Designation: F2656/F2656M – 20

Standard Test Method for Crash Testing of Vehicle Security Barriers[1]

This standard is issued under the fixed designation F2656/F2656M; 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

Original perimeter barrier test methods were first published in 1985 by the Bureau of Diplomatic Security to assess the crash performance of perimeter barriers and gates. Since that time, the frequency and scale of attacks using vehicles with or without an explosive payload have increased both internationally and domestically. Therefore, there is a need to address a broad spectrum of possible incident conditions such as credible threat vehicle types for the locale, attack velocities of the different vehicles, and different acceptable penetration limitations. Also, there are different evaluation criteria for different agencies that fulfill their unique access control operations, aesthetics, and other organizational requirements. This test method was originally developed to expand the previous Department of State, Bureau of Diplomatic Security's crash testing standard to meet the broader needs of multiple organizations responsible for the protection of U.S. assets domestically and abroad.

Published test standards for vehicle perimeter security devices have previously been maintained by the U.S. State Department, Bureau of Diplomatic Security. The Specification for Vehicle Crash Test of Perimeter Barriers and Gates was first published in 1985 as SD-STD-02.01. In that standard, the test vehicle was specified as a medium-duty truck weighing 6800 kg [15 000 lb]. The payload was to be securely attached to the frame and nominal impact velocities were 50, 65, and 80 km/h [30, 40, and 50 mph]. Penetration limits were 1, 6, and 15 m [3, 20, and 50 ft] and were measured from the attack face of the perimeter security device to the final resting position of the front of the frame rails of the test vehicle.

In 2003, the U.S. State Department, Bureau of Diplomatic Security issued an updated standard (SD-STD-02.01, Revision A) for the testing of perimeter barriers. This update was done for several reasons. The foremost reason for change was limited setback distances precluded the use of any devices at their facilities or compounds that did not meet the highest test level, that is, those allowing more than 1-m [3-ft] penetration distance. Therefore, the revised standard only uses a 1-m [3-ft] penetration distance. Secondly, the method of rigid attachment of the ballast to the test vehicle was not simulating likely payload configurations and was altering the structural integrity of the test vehicle. Consequently, the updated standard requires a payload consisting of 208-L [55-gal] steel drums strapped together that have been filled with soil. This assembly is then strapped to the vehicle load platform. The third reason for change was based on the observation that the cargo bed of trucks could effectively penetrate certain types of barriers. Accordingly, the penetration distance is now measured from the inside face or non-impact surface of the barrier to the front of the cargo bed when the vehicle has reached its final position. Lastly, it was determined that the trucks used different platforms within a given class affecting result consistency. The revised test standard required the use of very specific diesel-powered medium-duty trucks.

In 2007, ASTM first published Test Method F2656 for Vehicle Crash Testing of Perimeter Barriers. It included the same test vehicle as specified in the 2003 SD-STD-02.01, Revision A, but additional test vehicles were added. They were the small passenger car, a ½-ton regular cab pickup, and a tandem axle dump truck. In addition, penetration ratings were reestablished and included the highest rating established by the 2003 SD-STD-02.01. Occupant risk values as established in NCHRP Report 350 were also added.

The previous version of Test Method F2656/F2656M incorporated two additional vehicles, the large passenger sedan and a Class 7 cab-over with a single rear axle. Additionally, the small car and pickup have been updated to match the latest AASHTO *Manual for Assessing Safety Hardware* (MASH), the update to NCHRP Report 350. Class 7 cab-over is compatible with European standards and is designated C7. Additional definitions and recommendations have also been added and the word "perimeter" has been deleted from the title to reflect more accurately all barriers tested under this test method. Since it was determined that the P4 rating did not have substantial relevance, this rating has been eliminated. To keep up with current terminology, the term "reduced risk" is discussed in that version of Test Method F2656/F2656M.

Test Method F2656/F2656M-20 has incorporated two major changes from F2656-15. The first and most significant change is all penetration ratings are referenced to the leading impact edge of the barrier being tested. This serves to remove any ambiguity relating to barrier size or footprint and the previous determination of reference points on trailing edges. It also serves to harmonize with the international standard ISO IWA14-1. Secondly, because the previous bed attachment requirement is inadequate demonstrated by loss of bed attachment, the number of shear plates has been increased to a minimum of three on each frame rail.

[1] This test method is under the jurisdiction of ASTM Committee F12 on Security Systems and Equipment and is the direct responsibility of Subcommittee F12.10 on Systems Products and Services.

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1. Scope

1.1 This test method provides a range of vehicle impact conditions, designations, and penetration performance levels. This will allow an agency to select passive perimeter barriers and active entry point barriers appropriate for use at facilities with a defined moving vehicle threat. Agencies may adopt and specify those condition designations and performance levels in this test method that satisfy their specific needs. Agencies may also assign certification ratings for active and passive perimeter barriers based on the tests and test methodologies described herein. Many test parameters are standardized to arrive at a common vehicle type and mass, and replication, and produce uniform rating designations.

1.2 Compliance with these test procedures establishes a measure of performance but does not render any vehicle perimeter barrier invulnerable to vehicle penetration. Caution should be exercised in interpreting test findings and in extrapolating results to other than test conditions and to user site conditions. This standard does not confirm the performance of the test barrier in the user site conditions. While computer simulations are powerful tools that are useful in the development of new and improved barriers or in estimating performance under differing conditions, the analytical models and methods must be validated against physical test data. When performing a test, developers and users are encouraged to address specific or unusual user site conditions as needed.

