distribution of the concrete with minimal segregation.

NOTE 5—One third of the volume of the slump mold fills it to a depth of 2⅝ in. [70 mm]; two thirds of the volume fills it to a depth of 6⅛ in. [160 mm].

7.2 Rod each layer 25 times uniformly over the cross section with the rounded end of the rod. For the bottom layer, this will necessitate inclining the rod slightly and making approximately half of the strokes near the perimeter, and then progressing with vertical strokes spirally toward the center. Rod the bottom layer throughout its depth. For each upper layer, allow the rod to penetrate through the layer being rodded and into the layer below approximately 1 in. [25 mm].

7.3 In filling and rodding the top layer, heap the concrete above the mold before rodding is started. If the rodding operation results in subsidence of the concrete below the top edge of the mold, add additional concrete to keep an excess of concrete above the top of the mold at all times. After the top layer has been rodded, strike off the surface of the concrete by means of a screeding and rolling motion of the tamping rod. Continue to hold the mold down firmly and remove concrete from the area surrounding the base of the mold to preclude interference with the movement of slumping concrete. Remove the mold immediately from the concrete by raising it carefully in a vertical direction. Raise the mold a distance of 12 in. [300 mm] in 5 ± 2 s by a steady upward lift with no lateral or torsional motion. Complete the entire test from the start of the filling through removal of the mold without interruption and complete it within an elapsed time of 2½ min.

7.4 Immediately measure the slump by determining the vertical difference between the top of the mold and the displaced original center of the top surface of the specimen. If a decided falling away or shearing off of concrete from one side or portion of the mass occurs (Note 6), disregard the test and make a new test on another portion of the sample.

NOTE 6—If two consecutive tests on a sample of concrete show a falling away or shearing off of a portion of the concrete from the mass of the specimen, the concrete probably lacks necessary plasticity and cohesiveness for the slump test to be applicable.

8. Report

8.1 Report the slump in terms of inches [millimetres] to the nearest ¼ in. [5 mm] of subsidence of the specimen during the test.

9. Precision and Bias[4]

9.1 *Precision*—The estimates of precision for this test method are based upon results from tests conducted in Fayetteville, Arkansas by 15 technicians from 14 laboratories representing 3 states. All tests at 3 different slump ranges, from 1.0 in. [25 mm] to 6.5 in. [160 mm], were performed using one load of truck-mixed concrete. The concrete was delivered and tested at a low slump, with water then being added and mixed into the remaining concrete to independently produce moderate and finally high-slump concrete. The concrete mixture that used a No. 67 crushed limestone aggregate and a washed river sand, contained 500 lb of cementitious materials per cubic yard [297 kg of cementitious material per cubic metre]. The 500 lb [227 kg] were equally divided between a C150, Type I/II cement and a Class C fly ash. A double dosage of a chemical retarder was used in an attempt to minimize slump losses and maintain workability of the concrete. Concrete temperatures ranged from 86 to 93 °F [30 to 34 °C]. Slump losses averaged 0.68 in. [17 mm] during the 20 min required to perform a series of 6 tests at 1 slump range. Testing was performed alternately using metal and plastic molds, which were determined to produce comparable results. Precision data thus applies to both metal and plastic molds. A total of 270 slump tests were performed.

9.1.1 *Inch-Pound [SI]*—The data used to develop the precision statement were obtained using metric units (millimetres). The precision values shown in inch-pound units are conversions from the millimetre measurements, which were recorded to the nearest 1 mm.

9.1.2 *Measure of Variability*—The standard deviation was determined to be the most consistent measure of variability and was found to vary with the slump value.

9.1.3 *Single-Operator Precision*—The single-operator standard deviation represented by (1s) is shown in Table 1 by

[4] The test data used to develop this precision statement were based on tests performed in September 1997. Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:C09-1022. Contact ASTM Customer Service at service@astm.org.

TABLE 1 Precision

Slump and Type Index	Standard Deviation (1s)[A]		Acceptable Range of Two Results (d2s)[A]	
Single-Operator Precision:	in.	[mm]	in.	[mm]
Slump 1.2 in. [30 mm]	0.23	[6]	0.65	[17]
Slump 3.4 in. [85 mm]	0.38	[9]	1.07	[25]
Slump 6.5 in. [160 mm]	0.40	[10]	1.13	[28]
Multilaboratory Precision:				
Slump 1.2 in. [30 mm]	0.29	[7]	0.82	[20]
Slump 3.4 in. [85 mm]	0.39	[10]	1.10	[28]
Slump 6.5 in. [160 mm]	0.53	[13]	1.50	[37]

[A] These numbers represent, respectively, the (1s) and (d2s) limits as described in Practice C670.

average slump values. The reported results for the replicate readings apply to tests conducted by the same operator performing successive tests, one immediately following the other. Acceptable results of two properly conducted tests by the same operator on the same material (Note 7) will not differ from each other by more than the (d2s) value of the last column of Table 1 for the appropriate slump value and single-operator precision.

9.1.4 *Multilaboratory Precision*—The multilaboratory standard deviation represented by (1s) is shown in Table 1 by average slump values. The reported results for the replicate readings apply to tests conducted by different operators from different laboratories performing tests less than 4 min apart. Therefore, acceptable results of two properly conducted slump tests on the same material (Note 7) by two different laboratories will not differ from each other by more than the (d2s) value of the last column of Table 1 for the appropriate slump value and multilaboratory precision.

NOTE 7—"Same materials," is used to mean freshly mixed concrete from one batch.

9.2 *Bias*—This test method has no bias since slump is defined only in terms of this test method.

10. Keywords

10.1 concrete; concrete slump; cone; consistency; plasticity; slump; workability

SUMMARY OF CHANGES

Committee C09 has identified the location of selected changes to this standard since the last issue (C143/C143M – 15a) that may impact the use of this standard. (Approved June 1, 2020.)

(1) Revised 1.3.

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: C155 – 97 (Reapproved 2022)

Standard Classification of Insulating Firebrick[1]

This standard is issued under the fixed designation C155; 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.

1. Scope

1.1 This classification covers heat-insulating material known as insulating firebrick. This material is suitable for lining certain kinds of industrial furnaces.

NOTE 1—Insulating materials for use below 1000 °F (538 °C) are covered[2] by ASTM Committee C16 on Thermal Insulation.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *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]

C134 Test Methods for Size, Dimensional Measurements, and Bulk Density of Refractory Brick and Insulating Firebrick

C210 Test Method for Reheat Change of Insulating Firebrick

3. Significance and Use

3.1 This classification establishes an orderly grouping of insulating firebrick to provide group identifications for use by those producing or purchasing these materials. The group identification number is not meant to specifically designate the maximum service temperature, although the number times 100 does approximate the temperature (in degrees Fahrenheit) to be used to check the reheat change and can be used as a guide for relative temperature stability. The bulk density limits the weight per unit volume for any group as sold, but is not meant to be used for detailed engineering calculations.

