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Standard Guide for Transport Packaging Design[1]

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1. Scope

1.1 This guide covers an approach to design of packaging for distributing goods through the hazards of handling, storage, and transportation.

1.2 The principal content of this guide is the identification of the key steps involved in development of transport packages, including shipping containers, interior protective packaging, and unit loads. It is recognized that actual usage and application to individual design projects may vary appreciably without diminishing the value of the process. Consult with a packaging professional whenever needed.

1.3 This guide is not intended for design of primary packaging unless the primary package is planned for use as a shipping container.

1.4 The user of this guide must be aware of the carrier rules regarding packaging for shipment via each mode of transportation in which the transport package may move, such as the National Motor Freight Classification (less-than truckload) and the Uniform Freight Classification (railroad). For hazardous materials packaging, the packaging must perform to the requirements of the applicable modal regulations listed in Section 2.

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]

D642 Test Method for Determining Compressive Resistance of Shipping Containers, Components, and Unit Loads

D880 Test Method for Impact Testing for Shipping Containers and Systems

D996 Terminology of Packaging and Distribution Environments

D999 Test Methods for Vibration Testing of Shipping Containers

D1974 Practice for Methods of Closing, Sealing, and Reinforcing Fiberboard Boxes

D3332 Test Methods for Mechanical-Shock Fragility of Products, Using Shock Machines

D3580 Test Methods for Vibration (Vertical Linear Motion) Test of Products

D4003 Test Methods for Programmable Horizontal Impact Test for Shipping Containers and Systems

D4169 Practice for Performance Testing of Shipping Containers and Systems

D4728 Test Method for Random Vibration Testing of Shipping Containers

D4919 Guide for Testing of Hazardous Materials Packagings

D5276 Test Method for Drop Test of Loaded Containers by Free Fall

D5487 Test Method for Simulated Drop of Loaded Containers by Shock Machines

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

D6344 Test Method for Concentrated Impacts to Transport Packages

D6537 Practice for Instrumented Package Shock Testing For Determination of Package Performance

D6653 Test Methods for Determining the Effects of High Altitude on Packaging Systems by Vacuum Method

D6804 Guide for Hand Hole Design in Corrugated Boxes

D7030 Test Method for Short Term Creep Performance of Corrugated Fiberboard Containers Under Constant Load Using a Compression Test Machine

D7386 Practice for Performance Testing of Packages for Single Parcel Delivery Systems

D7387 Test Method for Vibration Testing of Intermediate Bulk Containers (IBCs) Used for Shipping Liquid Hazardous Materials (Dangerous Goods)

D7660 Guide for Conducting Internal Pressure Tests on United Nations (UN) Packagings

[1] This guide 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.

2.2 *ISO Standard:*

ISO 4180 Complete Filled Transport Packages—General Rules for the Compilation of Performance Test Schedules[3]

2.3 *Other Documents:*

National Motor Freight Classification[4]

Uniform Freight Classification, Rail Publication Service[5]

International Civil Aviation Organization Technical Instructions for the Safe Transport of Dangerous Goods by Air[6]

IMDG Code, International Maritime Dangerous Goods Code[7]

IATA Dangerous Goods Regulations[8]

United States Code of Federal Regulations Title 49, Transportation (CFR-49)[9]

International Safe Transit Association Procedures[10]

3. Terminology

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

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *interior protective packaging*—packaging materials or forms used within shipping containers to protect contents from damage in distribution by cushioning, bracing, spacing from container walls, preventing abrasion, filling voids, and so forth.

3.2.2 *transport packaging*—packaging for containment and protection of goods during handling, storage, and transportation in the physical distribution process. The scope of transport packaging includes all of industrial packaging as well as the shipping containers, interior protective packaging and unitizing required for consumer packages.

4. Significance and Use

4.1 This guide assists users in design and development of packaging intended for the protection of goods while they are in transit from point of origin to final destination. By following all steps of this guide, users will be assured that the most important factors are included in package design. In some cases, the sequence of steps may be changed, and often the steps may occur simultaneously with concurrent work activities.

4.2 The design process focuses on protection from hazards of handling, storage, and shipping while recognizing the economics of all other facets of distribution, including packaging materials and labor, and transportation.

4.3 In transport packaging, *distribution* is generally defined as inclusion of handling, storage, and transportation factors.

5. Procedure

5.1 *Introduction:*

5.1.1 Although no single procedure can be expected to meet all requirements for all design options, there are general areas of information that are necessary for the design process to be most useful. The more information in each of these areas that can be obtained accurately, the greater the probability of optimizing the final design for cost performance utility, timeliness, and environmental considerations. Other interested parties, such as customers or end users, should be contacted for any specific package design criteria.

5.1.2 The following sequence, listed in 5.2-5.12, may not always be applicable to every design process and may be changed to fit particular circumstances, products, markets, distribution methods, etc. Environmental hazards presented by the distribution environment (see 5.4) may be known long before a new product (see 5.2) is fully designed or ready for distribution (see 5.3). Such knowledge can in fact contribute to the design of the product to ultimately reduce the amount of packaging that will eventually be required. The user of this guide is encouraged to examine each particular situation and decide the best order in which to proceed, without omitting any of the basic steps that follow.

