Designation: F 1292 – 99

Standard Specification for Impact Attenuation of Surface Systems Under and Around Playground Equipment[1]

This standard is issued under the fixed designation F 1292; 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

The need for a systematic means of evaluating surfacing materials for use on playgrounds has been amply demonstrated by the current difficulty in assessing the relative merits of such surfaces amid a diversity of testing methods, agencies, and terminology. Consequently, the goal of this specification is to establish a uniform means for measure to compare characteristics of the materials in order to provide the potential buyer with a useful yardstick by which to measure available materials as a surface under and around playground equipment.

1. Scope

1.1 This specification covers minimum impact attenuation requirements, when tested in accordance with Test Method F 355, for surface systems to be used under and around any piece of playground equipment from which a person may fall. This specification applies to all types of material that can be used under playground equipment.

1.2 This specification does not imply that an injury cannot be incurred if the surface system complies with this specification.

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

1.4 The following precautionary statement pertains to the test method portions only, Sections 12 and 13, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

E 691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method[2]

F 355 Test Method for Shock-Absorbing Properties of Playing Surface Systems and Materials[3]

F 429 Test Method for Shock-Attenuation Characteristics of Protective Headgear for Football[3]

2.2 *SAE Standard:*

SAE J 211 Recommended Practice for Instrumentation for Impact Tests[4]

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 *around playground equipment*—the area under and surrounding playground equipment established as protection from falls from equipment.

3.1.3 *deceleration*—the time rate of reduction of velocity.

3.1.4 *g*—acceleration into gravity at the earth's surface at sea level (32 ft/s (9.8 m/s)).

3.1.5 *g-max*—the multiple of *g* that represents a maximum deceleration experienced during an initial impact.

3.1.6 *headform*—the striking part of a testing apparatus.

3.1.7 *head injury criteria (HIC)*—a measure of impact severity that considers the duration over which the most critical section of the deceleration pulse persists as well as the peak level of that deceleration.

3.1.8 *impact attenuation*—the ability of a surface system to reduce and dissipate the energy of an impacting body.

3.1.9 *impact velocity*—the velocity of a falling body at the time of impact.

[1] This test method is under the jurisdiction of ASTM Committee F08 on Sports Equipment and Facilities and is the direct responsibility of Subcommittee F08.63 on Playground Surfacing Systems.

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

[3] *Annual Book of ASTM Standards*, Vol 15.07.

[4] Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096.

3.1.10 *loose fill system*—a surface system consisting of small independent, movable components; that is, sand, gravel, wood chips, and so forth.

3.1.11 *non-loose fill system*—a surface system consisting of one or more components bound together; that is, foam composites, urethane/rubber blocks, asphalt, and so forth.

3.1.12 *surface system*—all materials that contribute to the impact absorbing unit.

3.1.13 *theoretical drop height*—equates the measured velocity of the headform at the moment of impact to a height that would generate the same velocity if the test were performed at sea level and there was no friction to retard the headform during a drop from that height.

3.2 For the definitions of other terms used in this specification, refer to Test Methods F 355 and F 429.

4. Performance Requirements

4.1 All surface systems must be tested in accordance with the performance requirements in 4.2. In addition, surfaces may also be tested in accordance with 4.3. Testing in accordance with the performance requirements in 4.3 is optional.

4.2 When tested in accordance with Test Method F 355 or the free fall test method in Annex A1, using an average of the last two of three drops, no value shall exceed 200 *g*-max or 1000 HIC for laboratory tests at temperatures of 30, 72, and 120°F (–1, 23, and 49°C), respectively.

4.3 When tested in the field at ambient temperature in accordance with Test Method F 355 or the free fall test method in Annex A1, using an average of the last two of three drops, no value shall exceed 200 *g*-max or 1000 HIC at the height specified by the initial owner/operator prior to purchase of the surface.

4.4 When the surface system, while in use, is tested in accordance with Test Method F 355 or the free fall test method in Annex A1, using an average of the last two of three drops, at each of three test sites, and exceeds 200 *g*-max or 1000 HIC at ambient temperature, as determined by Section 13, at the height specified by the initial owner/operator prior to the purchase of the surface, the surface system should be made to comply or the playground equipment on the surface should not be used until the surface complies.

