Designation: D4169 – 23$^{\varepsilon 1}$

Standard Practice for Performance Testing of Shipping Containers and Systems[1]

This standard is issued under the fixed designation D4169; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

ε[1] NOTE—Editorial corrections made throughout in March 2024.

1. Scope*

1.1 This practice provides a uniform basis of evaluating, in a laboratory, the ability of shipping units to withstand the distribution environment. This is accomplished by subjecting them to a test plan consisting of a sequence of anticipated hazard elements encountered in various distribution cycles. This practice is not intended to supplant material specifications or existing preshipment test procedures.

1.2 Consider the use of Practice D7386 for testing of packages for single parcel shipments.

1.3 The suitability of this practice for use with hazardous materials has not been determined.

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

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *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]

D642 Test Method for Determining Compressive Resistance of Shipping Containers, Components, and Unit Loads

D880 Test Method for Impact Testing for Shipping Containers and Systems

D951 Test Method for Water Resistance of Shipping Containers by Spray Method

D996 Terminology of Packaging and Distribution Environments

D999 Test Methods for Vibration Testing of Shipping Containers

D4003 Test Methods for Programmable Horizontal Impact Test for Shipping Containers and Systems

D4332 Practice for Conditioning Containers, Packages, or Packaging Components for Testing

D4728 Test Method for Random Vibration Testing of Shipping Containers

D5265 Test Method for Bridge Impact Testing

D5276 Test Method for Drop Test of Loaded Containers by Free Fall

D5277 Test Method for Performing Programmed Horizontal Impacts Using an Inclined Impact Tester

D5487 Test Method for Simulated Drop of Loaded Containers by Shock Machines

D6055 Test Methods for Mechanical Handling of Unitized Loads and Large Shipping Cases and Crates

D6179 Test Methods for Rough Handling of Unitized Loads and Large Shipping Cases and Crates

D6344 Test Method for Concentrated Impacts to Transport Packages

D6653 Test Methods for Determining the Effects of High Altitude on Packaging Systems by Vacuum Method

D7386 Practice for Performance Testing of Packages for Single Parcel Delivery Systems

[1] This practice is under the jurisdiction of ASTM Committee D10 on Packaging and is the direct responsibility of Subcommittee D10.21 on Shipping Containers and Systems - Application of Performance Test Methods.

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

***A Summary of Changes section appears at the end of this standard**

F1327 Terminology Relating to Barrier Materials for Medical Packaging (Withdrawn 2007)[3]
F2825 Practice for Climatic Stressing of Packaging Systems for Single Parcel Delivery
2.2 *Military Standards:*[4]
MIL-STD-810F Environmental Test Methods
MIL-STD-2073–1 DOD Standard Practice for Military Packaging
2.3 *Association of American Railroads Standards:*[5]
General Information Bulletin No. 2 Rules and Procedures for Testing of New Loading and Bracing Methods or Materials

3. Terminology

3.1 *Definitions*—General definitions for the packaging and distribution environments are found in Terminology D996.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acceptance criteria, n*—the acceptable quality level that must be met after the shipping unit has been subjected to the test plan. See Section 7.

3.2.2 *assurance level, n*—the level of test intensity based on its probability of occurring in a typical distribution cycle.

3.2.2.1 *Discussion*—Level I is a high level of test intensity and has a low probability of occurrence. Level III is a low level of test intensity, but has a correspondingly high probability of occurrence. Level II is between these extremes. For Distribution Cycle 18 (DC–18), see MIL-STD-2073–1 for definitions of military levels of protection.

3.2.3 *coefficient of restitution, n*—the ratio of the rebound velocity to the impact velocity.

3.2.4 *distribution cycle (DC), n*—the sequential listing of the test schedules employed to simulate the hazard elements expected to occur for a specific routing of a shipping unit from production to consumption. See Table 1.

3.2.5 *feeder aircraft, n*—small, potentially non-pressurized aircraft used to transport express packages.

3.2.6 *hazard element, n*—a specific event that occurs in a distribution cycle that may pose a hazard to a shipping unit. The element will usually be simulated by a single test schedule. See Section 9.

3.2.7 *small and lightweight package: for DC's 2,3,4,6,9,13, 14,15,16,17;* packages weighing under 10.00 lb (4.53 kg) and volume below 2.000 ft^3 (0.056 m^3).

3.2.8 *shipping unit, n*—the smallest complete unit that will be subjected to the distribution environment, for example, a shipping container and its contents.

3.2.8.1 *small shipping unit, n*—for DC-18, a small shipping unit is defined as one having no edge dimension or diameter over 60 in. (1.52 m) and a gross weight of 100 lb (45 kg) or less.

