



# Standard Test Methods for Equipment and Procedures Used in Evaluating the Performance Characteristics of Protective Headgear<sup>1</sup>

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 reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 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:*<sup>2</sup>

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:*<sup>3</sup>

218 S7.1.8 Motorcycle Helmets

2.3 *SAE Standard:*<sup>4</sup>

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

<sup>1</sup> 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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<sup>2</sup> 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.

<sup>3</sup> Available from National Highway Traffic Safety Administration (NHTSA), 400 7th St., NW, Washington, DC 20590.

<sup>4</sup> 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).

4.1.1.1 Discussion—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.

4.1.2.1 Discussion—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. For helmets equipped with adjustable fit systems, the headform sizes are determined by the fit at the smallest and largest limits of the adjustment.

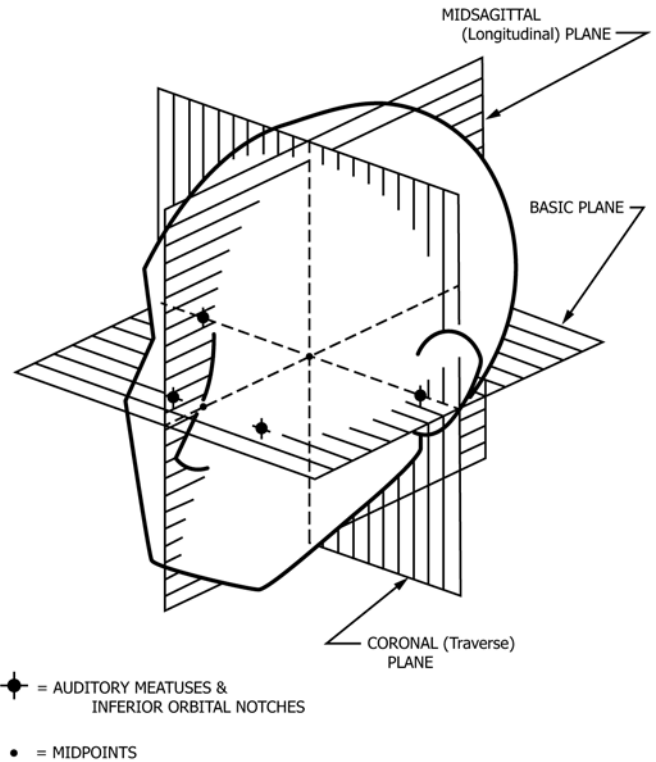


FIG. 1 Anatomical Planes

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).

4.1.5.1 Discussion—A helmet of a given size is further defined as a combination of structure(s) making up the primary energy-absorption structure covering part of the wearer’s head. Each structural size is made up of a specific size energy-absorbing structure that may include an outer or inner hard shell, or both.

TABLE 1 Table for Reference

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

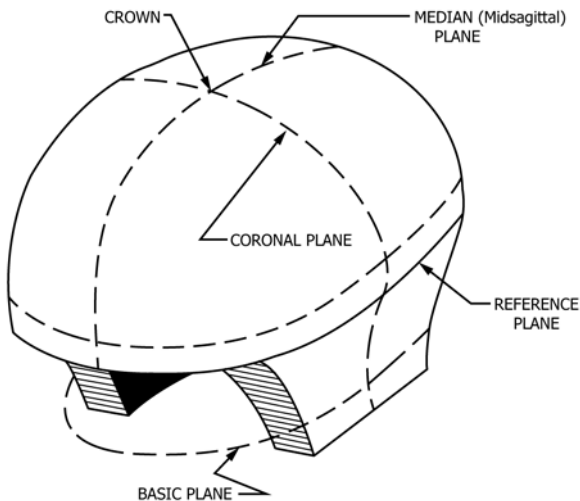


FIG. 2 Test Headform—Basic, Reference, and Midsagittal Planes

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 *helmet type, n*—a category of helmets which do not differ in basic construction components such as shell, energy-absorbing layer(s), retention system, or any other component that is tested.

4.1.7.1 *Discussion*—Difference in size alone does not constitute a different helmet type.