5. Summary of Test Method

5.1 Representative playground surface systems or surfacing material samples, or both, are tested in accordance with Test Method F 355 or the free fall test method described in Annex A1. Conduct laboratory tests at various drop heights and test temperatures. Conduct the field tests at the drop height specified and at the ambient temperature of the site within a specified range. The laboratory test method will determine the maximum drop height at which the *g*-max does not exceed 200 or the HIC does not exceed 1000. The field test method will determine the *g*-max and the HIC from the drop height specified by the initial owner/operator at the ambient temperature of the test.

6. Significance and Use

6.1 Data obtained from this specification are indicative of the relative impact attenuation characteristics of the playground surface system and can be used only for comparisons and for establishing minimum requirements.

7. Operator Qualifications

7.1 If not an employee of an accredited or recognized laboratory, the operator shall be trained and certified by the equipment supplier, including written and performance testing, to establish competency in performing appropriate Specification F 1292 testing.

8. Test Apparatus

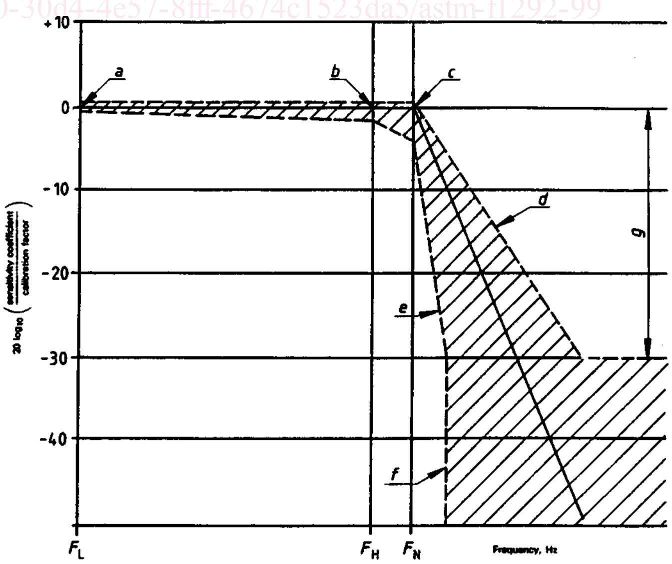
8.1 The signal from the acceleration transducer shall be conditioned with a low pass filter, complying to Channel Class 1000 of SAE J 211 (see Fig. 1).

8.2 The acceleration recording system must be capable of accurately resolving the deceleration to a minimum of ±5 *g* from 0 to 500 *g*.

8.3 The acceleration transducer must be capable of withstanding impacts of at least 1000 *g* without damage.

8.4 Use the ANSI metal Headform C from Test Method F 355 or the hemispherical headform from the free fall test method in Annex A1.

8.4.1 The ANSI metal Headform C from Test Method F 355, Procedure C, must be connected to guides (such as monorail, dual rail, or guide wires) using a follower or other mechanism. Alternatively, the hemispherical headform from the free fall test method in Annex A1 may be used if connected to a system of guides. A uniaxial or triaxial accelerometer must be used. The guidance system must allow the headform to be leveled prior to and during the drop tests in the crown position. The vertical accelerometer must be aligned to within 5° of the vertical axis. The accelerometer must be attached at the center of mass of the headform.



CFC	F_L Hz	F_H Hz	F_N Hz
1 000	< 0,1	1 000	1 650
600	< 0.1	600	1 000
180	< 0,1	180	300
60	< 0.1	60	100

Logarithmic scale

a ± 0,5 dB
b + 0,5; – 1 dB
c + 0,5; – 4 dB
d – 9 dB/octave
e – 24 dB/octave
f ∞
g – 30 dB

FIG. 1 Data Channel Dynamic Accuracy

8.4.2 The hemispherical headform from the free fall test method in Annex A1 must be used with a triaxial accelerometer. The vertical accelerometer must be aligned to within 5° of the vertical axis. The accelerometer must be attached at the center of mass of the headform.

