Designation: D 4003 – 98 (Reapproved 2003)

Standard Test Methods for Programmable Horizontal Impact Test for Shipping Containers and Systems[1]

This standard is issued under the fixed designation D 4003; 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 are intended to determine the ability of a package or product to withstand laboratory simulated horizontal impact forces.

1.2 The horizontal impacts used in these test methods are programmed shock inputs that represent the hazards as they occur in the shipping and handling environments. The environmental hazards may include rail switching impacts, lift truck marshalling impacts, and so forth. The following test methods apply:

1.2.1 *Method A, Rail Car Switching Impact*—This test method simulates the types of shock pulses experienced by lading in rail car switching, with the use of a rigid bulkhead on the leading edge of the test carriage, to simulate the end wall of a railcar and shock programming devices to produce representative shock pulses. With the use of backloading, this test method may also be used to simulate compressive forces experienced by lading loads during rail car switching. It is suitable for tests of individual containers or systems as they are shipped in rail cars. It may also be used to evaluate the effectiveness of pallet patterns to determine the effect of interaction between containers during rail switching operation impacts.

1.2.2 *Method B, Marshalling Impact Tests of Unit Loads*—This test method assesses the ability of unit loads to withstand the forces encountered during marshalling or loading operations.

1.3 The test levels may be varied to represent the mode on shipping and handling used for the item under test.

1.4 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

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

2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 996 Terminology of Packaging and Distribution Environments

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

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

E 122 Practice for Choice of Sample Size to Estimate a Measure of Quality of a Lot or Process

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, see Terminology D 996.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *acceleration*—the rate of change of velocity of a body with respect to time measured in in./s^2 (m/s^2).

3.2.2 *backload*—a duplicate specimen similar to the test package or weights to simulate the other lading in the transport vehicle.

3.2.3 *shock pulse*—a substantial disturbance characterized by a rise of acceleration from a constant value and decay of acceleration to the constant value in a short period of time.

3.2.4 *shock pulse programmer*—a device to control the parameters of the acceleration versus time-shock pulse generated by a shock test impact machine.

3.2.5 *velocity change*—the sum of the impact velocity and rebound velocity (the area under the acceleration—time curve).

4. Significance and Use

4.1 These test methods provide a measure of a shipping container's ability to protect a product from failure due to horizontal impacts. These measures are based on controlled levels of shock input and may be used for arriving at the optimum design of a container or system to protect a product against a specified level of shipping environment hazard.

4.2 These test methods provide a measure of a packaged product's ability to withstand the various levels of shipping

[1] These test methods are under the jurisdiction of ASTM Committee D10 on Packaging and are the direct responsibility of Subcommittee D10.22 on Handling and Transportation.

Current edition approved April 10, 1998. Published October 1998. Originally published as D 4003–81. Last previous edition D 4003–92.

[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.

environment hazards. These measures may be used to prescribe a mode of shipping and handling that will not induce damage to the packaged product or to define the required levels of protection that must be provided by its packaging.

4.3 Test Method A is intended to simulate the rail car coupling environment. Refer to Methods D 5277 for simulating the standard draft gear portion of that environment.

5. Apparatus

5.1 *Horizontal Impact Test Machine*:

5.1.1 The impact test machine shall consist of a guided test carriage with a flat test specimen mounting and an upright bulkhead that is at a 90° angle ±30 min (½ °) to the specimen mounting surface. The carriage should be of sufficient strength and rigidity so that the test specimen mounting surface and bulkhead remain rigid under the stresses developed during the test.

5.1.2 The impact test machine shall provide some means of moving the test carriage in a single guided horizontal direction of motion. The motion of the carriage shall be controlled in such a manner that its velocity change is known after the moment of impact.

5.1.3 The machine shall be equipped with programmable devices to produce shock pulses at the carriage bulkhead when the carriage strikes the impact reaction mass.

5.1.4 The machine shall have an impact reaction mass, sufficient in size to react against the force of impact from the carriage. The prescribed shock pulse limits will provide the controlling factor as to the design or concept of the reaction mass required.

5.1.5 Means shall be provided to arrest the motion of the carriage after impact to prevent secondary shock. The design shall prevent excessive lateral or over turning motion that could result in an unsafe condition or invalidate the test.

5.1.6 *Machine Setting*—Since the desired shock pulses are influenced by the response of the test specimen, pretest runs should be conducted with duplicate test specimens with equivalent dynamic loading characteristics and backload, if required, prior to actual test to establish the approximate machine equipment settings.