1.2.1 Often local terrain features, soil conditions, climate, or other items will dictate special needs at specific locations. Therefore, if user site conditions are likely to degrade a barrier's performance, the agency in need of a vehicle perimeter barrier should require testing with the specific user site conditions replicated for full-scale crash testing or numerical simulations that explicitly represent the user site conditions and have demonstrated connection to the "as-tested" soil configuration. For example, if the user site conditions are expansive clays, one could obtain user site materials and provide those to the test lab for the full-scale crash test.

1.3 Product/design certification under this test method only addresses the ability of the barrier to withstand the impact of the test vehicle. It does not represent an endorsement of the product/design or address its operational suitability.

1.4 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.5 This test method is intended to replace all previous versions of the test method for current and future testing.

1.6 *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 to determine the applicability of regulatory limitations prior to use.*

1.7 *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:*[2]

C39 Test Method for Compressive Strength of Cylindrical

[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.

Concrete Specimens
D1556 Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
D4429 Test Method for CBR (California Bearing Ratio) of Soils in Place (Withdrawn 2018)[3]
D6938 Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

2.2 *AASHTO Standards* [4]
M147-65 Standard Specifications for Transportation Materials and Methods of Sampling and Testing, Table 1 Grading Requirements for Soil-Aggregate Materials, Grading B
T099 Standard Method of Test for Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop

2.3 *ISO Standard* [5]
ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories

2.4 *SAE Standard* [6]
J211-1 Instrumentation for Impact Test – Part 1: Electronic Instrumentation
J211-2 Instrumentation for Impact Test – Part 2: Photographic Instrumentation

2.5 *U.S. Army Corps of Engineers – PDC Standard* [7]
List of DOD Certified Anti-Ram Vehicle Barriers[8]

2.6 *U.S. Department of State – DS* [9]
SD-STD-02.01 Specification for Vehicle Crash Test of Perimeter Barriers and Gates, April 1985
SD-STD-02.01, Revision A Test Method for Vehicle Crash Testing of Perimeter Barriers and Gates, March 2003

3. Terminology

3.1 *Definitions:*

3.1.1 *"A" pillar, n*—structural member forming the forward corner of the cab or passenger compartment.

3.1.2 *accredited independent testing laboratory, n*—testing laboratory accredited to perform the referenced testing procedures by a nationally recognized accrediting agency in accordance with ISO/IEC 17025 and led by a test director.

3.1.2.1 *Discussion*—Accredited independent testing laboratories may have no financial interest in or otherwise be affiliated with companies or individuals for which they perform accreditation testing. Hereinafter, accredited independent testing laboratories are referred to as either accredited facilities or testing laboratories. Other independent testing agencies actively pursuing accreditation and whose testing protocols are accepted by a federal agency may also conduct tests for a period of one year after performing the first test using this test method.

3.1.3 *agency, n*—specifier, responsible party, or owner.

3.1.4 *barrier, n—also referred to as a vehicle security barrier,* gate, bollard, wedges, drop arms, walls, wire ropes, net, planter, other structure, or topographic feature (that is, berms, rocks, ha-has, ditches, trenches or steep inclines) that provides protection against a vehicle trying to gain access overtly to a compound or facility.

3.1.4.1 *Discussion*—Active barriers can be deployed to serve as a security device and can be stored to allow traffic passage while passive barriers are generally permanent. Sometimes barriers are also portable; these can be active or passive. The perimeter is typically the outermost boundary over which the facility has control and is normally defined by the property line

3.1.5 *barrier reference point, n*—the leading impact edge of the barrier as shown in Annex A1 which, in conjunction with the vehicle reference point, determines the dynamic penetration distance.

3.1.5.1 *Discussion*—For barrier types not shown, the barrier reference point shall be determined by using same 'leading impact edge of the barrier methodology' portrayed by barrier reference points in Annex A1.

3.1.6 *berm, n*—mounded section of available material such as soil, gravel, rock, and so forth.

3.1.7 *bollard, n*—hollow or solid section posts or series of posts, usually metal, concrete, wood, or combinations of same, used to channel or restrict vehicular traffic which includes fixed, removable, and operable/retractable posts.

3.1.8 *condition designation, n*—relates vehicle type and vehicle velocity to the kinetic energy for which testing is conducted.

3.1.9 *continuous barrier, n*—any barrier that relies on a continuous foundation or a continuous structural element to resist penetration by vehicles.

3.1.10 *debris, n*—post-impact barrier, ballast, and vehicle components dispersed as a result of impact.

3.1.11 *disabled, adj*—used in conjunction with the vehicle and barrier description after impact.

3.1.11.1 *Discussion*—Disabled barrier pertains to an active barrier that is not operable after impact as a result of damage caused by the test impact. Disabled barrier also pertains to the post-test barrier conditions if it is no longer in a deployed position. Disabled vehicle pertains to the vehicle being unable to proceed under its own power immediately after impact as a result of damage caused by the test impact. It is appropriate and necessary to discuss the level of damage to the vehicle in determining what extent the vehicle is disabled, for example, the radiator or the oil pan or both may be ruptured that would

