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Standard Specification for Impact Attenuation of Surfacing Materials Within the Use Zone of Playground Equipment[1]

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INTRODUCTION

Surveys by the United States Consumer Product Safety Commission (CPSC)[2] and others have shown that falls from playground equipment onto the underlying surface are a significant cause of injuries to children. Severe head injuries are the most frequently implicated cause of death in playground equipment-related falls. Use of appropriate impact-attenuating surfacing materials in the use zone of playground equipment can reduce the risk of fall-related injury. In particular, it is believed that the risk of life-threatening head injuries is reduced when appropriate surfacing materials are installed.

This specification specifies impact attenuation performance requirements for playground surfaces and surfacing materials and provides a means of determining impact attenuation performance using a test method that simulates the impact of a child's head with the surface. The test method quantifies impact in terms of *g*-max and Head Injury Criterion (HIC) scores. *g*-max is the measure of the maximum acceleration (shock) produced by an impact. The Head Injury Criterion or HIC score is an empirical measure of impact severity based on published research describing the relationship between the magnitude and duration of impact accelerations and the risk of head trauma.

The purpose of this specification is to reduce the frequency and severity of fall-related head injuries to children by establishing a uniform and reliable means of comparing and specifying the impact attenuation of playground surfaces. Its use will give designers, manufacturers, installers, prospective purchasers, owners, and operators of playgrounds a means of objectively assessing the performance of surfacing materials under and around playground equipment and hence of evaluating the associated injury risk.

This specification determines the critical fall height for the surface material or surfacing system at each of three temperatures.

1. Scope

1.1 This specification establishes minimum performance requirements for the impact attenuation of playground surfacing materials installed within the use zone of playground equipment.

1.2 This specification is specific to surfacing used in conjunction with playground equipment, such as that described in Specifications F1148, F1487, F1918, CSAZ614 (Canada), and SS457 (Singapore).

1.3 This specification establishes an impact attenuation performance criterion for playground surfacing materials; expressed as a critical fall height.

1.4 This specification establishes procedures for determining the critical fall height of playground surfacing materials under laboratory conditions. The laboratory test is mandatory for surfaces to conform to the requirements of this specification.

1.5 The laboratory test required by this specification addresses the performance of dry surfacing materials.

1.6 This specification also provides optional procedures to determine the critical fall height under wet or frozen test conditions, or both.

1.7 The critical fall height of a playground surfacing material determined under laboratory conditions does not account for important factors that have the potential to influence the

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[2] U.S. CPSC Special Study. Injuries and Deaths Associated with Children's Playground Equipment, April 2001. U.S. Consumer Product Safety Commission, Washington, DC.

actual performance of installed surfacing materials. Factors that are known to affect surfacing material performance include but are not limited to aging, moisture, maintenance, exposure to temperature extremes (for example, freezing), exposure to ultraviolet light, contamination with other materials, compaction, loss of thickness, shrinkage, submersion in water, and so forth.

1.8 The impact attenuation specification and test methods established in this specification are specific to the risk of head injury. There is only limited evidence that conformance with the requirements of this specification reduces the risk of other kinds of serious injury (for example, long bone fractures).

NOTE 1—The relative risk of fatality and of different degrees of head injury may be estimated using the information in Appendix X1, which shows the relationships between the Head Injury Criterion (HIC) scores of an impact and the probability of head injury.

1.9 This specification relates only to the impact attenuation properties of playground surfacing materials and does not address other factors that contribute to fall-related injuries. While it is believed that conformance with the requirements of this specification will reduce the risk of serious injury and death from falls, adherence to this specification will not prevent all injuries and deaths.

