Designation: F 1614 – 99

An American National Standard

Standard Test Method for Shock Attenuating Properties of Materials Systems for Athletic Footwear[1]

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1. Scope

1.1 This test method covers the measurement of certain shock attenuating characteristics, rapid rate force-displacement relationships, of materials systems employed in the midsole of athletic footwear intended for use in normal running movements. This test method covers three different procedures for performance of the rapid rate force application: Procedure A for falling weight impact machines, Procedure B for compression force controlled machines, and Procedure C for compression displacement controlled machines.

1.2 The material system response for rapid rate force application may be different for each of the three procedures of this test method.

1.3 This test method is empirically based on the use of an 8.5-kg mass dropped from 50 mm (1.97 in.) to generate peak compressive forces which are comparable to that experienced by a midsole in heel strike tests for normal running movement.[2,3] This requires the specimen to be rigidly supported and the energy to be delivered through a 45-mm (1.8-in.) diameter flat tup.

1.4 This test method imposes an impulse to generate a rapid rate compressive force-displacement hysteresis cycle and evaluates shock attenuating characteristics of the specimen. The maximum energy applied to the specimen occurs at peak displacement and must be within ±10 % of a reference value that is used to normalize the data for comparative purposes.

1.5 Shock attenuating characteristics, for this test method, are in terms of absorbed energy loss during the hysteresis cycle, peak pressure, maximum strain, and average stiffness. Each of these characteristics will have varying importance, depending on the design objectives for the material system in the athletic footwear product.

1.6 Test results obtained by this test method shall be qualified by the specimen thickness and the reference maximum energy applied.

1.6.1 Nominal specimen thickness values for this test method are in the range from 5 to 35 mm (0.2 to 1.4 in.), see 7.1.

1.6.2 The standard value for the reference maximum energy applied of this test method is 5.0 J. Other values may be used, if they are clearly stated in the report.

NOTE 1—For Procedure A, the use of a 8.5-kg mass and an initial distance of 50 mm between tup and specimen will produce the required impulse and result in maximum energy applied values in the range of 5 ± 0.5 J (44.2 ± 4.4 in.-lb), depending on specimen thickness and material response.

NOTE 2—For Procedures B and C, the required impulse is produced by having the maximum energy applied within the range of ±10 % of the reference value (5 J, see 1.6.2) and the time to peak controlling variable (force or displacement) being 15 ± 5 ms.

NOTE 3—There is no evidence to support comparisons of data for tests which used either different reference maximum energy applied values or for Procedure A, different mass and drop height conditions.

NOTE 4—Applications involving more vigorous (for example, basketball) use of athletic shoes may require shock absorption tests which utilize larger reference impulse values to generate comparable compressive force hysteresis cycles.

NOTE 5—Shock attenuation is strongly dependent on specimen thickness. This test method can be used to identify the effects of thickness variations on shock attenuating properties of midsole materials and athletic footwear products, see 7.2.

[1] This test method is under the jurisdiction of ASTM Committee F-8 on Sports Equipment and Facilities and is the direct responsibility of Subcommittee F08.54 on Footwear.

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[2] Misevich, K. W. and Cavanagh, P. R., "Material Aspects of Modeling Shoe/Foot Interaction," *Sports Shoes and Playing Surfaces*, (E. C. Frederick, ed), Human Kinetics: Champaign, Illinois, 1982, pp. 47–75.

[3] Denoth, J., "Load on the Locomotor System and Modeling," Chapter 3, *Biomechanics of Running Shoes*, (B. M. Nigg, ed.), Human Kinetics: Champaign, Illinois, 1986, pp. 63–116.

NOTE 6—Comparisons of different material systems by this test method should take careful consideration of prior impact conditioning. The ability of footwear materials to attenuate shock tends to decrease with repeated impact.[2]

1.7 The values stated in SI units are to be regarded as the standard. The inch-pound units given in parentheses are for information only.

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:* [4]

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing

D 3763 Test Method for High-Speed Puncture Properties of Plastics Using Load and Displacement Sensors

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

F 355 Test Method for Shock-Absorbing Properties of Playing Surface Systems and Materials

F 869 Definitions of Terms Relating to Athletic Shoes and Biomechanics

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *acceleration*—the time rate of change of velocity.

3.1.2 *accelerometer*—a transducer for measurement of the acceleration of the impact mass.

