



Designation: D8409 – 21

Standard Guide for Conducting Stacking Tests on UN Packagings Using Guided or Unguided Loads¹

This standard is issued under the fixed designation D8409; 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.

1. Scope

1.1 This guide is intended to provide a standardized method and a set of basic instructions for conducting stacking tests on United Nations (UN) non-bulk, intermediate bulk container (IBC), and Large Packagings. Using guided or unguided loads in accordance with the U.S. Department of Transportation Title 49 Code of Federal Regulations (CFR) and the UN Recommendations on the Transport of Dangerous Goods (“The Orange Book”). The combination or interchange of these regulations will be referred to as the Hazardous Material Regulations (HMR).

1.2 The Dangerous Goods Regulations require performance tests to be conducted on packaging designs prior to being authorized for use. The regulations do not include standardized procedures to accomplish this which can result in differences between testing facilities. The purpose of this document is to provide guidance and to establish a set of common practices for conducting stack testing on packagings undergoing UN certification.

1.3 The user of this guide must be trained in accordance with 49 CFR as required by 172.700 and should be familiar with other applicable hazardous materials regulations such as; International Civil Aviation Organization (ICAO) Technical Instructions for the Safe Transport of Dangerous Goods by Air, the International Maritime Dangerous Goods Code (IMDG Code), and carrier rules such as International Air Transport Association (IATA) Dangerous Goods Regulations.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units 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*

¹ This guide is under the jurisdiction of ASTM Committee D10 on Packaging and is the direct responsibility of Subcommittee D10.22 on Hazardous Materials. Current edition approved Oct. 15, 2021. Published December 2021. DOI: 10.1520/D8409_D8409M-21.

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
- D685 Practice for Conditioning Paper and Paper Products for Testing
- D996 Terminology of Packaging and Distribution Environments
- D4332 Practice for Conditioning Containers, Packages, or Packaging Components for Testing
- D4577 Test Method for Compression Resistance of a Container Under Constant Load
- D4919 Guide for Testing of Hazardous Materials (Dangerous Goods) Packagings

2.2 ISO Standards:³

- ISO 2234 Packaging – Complete, filled transport packages – Stacking tests using static load
- ISO 16495 Packaging – Transport packaging for dangerous goods – Test methods

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.

³ Available from International Organization for Standardization (ISO), ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <https://www.iso.org>.

2.3 *Federal Standard*.⁴

U.S. Department of Transportation Code of Federal Regulations Title 49, Transportation (49 CFR) Parts 100-185

2.4 *UN Standard*.⁵

UN United Nations Recommendations on the Transport of Dangerous Goods, Model Regulations (UN Orange Book)

2.5 *IATA Standard*.⁶

IATA International Air Transport Association (IATA) Dangerous Goods Regulations

2.6 *ICAO Standard*.⁷

ICAO Technical Instructions for the Safe Transport of Dangerous Goods by Air

2.7 *IMDG Standard*.⁸

International Maritime Dangerous Goods Code (IMDG Code)

3. Terminology

3.1 *Definitions*:

3.1.1 General definitions for packaging and distribution are found in Terminology **D996**.

3.2 *Definitions of Terms Specific to This Standard*:

3.2.1 *deflection, n*—amount of vertical deformation in the height of the package under the test load during the test period.

3.2.2 *dynamic compression test, n*—a top loading compression test performed using a machine capable of applying a dynamic top loading on a package. This test is performed in conformance with Test Method **D642** and the regulations as applicable.

3.2.3 *guided load, n*—a static top loading test performed with fixed platen compression machines or in a “dead load” stack arrangement where the packaging and weight stack are constrained from tipping due to deformation or collapse of the packaging.

3.2.4 *intermediate bulk container (IBC), n*—a rigid or flexible portable packaging, other than a cylinder or portable tank, which is designed for mechanical handling, has volumetric capacity of not more than 3000 L and includes: flexible, composite, and rigid IB Cs.

3.2.5 *large packaging, n*—a packaging that contains articles or inner packagings, which is designed for mechanical handlings, exceeds 400 kg net mass or has a volumetric capacity greater than 450 L but not more than 3000 L.

