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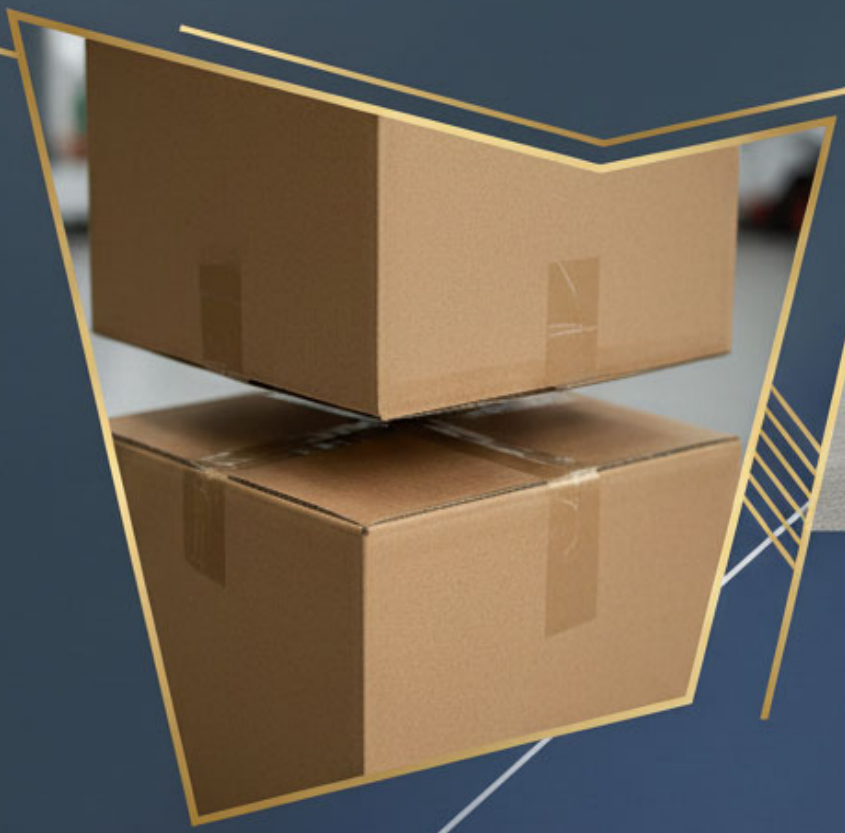

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Designation: D 4169 – 01$^{\epsilon 1}$

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

This standard is issued under the fixed designation D 4169; 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 Department of Defense.

ε[1] NOTE—Editorial corrections were made to metric conversions in March 2002.

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

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.* Specific precautionary statements are given in 1.1.

2. Referenced Documents

2.1 *ASTM Standards:*

D 642 Test Method for Determining Compressive Resistance of Shipping Containers, Components, and Unit Loads [2]

D 880 Test Method for Impact Testing for Shipping Containers and Systems [2]

D 951 Test Method for Water Resistance of Shipping Containers by Spray Method [2]

D 996 Terminology of Packaging and Distribution Environments [2]

D 999 Test Methods for Vibration Testing of Shipping Containers [2]

D 4003 Methods of Programmable Horizontal Impact Test for Shipping Containers [2]

D 4332 Practice for Conditioning Containers, Packages, or Packaging Components for Testing [2]

D 4728 Test Method for Random Vibration Testing of Shipping Containers [2]

D 5276 Test Method for Drop Test of Loaded Containers by Free Fall [2]

D 5277 Test Method for Performing Programmed Horizontal Impacts Using an Inclined Tester [2]

D 5487 Test Method for Simulated Drop of Loaded Containers by Shock Machines [2]

D 6055 Test Methods for Mechanical Handling of Unitized Loads and Large Shipping Cases and Crates [2]

D 6179 Test Methods for Rough Handling of Unitized Loads and Large Shipping Cases and Crates [2]

2.2 *Military Standards:* [3]

MIL-STD-2073-1 DOD Standard Practice for Military Packaging

3. Terminology

3.1 *Definitions* — General definitions for the packaging and distribution environments are found in Terminology D 996.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acceptance criteria*—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*—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*—the ratio of the rebound velocity to the impact velocity.