3.2.8.2 *large shipping unit, n*—for DC-18, a large shipping unit is defined as one having at least one edge dimension or diameter over 60 in. (1.52 m) or a gross weight in excess of 100 lb (45 kg), or it is one that has a gross weight exceeding 100 lb (45 kg) and is secured to a base or to the base of a shipping unit.

3.2.9 *test plan, n*—a specific listing of the test sequence to be followed to simulate the hazards anticipated during the distribution cycle of a shipping unit. Included will be the test intensity and number of sequential tests to be conducted. See 8.5.

3.2.10 *test schedule, n*—the specific procedure to be used, including the three assurance level intensities, and a reference to the test method that is the basis of the schedule.

3.2.10.1 *Discussion*—The purpose of the schedule is to simulate the forces occurring during any hazard element of the distribution cycle. See Section 9.

3.2.11 *total velocity change, (ΔV), n*—the sum of the impact and rebound velocities.

3.3 *Abbreviations:*

3.3.1 *TOFC*—trailer on flatcar.

3.3.2 *COFC*—container on flatcar.

3.3.3 *TL*—truckload.

3.3.4 *CL*—carload.

3.3.5 *LTL*—less than truckload.

4. Significance and Use

4.1 This practice provides a guide for the evaluation of shipping units in accordance with a uniform system, using established test methods at levels representative of those occurring in actual distribution. The recommended test levels are based on available information on the shipping and handling environment, and current industry/government practice and experience (**1-13**).[6] The tests should be performed sequentially on the same containers in the order given. For use as a performance test, this practice requires that the shipping unit tested remain unopened until the sequence of tests are completed. If used for other purposes, such as package development, it may be useful to open and inspect shipping units at various times throughout the sequence. This may, however, prohibit evaluating the influence of the container closure on container performance.

4.2 For Distribution Cycle 18, as referred to in MIL-STD-2073–1, the use of this practice is defined in subsequent sections identified as DC-18.

5. Test Specimen

5.1 Test specimens consist of representative samples of complete shipping units, including actual contents. Products with blemishes or minor defects may be used if the defective component is not to be studied by the test and if the defect is documented in the report. Dummy test loads are acceptable if testing the actual product might be hazardous. If a dummy load

[3] The last approved version of this historical standard is referenced on www.astm.org.
[4] Available from DLA Document Services, Building 4/D, 700 Robbins Ave., Philadelphia, PA 19111-5094, http://quicksearch.dla.mil.
[5] Available from Association of American Railroads (AAR), 425 Third St., SW, Washington, DC 20024, http://www.aar.org.
[6] The boldface numbers in parentheses refer to a list of references at the end of this standard.

TABLE 1 Distribution Cycles

DC	Distribution Cycle	Performance Test Schedule Sequence (see Section 9 for Test Schedule definition)						
		First	Second	Third	Fourth	Fifth	Sixth	Seventh
1	General Cycle—undefined distribution system	Schedule A Handling	Schedule D Stacked Vibration	Schedule F Loose-Load Vibration	Schedule G Rail Switching	Schedule J Concentrated Impact	Schedule A Handling	
2	Specially defined distribution system, user specified (see Appendix X2)			select from Schedules A through I				
3	Single package without pallet or skid, LTL motor freight	Schedule A Handling —Manual	Schedule D Stacked Vibration OR Schedule C Vehicle Stacking plus Schedule E Vehicle Vibration	Schedule F Loose-Load Vibration	Schedule J Concentrated Impact	Schedule A Handling—Manual	. . .	
4	Single package with pallet or skid, LTL motor freight	Schedule A Handling —Mechanical	Schedule D Stacked Vibration OR Schedule C Vehicle Stacking plus Schedule E Vehicle Vibration	Schedule F Loose-Load Vibration	Schedule J Concentrated Impact	Schedule A Handling—Mechanical	. . .	
5	Motor freight, TL, not unitized	Schedule A Handling	Schedule D Stacked Vibration	Schedule E Vehicle Vibration	Schedule J Concentrated Impact	Schedule A Handling	. . .	
6	Motor freight, TL, or LTL—unitized	Schedule A Handling	Schedule D Stacked Vibration OR Schedule C Vehicle Stacking plus Schedule E Vehicle Vibration	Schedule J Concentrated Impact	Schedule A Handling	Schedule B Warehouse Stacking	. . .	
7	Rail only, bulk loaded	Schedule A Handling	Schedule D Stacked Vibration	Schedule G Rail Switching	Schedule A Handling	. . .	. . .	
8	Rail only, unitized	Schedule A Handling	Schedule D Stacked Vibration	Schedule G Rail Switching	Schedule A Handling	Schedule B Warehouse Stacking	. . .	
9	Rail and motor freight, not unitized	Schedule A Handling	Schedule C Vehicle Stacking	Schedule E Vehicle Vibration	Schedule G Rail Switching	Schedule F Loose-Load Vibration	Schedule J Concentrated Impact	Schedule A Handling
10	Rail and motor freight, unitized	Schedule A Handling	Schedule D Stacked Vibration	Schedule G Rail Switching	Schedule J Concentrated Impact	Schedule A Handling	Schedule B Warehouse Stacking	
11	Rail, TOFC and COFC	Schedule A Handling	Schedule G Rail Switching	Schedule D Stacked Vibration	Schedule F Loose-Load Vibration	Schedule A Handling	. . .	
12	Air (intercity) and motor freight (local), over 150 lb (68.1 kg), or unitized	Schedule A Handling	Schedule D Stacked Vibration	Schedule I Low Pressure[A]	Schedule E Vehicle Vibration	Schedule J Concentrated Impact	Schedule A Handling	
13	Air (intercity) and motor freight (local), single package up to 150 lb (68.1 kg)†. Consider using Practice D7386 for single parcel carrier shipments.	Schedule A Handling	Schedule C Vehicle Stacking	Schedule F Loose-Load Vibration	Schedule I Low Pressure[A]	Schedule E Vehicle Vibration	Schedule J Concentrated Impact	Schedule A Handling
14	Warehousing (partial cycle to be added to other cycles as needed)	Schedule A Handling	Schedule B Warehouse Stacking	. . .	. . .	. . .	. . .	
15	Export/Import shipment for intermodal container or roll on/roll off trailer (partial cycle to be added to other cycles as needed)	Schedule A Handling	Schedule C Vehicle Stacking	Schedule A Handling	. . .	. . .	. . .	
16	Export/Import shipment for palletized cargo ship (partial cycle to be added to other cycles as needed)	Schedule A Handling	Schedule C Vehicle Stacking	Schedule A Handling	. . .	. . .	. . .	

