



Standard Test Method for Drop Test of Loaded Containers by Free Fall¹

This standard is issued under the fixed designation D5276; 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 test method covers procedures for the drop testing of loaded boxes, cylindrical containers, and bags and sacks by the free-fall method.

1.2 For containers not exceeding 110 lb (50 kg), this test method fulfills the requirements of ISO Standards 2206:1987 and 2248:1985. These ISO standards may describe procedures that do not meet the requirements for this test method.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *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

- D585 Practice for Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, and Related Product (Withdrawn 2010)³
- D644 Test Method for Moisture Content of Paper and Paperboard by Oven Drying (Withdrawn 2010)³
- D880 Test Method for Impact Testing for Shipping Containers and Systems
- D996 Terminology of Packaging and Distribution Environments
- D2463 Test Method for Drop Impact Resistance of Blow-Molded Thermoplastic Containers

¹ This test method 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 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 The last approved version of this historical standard is referenced on www.astm.org.

- D4003 Test Methods for Programmable Horizontal Impact Test for Shipping Containers and Systems
- D4169 Practice for Performance Testing of Shipping Containers and Systems
- D4332 Practice for Conditioning Containers, Packages, or Packaging Components for Testing
- D6055 Test Methods for Mechanical Handling of Unitized Loads and Large Shipping Cases and Crates
- D6179 Test Methods for Rough Handling of Unitized Loads and Large Shipping Cases and Crates
- E122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process
- E680 Test Method for Drop Weight Impact Sensitivity of Solid-Phase Hazardous Materials
- 2.2 ISO Standards:⁴
- ISO 2206 Packaging—Complete Filled Transport Packages, Identification of Parts When Testing
- ISO 2248 Packaging—Complete Filled Transport Packages, Vertical Impact Test by Dropping
- 2.3 Code of Federal Regulations:⁵
- Title 49 —Transportation (49 CFR)⁵

3. Terminology

3.1 *Definitions*—General terms for packaging and distribution environments are found in Terminology D996.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *cylinder*—for the purposes of this test method, a cylinder includes substantially cylindrical containers such as barrels, drums, kegs, and pails (fiber, metal, plastic, or wood, or combinations thereof).

3.2.2 *member*—a face, corner, or edge of a rectangular container; a chime, end, or sidewall of a cylindrical container; or a face, edge, corner, or butt of a bag or sack.

4. Significance and Use

4.1 This test method is intended for use in evaluating the capability of a container to withstand the sudden shock

⁴ Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

⁵ Available from U.S. Government Printing Office Superintendent of Documents, 732 N. Capitol St., NW, Mail Stop: SDE, Washington, DC 20401, <http://www.access.gpo.gov>.

resulting from a free fall, or to evaluate the capability of a container and its inner packing to protect its contents during the sudden shock resulting from a free fall. This test method may also be used to compare the performance of different package designs. This test method may also permit observation of the progressive failure of a container and the damage to its contents.

4.2 This test method is particularly suitable for containers that are normally handled manually during some part of their distribution cycle. Containers of such bulk or mass that they cannot be handled manually may be tested more satisfactorily in accordance with Test Method **D880**, Test Methods **D6055**, Test Methods **D6179**, or Test Methods **D4003**. See Practice **D4169** for additional guidance.

5. Apparatus

5.1 *Free-Fall Drop Test Equipment*, conforming to the following requirements:

5.1.1 It shall permit the container to be placed, prior to release, in a position that will ensure correct orientation, within 2 degrees upon impact, for flat-face drops or flat drops on ends or sidewalls of cylindrical containers, and within 5° upon impact for other drops, such as edge drops and corner drops for rectangular containers, bags, and sacks and diagonal drops on chimes on cylindrical containers.

5.1.2 It shall permit accurate control of the drop from specified heights.

5.1.3 It shall utilize lifting devices that will not damage the test container.

5.1.4 It shall provide a release mechanism that does not impart vertical, rotational, or sideways forces to the test container. If drop leaves are used, the apparatus shall provide a spring or other mechanism so that the leaves do not interfere with a free, unobstructed fall.

5.1.5 It shall provide an impact surface, horizontal and flat, massive enough to be immovable and rigid enough to be nondeformable under the test conditions.