4. Basis of Classification

4.1 The classification of insulating firebrick in accordance with Table 1 is based on bulk density (weight per cubic foot) and the behavior in the reheat change test conducted at the specified temperature.

5. Test Methods

5.1 The properties enumerated in this classification shall be determined in accordance with the following ASTM test methods:

5.1.1 *Bulk Density*—Test Methods C134.

5.1.2 *Reheat Change*—Test Method C210. For the purpose of this classification, the percentage of reheat change shall be obtained from only the 9 in. (228 mm) dimension of the test brick.

6. Retests

6.1 Because of variables resulting from sampling and the lack of satisfactory reproducibility in tests conducted by different laboratories, the material may be resampled and retested when requested by either the manufacturer or the purchaser. This may apply in instances when the first test results do not conform to the requirements prescribed in this classification. The final results to be used shall be the average of at least two sets of results, each of which has been obtained by following in detail the specified testing procedures.

7. Keywords

7.1 bulk density; insulating firebrick; refractories; reheat change

[1] This classification is under the jurisdiction of ASTM Committee C08 on Refractories and is the direct responsibility of Subcommittee C08.92 on The Joseph E. Kopanda Subcommittee for Editorial, Terminology and Classification.

Current edition approved Sept. 1, 2022. Published September 2022. Originally approved in 1940. Last previous edition approved in 2018 as C155 – 97 (2018). DOI: 10.1520/C0155-97R22.

[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.

TABLE 1 Grouping of Insulating Firebrick

Group No.	Reheat Change, Not More Than 2 % When Tested at °F (°C)	Bulk Density Not Greater Than lb/ft³ (g/cm³)
16	1550 (845)	34 (0.54)
20	1950 (1065)	40 (0.64)
23	2250 (1230)	48 (0.77)
26	2550 (1400)	54 (0.86)
28	2750 (1510)	60 (0.96)
30	2950 (1620)	68 (1.09)
32	3150 (1730)	95 (1.52)
33	3250 (1790)	95 (1.52)

Designation: E650/E650M – 24

Standard Guide for Mounting Piezoelectric Acoustic Emission Sensors[1]

This standard is issued under the fixed designation E650/E650M; 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.

1. Scope*

1.1 This guide covers guidelines for mounting piezoelectric acoustic emission (AE) sensors.

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *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.*

1.4 *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]

E976 Guide for Determining the Reproducibility of Acoustic Emission Sensor Response

E1316 Terminology for Nondestructive Examinations

3. Terminology

3.1 *Definitions:*

3.1.1 General terminology related to acoustic emission is defined in Terminology E1316, Section B: Acoustic Emission (AE) terms.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bonding agent, n*—a couplant that physically attaches the sensor to the structure.

3.2.2 *couplant, n*—a material used at the structure-to-sensor interface to improve the transfer of acoustic energy across the interface.

3.2.3 *mounting fixture, n*—a device that holds the sensor in place on the structure to be monitored.

3.2.4 *sensor, n*—a detection device that transforms the particle motion produced by an elastic wave into an electrical signal.

3.2.5 *waveguide, acoustic, n*—a device that couples acoustic energy from a structure to a remotely mounted sensor; for example, a solid wire or rod, coupled to a sensor at one end and to the structure at the other.

4. Significance and Use

4.1 The methods and procedures used in mounting AE sensors can have significant effects upon the performance of those sensors. Optimum and reproducible detection of AE requires both appropriate sensor-mounting fixtures and consistent sensor-mounting procedures.

5. Mounting Methods

5.1 The purpose of the mounting method is to hold the sensor in a fixed position on a structure and to ensure that the acoustic coupling between the sensor and the structure is both adequate and constant. Mounting methods will generally fall into one of the following categories:

5.1.1 *Compression Mounts*—The compression mount holds the sensor in intimate contact with the surface of the structure through the use of force. This force is generally supplied by springs, torqued-screw threads, magnets, tape, or elastic bands. The use of a couplant is strongly advised with a compression mount to maximize the transmission of acoustic energy through the sensor-structure interface.

5.1.2 *Bonding*—The sensor may be attached directly to the structure with a suitable adhesive. In this method, the adhesive acts as the couplant. The adhesive must be compatible with the structure, the sensor, the environment, and the examination procedure.

[1] This guide is under the jurisdiction of ASTM Committee E07 on Nondestructive Testing and is the direct responsibility of Subcommittee E07.04 on Acoustic Emission Method.

Current edition approved Dec. 1, 2024. Published January 2025. Originally approved in 1985. Last previous edition approved in 2017 as E650 – 17. DOI: 10.1520/E0650-24.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at www.astm.org/contact. 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**

6. Mounting Requirements

6.1 *Sensor Selection*—The correct sensors should be chosen to optimally accomplish the AE examination objective. Selection parameters to be considered are as follows: size, sensitivity, frequency response, surface-motion response, environmental compatibility, background noise, source location requirements, and material properties of the structure under examination. When a multichannel acoustic-emission examination is being conducted, a subset of sensors with characteristics similar to each other should be selected. See Guide E976 for methods of comparing sensor characteristics.

6.1.1 If the examination objective is to include AE source location, sensor selection may be governed by the material properties of the structure and may affect subsequent sensor spacing due to attenuation. It may be necessary to evaluate attenuation effects as part of the pre-examination procedure. If performed, the attenuation data shall be retained as part of the experimental record.

6.1.2 When a multichannel acoustic-emission examination is being conducted, a subset of sensors with characteristics similar to each other should be selected. See Guide E976 for methods of comparing sensor characteristics.

6.2 *Structure Preparation*—The contacting surfaces should be cleaned and mechanically prepared. This will enhance the detection of the desired acoustic waves by assuring reliable coupling of the acoustic energy from the structure to the sensor. Preparation of these surfaces must be compatible with the construction materials used in both the sensor and the structure. Possible losses in acoustic energy transmission caused by coatings such as paint, encapsulants, loose-mill scale, weld spatter, and oxides as well as losses due to surface curvature at the contact area must be considered.

6.2.1 The location of each sensor should be measured and marked accordingly on the structure and recorded as part of the examination record.

6.2.2 If surface preparation requires removing paint from a metal surface, the paint may be removed with a grinder or other mechanical means, down to bare metal. The area of paint removal should be slightly larger than the diameter of the sensor. If the metal surface is smooth, sandpaper may be used to roughen the surface prior to bonding.

6.2.2.1 After paint removal, the surface should be cleaned with a degreaser and wiped clean with a cloth.

6.2.2.2 If corrosion is present on the structure, additional cleaning may include using a conditioner (mild acid) and neutralizer to minimize potential corrosion beneath the sensor after mounting.