3.2.4 *distribution cycle (DC)*—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 *hazard element*—a specific event that occurs in a distribution cycle that may pose a hazard to a shipping unit.

[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] *Annual Book of ASTM Standards*, Vol 15.09.

[3] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

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TABLE 1 Distribution Cycles

DC	Distribution Cycle	Performance Test Schedule Sequence (see Section 9 for Test Schedule definition)					
		First	Second	Third	Fourth	Fifth	Sixth
1	General Cycle—undefined distribution system	Schedule A Handling	Schedule D Stacked Vibration	Schedule F Loose-Load Vibration	Schedule G Rail Switching	Schedule A Handling	
2	Specially controlled environment, user specified	select from Schedules A through H					
3	Single package environment, up to 100 lb (45.4 kg)	Schedule A Handling	Schedule C Vehicle Stacking	Schedule F Loose-Load Vibration	Schedule E Vehicle Vibration	Schedule A Handling	. . .
4	Motor freight, single package over 100 lb (45.4 kg)	Schedule A Handling	Schedule C Vehicle Stacking	Schedule F Loose-Load Vibration	Schedule E Vehicle Vibration	Schedule A Handling	. . .
5	Motor freight, TL, not unitized	Schedule A Handling	Schedule D Stacked Vibration	Schedule E Vehicle Vibration	Schedule A Handling	. . .	. . .
6	Motor freight, TL, or LTL—unitized	Schedule A Handling	Schedule D Stacked Vibration	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 A Handling
10	Rail and motor freight, unitized	Schedule A Handling	Schedule D Stacked Vibration	Schedule G Rail Switching	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 100 lb (45.4 kg), unitized	Schedule A Handling	Schedule D Stacked Vibration	Schedule E Vehicle Vibration	Schedule A Handling	. . .	. . .
13	Air (intercity) and motor freight (local, single package up to 100 lb (45.4 kg)	Schedule A Handling	Schedule C Vehicle Stacking	Schedule F Loose-Load Vibration	Schedule E Vehicle Vibration	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	. . .	. . .	. . .
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 per MIL-STD-2073-1	Schedule A Handling	Schedule B or Schedule C[A]	Schedule A Handling	Schedule H Environmental Hazard	Schedule F Loose-Load Vibration	Schedule A Handling

[A] For DC-18, perform the stacking test that results in the highest computed load value.

The element will usually be simulated by a single test schedule. See Section 9.

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

3.2.6.1 *small shipping unit*—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 150 lb (68 kg) or less.

3.2.6.2 *large shipping unit*—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 150 lb (68 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.

3.2.7 *test plan*—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.

3.2.8 *test schedule*—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.

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

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

3.3 *Abbreviations: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)**.[4] 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.

[4] The boldface numbers in parentheses refer to a list of references at the end of this practice.

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 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 $\pm$ 2°F (23 $\pm$ 1°C) and 50 $\pm$ 2 % relative humidity. Condition fiberboard containers in accordance with Practice D 4332. 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 atmospohere 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 D 4332, or Test Method D 951, or others (salt, spray, water immersion, humidity, or temperature). The same climatic 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 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.

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 3.2.6. 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 16.

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.

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 16.

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. Test Schedules

9.1 Test Schedules are categorized as follows:

Schedule	Test Schedule	Hazard Element	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

10. Schedule A–Handling–Manual and Mechanical

10.1 There are two types of handling hazard, manual and mechanical. The manual handling test should be used for single containers, small parcels, 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. Two test method options are permitted, free fall and simulated drop test using shock machines. While the two methods produce similar results, the shock machine method produces more control of orientations of impact; see Test Method D 5487 for limitations of the shock machine method.

10.2.1 For purposes of this procedure, the bottom of a small parcel is the surface on which the parcel rests in its most stable orientation.

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 Recommended drop heights, the number of drops, the sequence of drops, and the shipping unit orientation at impact are as follows:

Test Method D 5276, D 5487.