[3] The last approved version of this historical standard is referenced on www.astm.org.
[4] Available from American Association of State Highway and Transportation Officials (AASHTO), 444 N. Capitol St., NW, Suite 249, Washington, DC 20001, http://www.transportation.org.
[5] Available from International Organization for Standardization (ISO), 1 rue de Varembé, Case postale 56, CH-1211, Geneva 20, Switzerland, http://www.iso.ch.
[6] Available from Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001, http://www.sae.org.
[7] Available from the U.S. Army Corps of Engineers, Protective Design Center, 12565 W. Center Rd., Omaha, NE 68144-3869, https://pdc.usace.army.mil/library/BarrierCertification. Maintains 1985 list for penetration purposes.
[8] Available from the U.S. Army Corps of Engineers, Protective Design Center, 1616 Capital Avenue, Ste 9000, ATTN: CENWO ED S. Omaha, NE 68102-9000, https://pdc.usace.army.mil/library/BarrierCertification.
[9] Available from U.S. Department of State, Bureau of Diplomatic Security, Office of Physical Security Programs, Physical Security Division, Washington, D.C. 20520-1403

ultimately render the vehicle inoperable but would not immediately prevent the vehicle from proceeding under its own power, thus not being defined as disabled for the purposes of this test method. However, the vehicle is determined to be disabled if it is unable to move under its own power immediately after impact, for example, the motor is ejected or the axle is dislodged from the vehicle.

3.1.12 *ditch, n*—excavation into existing grade with varying cross sections such as "V" or "U" shaped.

3.1.13 *dynamic penetration distance, n*—during the crash event, the maximum horizontal penetration distance of the reference point on the test vehicle, as defined in 7.5.1, to the pre-test location of the barrier reference point.

3.1.13.1 *Discussion*—See Annex A1 for barrier reference point locations.

3.1.14 *final resting point, n*—distance from the pre-impact reference point on a barrier to the portion of the protective barrier that is furthest away from the original reference point at final rest.

3.1.14.1 *Discussion*—Additionally, it is the distance from the pre-impact reference point on a barrier to the defined vehicle reference point at final rest. This distance may be negative if the vehicle reference point did not pass the pre-impact reference point on a perimeter barrier.

3.1.15 *override, n*—type of crash in which a portion of a vehicle goes over a barrier.

3.1.16 *penetration rating, n*—rating achieved by a barrier based on maximum dynamic penetration distance for a given condition designation.

3.1.16.1 *Discussion*—Maximum dynamic penetration distance is defined in 3.1.13, final resting position is also recorded and will sometimes be referenced as the static penetration distance in 3.1.20, but has no effect on the penetration rating.

3.1.17 *rated-ASTM barrier, n*—vehicle security barrier tested in accordance with this test standard by an accredited facility that achieved a penetration rating as defined in 3.1.16.

3.1.18 *reduced occupant risk, n*—computed values for indicators of severe injury, the lateral and longitudinal occupant impact velocity is less than 12.20 m/s, and the ridedown acceleration is less than 20.49 g as recommended by MASH.[10]

3.1.18.1 *Discussion*—There is a minimum of two tests required. The first test is with the desired impact vehicle for rating the barrier and the second test is with the small passenger car (SC) impacting at the same location and angle as the first test with the SC traveling 100 km/h [60 mph]. No other changes are permitted for the second test.

3.1.19 *setback, n*—horizontal distance from the barrier reference point to the nearest surface of the asset being protected.

3.1.19.1 *Discussion*—Loss of setback is equivalent to the original setback minus the penetration distance as defined by 7.5.2 for the respective vehicles.

3.1.20 *static penetration distance, n*—horizontal distance measurement to the respective test vehicle reference point from the barrier reference point at final rest post-test.

3.1.20.1 *Discussion*—See Annex A1 for barrier reference point locations.

3.1.21 *structural component, n*—the portion of the barrier that provides the majority of the barrier's structural resistance to arrest the vehicle.

3.1.21.1 *Discussion*—For the purpose of this test method, the term 'Structural Component' does not include braces, façades, or other features that offer little resistance to the test vehicle.

3.1.22 *supplier, n*—manufacturer, distributor, designer, or constructor of the barrier system that is to be tested and can include contractors, engineers, and architects.

3.1.23 *test director, n*—employee of the testing laboratory responsible for all aspects of a test.

3.1.24 *test vehicle, n*—designated vehicle for specific crash testing.

3.1.25 *underride, n*—a type of crash in which a portion of a vehicle goes under a barrier.

3.1.26 *variable width barrier, n*—perimeter security devices such as gates, nets, wedges, and modular units that will likely be deployed with different functional widths.

3.1.27 *vehicle reference point, n*—the point on the vehicle used to determine maximum vehicle penetration during the crash test.

3.2 *Acronyms:*

3.2.1 *AASHTO*—American Association of State Highway Transportation Officials

3.2.2 *ACI*—American Concrete Institute

3.2.3 *DHS*—U.S. Department of Homeland Security

3.2.4 *DOD*—U.S. Department of Defense

3.2.5 *DOE*—U.S. Department of Energy

3.2.6 *DOS*—U.S. Department of State

3.2.7 *DOS-DS*—Department of State-Bureau of Diplomatic Security

3.2.8 *DOT*—U.S. Department of Transportation

3.2.9 *GSA*—General Services Administration

3.2.10 *ISO*—International Standards Organization

3.2.11 *MASH*—Manual for Assessing Safety Hardware[10]

3.2.12 *NCHRP*—National Cooperative Highway Research Program

3.2.13 *OBO*—Overseas Buildings Operations

3.2.14 *USACE-PDC*—United States Army Corps of Engineers-Protective Design Center

3.3 *Abbreviations:*

3.3.1 *fps*—frames per second

3.3.2 *ft/s*—feet per second

3.3.3 *g*—measure of acceleration referenced to gravity

3.3.4 *km/h*—kilometres per hour

[10] *Manual for Assessing Safety Hardware* (MASH), American Association of State Highway and Transportation Officials, Washington, DC, 2009.