6.2.2.3 If the structure is located in a marine environment, soluble salts (for example, chlorides, nitrates, sulfates) may still reside on the steel surface even after cleaning. These types of salts attract moisture from the air, and may result in additional corrosion beneath the sensor and failure of the bond. As such, a liquid soluble salt remover is recommended as an additional step in surface preparation prior to sensor mounting.

6.3 *Couplant or Bonding Agent Selection:*

6.3.1 The type of couplant or bonding agent should be selected with appropriate consideration for the effects of the environment (for example, temperature, pressure, composition of gas, or liquid environment) on the couplant and the constraints of the application. It should be chemically compatible with the structure and not be a possible cause of corrosion. In some cases, it may be a requirement that the couplant be completely removable from the surface after examination. In general, the selection of the couplant is as important from an environmental standpoint as it is from the acoustical standpoint.

6.3.2 For sensors that are primarily sensitive to particle motion perpendicular to their face, the viscosity of the couplant is not an important factor. Most liquids or greases will work as a couplant if they wet the surfaces of both the structure and the sensor. For those few sensors which are sensitive primarily to motion in the plane of their face, a very high-viscosity, shear type couplant or a rigid bond is recommended.

6.3.2.1 Testing has shown that in most cases, when working at frequencies below 500 kHz, most couplants will suffice. However, due to potential loss of high frequency (HF) spectra when working above 500 kHz, a low viscosity couplant or rigid bond, relative to sensor motion response, is recommended. Additionally, when spectral response above 500 kHz is needed, it is recommended that FFT be performed to verify adequacy of HF response.

6.3.3 The thickness of the couplant may alter the effective sensitivity of the sensor. The thinnest practical layer of continuous couplant is usually the best. Care should be taken that there are no entrapped voids in the couplant. Unevenness, such as a taper from one side of the sensor to the other, can also reduce sensitivity or produce an unwanted directionality in the sensor response.

6.3.4 A useful method for applying a couplant is to place a small amount of the material in the center of the sensor face, then carefully press the sensor on to the structure surface, spreading the couplant uniformly from the center to the outside of the sensor face. Typically, this will result in a small band (fillet) of couplant around the outside circumference of the sensor.

6.3.5 In some applications, it may be impractical to use a couplant because of the nature of the environment (for example, very high temperatures or extreme cleanliness requirements). In these situations, a dry contact may be used, provided sufficient mechanical force is applied to hold the sensor against the structure. The necessary contact pressure must be determined experimentally by comparing the sensor response with and without couplant. As a rough guide, this pressure should exceed 0.7 MPa [100 psi].

6.3.6 Great care must be taken when bonding a sensor to a structure. Surface deformation, that can be produced by either mechanical loading or thermal expansion, may cause a bond to crack, peel off, or, occasionally, destroy the sensor. Bond cracking is a source of acoustic emission. A pliant adhesive may work better in some cases. If differential expansion between the sensor, the bond, and the surface is a possibility, a suitable bonding agent should be confirmed by experiment.

6.3.7 When bonding agents are used, the possibility of damaging either the sensor or the surface of the structure during sensor removal must be considered.

6.3.7.1 To minimize damage to the sensor during removal, any excess bonding agent may be gently removed from around the base of the sensor using a small chisel and hammer or mallet. Place a small block of wood, or the handle of the chisel, at the base of the sensor. Using a hammer or mallet gently tap the side of the block or handle to generate a shear force at the base of the sensor to break the bond. Attempting to pry or twist off the sensor by hand, or striking the side of the sensor at the top will often cause the ceramic face or wear plate of the sensor to debond from the sensor housing and destroy the sensor.

6.3.7.2 Any bonding agent remaining on the face of the sensor after removal may be gently chipped off or removed with a grinder at low speed to avoid damage to the wear plate.

6.3.8 The use of double-sided adhesive tape as a bonding agent is not recommended.

6.3.9 Hot melt glue is not recommended if the spectral frequencies of interest are above 200 kHz due to response falloff.[3]

6.4 *Mounting Fixture Selection:*

6.4.1 Mounting fixtures must be constructed so that they do not create extraneous acoustic emission or mask valid acoustic emission generated in the structure being monitored.

6.4.1.1 The mount must not contain any loose parts of particles.

6.4.1.2 Permanent mounting may require special techniques to prevent sensor movement caused by environmental changes.

6.4.1.3 Detection of surface waves may be suppressed if the sensor is enclosed by a welded-on fixture or located at the bottom of a threaded hole. The mounting fixture should always be designed so that it does not block out a significant amount of acoustic energy from any direction of interest.

6.4.2 The mounting fixture should provide support for the signal cable to prevent the cable from stressing the sensor or the electrical connectors. In the absence of a mounting fixture, some form of cable support should be provided. Care should be taken to ensure that the cable can neither vibrate nor be moved easily. False signals may be generated by the cable striking the structure and by triboelectric effects produced by cable movement.

6.4.3 Where necessary, protection from the environment, such as encapsulation, should be provided for the sensor or sensor and mounting fixture.

6.4.4 The mounting fixture should not affect the integrity of the structure being monitored.

6.4.4.1 Permanently installed mounting fixtures must be constructed of a material compatible with the structure. Possible electrolytic effects or other forms of corrosion must be considered when designing the mounting fixture.

6.4.4.2 Alterations of the local environment by the mount, such as removal of the insulation, must be carefully evaluated and corrected if necessary.

6.4.5 The mounting fixture should be designed to have a minimal effect on the response characteristics of the sensor.

6.4.6 Mounting fixtures and waveguides should be designed to provide isolation of the sensor case from the fixture or waveguide that is in contact with the structure to avoid grounding the sensor to the structure ground, especially those sensors that use an isolated sensor face (for example, epoxy or ceramic face). Failure to isolate the sensor will result in a ground loop and will create a significant amount of electrical noise in the AE system and may mask detection of the AE activity of interest.

6.5 *Waveguides*—When adverse environments make direct contact between the sensor and the structure undesirable, an acoustic waveguide may be used to transmit the acoustic signal from the structure to the sensor. The use of a waveguide adds another boundary transition with its associated losses between the structure and the sensor, and will distort, to some degree, the characteristics of the acoustic wave.

6.5.1 An acoustic waveguide should be mounted to ensure that its surface will not contact any materials that will cause signal damping in the waveguide.

6.5.2 If acoustic waveguides are used when acoustic-emission source location is being performed, the extra time delay in the waveguides must be accounted for in the source location program.

7. Verification of Response

7.1 After the sensor(s) is mounted on a structure, adequate response should be verified by injecting acoustic signals into the structure and examining the detected signal either on a digital waveform recorder or with the AE system to be used in the examination. If there is any doubt as to the sensor response, the sensor should be remounted.

