IoPP Transport Packaging Committee

Guide to Packaging Freight Shipments

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Scope

These guidelines are voluntary and intended to assist in designing packages and other shipping units weighing 151 pounds or greater, that will perform satisfactorily as single entities in a domestic or international freight carrier environment. These guidelines are not to be considered approved carrier packaging specifications. Following part or all of these guidelines will not guarantee the automatic approval of a damage claim by any carrier.

Terminology

The following terms are specific to this guide:

Performance-based: Design criteria focused on achieving a satisfactory performance to specified elements, such as degree of hazard.

Shipping Unit: The complete unit that will be subjected to the distribution environment, for example a crate, box, bag, pallet, or bundle capable of movement by mechanical handling equipment.

Single Package: A single shipping container, including any interior protective packaging, which provides a means of protecting and handling a product.

Freight Carriers: Distribution carriers that utilize air, ocean or land to transport shipments weighing over 150 pounds or shipments that are unitized or palletized.

Freight Shipment: A shipment tendered to a freight carrier

Oversize Shipment: A shipping unit exceeding the carrier's size or weight requirements.

Transport Package: A shipping unit that provides containment and protection to goods during handling, storage, and transportation. The term includes all industrial packaging and the shipping containers for consumer products.

Significance and Use

This guide addresses the transportation environment, which includes manual handling and the use of mechanical handling equipment.

These guidelines will assist users in design and development of packaging intended for protection of goods while they are in transit from point of origin through various freight

systems until reaching their final destination. **The focus of this guide is shipments weighing more than 151 pounds.**

This guide includes domestic and international freight parcel shipments. **Shipments of regulated hazardous materials are excluded** from this guide. If a hazardous substance is to be packaged for shipment, seek guidance from the in-house hazardous materials specialist or the carrier. Additional information is available at the Department of Transportation website, **http://hazmat.dot.gov**, or phone 800-467-4922.

This guide is not a set of detailed material specifications and design procedures. This guide is a listing of desired performance criteria for the transport package. Generally, the transport package addressed by the guide will be secondary packaging, although for some goods the transport package will be primary packaging. The following section on "The Shipping Environment" also applies to *unpackaged* products (tires, spools of wire, castings, etc.) since freight carriers transport many types of unpackaged goods.

To facilitate development of proper packaging, users of this guide should be aware of the characteristics of package contents, including:

- Ability of the contents to withstand the effects of shock, compression and vibration during handling and transportation;
- Ability to support a load in compression
- Susceptibility to abrasion, moisture, corrosion, temperature, static electricity and magnetic fields.

The Shipping Environment

The normal shipping hazards found in the freight environment can vary by mode. Truckload, LTL, railcar, ocean and airfreight shipping environments typically include hazards that are unique to those modes as well as their common hazards. Many of the more severe hazards are due to the number of separate handlings required and the mechanized material handling equipment used.

Typical Carrier Systems: Most freight carriers rely on a "hub-and-spoke" network

to cover large areas and offer fast, predictable transit times for shipments. The hub-and-spoke system uses major sorting facilities, often called "hubs" or "depots", acting as exchange points for packages moving long distances. Hubs are designed to sort thousands of packages an hour, permitting the quick exchange and redirection of freight.

Each hub is connected to a number of terminals or operating centers, which serve as home base for the local freight delivery vehicles and where the pickup and delivery service within specific geographic areas are provided. Operating center boundaries are contiguous so that every address is

covered. This system allows next-day ground service to destinations where such is possible**.** In this system, just because a shipment is designated as a freight package for "next-day air" does not necessarily mean it will travel in an aircraft.

Within each hub or operating center, the freight shipment may travel through the system in a variety of ways, depending on the characteristics of the packaging and the equipment and processes utilized by that particular facility. Shipments can be classified as either *regular* or *irregular*.

Regular freight shipments are those that fall within the carrier's guidelines and are easily handled and transported without special care. Regular Package designers should check their carrier to determine the carrier's specific size and weight limits.

Irregular shipments may be:

- Odd or unwieldy shaped shipments making them difficult to handle without damage
- Oversize with dimensions exceeding the carrier's standard limits
- Configured or labeled in such a way as to prohibit stacking
- A potential hazard to other shipments or personnel
- A shipment without any type of shipping container

During relatively short distance shipments (300 miles), some carriers may load/reload packages as many as five times and handle them using multiple methods including manually and mechanically**,** or automatic handling**.** Longer distances will likely result in more loading, unloading, and sorting operations. These operations present a number of hazards that could cause damage if the packaging does not provide adequate protection.