3.1.3 *compression cycle*—the complete impact event of increasing displacement and decreasing displacement.

3.1.4 *displacement*—the linear motion of the tup during impact force application. Synonymous with deflection.

3.1.5 *dynamic*—*in this standard*, refers to events which occur with durations of approximately 0.005 to 0.05 s.

3.1.6 *energy*—the capacity for doing work and overcoming resistance. The energy of the test machine is used for the work of specimen displacement. Measured as the integral of force with respect to the distance through which the force is exerted.

3.1.7 *force*—the reaction of the resistance of a object to displacement or motion, or both. The interaction between test machine and specimen during compression displacement is represented as a force. Synonymous with load.

3.1.8 *g*—the ratio of the magnitude of impact mass acceleration to the gravitational acceleration constant, expressed in the same units.

3.1.9 *gravity driven*—motion is controlled by the gravitational forces, as for the dropping of the impact mass.

3.1.10 *hysteresis*—the force takes on different values for increasing displacement than for a decreasing displacement.

3.1.11 *hysteresis energy*—the energy loss during the compression cycle.

3.1.12 *hysteresis energy ratio*—the ratio (HER) of hysteresis energy to the maximum energy applied.

3.1.13 *impact*—a dynamic contact interaction between two solid bodies. *In this standard*, refers to force interactions within the time range from 0.005 to 0.05 s.

3.1.14 *impulse*—the change in momentum effected by a force. Measured as the product of force and the time over which the force is exerted.

3.1.15 *load*—synonymous with force.

3.1.16 *mass*—a fundamental unit of measure (units are kilograms) that is independent of the specific gravitational acceleration constant (g). See *weight*.

3.1.17 *maximum energy applied*—this is the energy applied to the specimen at maximum compression displacement.

3.1.18 *pressure*—the ratio of force to the transverse cross-sectional area of the tup.

3.1.19 *rigid*—a relative term used here to identify an impact condition for which the previously stationary object has minimal or insignificant displacement as a result of the collision by the moving object.

3.1.20 *shock*—a short duration high force part of an impact.

3.1.21 *shock attenuation*—the reduction of peak force with the increase of the time over which the force is applied.

3.1.22 *stiffness*—the resistance to displacement. Measured as the ratio of force to displacement.

3.1.23 *average stiffness*—the ratio of peak force to the corresponding displacement.

3.1.24 *strain*—the ratio of displacement to specimen thickness.

3.1.25 *transducer*—a measurement device which senses the physical quantity of interest and generates an electrical signal in proportion to its magnitude.

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

3.1.27 *velocity*—the speed or time rate of change of displacement, for the test machine tup.

3.1.28 *weight*—the measure of mass (m) that is relative to the gravitational acceleration constant (g). Weight = mg. The 8.5-kg mass (m) has a weight of 83.27 N (18.72 lb) at g = 9.81 m/s^2 (32.17 ft/s^2).

4. Summary of Test Method

4.1 A test specimen is loaded in compression at a rapid rate which, because of the method of force application, is different for each of the three procedures. The specimen is supported on a rigid foundation and force is applied through a circular flat face of 45-mm (1.8-in.) diameter. Force and displacement transducers are employed for measurement of the complete loading and unloading compression cycle. Procedure A provides for optional determination of specimen displacement by calculation.

4.2 The three procedures covered by this test method have a common requirement for the maximum energy applied to be within ±10 % of a standard reference value of 5 J (44.2 in.-lb). Other reference energy values may be used, if they are clearly stated in the report (see 1.3 and Note 3).

4.2.1 Procedure A uses gravity-driven impact of an 8.5-kg mass as the method for force application. The impact velocity and resultant rate of force application are determined by a

[4] 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.

standard drop height (50 mm). The maximum force, maximum displacement, and maximum energy applied to the specimen are determined by the inherent shock attenuation characteristics of the material system. The maximum energy applied to the specimen (*UM*) is usually in the range from 4.5 to 5.5 J (39.8 to 48.7 in.-lb), depending on specimen displacement (*DM*).

NOTE 7—For Procedure A, typical values for *UM* at *DM* are:

DM (mm)	UM (J)
5	4.6
10	5.0
15	5.4

4.2.2 Procedure B uses hydraulic, pneumatic, or screw-driven machines to apply a preselected force function, through a machine control process. This function is adjusted to have the time to reach peak force be in the range of 15 ± 5 ms. The maximum displacement and maximum energy applied to the specimen are determined by the selected force level and the inherent shock attenuation characteristics of the material system of the test specimen. The force is selected to yield maximum energy applied to the specimen in the range from 4.5 to 5.5 J (39.8 to 48.7 in.-lb).