4.1.8 *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.

4.1.8.1 *Discussion*—The longitudinal plane corresponds to the midsagittal plane (see Figs. 1 and 2).

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

4.1.10 *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  $5.0 \pm 0.1$  kg unless otherwise specified in the individual performance specification.

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

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

4.1.13 *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.

4.1.13.1 *Discussion*—The reference headforms should include surface markings corresponding to the basic, coronal, midsagittal, and reference planes (see Figs. 1 and 2).

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

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

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

4.1.17 *size, n*—a combination of structure(s) making up the primary energy-absorption structure covering part of the wearer’s head.

4.1.17.1 *Discussion*—Each structural size is made up of a specific size energy-absorbing structure that may include an outer or inner hard shell, or both.

4.1.18 *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 form angles of no less than  $40^\circ$  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 requirements as those specified for the drop assembly incorporated with the test headforms (see 7.3.2), using the  $5 \pm 0.1$  kg drop mass.

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

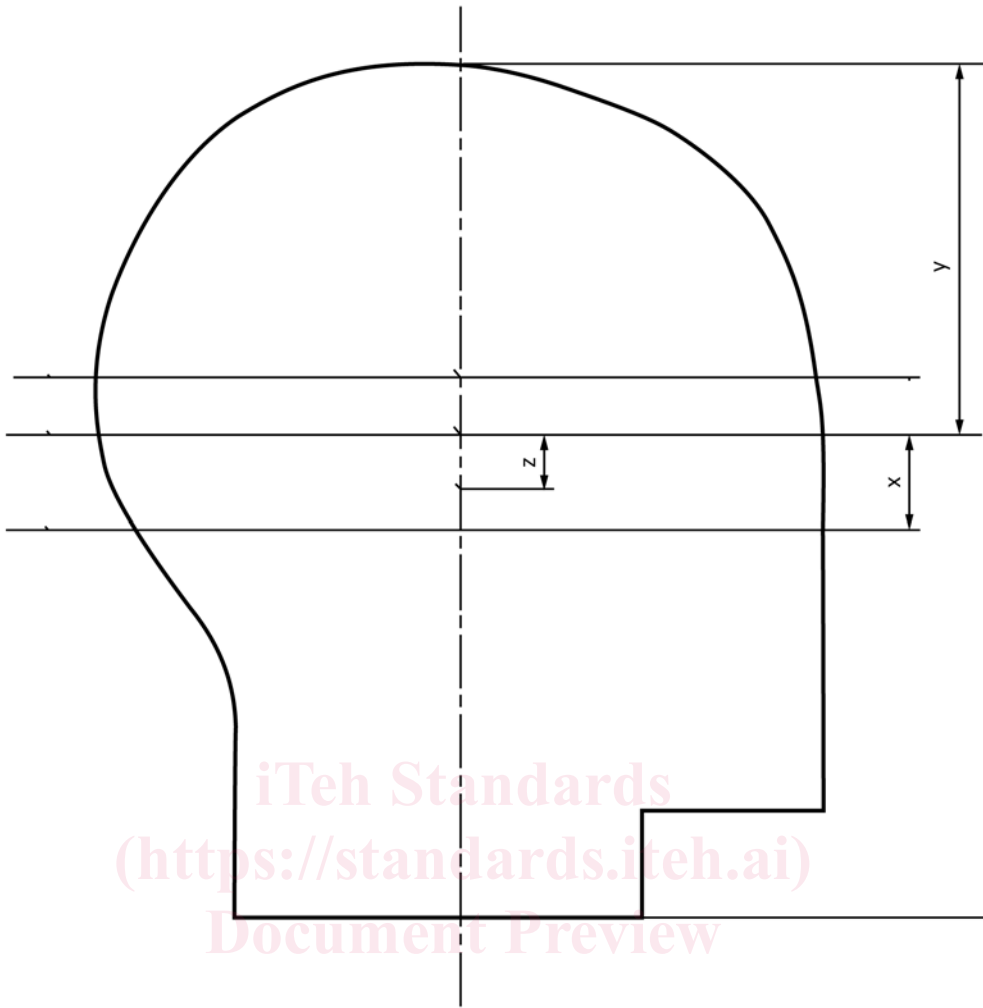
4.1.20 *test headforms, n*—test headforms that correspond to the physical dimensions defined in Specification F2220 as sizes A, C, E, J, M, and O. The weight of the drop assembly including the headform shall be  $5.0 \pm 0.10$  kg unless a variable mass drop assembly configuration is specified. If a 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. Fig. 2).