3.3.5 *lbm*—pounds mass

3.3.6 *m/s*—metres per second

3.3.7 *mph*—miles per hour

4. Summary of Test Method

4.1 The complete, comprehensive set of engineering drawings and specifications for a barrier that is to be tested shall be submitted by the supplier to the testing laboratory at least 14 days before testing. These documents shall become part of the permanent test record and report. If a supplier desires to obtain listing of their barrier by one of several agencies that maintain such lists, then see Appendix X3 for additional information.

4.2 Before testing, an approved test vehicle, test velocity, and desired penetration rating is selected by the supplier in coordination with the test director and others who might be involved. The test is then conducted at the chosen velocity using the defined test vehicle and ballast conforming to this test method. Required test data shall be captured and reported.

4.3 The test director shall determine the validity of the test and, if found valid, shall assign a penetration rating for the barrier. The vehicle security barrier shall then become a rated ASTM vehicle perimeter barrier with a Condition Designation and Penetration Rating. In the case of a mistake being discovered after a test report has been written, the test director shall amend his/her test report and the rating issued to correct the mistake.

5. Significance and Use

5.1 This test method provides a structured procedure to establish a penetration rating for vehicle perimeter barriers subjected to a vehicle impact. Knowing the penetration rating helps to select an appropriate barrier for site-specific conditions around a facility.

5.2 The barrier penetration rating does not imply that a barrier will perform as rated in all site conditions, approach routes, and topography. Also, only single-specimen tests at a specified impact location are required by this test method, and therefore, not all points of impact can be tested and validated for the penetration rating. Other impact locations may respond differently.

6. Apparatus

6.1 Appendix X1 provides recommendations on methods of data acquisition that are required by this test method and Appendix X2 provides example forms that may be used for parameters to be measured before, during, and after collision, including measurement tolerances and techniques.

6.2 Pre-test data acquisition shall document the as-built, untested barrier and test vehicle configuration. Documentation includes as-built specifications and drawings for the test article, measurements, and photography. Survey points for elevation of any base slab, columns, bollards, barrier, or barrier support elements that may define deformation, translation, rotation, and uplift should be recorded in pre-test and post-test states.

6.3 During the test, vehicle impact velocity shall be measured. Video documentation, with perpendicular (profile) view shall be provided. Overhead and oblique views should be provided in all tests. Photographic instrumentation specifications shall be in accordance with SAE Standard J211-2. The lens error as referenced by Section 3.1.1 of SAE J211-2 shall not exceed 3 % for lenses <50-mm [2-in.] focal length and shall not exceed 1 % for lenses equal to or greater than 50-mm [2-in.] focal length. Minimum high-speed film or video shall be 400 fps or greater. Determination of impact time = 0 s shall be established by the use of a contact ribbon switch mounted to the front face of the barrier or vehicle bumper triggering a strobe flash that can be recorded on the video documentation for cross-referencing between video sources.

6.4 Vehicle acceleration shall be measured. Accelerometer location is shown in Figs. X2.1-X2.4 in Appendix X2. Electronic instrumentation specifications shall be in accordance with SAE Standard J211-1. Occupant risk values are to be computed per the method of A5.2 “Occupant Risk” in MASH from the acceleration data. Reported occupant risk values only pertain to the system and vehicle as tested.

6.5 After the test, barrier deformation, vehicle penetration, and damage of both test article and vehicle shall be documented with measurements, data recordings, and photography. See 6.2 for data collection points. Other parameters peculiar to a barrier may entail additional documentation. For instance, a gate may be shown to be operational after the collision, even though this is not a requirement of this test method. The maximum horizontal distance between two barriers measured above the finished ground surface shall be recorded.

7. Test Criteria

7.1 *Impact Performance:*

7.1.1 The level of impact kinetic energy that a barrier is to withstand shall be established by the supplier in consultation with the test director and others who might be involved. This level is then compared with the kinetic energy levels shown in Table 1 to select a test vehicle and associated test impact velocity. Actual test velocity shall be within the permissible range indicated to receive the condition designation. During the test, the amount of vehicle penetration of the test barrier at the required impact velocity determines the dynamic penetration rating for the condition designation. Test vehicle dynamic penetration shall be referenced to the vehicle reference points in 7.5.2.

7.1.2 There are four nominal vehicle test velocities in this test method. These nominal velocities are 50, 65, 80, and 100 km/h [30, 40, 50, and 60 mph]. The velocity and associated vehicle determine the condition designation (see last column in Table 1).

7.2 *Test Site:*

7.2.1 Tests shall be conducted at an accredited facility. These facilities shall have adequate space to accelerate the test vehicle to the desired impact velocity and have 30 m [98 ft] minimum behind the barrier reference point, as shown in Annex A1, in accordance with Table 2. In general, the space needs to be level with unobstructed impact regions and not contain curbs, dikes, or ditches in front of the test article installation except where test requirements specify such features as part of the barrier system. Lateral clearance to adjacent