7.1.1 The test signal may be injected by an external source such as the Hsu-pencil source, or a gas jet (helium or other suitable gas), or by applying an electrical pulse to another sensor mounted on the structure. For a description of these methods see Guide E976.

7.2 *Periodic Verification*—On an extended acoustic emission examination, it may be desirable to verify the response of the sensors during the examination. Verification should be performed whenever circumstances indicate the possibility of a change in the coupling efficiency.

7.3 *Post Verification*—At the end of an acoustic emission examination, it is standard practice to verify that all sensors are still working and that there have been no dramatic changes in coupling efficiencies.

8. Report

8.1 Any report of the mounting practice should include details of the sensor mounting fixture(s), surface preparation method, and the couplant that was used.

9. Keywords

9.1 acoustic emission; acoustic emission sensors; acoustic emission transducers; AE; bonding agent; couplant; mounting fixture; waveguide

[3] Wu, B.S., McLaskey, G.C., "Broadband Calibration of Acoustic Emission and Ultrasonic Sensors from Generalized Ray Theory and Finite Element Models," *Journal of Nondestructive Evaluation*, 37:8, 2018, https://doi.org/10.1007/s10921-018-0462-8. See figure 10 and related text.

SUMMARY OF CHANGES

Committee E07 has identified the location of selected changes to this standard since the last issue (E650 – 17) that may impact the use of this standard. (Approved Dec. 1, 2024)

(1) Updated Terminology Section 3 to be compliant with form and style. Also rearranged the sections to be consistent across other AE standards.
(2) Added "shear type" after "high viscosity" in 6.3.2 to provide better clarification and guidance.
(3) Added clarification in 6.3.5 that contact pressure needs to be determined experimentally by comparing response with and without couplant.
(4) Added clarification in 6.3.6 for using a pliant adhesive when bond cracking is a concern.
(5) Added clarification that hot-melt glue is not recommended for spectral frequencies above 200 kHz in 6.3.9 and added reference in footnote 3.
(6) Replaced "oscilloscope" with "digital waveform recorder" in 7.1.
(7) Changed "good" to "standard" in 7.3.

INTERNATIONAL

Designation: E1778 – 98a (Reapproved 2024)

Standard Terminology Relating to Pavement Distress[1]

This standard is issued under the fixed designation E1778; 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.

1. Scope

1.1 This terminology provides definitions for pavement distress for airfields, highways, roads, streets, and parking lots of all functional classifications.

1.2 This terminology covers surfaces paved with either bituminous or portland cement concrete. It does not include other paved or unpaved surfaces.

1.3 This terminology includes most of the significant types of pavement surface distresses, but it is not all inclusive.

1.4 Not all distresses noted are applicable to all pavement categories listed in 1.1.

1.5 Severity levels are not addressed in this terminology but are addressed in other ASTM test methods and practices (for example, Test Method D5340). However, a knowledge of severity levels is required for evaluating many of the distresses defined in this terminology.

1.6 *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]

D5340 Test Method for Airport Pavement Condition Index Surveys

3. Terminology

GENERAL

bituminous pavement, *n*—a pavement comprising an upper layer or layers of aggregate mixed with a bituminous binder, such as asphalt, coal tars, and natural tars for purposes of this terminology; surface treatments such as chip seals, slurry seals, sand seals, and cape seals are also included.

continuously reinforced concrete pavement (CRCP), *n*—portland cement concrete pavement with sufficient longitudinal steel reinforcement to control transverse crack spacings and openings in lieu of transverse contraction joints for accommodating concrete volume changes and load transfer.

crack, *n*—fissure or discontinuity of the pavement surface not necessarily extending through the entire thickness of the pavement.

depression, *n*—localized pavement surface areas at a lower elevation than the adjacent paved areas.

free edge, *n*—an unrestrained pavement boundary.

joint, *n*—a discontinuity made necessary by design or by interruption of a paving operation.

joint seal deterioration, *n*—any condition which enables incompressible materials or water to infiltrate into a previously sealed joint from the surface.

Discussion—Ability to prevent water infiltration is an attribute that cannot always be readily determined visually.

jointed concrete pavement (JCP), *n*—portland cement concrete pavement that has transverse joints placed at planned intervals.

lane-to-shoulder dropoff, *n*—(*highways, roads and streets only*) difference in elevation between the traveled surface and the shoulder surface.

longitudinal cracking, *n*—cracks in the pavement predominantly parallel to the direction of traffic.

pavement distress, *n*—external indications of pavement defects or deterioration.

portland cement concrete pavement, *n*—a pavement having a surface of aggregate mixed with portland cement paste binder or a mixture of portland cement and other pozzolans.

pumping, *n*—ejection of liquid or solid material or both from beneath the pavement through a crack or joint.

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[1] This terminology is under the jurisdiction of ASTM Committee E17 on Vehicle - Pavement Systems and is the direct responsibility of Subcommittee E17.42 on Pavement Management and Data Needs.

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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.

shoving, *n*—the horizontal displacement of a localized area of the pavement surface which may also include some vertical displacement.

Discussion—Generally associated with turning, braking or accelerating vehicles. Can also be due to concrete expansion against adjacent bituminous pavement.

slippage cracking, *n*—cracking associated with the horizontal displacement of a localized area of the pavement surface.

swell, *n*—a hump in the pavement surface that may occur over a small area or as a longer, gradual wave; either type of swell can be accompanied by surface cracking.

transverse cracking, *n*—cracks in the pavement that are predominantly perpendicular to the direction of traffic.

BITUMINOUS PAVEMENT DISTRESSES

alligator (crocodile) cracking, *n*—interconnected or interlaced cracks forming a pattern which resembles an alligator's hide.

bituminous bleeding, *n*—excess bitumen on the surface of the pavement, usually found in the wheel paths.

block cracking, *n*—a pattern of cracks that divide the pavement into approximately rectangular pieces, ranging in size from approximately 0.1 m^2 to 1.0 m^2 (1 ft^2 to 100 ft^2).

corrugation, *n*—transverse undulations at regular intervals in the surface of the pavement consisting of alternate valleys and crests not more than 1 m (3 ft) apart.

edge cracking, *n*—crescent-shaped cracks or fairly continuous cracks that are located within 0.6 m (2 ft) of the pavement edge.

jet-blast erosion, *n*—(*airfields only*) darkened areas on the pavement surface where bituminous binder has been burned or carbonized; localized burned areas may vary in depth up to approximately 15 mm (½ in.).

oil spillage, *n*—a localized deterioration or softening of the pavement surface caused by the spilling of oil, fuel, or other solvents.

polished aggregate, *n*—exposed aggregate worn sufficiently smooth to affect frictional characteristics.

potholes, *n*—bowl-shaped holes in the pavement surface, greater than 0.1 m (4 in.) in diameter, and more than 25 mm (1 in.) in depth.

raveling, *n*—loss of pavement surface material involving the dislodging of aggregate particles and degradation of the bituminous binder.

reflection cracking at joints, *n*—cracks in bituminous overlay surfaces that occur over concrete pavements at joints.

rut, *n*—a contiguous longitudinal depression deviating from a surface plane defined by transverse cross slope and longitudinal profile.

