Designation: F355 – 23

An American National Standard

Standard Test Method for Impact Attenuation of Playing Surface Systems, Other Protective Sport Systems, and Materials Used for Athletics, Recreation and Play[1]

This standard is issued under the fixed designation F355; 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 measures the impact attenuation of surface systems and materials, specifically the peak impact acceleration ("impact shock") and calculates the Head Injury Criteria produced under prescribed impact conditions.

1.2 This test method is applicable to surface systems intended to provide impact attenuation, made of naturally occurring or synthetic materials.

1.3 This test method is applicable to impact attenuating mats and padding used in sports facilities, including, but not limited to: stadium wall padding, gymnastic mats, wrestling mats, turf playing systems, pole vault landing systems, and playground protective surfacing.

1.4 This test method is used to measure the impact attenuation of materials and components used as protective padding on trampoline frames, goal posts, etc., provided the material or component can be tested separately from the equipment to which it is attached.

1.5 Without modifications, this test method shall not be used to test materials and components that are attached to structures or equipment or finished products, unless the impact attenuation of the whole system is of interest.

1.6 While it is widely believed that lower values for impact attenuation can reduce the severity of impact-related injuries, the relationships between the results of this test method and specific injury risk are within automotive testing data.

1.7 The values stated in SI units are to be regarded as the standard. The values 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *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]

D5874 Test Methods for Determination of the Impact Value (IV) of a Soil

E105 Guide for Probability Sampling of Materials

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

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

F1702 Test Method for Measuring Impact-Attenuation Characteristics of Natural Playing Surface Systems Using a Lightweight Portable Apparatus

F2650 Terminology Relating to Impact Testing of Sports Surfaces and Equipment

2.2 *SAE Standard:*

SAE J211/1 Instrumentation for Impact Tests - Part 1 - Electronic Instrumentation (rev. July 2007)[3]

3. Terminology

3.1 Definitions of terms related to impact testing of sports surfaces equipment are found in Terminology F2650, except as noted.

3.2 *Definitions:*

[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 F08.52 on Miscellaneous Playing Surfaces.

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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 SAE International (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.

3.2.1 *drop height, n*—height from which the missile is dropped during an impact test, measured as the vertical distance between the lowest point of the elevated missile and surface under test.

3.2.2 *head injury criterion (HIC), n*—a specific integral of the acceleration-time history of an impact, used to determine relative risk of head injury. See Appendix X1.

3.2.3 *HIC interval, n*—the time interval within the acceleration-time history of an impact over which the HIC integral is evaluated.

3.2.4 *impact, n*—contact caused by a moving object (for example, an impact test missile) striking another object (for example, a surface) and during which one or both bodies are subject to high accelerations.

3.2.5 *impact test, n*—a procedure in which the impact attenuation of a playground surface or surfacing materials is determined by measuring the acceleration of a missile dropped onto the surface.

3.2.6 *free-fall impact test, n*—an impact test in which the trajectory of the missile is not restrained by rails, wires, or mechanisms or structures of any type.

3.2.7 *impact test results, n*—one or more measured or calculated values from one or more impact tests used to define the impact attenuation of a playground surface or surfacing materials.

3.2.8 *impact test site, n*—point on the surface of an installed playground surface that is selected as the target of an impact test.

3.2.9 *impact velocity, n*—the velocity (V_0) of a falling body (for example, a missile) at the instant of impact.

3.2.10 *missile, n*—a rigid object of specified mass and dimensions; used to impart an impact to a surface.

3.2.11 *impact test system, n*—a device or system for performing an impact test in which an instrumented missile is used to impact the surface or surfacing materials as specified in the appropriate specification or test procedure.

3.2.12 *missile reference plane, n*—the plane of the flat circular face of the hemispherical missile.

3.2.13 *reference drop height, n*—a specification of the drop height of an impact test.

3.2.14 *reference MEP pad, n*—a modular elastomer programmer pad with consistent and known impact attenuation properties that is used to verify proper functioning of the impact test equipment.

3.3 *Definitions of Terms Related to the Measurement of Acceleration Used in Annexes:*

3.3.1 *accelerometer, n*—a transducer for measuring acceleration.