4.2.3 Procedure C uses hydraulic, pneumatic, or screw-driven machines to apply a preselected displacement function, through a machine control process. This function is adjusted to have the time to reach peak displacement be in the range of 15 ± 5 ms. The maximum force and maximum energy applied to the specimen are determined by the selected displacement level and the inherent shock attenuation characteristics of the material system. The displacement is selected to yield maximum energy applied to the specimen in the range from 4.5 to 5.5 J (39.8 to 48.7 in.-lb).

5. Significance and Use

5.1 This test method is used by athletic footwear manufacturers both as a tool for development of midsole material systems and as a test of the general characteristics of the athletic footwear product (see 1.4-1.6.2 and Notes 1-6). Careful adherence to the requirements and recommendations of this test method shall provide results which can be compared between different laboratory sources.

5.2 Dynamic data obtained by these procedures are indicative of the shock attenuating properties (see 1.5) of the material systems under the specific conditions selected.

5.3 This test method is designed to provide force versus displacement response of materials systems for athletic footwear under essentially uniaxial compression conditions at impact rates, which are similar to that for heel strike in normal running movements.[2,3] That is, peak forces of up to 2 kN (450 lb) in times of 10 to 20 ms.

5.4 The peak or maximum values of force, pressure, displacement, and strain are dependent on the maximum energy applied to the specimen. These values are normalized to provide comparative results for a reference maximum energy applied to the specimen of 5 J.

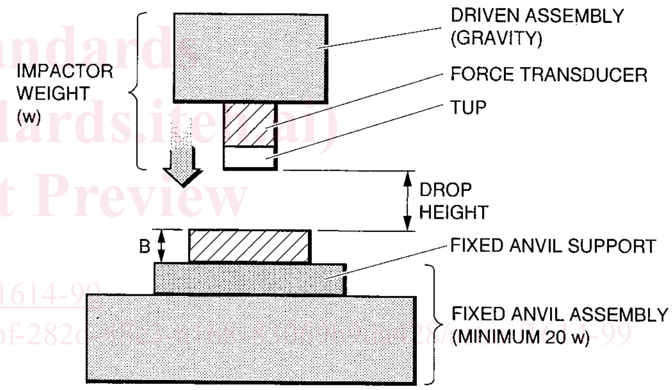
5.5 Shock attenuating characteristics are strongly dependent on specimen thickness and prior history of force application. Therefore, results should be compared only for specimens of essentially the same thickness and prior impact conditioning (see Notes 3-6). There are no currently acceptable techniques for normalizing results for specimen thickness variations.

5.6 Shock attenuating values (see 1.5) determined by this test method, for materials systems of athletic footwear, may not correlate with the similar values experienced by a runners heel or foot.

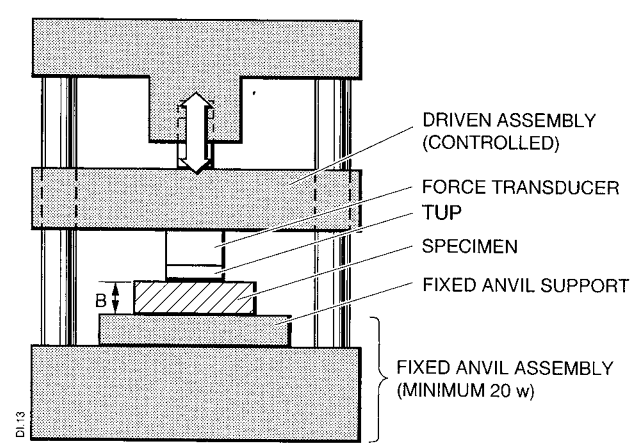
6. Apparatus

6.1 The testing machine shall consist of two assemblies, one fixed and the other driven by a suitable method to achieve the required maximum energy applied to the specimen and loading time (that is; hydraulic, pneumatic, mechanical, or gravity), see Fig. 1. Procedure A results in a maximum energy applied to the specimen through use of a specific mass dropped from a specific height. Procedures B and C require the apparatus to impose a displacement which results in a maximum energy applied to the specimen of 5.0 ± 0.5 J (44.2 ± 4.4 in.-lb) with the time to reach peak displacement being 15 ± 5 ms.