PORTLAND CEMENT CONCRETE PAVEMENT SURFACE DISTRESSES

blowups, *n*—localized upward movement of the pavement surface at transverse joints or cracks, often accompanied with shattering of the concrete in that area.

corner breaks, *n*—(*JCP only*) a portion of the slab separated by a crack that intersects the adjacent transverse and longitudinal joints, describing approximately a 45 degree angle with the direction of traffic where the length of the sides is from 0.3 m (1 ft) to one half the width of the slab.

durability "D" cracking, *n*—closely spaced crescent-shaped hairline cracking pattern that initiates adjacent to joints, cracks, or free edges, first manifesting itself at the intersection of joints, cracks or free edges; dark coloring of the cracking pattern and surrounding area often exists with "D" cracking.

faulting of joints and cracks, *n*—difference in elevation across a joint or crack.

joint spalling, *n*—cracking, breaking, or chipping of concrete pavement edges within 0.6 m (2 ft) of a joint.

lane-to-shoulder separation, *n*—(*highways, roads and streets only*) widening of the joint between the edge of the slab and the shoulder.

map cracking, *n*—a series of interconnected cracks that extend only into the upper portion of the slab.

patch, *n*—a portion of pavement surface which has been replaced or where additional material has been applied to the pavement after original construction.

popouts, *n*—small holes in the pavement surface, normally ranging in diameter from 25 mm (1 in.) to 100 mm (4 in.) and depth from 13 mm (0.5 in.) to 50 mm (2 in.).

pumping, *n*—ejection of water, material, or both from beneath the pavement through a crack or joint.

Discussion—The mechanism for ejection is not necessarily limited to traffic loading.

punchouts, *n*—a broken area of a concrete slab bounded by closely spaced cracks (usually less than 1 m (3 ft)).

scaling, *n*—the deterioration of the upper concrete slab surface, normally 3 mm (0.125 in.) to 13 mm (0.5 in.) in depth, resulting in the loss of surface mortar.

transverse construction joint deterioration, *n*—(*CRCP only*) series of closely spaced transverse cracks or a large number of interconnecting cracks occurring near a construction joint.

4. Significance and Use

4.1 This terminology provides a reference for defining pavement distress types regardless of the ultimate intended use for the data or the amount, or both, of pavement to be surveyed.

4.2 This terminology may be used with both manual and automated distress surveys. The terminology will allow equipment manufacturers to develop automated methodologies that will help address the needs of agencies at all levels of government, based on a common set of definitions, while at the same time being readily adaptable for use with manual surveying.

4.3 This terminology will allow agencies to identify and define pavement distresses in the same terms. Similarly, it allows agencies at the same level to discuss and compare pavement surface distresses using common terms.

4.4 There are many different uses for distress surveys; however, from an engineering point of view, the purpose for conducting these surveys may include one or more of the following:

4.4.1 Describe present pavement condition,

4.4.2 Predict future pavement condition (deterioration curves),

4.4.3 Identify current and future pavement maintenance and construction needs,

4.4.4 Facilitate pavement maintenance and construction programming,

4.4.5 Determine effectiveness of alternative treatments,

4.4.6 Select maintenance treatment,

4.4.7 Identify needed spot improvements, and

4.4.8 Develop maintenance and construction quantity estimates.

5. Hazards

5.1 The collection of pavement distress information is a hazardous activity generally conducted in the presence of operational traffic. If the facility is closed for inspection, all regulatory and professional practice standards must be applied to provide traffic protection and traffic control for those personnel in the work zone.

5.2 If the data are collected using an automated device that travels at highway speeds, this activity should also be conducted in accordance with appropriate local and national regulatory methods and safety procedures. Appropriate adherence to traffic laws, common driving practices, and safety measures is essential.

5.3 Traffic is a hazard to inspectors who must walk on the pavement to perform manual condition surveys. Inspection must be approved by and coordinated with the local authority.

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INTERNATIONAL

Designation: F1163 – 23

An American National Standard

Standard Specification for Protective Headgear Used in Horse Sports and Horseback Riding[1]

This standard is issued under the fixed designation F1163; 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

Horse sports and horseback riding are sports with intrinsic hazards. It is recognized that it is not possible to write a protective headgear performance standard that will result in headgear that can protect against injury or death in all accidents. It is also recognized that serious injury or death can result from both low-energy and high-energy impacts, even when protective headgear is worn. It is further recognized that protective headgear must be acceptable to the user and to the regulating associations or agencies requiring its use. Acknowledging these limitations, this specification was developed using resources in medical, scientific, mechanical engineering, human factors, and biomechanical fields.

This specification incorporates many aspects of other recognized headgear performance standards. This specification draws from work done by others where appropriate for this specification. These standards may be referenced. It should be noted that this specification specifies a laboratory test of completed headgear to measure its ability to reduce head acceleration when impacting various shaped objects. It is known that headgear that performs well under this specification will mitigate head injury in actual use within its design limits.

1. Scope

1.1 This specification covers minimum performance criteria and describes test methods for protective headgear for use in horse sports and horseback riding.

1.2 It is not the intention of this specification to bar from consideration materials of improved quality or performance not known at the time of development of this specification.

1.3 All testing and requirements of this specification shall be in accordance with Test Methods F1446, except where noted herein.

1.4 The values stated in SI units are to be regarded as the standard.

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

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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 Document

2.1 *ASTM Standards:*[2]

F1446 Test Methods for Equipment and Procedures Used in Evaluating the Performance Characteristics of Protective Headgear

F2220 Specification for Headforms

3. Terminology

3.1 *Definitions*—The terms used in this specification are defined in accordance with Test Methods F1446.

[1] This specification is under the jurisdiction of ASTM Committee F08 on Sports Equipment, Playing Surfaces, and Facilities and is the direct responsibility of Subcommittee F08.53 on Headgear and Helmets.

Current edition approved Jan. 1, 2023. Published February 2023. Originally approved in 1988. Last previous edition approved in 2015 as F1163 – 15. DOI: 10.1520/F1163-23.

[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.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *cradle, n*—headband or other head-fitting device and those internal parts of the headgear in contact with the head.

3.2.2 *drawlace, n*—lace used for making adjustments to the fit of the cradle on the wearer's head.

4. Headforms

4.1 Headforms to be used in this specification are in accordance with the section on Apparatus of Test Methods F1446. The appropriate size headform shall be selected (see definition of headform size selection in the Terminology section of Test Methods F1446) for the helmet to be tested.