5.2 *Identify Physical Characteristics of the Package Contents*—It is important to know more about the package contents (goods) than simply its dimensions and weight. The package designer must be aware of physical and chemical characteristics and hazardous properties so proper packaging can be developed. These include: susceptibility to abrasion, corrosion, temperature, static electricity, or magnetic fields; the ability to hold a load in compression, the contents' ability to withstand the effects of shock and vibration during distribution, and intended shelf life. See Test Methods D3332 and D3580 for methods of determining shock and vibration fragility of products.

5.3 *Determine Marketing and Distribution Requirements:*

5.3.1 Package design must include consideration of marketing and distribution requisites in addition to product characteristics. These requirements, in many cases, take the form of marketing graphics, product identification, and compliance labeling.

5.3.1.1 Compliance labeling can also take many forms. Some items to consider are identification of country of origin, hazardous materials transportation regulations, Truth in Packaging requirements, and bar coding. Besides the actual printed graphics, one may want to consider proper substrate for printing and any required coatings.

5.3.1.2 Distribution requirements can likewise take on many forms of consideration including: the number of units that will ship in a container; the composition and attributes of the primary package; the identity of customers and their handling and storage requirements; the package disposal criteria; total volume expected per shift/day/year; expected life cycle; the planned modes of transport; domestic and international rules or regulations for packaging via those transport modes; types of

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

[4] Available from National Motor Freight Traffic Association (NMFTA), 1001 North Fairfax St., Suite 600, Alexandria, VA 22314, http://www.nmfta.org.

[5] Available from Railinc, 7001 Weston Pkwy, Suite 200, Cary, NC 27513.

[6] Available from International Civil Aviation Organization (ICAO), 999 University St., Montreal, Quebec, H3C 5H7, Canada.

[7] Available from International Marine Organization, 4 Albert Embankment, London, Ontario 5E1 7SR Canada.

[8] Available from International Air Transport Association (IATA), Customer Service Rep., 800 Place Victoria, P.O. Box 113, Montreal, Quebec H4Z 1M1.

[9] 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.

[10] Available from International Safe Transit Association (ISTA), 1400 Abbott Road, Suite 160, East Lansing, MI 48823-1900.

distribution channels; maximizing loads in carrier vehicles; freight classification; handling and storage requirements; production equipment; environmental issues; etc.

5.3.1.3 This listing is not all inclusive and other considerations than these also may be important to the total package design.

5.4 *Identify Environmental Hazards Your Packages May Encounter*—Knowledge of the distribution environment is key to designing an optimum transport package. Major hazards to be expected in the environment are: rough handling; vibration and shock in-transit; compression in storage or in-transit; high humidity and water; atmospheric pressure; salt/corrosion; static electricity; temperature extremes; pilferage; insect infestation; and concentrated impact forces. Identifying these hazards and quantifying them may include observation, conducting measurements, or reading research reports (see the references listed in Practice D4169).

5.5 *Consider All Available Alternatives :*

5.5.1 There are many alternatives available for shipping containers, interior protective packaging, and unit loads. All should be considered and reviewed before selecting the final types for further development. Trade-off comparison analysis techniques often help in the selection process. Rather than considering only materials that one has experience with, comparing paper versus plastic versus wood versus metal is a good exercise at times to assure the optimum solution for a particular project.

5.5.2 Three major factors influencing selection of alternatives are: package performance, total system cost, and environmental impact of materials.

5.5.2.1 The final package design will also have a significant impact on overall distribution costs. It will influence materials costs, labor costs, capital requirements, overhead allocations, handling costs, freight and transportation costs, damage costs, and those costs and issues involved with the eventual disposal of the package components.

5.5.2.2 The overall environmental impact of a design may be quite difficult to quantify. Factors such as broad access to recycling systems or markets will have significant impact on this issue. One commonly used approach to dealing with environmental impact for broadly distributed goods has been to use a design approach prioritizing the common concerns of Reduce, Reuse, Recycle, Energy Recovery, and Safe Disposal. For packages developed for products having focused markets in specific locations, it may be more beneficial to emphasize a single element of the preceding concerns (that is, returnable packaging for products sold only locally, and so forth). The design approach could also be altered to either increase environmental efficiency or comply with appropriate regulations, legislation, or organization policies.

5.5.2.3 One means of evaluating the overall effectiveness of a package design is to benchmark or compare it to designs from competitors for like products or to designs from companies or organizations recognized for packaging excellence. Often such comparisons can help confirm original design assumptions (required performance levels, acceptable costs, and so forth) and can provide an additional level of confidence for a new design. If a benchmarking effort indicates the design is not within the original design assumptions, a design review might be in order.

5.6 *Design the Transport Package :*

5.6.1 After basic materials and information are established in the previous steps, the designer can then systematically develop a transport package, and unit load where appropriate. Each component of the transport package is analyzed for strength and other required properties and compared to technical data available from suppliers. Some packaging materials have good design data available, but most do not. Designers frequently rely on experience to reach a successful solution, but others may find that lack of information makes it difficult to arrive at an optimum solution. Such lack of information may require that the designer approach the supplier or suppliers involved to request that they take whatever steps are necessary to provide the information needed. If this approach is not feasible, third-party laboratories, consultants, or academic institutions may be an alternative resource.

