Designation: F 1446 – 01

Standard Test Methods for Equipment and Procedures Used in Evaluating the Performance Characteristics of Protective Headgear[1]

This standard is issued under the fixed designation F 1446; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

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

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. Acknowledging these limitations, these test methods were developed using resources in medical, scientific, mechanical engineering, human factors, and biomechanical fields.

These test methods incorporate many aspects of other recognized headgear performance standards. They draw from work done by others where appropriate for these test methods. These standards may be referenced. It should be noted that these test methods specify a laboratory test of completed headgear to measure its ability to reduce head acceleration when impacting various shaped objects.

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 performance standard specifications.

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.

1.2.2 Strength of the retention system and its attachment.

1.2.3 Special tests for particular protective headgear uses will be specified in the individual standard specifications 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 These test methods incorporate or reference sections of standards from the following U.S. and foreign standards organizations: DOT, ASTM, ANSI, Snell, E22, BSI, ASA, SP1, and CSA.

2.2 *ISO/DIS Standard:*[2]

6220-1983 Headforms for Use in the Testing of Protective Helmets

2.3 *Federal Motor Vehicle Safety Standard:*[3]

218 S7.1.8 Motorcycle Helmets

2.4 *SAE Standard:*[4]

J211 Recommended Practice for Instrumentation for Impact Tests—Requirements for Channel Class 1000, October 1988

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *basic plane, n*—(Frankfort Horizontal Plane) an anatomical 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 ISO headforms are marked with a plane corresponding to this basic plane (see Figs. 1 and 2).

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

Current edition approved June 10, 2001. Published September 2001. Originally published as F 1446 – 93. Last previous edition F 1446 – 00.

[2] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

[3] Available from Department of Transportation, National Highway Traffic Safety Administration, Office of Vehicle Safety Standards, 400 7th St. S.W., Washington, DC 20590.

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

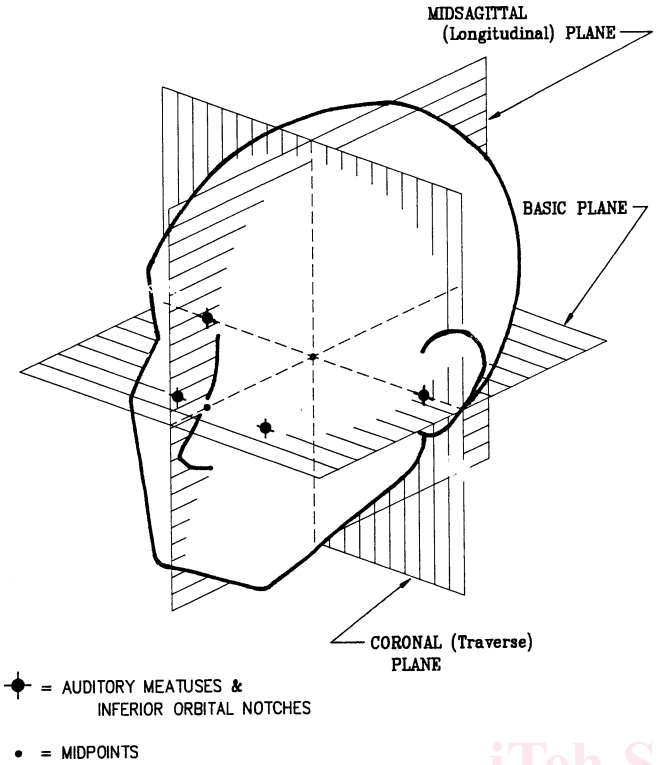


FIG. 1 Anatomical Planes

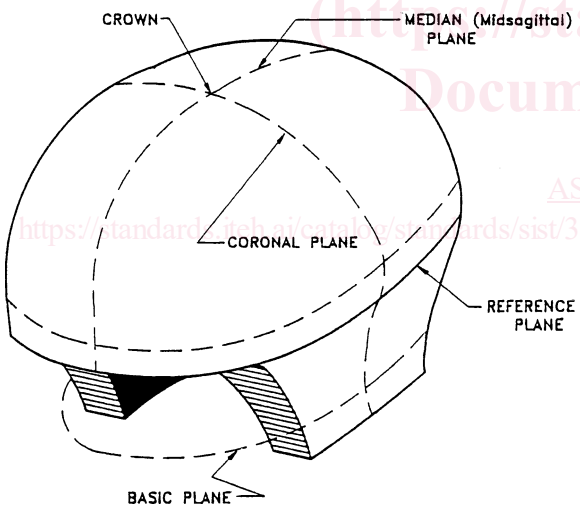


FIG. 2 ISO Headform—Basic, Reference, and Median Planes

3.1.2 *coronal plane*, *n*—an anatomical plane perpendicular to both the basic and midsagittal planes and containing the midpoint of a line connecting the superior rims of the right and left auditory meatuses. The ISO headforms are marked with a traverse plane corresponding to this coronal plane (see Figs. 1 and 2).