TABLE 1 Impact Condition Designations

Test Vehicle/Minimum Test Inertial Vehicle, kg [lbm]	Nominal Minimum Test Velocity, km/h [mph]	Permissible Speed Range, km/h [mph]	Kinetic Energy, KJ [ft-kips]	Condition Designation
Small passenger car (SC) 1100 ± 25 [2420 ± 55]	50 [30]	45.0-60.0 [28.0-37.9]	106 [78]	SC30
	65 [40]	60.1-75.0 [38.0-46.9]	179 [131]	SC40
	80 [50]	75.1-90.0 [47.0-56.9]	271 [205]	SC50
	100 [60]	90.1- above [57.0-above]	424 [295]	SC60
Full-size Sedan (FS) 2100 ± 50 [4630 ± 110]	50 [30]	45.0-60.0 [28.0-37.9]	203 [37]	FS30
	65 [40]	60.1-75.0 [38.0-46.9]	342 [247]	FS40
	80 [50]	75.1-90.0 [47.0-56.9]	519 [387]	FS50
	100 [60]	90.1-above [57.0-above]	810 [557]	FS60
Pickup truck (PU) 2270 ± 50 [5000 ± 110]	50 [30]	45.0-60.0 [28.0-37.9]	222 [164]	PU30
	65 [40]	60.1-75.0 [38.0-46.9]	375 [273]	PU40
	80 [50]	75.1-90.0 [47.0-56.9]	568 [426]	PU50
	100 [60]	90.1- above [57.0-above]	887 [613]	PU60
Standard Test Truck (M) 6800 ± 140 [15 000 ± 309]	50 [30]	45.0-60.0 [28.0-37.9]	656 [451]	M30
	65 [40]	60.1-75.0 [38.0-46.9]	1110 [802]	M40
	80 [50]	75.1-above [47.0-above]	1680 [1250]	M50
Class 7 Cabover (C7) 7200 ± 150 [15 873 ± 331]	50 [30]	45.0-60.0 [28.0-37.9]	673 [497]	C730
	65 [40]	60.1-75.0 [38.0-46.9]	1199 [884]	C740
	80 [50]	75.1-above [47.0-above]	1872 [1381]	C750
Heavy goods vehicle (H) 29 500 ± 590 [65 000 ± 1300]	50 [30]	45.0-60.0 [28.0-37.9]	2850 [1950]	H30
	65 [40]	60.1-75.0 [38.0-46.9]	4810 [3470]	H40
	80 [50]	75.1-above [47.0-above]	7280 [5430]	H50

TABLE 2 Penetration Ratings

Designation	Dynamic Penetration Rating
P1	≤1 m [3.3 ft]
P2	1.01 to 7 m [3.31 to 23.0 ft]
P3	7.01 to 30 m [23.1 to 98.4 ft]

TABLE 3 Recommended Soil Foundation Material (from AASHTO M147-65)

Sieve Size, mm [in.]	Mass % Passing
50.0 [2]	100
25.0 [1]	75-95
9.5 [⅜]	40-75
4.75 [No. 4]	30-60
2.00 [No. 10]	20-45
0.425 [No. 40]	15-30
0.075 [No. 200]	5-20

objects shall be a minimum of 3 m [10 ft]. The surface shall replicate anticipated field deployed conditions. This is done in an attempt to minimize unrealistic effects on the barrier's test performance from the test boundary conditions.

7.2.2 Unless otherwise required, in test barriers requiring embedment in soil, including concrete footings, the soil shall be low-cohesive, well-graded crushed stone or broken gravel of a particle size distribution comparable to Table 3. The low-cohesive soil shall have a depth equal to the bottom of the foundation and a width equal to 1.5 times the foundation depth behind the test barrier or 0.6 m [2 ft], whichever is greater up to a maximum of 2.4 m [8 ft]. The low-cohesive soil shall be compacted fill to a density of not less than 90 % maximum dry density in accordance with Test Method D1556 and Test Methods D6938 and AASHTO Method of Test T099 and meet Table 3 for gradation. If testing for site-specific soil conditions

is being conducted, then testing may be performed in replicated site soil conditions and reported in the test report. The lateral bearing pressure and moisture content shall be recorded and reported. These values shall be determined from standard test methods. It is recommended that Test Method D4429 be used to determine the lateral bearing pressure. (If lateral loads are expected, the low-cohesive soil shall extend the same distance laterally.)

7.2.3 For test barriers that are surface mounted, testing shall be on a surface established by the supplier in consultation with the test director and any others who might be involved. Regardless of the surface on which the barrier is mounted, the profile of the test bed to a depth of 0.6 m [2 ft] shall be determined and documented in the test report.

7.3 *Test Article*—The test barrier shall be constructed and erected in a manner representative of the proposed actual service installation and conform to supplier specifications and drawings. Any deviations from fabrication, specification, or erection details shall be noted in the test report.

7.4 *Test Vehicle*—The test vehicle shall be structurally sound (no major rust or structural weakness), have an unmodified bumper, and not have any structural additions or modifications that may enhance test performance. Tires shall be of the size and type recommended by the manufacturer and inflated to recommended pressure. Note that there might be agency-specific vehicle requirements to which the test must comply to enable the barrier's inclusion on the agency's approved barrier list.

7.4.1 *Small Passenger Car (SC)*—The small passenger car shall be manufactured within ten years of the test date and should be selected based on sales information for the applicable years. The vehicle may be a sedan or coupe configuration. The gross vehicle test mass shall be 1100 ± 25 kg [2420 ± 55 lb]. If ballasting is required, water may be added to the fuel tank or weights evenly distributed and securely anchored to the occupant compartment floor. Care should be taken to distribute the ballast uniformly.

7.4.2 *Full-Size Passenger Sedan (FS)*—The full-size passenger sedan shall be manufactured within ten years of the test date and should be selected based on sales information for the applicable years. The gross vehicle test mass shall be 2100 ± 50 kg [4630 ± 110 lb]. If ballasting is required, water may be added to the fuel tank or weights evenly distributed and securely anchored to the occupant compartment floor. Care should be taken to distribute the ballast uniformly.