5.1.6.1 The control parameters that must be specified include:

5.1.6.2 The desired velocity change (impact plus rebound velocity of the test carriage),

5.1.6.3 The desired pulse, shape, duration, and acceleration levels, and

5.1.6.4 The desired backload weight/friction relationship.

5.2 *Specimen Backload Equipment*:

5.2.1 During some horizontal impacts, the forces that test units encounter include both the shock forces of the acceleration as well as compressive forces resulting from other products impacting against them. This will necessitate sufficient carriage strength and platform space to provide a location for the desired backload weights.

5.2.2 Specially adapted backloading fixtures may be used to provide an even loading of the backload weight over the entire back surface area of the test specimen, or additional product samples may be used to create the desired backload.

5.2.3 The backload weight and frictional characteristics must be specified for each test procedure and reported.

5.3 *Instrumentation*:

5.3.1 An accelerometer, a signal conditioner, and a data display or storage apparatus are required to measure the acceleration-time histories. The velocity change is obtained by integrating the impact shock record measured on the carriage bulkhead.

5.3.2 The instrumentation system shall be accurate to within ±5 % of the actual value. The long pulse durations involved in this test method require an instrumentation system with good low-frequency response. As an alternative, instrumentation capable of recording direct current (dC) shall be acceptable. For short pulse durations the high-end frequency response should be twenty times the frequency of the pulse being recorded. For example, the 10-ms pulse has a full pulse duration of 20 ms and a frequency of 50 Hz. Therefore, the instrumentation system should be capable of measuring 1000 Hz. (20 × 50 Hz).

NOTE 1—As a guide, the following equation may be used to determine the adequacy of instrumentation low-frequency response:

$$\text{low}-\text{frequency response point (LFRP)} = 7.95/\text{pulse width (PW) (ms)} \quad (1)$$

where *LFRP* is the low frequency 3-db attenuation roll-off point, expressed in hertz (cycles per second), of an instrumentation system that will ensure no more than 5 % amplitude error, and *PW* is the pulse width of the acceleration pulse to be recorded, measured in milliseconds at the baseline. For example, an intended shock acceleration signal with a duration of 300 ms, the *LFRP* of the instrumentation would have to be at least equal to or lower than 0.027 Hz.

5.3.3 Optional instrumentation may include optical or mechanical timing devices for measuring the carriage image and rebound velocities for determining the total velocity change of the impact. This instrumentation system, if used, shall have a response accurate to within ±2.5 % of the actual value. Total velocity change must be measured to within ±5.0 % of its total value.

6. Precautions

6.1 These test methods may produce severe mechanical responses in the test specimen. Therefore, operating personnel must remain alert to the potential hazards and take necessary safety precautions. The test area should be cleared prior to each impact. The testing of hazardous material or products may require special precautions that must be observed. Safety equipment may be required and its use must be understood before starting the test.

7. Sampling

7.1 The number of test specimens depends on the desired degree of precision and the availability of specimens. Practice E 122 provides guidance on the choice of sample size. It is recommended that at least three representative test specimens be used.

8. Test Specimen

8.1 The package and product as shipped or intended for shipment constitutes the test specimen. Apply sensing devices to the package, product, or some component of the product to measure the response levels during impact. Test loads of equal configuration, size, and weight distribution and packaging are acceptable if testing the actual product might be hazardous or impractical. Care must be taken to duplicate the load characteristics of the product.

9. Conditioning

9.1 It is recommended that atmospheres for conditioning be selected from those shown in Practice D 4332. Unless otherwise specified, precondition and condition fiberboard and other paperboard containers in accordance with the standard atmosphere specified in Practice D 4332.

10. Procedure

10.1 *Test Method A—Rail Car Switching Impact Test*:

10.1.1 Prior to initiating the test, write the test plan including the following information:

10.1.1.1 The number of impacts the unit will receive,

10.1.1.2 The velocity change for each of the desired impacts,

10.1.1.3 The pulse duration of the impact shock, and

10.1.1.4 The weight and configuration of the backload used.

NOTE 2—The number of impacts to which a product will be subjected in transit may range from 2 to 15. The velocity changes range between 1 and 10 mph (1.6 and 16 kmph) with an average velocity change of approximately 5 mph (8 kmph). The duration of the impact shocks is dependent on the draft gear of the rail cars used to transport the products. The duration normally ranges from 30 ms for standard draft gear to in excess of 300 ms for long travel draft gear of cushioned underframes. The acceleration levels observed are normally a function of the velocity change and pulse duration rather than a controlling input parameter. The accelerations corresponding to the above durations are about 15 g and less than 1 g, respectively. It must be realized that rail car switching impacts normally occur many times during shipment. It is recommended that a test consist of a number of lower level impacts or an incremental series of increasing impact magnitude rather than a single large magnitude impact. This type of testing also provides better information by bracketing the failure between two impacts levels.