3.2.6 *load spreader, n*—rigid plate that spreads the stack load across the entire top surface area of the package under the

load. The load spreader shall extend to the outside edge of the perimeter or beyond the perimeter of the test specimen.

3.2.7 *packagings, n*—receptacles and any other components or materials necessary for the receptacle to perform its containment function in conformance with the minimum requirements of the HMR; and includes non-bulk, IBC, and Large Packagings.

3.2.8 *stacking test (top load compression test), n*—a test designed to ascertain the performance capability of a packaging under top load compressive forces in storage or transportation. It is a required design type test for all non-bulk packagings except bags, and all IB Cs intended to be stacked.

3.2.9 *unguided load, n*—a constant top loading test performed with floating (swivel) platen compression machines or a “dead load” (constant load) mass applied in manner that would allow the stack load to tip over in the event of excess deformation or collapse of the packaging. Floating platens swivel to maintain constant load on parts of the packaging that are deforming under pressure.

3.2.9.1 *Discussion*—Additional packaging terms and definitions specific to the regulations are located in 49 CFR, Section 171.8, and the Orange Book, Section 1.2.1.

4. Significance and Use

4.1 This guide is intended to provide a standardized method and a set of basic instructions for performing stack testing on UN packaging designs using either guided or unguided top loads. This guide provides the suggested minimum information that should be documented when conducting stacking test and provides information for recommended equipment.

4.2 All packaging design types other than bags must be subjected to a stacking test. Packagings subject to the stacking test must be capable of withstanding a superimposed top load of a specified minimum mass for a specified period of time without failure as these parameters are defined in the regulations. The test is not intended to determine the absolute top load capability of a packaging.

NOTE 1—When quantification of box compression strength is desired for determining stacking strength or for design purposes use Test Method **D642** and conditioning as recommended in **4.5**.

4.3 Design qualification testing procedures are intended, as explicitly stated in the HMR, to be the minimum performance capability levels for packaging manufactured to transport Hazardous Materials under conditions normally incident to transportation.

4.4 The HMR tests are designed to be gross package capability evaluations that can be performed in a similar manner in all parts of the world, but under circumstances with some variance in test facility capabilities. This is an intentional feature of the test designs and protocols. The focus of HMR testing is not the determination of quantifiable, comparison data to allow for analytical evaluation.

4.5 It is recommended that facilities performing the HMR tests consult the guidance on conditioning in the relevant ASTM documents for any particular packaging material as

⁴ Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402-9371 (website: <https://www.phmsa.dot.gov/phmsa-regulations>).

⁵ Available from the UN Economic Commission for Europe, Information Service, Palais des Nations, CH-1211 Geneva 10 Switzerland (website: <http://www.unece.org/trans/danger/danger.htm>).

⁶ Available from the International Air Transport Association (IATA), 800 Place Victoria PO Box 113 Montreal - H4Z 1M1 Quebec - Canada (website: <http://www.iata.org>).

⁷ Available from the International Civil Aviation Organization, (ICAO) 999 University Street, Montréal, Quebec H3C 5H7, Canada (website: <http://www.icao.org>).

⁸ Available from the International Marine Organization (IMO), 4 Albert Embankment, London, SE1 7SR United Kingdom (website: <http://www.imo.org>).

applicable. The following conditioning documents, Practices **D4332** and **D685**, are commonly used.

5. Apparatus

5.1 *Closing equipment* such as; torque wrenches, torque meters, lid presses, cover/closure crimping tools, etc., to close the container as for transport.

5.2 *Top Load Equipment*—Constant (dead) load weights or mechanical compression system (machine), such as those described in Test Method **D4577** or Test Method **D642**.

5.3 *Stacking fixture (optional)* may be used to aid in applying force load, aligning weights, or improve safety if stack load weights should topple

5.4 *Load spreader* used as necessary to ensure even distribution of the top load.

5.5 *Measuring device* appropriate to the task if needed.