7.4.3 *Pickup Truck (PU)*—The pickup truck shall be a ½-ton-rated body style and manufactured within ten years of the test date and should be selected based on sales information for the applicable years. Four-door, crew cab pickups shall be used. The ½-ton crew cab pickup has been shown to be a good surrogate for the sport utility vehicle. The gross vehicle test mass shall be 2270 ± 50 kg [5000 ± 110 lb]. If ballasting is required, care should be taken to distribute the ballast uniformly.

TABLE 4 Typical U.S. Small Passenger Car (SC)

Make	Model	GVW, kg [lb]	Curb Weight, kg [lb]
Kia	Rio	1560 [3438]	1125 [2480]
Toyota	Yaris	1061 [2340]	1041 [2295]

TABLE 5 Typical U.S. Full Size Passenger Sedan (FS)

Make	Model	GVW, kg [lb]	Curb Weight, kg [lb]
Ford	Taurus	2440 [5379]	1831 [4037]
Dodge	Charger	2313 [5100]	1797 [3961]
Kia	Cadenza	1985 [4376]	1664 [3668]

TABLE 6 Typical U.S. ½ Ton Pickup Trucks (PU)

Make	Model	GVW, kg [lb]	Curb Weight, kg [lb]
Chevrolet	1500 Crew Cab 4 Door	3084 [6800]	2313 [5100]
Ford	F150	2926-3720 [6450-8200]	2125 [4685]
Dodge	Ram 1500 Quad Cab	2722-3084 [6000-6800]	2263 [4990]

7.4.4 *Standard Test Truck (M)*—The standard test truck will be equipped with a conventional cab. The conventional M vehicle shall be equipped with a diesel engine and tested at a test inertial vehicle mass of 6800 ± 140 kg [15 000 ± 309 lb]. U.S. standard test trucks have gross vehicle mass ratings of 11 612 to 14 970 kg [25 600 to 33 000 lb] and a wheelbase of 6.0 ± 1.25 m [236 ± 50 in.]. A commercially manufactured flat bed, 6.1 ± 1.5 m [20 ft ± 60 in.] long shall be installed per the vehicle manufacturer's specifications. "U" bolts shall be spaced at 1.0 ± 0.2 m [3 ft ± 8 in.] on center, unless otherwise specified by the vehicle manufacturer and shear plate connections shall be provided on the front, middle, and rear of the flat bed as specified by vehicle manufacturer. Ballast material shall be soil-filled, 208-L [55-gal] steel drums attached to the vehicle cargo bed, as described in 7.4.4.3.

7.4.4.1 Illustrative U.S. manufactured standard test trucks are given in Table 7.

7.4.4.2 Table 7 is not all inclusive; comparable vehicles may be acceptable as a test vehicle.

7.4.4.3 The ballast will be standard, round, "open top" (removable top, secured with ring and nut/bolt, or level-lock mechanism), 208-L [55-gal] metal drums filled with soil. The 208 L [55-gal] drums are nominally 610 ± 51 mm [24 ± 2 in.] in diameter and 914 ± 51 mm [36 ± 2 in.] in outside height. (ISO "containerizable" steel drums may also be used. These are nominally 595 mm [23 7/16 in.] with the same inside diameter as the standard 208-L [55-gal] drum. Three horizontal cargo

TABLE 7 Typical U.S. Standard Test Trucks (Conventional Cab) (M)

Make	Model	GVW, kg [lb]
Ford	650	11 612-13 154 [25 600-29 000]
Ford	750	11 612-16 783 [25 600-37 000]
Freightliner	M2 106	8850-14 970 [19 500-33 000]
International	4300	9752-14 970 [21 500-33 000]
International	4400	9752-14 970 [21 500-33 000]

straps and a minimum of one cargo strap over the top of each row of steel drums are required. Photos of a typical test vehicle configuration and ballast attachment using 4540 kg [10 000-lb] ultimate capacity cargo straps are shown in Figs. 1 and 2.

FIG. 1 Typical Text vehicle Configuration, Side View

specified by vehicle manufacturer. Ballast material shall be soil-filled, 208-L [55-gal] steel drums attached to the vehicle cargo bed, as described in 7.4.5.3.

7.4.5.1 Illustrative U.S. manufactured Class 7 Cabovers and Cab Forward Class 7 trucks are given in Table 8.

7.4.5.2 Table 8 is not all inclusive; comparable vehicles may be acceptable as a test vehicle.

7.4.5.3 The ballast will be standard, round, "open top" (removable top, secured with ring and nut/bolt, or level-lock mechanism), 208-L [55-gal] metal drums filled with soil. The 208-L [55-gal] drums are nominally 610 + 51 mm [24 + 2 in.] in diameter and 914 + 51 mm [36 + 2 in.] in outside height. (ISO "containerizable" steel drums may also be used. These are nominally 595 mm [23 7⁄16 in.] with the same inside diameter as the standard 208-L [55-gal] drum. Three horizontal cargo

FIG. 2 Typical Ballast Attachment, Rear View

7.4.5 *Cabover/Cab Forward Class 7 Truck (C7)*—The Class 7 Cabover/Cab Forward Class 7 Truck test vehicle shall be equipped with a diesel engine and tested at a test inertial vehicle mass of 7200 ± 150 kg [15 873 ± 331 lb]. Class 7 trucks have gross vehicle mass ratings of 11 800 to 14 970 kg [26 000 to 33 000 lb] and shall have a wheelbase of 6.0 ± 1.25 m [236 ± 50 in.]. A commercially manufactured flat bed, 6.1 ± 1.5 m [20 ft ± 60 in.] long shall be installed per the vehicle manufacturer's specifications. "U" bolts shall be spaced at 1.0 ± 0.2 m [3 ft ± 8 in.] on center, unless otherwise specified by the vehicle manufacturer and shear plate connections shall be provided on the front, middle, and rear of the flat bed as straps and a minimum of one cargo strap over the top of each row of steel drums are required. Photos of a typical test vehicle configuration and ballast attachment using 4540 kg [10 000 lb] ultimate capacity cargo straps are shown in Figs. 1 and 2.