8.5 The minimum system sampling rate required is 16 000 Hz or 16 000 samples/s.

8.6 The HIC shall be calculated based on the following mathematical expression:

$$HIC = \left[(t_2 - t_1) \left(\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} \mathrm{a}dt \right)^{2.5} \right]_{max} < 1000 \qquad (1)$$

The specified algorithm and verification calculations for HIC are included as Appendix X2.[5]

9. Test Sample

9.1 Each sample of surfacing material shall represent the playground surface system as it is intended to be used in place, including seams, partitions, corners, and fasteners/anchors or other areas that may result in less than optimal impact characteristics.

9.2 In the case of non-loose fill playground surface systems, the minimum sample shall be 12 by 12 in. (300 by 300 mm).

9.3 In the case of loose fill playground surface systems, a box with a minimum inside dimension of 18 by 18 in. (450 by 450 mm) and side walls of sufficient height to hold the loose fill material at the thickness of intended use and to keep the loose fill materials in place should be constructed around the base of the test equipment. The loose fill materials shall be poured to an even depth and the surface leveled and left undisturbed for the entire test period.

10. Number of Specimens

10.1 At least nine specimens of a specific playground surface system shall be submitted for laboratory testing.

11. Sample Conditioning

11.1 Laboratory samples shall be preconditioned at 50± 10 % relative humidity 72 ± 5°F (23 ± 3°C) for a minimum of 24 h prior to beginning testing.

11.2 Samples tested at various temperatures, 30, 72, and 120°F, (−1, 23, and 49 ± 1°C, respectively) shall be conditioned for 4 h minimum. Testing must be started within 1 min of taking each sample out of the environmental chamber with a time interval between drops of 3 ± 0.25 min. If the test intervals are not met, an additional conditioning period of 4 h will be necessary.

12. Laboratory Procedure (Test Method)

12.1 Test all samples of the surface system in accordance with the selected test method, Test Method F 355, or the free fall test method in Annex A1, with the headform impacting in the crown position.

12.2 Conduct impact tests considering the following criteria:

12.2.1 Carry forth the impact test to a maximum drop height in whole foot increments, that is, 1, 2, 3 ... *n*, that gives both a deceleration force of 200-*g* max and an HIC of 1000 or less. It must also be measured at intervals of 1 ft over and under this maximum drop height.

12.2.2 An impact test consists of three drops at the same impact site, at each height. The impact site shall be at the location that exhibits the least optimal impact characteristics (as described in 9.1). Calculate the average of the second and third drops.

12.2.3 The impact test uses a different sample at all heights at the given temperatures.

12.2.4 The impact test samples are to be tested at the three specific temperatures of 30, 72, and 120°F (−1, 23, and 49°C, respectively) after the required conditioning.

12.2.5 If for any reason during the test, the headform holding fixture interferes with the test, note it in the report and discontinue the test. The information recorded shall be considered invalid.

12.2.6 When using Test Method F 355, measure and record the impact velocity for each drop. It cannot vary more than ±0.5 ft/s from the theoretical free fall velocity at the drop height used.

13. Field Test Procedure (Test Method)

13.1 Test at least three different impact sites of each surface system in use in accordance with the selected test method, either Test Method F 355 or the free fall test method in Annex A1 with the headform in the crown position. The selected impact sites shall include those areas that may exhibit less than optimal impact characteristics. These areas may be high traffic or compressed areas as well as areas containing seams, partitions, corners, and fasteners/anchors.

13.2 Conduct impact test in accordance with the following criteria:

13.2.1 Carry forth the impact tests at the drop height, as specified by the initial owner/operator.

13.2.2 The impact test shall have three drops at each of the impact sites, for a total of nine impacts. Report the average of the second and the third drops for both *g*-max and HIC values.

13.2.3 Insert a temperature measuring device into the surface system (within 6 in. (152 mm) of the impact site) at the time of the impact test, to measure the temperature of the surface system, at a ½-in. (12.5-mm) depth or no more than half the depth of the surface system.

13.2.4 Measure and record the impact velocity for each drop. The impact velocity cannot vary more than ±0.5 ft./sec. from the theoretical free fall velocity at the drop height used.

14. Report

14.1 Report the following information:

14.1.1 The sample identification, including type, source, size, and thickness.

14.1.2 Test procedure used and missile description, including mass, geometry, and orientation.

14.1.3 Testing conditions, including sample temperatures and drop heights employed.

14.1.4 Individual drop values and the average of the second and third drop values for both *g*-max and HIC values.

[5] Chou, C., and Nyquist, G., "Analytical Studies of the Head Injury Criterion," *Society of Automotive Engineers*, SAE Paper No. 740082, 1974.