TABLE 1 *Continued*

DC	Distribution Cycle	Performance Test Schedule Sequence (see Section 9 for Test Schedule definition) First	Second	Third	Fourth	Fifth	Sixth	Seventh
17	Export/Import shipment for break bulk cargo ship (partial cycle to be added to other cycles as needed)	Schedule A Handling	Schedule C Vehicle Stacking	Schedule A Handling	. . .	. . .	. . .	
18	Non-Commercial Government shipments in accordance with MIL-STD-2073–1	Refer to Annex A1 for Test Schedules applying to DC-18.						

† Editorially corrected.

[A] This high altitude, non-pressurized transport simulation test may be deleted from this distribution cycle when testing shipping units that contain primary packages that have a porous material.

is used, it should be instrumented to determine if the fragility level of the actual product has been exceeded. Take care to duplicate the load characteristics of the actual product, and avoid unnecessary prehandling.

5.2 Care must be taken to ensure that no degradation has occurred to either the product or the package if the test packages have been shipped to the test site. If any doubt exists as to the condition of the package, repack the product in new packaging material before testing.

5.3 The number of test replications depends on the desired objectives of the testing and the availability of duplicate products and shipping containers. Replicate testing is recommended to improve the reliability of the test results.

6. Conditioning

6.1 If the distribution cycle contains climatic conditions that have an effect on the performance characteristics of the product, shipping container, or components such as cushioning, use one of the following procedures. (It should be noted that different atmospheric conditions are likely to exist between the origin and destination points of a distribution cycle, particularly for export/import cycles.)

6.1.1 Conduct the test at standard conditions and compensate for the effects of any climatic condition. Condition the shipping units to a standard atmosphere of 73.4 °F ± 2 °F (23 °C ± 1 °C) and 50 % ± 2 % relative humidity. Condition fiberboard containers in accordance with Practice D4332. The same atmospheric condition should be used for any assurance level. A conditioning period of 72 h, or sufficient time to reach equilibrium of all parts of the package and product is recommended. Tests should be conducted in the conditioned atmosphere whenever possible. If not possible, conduct the tests as soon after removal from the conditioning atmosphere as practicable. Recondition the shipping units to the standard atmosphere as necessary during the test plan.

6.1.2 In some circumstances, it may be necessary to conduct some or all of the tests at special climatic conditions, such as those given in Practice D4332, F2825 or Test Method D951, or others (salt, spray, water immersion, humidity, or temperature). The same climatic condition should be used for any assurance level. A conditioning period should be provided which will allow sufficient time to reach equilibrium of all parts of the package and product. Tests should be conducted in the conditioned atmosphere whenever possible. If not possible, conduct the tests as soon after removal from the conditioning atmosphere as practicable. Recondition the shipping units as necessary during the test plan. For atmospheres other than the standard conditioning atmosphere, the user must determine the appropriate compressive load factor for warehouse and vehicle stacking, as the factors given in 11.2 are based on testing under the standard test atmosphere.