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, small–parcel environment), this drop should be in the most critical or damage–prone orientation, as defined in Test Method D 5276.

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 D 5487.

10.2.4 *DC-18* —Description of this schedule is in accordance with 10.2.3, except that the height of the last impact of the last manual handling sequence is the same as all other impacts (ignore Note 1). Use the first sequence impact orientations for the third handling schedule in DC–18. Use Mechanical Handling (10.3) for large shipping units (see 3.2.6.2). Test small shipping units (see 3.2.6.1) using the following test levels:

Shipping Weight, lb (kg)	Drop Height, in. (mm) Assurance Level I	II
0 to 30 (0 to 13.6)	30 (762)	24 (610)
over 30 to 75 (to 34)	24 (610)	18 (457)
over 75 to 150 (to 68)	18 (457)	15 (381)

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 and unitized loads to withstand the mechanical handling hazards that occur during loading, unloading, sorting, or stacking. Different test methods are used for large shipping cases and crates 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* —Perform the following test sequences:

Test Method —D 6179, D 880, D 4003.

Conditioning —See Section 6.

10.3.1.1 *Fork Lift Truck Handling* —One drop on each opposite base edge in accordance with Method C of Test Methods D 6179 and one drop on each of two opposite base corners in accordance with Method B of Test Methods D 6179.

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* — One drop flat on bottom and one drop on base edge in accordance with Method D of Test Methods D 6179. 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 D 880, Procedure B. Alternately, use Test Method D 4003 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 D 6179.

10.3.1.5 *Tipover Test*— In accordance with Method G of Test Methods D 6179.

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

Test Method —D 880, D 4003, D 6055, D 6179.

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 6055, 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

10.3.2.2 *All Methods of Truck Handling* —Impact all four sides of the shipping unit in accordance with Test Method D 880 Procedure B. Alternately, use Test Method D 4003 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 drop on each opposite base edge in accordance with Method C of Test Methods D 6179.

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 (76)

10.3.3 *DC–18* — For large shipping units, this schedule is intended to provide a number of testing variations describing specific mechanical handling hazards that occur in government distribution for shipping cases, crates, unitized loads, and cylindrical containers. Required tests for rectangular shipping units include: tip/tipover; fork lift truck transport; rotational drops, both edgewise and cornerwise; and lateral impacts. For Assurance Level I, shipping cases and crates and unitized loads shall also be subjected to sling handling, and shipping cases and crates shall be subjected to grabhook handling. For cylindrical shipping units, only rotational edgewise drop tests shall apply. Table 2 shall be used as a guide in determining both the required tests and the sequence to be followed.

10.3.3.1 Tests specific to government shipments include the following:

(1) Shipping Cases, Crates, and Unitized Loads–Tip/Tipover —Shipping cases and crates shall be subjected to both tip and tipover tests for Assurance Level I, following the requirements of Test Method D 6179 Methods F and G. For unitized loads, only the tip test will be required. The tip test shall be performed for Assurance Level II for all rectangular shipping units. Tip/tipover requirements shall only be required during the first handling sequence of DC–18. The tip test is useful for determining acceptable shipping unit dimension and center of gravity. For tipover, one impact is required on each of two opposite sides, as determined by the initial side having the lowest height–to–width ratio.

(2) Shipping Cases, Crates, and Unitized Loads—Fork Lift Truck Transport Pick up, transport around test course as defined in Test Methods D 6055 Method A, for a total of two cycles (round trips) in the case of Assurance Level I, and one cycle for Assurance Level II. Within the minimum 100 ft (30.5 m) obstacle zone, parallel pairs of 1 by 6 in. (25 by 150 mm) boards, of a length to extend completely across the aisle and spaced 54 in. (1.37 m) apart, are laid flat at intervals of 30, 60, and 90 ft (9.1, 18.3, and 27.4 m). Board angles to the truck's path shall be 90, 60, and 75 degrees respectively, with the left wheel striking first over the second obstacle (board pairs) and the right wheel first over the third.