6.1.1 *Fixed Anvil Assembly*, consisting of flat rigid plate with elastic cords (or equivalent) for holding specimen in position during multiple impacts. This specimen support shall be normal to the direction of force application, and have a



a. Procedure A.



b. Procedure B or C.

FIG. 1 Mechanical Apparatus

geometry which provides complete contact with the bottom of the specimen over an area which is at least as large as a 76-mm diameter circle. This support area shall be centered beneath the tup of the driven plunger assembly (see 6.1.2 and Fig. 2). Rigid is in reference to the physics of momentum transfer.

6.1.1.1 *Procedure A*—For the impact conditions of Procedure A, rigid can be achieved by having the fixed anvil assembly have a mass which is at least twenty times greater than that of the falling mass. The mass of the fixed anvil assembly shall be 170 kg (weight of 374 lb) or greater.

6.1.1.2 *Procedures B and C*—Rigid conditions for Procedures B and C can be obtained by limiting the displacement of the fixed anvil assembly to no more than 2 % of that applied to the specimen.

6.1.1.3 Specimens shall be secured to the fixed anvil support by any suitable technique that prevents transverse movement during the cyclic load conditioning (see Section 8) and does not prestrain the area of the specimen to be contacted by the tup more than 5 % (see 11.4).

NOTE 8—For Procedure A, elastic cords or duct tape have been successfully employed to secure the specimen to the fixed anvil support. For Procedures B and C see 9.3.2 and 9.3.3, respectively.

6.1.2 *Driven Plunger Assembly*, consisting of moveable mass with tup of flat circular diameter of 45± 0.1 mm (1.772 ± 0.004 in.) that is normal to the direction of force application, see Fig. 1 and Fig. 2. The edge of the tup shall be rounded, with a radius of 1.0 ± 0.25 mm (0.04 ± 0.01 in.) to prevent adverse specimen tearing at the edge. The tup area shall be centered on

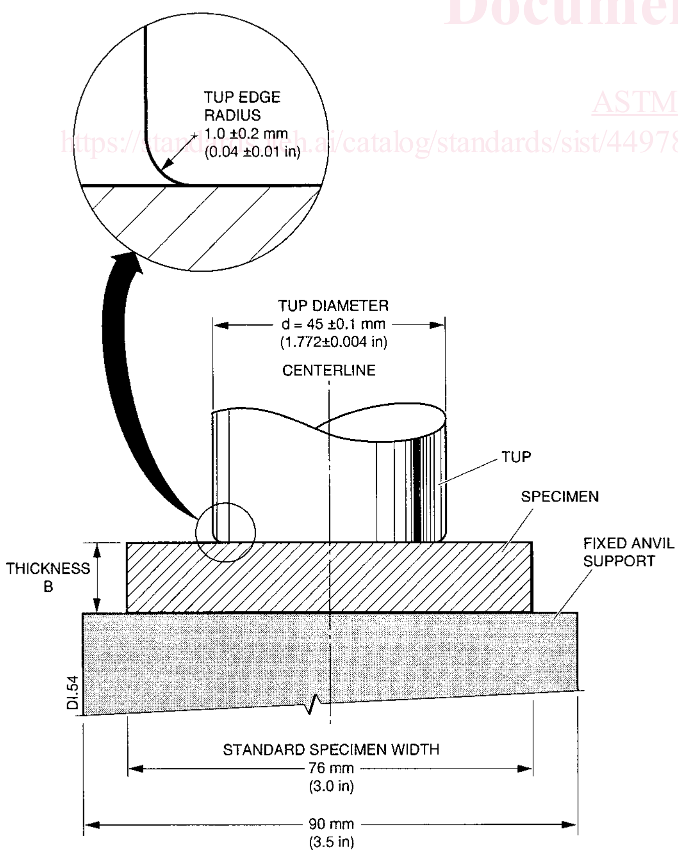


FIG. 2 Dimensional and Alignment Details

the fixed anvil assembly with the direction of force application being coincident ±2.5 mm (0.1 in.) with a line which passes through the center of mass of both the fixed anvil support and driven plunger assemblies, see Fig. 2.

6.1.2.1 The testing machine shall be capable of cycling (that is, loading and unloading as one cycle) the compression displacement of the specimen, see 8.2.2.