NOTE 3—The backload weight/friction requirement is not well-defined due to lack of environmental measurements of lading force levels. Through preliminary testing, backload pressures ranging from 0.3 to 1.0 psi (2 to 7 kPa) on the container impacting surface have created damage levels normally observed in distribution. These pressures are based on a coefficient of friction of 0.5 on a horizontal surface. See Appendix X1 for further discussions.

10.1.2 After the test parameters have been established, place a duplicate test specimen on the test carriage, positioned at the center of the specimen mounting surface with the face or edge that is to receive the impact firmly positioned against the upright bulkhead. If duplicate test specimens are not available, use as similar a specimen as possible. Weights equivalent to the weight of the product to be tested are not recommended unless they can simulate the reactive or compliant nature of the test specimen.

10.1.3 Then backload the duplicate test specimen with additional product samples or the specially adapted backloading fixture that provides an even loading of the backload weight over the entire back surface area of the test specimen as specified in the test plan. Impact the test carriage with various test machine setups into the programmers to produce the desired pulse durations.

NOTE 4—Continue the pretesting until the desired range of velocity changes is obtained. This pretesting is not necessary if the levels of the major test parameters are known from previous experience.

NOTE 5—The type of programmers used shall be selected on the basis of the shock pulse, waveform, and duration desired.

10.1.4 Replace the duplicate specimen with the actual test specimen and place it at the center position of the specimen mounting surface with the face or edge that is to receive the impact firmly positioned against the bulkhead. Backload the test specimen with additional product or specially adapted backloading fixture used in 10.1.2 and set the test machine to achieve the desired velocity change.

10.1.5 Release the carriage to impact against the programmer for a single impact. Record the acceleration time profile of the carriage bulkhead and determine the velocity change (impact plus rebound velocity) of the test carriage.

10.1.6 Inspection of the packaged product may be conducted between each test impact to examine the effect of the impact on the product and package.

10.1.7 The test container should be subjected to the desired numbers of impacts at various velocity changes and number of impacts specified in the test plan. Each axis of concern of the test package can be evaluated in a similar manner as described in 10.1.2-10.1.7.

10.2 *Test Method B—Marshalling Impact Test*:

10.2.1 Unit loads may be subjected to impacts when handled with mechanical equipment such as powered pallet trucks (pallet jacks), forklift trucks, straddle carriers, or other heavy materials handling equipment. These impacts may cause damage to the product or package. The impact test conditions to simulate marshalling hazards can be determined by knowing the fork truck weight and the test specimen (unit load) weight and selecting an impact velocity, a pulse duration and other impact conditions.[3] Knowing these variables, a shock pulse can be determined and programmed into the Impact Test Machine. To determine the impact level to simulate marshalling, use the following equation:

$$G_p \times T = K \left(\frac{1 + e}{1 + R} \right) V_t \tag{2}$$

where:

G_p = shock pulse peak acceleration for a half-sine in G's,
T = shock pulse duration in ms,
e = coefficient of restitution,
K = a proportionality constant whose value depends on the units used for impact velocity. K will be 48.7 for velocity in ft/s and 14.8 for velocity in m/s,
R = Ratio of the weight of the test specimen, to the weight of the fork truck, and
V_t = Impact velocity of the fork truck in ft/s (m/s).

NOTE 6—The coefficient of restitution lies between 0.0 and 1.0. A study[3] measuring impact conditions found durations on various combinations of unit loads and pallet types in two clusters, one varied between

[3] Rodriquez, Singh, and Burgess, "Study of Lateral Shocks Observed During Fork Truck and Pallet Jack Operations for the Handling of Palletized Loads," *Packaging Technology and Science*, Vol 7, 1994, pp. 205-211.

1-ms and 5-ms and the second from 8-ms to 13-ms dependent on the various factors described by the Eq 1. The results of the study were based on impact data collected on: corrugated boxes on wooden pallets, rigid plastic bulk bins, and plastic drums on wooden pallets. The impact velocity V_t was found to range from 1 ft/s (.3 m) for average impact conditions to 4 ft/s (1.2 m/s) for severe conditions. Impact velocity varies with the type of material handling equipment under investigation from walking hand trucks to seated drive fork trucks.

NOTE 7—If the impact conditions are not known use a 15 g. 10-ms half sine shock pulse calculated using an *e* of 0.5, an impact velocity of 2.5 ft/s (0.76 m/s), and a *R* of ⅕ in Eq 1.