3.3.1.1 *sensor, n*—alternative term for accelerometer.

3.3.1.2 *transducer, n*—the first device in data channel, used to convert a physical quantity to be measured into a second quantity (such as an electrical voltage) which is processed by the remainder of the channel.

3.3.1.3 *triaxial accelerometer, n*—a transducer or combination of transducers used for measuring the three vector components of acceleration in three dimensions, relative to three orthogonal spatial axes.

3.3.2 *accelerometer data channel, n*—all of the instrumentation used to communicate information about the physical quantity of acceleration from its origin to the point of presentation.

3.3.2.1 *Discussion*—The data channel includes all transducers, signal conditioners, amplifiers, filters, digitizers, recording devices, cables and interconnectors through which the information passes and also includes the analytical software or procedures that affect the frequency, amplitude, or timing of the data.

3.3.3 *Z axis, n*—axis of motion (fall) perpendicular to a horizontal surface.

3.3.4 *Y axis, n*—one of two axes forming a plane parallel to a horizontal surface.

3.3.5 *X axis, n*—one of two axes forming a plane parallel to a horizontal surface.

4. Summary of Test Method

4.1 A test specimen or installed surface system is impacted at a specified velocity or from a specified height with a specific missile of given mass and geometry as stipulated in a specification or test method. An accelerometer mounted in the missile is used to record the acceleration-time history of the impact. The peak acceleration and duration are used as a measure of impact severity.

4.2 This test method defines two missiles for use in playing surface impact tests:

4.2.1 *Missile A* has a cylindrical impacting surface, with specified mass and geometry and a circular, flat, metal impacting surface. This missile is used with a friction free guidance tube.

4.2.2 *Missile E* has a hemispherical impacting surface of specified mass and geometry and is used with a support structure and without a guidance system (“free-fall”).

4.2.3 Both missiles shall be fitted with triaxial accelerometers.

4.2.4 The specific masses and geometries of the missiles are detailed in Annex A1.

5. Significance and Use

5.1 The results of this method quantify the impact attenuation of playing surface and system specimens under the specific test conditions, either within a laboratory or the location the surface system is installed for use.

5.2 The test method measures the outcome of impacts performed under specific conditions. It does not quantify the intrinsic material properties of the tested specimens.

5.3 Test results from different specimens obtained under the same conditions (that is, the same missile mass and geometry, drop height, etc.) are used to compare impact attenuation under those conditions.

5.4 Test results obtained under different conditions are not comparable. Specifically obtained with different missiles are not equivalent and cannot be directly compared. Similarly, test results obtained using the same missile, but using different drop heights, are not directly comparable.

6. Apparatus

6.1 The user is to select the appropriate apparatus as called for in the test method or specification for the testing.

NOTE 1—The apparatus is detailed in Annex A1.

7. Test Specimen

7.1 Test specimens shall represent the surface system or protective padding as it is intended to be used. The minimum distance between the outer dimension of the missile and the edge of the specimen shall be at least 25.4 mm (1 in.) and no less than the thickness of the specimen.

7.2 Where the sample is to be tested in a controlled laboratory a method of confinement for the sample is required when specified in the appropriate standard.

7.3 Where the test is to be performed on an installed surface or in a location where it is to be used, there will be a testing protocol in the system specifications that will state the test procedure. The procedure typically includes the impact velocity or drop height, test locations, surface preparation, temperature and requirements for the collection, recording, preservation, and reporting of data.

7.4 Where the missiles of Annex A1 are used in the testing of surface systems, the appropriate specification shall provide any reference or confirmation procedures required.

8. Number of Specimens

8.1 The number of specimens tested as a sample often varies widely, depending upon the intended use of the data. It is recommended that at least two specimens be tested for each set of conditions. To obtain a specific quality assurance level, the sampling procedures of Practices E105 and E122 shall be followed.

8.2 The appropriate specification will have requirements for number and size of samples required for laboratory testing.

8.3 Where the testing is to take place at the site of installation or use, the appropriate standard provides direction to the person performing the testing as to the number of test locations and how they are determined.