6.1.3 *Procedure A*—The standard method requirement for a maximum energy applied of 5 ± 0.5 J (44.2 ± 4.4 in.-lb) is achieved by use of specific impact mass and drop height. Acceptable values for these machine variables are 8.5 ± 0.1 kg for mass (a weight of 18.7 ± 0.2 lb) and 50 ± 2.5 mm (1.97 ± 0.098 in.) for initial (first impact cycle) drop height, see Fig. 1(*a*). The mass of the tup is included in the total impact mass and shall be less than 0.2 kg (0.4 lb). This can be accomplished by use of aluminum alloy 6061.

NOTE 9—The maximum energy applied is dependent on specimen displacement, see Note 7. The displacement will vary with the specimen thickness and for most material systems of interest for athletic footwear, the maximum displacement for this test method will be in the range from 5 to 15 mm (0.2 to 0.6 in.).

6.1.3.1 The velocity of the driven plunger assembly at the start of specimen compression shall be measured by any suitable means which has an accuracy of at least ±2 %, see 6.3.

6.1.3.2 Adverse loss of energy by the falling mass shall be avoided by having the measured impact velocity for the first impact cycle be within ±2 % of that for a free-falling object, that is given by $(2\ g\ h)^{0.5}$, where g is the gravitational constant and h is the drop height.

6.1.3.3 The velocity at the beginning of impact loading (for the 26th impact cycle) depends on the unrecovered specimen thickness. Velocity for the first impact cycle shall be in the range from 0.94 to 1.02 m/s (3.08 to 3.35 ft/s).

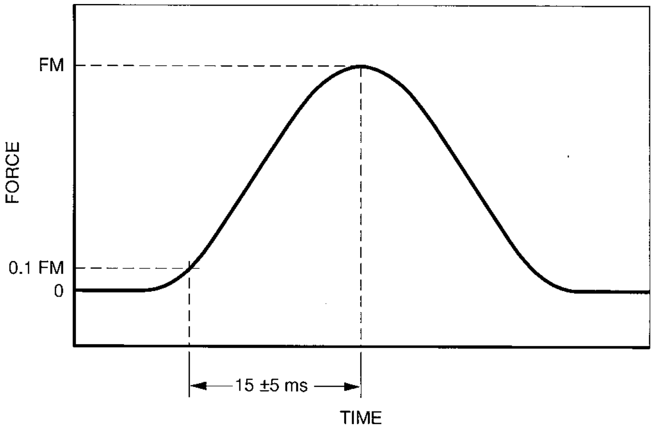
6.1.3.4 The testing machine shall be capable of initiating the impact cycle (that is, loading and unloading as one cycle) at a rate of one every 2 ± 1 s for the specimen conditioning (see section 8.2.2).

NOTE 10—For Procedure A the rates of loading and unloading are controlled by the initial impact velocity and the inherent shock attenuating properties of the specimen. Typical times to peak force will be in the range from 10 to 20 ms.

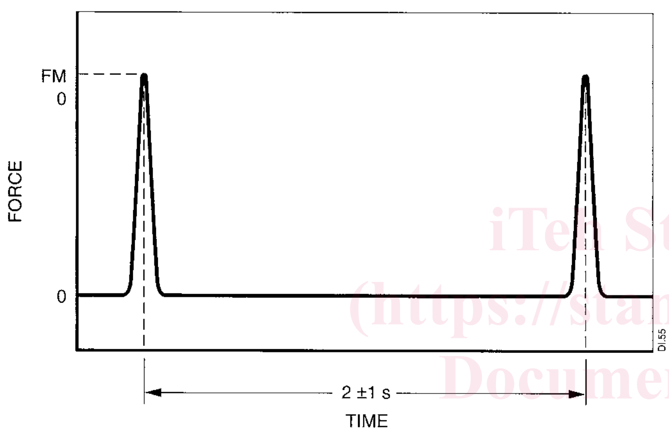
6.1.3.5 *Procedure B*—For Procedure B the rate of loading and unloading is controlled by the machine, see Fig. 1(*b*). The peak force selected for machine control shall be reached in a loading time of 15 ± 5 ms. The force-time curve shape, for the complete load/unloading cycle, can approximate that for a half sine function, see Fig. 3(*a*) and Note 11. Specimen conditioning (see section 8.2.2) requires a pause of 2 ± 1 s between load cycles, see Fig. 3(*b*).