5.1.5.1 The impact surface shall be of concrete, stone, or steel. If the dropping surface is a steel plate, it must be at least ½ in. (13 mm) thick and must be anchored firmly to the mass.

NOTE 1—Grout (a thin mortar used to fill crevices) is recommended over the entire surface of the mass below the plate to ensure positive contact.

5.1.5.2 The impact surface shall be integral with a mass at least 50 times that of the heaviest container to be tested. Neither the depth nor width of the mass shall be less than half the length.

5.1.5.3 For drop testing of containers not exceeding 110 lb (50 kg), the impact surface shall be flat, such that no two points on the surface differ in level by more than 5/64 in. (2 mm).

5.1.5.4 The impact surface shall be rigid, such that it will not be deformed by more than 0.0039 in. (0.1 mm) when an area of 0.1550 in.² (100 mm²) is loaded statically with 22.05 lb (10 kg) anywhere on the surface.

5.1.5.5 The impact surface shall be sufficiently large to ensure that the containers being tested fall entirely upon the surface.

5.1.6 A rupture hazard may be used for determining the rupture resistance of cylindrical containers or bags. Unless otherwise specified, the rupture hazard should consist of a 4 by 4-in. (102 by 102-mm) timber, of oak or other wood of equivalent hardness, approximately 4 ft (1.2 m) long, having the edges rounded to a radius of not more than ¼ in. (6.35 mm).

5.1.6.1 For testing of 49 CFR—DOT 21C fiber drums, a 2 by 6-in. (51 by 152-mm) timber, with a 6-in. (152-mm) vertical dimension, shall be used. The drum shall be dropped at right angles to the timber. The drop height shall be measured from the top of the timber.

5.1.7 For very large containers, it may be necessary to use a hoist, sling, and tripping devices, or a solenoid-operated drop test mechanism and suspension devices, such as those described in **Appendix X1**.

5.1.8 *Conditioning Apparatus*—Adequate facilities shall be provided for conditioning test specimens at the proper humidity and temperature prior to testing, in accordance with the specification covering the containers to be tested.

5.1.8.1 *Conditioning*—Depending on the purpose of the tests, containers may be conditioned prior to the drop test by either a different physical test, water immersion, exposure to water spray, or exposure to standard or other fixed air temperature or humidity conditions. It is recommended that special atmospheres for conditioning be selected from those given in Practice **D4332**. Unless otherwise specified, fiber-board or paperboard containers shall be conditioned in accordance with the preconditioning and standard conditioning atmospheres specified in Practice **D4332** (see also Practice **D4169** for additional guidance).

5.1.8.2 Where the moisture content of fiberboard containers is determined, it should be determined in accordance with Test Method **D644**.

6. Sampling

6.1 The test specimens and number of samples shall be chosen to permit an adequate determination of representative performance. Practice **E122** is recommended. Unless otherwise specified, Practice **D585** shall be used for acceptance testing of fiberboard containers.

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

7. Test Specimens

7.1 When the protective capability of a container is to be evaluated, it is preferable to pack the container with the actual contents for which it was designed (**Note 2**). When the capability of a container to withstand rough handling is to be evaluated, pack the container with either the actual contents or a load simulating the contents. Regardless of which procedure is used, close the container in the same manner that will be used in preparing it for shipment.

NOTE 2—Where the use of actual contents is not feasible because of excessive cost or danger, a dummy load simulating the contents with respect to dimensions, center of gravity, moment of inertia, density, flow characteristics, etc. may be used. Accelerometers or other indicating

mechanisms may be installed.

7.2 Close and seal the container in the normal manner. Dry and age sufficiently so that any adhesive, protective coatings, sealing tape, and so forth will have reached their final normal condition.

8. Procedure

8.1 Identify members as specified in **Annex A1**, by marking, at a minimum, Faces 1, 2, and 5 of rectangular containers; Positions 1, 3, 5, and 7 of cylindrical containers; and Faces 1, 4, and 5 of sacks and bags.

8.2 Unless otherwise specified, establish failure criteria prior to the commencement of testing. (See Practice **D4169**, Acceptance Criteria.)

8.3 Test containers that have been conditioned in the conditioned atmosphere or immediately upon removal from that atmosphere.