9. Conditioning

9.1 In a laboratory, do not stack the specimens during any conditioning. They shall be under the intended use condition or preconditioned at 50 ± 2 % relative humidity and 23 ± 2°C for a minimum of 4 h, or until desired temperature is attained. The specification to which the sample is being tested outlines all requirements for conditioning of laboratory test samples.

9.2 The specification to which the surface system is being tested in the field outlines all requirements of conditioning or preparation requirements for the surface or the selection of the test location.

NOTE 2—Due to differing thermal conductivities and the extreme time dependence of temperature profiles in most materials exposed to extreme surface temperature changes, there may be variability introduced by this type of testing.

10. Procedure

10.1 Perform an instrument check as described for the appropriate instrument in A1.21. Reference drops are performed appropriate to the test.

10.2 Place the specimen under the missile, or orient the dynamic test equipment over the playing surface system.

10.3 *Drop Height Control:*

10.3.1 For "A" missile tests the guidance tube used shall have a release mechanism located to provide the drop height as required by the specification to which the tests are being performed.

10.3.2 For "E" missile tests the missile shall be supported at the specified drop height above the surface by a structure such as a tripod with the missile elevated to the drop height as required by the specification to which the tests are being performed.

NOTE 3—For test specifications where an impact velocity rather than a drop height is specified, the drop height shall be calculated as:

$$h = v^2/2g \quad (1)$$

where:

h = drop height cm (in.)
v = velocity cm/s (in./s)
g = acceleration due to gravity 981 cm/s^2 (386 in/s^2)

10.4 Release the missile, and record the results in accordance with the recommended procedures of the equipment manufacturers.

10.5 Make three consecutive drops at intervals of 1 ± 0.5 min, unless otherwise specified.

10.6 Ensure the measured drop height corresponds with the drop height measured by the test instrument.

11. Evaluation of the Data

11.1 Select the appropriate calculations as the relevant specification.

11.2 G_{max}—Determine the maximum deceleration in the time-deceleration history to the closest G.

11.3 The drop test data shall be reviewed at the time of testing and evaluated for G_{max}, velocity, and anomalies in the data, for example large variation in peak from one drop to the other for the same location, that could affect the validity of the data. The actual measured drop height shall be compared to the calculated drop height reported by the instrument (A1.19.1) to ensure the missile trajectory was not impeded in any way.

11.3.1 Where an anomaly is found, the testing shall be terminated and the device brought into compliance prior to proceeding.

12. Report

12.1 Report the following information:

12.1.1 Complete identification of material tested, including type, source, manufacturer's lot number (if appropriate), thickness (if measurable), and any other pertinent information,

12.1.2 Conditions of test, including temperatures, humidity, and any other pertinent data,

12.1.3 Date of test,

12.1.4 Missile used (A or E), manufacturer, model and serial number,

12.1.5 Measured impact velocity or drop height as provided by impact test instrument,

12.1.6 Impact data for each drop and average values of last two of three impacts or as specified,

12.1.7 G_{max},

12.1.8 Head Injury Criterion (HIC) depending on specification,

12.1.9 Date of most recent reference drops, and

12.1.10 Date of most recent calibration certificate of the test instrument.

12.2 Where additional reporting requirements are called for by the standard to which the test is being performed, this shall be added to that report.

13. Precision and Bias

13.1 *Precision Procedure A*—The reproducibility is estimated to be ±15 % between laboratories and ±2.5 % within a laboratory.

NOTE 4—This precision statement is based on a series of round-robin tests. The data were analyzed in accordance with Practice E691.

13.2 *Precision Procedure E*—In a preliminary inter-laboratory study, three samples (two reference MEP pads and a unitary surface sample) were tested by five laboratories, using a total of seven different impact test systems. Based on this study the inter-laboratory reproducibility limit of the test method is estimated to be ±5 % for g-max and ±10 % for HIC. The estimate assumes that laboratories will conform to the equipment requirements of this specification and that the tested specimen has minimal inherent variability.