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

1.11 *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.*

1.12 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

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

F355 Test Method for Impact Attenuation of Playing Surface Systems, Other Protective Sport Systems, and Materials Used for Athletics, Recreation and Play

F1148 Consumer Safety Performance Specification for Home Playground Equipment

F1487 Consumer Safety Performance Specification for Playground Equipment for Public Use

F1918 Safety Performance Specification for Soft Contained Play Equipment

F2075 Specification for Engineered Wood Fiber for Use as a Playground Safety Surface Under and Around Playground Equipment

F3313 Test Method for Determining Impact Attenuation of Playground Surfaces Within the Use Zone of Playground Equipment as Tested in the Field

2.2 *Federal Documents:*[4]

U.S. Consumer Product Safety Commission, Publication 325 Handbook for Public Playground Safety

U.S. Consumer Product Safety Commission Special Study: Injuries and Deaths Associated with Children's Playground Equipment. April 2002

U.S. Department of Justice 2010 Standard for Accessible Design

2.3 *ISO Document:*[5]

ISO/TR 20183 Sports and other recreational facilities and equipment – Injury and safety definitions and thresholds – Guidelines for their inclusion in standards

3. Terminology

3.1 *Definitions of Terms Related to Playground Installations:*

3.1.1 *critical fall height (CFH)*—a measure of the impact attenuation performance of a playground surface or surfacing materials; defined as the highest theoretical drop height from which a surface meets the impact attenuation performance criterion specified by this specification. The critical fall height approximates the maximum fall height from which a life-threatening head injury would not be expected to occur.

3.1.2 *designated play surface*—any elevated surface for standing, walking, sitting, or climbing, or a flat surface larger than 2.0 in. (51 mm) wide by 2.0 in. (51 mm) long having less than 30° angle from horizontal.

3.1.3 *fall height*—the vertical distance between a designated play surface and the playground surface beneath it.

3.1.3.1 *Discussion*—Fall heights for specific types of play structure are defined in Specifications F1148, F1487, F1918, CSAZ614, and SS457.

3.1.4 *playground equipment*—any fixed physical structure installed in a designated play area that is accessible to children for activities such as climbing, swinging, sliding, rocking, spinning, crawling, creeping, or combinations thereof.

3.1.5 *playground surface*—a manufactured or natural material used to cover the ground below playground equipment, including foundations, substrates, and any compliant surfacing materials intended to attenuate impact.

3.1.6 *play structure*—a free-standing structure with one or more components and their supporting members.

3.1.7 *public use playground equipment*—a play structure anchored to the ground or not intended to be moved, for use in play areas of schools, parks, child-care facilities, institutions,

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For Annual Book of ASTM Standards volume information, refer to the standard's Document Summary page on the ASTM website.

[4] Available from U.S. Government Printing Office, Superintendent of Documents, 732 N. Capitol St., NW, Washington, DC 20401-0001, http://www.access.gpo.gov.Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

[5] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

multiple-family dwellings, private resorts and recreation developments, restaurants, and other areas of public use.

3.1.8 *specifier*—person or entity responsible for specifying the performance requirements of a playground surface (for example, an architect or the prospective purchaser, owner, or operator of a playground).

3.1.9 *surfacing materials*—materials used to cover the surface of the playground use zone.

3.1.9.1 *loose-fill surface*—a compliant top layer of small, independently, movable components; for example, wood fiber, bark mulch, wood chips, shredded foam, shredded rubber, sand, gravel, and so forth.

3.1.9.2 *aggregate surface*—a loose-fill surface in which the compliant top layer is made of particulate materials (for example, sand, gravel, crushed marble, slag, cinders, calcined materials).

3.1.9.3 *unitary surface*—a compliant top layer of one or more material components bound together to form a continuous surface; for example, urethane and rubber composites, molded foam, molded rubber mats.

3.1.10 *use zone*—the area beneath and immediately adjacent to a play structure or playground equipment that is designated for unrestricted circulation around the equipment and on whose surface it is predicted that a user would land when falling from or exiting the equipment.

3.2 *Definitions of Terms Related to Impact Testing:*

3.2.1 *acceleration*—the rate of change of velocity with time, expressed in units of m s^{-2} (ft s^{-2}).

3.2.2 *drop height*—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.

3.2.3 *g*—common notation for accelerations expressed in units of *standard gravity*, where 1 *g* = 1 standard gravity.

3.2.4 *g-max*—the maximum acceleration of a missile during an impact, expressed in *g* units.