4.2 Test headforms used in this specification shall use the variable mass drop assembly configuration for impact testing as specified in the definition of test headforms in the terminology section and in Table 2 of Test Methods F1446.

5. Anvils and Impact Velocities

5.1 Anvils to be used for impact tests in this specification are the flat anvil described in the section and figure on Flat Anvil of Test Methods F1446, and the equestrian hazard anvil described in Fig. 1 of this specification. The circular portion of the equestrian hazard anvil shall have a radius of 66.7 ± 0.5 mm, with facial surfaces inclined at an angle of 45 ± 2°. The edge rail at the intersection of the facial surfaces shall have a radius of 0.4 mm maximum.

5.2 The helmet shall be dropped onto the flat anvil from a theoretical drop height of 1.8 m to achieve an impact velocity of 6.0 m/s ± 3 %.

5.3 The helmet shall be dropped onto the equestrian hazard anvil from a theoretical drop height of 1.3 m to achieve an impact velocity of 5.0 m/s ± 3 %.

5.4 The impact velocity shall be measured during the last 40 mm of free-fall for each test and shall be within ±3 % of the velocities specified in 5.2 and 5.3.

6. General Requirements and Marking

6.1 Select the appropriate reference headform in accordance with the definition of headform size selection in the Terminology section of Test Methods F1446.

6.2 Position the helmet in accordance with the section on Test Procedures of Test Methods F1446.

6.3 All helmets shall meet the requirements of the sections on Configuration, Materials, and Internal Projection of Test Methods F1446.

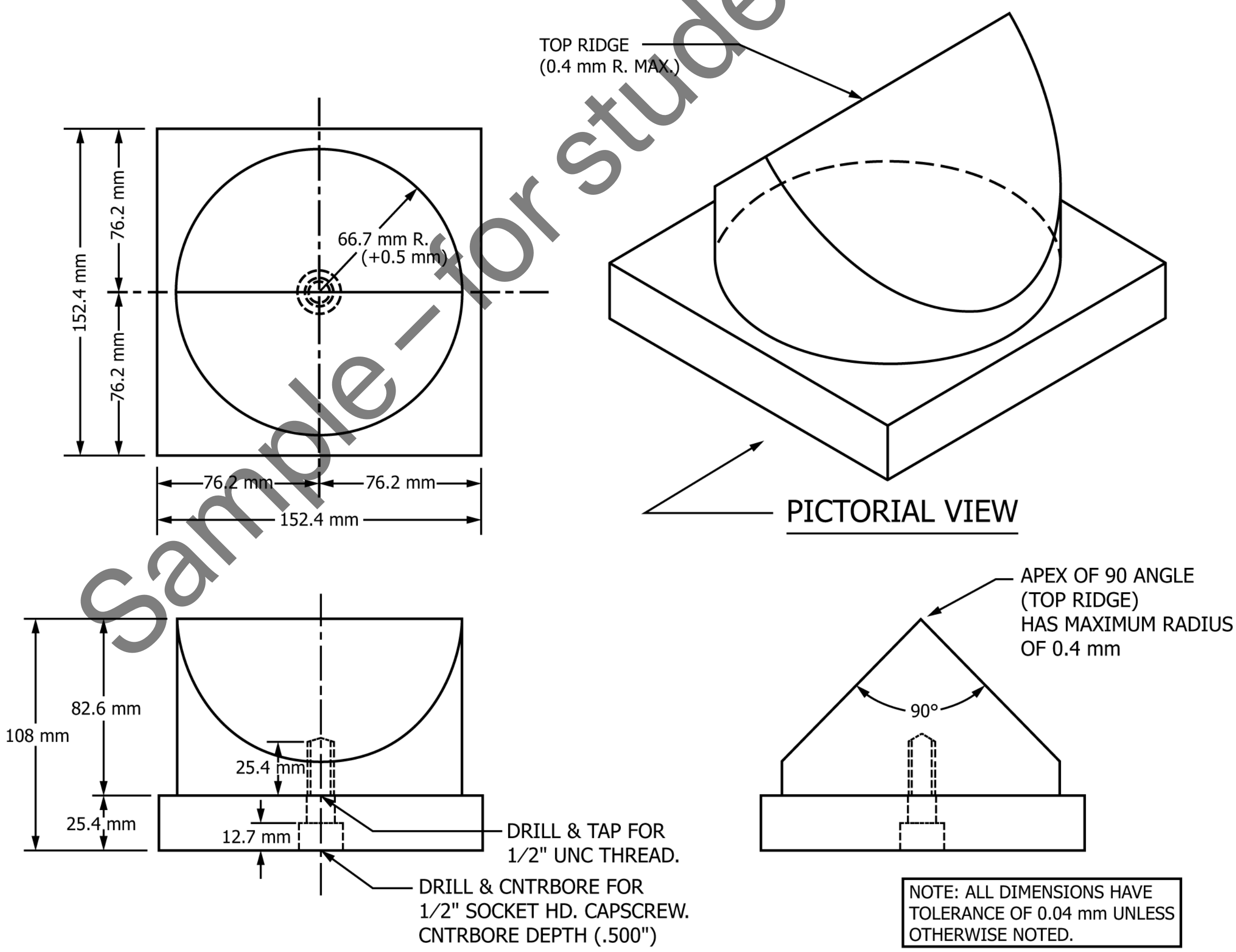


FIG. 1 Equestrian Hazard Anvil ("V" Anvil)

6.3.1 All reporting shall be described in the section on Reporting of Test Methods F1446.

6.3.2 Use the method described in the section on Reference Marking of Test Methods F1446.

6.4 Maintaining the force and position described in this section, draw the test line on the outer surface of the helmet as shown in Fig. 2. Helmet impacts shall be made with the flat anvil centered on or above the test line described in Fig. 2, and with no part of the top ridge of the equestrian hazard anvil extending below the test line described in Fig. 2

6.5 Measure peripheral vision in accordance with the section on Peripheral Vision and figure on Field of Vision of Test Methods F1446.

7. Conditioning and Number of Samples

7.1 Select samples as described in the section on Samples for Testing of Test Methods F1446. The test normally requires five samples of each shell/liner combination.