5.6.2 Evaluation and improvement of package design can be shortened by conducting engineering tests in package development. Most helpful in the design process is the establishment of test requirements prior to finalizing for sample making. Tests such as impact, vibration, and compression not only identify shortcomings in design, but also help to fine-tune to an optimum solution for anticipated hazards. Test Methods D642, D880, D999, D4003, D4728, D5276, D5487, D6055, D6179, D6344, D6653, D7030, D7387, and D7660 are frequently utilized for this purpose. (See Section 2 for these test methods.)

5.6.3 An additional benefit of engineering tests during package development can be realized by the inclusion of instrumentation during the test procedures (see Practice D6537). Through instrumented measurements of the package's performance during such testing, the designer can determine more precisely the margin by which the package being tested either meets or fails the design criteria. If the package is insufficient, the designer can use the measured values to establish the best and most efficient ways in which to improve the design. When the package passes the design criteria, the designer can also gain valuable information through instrumentation to determine whether the design is too conservative and might result in overpackaging.

5.7 *Select the Proper Type of Closure for the Shipping Container*—The effectiveness of the transport package in retaining and protecting its contents in distribution is influenced by the package closure and method. In addition to handling hazards, method of packing, and type of product to be packed, the selection of the closure should include consideration of any rules or regulations pertaining to the product, package, or transport mode. For fiberboard boxes, Test Method D1974 provides guidance for methods of closure.

5.8 *Determine Adequacy of Protection by Performance Tests:*

5.8.1 After the package design is completed, its adequacy for protecting goods in-transit should be checked prior to actual shipment. The accepted practice is to perform laboratory pre-shipment testing procedures designated as performance

tests. This consists of subjecting the package to a sequence of anticipated hazards/tests in the laboratory for the purpose of a pass/fail decision. Will it protect its contents all the way through distribution? In developing a test plan that would best subject the packages to the hazards that may be encountered within the distribution cycle, refer to the following: Practice D4169, Guide D6804, Practice D7386, ISO 4180, Rule 180 (NMFC), ISTA, or CFR 49, or Specification D4919.

5.8.2 The performance tests in Practice D4169 utilize ASTM test methods having considerable experience and history behind their development and use, and a successful completion of a properly designed and formulated performance test sequence greatly increases the probability of damage-free shipments for the distribution cycle intended. For users who can clearly define their distribution cycles, but find them different than the standard cycles listed, Practice D4169 also provides a means of developing a unique sequence of tests, resulting in performance tests which can more precisely simulate the actual conditions of the user's environment.

5.8.3 The inclusion of instrumentation during performance testing for verification of design may provide added beneficial information (see Practice D6537). Through such measurements of the package's performance in such testing, the designer can determine more precisely the margin by which the package being tested either meets or fails the performance criteria. If the package is insufficient, the designer can use the measured performance values to establish the best and most efficient ways in which to improve the design. Even if the package passes the performance verification procedures, the designer can gain valuable information through instrumentation to determine whether the design is too conservative and might result in overpackaging.

5.9 *Redesign the Package or Product if Required:*

5.9.1 If the package or product fails to pass the performance tests, one or both need to be redesigned and the performance test repeated.

5.9.2 Testing may reveal potential product improvements that may help increase the strength of the product through product redesign. This is especially important when the cost of the product redesign is less than the extra packaging that would be required if product improvements were not made. Use Product Fragility Test Methods D3332 and D3580 to identify product improvement opportunities and measure the increase in strength when product improvements have been made.

5.10 *Develop the Methods of Packing* —An important part of package design is determining the optimum method and equipment for packing of goods in shipping containers. Although this may be the responsibility of someone else, that is, industrial engineering, the package designer must be aware of cost factors and the appropriateness of mechanizing or automating all or part of the operations. Sometimes a trade-off of package design for improved packing methods is required to achieve overall system economy. Ease and economy of packing, closure, and opening are key factors to consider. Whenever an improved packing method or equipment requires a new or modified package design, be sure to test the redesigned package.

5.11 *Document ALL Work*—One step often overlooked in the design process is documentation. This includes documenting original requirements, test results, specifications, drawings, and methods of packing. Names of persons involved should always be included on all documents. Drawings should be in company standard formats with appropriate designations for reference in the corporate specification system. Relying on supplier sketches or drawings as the reference document is not advisable. They should be transferred to company format so purchasing, manufacturing and engineering can reference them.

5.12 *Monitor Shipping Experience* —When a new or modified packaging design has been implemented, it is beneficial to monitor its performance during actual production, distribution, sale, and use. One method is to use customer complaints as a measurement, although this may understate actual problems. It is often better to proactively audit field performance by inspections, customer feedback forms, or by direct customer interviews. Feedback on this shipping experience can be used as the package design is considered for modification.

6. Keywords

6.1 compression; distribution environment; handling; impact; interior protective packaging; performance test; shipping container; shock; transport package; unit load; vibration