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

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

3.2.7 *impact*—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.

3.2.8 *impact attenuation*—property of a playground surface that, through localized deformation or displacement, absorbs the energy of an impact in a way that reduces the magnitudes of peak impact force and peak acceleration.

3.2.9 *impact test*—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.

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

3.2.9.2 *guided impact test*—an impact test in which the trajectory of the missile is restrained by rails, wires, or other mechanism or structure.

3.2.9.3 *impact test results*—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.

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

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

3.2.12 *missile*—a rigid object of specified mass having a hemispherical surface of specified radius; used to impart an impact to a surface.

3.2.13 *performance criterion*—limiting values of one or more impact test results used to specify minimum impact attenuation performance.

3.2.14 *qualified personnel*—those with current knowledge, training, skill, education and experience who have successfully demonstrated the ability to solve or resolve problems relating to the subject matter and work through the application of professional judgement.

3.2.15 *reference drop height*—a specification of the theoretical drop height of an impact test.

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

3.2.17 *reference temperature*—a specification of the temperature conditioning of a surfacing materials on which an impact test is performed.

3.2.18 *sample test point*—point on the surface of a sample selected as the target of an impact test.

3.2.19 *standard gravity*—the nominal value of the acceleration due to gravity at sea level having an international standard value of exactly 9.806 65 m s^{-2} (approximately 32.174 ft s^{-2}).

3.2.19.1 *Discussion*—Accelerations may be expressed in units of standard gravity.

3.2.20 *theoretical drop height*—the drop height (*h*) that, under standard conditions, would result in an impact velocity equal to a missile's measured impact velocity (V_0).

3.2.20.1 *Discussion*—The standard conditions assume that friction and air resistance do not affect the acceleration of the missile and that the acceleration due to gravity is equal to the standard value of *g* at sea level. In a free-fall impact test, the actual drop height will approximate the theoretical drop height. In a guided impact test, the theoretical drop height will be less than the actual drop height, due to the effects of friction in the guidance mechanism.

4. Performance Requirements

4.1 *Surface Performance Parameters*—The average *g*-max and average Head Injury Criterion (HIC) scores calculated from the last two of a series of three impact tests shall be used as measures of surface performance.

4.2 *Performance Criterion*—The performance criterion used to determine conformance with the requirements of this specification shall be: a *g*-max score not exceeding 200 *g* and a HIC score not exceeding 1000.

4.3 *Critical Fall Height:*

4.3.1 The critical fall height of the playground surface shall have been determined in accordance with the requirements of Section 15 of this specification, using reference temperatures of 25, 72, and 120°F (–6, 23, and 49°C), surface performance parameters, and the performance criterion.

NOTE 2—The specified temperatures span the range experienced by most playgrounds. If higher or lower surface material temperatures prevail when the playground is used, additional tests at higher or lower temperatures may be specified.

NOTE 3—*Wet/Frozen Test*—The specifier may require that surfacing materials be tested to determine critical fall height under wet or frozen surface conditions, or both. Procedures for wet/frozen conditioning are described in Annex A1.

4.3.2 The laboratory test used to determine critical fall height shall have been conducted on surfacing material samples identical in design, materials, components, thickness, and manufacture as the installed playground surface.

4.3.3 The laboratory test used to determine critical fall height of materials specified for use in a playground shall have been conducted no more than five years prior to the date of installation of the playground surface.

4.3.4 Test Method F3313 is a test method for conducting *g*-max and HIC testing on an installed playground surface to ensure quality control of surfaces as they are installed.

5. Summary of Test Method

5.1 *Critical Fall Height Test*—The impact attenuation of surfacing materials is measured using an impact test in which a missile is dropped onto the playground surface from a predetermined drop height. The acceleration of the missile during the impact is measured using an accelerometer and associated data recording equipment. The acceleration time history is analyzed to determine *g*-max and HIC scores. For each playground surface sample at each reference temperature and drop height, scores from the second and third of three consecutive drops are averaged to give average scores. No modification of the playground surface sample shall be permitted between the three impacts.