14.1.5 The theoretical drop heights used.

14.1.6 The deceleration/time trace in 0.5-ms intervals.

NOTE 1—The preferred method of exhibiting the data would be in chart form (see Figs. 2 and 3).

15. Precision

15.1 Potential sources of error or deviations are as follows:

15.1.1 Variations in the time needed to conduct the test result in variable levels of recovery of the material during the room temperature tests. This variation is accentuated in non-room temperature tests by the addition of changing temperature conditions within the sample to the variable recovery of the material.

15.1.2 Variations in the impact velocity brought about by changes in drop height or friction in the drop guidance mechanism.

15.1.3 Use of missiles other than those referenced in this specification may cause substantial variations in results.

15.2 An interlaboratory study was conducted in 1996-97 during the development of this test method. Seven laboratories ran pairs of tests on eight surface materials using Test Method F 355, Procedure C. The same laboratories also ran pairs of tests on the same surface materials using the free fall test method. In both series of tests, *g*-max and HIC values were determined. From the results of these tests, precision statistics were calculated in compliance with Practice E 691.

15.2.1 The precision results are summarized in Tables 1-4.

15.2.2 A statement on bias cannot be made because no reference surfaces are available.

15.2.3 An earlier interlaboratory study was completed in 1989.[6] The technique used to analyze the study data resulted in a ± figure being generated for test method precision. Applying this method to the 1996-7 study, the results described in Tables 5 and 6 were obtained.

NOTE 2—The method used to generate Tables 5 and 6 is not as statistically accurate as the analysis used in 15.2.1. It is provided for informational purposes only.

16. Keywords

16.1 impact attenuation; playground; surface system

[6] Available from ASTM Headquarters. Request RR:F08-1002.

SAMPLE IDENTIFICATION ______________________

SAMPLE DIMENSIONS ______________________

TEST PROCEDURE ASTM F 355, Procedure C

MISSILE Headform Mass ______ lbs. (_____ kg.)

Orientation of Headform ____________________________

TEMPERATURE	30°F (-1°C)		72°F (23°C)		120°F (49°C)	
	1 2 3 g max	Ave 2&3 (HIC)	1 2 3 g max	Ave 2&3 (HIC)	1 2 3 g max	Ave 2&3 (HIC)
Sample Number	1		2		3	
Drop Height ft (m) Velocity ft/sec (m/sec)						
Sample Number	4		5		6	
Drop Height ft (m) Velocity ft/sec (m/sec)						
Sample Number	7		8		9	
Drop Height ft (m) Velocity ft/sec (m/sec)						

FIG. 2 Suggested Laboratory Test Report Form

13. REPORT

13.1. Report the following information:

SAMPLE IDENTIFICATION ______________________

SAMPLE DIMENSIONS ______________________

TEST PROCEDURE ASTM F 355, Procedure C

MISSILE Headform Mass ______ lbs. (_____ kg.)

Orientation of Headform ____________________________

PLAYGROUND SURFACE TEMPERATURE						
	1 2 3 g max	Ave 2&3 (HIC)	1 2 3 g max	Ave 2&3 (HIC)	1 2 3 g max	Ave 2&3 (HIC)
Impact Site Number	1		2		3	
Drop Height ft (m) Velocity ft/sec (m/sec)						

FIG. 3 Suggested Field Test Report Form

TABLE 1 Precision Statistics for *g*-max, Test Method F 355, Procedure C

Material	Average	Repeatability Standard Deviation (S_r)	Reproducibility Standard Deviation (S_R)	Repeatability Limit (r)	Reproducibility Limit (R)
D	52.4	2.0	7.8	5.6	21.8
E	62.9	9.1	11.4	25.5	31.9
H	107.2	3.8	7.9	10.6	25.8
A	125.0	2.6	9.5	7.3	26.6
C	143.8	1.9	7.7	5.3	21.6
G	193.2	15.2	17.1	42.6	47.9
B	202.0	2.6	14.6	7.3	40.9
F	234.3	3.2	12.0	9.0	33.6