8.4 Conduct drop test procedures by dropping the container on either one member or several different members in a prescribed sequence (cyclical testing).

8.4.1 When the container is to be dropped flat on a face, position it so that, upon impact, there is no more than a 2° angle between the plane of this face and the impact surface.

8.4.2 When a rectangular container or bag is to be dropped on an edge, position it so that, upon impact, this edge makes no more than a 2° angle with the impact surface, and the plane containing this edge and the center of gravity of the container makes no more than a 5° angle with the vertical.

8.4.3 When a rectangular container or bag is to be dropped on a corner, position it so that, upon impact, the line containing this corner and the center of gravity of the container makes no more than a 5° angle with the vertical.

8.4.4 When a cylindrical container is to be dropped on either a chime or a circumferential edge, position it so that, upon impact, a plane containing this edge and the center of gravity of the container makes no more than a 5° angle with the vertical plane perpendicular to the drop surface.

8.4.5 When determining the rupture resistance of cylindrical containers or bags, place a rupture hazard (see **5.1.6**) on the target surface, and position it so that, unless otherwise specified, the center of the cylinder sidewall or face edge or butt of the bag impacts across the hazard.

8.4.6 Before each drop of a bag or sack, distribute the contents uniformly throughout the bag or sack.

8.5 *Height of Drop*—Determine the height of the drop by measuring from the bottom surface, edge, or corner of the container to the impact surface.

9. Report

9.1 Report the following information:

9.1.1 Reference to this test method, including a statement to the effect that all tests were conducted in full compliance with the requirements of this test method, or noting any variations and their details.

9.1.2 Dimensions of the container under testing; complete structural specifications; kinds of materials; description and specifications for blocking and cushioning, if used; spacing,

size, and type of fasteners; method of closing and strapping, if any; drying and aging time, if any; and tare and gross masses.

9.1.3 Description of the contents of the container under testing and, if not tested with the actual contents intended to be shipped, description of these actual contents.

9.1.4 Number of specimens tested per sample.

9.1.5 Method of conditioning the container, if any; moisture content of the wood, plywood, or fiberboard, if determined; and results of any supplementary tests of the materials from which the container is made.

9.1.6 Description of apparatus and special instrumentation, if used.

9.1.7 Whether a 4 by 4 timber was used as a hazard. Where a hazard other than that specified in **5.1.6** is used, a description of the hazard used.

9.1.8 Details of the failure criteria used.

9.1.9 Member(s) tested (see **Annex A1**).

9.1.10 Description of the prescribed test sequence, if used.

9.1.11 Drop height(s).

9.1.12 Size of the increment, if a variable height drop test procedure is used.

9.1.13 Number of drops (at each incremental height, if applicable).

9.1.14 Detailed record of the test results for each container, including damage to the container and contents, together with any other observation that may assist in interpreting the results correctly or aid in improving the design of the container or method of packaging, blocking, or bracing.

9.1.15 Where a mean failure height is determined by dropping, a statement of this mean and the estimated standard deviation and level of confidence.

9.1.16 Name and address of the testing agency, date, and signature of a responsible representative of the testing agency.

10. Precision and Bias

10.1 *Precision*⁶:

10.1.1 A precision statement is not applicable when the drop test is conducted at a specified drop height to determine conformance with established acceptance criteria.

10.1.2 When the drop test is conducted to determine the drop height to failure, the observed precision is a combination of the precision of the test method (including apparatus, operators, etc.) and the precision of the packaged product being tested. Experience has shown that the observed precision is highly dependent on the particular packaged item being tested. Research Report D10–1004 describes an interlaboratory test program of three packaged items, establishing drop heights to failure. The mean drop heights to failure for the three types of packaging were 39, 42.6, and 47.7 in. (991, 1083, and 1212 mm). The repeatability (within laboratory) standard deviation ranged from 3 to 10 in. (75 to 250 mm) for these items. The pooled reproducibility (between laboratory) standard deviation was 2.25 in. (57 mm). The research report suggests that tests of some items produce data that are not distributed normally; log-normal, Weibull, or other distributions may be applicable.

⁶ Supporting data are available from ASTM Headquarters. Request RR:D10-1004.