6.1.3 When conducting testing using DC-13, the Practice F2825 environmental conditioning may be applicable.

7. Acceptance Criteria

7.1 Acceptance criteria must be established prior to testing and should consider the required condition of the product at receipt. The organizations conducting the test may choose any acceptance criteria suitable for their purpose. It is advisable to compare the type and quantity of damage that occurred to the test specimens with the damage that occurs during actual distribution and handling or with test results of similar containers whose shipping history is known.

7.2 In many cases, the acceptance criteria can be the following:

Criterion 1—Product is damage-free.
Criterion 2—Package is intact.
Criterion 3—Both criteria 1 and 2.

Often, this means that the shipping container and its contents are suitable for normal sale and use at the completion of the test cycle. Detailed acceptance criteria may allow for accepting specified damage to a product or its package. The form and content of acceptance criteria may vary widely, in accordance with the particular situation. Methods may range from simple pass-fail judgments to highly quantitative scoring or analysis systems.

8. Procedure

8.1 *Define Shipping Unit*—Describe shipping unit in terms of size, weight, and form of construction. See 3.2.8. Determine whether the container will be manually or mechanically handled.

8.2 *Establish Assurance Level*—Specify a level of test intensity. The level should be one of three pre-established assurance levels. This must be pre-established based on the product value, the desired level of anticipated damage that can

be tolerated, the number of units to be shipped, knowledge of the shipping environment, or other criteria. Assurance Level II is suggested unless conditions dictate otherwise. Assurance Level I provides a more severe test than II. Assurance Level III provides a less severe test than II. The assurance level may be varied between schedules (see Sections 10 – 15) if such variations are known to occur. The test levels used should be reported. See Section 18.

8.3 *Determine Acceptance Criteria*—Acceptance criteria are related to the desired condition of the product and package at the end of the distribution cycle. See Section 7.

8.4 *Select Distribution Cycle*—Select a Distribution Cycle from the available standard distribution cycles compiled in Table 1. Use the DC that most closely correlates with the projected distribution. When the distribution is undefined, the general distribution cycle DC-1 should be selected. When the anticipated distribution is well understood, a special distribution cycle DC-2 may be specified. In using DC-2, the user selects test schedules from Section 9 and specifies the test sequence (see Appendix X2 for more details). For purposes of DC-3 and DC-13, the bottom of a single package is the surface on which the package rests in its most stable orientation. The identified bottom should be utilized for purposes of determining the starting orientation of each test schedule within the above stated distribution cycles.

8.5 *Write Test Plan*—Prepare a test plan by using the sequence presented in Table 1 for the distribution cycle selected. Obtain the test intensities from the referenced schedules. The test plan intensity details must take into account the assurance levels selected as well as the physical description of the shipping unit. Table 1 thus leads to a detailed test plan consisting of the exact sequence in which the shipping unit will be subjected to the test inputs. The test schedules associated with each element reference the existing ASTM test methods for clarification of the equipment and techniques to be used to conduct the test.

8.5.1 Sample test plans are provided in Appendix X1.

8.6 *Select Samples for Test*—See Section 5.

8.7 *Condition Samples*—See Section 6.

8.8 *Perform Tests*—Perform tests as directed in reference ASTM standards and as further modified in the special instructions for each test schedule.

8.9 *Evaluate Results*—Evaluate results to determine if the shipping units meet the acceptance criteria. See Section 7.

8.10 *Document Test Results*—Document test results by reporting each step. See Section 18.

8.11 *Monitor Shipments*—When possible, obtain feedback by monitoring shipments of the container that was tested to ensure that the type and quantity of damage obtained by the laboratory testing correlates with the damage that occurs in the distribution cycle. This information is very useful for the planning of subsequent tests of similar shipping containers.

9. Hazard Elements and Test Schedules

9.1 Hazard Elements and Test Schedules are categorized as follows:

Schedule	Hazard Element	Test	Section
A	Handling—manual and mechanical	drop, impact, stability	10
B	Warehouse Stacking	compression	11
C	Vehicle Stacking	compression	11
D	Stacked Vibration	vibration	12
E	Vehicle Vibration	vibration	12
F	Loose Load Vibration	repetitive shock	13
G	Rail Switching	longitudinal shock	14
H	Environmental Hazard	cyclic exposure	15
I	Low Pressure Hazard	vacuum	16
J	Concentrated Impact	impact	17

10. Schedule A—Handling—Manual and Mechanical

10.1 There are two types of handling hazard element, manual and mechanical. The manual handling test should be used for single containers, smaller packages, and any shipping container that can be handled manually, up to a weight of 200 lb (90.7 kg). Mechanical handling should be used for unitized loads, large cases and crates, and any shipping container or system that will be handled by mechanical means. Manual and mechanical handling are described further in 10.2 and 10.3.