TABLE 8 Typical U.S. Class 7 Trucks (Cabover) (C7)

Make	Model	GVW, kg [lb]
Isuzu	FTR 900	11 801-15 074 [26 001-33 000]
UD (Nissan)	3300	11 801-15 074 [26 001-33 000]

7.4.6 *Heavy Goods Vehicle (H)*—The heavy goods vehicle shall be a tandem axle dump truck or tandem axle with drop axle with a minimum gross vehicle mass of 27 300 kg [60 000 lb] and shall be tested at 29 500 ± 590 kg [65 000 ± 1300 lb]. Ballasting shall be achieved by the placement of mass concrete in the bed of the dump truck. The concrete shall achieve at least 2500 psi strength before testing is conducted. Concrete shall be tested according to Test Method C39.

7.4.7 *User-Defined Vehicle (U)*—End users may have requirements for specific vehicle types. When ballast is used in the user-defined vehicle, all ballast shall be securely attached to the test vehicle to be retained during the impact and locations documented.

7.4.8 *Accelerometer Location*—Location of the principle accelerometers shall be placed as close to the vehicle center of mass as possible and documented on forms shown in Appendix X2. The vehicle structure should not be modified to accommodate the accelerometer mounting. It is acceptable to mount the accelerometers on the frame rails of the standard test truck and heavy goods vehicle at the longitudinal center of mass location. In passenger vehicles and pickups, the accelerometers should be placed in the occupant compartment as close to center of mass as practical. Many testing agencies use an accelerometer mounting bracket attached directly to the floor of the vehicles between the front passenger seating positions.

7.5 *Vehicle Penetration Limitations:*

7.5.1 Most agencies are concerned with the location of the potential explosives relative to the asset being protected. Therefore, likely placements of the explosives will be in the passenger compartment or trunk of the full size passenger sedan (FS), and small passenger car (SC) and in the cargo beds of the pickups and larger vehicle. Hence, the measurement vehicle referenced points discussed in the following.

7.5.2 *Reference Points*—Limits on vehicle dynamic penetration shall be referenced to the original pre-test reference point of the barrier being tested. See Annex A1 and Figs. X2.1-X2.4 in Appendix X2. Reference points on undefined types of barriers shall be determined by the test director.

7.5.2.1 The test vehicle reference point shall be the leading edge of the base of the "A" pillar on the small passenger car (SC), the full-size passenger sedan (FS), and the pickup truck (PU). The test vehicle reference point will be the leading lower vertical edge of the cargo bed on the standard test Truck (M), the Class 7 cabover (C7), and the heavy goods vehicle (H).

7.5.3 *Vehicle Penetration Ratings*—In Table 2, penetration ratings for the predetermined limits P1, P2, and P3 are assigned. The dynamic penetration distance shall be reported and assigned one of the penetration ratings. If brakes are applied during the test, location of brake application shall be reported and the test does not receive an ASTM rating.

8. Preparation of Apparatus

8.1 *Test Article:*

8.1.1 Each device, assembly, or structure used in a barrier shall be identified and documented by engineering drawings and specifications.

8.1.1.1 All proprietary information shall be clearly indicated in the documents. All such information provided to the test director shall be safeguarded and shall not be disclosed to unauthorized personnel.

8.1.1.2 Each drawing shall include the barrier title/description, drawing number, and date and shall be submitted in A4 (21.6 by 27.9-cm [8½ by 11-in.]) format. Each drawing shall identify the barrier in exact detail. Assembly drawings shall show the arrangement, locations, and dimensions of all components.

8.1.1.3 Specifications for materials used, location and type of all welds, and size and spacing of all rebar shall be included in the documents.

8.1.2 Standard commercial materials used in construction shall conform to configuration and performance standards established for the material by appropriate industrial specifications and shall be cited in the specifications, such as ACI for concrete strength.

8.1.3 Nonstandard materials or devices used in configurations not otherwise controlled by recognized industrial or manufacturer specifications shall be accompanied by full-disclosure drawings (fabrication, engineering, or design drawings, or combinations thereof) and specifications.

8.2 *Test Article Installation:*

8.2.1 For gates, adjacent structures used to support the gate and resist induced forces during the crash test shall be specified and documented. Such structures (including their foundations) are considered to be part of the test article and shall be documented in the test report.

8.2.2 The length of a continuous barrier test article, excluding terminals and anchors, shall be not less than three times the width in which deformation is predicted, but not less than 6 m [20 ft]. These include walls, fences, and similar devices. When a single device is tested in a minimum width configuration, field installations shall not exceed anchorage distances used in the test installation.

8.2.3 A freestanding barrier, such as a portable concrete barrier or planter, which depends on frictional resistance between it and the ground to resist movement, shall be tested on the same general type of ground or pavement surface where it will be used. The type of pavement surface, as well as end anchorage used, shall be reported.

8.2.4 Other test articles or vehicle arrest devices such as ditches and berms may be evaluated by this test method provided they have adequate descriptions, drawings, and specifications.

