Designation: D6653/D6653M – 13

Standard Test Methods for Determining the Effects of High Altitude on Packaging Systems by Vacuum Method[1]

This standard is issued under the fixed designation D6653/D6653M; 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 These test methods determine the effects of pressure differential when packaged products are transported via certain modes of transport, such as feeder aircraft or ground over high mountain passes. The results of these tests are intended to be used for qualitative purposes.

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

1.3 *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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D996 Terminology of Packaging and Distribution Environments

D3078 Test Method for Determination of Leaks in Flexible Packaging by Bubble Emission

D4169 Practice for Performance Testing of Shipping Containers and Systems

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

D4991 Test Method for Leakage Testing of Empty Rigid Containers by Vacuum Method

D5094 Test Methods for Gross Leakage of Liquids from Containers with Threaded or Lug-Style Closures

E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

2.2 *Other:*

Altitude-pressure tables based on the United States Standard Atmospheres[3]

3. Terminology

3.1 *Definitions*—Terms and definitions used in these test methods may be found in Terminology D996.

3.2 *Definition of Term:*

3.2.1 *feeder aircraft, n*—small, potentially nonpressurized aircraft used to transport express air packages to remote areas.

4. Significance and Use

4.1 Packaged products transported via the feeder aircraft network are liable to experience altitudes as high as 5 791 m [19 000 ft].[4] When exposed to these high altitude conditions, products or packaging systems, or a combination thereof, may be affected negatively by the resultant pressure differential.

4.2 These test methods are suitable for evaluating the effect of high altitude on packaging systems.

4.3 These test methods are suitable for package or product, or both, development and engineering.

4.4 Other test methods, such as Test Methods D3078, D4991 and D5094, test for leakage of packaging systems by vacuum method and are applicable for testing the effects of high altitude.

5. Apparatus

5.1 *Vacuum Chamber*—Any suitable chamber capable of withstanding approximately one atmosphere pressure differential fitted with a flat-vacuum-tight cover or equivalent chamber providing the same functional capabilities, such as an altitude chamber.

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

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

[3] Available from http://naca.larc.nasa.gov/reports/1936/naca-report-538/.

[4] Based on field testing analysis. See Singh, S. P., Singh, J., Stallings, J., Burgess, G., and Saha, K., "Measurement and Analysis of Temperature and Pressure in High Altitude Air Shipments," *Journal of Packaging Technology and Science*, Vol. 23, Issue 1, pp. 35 – 46, December 2009.

5.2 *Vacuum Gage, Inlet Tube from a Source of Vacuum and Outlet Tube to the Atmosphere,* shall be sealed to the chamber. The inlet and outlet tubes shall be equipped with hand operated valves. The vacuum gauge shall be laboratory quality with a full-scale range of 0 to 100 kPa [0 to 30 in. Hg] with minimum graduation no greater than 2 kPa [1 in. Hg] and accuracy to within 2 %.

5.3 *The Chamber,* shall be large enough to contain the test specimen, as well as allow for the expansion of the product or package, or both.

6. Sampling

6.1 The test specimens and number of samples shall be chosen to permit an adequate determination of representative performance (see Practice E122).

6.2 In the absence of any sampling plan, at least three representative specimens should be selected for performance evaluation.

7. Test Specimen

7.1 A test specimen shall consist of an assembled packaging system, representative of a production run package, or components of an assembled packaging system, to include primary and/or secondary packaging.

8. Conditioning

8.1 Test specimens shall be conditioned to 5.6 ± 2°C [42 ± 3.6°F] for a minimum of 24 h prior to testing.

8.2 Test specimens shall be tested in and at conditions of 5.6 ± 2°C [42 ± 3.6°F].[4]

8.3 If conditioning prior to testing or during test is not possible, then it recommended to condition test specimen to a standard conditioning atmosphere of 23 ± 2°C [73.4 ± 3.6°F] for a minimum of 24 h prior to testing (see Practice D4332)

8.4 Conditioning specifications may be modified based on knowledge of shipping environment, product value, desired damage level acceptances, or other criteria (see Appendix X1 for guidance).

9. Procedure

9.1 Place the test specimen in the vacuum chamber. Close the chamber inlet valve, open the outlet valve and turn the vacuum source on so that the gauge rises at an approximate rate of 305 m [1 000 ft] 30-60 s until the appropriate pressure is achieved.

9.1.1 Attain a pressure equivalent to 4 877 m [16 000 ft] ± 5 % for test specimens tested at condition specifications.[4]

9.1.2 Attain a pressure equivalent to 4 267 m [14 000 ft] ± 5 % if testing the test specimens at the condition specifications is not possible (see 8.1, 8.3 and Table X1.1).

9.1.3 The vacuum pressure may be modified based on knowledge of shipping environment, product value, desired damage level acceptances, or other criteria (see Appendix X1 and Table X2.1 for guidance).

9.2 Maintain the vacuum for 60 min. The test duration may be modified based on knowledge of shipping environment, product value, desired damage level acceptances, or other criteria (see Appendix X1 and Table X2.1 for guidance).

9.3 Partially open the chamber inlet valve and release the vacuum at a rate of approximately 305 m [1 000 ft] per 30-60 s.