10.2 *Bias*—No justifiable statement can be made on the bias of this test method since a true value cannot be established by an accepted referee test method.

11. Keywords

11.1 bags; boxes; cylindrical containers; drop test; drums; free fall; packaging; sacks

ANNEXES

(Mandatory Information)

A1. IDENTIFICATION OF MEMBERS

A1.1 *Rectangular Containers*—The procedure for identification of the members (faces, edges, and corners) of rectangular containers shall be as follows (see Fig. A1.1):

A1.1.1 Facing one end of the box with the manufacturer’s joint, where applicable, on the observer’s right, designate the top of the box as 1, the right side as 2, the bottom as 3, the left side as 4, the near end as 5, and the far end as 6.

A1.1.2 Identify the edges by the numbers of the two faces that form that edge; for example, 1-2 identifies the edge formed by the top and right side, and 2-5 identifies the edge formed by the right side and near end. (The 2-5 edge is the edge having a vertical manufacturer’s joint, and the 2-3 edge is the edge having a horizontal manufacturer’s joint in fiberboard containers.)

A1.1.3 Identify the corners by the numbers of the three faces that meet to form that corner; for example, 1-2-6 identifies the corner at which the top, right side, and far end meet.

A1.2 *Cylindrical Containers*—The procedure for identification of the members (tops, bottoms, sidewalls, and chimes) of cylindrical containers shall be as follows (see Fig. A1.2):

A1.2.1 The ends of two perpendicular diameters on the upper surface of the cylindrical container shall be designated as 1, 3, 5, and 7; and the other ends of lines parallel to the cylinder axis passing through these points respectively shall be designated as 2, 4, 6, and 8. If the package has one or more side seam joints, one of the joints should occupy the position of 5-6.

A1.2.2 Identify diagonal drops on chimes by designating the drop point by number, that is, drop on 1. Where it is desirable to drop on a midpoint between two locations on the chime, such a point can be designated using two numbers, that is, drop on 1-3.

A1.2.3 Identify flat drops on sidewalls by designating the drop point by two numbers, that is, drop on 3-4. Where it is desirable to drop on a midpoint between two locations on the sidewall, such a point can be designated using four numbers, that is, drop on 1-3-2-4.

A1.2.4 Identify flat drops on ends using the four numbers of that end, that is, 1-3-5-7 or 2-4-6-8.

A1.3 *Sacks and Bags*—The procedure for identification of the members (faces, sides, tops, and bottoms) of bags and sacks shall be as follows (see Fig. A1.3):

A1.3.1 Facing the front of the bag with the top up, designate the front of the bag as 1, the right side edge as 2, the rear side as 3, the left side edge as 4, the bottom as 5, and the top as 6. (Where a bag or sack has one or more side seams, Side 2 shall include a side seam.)