8.2.5 Variable-width barriers, such as nets, wedges, fences, and so forth, shall be tested in minimum- and maximum-width configurations. Interpolations between maximum and minimums is allowed if structural modifications are not made. Structural components, including spacing of support members and connections, shall be similar to barriers tested at minimum and maximum widths. Spacing of structural components shall remain constant across varying widths of barriers; any deviations from the maximum and minimum tested structural component spacing is unacceptable. Acceptance of interpolations will be at the discretion of the end user. Extrapolations are not allowed outside the tested parameters.

NOTE 1—Variable-width barriers will require a minimum of two tests and additional tests may be necessary. Barriers that span multiple lanes of

traffic will react differently under different loading conditions, such as quarter-point impacts. Opportunities for an underride or override may also be a concern.

9. Procedure

9.1 *Compliance*—Once a test article is committed to testing for the purpose of obtaining a rating, a report of all testing conducted on the device or assembly shall be developed by the test director of the test laboratory regardless of the test outcome. Test documentation indicating compliance with the vehicle impact resistance requirements and test results may be submitted to other interested agencies by the test agency of the tested system.

9.2 *Pre-test Submissions*—The supplier shall provide a test plan consisting of drawings and specifications of the device, assembly, or structure to be tested; configuration disclosure documentation; description of the proposed test vehicle; and proposed impact conditions to the test director at least 14 days in advance of testing. The supplier may provide the same information to the technical representatives of any other interested agency.

9.3 *Impact Conditions:*

9.3.1 The method of vehicle guidance before impact is optional, providing the guidance system or its components do not affect significant changes in the vehicle dynamics during and immediately after collision. The test vehicle may be pushed, towed, or self-powered to the programmed speed. If pushed or towed, the prime mover and guidance system shall be disengaged before impact.

9.3.2 The test vehicle shall approach and impact the test article at 90 ± 3°. Vehicle impact shall be centered on the most vulnerable section or part of the test article as determined by the test director and any other interested agency representative. Actual impact point shall be within ±0.3 m [1 ft] of this target. The test impact direction shall be indicated on the drawings submitted to the testing agency.

9.3.3 Actual vehicle impact speed shall be within the permissible range shown in Table 1 to receive the rating for the designated condition level at the intended nominal speed. Tests with vehicle impact speed outside this range are not valid for the rating assignment but may be rated by the test director at an appropriate condition level.

9.4 *Evaluation of Performance Level:*

9.4.1 Measurement of the extent to which the "A" pillar of the passenger cars or the lower front edge of the larger test vehicles cargo bed penetrates or vaults over the system relative to the reference points designated in Fig. A1.1 and Fig. A1.2 shall be recorded.

9.4.2 The penetration ratings designated in 7.5 shall be applied to all test levels. Penetration measurements may be negative if the pre-test reference point of the vehicle does not reach the pre-test reference point of the barrier.

9.4.3 The level of damage to the vehicle shall be recorded to support the determination of whether or not the vehicle is disabled. It shall also be recorded if the vehicle is disabled.

9.4.4 The lateral and longitudinal occupant impact velocity as well as the ridedown acceleration shall be recorded. If the barrier is being evaluated for reduced occupant risk an additional test shall be conducted using the small passenger car (SC) impacting at the same location and angle with an impact velocity of 100 km/h [60 mph].

9.4.5 If claiming reduced occupant risk, no other changes shall be allowed on the second test other than those stated here. Additional discussion of occupant risk factors can be found in Appendix X4.

9.5 *Rating Assignment and Certification*—If the tests are conducted in accordance with this test method, the tested barrier shall be assigned a condition level based on vehicle type and impact velocity and a penetration rating based on dynamic penetration distance. An ASTM condition level shall not be reported without an associated penetration rating and the standard used, for example ASTM Test Method F2656/F2656M-20 M30 P1. If user site specific conditions are used for the test, such as soil conditions other than outlined in 7.2.2, it shall receive an "U" designation after the penetration rating, for example ASTM Test Method F2656/F2656M-20 M30 P1 U.

10. Report

10.1 The test report, prepared by the test director of an accredited testing facility, shall include, but not be limited to, the following sections:

10.1.1 *Identification*—Name, address, and contact data of testing organization, responsible personnel, test facility location, and test date.

10.1.2 *Barrier Description*—Describe as-built test article, including tested width, photographs, detailed engineering drawings with dimensions and material specifications, of all components of the barrier, including, but not limited to foundation details, rebar sizing and spacing, and concrete properties. Proprietary material properties, dimensions, and references to design revisions from any earlier tests shall be included as part of the certified report. The report shall be handled as manufacturer's proprietary information. Describe special fabrication and installation procedures (such as heat treatment, weldments, bolt tension, galvanizing in critical stressed areas, concrete mix design strength on day of test, and so forth) that may influence dynamic behavior. The construction process shall be documented with photographs. Edited fabrications, plans, and specifications will include deviations to barrier plans. These "as-built" drawings shall be included in the test report. If original designs are also included, they shall be watermarked as "original design—not tested configuration" or similar.

10.1.3 *Test Vehicle Description*—Describe vehicle (make, model, year, engine type, tire size, test weight, condition, bed, and ballast configuration). Provide measurements and accelerometer locations. The format shown in Appendix X2 may be used.

10.1.4 *Test Procedure*—Describe the test facility and associated equipment, data acquisition systems, and procedures used in calibrating and processing data. Include soil properties and other conditions applicable to barrier performance. Soil conditions shall comply with 7.2.2 and reported including gradation, compaction, classification, and moisture content as a minimum. If testing in site specific conditions, soil properties