Transportation Hazards

There are many possible hazards in this environment, but the five principal ones are: shock; vibration; compression; extreme climate conditions; and altitude.

Shock - will occur during handling when shipments are dropped, are struck by (or strike) other packages or objects during the sorting operation, or when they shift or fall during transit. The impacts create shock, which may cause fatigue or damage to the packaging and their contents. Recent studies of the handling environment of freight carriers have shown that the majority of shocks result from non free-fall impacts and that most impacts are equivalent to drops from a relatively low height.

Recent studies also indicate that impacts to shipments are mostly rotational drops on edges and somewhat less on corners. Few perfect flat or perfect edge/corner drops are encountered. Most impacts occur on the bottom surface, corners or edges of the shipments. From the package-engineering standpoint, packages should be designed to withstand shock from any direction. Due to the manual and mechanical handling methods, freight carriers may not guarantee orientation or shock labels, or "keep upright" arrows. Therefore, transit

orientation may be different than the intended orientation. More likely, freight shipments will travel in the most stable orientation, usually the package's lowest center of gravity. This helps prevent freight packages from falling over during the normal loading or sorting process.

If irregulars are handled mechanically with forklift trucks, freight package impacts are most often the result of contact with the forklift, other freight shipments or the freight shipment

falling from the forklift during handling. The drop distance will depend on the height of the load being handled and the distance of the forklift blades from the surface, distances typically ranging from 4 to 48 inches. (These types of drops do not occur as frequently as impacts) -Other types of impacts that occur during forklift handling include: impacts with pallets and other freight shipments; impacts with fork lift blades as freight packages bounce during handling; and impacts as freight packages are loaded into or unloaded from trailers, trucks, freight containers, racks or carts during sorting or transportation.

Vibration- occurs when a freight package is mechanically moved or transported. Mechanical handling induces a low level of vibration into freight packages as the freight packages bounce on the pallet or directly on the forklift blades during transit. Manual sorting induces virtually no notable vibration. Wide variations of transportation vibration may also occur in different rural and developed areas of the world, which require special considerations or local data collection utilizing the latest vibration measurement technology.

In-transit motions subject freight packages to many levels of vibration over different durations of time. Aircraft and ocean going vessel vibration is typically low amplitude depending on origin, destination, and the carrier's network. Truckload and trailer on flatbed railcar (TOFC, sometimes called piggyback) will subject the freight packages to much higher amplitudes than aircraft or ocean vessels. The duration can range from 5 minutes to several days. Vibration can result in damage including scuffing, abrasion, loosening of fasteners and closures, freight package or freight product fatigue and failure.

Compression- may be a static condition, as in a trailer, railcar, ocean container or aircraft when the freight package is under load from other freight packages and the vehicle is not moving. Or it may be a dynamic condition, when the trailer, ocean container or aircraft is in motion. Dynamic compression will impose both vertical and lateral compressive forces when pressure is exerted onto the side of a freight package. This can occur when forklift-handling equipment is used to push loads into place inside a truck, trailer, rail car or aircraft container. When freight packages are pressed at mid-panel, the vertical side panels are more likely to bend or deflect. This deflection can cause internal EPS or other rigid cushioning or molded pulp inserts to fail and cause harm to the content or it's accessories. Ultimately, dynamic compression degrades the compression strength of the outer freight package container. In many instances stacking is unavoidable due to space and time constraints. Even with labels, such as "Do Not Stack" and "Top Load Only" warnings, special labels may not be guaranteed.

Freight handlers may at times use an interlocking method rather than column stacking when loading freight shipments into trailers or aircraft containers, usually building a "wall" across the trailer or container. (Interlocking reduces corrugated box stacking strength up to 50%, compared to column stacking. However, interlocking patterns are more stable and better suited for random size shipments). Although the recommended practice is to load lighter shipments on top of heavier shipments and smaller shipments on top of larger shipments, there is no guarantee of this since freight packages arrive in a random fashion to the build-up or loading area and must be loaded as received.

Freight handling and sorting operations contribute lower levels of compressive forces than in-transit movement. One exception to this is when freight shifts in-transit. This can create a large dynamic compressive force as heavier packages slide into, and accumulate against, other freight packages. Other instances of high compressive force can occur when pallets and forklifts are used to sort or load and unload freight packages. This is especially true when freight packages overhang the pallet or are pushed into another pallet or against a vehicle or container wall. Compression damage can also occur when pallet loads are stacked on top of each other. A loaded freight pallet with bottom deck boards will cause less damage to a load below it compared to a freight pallet with no bottom deck boards. A freight pallet with full bottom deck provides the best load support.