(3) Shipping Cases, Crates, Unitized Loads and Cylindrical Containers–Rotational Drops —For edge drops, use Method A of Test Methods D 6179 with a 6 in. (150 mm) height timber edge support. In the case of rectangular shipping units, drops are made on each opposite edge of the unit's base, for a total of four impacts. For cylindrical shipping units, drops shall be made with the unit on its side, such that impacts occur on top and bottom rims at diagonally opposite quadrants. Care must be taken to prevent the container from rolling on the support. Additional impacts shall be made in the same manner in different quadrants separated by an approximate 90°, for a total of four drops. For corner drops, use Method B of Test Methods D 6179, except that one corner of the shipping unit base shall be supported on a 6 in. (150 mm) height block while the other corner on the same end or side rests on a 12 in. (300 mm) height block. Each corner will be impacted, for a total of four drops. Both edgewise and cornerwise drops shall be performed on large rectangular shipping units. For all rotational drops, test with the lowest drop height indicated by either gross weight or maximum dimension, using the following test levels:

Gross Weight, lb (kg) or Maximum Dimension, in (mm)	Drop Height, in. (mm) Assurance Level I	II
over 150 to 250 (68 to 113) or over 60 to 66 (1524 to 1676)	30 (762)	24 (610)
over 250 to 500 (to 227) or over 66 to 78 (to 1981)	24 (610)	18 (457)
over 500 to 1000 (to 454) or over 78 to 90 (to 2286)	18 (457)	12 (305)
over 1000 (over 454) or over 90 (2286)	12 (305)	9 (229)

(4) Shipping Cases, Crates, and Unitized Loads–Lateral Impacts —Note that this test is to be performed only during the second handling sequence of Distribution Cycle 18. Testing shall be in accordance with Test Method D 880, Procedure B. Alternately, testing may be in accordance with Test Method D 4003, 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. Selection of apparatus, as defined within these test methods, shall also be at the option of the package designer/contractor. As a requirement for Assurance Level I, the impact velocity shall be 7.3 ft/s(2.23 m/s). One lateral impact shall be performed on each side (including ends) surface having a dimension less than 9.5 ft (2.9 m). A 4 by 4 in. (100 by 100 mm) timber, placed so as to contact the lower edge of the shipping unit, shall be used as an impacting hazard when evaluating unitized loads and demountable shipping cases.

(5) Shipping Cases, Crates, and Unitized Loads–Grabhook/Sling Handling —Test shipping cases and crates for grabhook handling, in accordance with Method E of Test Methods

TABLE 2 Mechanical Handling for DC–18, Required Tests and Sequence

Large Shipping Unit	Assurance Level[A]	Tip[B]	Tipover[B]	Forklift Transport	Rotational Drops		Lateral Impacts[C]	Grabhook Handling[D]	Sling Handling[D]
					Edge	Corner			
Shipping Cases & Crates	I	X	X	2 cycles	X	X	X	X	X
	II	X	-	1 cycle	X	X	-	-	-
Unitized Loads	I	X	-	2 cycles	X	X	X	-	X
	II	X	-	1 cycle	X	X	-	-	-
Cylindrical	I	-	-	-	X	-	-	-	-
	II	-	-	-	X	-	-	-	-

[A] As referenced in 3.2.2, Assurance Levels I and II equate to military levels of protection A and B, respectively.
[B] Test to be performed only during the first handling sequence of DC-18.
[C] Test to be performed only during the second handling sequence of DC-18.
[D] Test to be performed only during the third handling sequence of DC-18.

D 6055, only for Assurance Level I. Test shipping cases, crates, and unitized loads for sling handling, per Method F of Test Methods D 6055, only for Assurance Level I. Note that this test is performed only during the third handling sequence of DC–18.

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 D 642.

Conditioning—73.4 ± 2°F (23 ± 1°C), 50 ± 2 % relative humidity in accordance with Practice D 4332.

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 stress–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 stress-bearing interior packaging with rigid inserts such as wood.	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
4. If the product supports a known portion of the load, the F factor is calculated in the following manner:						

$$F = P(F_p + C(F_c \quad (1)$$

where:

F_p = factor given above for compression package (construction Type 3),
P = percent of load supported by product,
F_c = factor given above for appropriate container construction, and
C = percentage of load supported by container.