3.1.3 *extent of coverage*, *n*—the area of the head covered by the protective headgear being tested, as measured on a reference headform.[5]

[5] Available from Research & Testing Company, 1415 Park Ave., Hoboken, NJ 07030.

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

3.1.5 *headform size selection*, *n*—helmets shall be tested on the appropriate test headform, or two sizes of the test headforms, as determined by the testing laboratory. Helmets shall be tested on the largest and smallest size test headforms on which they fit. If a smaller size of the same model fits the smaller headform, the larger helmet will be tested on the larger headform only. When two headform sizes are required, each test set of four helmets will include at least one peripheral test, impact test, and dynamic retention test on each specified headform size.

3.1.5.1 *Discussion*—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.

3.1.6 *headgear*, *n*—See *helmet*.

3.1.7 *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 a specified area of coverage (as defined in the individual performance specification).

3.1.8 *helmet positioning index (HPI)*, *n*—the vertical distance from the brow of the helmet to the basic plane, when placed on a reference headform. The size of headform and vertical distance shall be specified by the manufacturer.

3.1.9 *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 auditory meatus. The ISO headforms are marked with a longitudinal plane corresponding to this midsagittal plane (see Figs. 1 and 2).

3.1.10 *modular elastomer programmer (MEP)*[5], *n*—a cylindrical-shaped pad used as the impact surface for the spherical impactor. The MEP is 6.0 in. (152 mm) in diameter, and 1.0-in. (25-mm) thick. It is affixed to the top surface of a flat, 0.25-in. (6.35-mm) thick aluminum plate. The durometer of the MEP is 60 ± 2 Shore A.

3.1.11 *preload ballast*, *n*—a "bean-bag" filled with lead shot placed on the helmet to secure its position on the headform. The weight of the preload ballast is specified in the individual standard specification.

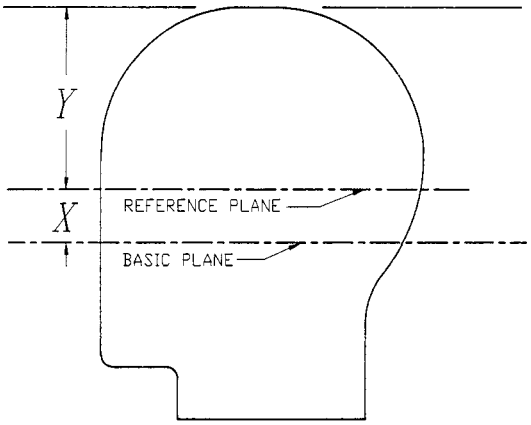
3.1.12 *projection*, *n*—any part of a helmet, internal or external, that extends beyond the faired surface and is likely to cause injury.

3.1.13 *reference headforms*[5], *n*—measuring headforms contoured in the same configuration as the test headforms Sizes A, E, J, M, or O, as defined in ISO/DIS 6220-1983. The reference headforms shall include surface markings corresponding to the basic, coronal, midsagittal, and reference planes (see Figs. 1 and 2).

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

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

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



HEADFORM	SIZE, mm	X, mm	Y, mm
A	500	24	90
E	540	26	96
J	570	27.5	102.5
M	600	29	107
O	620	30	110

FIG. 3 Location of Reference Line

3.1.17 *spherical impactor*[5], *n*—A device made of a 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 2.875 in. (73 mm) on its bottom surface. All radii from the center of curvature of the impact face to its outer edge shall form 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 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 16.3).

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

3.1.19 *test headforms*, *n*—test headforms defined in ISO/DIS 6220-1983 as Size A, E, J, M, and O. The test headforms shall include surface markings corresponding to the basic, coronal, midsagittal, and reference planes (see Fig. 2).

3.1.20 *test line*, *n*—a line drawn on the helmet as specified in the individual standard specification.