NOTE 11—There are a variety of acceptable techniques for approximating the half sine function. The haversine is an example of an acceptable function for this test method.

6.1.3.6 *Procedure C*—For Procedure C the rate of loading and unloading is controlled by the machine. The peak displacement selected for machine control shall be reached in a loading time of 15 ± 5 ms. The displacement-time curve shape, for the complete loading/unloading cycle, can approximate that for a



a. Time Requirements for Impulse.



b. Time Requirements for Cyclic Load Conditioning.

FIG. 3 Rapid Rate Force-Time Details for Procedures B and C

half sine, see Fig. 3(*a*) and Note 11. Specimen conditioning (see section 8.2.2) requires a pause of 2 ± 1 s between load cycles, see Fig. 3(*b*).

6.2 The instrumentation for data acquisition and display shall consist of systems for determination of force and displacement during the complete impact cycle (loading and unloading), as well as, the system for generation of the force-displacement relationships, see Appendix X2.

6.2.1 *Force Sensing System*—A force transducer, of sufficiently high natural frequency, used together with a calibrating network for adjusting force sensitivity. This transducer shall be securely fastened so that force can be measured within ±2.5 mm (0.1 in.) of the central axis of the driven plunger assembly.

6.2.1.1 A variety of dynamic force transducers are commercially available and include: strain gage devices, piezo-electric transducers, and accelerometers. For Procedure A, the mass of the tup assembly between force transducer sensing area and specimen can influence the force or acceleration data, see X2.1.5. The calibration factor employed for converting transducer voltage values to force or acceleration units can be adjusted to account for the effects of the tup assembly mass, see M_r in X2.1.5.

6.2.1.2 The force transducer shall be capable of measuring compressive forces of up to 3.5 kN (781 lb). Peak force is dependent on specimen thickness and material properties. Values will be less than 2 kN (450 lb) for impact loading of a typical midsole material by this test method.

6.2.1.3 The minimum acceptable natural frequency for this test method is 500 Hz. The mass of the tup (see 6.1.2) attached to the force transducer will reduce the resonant frequency. Therefore, this natural frequency requirement applies to the assembly of tup and force transducer. This requirement does not apply for use of a force platform in the fixed anvil assembly. The requirement for natural frequency applies to all links of the instrument train from force transducer through to signal recording and display instrumentation. This is an "end-to-end" system requirement.

6.2.1.4 The minimum acceptable sampling rate for force or acceleration measurements is 1000 Hz (that is, measurement resolution of 1.0 ms).

6.2.1.5 The force transducer shall be employed in a manner which results in determination of any peak force to within ±3 % of value, see 6.3.

6.2.2 *Displacement Sensing System*—A means of monitoring the displacement of the moving assembly during the loading and unloading of the complete impact event. This can be accomplished through the use of a transducer or potentiometer attached directly to the system. Photographic or optical systems can also be utilized for measuring displacement. Typical displacement values will be in the range from 5 to 15 mm (0.2 to 0.6 in.) for specimen thicknesses of 5 to 35 mm (0.4 to 1.4 in.).

6.2.2.1 The minimum acceptable natural frequency for this test method is 500 Hz. The requirement for natural frequency applies to all links of the instrument train from displacement transducer through to signal recording and display instrumentation.

6.2.2.2 The minimum acceptable sampling rate for displacement measurements is 1000 Hz (that is, measurement resolution of 1.0 ms).

6.2.2.3 The determination of displacement shall be such that the reported values are within ±3 % of actual value, see 6.3.

6.2.2.4 *Procedure A*—For this procedure, displacement may be calculated as a function of velocity, impact mass, and the force (or acceleration) versus time data, through use of a suitable microprocessor system. Typical analytical relationships for this calculation are given in Appendix X2.

NOTE 12—When displacement is determined by a direct contacting (that is, attached to "fixed anvil assembly" and "driven plunger assembly") transducer, care must be taken to avoid adverse frictional energy loss, see 6.1.2.1.

6.2.2.5 *Procedures B and C*—For most machines displacement is measured directly from the driven assembly by a suitable transducer. The requirements of 6.2.2.1-6.2.2.3 are applicable to these procedures.

6.2.3 *Recording and Display Instrumentation*—Use any suitable means to record and display the data developed from the force and displacement sensing systems, provided the response characteristics are capable of presenting the data sensed with minimal distortion.