If a full pallet load is tested, F factors may be 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.

$$L = M \times J \frac{H - h}{h} \times F \quad (2)$$

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. If the average shipping density factor (M_f) for the specific distribution system is not known, use a value of 10 lb/ft^3 (160 kg/m^3).

$$L = M_f \times J \frac{l \times w \times h}{K} \times \frac{H - h}{h} \times F \quad (3)$$

where:

L = computed load, lbf or N,
M_f = shipping density factor, lb/ft^3 or kg/m3,
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 Note 3,
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.

NOTE 3—The value for H, when unknown, is reduced to 54 in.(1.4 m) from 108 in.(2.7 m) for packages under 30 lb(13.6 kg) and 2.0 ft^3(0.056 m^3) or less in size when applied to a vehicle stacking hazard in LTL shipments.

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

12.1 The test levels and test methods for these schedules of the distribution cycle are intended to determine the ability of shipping units 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 a Schedule D–stacked vibration or Schedule E–vehicle vibration (no stacking) test as defined by the distribution cycle. Two test method options are permitted, sine and random. The two methods are not equivalent; they will not necessarily produce the same results. The random test method results in a better simulation of actual transport vibration environments, and is the preferred method for qualification. The sine test method is often used in conjunction with the

random method as a means of determining and observing system resonances.

12.2 *Schedule D–Stacked Vibration* —Perform the test along the vertical axis with the load in the normal shipping orientation. It is permissible to use a concentrated dead load to simulate an upper unit load or mixed commodities. The concentrated load may be calculated from the formulas in 11.3 and 11.4, with the *F* factor set equal to 1. Recommended intensities and durations for the random tests are given in 12.4, and those for sine tests are given in 12.5

12.3 *Schedule E-Vehicle Vibration* —Perform the test for each possible shipping orientation. 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 D 4728, Method A or B.[A]
Conditioning —See Section 6.
Special Instructions—The following power spectral densities, as defined by their mode of transport, frequency and amplitude breakpoints, and test durations are recommended. The Truck test is recommended for Distribution Cycles 1, 3, 4, 5 and 6. The Rail test is recommended for Distribution Cycles 7, 8 and 11. A 60 min Truck test followed by a 120 min Rail test is recommended for Distribution Cycles 9 and 10. A 60 min Truck test followed by a 120 min Air test is recommended for Distribution Cycles 12 and 13.

Truck:

	Power Spectral Density Level, g^2/Hz		
	Assurance Level	Assurance Level	Assurance Level
Frequency, Hz	I	II	III
1	0.0001	0.00005	0.000025
4	0.02	0.01	0.005
16	0.02	0.01	0.005
40	0.002	0.001	0.0005
80	0.002	0.001	0.0005
200	0.00002	0.00001	0.000005
Overall, g rms	0.73	0.52	0.37
Duration, min[B]	180	180	180

Rail:

	Power Spectral Density Level, g^2/Hz		
	Assurance Level	Assurance Level	Assurance Level
Frequency, Hz	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	0.20
Duration, min[B]	180	180	180

Air:

	Power Spectral Density Level, g^2/Hz		
	Assurance Level	Assurance Level	Assurance Level
Frequency, Hz	I	II	III
2	0.0004	0.0002	0.0001
12	0.02	0.01	0.005
100	0.02	0.01	0.005
300	0.00002	0.00001	0.000005
Overall, g rms	1.49	1.05	0.74
Duration, min[B]	180	180	180

[A] If Method B is used, the drive signal must be equalized for the specific shaker and shipping unit dynamics per Test Method D 4728, Section 8.

[B] For vehicle vibration tests in multiple shipping unit orientations, the total duration should be distributed evenly between the orientations tested.