5.2 The critical fall height of surfacing materials is determined by impact testing representative samples at a range of drop heights. The surfacing material is tested at temperatures of 25, 72, and 120°F (–4, 23, and 49°C). The critical fall height is determined as the highest theoretical drop height from which the surface performance parameters meet the performance criterion.

6. Significance and Use

6.1 The purpose of this specification is to establish minimum impact attenuation requirements for playground surfacing materials in order to reduce the risk of severe head injury from falls.

6.2 This specification provides a uniform means of quantifying the impact attenuation performance of playground surfacing materials and is appropriately used to compare the relative performance of different playground surfacing materials.

6.3 This specification is to be used as a reference for specifying the impact attenuation performance of playground surfacing materials.

6.4 In combination with data relating impact test scores to head injury, the information generated by application of this specification is suitable to estimate the relative risk of a severe head injury due to a fall.

7. Equipment Operator Qualifications

7.1 Impact tests shall be conducted by qualified personnel.

8. Test Apparatus

8.1 *Temperature Measuring Device*—The thermometer, digital temperature gage, or other sensor used to measure surface temperature shall have a functional range of at least from 20 to +130°F (–7 to +54°C), a resolution of 1.0°F (0.6°C), and an accuracy of ±1.0°F (0.6°C). The temperature sensor shall be capable of penetrating the playground surface to a depth of at least 1 in. (2.5 cm).

8.2 *Impact Test System*—A device or system for performing an impact test in which an instrumented missile is dropped onto a playground surface or surfacing material.

8.2.1 *Missile*—The test will be conducted using Missile E as specified in Test Method F355.

8.2.2 *Guided Impact Tests*—It is acceptable to rigidly attach a supporting assembly (for example, a handle or ball arm) to the missile as a means of connecting it to an external guidance system. The total mass of the drop assembly, which is the combined mass of the missile, accelerometer, and supporting assembly shall be 10.1 ± 0.05 lb (4.6 ± 0.02 kg). The mass of the supporting assembly alone shall not exceed 3.0 lb (1.4 kg).

8.2.2.1 For guided impact tests, it is acceptable for the missile to be connected to low-friction guides (such as monorail, dual rails, or guide wires) using a follower or other mechanism in order to constrain the fall trajectory of the missile to a vertically downward path. The guidance system 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.

8.2.3 *Support Structure for Free-Fall Impact Tests*—For free-fall impact tests, 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.

8.2.4 *Drop Height Control Mechanism*—The guidance mechanism of 8.2.2.1 or the support structure of 8.2.3 shall incorporate a means of repeatedly positioning the missile at a predetermined drop height.

8.2.5 *Release Mechanism*—A manual or electronically operated quick-release mechanism shall be provided as a means of initiating a drop of the missile. The operation of the release mechanism shall not influence the fall trajectory of the missile following release.

9. Calculations

9.1 *Theoretical Drop Height:*

9.1.1 The theoretical drop height, h, shall be calculated from a measurement of impact velocity, v, using the formula $h = v^2 / 2g$, where g is the acceleration due to gravity.

9.1.2 Alternatively, in a free-fall test, one method to calculate the theoretical drop height, h, is by a measurement of fall time, t, using the formula $h = ½\ g\ t^2$.

9.1.3 *Resultant Acceleration*—If a triaxial accelerometer is used, the resultant acceleration at each point in the time history of the impact shall be calculated as $A_R = \sqrt{A_x^2 + A_y^2 + A_z^2}$ where A_R is the resultant acceleration and A_x, A_y, and A_z are the accelerations recorded by accelerometers aligned with the X, Y, and Z missile axes.

9.2 *g-max*—The g-max of score is determined as the maximum value of acceleration recorded during an impact. If a triaxial accelerometer is used, g-max shall be determined as the maximum value of the resultant acceleration.

9.3 *Average g-max*—Determine the average g-max score by averaging the g-max score of the second and third of a series of three impact tests.