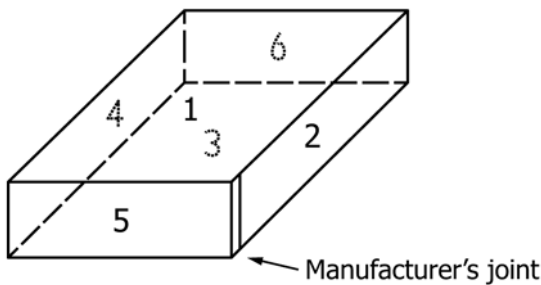


FIG. A1.1 Members of Rectangular Containers

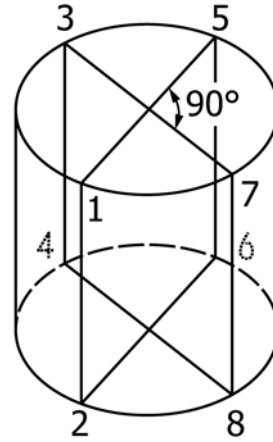


FIG. A1.2 Members of Cylindrical Containers

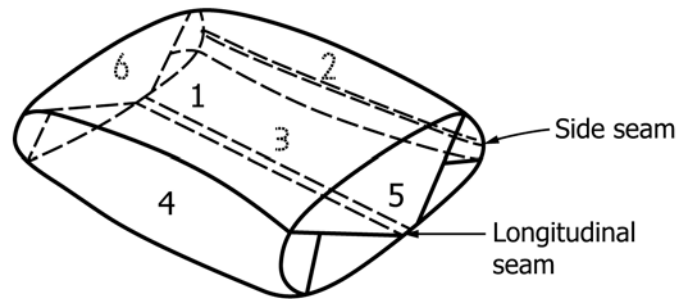


FIG. A1.3 Members of Sacks and Bags

A2. TEST CYCLES AND PROCEDURES

A2.1 The choice of a test cycle or specific procedure depends on the purposes of the tests. Sometimes the drop height, test cycles, and detailed procedures are prescribed in a contract, regulation, or some other standard. Other times a detailed test plan must be determined based on the engineering and business judgments of the interested parties. The drop height, package orientation, and cycle may be chosen based upon knowledge of the shipping environment, knowledge of the type and severity of drop needed to cause certain types of damage to the package or contents, or previous testing or field experience with similar packages. The test plan should also consider the type of information desired from the testing: a statement whether or not preestablished acceptance criteria was obtained; qualification of damage, determination of the drop height to failure; the number of drops to failure, etc.

A2.1.1 This annex covers some test cycles and procedures for using the drop test, but other cycles and procedures are available or may be developed.

A2.2 *Constant Drop Height Procedures*—These procedures consist of single or multiple drops from a constant drop height. Replicate samples should be subjected to identical procedures for comparison and for statistical analysis. Typical types of drop cycles are as follows:

A2.2.1 *Single Drop*—Drop the test package from an orientation and height specified.

A2.2.2 *Ten Drop Cycle (Boxes)*—Drop the test package on a bottom corner (for example, 2-3-5), the shortest edge radiating from that corner, the next longest edge radiating from that corner, the longest edge radiating from that corner, flat on the smallest two faces, flat on the next two largest faces, and flat on the two largest faces.

A2.2.3 *Four Drop Cycle (Boxes)*—Drop the test package on a corner, the shortest edge radiating from that corner, the next longest edge radiating from that corner, and the longest edge radiating from that corner.

A2.2.4 *Twenty-Six Drop Cycle (Boxes)*—Drop the test package on each flat face, edge, and corner.

A2.2.5 *Eight Corner Drop Cycle (Boxes)*—Drop the test package on each of the eight corners.

A2.2.6 *Twelve Edge Drop Cycle (Boxes)*—Drop the test package on each of the twelve edges.

A2.2.7 *Four Rim Drop Cycle (Cylindrical Containers)*—Drop the test package once on each half of the top and bottom rims.

A2.2.8 *Six Flat Drop Cycle*—Drop the test package flat on each face for a box or each end and four sides for a bag or cylinder. With a cylinder, the four side drops shall be 90° apart.

A2.2.9 *Repeated Drop Cycle*—Drop the test package for a prescribed drop or drop cycle. Continue dropping on similar cycles until a specified type of damage is noted to the package or contents. This procedure determines the number of drops or cycles required to damage the package or contents.

A2.2.10 *Critical Orientation*—When a drop is specified for a most critical or damage-prone orientation, a single drop is required on that orientation. The determination of the critical orientation must be provided. It may be a formal study of the relationship between drop orientation and damage, other engineering analyses of that product and package, or laboratory and field experience with similar packages.

A2.2.11 *Hazard Drop*—Drop the test package onto a specified hazard from a specified height and orientation.

A2.3 *Progressive Drop Height Procedure:*

A2.3.1 Drop the test package from an initial drop height chosen to be unlikely to cause predefined damage to the package or contents. This will be in a prescribed orientation or a prescribed cycle of drops. If no damage occurs from the initial drop height, increase the drop height by a predetermined increment. Repeat the drop or drop cycle on the same package until the predefined damage has occurred. It is common to estimate the critical drop height as the midpoint between the last successful test and the test which caused damage; use of the successful test point before failure may be considered a more conservative estimate. Replicate samples should be subjected to identical procedures to determine the consistency of the failure point. A normal distribution cannot be assumed for statistical analysis; a log-normal or Weibull distribution are often better.

A2.3.2 This procedure can produce damage or failure based on the cumulative effects of all previous drops. Sometimes a single drop or drop cycle from a height which caused cumulative damage of this procedure will not cause similar damage to the package or contents.