13.3 Potential sources of error or deviations that were accounted for in the procedure are as follows:

13.3.1 Variations in the time between impacts required,

13.3.2 Variations in the impact velocity as a result of differences in drop height or friction in the drop guidance system, and

13.3.3 Variations in test laboratory temperatures.

13.3.4 Variations in the anvil, floor, or subbase on which the sample was laid.

14. Keywords

14.1 G_{max}; head injury criterion (HIC); impact; playground; playing surfaces; shock absorbing; surface materials

ANNEXES

(Mandatory Information)

A1. APPARATUS

A1.1 *Anvil*—For tests performed on surface samples in a laboratory, the surface sample shall be mounted on a rigid anvil or base having a mass at least 100 times that of the missile. A bare concrete floor shall be considered a suitable anvil.

A1.2 *Missile:*

A1.2.1 The user is to select the appropriate missile as called for in the surface specification. The missile shall have one of the combinations of mass and geometry specified in Table A1.1. (See also Fig. A1.1.)

A1.2.2 The missile includes cavities and additional components required to accommodate the attachment of sensors or to attach a supporting assembly. The form of any cavities or additional components shall be generally symmetrical about the Z-axis of the level missile such that center of mass lies within 0.08 in. (2 mm) of the Z-axis and the moments of inertia about any two horizontal axes do not differ by more than 5 %. (See Fig. A1.2.)

NOTE A1.1—An additional missile described as Missile "D" has been removed from this revision as it is individually and fully detailed in Test

TABLE A1.1 Missile Mass and Geometry

Missile	Impacting Surface Shape	Mass	Geometry
A	Cylindrical	9.1 ± 0.050 kg (20.0 ± 0.11 lb)	Circular face with an area of 129 ± 2.0-cm^2 (20 ± 1.0-in.^{2}) and a circumference-relieved radius of 2 ± 0.25 mm (0.08 ± 0.01 in.) to eliminate sharp edges
E	Hemispherical	4.6 ± 0.02 kg (10.1 ± 0.05 lb)	Hemispherical face with a diameter of 160 ± 2 mm (6.3 ± 0.1 in.)