9.4 *Determination of Missile Angle*—In a free-fall impact test, the angle of the missile at the onset of impact and at the instant of maximum acceleration shall be calculated. For the purposes of this calculation, the onset of impact shall be the data sample at which the resultant acceleration first meets or exceeds a threshold value of 5 g. The angle shall be calculated from the component accelerations. The cosine of the missile angle shall be calculated as:

$$\cos\left(\theta_{headform}\right) = \frac{A_z}{A_R}$$

9.5 *Head Injury Criterion*[6]—The HIC score of an impact shall be computed as follows:

9.5.1 In the acceleration-time history of the impact, locate the time point T_0 at a point immediately preceding the onset of the impact and the time point T_1 at a point immediately following the cessation of the impact.

9.5.2 For each time interval (t_1, t_2) for which $t_1 \geq T_0$, $t_2 > t_1$ and $t_2 \leq T_1$ evaluate and record the trial HIC integral:

$$\text{Trial HIC}(t_1, t_2) = (t_2 - t_1)\left[\frac{1}{(t_2 - t_1)}\int_{t=t_1}^{t_2} a_t\ dt\right]^{2.5}$$

where:

a_t = acceleration at time t, defined as the resultant acceleration if a triaxial accelerometer is used.

9.5.3 For each time interval (t_1, t_2) calculate and record the trial HIC interval, $t_2 - t_1$.

9.5.4 The HIC score for an impact is determined as the maximum value of all the Trial HIC (t_1, t_2) scores.

9.5.5 The numerical procedures used to calculate HIC shall provide results that are within ±1 % of the true value.

10. Instrumentation Check

10.1 Check the proper operation of the test apparatus by performing a series of impact tests on a reference MEP pad immediately prior to the start of testing and within 24 h of completion of the tests.

10.2 The reference MEP pad shall be provided by the equipment manufacturer or by another agency capable of ensuring reproducible reference pads and shall have been assigned a reference drop height and a nominal g-max score.

10.3 Perform three impact tests on the reference MEP pad from the reference drop height with an interval of 1.5 ± 0.5 min between impacts.

10.4 Determine the average g-max score by averaging the g-max scores from the second and third drops.

10.5 Compare the average g-max score to the nominal g-max score provided with the reference MEP pad.

10.6 If the difference between the recorded g-max score and the nominal g-max score exceeds either the manufacturer's specified tolerance or 5 % of the nominal g-max score, the equipment does not conform to the requirements of this specification and shall not be used.

11. Impact Test Procedure

11.1 *Data Recording:*

11.1.1 Determine the test point of the conditioned sample.

11.1.1.1 If the sample has nonuniform properties (due to uneven thickness, seams, fasteners, or other factors) the sample test point shall be the point on the surface of the specimen expected to show the least favorable impact attenuation properties that lies within an area no closer than 3.0 in. (75 mm) to the edge of the sample.

11.1.1.2 *Procedure for Determining Least Favorable Impact Location:*

(1) Least favorable impact location shall be determined using the average of the last two of three impacts, from impacts performed at 23°C, at all applicable locations.

(2) Once the average is calculated, divide the g value by 200, and divide the HIC value by 1000. The resulting calculations are percentages of the maximum allowable value for both g and HIC.

(3) Determine the highest percentage of maximum allowable value, either g's or HIC, for all locations tested. This

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

calculated highest percentage of the maximum allowable value(s), shall be considered the least favorable impact location.

(4) Subsequent to determining the least favorable impact location remaining temperature testing (–6°C and 49°C) shall be performed at the determined least favorable impact location only.

(5) Exemptions to 11.1.1.1—Poured-in-place (for example, SBR with EPDM, TPV or turf top cap) and bonded safety surfaces are exempt from least favorable impact location. Laboratory testing has been provided demonstrating that the maximum values obtained among locations for these types of surface are minimal/insignificant.

11.1.1.3 If the sample has uniform properties, the sample test point shall be the center of the sample's top surface.

11.1.2 Mount the sample to be tested on a flat, rigid anvil or floor beneath the impact test system.

11.1.3 Align the sample test point with the point of impact of the missile and fix the sample to the anvil or floor using an appropriate means that does not alter the sample's impact attenuation properties (for example, with double-sided adhesive tape).

NOTE 4—Tests with unitary surface samples show that the variability of *g*-max and HIC scores is increased by a factor of four or more if the sample is not fixed to the underlying surface.

11.1.4 Before the first drop in any series, elevate the missile to the reference drop height. For subsequent drops in a series, the missile shall be elevated to the same point, notwithstanding the formation of cavities of other elevation changes in the surface being tested.

11.1.5 Before the first drop in any series, measure and record the drop height.

11.1.6 Release the missile and record the outputs of the acceleration measuring system and the drop height measuring system. If the trajectory of the missile prior to and during impact is impeded by any fixtures, human intervention, or other means, data from the trial shall be discarded.

11.1.7 Record the depth of any cavity in the surface formed by the impact.

NOTE 5—The depth is conveniently determined by measuring the distance between the lowest point of the elevated missile and the surface under test. The cavity depth is the difference between this measurement and the originally measured drop height.

11.2 *Data Check:*

11.2.1 Examine the acceleration display. The recorded acceleration pulse shall conform to the following requirements:

11.2.1.1 The acceleration pulse shall consist of a single primary impact event.

11.2.1.2 Prior to the onset of impact, the recorded acceleration value needs to be 0 ± 2 *g*.

11.2.1.3 The acceleration waveform needs to descend from its maximum value to a stable value of 0 ± 2 *g* without overshooting the zero baseline by more than 2 *g*.

NOTE 6—Excessive overshoot of the acceleration signal after an impact is indicative of transducer or signal processing error. Overshoot is frequently symptomatic of inadequate low frequency response in the accelerometer data channel(s).

11.2.2 If the recorded acceleration pulse does not conform to the specifications of 11.2, the test shall be restarted using a freshly conditioned specimen.

11.3 *Data Analysis:*

11.3.1 Calculate and record the *g*-max and HIC scores.

11.3.2 Calculate and record the theoretical drop height. If the calculated theoretical drop height differs from the measured drop height by more than ±3 in (±76 mm) or by more than ±2.5 % of the measured drop height, data from the trial shall be discarded.

NOTE 7—A difference between theoretical drop height and actual drop height that is greater than the specified margin may indicate an error in measurement of impact velocity, an error in the measurement of fall time, or that the fall of the missile was retarded by excessive friction in the guidance mechanism.

11.3.3 If a free-fall impact test is used, calculate the missile angle at the onset of impact and at the instant of maximum resultant acceleration, in accordance with 9.4. If the calculated missile angle at either point exceeds 10° (that is, the cosine of the missile angle is less than 0.966), data from the trial shall be discarded.

CRITICAL FALL HEIGHT TEST (Laboratory Test)

12. Temperature Conditioning

12.1 The critical fall height of a playground surface or surfacing material shall be determined under laboratory conditions by performing a series of impact tests at reference temperatures of 25, 72, and 120 ± 2°F (–4, 23, and 49 ± 1°C).

12.2 *Temperature Conditioning:*

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

12.2.2 For testing at each reference temperature, three samples shall be conditioned at the reference temperature ±2°F (±1°C) for a minimum of 8 h. Testing of a sample must be started within 1 min and all tests must be completed within 7 min of the sample's removal from the conditioning environment. If the testing is not started or completed within the specified interval, the sample must be conditioned for an additional 8 h.

12.3 *Temperature Stability Requirements:*

12.3.1 Surface temperature shall be measured using the temperature measuring device specified in 8.1. Temperature measurements shall be made at the sample test point before the first impact and after the third impact in any series. The probe shall be inserted to a minimum depth of 1 in. (25 mm) or 50 % of the thickness of the sample, whichever is least. During testing at the reference temperature of 25°F (–4°C), the temperature of the specimen must not exceed 30°F (–1°C). If the temperature exceeds 30°F (–1°C), the specimen must be reconditioned to the reference temperature for a period of 8 h and the test restarted.

12.3.2 During testing at the reference temperature of 120°F (49°C), the temperature of the specimen must not fall below 115°F (46°C). If the temperature falls below 115°F (46°C) the