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

4.1.22 *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



Headform Label	X, mm	Y, mm	Z, mm
F2220-A	24.0	89.7	11.1
F2220-C	25.0	91.2	11.5
F2220-E	26.0	96.0	11.9
F2220-J	27.5	102.5	12.7
F2220-M	29.0	107.0	13.3
F2220-O	30.0	110.0	13.7

FIG. 3 Location of Reference Line

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

Headform Label	Drop Assembly Mass
F2220-A	3.1 ± 0.10 kg
F2220-C	3.6 ± 0.10 kg
F2220-E	4.1 ± 0.12 kg
F2220-J	4.7 ± 0.14 kg
F2220-M	5.6 ± 0.16 kg
F2220-O	6.1 ± 0.18 kg

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 Fig. 4 and Fig. 5, respectively. The mass of the drop weight and drop height are specified in the individual performance specification standards.

7.2.1 *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 cable and hook shall be a flexible strap or cable and attaching hook which connect the guide rod to the upper edge of the helmet. The flexible strap or cable shall be of material having an

elongation of no more than 18 mm/m when loaded with 1000 N. The guide rod and drop weight are similar to those in the dynamic retention strength test minus the simulated mandible. This equipment shall allow a drop weight to slide in a guided free fall to impact a rigid stop. No pad shall be used between the drop weight and the rigid stop. The mass of the roll-off test apparatus, excluding the drop weight, shall be 1.0 -0.0 +0.2 kg.

7.2.2 *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 (see Fig. 5). No pad shall be used between the drop weight and the rigid stop. The guide rod and drop weight shall consist of a simulated mandible, guide rod with rigid stop, drop weight and electronic position measuring system(s). The entire dynamic test apparatus, including the drop weight shall hang loosely restrained from non-vertical movement on the retention system. The mass of the dynamic test apparatus, excluding the drop weight, shall be  $7 \pm 0.1$  kg.

7.2.2.1 *Electronic Position Measuring System*—A device to measure the dynamic and residual displacement of the moving parts of the test fixture. Such devices shall have a minimum sampling rate of 1000 Hz.

7.2.2.2 *Simulated Mandible Fixture*—This fixture shall consist of two metal bars that spin freely, each with a diameter of  $12.5 \pm 0.5$  mm, that have a center distance of  $76.0 \pm 1$  mm.