6.2.3.1 The requirements of 6.2.1.3-6.2.1.5 and 6.2.2.1-6.2.2.3 for force and displacement sensing systems, respectively, are applicable to the recording instrumentation.

6.2.3.2 The apparatus should display either force as a function of displacement, or force and displacement as a function of a common time scale. It is convenient to also display the calculated (see 11.5) specimen absorbed energy as a function of time or displacement. One of the preferred data displays is illustrated in Fig. 4.

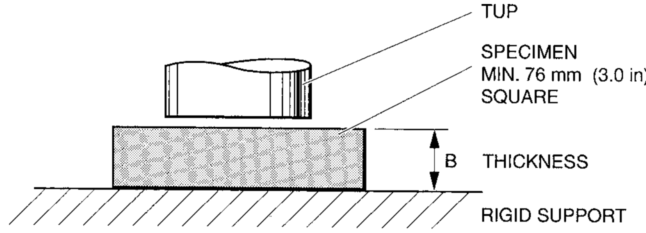
6.2.3.3 A variety of microprocessor-based systems for recording and generation of data displays are commercially available.

6.3 The complete mechanical and electronic apparatus shall be checked for calibration and performance to the requirements of 6.1 and 6.2 at least once every twelve months.

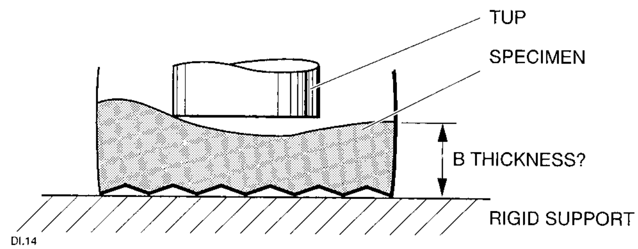
7. Specimens

7.1 *Geometry*—The standard specimen geometry shall be as shown in Fig. 5(*a*). This is a block of thickness, *B*, with parallel faces for those in contact with the driven assembly tup and fixed anvil support. The minimum cross-sectional dimensions are 76 mm^2 (3 in.^{2}). The *B* dimension shall be in the range from 5 to 35 mm (0.2 to 1.4 in.) and is a critical value for identification/qualification of the resultant test data.

7.2 *Nonstandard Geometry*—This test method might be used to measure the shock-attenuating characteristics of specimens having irregular surface alignments at tup and support anvil surfaces, see Fig. 5(*b*). This could be the case for end-use product specimens of insole/midsole/outsole. The validity for comparisons of results from tests of specimens of nonstandard geometry has not been determined.

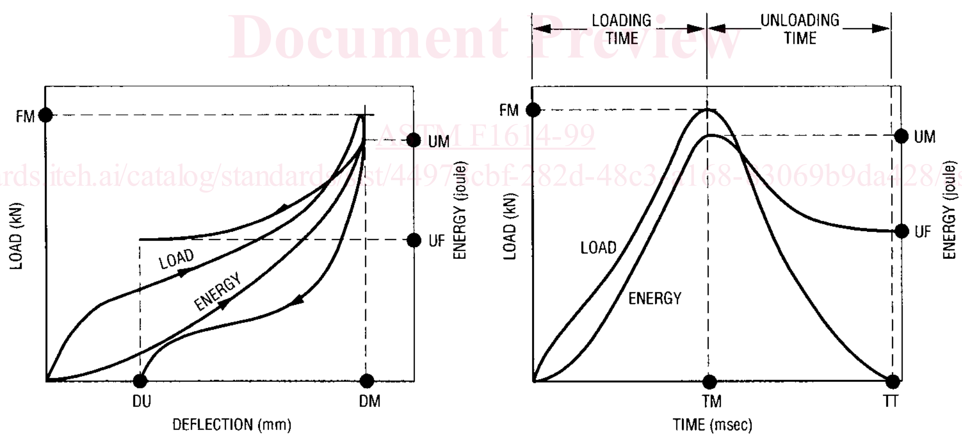


a. Standard Specimen.



b. Non-Standard Specimen.

FIG. 5 Specimen for Shock Absorbing Tests



DESCRIPTION	DATA PARAMETER TIME	LOAD	ENERGY	DEFLECTION
End of First Half of Compression Cycle	TM	FM	UM	DM
Completion of Compression Cycle	TT	—	UF	DU

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FIG. 4 Typical Data Displays for Shock Absorbing Tests