A2.4 Up and Down Procedure:

A2.4.1 This procedure is used when the median drop height (H_{50}) to failure is desired but the progressive height procedure cannot be used because of the effects of cumulative damage. This procedure varies the drop height for each drop or cycle but with a new test specimen for each. The number of test specimens depends on the purpose of the tests but will usually require eleven or more replicate test specimens; using much larger sample sizes will result in higher confidence in the resulting statistics. It is best to choose an odd number of test specimens.

A2.4.2 Drop the first test package for a prescribed drop or drop cycle from a drop height estimated as being the average drop height to failure. If this specimen passes at this drop height, the next test will be at a higher drop height with a new package. If it fails, the next test will be a lower drop height. The height of each drop is thus determined by the result of the previous test. The drop height increment is a constant and should be between $\frac{1}{2}$ and 2 times the estimated standard deviation; it often may be 3 to 4 in. (75 to 100 mm).

A2.4.3 If a normal distribution can be assumed, estimation of the average or median drop height to failure begins with counting the number of passes and failures. If there are more passes than failures, compute the arithmetic mean of the height of the failures and subtract $\frac{1}{2}$ of the drop height increment. If

there are more failures than passes, average the height of the passes and add $\frac{1}{2}$ of the drop height increment.

A2.4.4 To estimate the standard deviation of the drop height to failure, calculate the standard deviation of the test data: the drop height of the passes, of failures, whichever is less frequent. This must be based on n , the number of passes or failures, and not $n - 1$ as is found on some calculators.

$$S = 1.62 \left(\frac{S_t^2}{d^2} + 0.029 \right) \quad (\text{A2.1})$$

where:

- S = estimated standard deviation of the drop heights to failure,
- S_t = calculated standard deviation of test data for passes or failures, whichever is less frequent, and
- d = drop height increment.

A2.4.5 A normal distribution cannot always be assumed. Several texts^{7,8,9} on experimental statistics and standards, describe this test procedure in more detail, provide additional calculations, and discuss methods to compensate for non-normal distributions (see Test Methods **D2463** and **E680**). The use of a log-normal distribution is often suggested but this requires the drop height increment to be a constant based on the logarithms of the drop height, thus the actual drop height increment would change with the drop height.

⁷ Dixon, W. J., and Massey, F. J., *Introduction to Experimental Statistical Analysis*, McGraw Hill, 1969, pp. 337-393.

⁸ Lipson, C., and Sheth, N. J., *Statistical Design and Analysis of Engineering Experiments*, McGraw Hill, 1973, pp. 270-274.

⁹ Natrella, M. G., "Experimental Statistics," *NBS Handbook 91*, U.S. GPO, 1963, Chapter 10.

APPENDIX

(Nonmandatory Information)

X1. DROP TEST MECHANISMS

See **Figs. X1.1-X1.4**.