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

4. Significance and Use

4.1 The purpose of these test methods is to provide reliable and repeatable test methods for the evaluation of various types of protective headgear. Use of these test methods in conjunction with the specific individualized standard specifications 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.

5. Certification

5.1 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.

6. Test Headforms

6.1 *General*—These test methods specify five headform sizes, A, E, J, M, and O, for performing reference measurements, impact, dynamic retention, and penetration tests. These headforms shall be made of KIA magnesium material and shall conform to the external dimension requirements of each particular headform size, as specified in ISO/DIS 6220-1983.

7. Construction

7.1 *General*—The helmet shall be constructed to reduce the acceleration of the wearer's head and to remain on the wearer's head during impact.

7.2 *Projections*—Individual standard specifications may include provisions related to internal and external projections.

7.2.1 *Internal Projections*—Unless otherwise provided by individual standard specifications, any internal rigid projections that can contact the wearer's head during impact shall be protected by some means of cushioning or force spreading.

7.3 *Retention System*—The retention system shall be designed and constructed to meet the requirements of Section 15 and any other requirements called for in the individual standard specification.

8. Materials

8.1 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, or transfers and other additions will affect the helmet adversely, a warning shall be provided.

9. Labeling

9.1 Each helmet shall be marked in such a way that the following information is easily legible by the user and is likely to remain legible throughout the life of the helmet:

9.1.1 Model designation.

9.1.2 Name of manufacturer.

9.1.3 Month and year of manufacture.

9.1.4 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.

9.1.5 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.

9.1.6 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.

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

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

10. Samples for Testing

10.1 *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.

10.2 *Number of Samples*—A test normally requires four samples of each shell/liner size combination. In addition, one sample shall be submitted, if required, for use in accordance with each individual performance standard specification.

11. Test Schedule

11.1 For each set of four samples, one helmet will be measured on the reference headform for extent-of-coverage, as specified in the individual standard specification.

11.2 One of each of the four helmets will be assigned to each of four conditioning environments specified in Section 12.

11.3 Testing must begin within 1 min after removal from the conditioning environment. 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, before further testing.

12. Conditioning Environments

12.1 *Ambient Condition*—The first condition is the ambient condition of the test laboratory, which 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.

12.2 *Low Temperature*—The second condition is at a temperature of −13 to −17°C. The helmet shall be kept in this environment for 4 to 24 h prior to testing.

12.3 *High Temperature*—The third condition is at a temperature of 47 to 53°C. The relative humidity cannot exceed 25 %. The helmet shall be kept in this environment for 4 to 24 h prior to testing.

12.4 *Water Immersion*—The fourth condition is full immersion in potable water at a temperature of 15 to 23°C. The helmet shall be kept in this environment for 4 to 24 h prior to testing.

13. Report

13.1 *Record of Test*—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. An original copy of the test summary must be kept by the test laboratory, on paper, with the signature of the technician who performed the test. The test summary shall include the following information:

13.1.1 Manufacturer's name and location,

13.1.2 Model and size of each helmet in the set of four test helmets,

13.1.3 Identifying code for each helmet in each environmental condition,

13.1.4 Observed temperatures in each conditioning environment, and the relative humidity and temperature of the laboratory,

13.1.5 Performance impact results in sequence stating the location of impact, type of anvil used, velocity prior to impact, and maximum acceleration,

13.1.6 Parameters and measured results of the retention tests,

13.1.7 Name and location of the test laboratory,

13.1.8 Signature of the technician who performed the test,

13.1.9 Date of the test,

13.1.10 Calibration test results, and

13.1.11 Other data required by the individual standard specifications.

14. Reference Marking and Peripheral Vision

14.1 A reference headform mounted with the basic plane horizontal shall be used for reference marking. 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 in accordance with the HPI. The test line and 25-mm impact centerline (see 18.2) shall be drawn on the helmet.

14.2 Peripheral vision is measured horizontally to each side of the midsagittal plane through Point K (see Fig. 4). The vision shall be unobstructed through a minimum of 105° on either side of the midsagittal plane from Point K.