TABLE 2 Precision Statistics for *g*-max, Free Fall Test Method

Material	Average	Repeatability Standard Deviation (S_r)	Reproducibility Standard Deviation (S_R)	Repeatability Limit (r)	Reproducibility Limit (R)
D	54.4	7.6	9.4	21.3	26.3
E	51.5	11.0	11.0	30.8	30.8
H	100.9	3.9	6.9	10.9	19.3
A	118.0	2.1	6.2	5.9	17.4
C	148.9	5.6	10.0	15.7	28.0
G	180.6	5.7	9.1	16.0	25.5
B	213.0	7.9	16.3	22.1	45.6
F	247.1	10.9	20.2	30.5	56.6

TABLE 3 Precision Statistics for HIC, Test Method F 355, Procedure C

Material	Average	Repeatability Standard Deviation (S_r)	Reproducibility Standard Deviation (S_R)	Repeatability Limit (r)	Reproducibility Limit (R)
D	145.0	12.0	30.5	33.6	85.4
E	211.9	47.4	79.4	132.7	222.3
H	600.0	14.4	103.2	40.3	289.0
A	628.7	130.0	166.0	364.0	464.8
C	731.0	13.0	103.4	36.4	289.5
G	1162.0	31.9	177.0	89.3	495.6
B	1433.0	148.3	220.4	415.2	617.1
F	1849.0	17.3	188.2	48.4	527.0

TABLE 4 Precision Statistics for HIC, Free Fall Test Method

Material	Average	Repeatability Standard Deviation (S_r)	Reproducibility Standard Deviation (S_R)	Repeatability Limit (r)	Reproducibility Limit (R)
D	144.4	26.1	35.7	73.1	100.0
E	120.0	45.7	47.8	128.0	133.8
H	585.3	34.1	87.4	95.5	244.7
A	557.0	31.2	81.3	87.4	227.6
C	767.0	44.6	110.9	124.9	310.5
G	1262.0	87.8	194.8	245.8	545.4
B	1330.0	71.8	162.4	201.0	454.7
F	1849.0	295.9	398.7	828.5	1116.4

TABLE 5 Combined Results - Loose Fill and Non-loose Fill Materials

Uniaxial: Peak G (F 355, Procedure C)	±24 %
Free Fall: Peak G	±20 %
Uniaxial: HIC (F 355, Procedure C)	±54 %
Free Fall: HIC	±40 %

TABLE 6 Non-loose Fill Materials Only

Uniaxial: Peak G (F 355, Procedure C)	±21 %
Free Fall: Peak G	±11 %
Uniaxial: HIC (F 355, Procedure C)	±31 %
Free Fall: HIC	±24 %

ANNEXES

(Mandatory Information)

A1. FREE FALL TEST METHOD

A1.1 A nonguided headform may be used for impact testing of playground surface systems or surfacing material samples.

A1.2. Terminology

A1.2.1 *Definition of Term Specific to This Annex:*

A1.2.1.1 *free fall*—the trajectory of the headform is not restrained by rails, wires, or a mechanism or structure of any type.

A1.3 Apparatus

A1.3.1 *Headform Design*—The headform as a 10.1 ± 0.1 lb (4.6 ± 0.05 kg) hemispherical missile of diameter 6.300 ± 0.200 in. (160 ± 5 mm). An optional handle may be affixed to the headform provided that the total weight of the headform and handle combination does not exceed 10.1 ± 0.1 lb (4.6± 0.05 kg).

A1.3.2 *Accelerometer*—Rigidly attach a triaxial accelerometer at the center of mass of the headform.

A1.3.2.1 One axis of the accelerometer must be mounted parallel within 5° to the primary axis of impact of the headform. This axis of the accelerometer shall have a linear output signal from 0 to 500 *g*.

A1.3.2.2 The remaining two axes of the accelerometer must define a plane normal to the primary axis. Both of these axes shall have a linear output signal from 0 to ± 500 *g*.

A1.3.2.3 All axes of the accelerometer must be capable of withstanding impacts of 1000 *g* without damage.

A1.3.2.4 Connect the output signal of the accelerometer to the recording device by a flexible multiple conductor cable. The cable shall be sufficiently flexible so as to not influence the trajectory of the headform before or during the impact test. The fully extended length of the cable shall be at least two times the drop height specified by the initial owner/operator. The cable shall be of self-coiling design. The cable shall be attached to the headform and recording device by a single multiple contact electrical connector with integral locking action.

