Designation: F1976 – 13

An American National Standard

Standard Test Method for Impact Attenuation of Athletic Shoe Cushioning Systems and Materials[1]

This standard is issued under the fixed designation F1976; 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 test method describes the use of a gravity-driven impact test to measure certain impact attenuation characteristics of cushioning systems and cushioning materials employed in the soles of athletic shoes.

1.2 This test method uses an 8.5 kg mass dropped from a height of 30-70 mm to generate force-time profiles that are comparable to those observed during heel and forefoot impacts during walking, running and jump landings.

1.3 This test method is intended for use on the heel and or forefoot regions of whole, intact athletic shoe cushioning systems. An athletic shoe cushioning system is defined as all of the layers of material between the wearer's foot and the ground surface that are normally considered a part of the shoe. This may include any of the following components: outsole or other abrasion resistant outer layer, a midsole of compliant cushioning materials or structures forming an intermediate layer, an insole, insole board, or other material layers overlying the midsole, parts of the upper and heel counter reinforcement which extend beneath the foot, and an insock, sockliner or other cushioning layers, either fixed or removable, inside the shoe.

1.4 This test method may also be employed in to measure the impact attenuation of cushioning system components and cushioning material specimens.

1.5 This test method is not intended for use as a test of shoes classified by the manufacturer as children's shoes.

1.6 The type, size or dimensions and thickness of the specimen, the total energy input and prior conditioning shall qualify test results obtained by this test method.

1.6.1 The range of tests results is limited by the calibrated range of the test device's force transducer. Combinations of thin specimens, high specimen stiffness and high total energy input may produce forces that exceed the transducer's capacity and are hence not measurable. In practice, the specified force transducer range (10 kN) accommodates more than 99 % of typical shoe soles and cushioning material specimens that are 7 mm or more in thickness at a total energy input of 5 Joules.

1.6.2 The nominal value of the total energy input applied by this test method is 5 J for shoes, such as running shoes, which are subject to moderate impacts during normal use. Total energy inputs of 7.0 J and 3.0 J may be used for shoes (e.g basketball shoes) which are subject to higher impact loads during normal use. Other values of total energy input may be used, if they are stated in the report.

1.6.3 Results from tests performed with different total energy inputs or with different masses are not directly comparable.

1.6.4 Specimen thickness has a significant effect on impact attenuation outcomes. Consequently, results from tests of material specimens of different thicknesses cannot be directly compared.

1.6.5 The impact attenuation of cushioning materials may change over time and with use (e.g. wear or durability testing) or prior conditioning (e.g. from previous tests). Consequently, test results obtained using this test method shall be qualified by the age and prior conditioning of the samples.

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

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

2. Referenced Documents

2.1 *ASTM Standards:*[2]

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

F1614 Test Method for Shock Attenuating Properties of

[1] This test method is under the jurisdiction of ASTM Committee F08 on Sports Equipment, Playing Surfaces, and Facilities and is the direct responsibility of Subcommittee F08.54 on Athletic Footwear.

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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.

Materials Systems for Athletic Footwear (Withdrawn 2014)[3]

F2650 Terminology Relating to Impact Testing of Sports Surfaces and Equipment

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method, refer to Terminology F2650.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *low impact*—impact during which the peak ground reaction force is less than 1.5 body weights and the peak axial deceleration of the lower leg is less than 4 g.

3.2.2 *moderate impact*—impact during which the peak ground reaction force is greater than 1.5 body weights and less than 3 body weights and the peak axial deceleration of the lower leg is greater than 4 g but less than 8 g.

3.2.3 *high impact*—impact during which the peak ground reaction force exceeds 3 body weights or the peak axial deceleration of the lower leg exceeds 8 g.

3.2.4 *shoe upper*—vamp, tongue, heel counters, throat, collar, and other parts of the shoe that do not form part of the cushioning system.

3.2.5 *tup*—leading surface of moving portion of test machine in contact with specimen during the impact cycle.

4. Summary of Test Method

4.1 The test apparatus consists of a rigid foundation with a support structure that guides the fall of an 8.5 kg, gravity driven missile. The apparatus includes a mechanism for positioning the missile at a predetermined drop height, then cyclically releasing it at a nominal rate of 30 cycles per minute.

4.2 A test specimen is supported by the rigid foundation. The drop height is adjusted to produce a specified total energy input, typically 5 Joules. Specimens are subjected to a series of 30 impacts with a nominal interval of 2.0 s. The first 25 drops used to condition the specimen and the last five drops used for measurements. Force and displacement time histories are measured with appropriate transducers and recorded. The primary outcomes of the test are the peak acceleration during the impact (g-max), time to peak acceleration (t-max), peak compressive displacement (x-max) of the specimen and energy return/loss due to hysteresis.

5. Significance and Use

5.1 This test method is used by athletic footwear manufacturers and others, both as a tool for development of athletic shoe cushioning systems and as a test of the general cushioning characteristics of athletic footwear products, materials and components. Adherence to the requirements and recommendations of this test method will provide repeatable results that can be compared among laboratories.

[3] The last approved version of this historical standard is referenced on www.astm.org.

5.2 Data obtained by these procedures are indicative of the impact attenuation of athletic shoe cushioning systems under the specific conditions employed.

5.3 This test method is designed to provide data on the force versus displacement response of athletic footwear cushioning systems under essentially uniaxial impact loads at rates that are similar to those of heel and forefoot impacts during different athletic activities.

5.4 The peak or maximum values of force, acceleration, displacement, and strain are dependent on the total impact energy applied to the specimen. These values are normalized to provide comparative results for a reference value of total energy input.

5.5 Impact attenuation outcomes are strongly dependent on initial conditions (impact mass, impact velocity, contact area, etc.) and on specimen size and the specimen's prior history of compressive loading. Therefore results should be compared only for specimens of the same nominal size and prior conditioning.

NOTE 1—Impact test outcomes have been found to correlate with in-vivo loads (peak ground reaction force, peak plantar pressure, lower extremity acceleration) experienced by runners. Relationships between test outcomes and subjective perceptions of cushioning have also been found. However, there is no direct evidence of a correlation between scores on this test method and the probability of injury among users of a particular athletic footwear product.

6. Test Apparatus

6.1 The test device (Fig. 1) shall consist of two primary assemblies, the first providing a fixed anvil and structures for the support, alignment and guidance of a second, gravity-driven missile assembly (Fig. 1).

6.2 *Fixed Anvil Assembly,* (Fig. 1(A)) consisting of an effectively rigid anvil having a minimum mass of 170 kg and providing a flat, rigid surface for specimen support. The specimen support surface shall be planar, normal to the vertical direction of missile travel, centered under the tup of the gravity-driven assembly and of sufficient area to support the entire lower surface of the specimen.

6.2.1 *Support and Guidance*—The fixed assembly shall provide linear bearings or other means guidance for a gravity-driven missile such that the motion of the missile is vertical and normal to the plane of the specimen support surface.

6.2.2 *Lift and Drop Mechanism*—A means of lifting the missile above the upper surface of the specimen, repeatably positioning it with an accuracy of ±0.5 mm releasing it to initiate a gravity-driven drop.

6.2.2.1 The testing machine shall be capable of initiating the impact cycle (that is, loading and unloading as one cycle) at a rate of one every 2 ± 1 s.

NOTE 2—The adjustable range of the lift and drop mechanism must accommodate the thickness of the specimen (typically 10 to 50 mm) plus the drop height required to produce the specified total input energy (typically 30 to 70 mm).

6.2.3 *Friction*—The missile assembly shall move freely, with minimum friction between the missile and the bearings or other guidance structure. Any friction shall be such that the measured free-fall velocity, V_0, from a drop height h, shall be

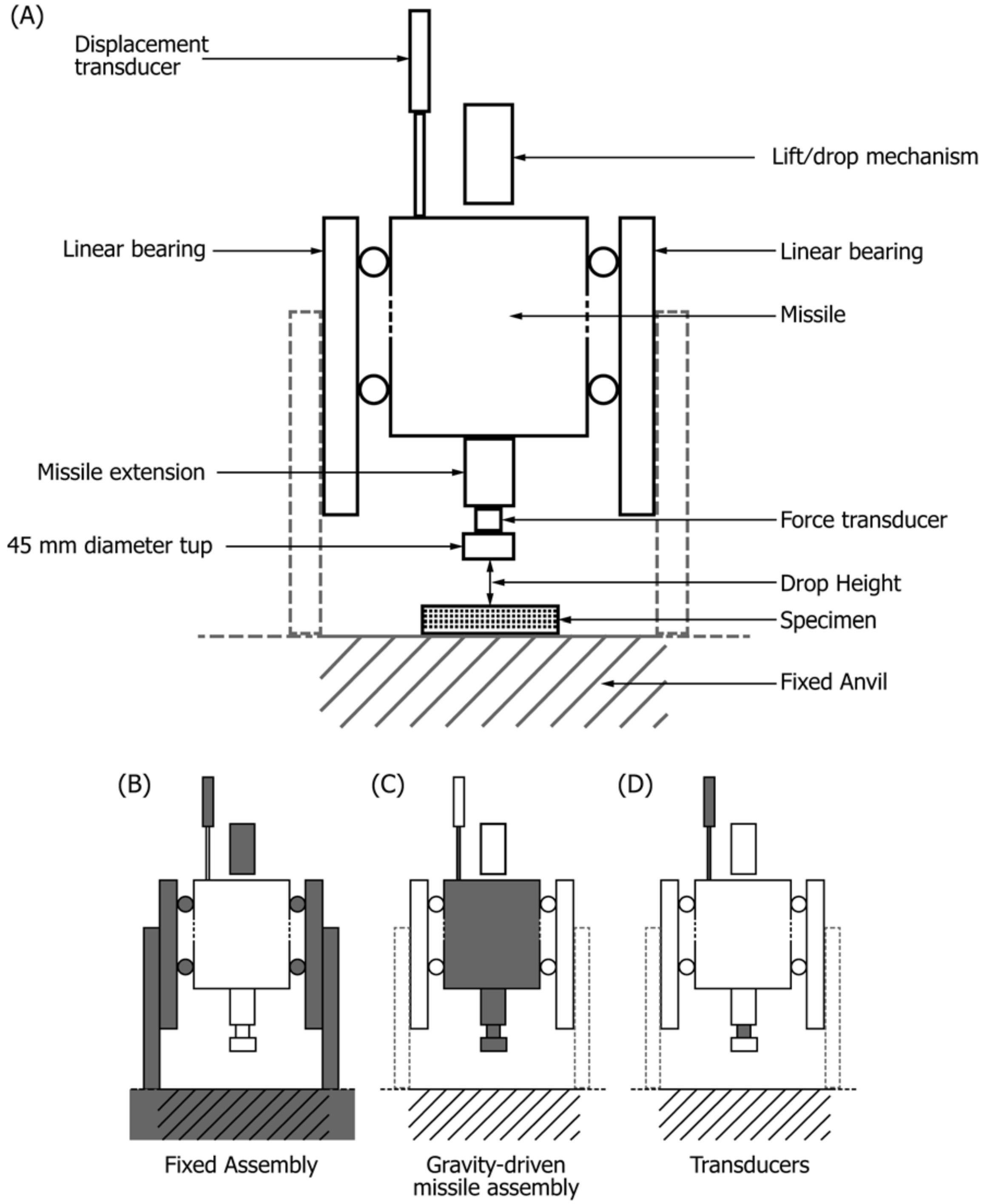


FIG. 1 Schematic Diagram of the Test Device

within ±2 % of the theoretical value given by V = √(2 *g* h) where *g* is the acceleration due to gravity.

6.3 *Missile Assembly*—A gravity-driven missile assembly (Fig. 1(C)) consisting of a main missile body, a missile extension and a tup and incorporating a force transducer (see 6.4). The total mass of the assembly shall be 8.5 ± 0.1 kg.

6.3.1 *Missile Extension*—The missile extension shall be constructed in a manner that allows the tup to contact and penetrate the specimen without any other portion of the missile assembly making contact with the surface of the specimen or other specimen components (for example, sidewalls and upper components).

6.3.2 *Tup*—The tup shall be cylindrical with a circular face 45.0 ± 0.1 mm in diameter and an edge radius of 1.0 ± 0.2 mm (Fig. 2). The total mass suspended from the force transducer (that is, the mass of the tup and its means of connection shall not exceed 0.20 kg).

NOTE 3—Tups of appropriate mass and stiffness can be constructed

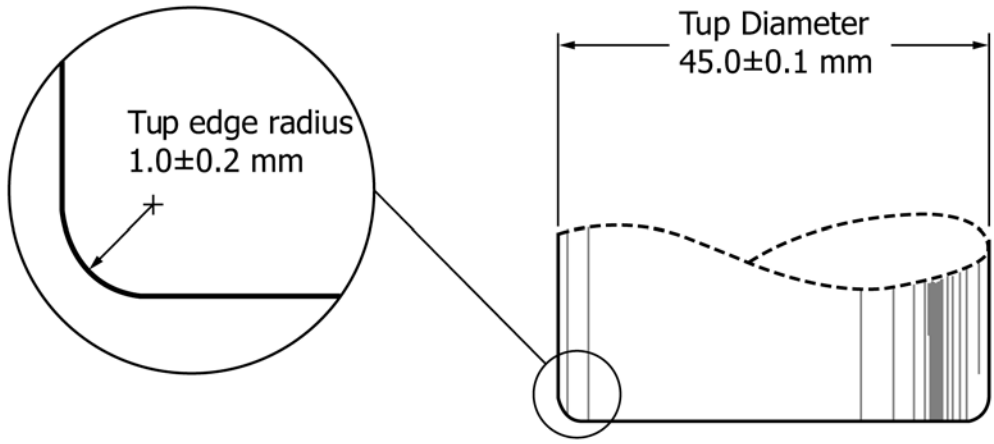


FIG. 2 Tup Geometry

from aluminum alloy 6061.

6.4 *Force Transducer*—A force measuring device mounted rigidly between the missile extension and the tup with its sensitive axis aligned (±0.5 mm) with a vertical line passing through the center of the tup's circular face.

6.4.1 The force transducer shall have a calibrated measurement range in compression, of at least 0 to 10 kN range, a discharge time constant exceeding 2 s and nonlinearity not exceeding 1 % full scale.

6.4.2 Accelerometers are not acceptable substitutes for force transducers in this application.

6.5 *Displacement Transducer*—A means of measuring the position and displacement of the missile assembly relative to the fixed anvil assembly. The transducer may be mechanical, having a fixed end attached to the support structure and a moving end attached to the missile assembly. Optical and other 'non-contact' transducers are also acceptable provided they meet the requirements of 6.5.1.

6.5.1 The displacement transducer shall have a calibrated range equal to or greater than the range of motion of the missile assembly, typically 100 to 150 mm (see Note 2) an accuracy of ±0.1 mm, a flat (±1 %) frequency response from 0 to 1000 Hz and nonlinearity not exceeding 1 % full scale. Mechanical transducers attached to the missile should also be resistant to impact shock magnitudes of at least 100 g.

6.6 *Calibration*—Force and displacement transducers shall be calibrated in accordance with the manufacturer's recommendations and at the recommended interval.

6.7 *Data Recording*—An analog to digital converter or other means of recording force transducer output with a resolution of ±1 N and displacement output with a resolution of ±0.1 mm.

6.7.1 *Sample Rate*—The data recorder shall have a minimum sample rate of 5000 samples/s.

6.7.2 *Anti-aliasing Filter*—Input signals shall be filtered, prior to digitization, using analog filters with -3dB cut-off frequencies equal to 50 ± 10 % of the actual sample rate employed (that is, 2500 ± 100 Hz for a sample rate of 5000 samples/s).

6.7.3 *Digital Filter*—Digitized data shall be digitally filtered using a fourth order low pass IIR filter (for example, a digital Butterworth filter) with a -3dB cut-off frequency of 500 Hz.

6.8 *Display*—A means of displaying force and displacement data as a function of a common time scale or force as a function of displacement, or both (see Fig. 3).

7. Test Specimen

7.1 *Preparation of Test Specimens*—The cushioning test specimen shall be isolated from the shoe by cutting away the upper. The lower portion of the upper (that which extends 10 ± 5 mm (0.4 ± 0.2 in.) above the top surface of the cushioning system) shall not be removed, providing it does not interfere with the falling mass.

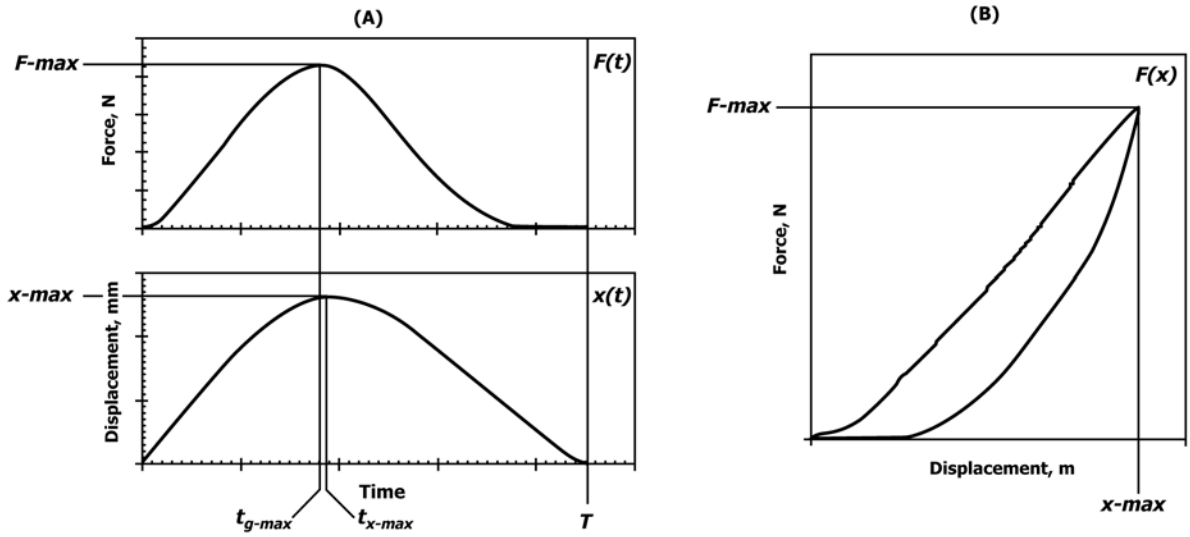
NOTE 4—The retention of a rim of upper materials around the edge of the test specimen prevents disturbance of the cushioning materials during removal of the upper, preserves the attachments between the sole and the upper (which can influence shock attenuation), and serves as a retainer for any loosely attached components of the cushioning system that normally reside inside the shoe (an insock, for example).

7.2 *Geometry*—In order for this test method to be applicable, the region of the cushioning system to be tested shall have an approximately flat surface, approximately circular in shape, with a minimum diameter of 65 ± 2 mm (2.6 ± 0.1 in.). The center of this presenting surface shall coincide with the center of the tup of the test apparatus, such that on initial contact between the tup and the test specimen there is a minimum of 5 ± 1-mm (0.2 ± 0.05-in.) clearance between the edge of the tup and the edge of the test specimen, in all directions.

NOTE 5—The geometry of the test specimen will vary with the design of the shoe under test. Since the geometry of the shoe is a factor which influences shock attenuation, the influence of which may be tested with this test method, no standard specimen geometry is defined. The validity for comparisons of results from tests of specimens of different geometries, thicknesses, and sizes has not been determined.

7.3 *Alignment of Test Specimens*—The standard methods of aligning test specimens with the test apparatus are as follows:

7.3.1 *Heel*—For tests of shock attenuation in the heel of a shoe, test specimens shall be aligned with the test apparatus as shown in Fig. 4 such that the center of the tup coincides with a point on the top surface of the shoe that is 12 %± 2 mm (12 % ± 0.08 in.) of the internal length of top surface of the test specimen from the heel end and equidistant from the medial and lateral edges of the test specimen.



NOTE 1—(A) Force and displacement as a function of a common time scale. (B) Force as a function of displacement.

FIG. 3 Example Charts

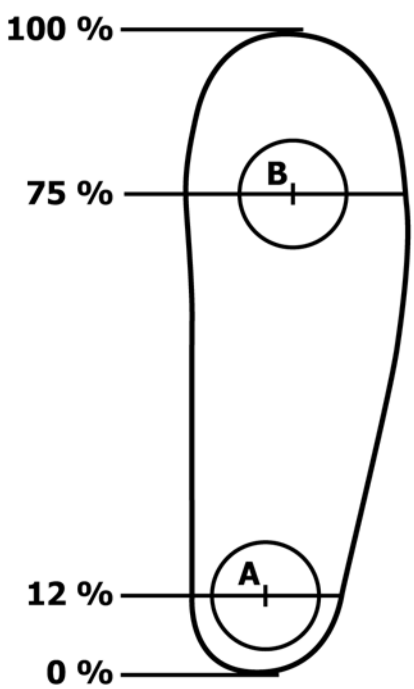


FIG. 4 Plan View of Shoe Sole Sample Showing Alignment of the Tup for (A) Heel and (B) Forefoot Tests