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

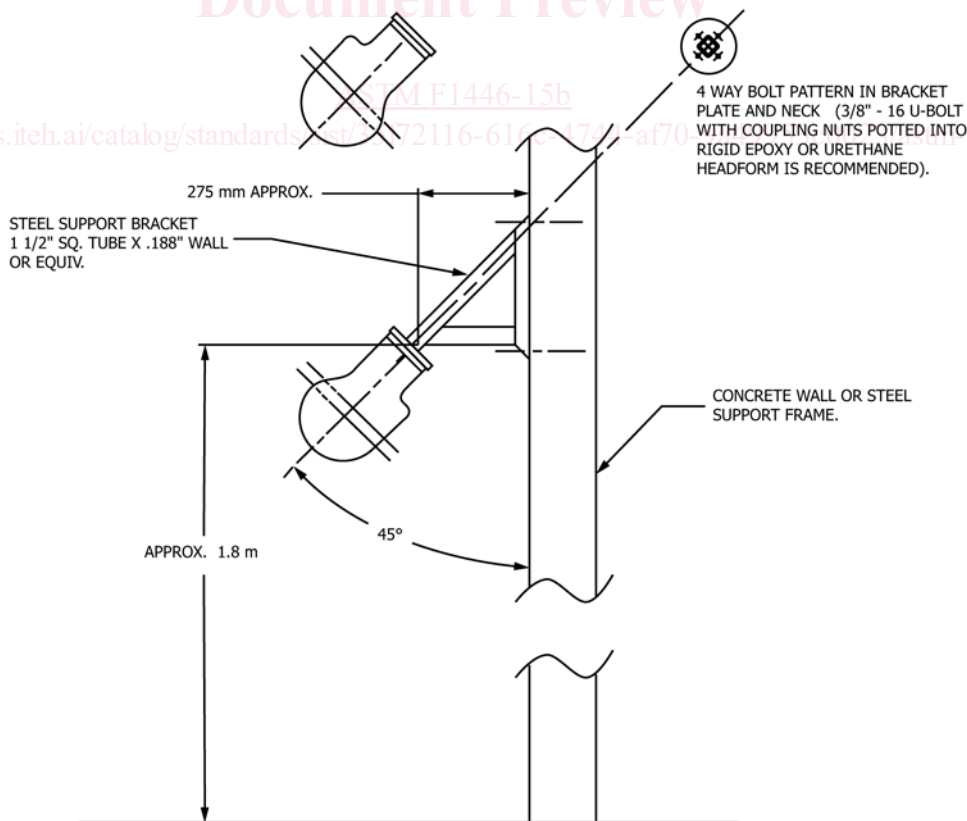


FIG. 4 Typical Apparatus for Roll-off (Stability) Test

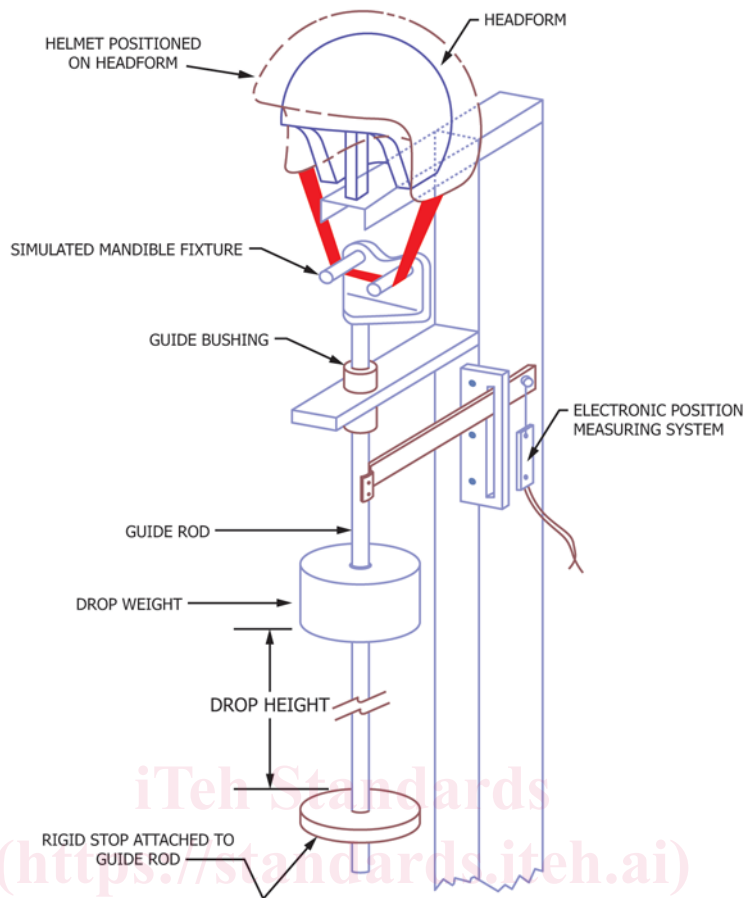


FIG. 5 Typical Apparatus for Testing Strength and Extension of Retention System

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) specified 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  $60 \pm 2$  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  $48 \pm 1$  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  $75 \pm 1$  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 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  $5 \pm 0.1$  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  $9810 \text{ m/s}^2$  (1000 g) in the headform. The uniaxial