Climatic conditions- Environmental conditions which may cause damage due to effects of temperatures and humidity. In most instances, carrier vehicles, as well as rail cars, are not conditioned. Therefore packages will be exposed to the same, or more extreme temperature and humidity inside the vehicle than exists outside. Freight packages may be exposed to temperatures as high as 140°F or as low as -50°F inside the vehicle, and relative humidity as high as 100%. The only exception is when a freight shipment is inside a temperature controlled trailer, ocean container, or aircraft. Large cargo aircraft are normally conditioned to approximately 68°F to 74°F (refer to carrier for their specific aircraft temperature information).

Altitude- Freight shipments may be exposed to altitudes as high as 20,000 feet in air shipments that travel in non-pressurized aircraft. Large cargo jets are pressurized to approximately 8,000 feet. Over-the-road altitudes can vary as the shipments move through, across or over mountains. Domestic shipments in the USA typically do not exceed altitudes of 12,000 feet.

Other conditions- Several other conditions encountered in most freight shipment delivery systems are different than those in other modes of transport. These include the orientation of packages when tilted on inclines and in flight, and the "bridging" of long packages inside trailers or unit load devices. These conditions are also prevalent during Ocean vessel transportation.

Loading and unloading of trailers and ocean containers may require forklifts to travel on incline ramps where package tilting can occur. Maintaining orientation is more difficult as the available space becomes limited. Pallet loaded freight shipments are normally kept upright but un-palletized freight shipments can be loaded in any orientation that allows them to fit into the available space.

In-transit inclines vary greatly between modes of transportation. Compared to trucks, aircraft are unique because they can move quickly and sharply in all three directions at the same time. For example, the maximum operation angles for two common all-cargo aircraft are listed below:

DC-8: 30-degree bank max, 10-degree descent max, 15-degree climb max.
DC-10: 30-degree bank max, 10-degree descent max, 20-degree climb max.

Ocean vessels may move in six different directions simultaneously (heave, yaw, pitch, roll, surge and sway). The severity and frequency of these motions is dependent on a number of factors including the vessel size, weight, load configuration, and tide, weather or sea conditions. These forces in transit, in addition to load shifting and vibration, may cause shipments to move in virtually any orientation and angle.

Bridging occurs when a long package is only supported near its ends. Damage can occur if the bridged package is struck near its center by another freight shipment, forklift, or other type of material handling equipment. In transit, long packages may be oriented such that they are not supported along their entire face (bridged), thereby incurring both dynamic and static forces.

- **Carrier Requirements/Restrictions:** Each carrier has its own Terms and Conditions (T&C) that affect freight packaging; it is the shipper's responsibility to determine if their freight shipments meet those carrier's Terms and Conditions. Among the requirements or restrictions commonly listed are: Size Limits; Weight Limits; Perishables; Labeling; Special Commodity packaging instructions; Shipments requiring advanced arrangements; Not Acceptable Items; Limitation of Liability; and Maximum Declared Values. To find a carrier's Terms and Conditions go to the carrier's Tariff that is posted on its website or published copies.

General Design Recommendations (by freight package type)

The following general design recommendations are presented in three categories of freight shipment package types:

- **Type 1**- factory packed, pre-engineered custom freight shipment package design, dedicated to one product
- **Type 2**- miscellaneous freight items packed in random order at fulfillment centers, catalog houses, and pick & pack consolidation operations
- **Type 3**- occasional freight packages prepared for miscellaneous items

Type 1- Factory packed in pre-engineered custom packages: To assure adequate protection from shock and vibration, the freight package designer should determine the

product's level of fragility. Fragility level identifies how much force is required to cause an unacceptable level of damage to the product. The most accurate way to do this is damage boundary (fragility) assessment using laboratory shock and vibration equipment, testing to ASTM Test Methods D 3332 and D 3580. If that is not available, a reasonable estimate should be made based on similar products or by working with the product designer to develop an estimate.

Generally, the product should be positioned in the center of the freight package system unless either the fragility is known to differ by orientation, or it is critical to change the freight package center of gravity. Style of corrugated or other appropriate shipping container will depend largely on the method of packing to be used as well as shape and orientation of the packaged contents. Container strength and protective packaging within the container should be cost effective, consistent with product protection, packing labor, and any customer requirements.

Freight products of higher value should be packaged using higher strength and level of product protection than that used with moderate value products. Establishing a benchmark of percent cost of packaging to total product manufacturing cost will assist in determining if packaging costs are equitable within a shipper's product line. However, other cost factors such as cost of failures, shipment returns, and assembly of packaged products, usability and transportation costs can far exceed the direct packaging costs.