15. Dynamic Strength Retention Test

15.1 *Summary of Test Method*—A falling mass delivers an impact load to the retention system. The mass, velocity, and allowable elongation are specified in the individual standard specification. See Fig. 5 for a typical test apparatus setup.[5]

15.2 *Procedure*—Place the helmet on the designated headform. Fasten the strap of the retention system under a stirrup that approximates the shape of the bone structure of the lower jaw. This stirrup shall consist of two metal bars each with a diameter of 12.5 ± 0.5 mm that have a center distance of 76.0 ± 1 mm. 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. The entire dynamic test apparatus hangs freely on the retention system. The entire mass of the support assembly, excluding drop weight, must be 7.0 kg ± 5 %. Raise the striker to the drop height and allow the striker to drop 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 mass of the striker, drop height, and allowable displacement are specified in the performance standard.

15.3 The procedures and tests in 15.2 shall precede all other impacts or tests.

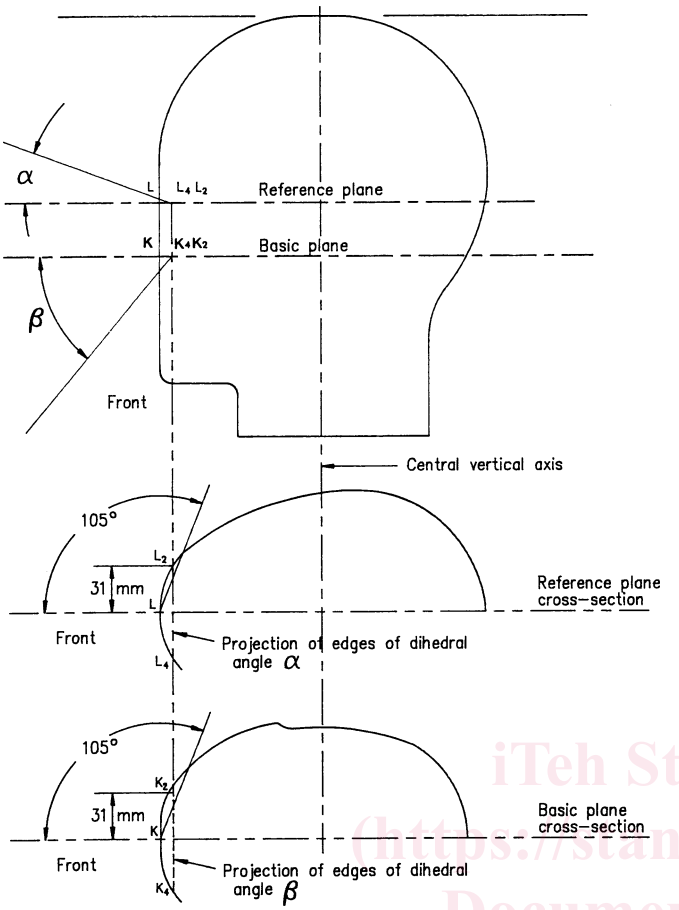


FIG. 4 Field of Vision

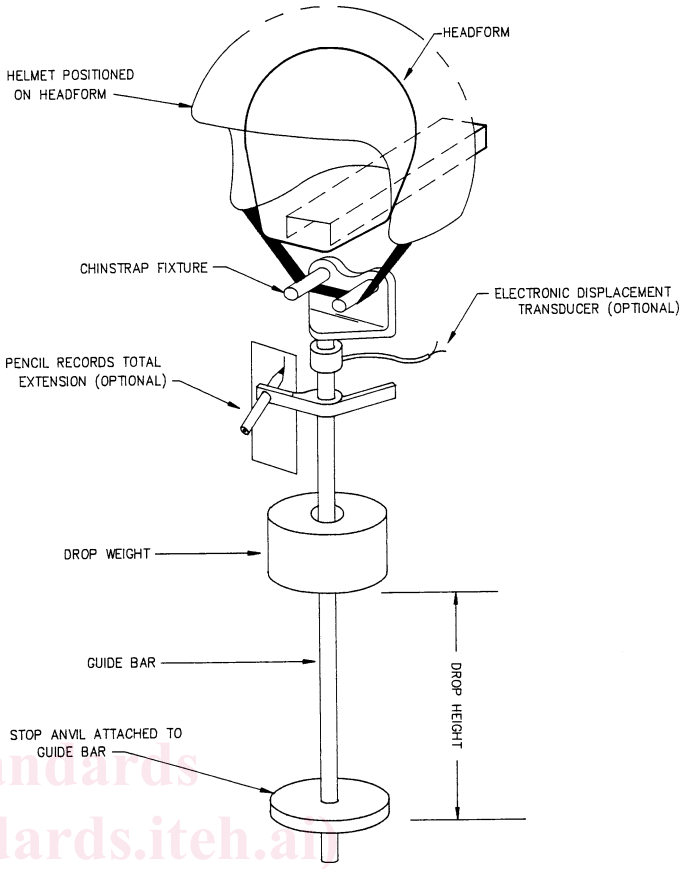


FIG. 5 Apparatus for Test of Retention System Strength and Extension

16. Impact Test Instruments and Equipment

16.1 *Measurement of Impact Attenuation*—Impact attenuation is determined by measuring the acceleration of the test headform during impact. 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 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. Maximum allowable accelerations are specified in the individual helmet specifications.

16.2 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.

16.3 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. 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).

16.4 *Impact Anvils*—The selection of anvils to be used for testing any given type of helmet is noted in the individual standard specifications. The construction specifications for several types of anvils are contained in 16.4.1 through 16.4.5. Other anvils may be specified (including construction specifications) in individual standard specifications. All of the anvils specified in these test methods are constructed of steel and shall be solid (that is, without internal cavities).

16.4.1 *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).

16.4.2 *Hemispherical Anvil*—The hemispherical anvil shall have a spherical surface with a radius of 48 ± 1 mm. The spherical surface shall constitute one half of the surface of a sphere (see Fig. 8).

16.4.3 *Cylindrical Anvil*—The cylindrical anvil shall be one half of a cylinder with a diameter of 75 ± 1 mm and a minimum length of 200 mm (see Fig. 9).

16.4.4 *Triangular Hazard Anvil*—The triangular hazard anvil shall have a 90 ± 0.5° 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).

16.4.5 *Curbstone Anvil*—The curbstone anvil shall have two faces making an angle of 105 ± 0.5° and meeting along a striking edge with a radius of 15 mm (±0.5 mm). The height shall be not less than 50 mm and the length not less than 200 mm (see Fig. 11).

