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Standard Practice for Performance Testing of Shipping Containers and Systems¹

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 reappraisal. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reappraisal.

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

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:²

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

D 880 Test Method for Impact Testing for Shipping Containers and Systems

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

D 996 Terminology of Packaging and Distribution Environments

D 999 Test Methods for Vibration Testing of Shipping Containers

D 4003 Methods of Programmable Horizontal Impact Test for Shipping Containers and Systems

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

D 4728 Test Method for Random Vibration Testing of Shipping Containers

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

D 5277 Test Method for Performing Programmed Horizontal Impacts Using an Inclined Impact Tester

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

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

~~D 6179 Test Methods for Rough Handling of Unitized Loads and Large Shipping Cases and Crates²~~ Test Methods for Rough Handling of Unitized Loads and Large Shipping Cases and Crates

D 6653 Test Methods for Determining the Effects of High Altitude on Packaging Systems by Vacuum Method

F 1327 Terminology Relating to Barrier Materials for Medical Packaging

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

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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*, Vol 15.09, volume information, refer to the standard's Document Summary page on the ASTM website.

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

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

3.2.6 *hazard element*—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.

3.2.6

3.2.7 *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 3.2.7.1 *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 3.2.7.2 *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

3.2.8 *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

3.2.9 *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

3.2.9.1 *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

3.2.10 *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.

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.

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



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
2	Specially defined distribution system, user specified (see Appendix X2)						select from Schedules A through I
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	...	...
12	Air (intercity) and motor freight (local), over 100 lb (45.4 kg), unitized	Schedule A Handling	Schedule D Stacked Vibration	Schedule I Low Pressure ^A	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	...
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 I Low Pressure ^A	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
18	Non-Commercial Government shipments per MIL-STD-2073-1	Schedule A Handling	Schedule B or Schedule C ^B	Schedule A Handling	Schedule H Environmental Hazard	Schedule F Loose-Load Vibration	Schedule A Handling

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 $73.4 \pm 2^\circ\text{F}$ ($23 \pm 1^\circ\text{C}$) 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 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 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 4.6.17.

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.~~ and specifies the test sequence (see Appendix X2 for more details).

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 1617.

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: Hazard Elements and Test Schedules

9.1 Hazard Elements and Test Schedules are categorized as follows:

Schedule	Test Schedule	Hazard Element	Test
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

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, 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 -		
	Box	First Sequence of Distribution Cycle 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 -		
	Box	Second Sequence of Distribution Cycle 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 3-2-6-23.2.7.2). Test small shipping units (see 3-2-6-13.2.7.1) 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 rotational flat drop ~~on~~ from each opposite base edge in accordance with Method C of Test Methods D 6179 and one rotational drop on each of two diagonally 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)