Customer preferences regarding package aesthetics, design features, and environmental impact may affect exterior and interior packaging choices, but must be balanced against the need to minimize costs, while providing the product with adequate protection.

Type 2- Miscellaneous items packed in random order: In this situation, one or more freight items are packed together as a single freight shipment. Many companies have successfully developed packaging guidelines that define relative product fragility and the amount/thickness of protective packaging required. In the absence of these, a minimum of three to four (3-4) inches thickness of protective packaging or space separation between contents and container walls should be provided. The packager generally considers product fragility during packing. Items deemed more fragile should have greater clearance from container walls and more separation from other items inside the container. The same rationale should be applied to products of higher than average value, i.e. products having much higher value than the shipper's average value for the same cubic volume should be packed in larger and stronger boxes or crates with additional cushioning materials.

If the freight-shipping container is a corrugated fiberboard box, use a style that is easily filled by the packer (usually an RSC style). Interior packaging materials should provide adequate protection based on the fragility of package contents and be of sufficient strength to maintain any required clearance between contents and all six-container walls (top, bottom, and four sides), and also to prevent contents from puncturing through the container walls. Hourly rate of packing will also be an important factor in selecting packaging materials, as higher rates may show that costlier materials are more effective when labor is included.

Unpacking and disposal of freight packaging materials are important to most customers receiving these types of packages. Some types of void fill materials may not be acceptable

for that reason. Environmental impact of all packaging materials is important and some customers may require that containers and interior packaging be made of the same material for co-mingling by recyclers.

Type 3- Occasional packaging of miscellaneous freight items: These are freight packages prepared infrequently on an occasional basis by factories, warehouses, mailing stores, or individuals. The contents vary each time and may be any item acceptable for shipment by freight carriers.

Although fragility levels of these types of items are important, fragility is often not known or easily estimated and the most important factor in determining amount of packaging becomes the intrinsic value of the item. Higher value items should be packed in stronger containers with more cushioning protection than average value items. At least three (3) inches of cushioning material of sufficient density for item weight should be used on all six sides of the content. The amount of cushioning may not be as important a factor for wood crated products that are large and heavy, especially if they have an integrated pallet. In these instances, blocking and bracing the item inside the packaged system so that it can't contact the outer crate walls (sides and top) may well be the most important characteristic of the package. To avoid accidental tipping actions, tall-crated shipments must have a low center of gravity to be capable of remaining upright when tilted to a maximum of 22 degrees from horizontal on a single edge. (See Test Procedures)

Because these items are shipped to customers sporadically and in low volume, environmental impact and related issues are generally not a factor.

Shipping Containers

Most freight carrier systems are designed to handle palletized shipments. Other types of containers such as wire containers, steel containers, bulk containers, crates or wood boxes are also handled individually by forklift or pallet jack or other mechanical lifting equipment.

Defining Types of Loads: A general terminology of the packaging and transportation industry is used to describe three types of loads- easy, average, or difficult.

- Easy loads are items of moderate density (up to 15 pounds per cubic foot) that may completely fill the container or be packaged in interior receptacles. They are not readily damaged by puncture or shock, do not shift or move inside the package system, nor present a hazard to other freight shipments.
- Average loads are moderately concentrated items that provide partial support to all surfaces of the container. Average loads may be placed directly in the shipping container or employ intermediate packaging.
- Difficult loads are items that require a high degree of protection to prevent puncture or distortion, or reduce transmitted shock, and do not support the container. Fragile objects and delicate instruments (having a fragility of 50 G's or less), high-density items, and small bulk items are in this category. Items with uneven weight distribution may also fall into this category.

Corrugated Fiberboard Boxes: *[See IoPP Guide to Packaging for Small Parcel Shipments for additional information]* To adequately protect contents in unitized loads, corrugated fiberboard boxes must be durable and strong enough to resist lateral impacts and dynamic compressive forces. Containers meeting the requirement of Rule 222 are generally accepted…

The BMC (Box Makers Certificate) is required by trucking companies that subscribe to the National Motor Freight Classification and by railroads as an indication of certified minimum strength of corrugated fiberboard for a maximum allowable gross weight and overall box dimensions.

To avoid repackaging individual cartons when shipped as single parcel shipments, refer to the IoPP Guide to Packaging for Small Parcel Shipments to determine individual box strengths recommendations.