10.2 *Manual Handling*—The test levels and the test method for this schedule of the distribution cycle are intended to determine the ability of the shipping unit to withstand the hazards occurring during manual handlings, such as loading, unloading, stacking, sorting, or palletizing. The main hazards from these operations are the impacts caused by dropping or throwing. Size, weight, and shape of the shipping unit will affect the intensity of these hazards. Several test method options are permitted, including free fall and simulated drop test using shock machines. While these test methods produce similar results, the shock machine method produces more control of orientations of impact; see Test Method D5487 for limitations of the shock machine method.

10.2.1 For long narrow packages that are mechanically sorted, another hazard to be simulated is bridge impact (10.2.4).

10.2.2 Mechanical handling (10.3) may be used when it is anticipated that handling will be by mechanical means only.

10.2.3 For the free-fall and shock machine tests, recommended drop heights, the number of drops, the sequence of drops, and the shipping unit orientation at impact are as follows:

Test Methods—D5276, D5487.

Conditioning—See Section 6.

Shipping Weight, lb (kg)	Drop Height, in. (mm) Assurance Level		
	I	II	III
0 to 20 (0 to 9.1)	24 (610)	15 (381)	9 (229)
20 to 40 (9.1 to 18.1)	21 (533)	13 (330)	8 (203)
40 to 60 (18.1 to 27.2)	18 (457)	12 (305)	7 (178)
60 to 80 (27.2 to 36.3)	15 (381)	10 (254)	6 (152)
80 to 100 (36.3 to 45.4)	12 (305)	9 (229)	5 (127)
100 to 200 (45.4 to 90.7)	10 (254)	7 (178)	4 (102)

Number of Impacts at Specified Height	Impact Orientation First Sequence of Distribution Cycle		
	Box	Bag or Sack	Cylindrical Container
One	top	face	top
Two	adjacent bottom edges	two sides	two sides 90° apart
Two	diagonally opposite bottom corners	both ends	bottom edges 90° apart
One	bottom	opposite face	bottom

Number of Impacts at Specified Height	Impact Orientation Second Sequence of Distribution Cycle		
	Box	Bag or Sack	Cylindrical Container
One	vertical edge	face	top
Two	adjacent side faces	two sides	two sides 90° apart
Two	one top corner and one adjacent top edge	both ends	bottom edges 90° apart
One	see Note 1	see Note 1	see Note 1

NOTE 1—On the last impact of the last manual handling sequence in a distribution cycle, the impact should be made at *twice* the specified height or equivalent velocity change. (This is the final (sixth) drop in the sequence, not an additional drop.) The drop should be in the impact orientation most likely for a drop to occur, usually the largest face or the bottom. For distribution cycles where any drop orientation is possible (that is, shipments by means of carriers that mechanically sort packages), this drop should be in the most critical or damage-prone orientation, as defined in Test Method D5276.

NOTE 2—The equivalent velocity change corresponding to the specified drop height used for the shock machine method shall be calculated as specified in Test Method D5487.

10.2.4 *Bridge Impact Test:*

Test Method—D5265.

Conditioning—See Section 6.

10.2.4.1 Conduct bridge impacts on long, narrow shipping units which have a length of at least 36 in. (915 mm) and each of the other two dimensions are 20 % or less of the longest dimension.

10.2.4.2 These tests are required only once in any test schedule sequence.

10.3 *Mechanical Handling*—The test levels and the test method for this schedule of the distribution cycle are intended to determine the ability of large and heavy shipping units, single packages with pallet or skid, and unitized loads to withstand the mechanical handling hazards that occur during loading, unloading, sorting, or stacking. For large shipping cases and crates and any single package with pallet or skid, different test methods are used versus unit loads. For various types of unit loads, test methods also vary, depending on the method of truck handling: fork, clamp, spade, or pull/pack.

10.3.1 *Large Shipping Cases and Crates and Single Packages with Pallet or Skid*—Perform the following test sequences:

Test Methods—D6179, D880, D4003.

Conditioning—See Section 6.

10.3.1.1 *Fork Lift Truck Handling*—One rotational flat drop from each opposite base edge in accordance with Method C of Test Methods D6179 and one rotational drop on each of two diagonally opposite base corners in accordance with Method B of Test Methods D6179.

Gross Weight, lb (kg)	Drop Height, in. (mm) Assurance Level I	II	III
0 to 500 (0 to 226.8)	12 (305)	9 (229)	6 (152)
Over 500 (226.8)	9 (229)	6 (152)	3 (076)

10.3.1.2 *Crane Handling*—(Conduct this test only if cranes are used for handling in the distribution process.) One drop flat on bottom and one drop on base edge in accordance with Method D of Test Methods D6179. Use the same drop heights versus shipping unit weight as in 10.3.1.1.