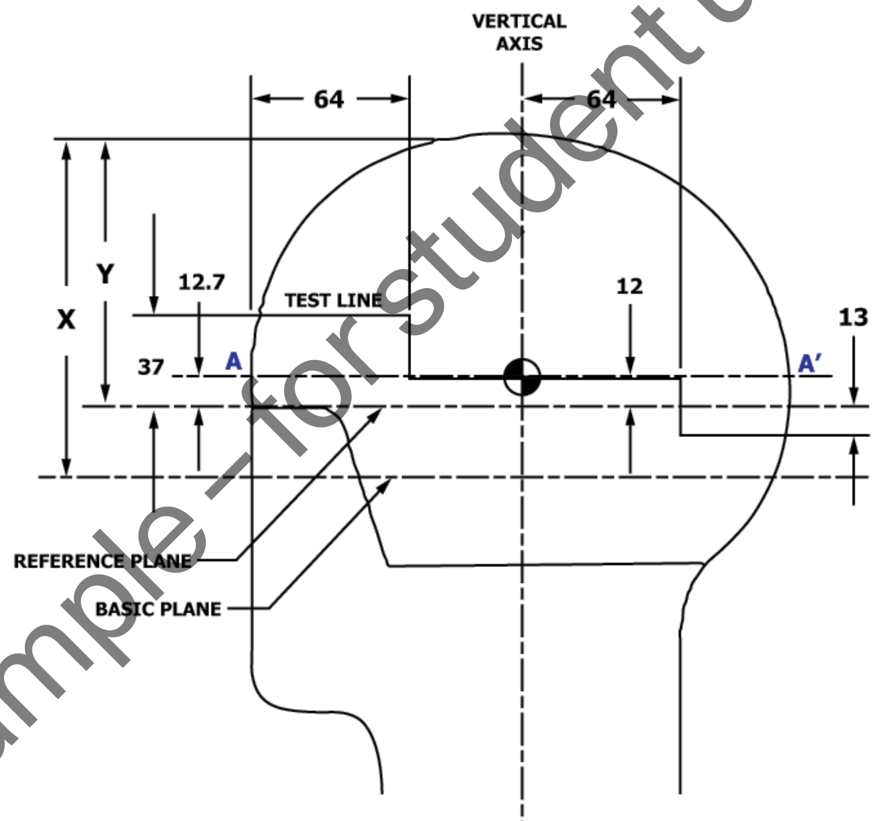
7.2 Condition the samples in accordance with the section on Conditioning Environments of Test Methods F1446. The environments to be used are: ambient, low temperature, high temperature, and water immersion.

8. Impact Sites

8.1 Each helmet shall be impacted at each of four sites; two sites upon the flat anvil and two sites upon the equestrian hazard anvil. The impact sites shall be centered on or anywhere above the center of impact line defined in Section 6. Impact centers shall be separated by a distance not less than one fifth of the circumference of the helmet. If there are any projections in the test area, at least one projection of each type shall be impacted. At least one impact shall be at the center of impact line at the front, rear, or side of the helmet.

9. Testing Schedule

9.1 Use the testing schedule in accordance with the section on Test Schedule of Test Methods F1446.



Headform Code Letter	Dimension *X*, mm	Dimension *Y*, mm
F2220-A	113.7	89.7
F2220-C	116.2	91.2
F2220-E	122	96.0
F2220-J	130	102.5
F2220-M	136	107.0
F2220-O	140	110.0

FIG. 2 Headform Basic Data

10. Peak Acceleration and Time Duration Requirements

10.1 The peak acceleration (*g*-max) of the impulse during the impact shall be measured with equipment described in accordance with the section on Impact Attenuation of Test Methods F1446.

10.2 The peak acceleration from any impact shall not exceed 300 g.

11. Retention System Testing

11.1 *Dynamic Loading Test*—All the conditioned test samples shall be subjected to the Dynamic Retention Test in accordance with Test Methods F1446, using a 4 kg drop mass from a height of 0.6 m. The retention system shall remain intact, and elongation shall not exceed 30 mm.

11.2 *Helmet Stability Test*—The roll-off test described in the section on Test Procedures of Test Methods F1446 shall be conducted on one ambient sample that has not been previously tested. The test shall be conducted using a 4-kg drop mass from a height of 0.6 m.

12. Lateral Compression

12.1 *General*—The helmet is subjected to lateral compressive forces and the deformations measured.

12.2 *Samples:*

12.2.1 One sample of each of the smallest and largest helmet sizes shall be tested. The samples shall be tested in the state "as received."

12.2.2 Samples may be sent with fabric trim around the helmet's perimeter removed. Oversized visors that wrap around the sides of the helmet, preventing the parallel plates in 12.3.1 from contacting the helmet shell, may also be removed.

12.3 *Procedure:*

12.3.1 The helmet shall be placed transversely between two guided rigid flat parallel plates of nominal size 300 by 250 mm, with its AA' plane aligned with the major centerline of the plates (Fig. 2).

12.3.2 An initial force of 30 N shall be applied perpendicular to the plates, so that the helmet is subjected to lateral force. After 30 s the distance between the plates shall be measured (dimension a).

12.3.3 The plates shall be closed at 3.5 to 5 mm per minute, up until a force on the helmet of 630 ± 20 N is reached, and shall be held for 30 s, after which the distance between the plates shall again be measured (dimension b).

12.3.4 The force shall be decreased to 30 N and shall be held for 30 s, after which the distance between the plates shall again be measured (dimension c).

12.3.5 Measurements shall be made to the nearest millimeter, and the extent of damage, if any, shall be noted.

12.3.6 The maximum lateral deformation is the difference between dimensions a and b.

12.3.6.1 The maximum lateral deformation of the helmet shall not exceed 30 mm.

12.3.7 The residual lateral deformation is the difference between dimensions a and c.

12.3.7.1 The maximum residual lateral deformation of the helmet shall not exceed 10 mm.

13. Labels and Warnings

13.1 In addition to the labeling requirements outlined in the section on Labeling of Test Methods F1446, the helmet shall have the following additional information:

13.1.1 This helmet designed only for equestrian use.

13.1.2 Uncoded month and year of manufacture.

13.1.3 Size or size range of the helmet.

13.1.4 The number designation of this specification.

13.1.5 Warning that the helmet should not be worn before carefully reading the attached fitting and care instructions.

13.1.6 Any other warnings, cautions, or instructions desired by the manufacturer.

14. Keywords

14.1 equestrian; horseback riding; horse driving; protective headgear

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Standard Practice for Training Exoskeleton Users [1]

This standard is issued under the fixed designation F3444/F3444M; 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.

1. Scope

1.1 This practice establishes the minimum training requirements, including general knowledge, skills, and abilities, for personnel who use an exoskeleton as part of their duties.

1.2 This practice applies only to exoskeletons and exosuits.

NOTE 1—For more advanced exoskeletons, those that are powered, or with IT data connections/links for data transfer, or combinations thereof, upload/download requirements, ensure exoskeleton user and system operators training includes addressing all precautions so they can quickly identify and resolve any data transfer problems experienced with a fully operational exoskeleton.

1.3 It is recognized that organizations and job responsibilities vary widely among military, medical, industrial, and emergency response communities. It is the responsibility of the user of this practice to identify the appropriate subject matter for its program and its specific needs.

1.4 Users of this practice should consult with the exoskeleton manufacturer to ensure they have the latest and most relevant information on the exoskeleton. In addition, all training should comply with laws and regulations regarding user safety and health as well as the safety of individuals in close proximity to the user.