A1.3.2.5 The axis nominally perpendicular to the impact surface shall be annotated *Z*. The axes forming the plane nominally parallel to the impact surface shall be annotated *X* and *Y*. This coordinate system complies with the right handed coordinate system, Orientation 2, of SAE J 211.

A1.3.3 *Recording Equipment*—The recording equipment shall meet the following criteria:

A1.3.3.1 *Acceleration Time*—The acceleration-time recording equipment shall have three input channels, each matched to the output signal levels of the triaxial accelerometer. Each input channel and accelerometer pair shall have a frequency response adequate to measure the peak acceleration to an accuracy of ±5 % of the true value. The total system, accelerometers and recorders, shall be capable of measuring impulses up to 500 *g* at frequencies from 2 to an accuracy of ±5 %. The minimum system sampling rate required is 20 000 Hz per input channel or 20 000 samples/s per input channels. The recording device must be capable of simultaneously sampling each of the three input channels at the specified sampling rate. Three independent digitizers or a single digitizer with three track and hold amplifiers is acceptable. Each acceleration data channel should comply with SAE J 211. A low pass filter having a 4-pole Butterworth transfer function and a corner frequency of 1650 Hz meets this requirement. Digitizer resolution shall be a minimum of twelve bits.

A1.3.3.2 *Displacement - Time*—Provision will be made to record the time, in seconds, from the release of the headform to the time of initial impact. The velocity at impact will be calculated by multiplying the fall time by the acceleration due to gravity (32.2 ft/s/s) to yield the velocity in feet per second. The time measurement function will be part of the recording device and will not require operator intervention to start and stop the measurement.

A1.3.3.3 *System Integrity*—Portable recording equipment shall provide continuous battery voltage monitoring. If recording equipment battery voltage falls below a level required for proper equipment operation, the recording function shall be inhibited and the person performing the test alerted by an indicator lamp or message on the LCD interface of the recording device. Auxiliary power means, such as automobile battery voltage converters or wall receptacle connected chargers, may be used to restore battery voltage to the acceptable operating level. Impact tests may be performed with the recording device connected to the auxiliary power source. Prior to use the recording equipment and headform shall be checked for proper operation by impact test on a reference surface material sample. The sample shall be provided by the recording device manufacturer and be furnished with reference impact test data including serial number of sample, drop height, ambient temperature, subsurface condition, *g*-max, and HIC. Average the results of the last two of three drops, and compare to the reference *g*-max and HIC. The manufacturer of the triaxial headform is to provide the criteria for the requirement for recalibration of the headform, recorder, and reference pad. The impact test on the reference sample will not be construed to be a calibration of the instrument, which can only be performed in a properly equipped metrology laboratory.

A1.3.3.4 *Calibration*—Check the recording equipment, headform, and reference surface material sample annually for proper calibration by returning them to the manufacturer's calibration laboratory or repair depot qualified by the manufacturer.

A1.3.3.5 *Impact Data and Waveform Display*—The recording device shall have a graphic display device capable of indicating the *g*-max, HIC, and impact waveform.

A1.3.3.6 *Drop Height Measurement and Control-Drop Height*, shall be measured from the top of the surface to be tested to the surface of the headform expected to initially impact the surface. Measurement shall be made with a steel rule or steel tape measure. Use a support structure or tripod to ensure repeatable drop height and location. The support structure or tripod shall be sufficiently rigid to support, with minimum deflection, the weight of the headform. The support structure or tripod must allow for the testing of the surface at any location within the playspace. A quick-release mechanism shall be provided to connect the headform to the support arm. The operation of the release mechanism shall not influence the trajectory of the headform during free fall. Erect the support structure or tripod in such a manner so as to prevent the headform from coming in contact with any part of the support structure or tripod before impact with the surface being tested.

A1.3.4 *Calculation*:

A1.3.4.1 *Triaxial Acceleration Component Summing*—The components of acceleration in each of the three axes must be vector summed to determine composite acceleration of the headform. Perform vector addition on each set of three samples to determine the composite acceleration for the respective sample period. The vector addition shall be based on the following mathematical expression: