



Standard Test Methods for Equipment and Procedures Used in Evaluating the Performance Characteristics of Protective Headgear¹

This standard is issued under the fixed designation F1446; 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 reappraisal. A superscript epsilon (ε) indicates an editorial change since the last revision or reappraisal.

INTRODUCTION

These test methods specify equipment and procedures used for testing protective headgear. Individual ASTM performance standards (standard specifications) will use these procedures and equipment. Test conditions, pass-fail criteria, and other performance requirements will be specified in the individual performance standards, tailored to the needs of a particular activity (for example, bicycling, skateboarding, skiing, etc.).

These test methods were developed using resources in medical, scientific, mechanical engineering, human factors, and biomechanical fields. However, it is recognized that it is not possible to write a protective headgear performance standard that will result in headgear that can protect against injury or death in all accidents. It is also recognized that serious injury or death can result from both low- and high-energy impacts, even when protective headgear is worn.

These test methods incorporate aspects of other recognized headgear performance standards. They draw from work done by others where appropriate for these test methods. These standards are referenced within this standard test method. It should be noted that these test methods specify laboratory tests of completed headgear to measure its ability to reduce head acceleration during use and other selected parameters.

1. Scope

1.1 These test methods cover laboratory equipment, procedures, and basic requirements pertinent to testing protective headgear. Deviations or additions, or both, to these test methods will be specified, as required, in individual ASTM performance standards.

1.2 *Requirements*—The protective headgear is to be tested under specified environmental conditions for the following:

1.2.1 Impact attenuation (the limiting of head acceleration) of the protective headgear, and

1.2.2 Strength and stability of the retention system and its attachment to the protective headgear.

1.2.3 Special tests for particular protective headgear uses will be specified in the individual performance standards to be used in conjunction with these test methods.

1.3 *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 Standard:*²

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

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

F2220 Specification for Headforms

2.2 *Federal Motor Vehicle Safety Standard:*³

218 S7.1.8 Motorcycle Helmets

2.3 *SAE Standard:*⁴

SAE J211 Recommended Practice for Instrumentation for Impact Tests—Requirements for Channel Class 1000

¹ These test methods are under the jurisdiction of ASTM Committee F08 on Sports Equipment, Playing Surfaces, and Facilities and are the direct responsibility of Subcommittee F08.53 on Headgear and Helmets.

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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 National Highway Traffic Safety Administration (NHTSA), 400 7th St., NW, Washington, DC 20590.

⁴ Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

3. Reference Table

3.1 For references to these test methods, the standard terms for reference are listed in bold type in **Table 1** with the items to consider for each method. For conditions and anvils, use the standard term listed in **Table 1**. Referring to section numbers in these test methods is not the recommended method for reference.

4. Terminology

4.1 Definitions:

4.1.1 *basic plane, n*—an anatomical plane (Frankfort Horizontal Plane) that includes the superior rim of the external auditory meatus (upper edge of the external openings of the ear) and the inferior margin of the orbit (the lowest point of the floor of the eye socket). The headforms are marked with the basic plane (see **Figs. 1 and 2**).

4.1.2 *coronal plane, n*—an anatomical plane perpendicular to both the basic and midsagittal planes and passing through the superior rims of the right and left auditory meatuses. The transverse plane corresponds to the coronal plane (see **Figs. 1 and 2**).

4.1.3 *field of vision, n*—angle of vision as measured on the reference headform (upward, downward, and peripheral).

4.1.4 *headform size selection, n*—helmets shall be tested on the appropriate test headform size(s), as determined by the testing laboratory. Helmets shall be tested on the largest and smallest size test headforms on which they fit. When multiple headform sizes are required, each test set of helmets will include at least one extent of coverage, vision test, retention test, and impact test on each specified headform size. “Fit” means that it is not physically difficult to put the helmet on the larger headform and that the helmet’s comfort or fit-foam is partially compressed on the smaller headform.

4.1.5 *helmet, n*—a protective device worn on the head in an effort to reduce or minimize injury to that portion of the head that is within an area above the test line (as defined in the individual performance standards).

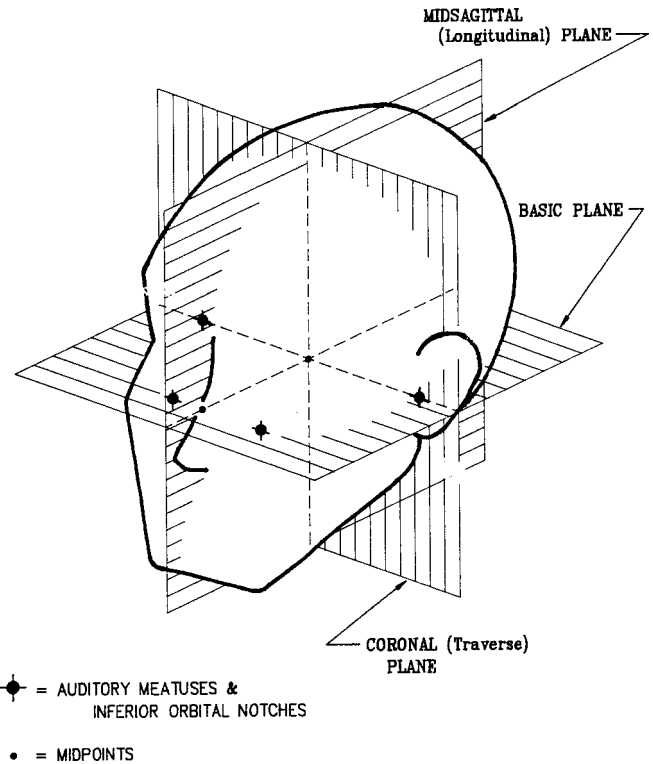


FIG. 1 Anatomical Planes

4.1.6 *helmet position index (HPI), n*—the vertical distance from the brow of the helmet to the basic plane, when the helmet is placed on a reference headform. The manufacturer shall specify the size of the headform and the vertical distance.

4.1.7 *midsagittal plane, n*—an anatomical plane perpendicular to the basic plane and containing the midpoint of the line connecting the notches of the right and left inferior orbital ridges and the midpoint of the line connecting the superior rims of the right and left external auditory meatus. The longitudinal plane corresponds to the midsagittal plane (see **Figs. 1 and 2**).

TABLE 1 Table for Reference

Terms for Reference	Section	Items to Consider for Each Method
Chin Bar Rigidity	12.9	Types defined: impact velocity, nominal drop height
Conditioning Environments	10	Types defined: ambient, low temperature, high temperature, water immersion
Configuration	12.2	Standard requirement defined
Dynamic Retention Test	12.7.1	Types defined: mass of drop weight, drop height, extension pass/fail criteria
Headforms	7.1	Headforms to be used in all tests in Test Methods F1446
Impact Anvil	7.3.1	Types defined: flat, hemispherical, cylindrical, triangular hazard, curb-stone
Impact Attenuation Test	12.8	Types defined: number of impact sites, impact velocity and theoretical drop height, and maximum peak g value
Internal Projections	12.5.1	Standard requirement defined
Labeling	12.4	Standard labeling requirements defined
Materials	12.3	Standard requirement defined
Peripheral Vision	12.6.1	Standard method of pass/fail for horizontal vision defined
Reference Marking	12.1	Standard method of marking defined, define test lines
Reporting	13	Standard report format defined
Roll-Off Test (Helmet Stability Test)	12.7.2	Types defined: mass of drop weight, drop height, standard method of pass/fail defined
Samples for Testing	8	Criteria to be considered in selecting number of samples
Selecting the Correct Headform	7.1.1	Method defined
Test Schedule	11	Standard test schedule defined

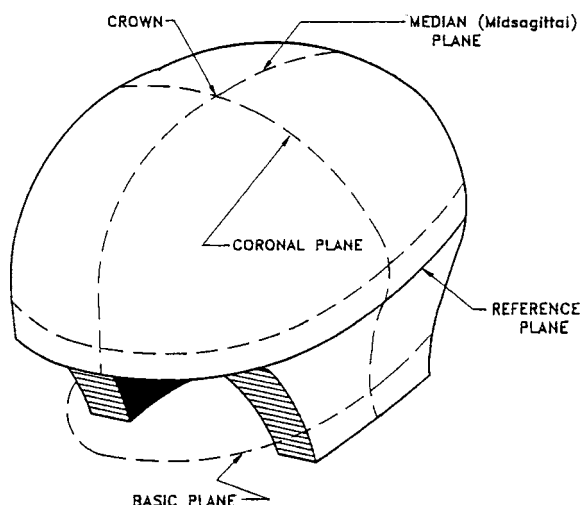


FIG. 2 Test Headform—Basic, Reference, and Midsagittal Planes

4.1.8 *modular elastomer programmer (MEP)*, *n*—a cylindrical-shaped pad used as the impact surface for the spherical impactor.

4.1.9 *preload ballast*, *n*—a “bean-bag” filled with shot placed on the helmet to secure its position on the headform. The weight of the preload ballast shall be 5.0 ± 0.1 kg unless otherwise specified in the individual performance specification.

4.1.10 *projection*, *n*—any part of a helmet, internal or external, that extends beyond the faired surface and is likely to cause injury.

4.1.11 *protective headgear*, *n*—see *helmet*.

4.1.12 *reference headforms*, *n*—measuring headforms contoured in the same configuration as the test headforms sizes A, C, E, J, M, and O, as defined in Specification F2220. The reference headforms should include surface markings corresponding to the basic, coronal, midsagittal, and reference planes (see Figs. 1 and 2).

4.1.13 *reference plane*, *n*—a plane marked on the headforms at a specified distance above and parallel to the basic plane (see Fig. 3).

4.1.14 *retention system*, *n*—the complete assembly that secures the helmet, in a stable position, on the wearer’s head.

4.1.15 *shield*, *n*—optional equipment used in place of goggles to protect the eyes.

4.1.16 *spherical impactor*, *n*—a device made of low resonance material (for example, magnesium), aluminum alloy, or stainless steel that couples mechanically with the ball arm connector of the drop assembly in place of the impact test headform. When mounted, the device presents a spherically machined impact face with a radius of 73 mm on its bottom surface. All radii from the center of the curvature of the impact face to its outer edge shall from angles of no less than 40° with the downward vertical axis. The center of curvature shall be within 5 mm of the vertical axis drawn through the center of the ball arm. The mass and center of gravity of the drop assembly including the impactor shall meet the same require-

ments as those specified for the drop assembly incorporated with the test headforms (see 7.3.2), using the 5 ± 0.1 kg drop mass.

4.1.17 *test area*, *n*—the area of the helmet on or above a specified test line, subject to impact or penetration testing.

4.1.18 *test headforms*, *n*—test headforms that correspond to the physical dimensions defined in Specification F2220 as sizes A, C, E, J, M, and O. The weight of the drop assembly including the headform shall be 5.0 ± 0.10 kg unless a variable mass drop assembly configuration is specified. If a variable mass configuration is specified, then the weight of the drop assembly shall comply with the weight specifications presented in Table 2. The test headforms may include surface markings corresponding to the basic, coronal, midsagittal, and reference planes (see Fig. 2).

4.1.19 *test line*, *n*—a line drawn on the helmet as specified in the individual performance standards.

4.1.20 *visor (peak)*, *n*—optional equipment for protection against sun or glare, and sometimes used as a rock or dirt deflector.

5. Significance and Use

5.1 The purpose of these test methods is to provide reliable and repeatable tests for the evaluation of various types of protective headgear. Use of these test methods in conjunction with the specific individual performance standards is intended to reduce the likelihood of serious injury and death resulting from impacts to the head sustained by individuals participating in sports, recreation, and other leisure activities in which protective headgear is worn.

6. Certification

6.1 These test methods permit self-certification. It is recommended that each manufacturer employ an independent test laboratory at least annually to test each model and size of protective headgear.

7. Apparatus

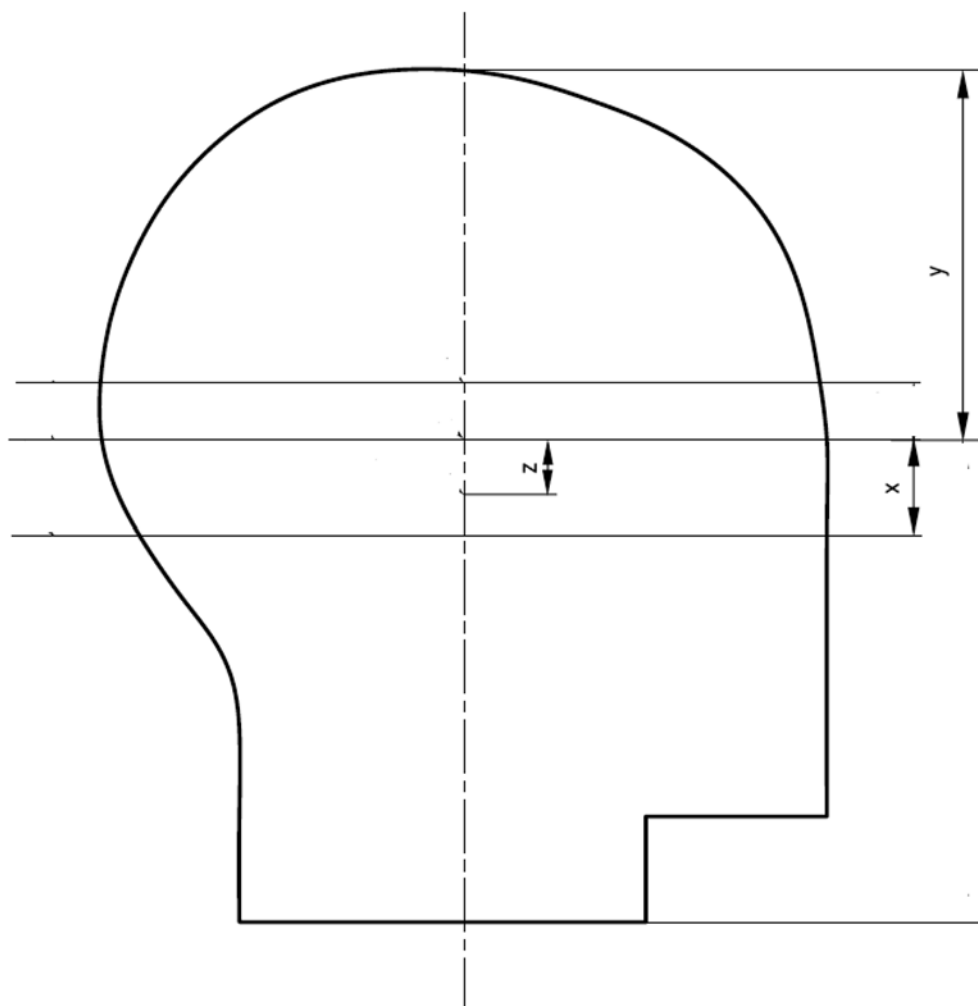
7.1 Test Headforms:

7.1.1 *General*—These test methods specify six headform sizes as identified in Specification F2220 (A, C, E, J, M, and O) for performing reference measurements, impact, roll-off, dynamic retention, penetration, and other tests required by the individual performance specification standards.

7.1.2 *Impact Headforms*—These headforms shall be made of K1A magnesium material and shall conform to the external dimension requirements of each particular headform size, as specified in Specification F2220.

7.1.3 *Other Headforms*—These headforms should be made of material of sufficient strength and stiffness to maintain their geometry during testing. They shall conform to the external dimension requirements of each particular headform size, as specified in Specification F2220. Full-chin headforms will be used as necessary.

7.2 *Retention System*—The test apparatus for the roll-off and dynamic retention testing are shown in Figs. 4 and 5 respectively. The mass of the drop weight and drop height are specified in the individual performance specification standards.



Headform Label	Size Designation (circumference, mm)	X, mm	Y, mm	Z, mm
A	495	23.5	89.7	11.1
C	515	24.5	92.7	11.5
E	535	25.5	96.0	11.9
J	575	27.5	102.4	12.7
M	605	29.0	107.2	13.3
O	625	30.0	110.2	13.7

FIG. 3 Location of Reference Line

TABLE 2 Test Headforms and Mass Specifications for Variable Mass Drop Assembly Configuration

Headform Label	Size Designation	Drop Assembly Mass
A	495 mm	3.1 ± 0.10 kg
C	515 mm	3.6 ± 0.10 kg
E	535 mm	4.1 ± 0.12 kg
J	575 mm	4.7 ± 0.14 kg
M	605 mm	5.6 ± 0.16 kg
O	625 mm	6.1 ± 0.18 kg

7.2.1 Roll-Off Cable and Hook—A flexible strap or cable and attaching hook connect the guide rod to the far edge of the helmet. The flexible strap or cable shall be of a material having

an elongation of no more than 18 mm/m when loaded with 1000 N. The cable and hook shall weigh less than 200 g.

7.2.2 Roll-Off Test Apparatus—The test apparatus shall be used to apply a shock load to a helmet secured to the headform by its own retention system. The geometry of the test headform shall comply with the dimension of the full chin reference headforms. The headform shall be secured in a test fixture with its vertical axis pointing downward at 45° to the direction of gravity (see Fig. 4). The test fixture shall permit rotation of the headform about its vertical axis and include a means to lock the headform in the face-up and face-down positions. The guide rod and hammer are similar to those in the dynamic retention

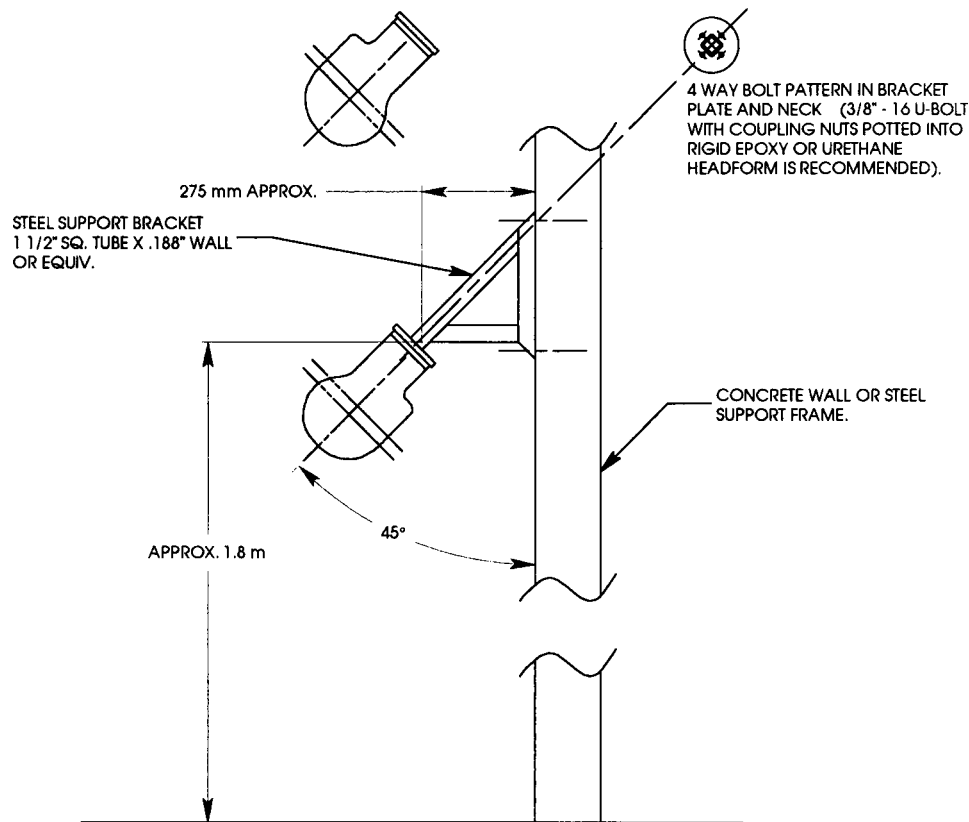


FIG. 4 Typical Apparatus for Roll-off (Stability) Test

strength test minus the simulated jawbone. This equipment shall allow a drop weight to slide in a guided free fall to impact a rigid stop anvil. The guide shall weigh 0.9 to 1.4 kg.

7.2.3 Dynamic Retention Test Apparatus—The retention system test equipment shall allow a drop weight to slide in a guided free fall to impact a rigid stop anvil (see Fig. 5). The geometry of the test headform shall comply with the dimension of the reference headforms. The headform shall be secured in a test fixture with its vertical axis pointing upward in the direction of gravity (see Fig. 5). The guide rod and hammer shall consist of a simulate jawbone, guide rod with stop, drop weight, and position measuring system(s). The entire dynamic test apparatus hangs freely on the retention system. The entire mass of the support assembly, excluding drop weight, must be $7 \text{ kg} \pm 5 \%$.

7.2.3.1 Simulated Jaw Bone—This stirrup shall consist of two metal bars that spin freely, each with a diameter of $12.5 \pm 0.5 \text{ mm}$, that have a center distance of $76.0 \pm 1 \text{ mm}$.

7.3 Impact Attenuation—The impact attenuation test apparatus shall allow determination of the impact attenuation characteristics of helmet (see Fig. 6).

7.3.1 Impact Anvils—The selection of anvils to be used for testing any given type of helmet is noted in the individual performance standards. The construction specifications for several types of anvils are given in Figs. 7-11. Other anvils may be specified (including construction specifications) in individual performance standards. All of the anvils, with the exception of the modular elastomer programmer (MEP) speci-

fied in these test methods, are constructed of steel and shall be solid (that is, without internal cavities).

7.3.1.1 Modular Elastomer Programmer (MEP)—The MEP is 152 mm in diameter and 25 mm thick. It is affixed to the top surface of a flat, 6.35-mm thick aluminum plate. The durometer hardness of the MEP is 60 ± 2 Shore A.

7.3.1.2 Flat Anvil—The flat anvil shall have a flat surface of a minimum 125-mm diameter circle and shall be at least 24 mm thick (see Fig. 7).

7.3.1.3 Hemispherical Anvil—The hemispherical anvil shall have a spherical surface with a radius of $48 \pm 1 \text{ mm}$. The spherical surface shall constitute one half of the surface of a sphere (see Fig. 8).

7.3.1.4 Cylindrical Anvil—The cylindrical anvil shall be one half of a cylinder with a diameter of $75 \pm 1 \text{ mm}$ and a minimum length of 200 mm (see Fig. 9).

7.3.1.5 Triangular Hazard Anvil—The triangular hazard anvil shall have a $90^\circ \pm 0.5^\circ$ striking edge with a 0.5- to 1.5-mm radius. The height shall be not less than 50 mm and the length not less than 200 mm (see Fig. 10).

7.3.1.6 Curbstone Anvil—The curbstone anvil shall have two faces making an angle of $105^\circ \pm 0.5^\circ$ and meeting along a striking edge with a radius of $15 \text{ mm} \pm 0.5 \text{ mm}$. The height shall be not less than 50 mm and the length not less than 200 mm (see Fig. 11).

7.3.2 Impact Test Apparatus—The geometry of the test headform shall comply with the dimension of the Specification F2220 reference headforms. The headform should be secured

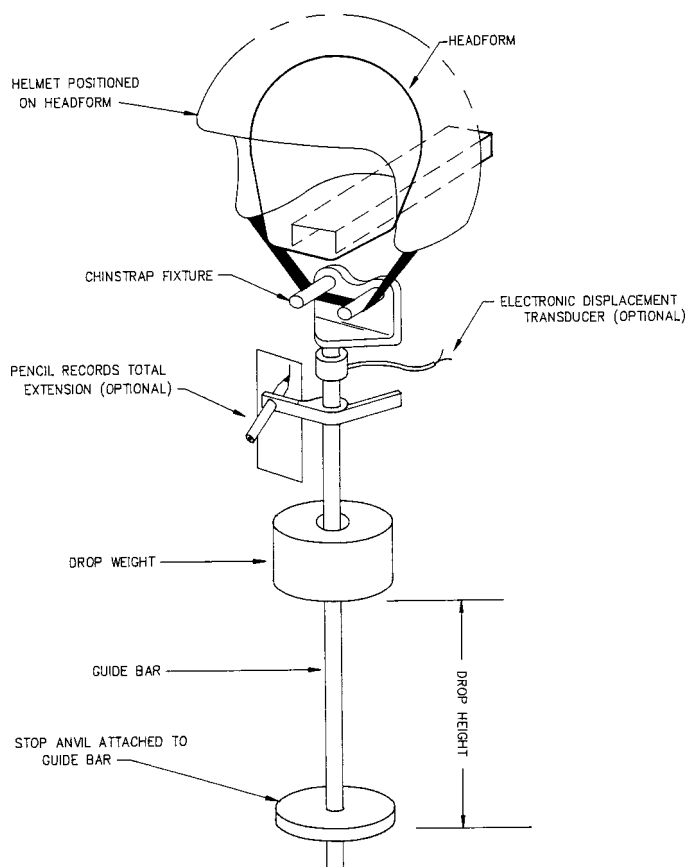


FIG. 5 Typical Apparatus for Retention System Strength and Extension Test

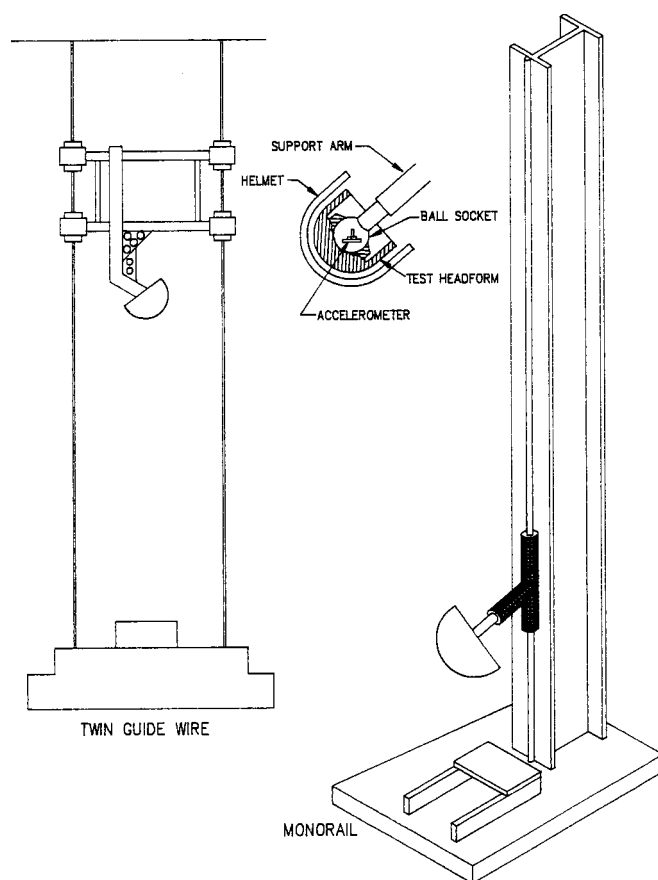


FIG. 6 Typical Apparatus for Impact Test

in a test fixture to allow for impact of the helmet at any location above the test line. The weight of the drop assembly (which is the combined weight of the instrumented test headform and supporting assembly, exclusive of the test helmet) for the drop test shall be 5 ± 0.1 kg unless a variable mass drop assembly configuration is specified. The weight of the supporting assembly cannot exceed 1.1 kg. The weight of the support assembly is the weight of the drop assembly minus the weight of the headform, ball clamp, ball clamp bolts, and accelerometer. The center of gravity of the headform shall be at the center of the mounting ball. The center of gravity of the combined test headform and supporting assembly must meet FMVSS 218 S7.1.8 with any type of guide system (see [Appendix X1](#)). The helmet and headform are dropped in a guided free fall, using a wire or rail guided apparatus (see [Fig. 6](#)), onto an anvil fixed to a rigid base.

7.3.3 Accelerometer—Acceleration is measured by a uniaxial accelerometer, which is capable of withstanding a shock of at least 9810 m/s^2 (1000 g) in the headform. The uniaxial accelerometer is mounted at the center of gravity of the test headform with the sensitive axis aligned within 5° of vertical. The acceleration data channel and filtering shall comply with SAE Recommended Practice J211. A low-pass filter (either analog or digital) with a 4-pole Butterworth transfer function and a corner frequency of 1000 Hz meets this requirement.

7.4 The apparatus shall consist of a striker that shall be guided. An example is shown in [Fig. 12](#). The striking surface

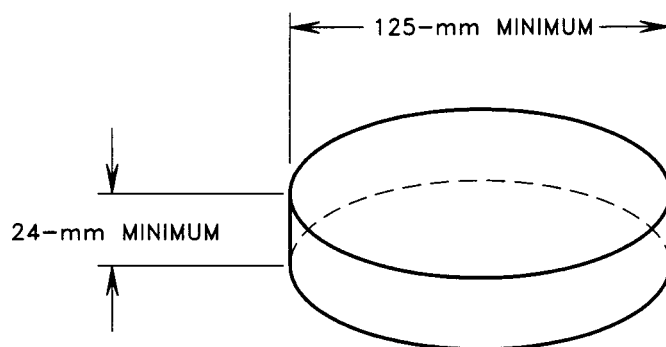


FIG. 7 Flat Anvil

shall be flat, steel, and have a diameter greater than 112 mm. The total mass of the striker and guide arm shall be 5 ± 0.2 kg. There shall be a means to securely mount a helmet as shown in [Fig. 12](#). A toggle clamp can be modified to firmly position the helmet by clamping against the inside rear of the helmet. A linear transducer shall be fixed against the inside of the helmet's chin bar to measure deflection. A means of measuring the velocity of the striker in its last 60 mm of fall shall be fitted.

8. Samples for Testing

8.1 Conditions and Attachments—Helmets shall be tested complete, in the condition as offered for sale. They must pass all tests with or without any included attachments.

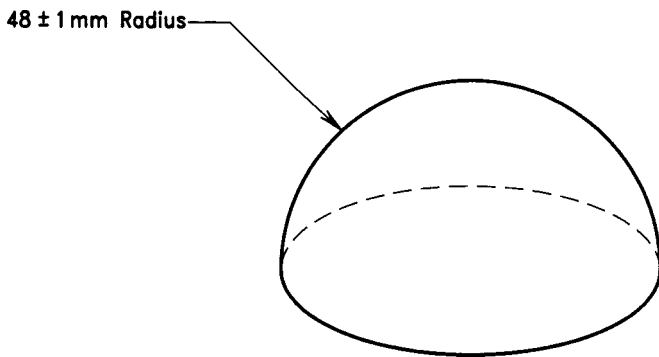


FIG. 8 Hemispherical Anvil

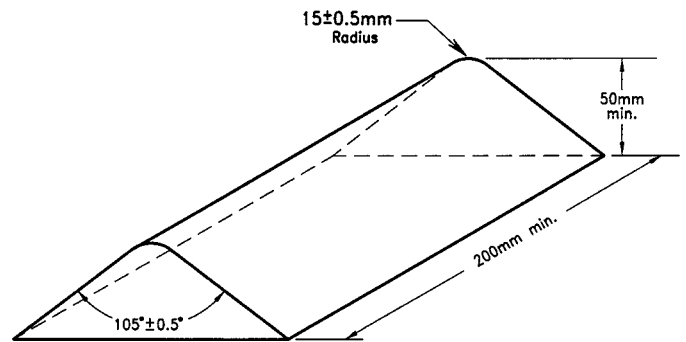


FIG. 11 Curbstone Anvil

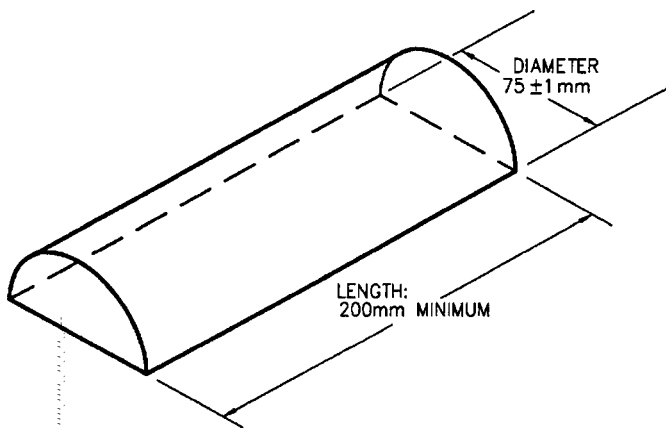


FIG. 9 Cylindrical Anvil

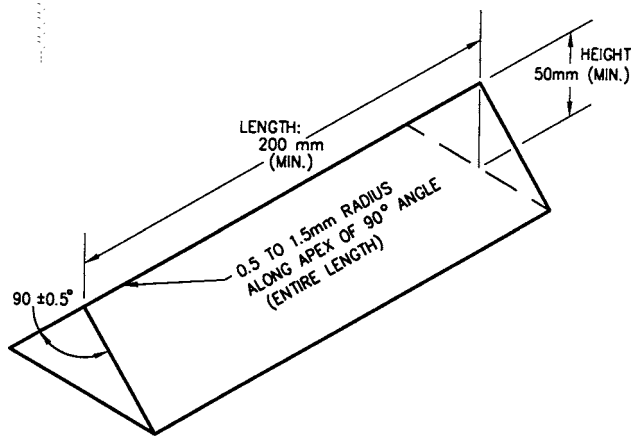


FIG. 10 Triangular Hazard Anvil

8.2 Number of Samples—A test normally requires samples of each shell/liner size combination. The number of test samples is defined in the individual performance standards.

9. Calibration and Standardization

9.1 Calibration—Instrumentation used in the testing shall be calibrated to manufacturer's specifications on a periodic basis. The duration of the calibration cycle shall be no more than one year.

9.2 Impact Attenuation Instrument System Check—The system instrumentation shall be checked before and after each series of tests by dropping the spherical impactor onto the MEP

pad at an impact velocity of 5.44 m/s ($\pm 2\%$). Impact velocity shall be measured during the last 40 mm of free fall for each test. The weight of the drop assembly (which is the combined weight of the instrumented spherical impactor and supporting assembly) for the drop test shall be 5 ± 0.1 kg. Three such impacts, at intervals of 75 + 15 s, shall be performed before and after each series of tests. The peak acceleration obtained during impact shall be 389 ± 8 g. If the average peak acceleration obtained in the post test impacts differs by more than 5 % from the average peak acceleration obtained in the pretest impacts, the following checks shall be made. Checks of the mechanical condition of the drop system and checks of the calibration of the instruments and transducers are required and all data obtained during that series of helmet tests should be discarded.

10. Conditioning Environments

10.1 The following conditions will be used unless otherwise stated in the individual performance standards. The helmets shall be kept in this environment for 4 to 24 h prior to testing. Testing must begin within 1 min after removal from the conditioning environment. Before further testing, the helmet must be returned to the conditioning environment within 3 min or be reconditioned for 5 min for each minute it is out of the conditioning environment beyond the allowed 3 min.

10.2 Ambient Condition—The ambient condition of the test laboratory shall be 17 to 23°C, with a relative humidity of 25 to 75 %. The barometric pressure in all conditioning environments shall be 75 to 110 kPa. All test helmets shall be stabilized within this ambient range for a minimum of 24 h prior to further conditioning and testing. Storage or shipment within this ambient range satisfies this requirement. The ambient test helmet does not need further conditioning.

10.3 Low Temperature—The low temperature is at a temperature of -13 to -17°C .

10.4 High Temperature—The high temperature is at a temperature of 47 to 53°C.

10.5 Water Immersion—The water immersion is full immersion in potable water at a temperature of 15 to 23°C.

11. Test Schedule

11.1 For each set of test samples, one helmet will be marked on the reference headform with the test line, as specified in the individual performance standards.

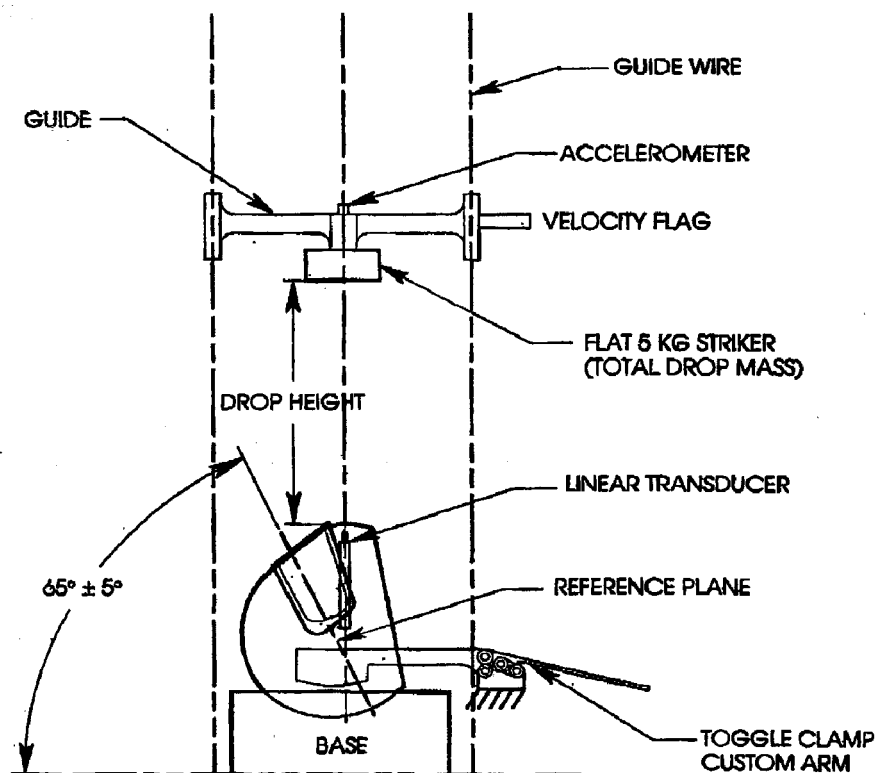


FIG. 12 Chin Bar Rigidity Test

11.2 This helmet will be inspected for the following:

- 11.2.1 Configuration,
- 11.2.2 Materials,
- 11.2.3 Labeling,
- 11.2.4 Projections, and
- 11.2.5 Vision.

11.3 Helmets will be assigned to each of conditioning environments specified.

11.4 Testing shall be performed in the following order unless otherwise stated in the individual performance standards:

- 11.4.1 Dynamic strength retention test,
- 11.4.2 Roll-off,
- 11.4.3 Impact attenuation, and
- 11.4.4 Other testing as required by the individual performance standards.

12. Test Procedures

12.1 *Reference Marking*—A reference headform mounted with the basic plane horizontal shall be used for reference marking. The helmet to be marked shall be placed on a reference headform the same size as the test headform to be used. The helmet shall be centered laterally and seated firmly on the reference headform with the preload ballast on the helmet, then positioned according to the helmet position index (HPI). Ensure that the brow is parallel to the basic plane. The test line shall be drawn on the helmet as required by the

individual performance standards. The center of impact sites shall be selected at any point on the helmet on or above the test line.

12.2 *Configuration*—The helmet shall be constructed to reduce or minimize injury to that portion of the head that is within an area above the test line and to remain on the wearer's head during impact.

12.3 *Materials*—Materials known to cause skin irritation or disease cannot be used in the helmet. Lining materials, if used, may be detachable for washing. If hydrocarbons, cleaning fluids, paints, transfers, or other additions will affect the helmet adversely, a warning shall be provided.

12.4 *Labeling*—Each helmet shall contain labels with at least the following information, using terms and symbols commonly known and easily visible to users. The label(s) should be likely to remain on the helmet and legible throughout the intended design life of the helmet.

12.4.1 The number of the standard specification which the manufacturer certifies that it meets, including the two-digit version year appended to the number.

12.4.2 Model designation.

12.4.3 Name of manufacturer.

12.4.4 Month and year of manufacture.

12.4.5 A label that warns the user that no helmet can protect against all possible impacts and that for maximum protection the helmet must be fitted and attached properly to the wearer's head in accordance with the manufacturer's fitting instructions.

12.4.6 A label that warns the user that the helmet may, after receiving an impact, be damaged to the point that it is no longer adequate to protect the head against further impacts, and that this damage may not be visible to the user. This label should also state that a helmet that has sustained an impact should be returned to the manufacturer for competent inspection or be destroyed and replaced.

12.4.7 A label that warns the user that the helmet can be damaged by contact with common substances (for example, certain solvents, cleaners, hair tonics, etc.) and that this damage may or may not be visible to the user. This label should also list any recommended cleaning agents or procedures, or both.

12.4.8 Any other warnings, cautions, or instructions specified in the individual standard specification.

12.4.9 Each helmet shall have accompanying fitting and positioning instructions including graphic representation of proper positioning.