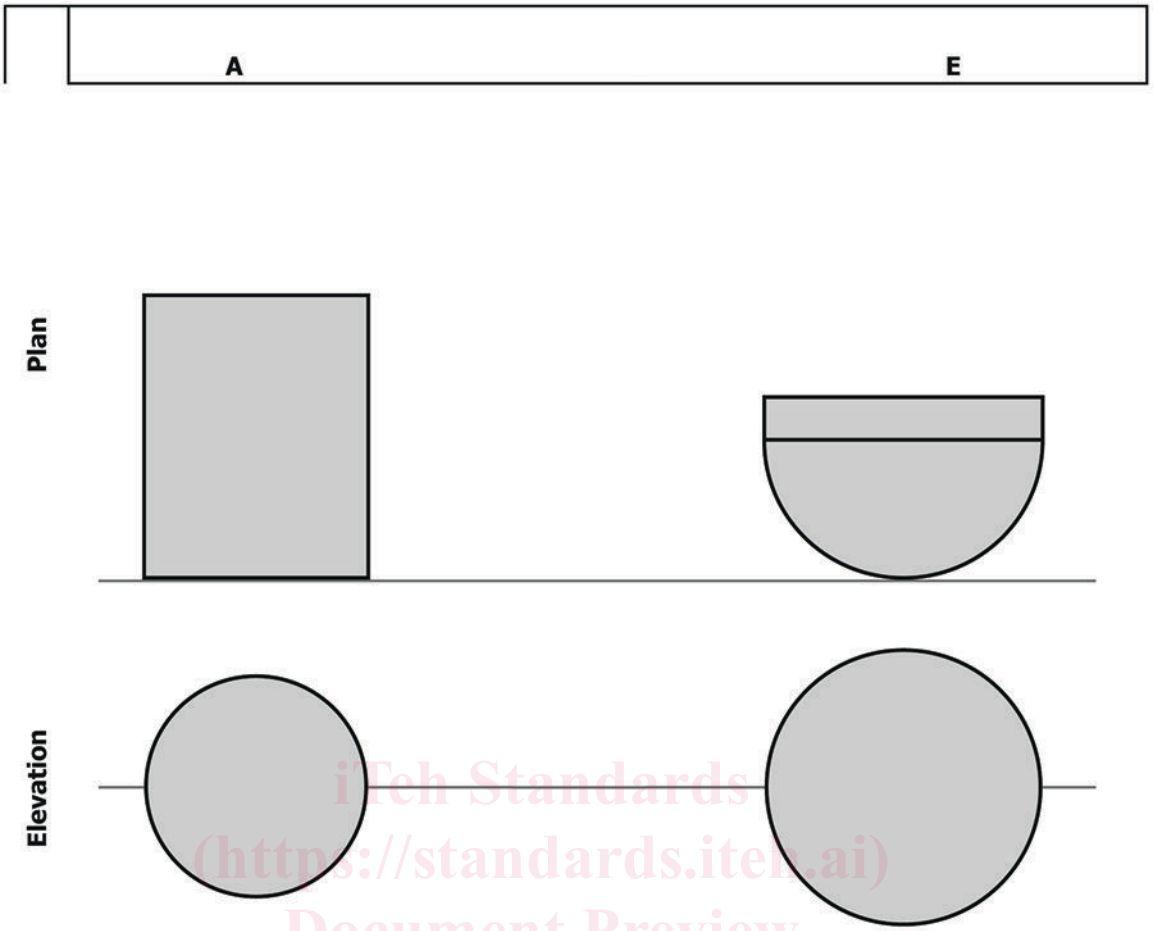

FIG. A1.1 Schematics Showing Approximate Relative Geometries of the A and E Missiles

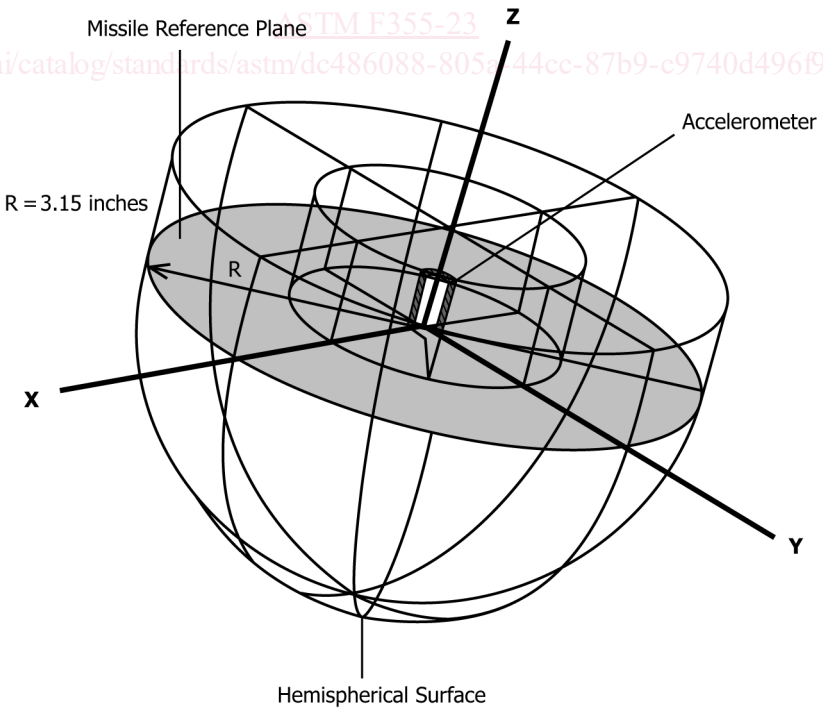

FIG. A1.2 Missile Reference Plane

Method F1702 and Test Methods D5874.

A1.3 *Guidance Mechanism for Guided Impact Tests Missile A*—Missile A is guided using a ventilated tube. The ventilation shall be sufficient to prevent the air compression caused by the falling missile from slowing the velocity of the missile. The guidance tube must allow the missile to be leveled prior to a drop and must maintain the missile in a level (±5°) attitude during the drop. The guidance mechanism shall be constructed in a manner that does not impede the trajectory of the missile during its fall or during its contact with the surface being tested; other than necessary impedance caused by friction in the guidance mechanism.