10.3.1.3 *Side Impact Test*—Impact all four sides of the shipping unit in accordance with Test Method D880, Procedure B. Alternately, use Test Method D4003 Method B using a short duration programmer, assuming the coefficient of restitution is 0.0 and the total velocity change is equivalent to the specified impact velocity.

Assurance Level	Impact Velocity ft/s (m/s)
I	5.75 (1.75)
II	4.0 (1.22)
III	3.0 (0.91)

10.3.1.4 *Tip Test*—In accordance with Method F of Test Methods D6179.

10.3.1.5 *Tipover Test*—In accordance with Method G of Test Methods D6179 if shipping unit fails Tip Test above.

10.3.2 *Unitized Loads*—Perform the following tests sequences as appropriate for the method of truck handling:

Test Methods—D880, D4003, D6055, D6179.

Conditioning—See Section 6.

10.3.2.1 *All Methods of Truck Handling*—Pick up, transport around test course, and set down in accordance with Test Methods D6055, Method A for fork lift, Method B for spade lift, Method C for clamp, and Method D for pull pack.

Assurance Level	Cycles (Round Trips)
I	8
II	5
III	3

(1) For shipments by means of less-than-truckload (LTL), simulate transfer terminal handling by performing fork lift truck transport over a floor hazard described as follows: a modified nominal 2 by 6 in. board with one edge beveled full height at 45° (see Fig. 1) shall be placed on the course in a position where both lift truck wheels on one side must pass over it during each handling sequence, and a second modified nominal 2 by 6 in. board shall be placed on the course after the 90° turn in such a position that both lift truck wheels on the opposite side must pass over it during each handling sequence.

10.3.2.2 *All Methods of Truck Handling*—Impact all four sides of the shipping unit in accordance with Test Method

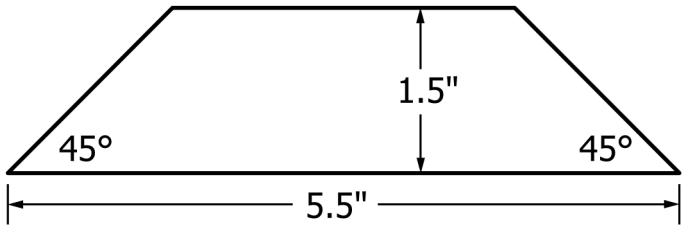

FIG. 1 Floor Hazard

D880 Procedure B. Alternately, use Test Method D4003, Method B using a short duration programmer, assuming the coefficient of restitution is 0.0 and the total velocity change is equivalent to the specified impact velocity.

Assurance Level	Impact Velocity ft/s (m/s)
I	5.75 (1.75)
II	4.0 (1.22)
III	3.0 (0.91)

10.3.2.3 *Fork Lift Truck Handling*—One rotational flat drop from each opposite base edge in accordance with Method C of Test Methods D6179.

	Drop Height, in. (mm) Assurance Level		
Gross Weight, lb (kg)	I	II	III
0 to 500 (0 to 226.8)	12 (305)	9 (229)	6 (152)
Over 500 (226.8)	9 (229)	6 (152)	3 (76)

11. Schedule B—Warehouse Stacking and Schedule C—Vehicle Stacking

11.1 The test levels and the test methods for these schedules of a distribution cycle are intended to determine the ability of the shipping unit to withstand the compressive loads that occur during warehouse storage or vehicle transport. The required loading must consider the effects of length of time in storage, the alignment or stacking pattern of the container, variability in container strength, moisture content, temperature, previous handling and transportation, method of load support, and vibration. The minimum required loads for typical shipping units which include the combined effects of the above factors are recommended below for Schedule B—Warehouse Stacking and Schedule C—Vehicle Stacking (select test levels for either warehouse or vehicle stacking as defined in the distribution cycle):

Test Method—D642.

11.2 Use the following test levels:

	F Factors Assurance Level					
	Schedule B—Warehouse			Schedule C—Vehicle		
Shipping Unit Construction	I	II	III	I	II	III
1. Corrugated, fiberboard, or plastic container that may or may not have load–bearing interior packaging using these materials, and where the product does not support any of the load.	8.0	4.5	3.0	10.0	7.0	5.0
2. Corrugated, fiberboard, or plastic container that has load-bearing interior packaging with inserts that are not temperature or humidity sensitive.	4.5	3.0	2.0	6.0	4.5	3.0
3. Containers constructed of materials other than corrugated, fiberboard, or plastic that are not temperature or humidity sensitive or where the product supports the load directly, for example, compression package.	3.0	2.0	1.5	4.0	3.0	2.0

NOTE 3—If shipping unit construction is unknown, default to the shipping unit construction Type 1 Factors.

If a full pallet load is tested, F factors may be reduced by 30 %. If testing unit loads on a pallet F factor is reduced by 30 %.