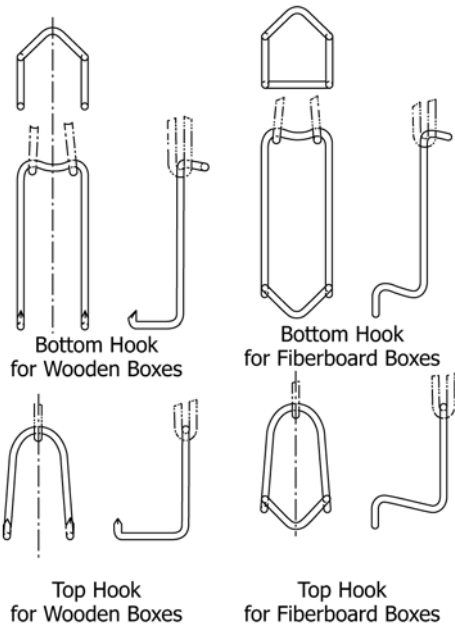


FIG. X1.1 Hooks for Hoist-Siling Drop Test Apparatus

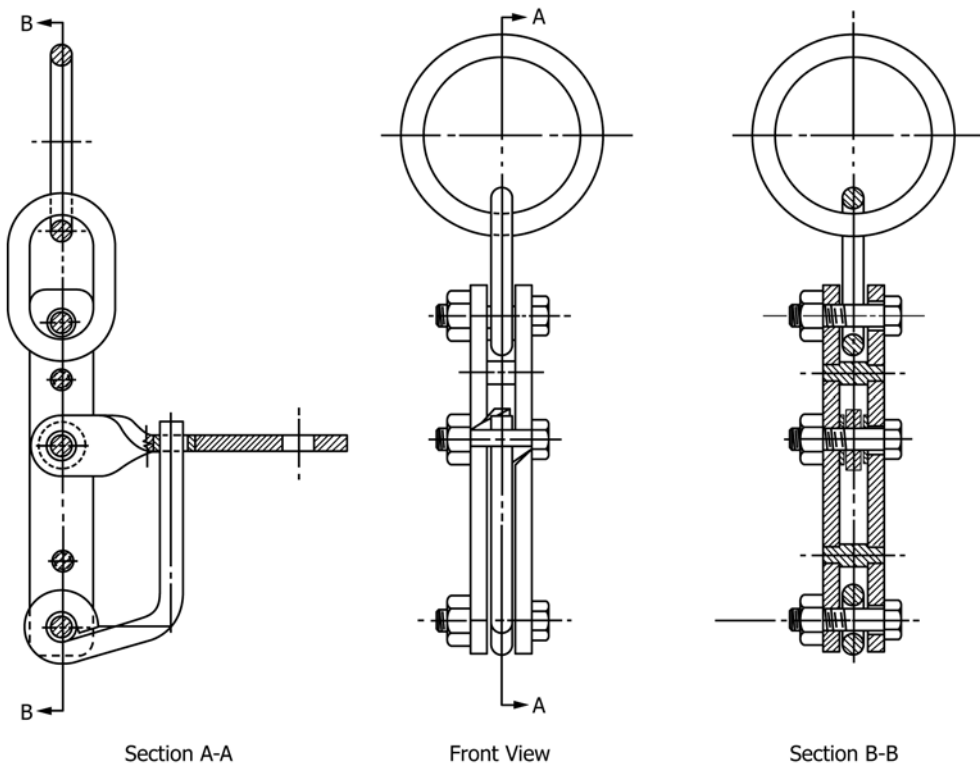


FIG. X1.2 Tripping Device for Hoist-Siling Drop Test Apparatus

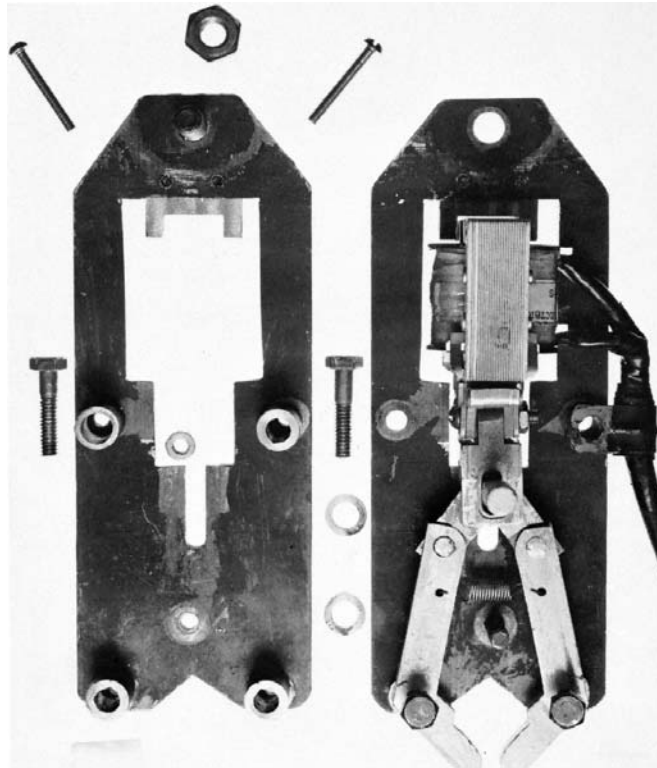


FIG. X1.3 Solenoid Release Mechanism With Face Plate Removed and Holding Jaws in Open Position



FIG. X1.4 Corner Suspension Device Attached to a Conventional Truck Corner Sealed Inside Box to Be Tested

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