12.5 Projections:

12.5.1 *Interior Projections*—Any internal rigid projections that can contact the wearer's head during impact shall be protected by some means of cushioning or force spreading. Visually inspect a single helmet from the set for the presence of any interior projections. Verify that if projections are present they are protected.

12.6 Vision:

12.6.1 *Peripheral Vision*—The helmet to be tested shall be placed on a reference headform the same size as the test headform to be used. The helmet shall be centered laterally and seated firmly on the reference headform with the preload ballast on the helmet, then positioned according to the HPI. Ensure that the brow is parallel to the basic plane. Measure the peripheral vision on a single sample of each helmet set. The peripheral vision is measured horizontally to each side of the midsagittal plane through Point K (see Fig. 13). The vision shall be unobstructed through an angle on either side of the midsagittal plane from Point K as identified in the individual performance standards.

12.7 *Retention System*—The retention system shall be designed and constructed to meet the requirements of this section and any other requirements called for in the individual performance standards.

12.7.1 Dynamic Strength Retention Test:

12.7.1.1 *Summary of Test Method*—A drop weight delivers an impact load to the retention system. The drop weight, drop height, and allowable elongation are specified in the individual performance standards. See Fig. 5 for a typical test apparatus setup.

12.7.1.2 *Procedure*—Following the user instructions, adjust the retention system to fit the appropriate reference headform. Then place the helmet on the appropriate size headform and adjust to the HPI provided by the manufacturer. Fasten the strap of the retention system under a stirrup that approximates the shape of the bone structure of the lower jaw. The retention system fastening system shall be aligned with the stirrup assembly so that no part of the retention system fastening system shall contact the stirrup assembly prior to release of the drop mass. This shall be achieved by loosening the retention

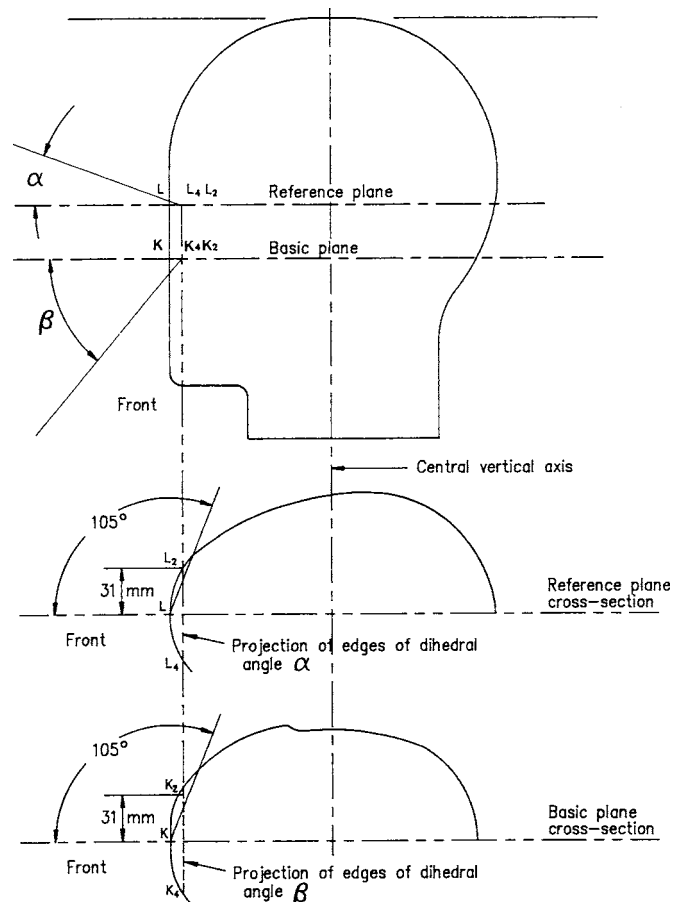


FIG. 13 Field of Vision

system, if necessary. The entire dynamic test apparatus hangs freely on the retention system. Raise the drop weight to the drop height and allow the drop weight to fall and impact the stop anvil. Measure elongation of the retention system in terms of vertical displacement of the dynamic test apparatus measured between the before-drop position and the maximum extension. The allowable displacement is specified in the performance standard.

12.7.2 Roll-Off:

12.7.2.1 *Summary of Test Method*—A drop weight delivers an impact load to the helmet in a manner to roll the helmet off the headform. The drop weight and drop height are specified in the individual performance standards. The test stand used for helmet roll-off (stability) testing is shown in Fig. 4. Unless specified in the individual performance standards, the retention system must remain intact and the helmet must remain on the headform.

12.7.2.2 *Procedure*—The helmet shall be placed on the appropriate size headform and adjusted to the HPI provided by the manufacturer. The headform is mounted face down for this sequence and the face up for a second test sequence. The helmet retention system shall then be adjusted according to the instructions furnished by the manufacturer. The guide rod and drop weight are similar to those in the retention strength test minus the simulated jawbone. The guide shall weigh 0.9 to 1.4 kg. A roll-off cable and hook connect the guide rod to the far edge of the helmet. The roll-off cable and hook is hooked to the

far center of the helmet and the cable is directed over the helmet along the midsagittal plane and then attached to the guide rod. The drop weight is raised the required distance from the stop on the guide rod and then dropped. The drop weight and drop height are determined by the individual performance standard.

12.8 Impact Attenuation—The helmet shall be designed and constructed to meet the requirements of this section and any other requirements called for in the individual performance standards.

12.8.1 Summary of Test Method—Impact attenuation is determined by measuring the acceleration of the test headform during impact. Acceleration is measured by a uniaxial accelerometer. The helmet and headform are dropped in a guided free fall, using a wire or rail guided apparatus (see Fig. 6), onto an anvil fixed to a rigid base. The required impact velocities, impact sites, and anvils are identified in the individual performance standards. Maximum allowable accelerations are specified in the individual performance standards. Other acceptance criteria may be defined in the individual performance standards.

12.8.2 Procedure:

12.8.2.1 Instrumentation Check—The system instrumentation shall be checked before and after each series of tests as identified in 9.2.

12.8.2.2 Impact Sites and Anvils—Each helmet shall be impacted at four sites, unless identified in the individual performance standards. The center of impact shall be at any point on or above the test line and at least one fifth of the maximum circumference of the helmet from any prior impact center. As many different anvils (called for in the individual performance standards) as possible shall be used on each helmet. All anvils called for in the individual performance standards shall be used within a given test set of helmets. Any anvil may be used at any site (unless otherwise noted by the individual performance standards). Additional impact sites may be designated by the individual performance standards.

12.8.2.3 Velocity—The impact velocities and theoretical drop heights (assuming 9.807-m/s^2 acceleration rate) for impact testing are specified in the individual performance standards. Impact velocity shall be measured during the last 40 mm of free fall for each test and shall be within the limits specified in the individual performance standards.