11.3 For warehouse stacking and vehicle stacking made up of identical shipping units, load the shipping unit to the computed load value, as calculated below. Remove the load within 3 s after reaching the specified value.

$$L = M \times J \frac{H - h}{h} \times F \quad (1)$$

where:

L = computed load, lbf or N,
M = mass of one shipping unit or individual container, lb or kg,
J = 1 lbf/lb or 9.8 N/kg,
H = maximum height of stack in storage or transit vehicle (if vehicle stack height is unknown, use 108 in. (2.7 m)), in. or m,
h = height of shipping unit or individual container, in. or m, and
F = a factor to account for the combined effect of the individual factors described above.

11.4 For vehicle stacking made up of mixed commodities and shipped in an LTL or small package delivery environment, load the shipping unit to the computed load value, as calculated below. Remove the load within 3 s after reaching the specified value.

$$L = M_f \times J \frac{l \times w \times h}{K} \times \frac{H - h}{h} \times F \quad (2)$$

where:

L = computed load, lbf or N,
M_f = shipping (freight) density factor, lb/ft^3 or kg/m^3,
J = 1 lbf/lb or 9.8 N/kg,
H = maximum height of stack in transit vehicle (if vehicle stack height is unknown, use 108 in. (2.7 m)), in. or m, see 11.4.2,
h = height of shipping unit or individual container, in. or m,
l = length of shipping unit or individual container, in. or m,
w = width of shipping unit or individual container, in. or m,
K = 1728 in.^{3}/ft^3 or 1 m^3/m^3, and
F = a factor to account for the combined effect of the individual factors described above.

11.4.1 Typical shipping density (freight) factors for mixed load and LTL shipments are from 10 lb/ft^3 (160 kg/m^3), which represents the 40th percentile to 30 lb/ft^3 (481 kg/m^3), which represents the 95th percentile of measured top load packages. If the average shipping (freight) density factor (M_f) for the specific distribution system is not known, a value of 12.0 lb/ft^3 (192.2 kg/m^3) is recommended (**14**, **15**).

11.4.2 The recommended maximum stack height (H) factor when unknown is defaulted to the maximum height of stack in transit vehicle value of 108 in. (2.7 m). If the transit vehicle height throughout logistic system is known, use the interior height of the transit vehicle in lieu of the maximum stack height of 108 in. (2.7 m).

The H factor may be reduced to 54 in. (1.4 m) if the package is considered to be small and lightweight (refer to Section 3). In these instances, it is assumed that the package will be placed in the upper half of the stack. This assumption should be carefully considered. This does not apply to unit loads of small and light packages.

See Maximum Stack Height (H) Decision Matrix below (Fig. 2):

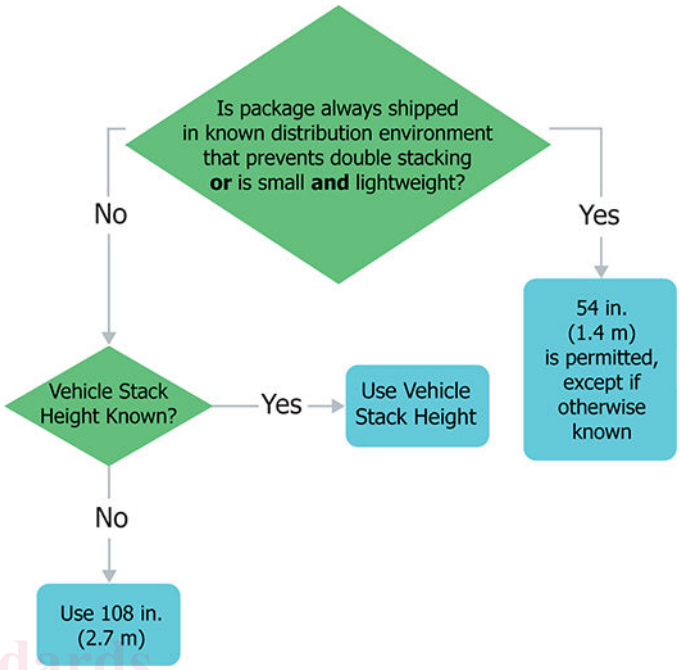

FIG. 2 Maximum Stack Height (H) Decision Matrix

12. Schedule D—Stacked Vibration and Schedule E—Vehicle Vibration

12.1 The test levels and test methods for these distribution cycles are intended to determine the shipping unit's ability to withstand the vertical vibration environment during transport and the dynamic compression forces resulting from vehicle stacking. The test levels and methods account for the magnitude, frequency range, duration and direction of vibration. Select the Schedule D—Stacked Vibration or Schedule E—Vehicle Vibration (no stacking) test as defined by the distribution cycle. Test methods for sine and random vibration are permitted testing options. The two methods are not equivalent and will not necessarily produce the same results. The random test method results is a better simulation of actual transport vibration environments, and is the preferred method for qualification. The sine test method is often used as a means of determining and observing system resonances and can be used in conjunction with the random method.