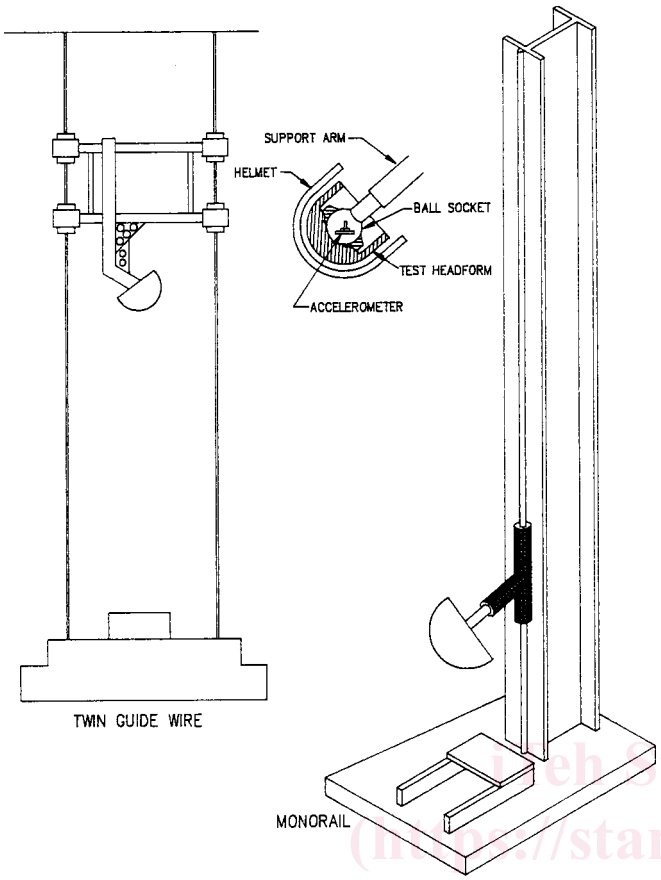


FIG. 6 Typical Impact Test Apparatus

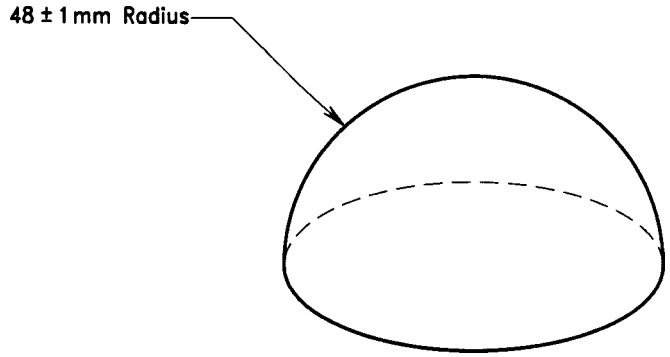


FIG. 8 Hemispherical Anvil

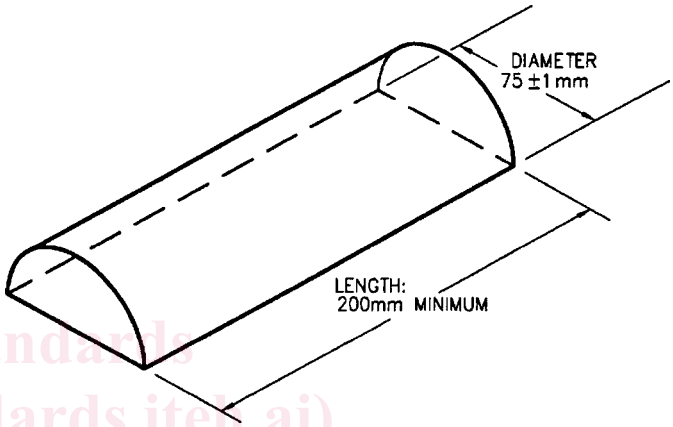


FIG. 9 Cylindrical Anvil

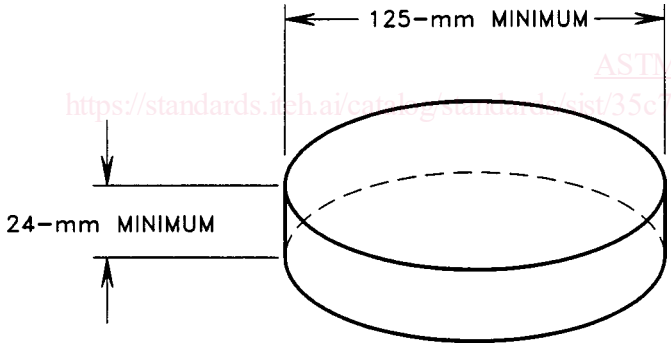


FIG. 7 Flat Anvil

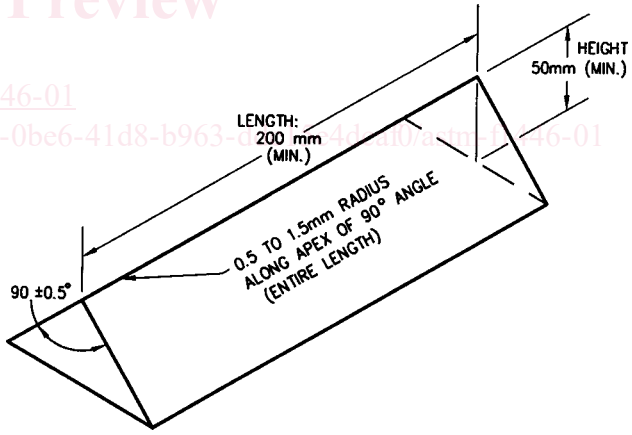


FIG. 10 Triangular Hazard Anvil

17. Instrument System Check

17.1 The system instrumentation shall be checked before and after each series of tests by dropping the spherical impactor (see 3.1.17) onto the MEP pad (see 3.1.10) at an impact velocity of 5.44 m/s (±2 %). The peak acceleration obtained during this impact should be 389 ± 8 g. Three such impacts, at intervals of 75 ± 15 s, shall be performed before and after each series of tests. If the peak acceleration obtained in the pretest impacts differs by more than 5 % from the peak acceleration obtained in the posttest impacts, recalibration of the instruments and transducers is required, and all data obtained during that series of helmet tests should be discarded.

18. Impact Attenuation Test

18.1 *Acceptable Acceleration Levels*—The maximum acceleration measured during impact cannot exceed the limit specified in the individual standard specification.

18.2 *Impact Sites*—Each helmet shall be impacted at four sites. The center of impact shall be at least 25 mm (arc width) above any point on 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 standard specification) as possible shall be used on each helmet. All anvils called for in the individual standard specification shall be used within a given test set of helmets. Any anvil may be used at any site (unless otherwise noted by the individual standard specification). Additional impact sites may be designated by the individual standard specification.