12.4.1 If more detailed information is available on the transport vibration environment or the damage history of the shipping unit, it is recommended that the above procedure be modified to use such information. The average test time required to reproduce shipping damage is dependent on the mode of failure, as well as the vibration level. Some over-stress and abrasion modes of failure will occur in much less than 3 h, while some fatigue failure modes may require more than 3 h to occur. Test durations ranging from 30 min to 6 h have been used successfully for different product or package types. The recommended 180–min duration is reasonable in the absence of specific shipping or testing experience.

12.5 *Sine Test Option* :

Test Methods D 999, Method B or C.

Conditioning —See Section 6.

Special Instructions —Dwell time is for each noted product or package resonance up to four discrete resonances. If more than four resonances are noted, test at the four frequencies where the greatest response is noted. In frequency sweeps it is advisable to consider the frequency ranges normally encountered in the type of transportation being considered. The resonant frequency(ies) may shift during test due to changing characteristics of the container system. It is suggested that the dwell frequency be varied slightly during the test to detect any shift and to continue testing at the frequency of maximum response. Use the following test levels:

Assurance Level	Frequency Range, Hz	Amplitude (O-Peak), g		Dwell Time, min
		Rail	Truck	
I	3 to 100	0.25	0.5	15
II	3 to 100	0.25	0.5	10
III	3 to 100	0.25	0.5	5

13. Schedule F - Loose Load Vibration

13.1 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 repetitive shocks occurring during transportation of bulk or loose loads. The test levels and test method account for amplitude, direction, and duration of the repetitive shocks.

13.2 Use the following test levels:

Test Method —D 999, Method A1 or A2.

Conditioning —See Section 6.

Special Instructions —Dwell time distributed 50 % along normal vertical shipping axis and remaining 50 % evenly along all other possible shipping orientations

Assurance Level	Dwell Time, min
I	60
II	40
III	30

13.3 *DC-18* —Description of this schedule is in accordance with 13.2, except that total dwell time for Assurance Levels I and II shall be 2 h if tested in one position, and 3 h if tested in more than one position.

14. Schedule G - Simulated Rail Switching

14.1 The test levels and test methods for this schedule are intended to determine the ability of the shipping unit to withstand the acceleration levels and compressive forces that might occur during rail switching operations.

Test Method D 4003, Test Method A or Test Method D 5277.

Conditioning—See Section 6.

Special Instructions —Three impacts shall be performed. For railcars with standard draft gear, shock durations of 40 ± 10 ms shall be used, as measured on the floor of the carriage. For railcars with long–travel draft gear, shock durations of 300 ± 50 ms shall be used.

Note that Test Method D 5277 is used for standard draft gear only.

For purposes of this test, the coefficient of restitution shall be considered 0.0, and the total velocity change shall be equivalent to the specified impact velocity. Container impact surface should be the same as occurs in actual shipment. If more than one orientation is possible, impact that surface which is known to be most sensitive to damage.

Refer to Test Methods D 4003 or D 5277 for specific instructions on how to instrument and conduct the test.

14.2 *Procedure* —Load shipping unit on carriage against bulkhead. Total backload shall be equivalent to a minimum of 3 ft lineal (0.9 m) of cargo. The package used as backload in contact with the test package must be identical to the test package.

14.3 *Test Levels* — Allow the carriage to impact a cushioned barrier in accordance with the following assurance levels:

Assurance Level	Number of Impacts	Impact Velocity mph	(m/s)
I	2	8	(3.58)
	1	6	(2.68)
II	2	6	(2.68)
	1	4	(1.79)
III	1	6	(2.68)
	2	4	(1.79)

14.4 *Procedure Modification* —If more detailed information is available on backload or shock characteristics it is recommended that the above procedure be modified to use such information. The specified backload and shock characteristic are intended to simulate the conditions that occur on rail cars equipped with standard type draft gear.

15. Schedule H - Environmental Hazard

15.1 This schedule is intended to provide for the anticipated and often rapid changes in ambient conditions associated with the military distribution of material. This hazard schedule determines the susceptibility of the total pack to the effects of moisture, temperature shock, or the combined effects of cyclic exposure. The result of conditioning may involve the observation/measurement of moisture or water within packs, evidence of corrosion on packaged items, or compromise of the enclosure's structural integrity such that physical protection can no longer be ensured. Testing shall be in accordance with Test Method D 951, where spray intensities of 4 + 1 in/h(100+25 mm/h) are used for Assurance Level I and 2 + 0.5 in/h(50 + 10 mm/h) for Level II.