7.3.2 *Forefoot*—For tests of shock attenuation in the forefoot of a shoe, test specimens shall be aligned with the test apparatus as shown in Fig. 4 such that the center of the tup coincides with a point on the top surface of the shoe that is 75 % ± 2 mm (75 % ± 0.08 in.) of the internal length of top surface of the test specimen from the heel end and equidistant from the medial and lateral edges of the test specimen.

8. Conditioning

8.1 Condition test specimens in accordance with Test Method F1614.

8.1.1 Test specimens in accordance with Test Method F1614, Procedure A, with the following adjustments:

8.1.1.1 Align the test specimen with the test apparatus in accordance with 7.2 of this test method.

8.1.1.2 The maximum energy applied to the test specimen must be within ±10 % of a reference value. The reference value shall be 5 J (44.2 in.-lbf) for shoes which are subject to moderate impacts during normal use and 7 J (61.9 in.-lbf) for shoes which are subject to high impacts during normal use. Reference energy values other than 5 J (44.2 in.-lbf) or 7 J (61.9 in.-lbf) may be used, if they are stated in the report.

NOTE 6—The goal of the impact test is to simulate the energy inputs, forces, and load rates applied to the shoe cushioning system during normal use. For general purposes, a reference energy of 5 J (44.2 in.-lbf) has been found appropriate for sports shoes. However, the reference energy may be varied depending of the type of shoe and whether the heel or forefoot is being tested. A reference energy of 5 J (44.2 in.-lbf) is recommended for testing shoe cushioning systems which are subjected to moderate impact (see 3.2.2) during normal use. These include running shoes (heel) and multipurpose fitness shoes (heel and forefoot). For shoe cushioning systems which are subjected to high impact (see 3.2.3) during normal use, a reference energy of 7 J (61.9 in.-lbf) is recommended. These include basketball, tennis, and volleyball shoes. This test method is not recommended for shoes that are not subject to moderate or high impact during normal use. These include shoes intended for exercise walking and for aerobics.

9. Calculation

9.1 In addition to the calculations specified in Test Method F1614, the following may be calculated:

9.1.1 *Normalization*—g-max scores shall be normalized to the reference energy in accordance with Section 10.2 of Test Method F1614. Specifically:

$$g - \max(\text{normalized}) = \quad (1)$$

$$g - \max(\text{measured}) * (\text{Reference Energy/Maximum Energy Applied})^{1/2}$$

9.1.2 *Peak G Score,* defined as the peak acceleration of the tup of the falling mass apparatus during an impact, expressed in gravitational units.

$$\text{Peak G score} = A/g \quad (2)$$

where:

A = peak deceleration, and
g = acceleration due to gravity = 9.81 m s^{-2} (33.2 ft s^{-2}).

When a force transducer is used, peak deceleration may calculated as follows:

$$A = -F/M \quad (3)$$

where:

A = peak deceleration,
F = peak force recorded with the force transducer, and
M = mass of the impactor.

10. Report

10.1 Report the following information:

10.1.1 Complete identification of the shoe tested, including type, shoe size or dimensions, source, manufacturer's code number, form, and previous history.

10.1.2 Specimen size and thickness.

10.1.3 Sources and types of test equipment.

10.1.4 Reference maximum energy applied.

10.1.5 For the series of five impact cycles, average value and standard deviation for each of the following properties:

10.1.5.1 Peak force, maximum displacement, time, maximum energy applied, and hysteresis energy ratio in accordance with Test Method F1614.

10.1.5.2 Peak G score in accordance with 10.1.

11. Precision and Bias

11.1 *Precision*—The precision of this test method for measuring peak force and hysteresis energy ratio are essentially as specified in Test Method F1614. Peak G score is directly derived as the product of the peak force measurement and a constant. Therefore, Peak G score has precision that is proportionate to that of the peak force measurement.

11.2 *Bias*—A statement on bias cannot be made because no reference samples are available.

12. Keywords

12.1 athletic shoes; cushioning; impact; shock attenuation; sports shoes