9.4 Open the chambers cover and remove the test specimen and examine for any damage or deformation.[5]

9.5 Record the results of examination.

10. Interpretation of Results

10.1 If a distribution packaging system was tested and the closure, shipping container, internal packaging and product are intact and free of damage, then the packaging system should be reassembled for testing in accordance with an industry accepted packaged-product performance test, such as Practice D4169. This will help determine if the pressure differential had an affect on the performance of the packaging system. It is recommended to test a new test specimen with the same packaged-product performance test without the altitude conditioning for comparative purposes.

11. Report

11.1 The report shall include the following information:

11.1.1 A statement that the test was conducted in compliance with these test methods or a description of the deviations from these test methods.

11.1.2 Identification of the specimen and the specific material(s) tested with any pertinent material specifications.

11.1.3 Description of the product, internal packaging, shipping container and closure system, where applicable.

11.1.4 Identification of any change to the product, internal packaging, shipping container and closure system.

11.1.5 The temperature conditioning prior to testing.

11.1.6 The vacuum, temperature and duration of the testing and temperature compensation factor used, if any.

12. Precision and Bias

12.1 No statement is made about either the precision or bias of these test methods since the results merely state whether there is conformance to the criteria for success specified in these procedures.

13. Keywords

13.1 air shipment; feeder aircraft; high altitude; packaging; vacuum testing

[5] Damage may be in the form of package failure, closure failure, material failure, product failure, or combination thereof.

APPENDIXES

(Nonmandatory Information)

X1. Altitude, Temperature and Duration Field Data[4]

X1.1 Cargo air jets typically are pressurized to approximately 2 438 m [8 000 ft]. Temperature is maintained to approximately 20 to 23°C [68 to 74°F].

X1.2 Packages transported on ground may experience altitudes as high as 3 658 m [12 000 ft] when shipped over certain mountain passes, especially in Colorado. Temperature extremes range from -15 to 30°C [5 to 86°F] with average mean temperatures of approximately -4 to 18°C [25 to 64°F].

X1.3 Nonpressurized feeder aircraft typically fly at approximately 3 962 m to 4 877 m [13 000 to 16 000 ft]. The highest recorded altitude in a nonpressurized feeder aircraft was 6 017 m [19 740 ft]. Temperature recordings ranged from approximately -4 to 24°C [25 to 75°F].

X2. Temperature and Pressure Correlation

TABLE X1.1 Pressure Conversion Table[A]

Altitude, m	Altitude, ft	Torr, mm Hg	in. Hg	kPa	psi
0	0	760.0	29.92	101.3	14.70
305	1 000	732.9	28.85	97.7	14.018
1 524	5 000	632.3	24.89	84.3	12.23
2 438	8 000	564.85	22.24	75.3	10.92
3 048	10 000	522.84	20.58	69.7	10.11
3 658	12 000	483.83	19.05	64.5	9.35
4 267	14 000	446.33	17.57	59.5	8.63
4 877	16 000	411.82	16.21	54.9	7.97
5 486	18 000	379.57	14.94	50.6	7.34
6 096	20 000	349.56	13.76	46.6	6.76
7 925	26 000	270.05	10.63	36.0	5.22
9 144	30 000	225.6	8.88	30.1	4.36
12 192	40 000	140.7	5.54	18.8	2.72
15 240	50 000	87.3	3.44	11.6	1.69

[A] kPa ÷ 0.1 = millibars.

Note—If using a vacuum kPa gage, you must subtract the desired kPa from 101.3 to achieve the vacuum kPa. For example, 101.3 – 97.7 = 3.6 vacuum kPa, equating into 305 m.

X2.1 Both temperature and altitude affect pressure. Table X2.1 illustrates the effect of temperature and altitude on pressure.

TABLE X2.1 Temperature and Pressure Correlation

Altitude, (m)	Atmospheric Data	Pressure (kPa) 30 °F	40 °F	50 °F	60 °F	70 °F	80 °F	90 °F
0	101.3	95.6	97.6	99.5	101.5	103.4	105.4	107.4
305	97.7	92.9	94.8	96.7	98.6	100.5	102.4	104.3
1 524	84.3	82.4	84.1	85.8	87.5	89.1	90.8	92.5
2 438	75.3	75.2	76.8	78.3	79.8	81.4	82.9	84.4
3 048	69.7	70.7	72.1	73.5	75.0	76.4	77.9	79.3
3 658	64.5	66.4	67.7	69.1	70.4	71.8	73.1	74.5
4 267	59.5	62.2	63.4	64.7	66.0	67.2	68.5	69.8
4 877	54.9	58.2	59.4	60.6	61.8	63.0	64.2	65.4
5 486	50.6	54.5	55.6	56.7	57.8	59.0	60.1	61.2
6 096	46.6	51.0	52.0	53.1	54.1	55.2	56.2	57.3
7 925	36.0	41.4	42.2	43.1	43.9	44.8	45.6	46.4
9 144	30.1	35.8	36.5	37.2	38.0	38.7	39.4	40.2
12 192	18.8	23.6	24.1	24.6	25.1	25.6	26.0	26.5
15 240	11.7	14.6	14.9	15.2	15.5	15.8	16.1	16.4