15.2 Test levels shall be as follows:

Assurance Level	Temperature, °F (°C)	Water Spray	Duration, h
I	120 to 130 (49 to 54)		16
	50 to 60 (10 to 15)	X	2
	–10 to 0 (–23 to –18)		2
	120 to 130 (49 to 54)	X	2
	50 to 60 (10 to 15)	X	2
	35 to 50 (2 to 10)		16
	120 to 130 (49 to 54)		4
	50 to 60 (10 to 15)	X	2
	35 to 50 (2 to 10)		2
	120 to 130 (49 to 54)		16
	50 to 60 (10 to 15)	X	2
	–10 to 0 (–23 to –18)		2
	35 to 50 (2 to 10)		3
	120 to 130 (49 to 54)		16
II	120 to 130 (49 to 54)		16
	50 to 60 (10 to 15)	X	2
	120 to 130 (49 to 54)		4
	50 to 60 (10 to 15)	X	2
	The cyclic sequence shall be repeated on three consecutive days. At the end of the three day period, the unit pack being tested shall then set overnight		
	120 to 130 (49 to 54)		16
III	Not applicable		

15.3 When specified in the contract, this test should be performed as part of the complete distribution cycle for the smallest complete shipping unit, as part of the contract.

16. Report

16.1 Report fully all the steps taken. At a minimum, the report should include:

16.1.1 Reference to this practice,

16.1.2 Description of product and shipping unit,

16.1.3 Distribution cycle (DC) and test plan,

16.1.4 Assurance levels and rationale,

16.1.5 Number of samples tested,

16.1.6 Conditioning used,

16.1.7 Acceptance criteria,

16.1.8 Vibration option used, random or sine,

16.1.9 Random vibration power spectral density plot, if used,

16.1.10 Variation from recommended procedures, and

16.1.11 Condition of specimens after test.

16.2 *Government Shipments* —In addition to 16.1.2-16.1.11, the complete report includes:

16.2.1 Party, other than contractor, performing testing,

16.2.2 Testing facility used, other than contractor's,

16.2.3 Government representative witnessing testing, and

16.2.4 When environmental hazard is performed for other than smallest complete shipping unit (see 15.3).

17. Precision and Bias

17.1 The precision and bias of this practice are dependent on those of the various test methods used, and cannot be expressly determined.

18. Keywords

18.1 compression test; distribution cycle; distribution environment; drop test; mechanical handling; package; packaging; random vibration; shipping container; shipping unit; vibration

APPENDIX

(Nonmandatory Information)

X1. Appendix-Example Test Plans

X1.1 The following examples will serve to illustrate the use of this practice:

X1.2 *Example A*—Test a packaged consumer product. The moderate value and volume of shipment are typical of other products in the shipper's line. No damage is acceptable and the package must be in good condition after the test. The fiberboard packaged product weighs 28 lb (12.7 kg), is 9 in. (0.23 m) high, and palletized 63 in. (1.6 m) high for storage and LTL shipment. The product does not support any of the load.

X1.2.1 *Step 1, Define Shipping Unit*—Shipping unit to be tested is a typical pallet load.

X1.2.2 *Step 2, Establish Assurance Level*—Assurance Level II will be used, based on value and volume of shipment.

X1.2.3 *Step 3, Determine Acceptance Criteria* at Assurance Level II:

Criterion 1—No product damage.

Criterion 2—All packages in saleable condition.

X1.2.4 *Step 4, Select Test Schedules*—DC–6 will be used for this palletized, LTL shipment.