A1.4 *Support Structure for Missile E*—A support structure (for example, a tripod) shall be used to ensure repeatable drop height and location. The support structure shall be sufficiently rigid to support the weight of the missile without visible deformation. The support structure shall be erected in a manner that does not impede the trajectory of the missile during its fall or during its contact with the surface being tested.

A1.5 *Drop Height Control Mechanism*—The support structure of A1.19.1 shall incorporate a means of repeatedly positioning the missile at a predetermined drop height.

A1.6 *Release Mechanism*—The operation of any release mechanism provided as a means of initiating a drop of the missile shall not influence the fall trajectory of the missile following release.

A1.7 *Acceleration Measurement System*—A transducer or transducers and associated equipment for measuring and recording the acceleration of the missile during an impact with an accuracy of within ±3 % of the true value.

A1.8 *Accelerometers*—A triaxial accelerometer shall be rigidly attached at the center of mass of the missile. The primary (Z) sensing axis of the accelerometer shall pass through the center of mass of the missile.

A1.8.1 The accelerometer shall be rigidly attached at the center of mass of the missile (±2 mm) with its axis of sensitivity aligned (±5°) with the missile's Z axis and passing through the center of mass of the missile.

A1.8.2 Accelerometers shall have a minimum sensitive range of ±400 g and be capable of tolerating accelerations of at least 1000 g along any axis.

A1.9 *Accelerometer Calibration*—Accelerometers shall be calibrated by reference to a National Institute of Standards and Technology (NIST) traceable standard using a shaker table to excite a range of frequencies and amplitudes determined suitable by the accelerometer manufacturer. The calibration procedure shall include, as a minimum, the range of frequencies from 20 to 2000 Hz.

NOTE A1.2—Accelerometer calibration is usually performed by the manufacturer.

A1.9.1 Accelerometers and the electronics of the accelerometer data channel shall be recalibrated at a time interval recommended by the equipment manufacturer or every two years, whichever is the lesser time interval.

A1.10 *Accelerometer Connections*—The means of providing power and signal connections to the accelerometer (for example, a cable) shall be constructed in a manner such that the connecting devices do not influence the trajectory of the missile before or during the impact test.

A1.11 *Accelerometer Signal Conditioning*—Any signal conditioning of amplifying electronics required for proper operation of accelerometers shall be of a type recommended by the accelerometer manufacturer and shall have impedance and frequency response characteristics that are compatible with the accelerometer.

A1.12 *Accelerometer Signal Filtering:*

A1.12.1 *Anti-Aliasing Filter*—To prevent aliasing in the digitized acceleration data, the acceleration signals shall be filtered with an analog low pass filter prior to digitization. The anti-aliasing filter shall have a corner frequency of 5000 ± 500 Hz or a maximum of 0.25× the single channel sampling rate.

A1.12.2 *Data Channel Filter*—Digitized data shall be filtered in accordance with the specification for an SAE Channel Class 1000 data channel, using a 4th order Butterworth. It is acceptable to substitute an analog filter provided it has 4-pole characteristics and conforms to the data channel specification.

A1.13 *Recording Device*—A digital recording device such as a digital storage oscilloscope, a dedicated waveform analyzer of a computer equipped with an analog to digital converter shall be used to capture the acceleration time signal produced during an impact. Analog oscilloscopes and other analog recording devices shall not be used.

A1.14 *Resolution*—The conversion from analog accelerometer signal to digital data shall be accomplished with a digitizer having a resolution of 0.25 g or less. (For example, a twelve bit digitizer spanning the range ±500 g has a resolution of 0.244 g.)

A1.15 *Sample Rate*—The minimum sampling rate of the recording device shall be 20.0 kHz per accelerometer channel.

A1.16 *Capacity*—The digitizer shall be capable of recording and storing data continuously for a minimum of 50 ms, beginning at least 5 ms before onset of the impact and ending no earlier than 5 ms after the cessation of the impact.

A1.17 *Display*—The recording system shall have the capability of graphically displaying the recorded acceleration-time data in order to allow inspection by the operator. The display shall allow inspection of all the data points recorded from at least 5 ms before the onset of impact until no less than 5 ms