12.2 *Schedule D—Stacked Vibration*—Perform the test along the vertical axis with the load in the normal shipping orientation or with the predetermined bottom orientation (as specified in DC-3) facing down. It is permissible to use a compressive dead load to simulate an upper unit load or mixed commodities.

12.2.1 The compressive load may be calculated from the formulas in 11.3 and 11.4, with the F factor set equal to 1 for both 11.3 and 11.4. The M_f factor for 11.4 is set equal to

12 lb/ft^3 (192.2 kg/m^3). Recommended intensities and durations for the random tests are given in 12.4, and those for sine tests are given in 12.5.

12.2.1.1 If user has knowledge of the specific shipping (freight) density factor (M_f) utilized for a known distribution system, use this value instead of default of 12.0 lb/ft^3 (192.2 kg/m^3) to derive appropriate shipping (freight) density factor (M_f).

12.3 *Schedule E—Vehicle Vibration*—Perform the test for each possible shipping orientation (up to three axes). Recommended intensities and durations for the random tests are given in 12.4, and those for sine tests are given in 12.5.

12.4 *Random Test Option:*

Test Method—D4728.

Conditioning—See Section 6.

12.4.1 The power spectral densities in Tables 2-4, as defined by their mode of transport, frequency and amplitude breakpoints, and test durations are recommended.

12.4.1.1 Conducting the Truck Profile test is recommended for Distribution Cycles 1, 3, 4, 5 and 6.

12.4.1.2 Conducting the Rail Profile test is recommended for Distribution Cycles 7, 8 and 11.

12.4.1.3 A 60 min test using the Truck Profile followed by a 120 min test using the Rail Profile is recommended for Distribution Cycles 9 and 10.

12.4.1.4 A 60 min test using the Truck Profile followed by a 120 min test using the Air Profile is recommended for Distribution Cycles 12 and 13.

TABLE 2 TRUCK—Power Spectral Density Levels

Frequency	Power Spectral Density Level, G^2/Hz		
	High Level	Medium Level	Low Level
1	0.00072	0.00072	0.0004
3	0.030	0.018	0.010
4	0.030	0.018	0.010
6	0.0012	0.00072	0.00040
12	0.0012	0.00072	0.00040
16	0.0060	0.0036	0.0020
25	0.0060	0.0036	0.0020
30	0.0012	0.00072	0.00040
40	0.0060	0.0036	0.0020
80	0.0060	0.0036	0.0020
100	0.00060	0.00036	0.00020
200	0.000030	0.000018	0.000010
Overall G_{rms}	0.70	0.54	0.40

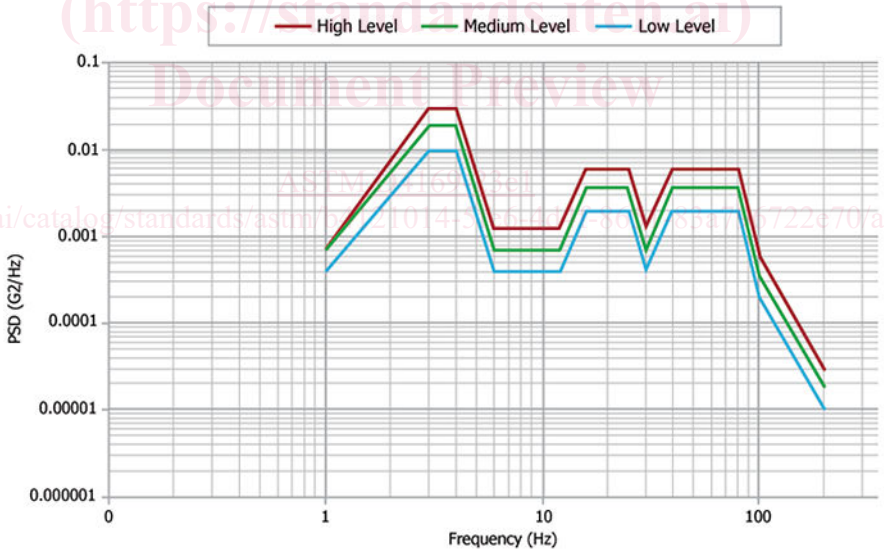

TABLE 3 RAIL—Power Spectral Density Levels

Frequency	Power Spectral Density Level G^2/Hz		
	Assurance Level		
	I	II	III
1	0.00002	0.00001	0.000005
2	0.002	0.001	0.0005
50	0.002	0.001	0.0005
90	0.0008	0.0004	0.0002
200	0.00002	0.00001	0.000005
Overall G_{rms}	0.41	0.29	0.2