12.8.2.4 Helmet Impact Testing—Prior to each test, position the helmet on the test headform as identified on the reference headform and adjusted to the HPI provided by the manufacturer. The helmet shall be secured so that it does not shift position prior to impact. During impact testing the retention system shall be secured in a manner that does not interfere with free fall or impact. Install the required anvil. Adjust the headform for an impact on the helmet at the identified site. Raise the drop assembly, with helmet, to the test drop height, measured from the lowest point of the helmet to the surface of the anvil, and allow the assembly to impact the anvil under a guided condition. Record the impact velocity and acceleration time history. Repeat this sequence until the required impacts are performed.

12.9 Chin Bar Rigidity Test:

12.9.1 The helmet shall be securely mounted on a rigid base such that the chin bar faces up with the reference plane of the helmet angled $65^\circ \pm 5^\circ$ as shown in Fig. 12. Deflection of the chin bar shall be measured with a linear transducer fixed against the inside of the helmet's chin bar. The velocity of the striker shall be measured within the last 60 mm of free fall. Unless otherwise specified in the individual performance standard, the maximum deflection of the chin bar shall not exceed 60 mm. The impact velocity and nominal drop height of the striker shall be specified in the individual performance standard.

13. Report

13.1 Record of Test—The manufacturer, retailer, or importer shall maintain complete test records and test summary reports for all certification testing, whether performed by the manufacturer or an independent laboratory. The records and acceleration wave-forms/data can be stored on paper, electronically, or on photographs.

13.2 Test Laboratory Record of Test—The test laboratory must keep an original paper copy of the test summary, with the signature of the technician who performed the test, for a period of no less than five years.

13.3 Test Summary—The test summary shall include the following information:

13.3.1 Manufacturer's name and location;

13.3.2 Model and size of each helmet in the set of test helmets;

13.3.3 Identifying code for each helmet in each environmental condition;

13.3.4 Observed temperatures in each conditioning environment and the relative humidity and temperature of the laboratory;

13.3.5 A summary of results from the configuration, materials, labeling, projections, and vision tests;

13.3.6 Parameters and measured results of the retention tests;

13.3.7 Parameters and measured results of the impact results in sequence stating the location of impact, type of anvil used, velocity prior to impact, and maximum acceleration;

13.3.8 Parameters and measured results for other testing as specified in the individual performance standards;

13.3.9 Equipment calibration and system check test results;

13.3.10 Name and location of the test laboratory;

TABLE 3 Repeatability and Reproducibility Limits^A

	S/MR	S/TW	J/MR	J/TW
Average Test Value	400	398	431	427
95 % repeatability limit (within laboratory)	12	8	8	9
95 % reproducibility limit (between laboratories)	66	41	40	40

^A S = spherical impactor, J = size J headform impactor, MR = monorail rig, TW = twin wire rig.

- 13.3.11 Signature and printed/typed name of the technician who performed the test;
- 13.3.12 Date of the test; and
- 13.3.13 Other data required by the individual performance standards.

14. Precision and Bias⁵

14.1 *Interlaboratory Test Program*—An interlaboratory study was run in which spherical impactors and standard magnesium headforms (size J) were impacted onto MEP pads. A total of eight labs participated, utilizing six Twin Wire rigs and seven Monorail rigs. Practice E691 was followed for the analysis of the data.

⁵ Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR: F08-1007.

14.2 *Test Results*—The precision information given in Table 3, in the units of measurement (g), is for the comparison of four test results, each of which is the average of ten test determinations:

14.2.1 *Precision*—The terms repeatability limit and reproducibility limit are used as specified in Practice E177. The respective standard deviations among test results may be obtained by dividing the limit values by 2.8.

14.2.2 *Bias*—Since there is no accepted reference material, method, or laboratory suitable for determining the bias for the procedure in this test method for measuring acceleration, no statement on bias is being made.

15. Keywords

15.1 helmet; individual performance standards; protective headgear

APPENDIXES

(Nonmandatory Information)

X1. HEADFORM CENTER OF GRAVITY⁶

X1.1 “S7.1.8 The center of gravity of the test headform is located at the center of the mounting ball on the supporting assembly and lies within a cone with its axis vertical, and forming a 10° included angle with the vertex at the point of impact. The center of gravity of the drop assembly lies with the rectangular volume bounded by $x = -0.25$ in. (–0.64 cm), $x = 0.85$ in. (2.16 cm), $y = 0.25$ in. (0.64 cm), and $y = -0.25$ in. (–0.64 cm) with the origin located at the center of gravity of the test headform. The rectangular volume has no boundary along the z -axis. The x - y - z axes are mutually perpendicular and have positive or negative designations in accordance with the right-hand rule (see Fig. 5).⁷ The origin of the coordinate axes

also is located at the center of the mounting ball on the supporting assembly (see Figs. 6-8).⁷ The x - y - z axes of the test headform assembly on a monorail drop test equipment are oriented as follows: From the origin, the x -axis is horizontal with its positive direction going toward and passing through the vertical centerline of the monorail. The positive z -axis is downward. The y -axis also is horizontal and its direction can be decided by the z and x -axes, using the right-hand rule.”

X1.2 “S7.1.9 The acceleration transducer is mounted at the center of gravity of the test headform with the sensitive axis aligned to within 5° of vertical when the test headform assembly is in the impact position. The acceleration data channel complies with SAE Recommended Practice J211 JUN 80, Instrumentation for Impact Tests, Requirements for Channel Class 1,000.”

⁶ This appendix is taken from FMVSS 218 (revised April 6, 1988), S7.1.8 and S7.1.9.

⁷ Obtain FMVSS 218 in its entirety to reference Figs. 5, 6, 7, and 8 of that document.

X2. PRACTICE E691 PRECISION STATEMENT

X2.1 *Requirements for Determining Precision of Test Method: Max g:*

X2.1.1 Carefully examine the data for cases having no data for a particular material within a lab. Unbalanced studies cannot be properly calculated by this program. (All labs not having the same number of materials.)

X2.1.2 The number of laboratories, materials, and determinations in this study *does* meet the minimum requirements for determining precision prescribed in Practice E691:

	This Study	Practice E691 Minimum
Laboratories	8	6
Materials	4	4
Determinations	10	2

X2.2 *Precision Statement for Test Method: Max g*—Precision, characterized by repeatability (S_r , r) and reproducibility (S_R , R), has been determined for the materials to be as indicated in Table X2.1.

**TABLE X2.1 Precision^A**

Material	Mean (g)	Sr (g)	SR (g)	r (g)	R (g)
S/MR	400.195	4.222	23.377	11.823	65.456
S/TW	397.798	2.729	14.416	7.641	40.366
J/MR	430.595	2.704	14.332	7.572	40.130
J/TW	426.996	3.042	14.255	8.517	39.913

^A S = spherical impactor, J = size J headform impactor, MR = monorail rig, TW = twin wire rig, Sr = repeatability standard deviation, SR = reproducibility standard deviation, r = 95 % confidence interval of repeatability, R = 95 % confidence interval of reproducibility.

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