5.6 Closing equipment, top load equipment, and measuring devices shall be calibrated as necessary.

6. Sampling, Test Specimens, and Test Units

6.1 Visually inspect packaging(s) to be tested for consistency with closing instructions and any defects. Verify all closures, plugs, gaskets, accessories, etc. match the closing instructions. Determine if the container has a properly formed sealing surface (record any blemishes or defects). Examine for and record any damage which might invalidate the test.

6.2 Number of specimens as required by current regulations being used for testing. These must be randomly selected specimens.

6.2.1 *Packagings (Non-Bulk)*—Three specimens is the minimum required.

6.2.2 *IBCs and Large Packagings*—One specimen is the minimum required.

6.3 Prepare the packaging for testing, as specified by the current regulations being utilized for the specific design type. When the specimen is required to be filled for testing, it shall be closed and secured in the same manner as for transport.

6.3.1 The fill capacity for single or inner packagings of non-bulk and inner packagings of Large Packagings is:

6.3.1.1 Solids must be filled to not less than 95 % of maximum capacity.

6.3.1.2 Liquids must be filled to not less than 98 % of maximum capacity.

6.3.1.3 Non-bulk combination packagings prepared for the stacking test may also be prepared without their inner packagings, unless it would invalidate the test. Packagings may be tested empty.

6.3.2 IBCs and Large Packagings, except flexible design types, must be filled to their maximum permissible gross mass.

6.3.2.1 Flexible IBCs or flexible Large Packagings must be filled to not less than 95 % of its capacity with the fill being evenly distributed and to the maximum net mass.

6.4 49 CFR permits the use of dynamic compression testing in place of the 24 hour or 28 day stacking test for periodic retests of non-bulk, IBCs, and Large Packagings. The test

specimens must be empty and unsealed. The dynamic compression test should be conducted in accordance with Test Method **D642**.

7. Conditioning

7.1 For design qualification testing, the minimum conditioning duration for paper or fiberboard packagings is 24 hours prior to testing. Unless testing is conducted in the conditioning atmosphere, it is recommended the test start as soon as possible, but no more than 15 minutes after removing the packaging test specimen from the conditioning atmosphere.

NOTE 2—When quantification of box compression strength is desired for determining stacking strength or for design purposes, more fully defined conditioning is advisable. For quantifying box stacking strength, it is recommended using conditioning as specified in Practices **D4332** and **D685** (see 4.4 and 4.5).

7.2 It is recommended to condition fiberboard packagings prior to testing in accordance with the conditioning atmosphere specified in Practices **D4332** and **D685**. These ASTM procedures recommend conditioning fiberboard and paper for a minimum of 72 hours.

7.3 Conditioning of specific packaging design types in accordance with the applicable regulation as outlined in 49 CFR is identified in **Table 1**.

8. Calculating Load

8.1 All calculations for minimum top load should be performed using SI units, where the results are stated in kilograms before conversion to other units of measure is made.

8.2 When no rounding requirements are provided, it is recommended to round up to the nearest tenth at each step when calculating the minimum load.

8.2.1 The steps to calculating the minimum load would include:

8.2.1.1 *Step 1*—The calculation of the number of containers,

8.2.1.2 *Step 2*—The calculation of the mass of the container, and

8.2.1.3 *Step 3*—The calculation of the minimum load.

NOTE 3—To calculate the absolute minimum, do not round until all calculations are complete. Accuracy should be reflected in the capability of the equipment used.

8.3 For non-bulk, the load is the mass of filled like-packagings that could be stacked on top of the test specimen during transport to the equivalent height of 3 m.

8.3.1 Calculation of top load for a non-bulk packaging tested with solids or liquids is:

$$\text{Minimum Top Load} = (n - 1) \times w \quad (1)$$

where:

n = minimum number of containers that when stacked, reach a height of 3 m. The number of packages is calculated using **Eq 2** and this number may not be an integer.

w = maximum total mass in kilograms (kg) of the subject package as it would be filled and prepared for testing in accordance with the regulations. This would be maximum gross mass of the package for transport.