10.2.2 A test specimen as is intended for shipment, should be used for the test.

10.2.3 Place the test specimen on the test carriage at the center position of the specimen mounting surface with the face or edge that is to receive the impact firmly positioned against the bulkhead. The test carriage should be impacted at the predetermined acceleration and duration test levels chosen. Each axis of concern can be evaluated in a similar manner.

11. Report

11.1 Report the following information:

11.1.1 Reference to this test method, noting any deviations from the test method,

11.1.2 Complete identification of the product and package being tested or pallet load and configuration in sufficient detail for proper identification,

11.1.3 Definition of the purpose of the test,

11.1.4 Descriptions of the test sequence, the acceleration level (s), time duration (s), and velocity change (s) where appropriate,

11.1.5 Method and orientation of test item (s) as it is positioned on the test carriage,

11.1.6 Conditioning methodology and levels,

11.1.7 Identification of apparatus and instrumentation used, including date of last calibration, manufacturers' names, model numbers, and serial numbers. Details of any known modifications thereto shall be included, and

11.1.8 Detailed description of type of damage resulting from the test. The criteria for damage to the package, product, or pallet load may be based on the obvious failure as cracking or breaking of some structural part of the product or package or dislodging of packages from a pallet. The damage criteria also may be based on the physical dimensions or displacement of the product or package, or the relationship of the various packages in a multiple package test,

12. Precision and Bias [4]

12.1 *Precision*:

12.1.1 This precision is usually conducted to determine if a container or shipping system completes the prescribed test without specified damage. With this situation, no statement can be made about the precision because the results merely state whether there is conformance to the criteria for success.

12.1.2 When the test is conducted to determine the input stress required to cause a specified type of damage, the precision depends largely upon the item being tested. The equipment, instrumentation, fixturing, methodology, and personnel also play important roles in precision. A research report indicates that there can be considerable variability between replicate tests for vertical impacts; it is believed that similar conclusions are true for horizontal impacts.

12.2 *Bias*—This test method has no bias because the results are defined only in terms of this test method.

13. Keywords

13.1 controlled; horizontal impact; pallet marshalling; rail car switching

[4] Supporting data are available from ASTM Headquarters, Request R:R:D10-1004.

APPENDIX

(Nonmandatory Information)

X1. GUIDE TO DETERMINATION OF A BACKLOAD

X1.1 For the loading of uniform packages, the primary determinant of backload able to create the type of crushing damage seen in rail distribution is package density. The force produced by decelerating a particular volume of lading would be proportional to the weight or mass of that volume. Thus the backload pressure can be determined, using the following relationship:

$$P = d \times F \tag{X1.1}$$

where:
P = backload pressure,
d = density, and
F = a constant.

This interaction factor F has been empirically determined to be 35 in., 88.9 cm, or 0.889 m for standard draft gear. This factor is effectively a measure of the depth of the load that exerts a force on an adjacent package under typical longitudinal impacts that occur when railroad cars are connected together. This factor is dependent on the rail car draft gear, pulse duration, and the coefficient of friction between the rail car floor surface and the lading.

X1.2 The total backload weight (mass) is determined by multiplying the backload pressure by the area over which it is applied. This relationship can be expressed as:

$$B_t = P \times A \tag{X1.2}$$

where

B_t = backload weight or mass,

P = backload pressure, and

A = cross-sectional area of the test specimen (W (width) × H (height)).

X1.3 The two expressions can be combined and expressed as follows:

$$B_t = M / L \times F \quad \text{(X1.3)}$$

where:

B_t = backload weight or mass,

M = weight or mass of the package, and

L = length of package (measured in direction parallel to impact direction).

If M is weight in pounds, F and L are distances in inches, and B_t is in pounds:

$$B_t \text{ (lb)} = M \text{ (lb)}/L \text{ (in.)} \times 35 \text{ in.} \quad \text{(X1.4)}$$

If M is mass in grams, F and L are distances in centimetres, and B_t is in grams:

$$B_t \text{ (g)} = M \text{ (g)}/L \text{ (cm)} \times 88.9 \text{ cm} \quad \text{(X1.5)}$$

If M is mass in kilograms, F and L are distances in metres, and B_t is in kilograms:

$$B_t \text{ (kg)} = \text{M (kg)}/L \text{ (m)} \times 0.889\, m \quad \text{(X1.6)}$$

X1.4 This test method of computing the backload provides a consistent method that has been shown to satisfactorily duplicate typical rail car switching impact damage. Other values for F may be used as dictated by user experience.