1.5 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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]

F3323 Terminology for Exoskeletons and Exosuits

F3392 Practice for Exoskeleton Wearing, Care, and Maintenance Instructions

2.2 *U.S. Code of Federal Regulations (CFR):*[3]

29 CFR 1910 Occupational safety and health standards

21 CFR 890.3480 Powered lower extremity exoskeleton

2.3 *Other Standards:*

ISO/IEC Guide 37:2012 Instructions for use of products by consumers[4]

ISO 01.110 Technical product documentation including rules for preparation of user guides, manuals, product specifications, etc. [4]

3. Terminology

3.1 *Definitions*—See Terminology F3323 for latest definitions:

3.1.1 *exoskeleton, n*—wearable device that augments, enables, assists, or enhances, or combinations thereof, physical activity through mechanical interaction with the body.

3.1.2 *organization, n*—depending upon the application and user community, the entity deploying exoskeleton technology.

4. Significance and Use

4.1 This practice establishes the minimum training criteria for exoskeleton users.

4.2 This practice does not supersede any established laws or regulations of international, national, federal, state, tribal, local, or regional governments.

[1] This practice is under the jurisdiction of ASTM Committee F48 on Exoskeletons and Exosuits and is the direct responsibility of Subcommittee F48.02 on Human Factors and Ergonomics.

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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 U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.

[4] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

4.3 A commonly used training practice is for a competent, qualified, or certified trainer to provide to the student with written, visual, and verbal training materials that elementally breakdown the intended subject matter into a series of achievable modules. The trainer describes and demonstrates each module, and then interactively has the exoskeleton student user repeat and demonstrate specified knowledge, skills, and abilities to verify and validate the complete transfer of that knowledge, skills, and abilities.

4.4 This practice by itself is not a training document. It is an outline of the topics required for training or evaluating exoskeleton users for competence, proficiency, certification, or license.

4.5 The knowledge, skills, and abilities presented in the following sections are not in any particular order and do not represent a training sequence.

5. General Exoskeleton User Training

5.1 An exoskeleton user should be trained to perform the following basic skills:

5.1.1 Donning and doffing the exoskeleton in a normal situation and in emergency situations;

5.1.2 Proper fitting adjustments;

5.1.3 Routine inspection, repairs, cleaning, decontamination, sanitation, and maintenance following manufacturer's instruction. See Practice F3392 for further guidance;

5.1.4 How to turn on/off, charge, swap power sources, switch settings, and modes, and all other settings necessary and applicable for safe routine use;

NOTE 2—During the exoskeleton set-up ensure that users and system operators take the same precautions they would for any computer based system. They should be aware and looking out for malicious attachments, phishing e-mails, spoofing; do not plug in unknown disks to machines, proper authentication practices, and understand the minimum requirements for expected connections and interactions, as applicable, in normal use and how a user may be able to test these or report anomalous behavior.

5.1.5 Identification of safe environments for use;

5.1.6 Use of all safety features of the device; and

5.1.7 Ability to safely don and navigate through the planned use environment.

5.2 After training, an exoskeleton user or licensed operator should be competent and be able to explain or demonstrate, or both, as it relates to the intended use of the exoskeleton, the following:

5.2.1 The known limitations of mobility, movement, and range of motion;

5.2.2 The load safety limits;

5.2.3 Utilization around other people;

5.2.4 Appropriate duration of exoskeleton usage;

5.2.5 Recommended acclimation process and period of usage;

5.2.6 Under what conditions should the user stop using the exoskeleton;

5.2.7 What inspection, repair, cleaning, decontamination, sanitation, and maintenance should be performed by the user or operator, or both, and when. See Practice F3392 for further guidance;

5.2.8 What should the user or anyone assisting, or both, do in an emergency situation;

5.2.9 How should the exoskeleton be stored;

5.2.10 What clothing or PPE, or both, should be worn with the exoskeleton;

5.2.11 How to report problems, adverse events, wear/tear, and potential hazards; and

5.2.12 Cleaning, decontamination, and sanitation of the exoskeleton after use and prior to storage.

5.3 After training and explaining, an exoskeleton user should demonstrate the ability to safely do the following:

5.3.1 Assemble the device in all available configurations, and verify the exoskeleton is in the proper configuration for its intended use;

5.3.2 Don and doff the exoskeleton in both routine and emergency situations;

5.3.3 Adjust the exoskeleton so that it is properly fitted, if necessary, with or without the assistance of another person;

5.3.4 Doff the exoskeleton with human assistance, if appropriate and necessary;

5.3.5 Move in a manner that is safe and appropriate for their intended use environment;

5.3.6 Perform a representative set of activities that the exoskeleton is intended to be used for;

5.3.7 Inspect and identify needed repairs, cleaning, decontamination, sanitation, or maintenance, or combinations thereof, following manufacturer instructions; and

5.3.8 Utilize the controls to turn on/off the exoskeleton, charge, swap power sources, switch modes, or similar activities necessary to perform their intended activities while wearing the exoskeleton.

6. General Non-User Exoskeleton Training

6.1 If individuals other than the exoskeleton user, such as a medical doctor, therapist, clinician, companion or assistant, or combinations thereof, is needed for safe and effective use of the exoskeleton, these individuals should be able to explain or demonstrate, or both, the ability to do the following:

6.1.1 Identify that an exoskeleton user is an appropriate candidate based on known or demonstrated, or both, physical or cognitive limitations;

6.1.2 Identify safe environments of use;

6.1.3 Assemble the device in all available configurations;

6.1.4 Effectively assist in donning and doffing of the exoskeleton on the user;

6.1.5 Effectively assist with fitting the exoskeleton to the user;

6.1.6 Effectively program the device to operate at all modes;

6.1.7 Describe when each mode should be used if the individual responsible for or assists in operation of the exoskeleton;

6.1.8 Use of all safety features that are within their control;

6.1.9 Proper cleaning, decontamination, sanitation, and maintenance of the exoskeleton;

6.1.10 Proper storage of the exoskeleton;

6.1.11 Utilize the controls to turn on/off the exoskeleton, charge, swap power sources, switch modes, or similar activities necessary to perform their intended activities while assisting the exoskeleton user;

6.2 Provide advanced or specialized training for super users or trained trainers and those that supervise exoskeleton users, including what to do to support the exoskeleton users in whatever ways they may need. This may include fitting and adjustments, working with the exoskeleton manufacturer, troubleshooting, and delivering general training for support staff or users.

6.3 Provide high-level awareness training for emergency medical service (EMS) providers and any effected people that may work around exoskeletons, for the safe doffing of the exoskeleton as appropriate and needed.

7. Keywords

7.1 exoskeleton; exosuit; training; wearable robotics

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