X1.2.5 *Step 5*, Write Test Plan:

Sequence	Test Schedule	Test Methods	Level
1	A Handling - Mechanical	D 6055 Method A	Pick up, transport around test course, set down, 5 cycles.
		D 880 Procedure B	Horizontal impact all four sides, 4.0 ft/s (1.22 m/s)
		D 6179 Method C	Rotational drop, one impact on two opposite base edges from 6 in. (0.152 m).
2	D Stacked Vibration	D 4728, Method A or B	"Truck" PSD profile, 0.52 g rms, duration 180 min. Test a column stack of seven individual containers [A]
3	A Handling - Mechanical	D 6055 Method A	Pick up, transport around test course, set down, 5 cycles.
		D 880 Procedure B	Horizontal impact all four sides, 4.0 ft/s (1.22 m/s)
		D 6179 Method C	Rotational drop, one impact on two opposite base edges from 6 in. (0.152 m).
4	B Warehouse Stacking	D 642	Compression to 756 lb (3360 N) (individual container [B] H=63 in., F=4.5).

[A] Alternative vibration test configurations, 1: test full pallet load, 2: test a single individual container with 168 lb dead weight load to simulate the pallet load.

[B] Alternative full pallet load compression test, 529 lb (2350 N) per bottom tier container.

X1.2.6 *Step 6, Select Samples for Test*—Select representative samples.

X1.2.7 *Step 7, Condition Samples*—Condition to 23 ± 1°C, 50 ± 2 % relative humidity, in accordance with Practice D 4332.

X1.2.8 *Step 8, Perform Tests*—Perform tests in accordance with the test plan in Step 5, as directed in the referenced ASTM standards and in the special instructions for each test schedule.

X1.2.9 *Step 9, Evaluate Results*—Examine products and packages to determine if the acceptance criteria have been met.

X1.2.10 *Step 10, Document Test Results*—Write a report to cover all steps in detail, in accordance with Section 16.

X1.3 *Example B*—Product to be tested is identical to the product from Example A, except that it will be shipped individually through the small parcel–surface distribution system. Additional information is that the container is 18 in. (0.46 m) long and 18 in. (0.46 m) wide. Height is 9 in. (0.23 m) and weight is 28 lb (12.7 kg).

X1.3.1 *Step 1, Define Shipping Unit*—Shipping unit to be tested is a single package.

X1.3.2 *Step 2, Establish Assurance Level*—Assurance Level II will be used, based on value and volume of shipment.

X1.3.3 *Step 3, Determine Acceptance Criteria* at Assurance Level II:

Criterion 1—No product damage.

Criterion 2—All packages in saleable condition.

X1.3.4 *Step 4, Select Test Schedules*—DC-3 will be used for this single package shipment of less than 100 lb (45.4 kg).

X1.3.5 *Step 5, Write Test Plan*:

Sequence	Test Schedule	Test Method	Level
1	A Handling—Manual	D 5276	One drop on top, two drops on adjacent bottom edges, two drops on diagonally opposite bottom corners, one drop on bottom, drop height 13 in. (330 mm).
2	C Vehicle Stacking	D 642	Compression to 589 lb (2620 N) (M_f=10.0 lb/ft^3, H=54 in., F=7.0).
3	F Loose Load Vibration	D 999, Method A1 or A2	20 min on bottom, 10 min on each of two adjacent sides.
4	E Vehicle Vibration	D 4728, Method A or B	"Truck" PSD profile, 0.52 g ms, duration 60 min on each of three adjacent sides.
5	A Handling—Manual	D 5276	One drop on vertical edge, two drops on adjacent side faces, one drop on top corner, one drop on adjacent top edge, drop height 13 in. (330 mm). One drop on bottom, drop height 26 in. (660 mm).

X1.3.6 *Step 6, Select Samples for Test*—Select representative samples.

X1.3.7 *Step 7, Condition Samples*—Condition to 23 ± 1°C, 50 ± 2 % relative humidity, in accordance with Practice D 4332.

X1.3.8 *Step 8, Perform Tests*—Perform tests in accordance with the test plan in Step 5, as directed in the referenced ASTM standards and in the special instructions for each test schedule.

X1.3.9 *Step 9, Evaluate Results*—Examine products and packages to determine if the acceptance criteria have been met.

X1.3.10 *Step 10, Document Test Results*—Write a report to cover all steps in detail, in accordance with Section 16.

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