Both, Mullen burst (Mullen) and Edgewise Crush Test (ECT) grades of fiberboard, are acceptable for corrugated fiberboard boxes in a **freight carrier environment**, however the two grades have different properties that may reflect in their performance during shipment. Mullen grade fiberboard is manufactured to attain certain minimum levels of tensile and tear strength, collectively measured by the Mullen burst test. ECT grade fiberboard is manufactured to attain a minimum level of crush resistance that relates to good stacking strength in the finished box. The ECT measures this strength. Although sufficient stacking strength is an important attribute needed in unitized loads, durability is even more important as the corrugated fiberboard box must retain and protect its contents during both manual and mechanical handling. Durability is closely related to tensile and tear properties. Appropriate consideration of either Mullen burst or ECT grades of fiberboard is an important factor in selecting the right corrugated fiberboard box for any given box size and content weight.

Several other properties of corrugated fiberboard boxes are useful to know as they relate to performance of boxes in unitized loads:

- Corrugated fiberboard is approximately one-half as strong in stacking strength at 85% relative humidity (RH) as in normal testing conditions of 50% RH.
- Corrugated fiberboard boxes under compressive load for approximately one week retain about 2/3 of their original machine-measured compression strength. Boxes in storage for a long period (approximately one year) retain about one-half of their original compression strength.
- Interlocked stacking of boxes reduces their compressive strength by up to 50%. Column stacking is preferable for good stacking performance.
- Misalignment of boxes in a column stack reduces stacking strength; ½ inch misalignment could reduce strength by 30%.
- Stacks of loaded boxes reach their maximum level of motion (natural frequency) during vertical vibration somewhere in the range of 6 to 12 Hz (cycles/second), no matter what they contain. This range of vibration frequency is common within both truck and rail transport.
- Therefore corrugated containers must use an adequate safety factor to achieve desired carton reliability over the expected life of the container.

Box closure is very important for single freight package shipments. Closure methods suited to shipment of palletized boxes may not be acceptable for the extra stress of individual shipments. Higher grades of closure materials and larger amounts of closure materials are often required. Many standard methods of box closure may be considered, including tape, adhesive, staples and banding (strapping or tape). For detailed discussion, refer to ASTM D1974 as a standard practice of closing, sealing and reinforcing fiberboard boxes. Single strip closure of tape is often acceptable when using premium grades of pressure sensitive tape or premium reinforced gummed paper tape. With lower grades of tape, or with large or "difficult" boxes, a more durable closure can be obtained by also using strips at right angles across flap joints at the ends of the box (six strip or H method). Individual packages weighing over 60 pounds may require reinforcement with bands of non-metallic strapping or reinforced tape.

Other Shipping Containers: Bundled shipments should be adequately compressed and reinforced to contain the contents within the bundle. Unitized packages should be adequately bundled together and secured to a pallet or other platform which can be handled with a forklift or pallet jack to prevent shifting and movement during loading, unloading, sorting and transportation activities.

Individual cans, pails and drums are acceptable with positive closures. Generally, friction closures by themselves are not acceptable. Protruding devices, such as locking rings, should be shielded with padding to prevent injury to handlers, equipment and other freight shipments.

Wood boxes and crates, spools, reusable containers, and stretch/shrink wrapped items are also acceptable providing they are adequately closed, reinforced and provide the desired level of protection from the normal hazards of distribution. Any protruding handles, hinges, latches, wheels/castors or other devices that may be damaged by contact with other freight shipments or material handling equipment should be padded, recessed or otherwise protected to prevent that possibility.

Interior Protective Packaging

To properly prepare a freight shipment, packers should use some type of interior protective packaging materials or forms within the shipping container. These materials or forms are utilized for one or more of the following functions:

1. cushioning the contents from shock and vibration;
2. bracing or blocking contents in position to eliminate movement within the container;
3. filling any voids remaining in the container after placing contents within it;
4. protecting surfaces from abrasion, scratching, etc.;

5. protecting contents from corrosion;
6. protecting from ESD (electro-static discharge) using modified versions of packaging materials;
7. protecting contents from temperature extremes.

The following table lists common applications for various materials or systems used as interior protective packaging, numbered with codes 1 through 7 as noted above.

Material or System	Common Applications
Air bags (inflatable engineered cushions)	1,2
Air bags (inflatable void fill)	3
Air bubble or cellular sheeting	1,2,3,4,6,7
Blow molded toroids	1,2
Converted paper pads- 2 & 3 ply	1,2,3
Corrugated or solid fiber die cuts, scored sheets, partitions, build-ups	1,2
Desiccants sealed within moisture-vapor barrier	5
Die-cut expanded paper cells with interleaving	1,2,3,4
Foam sheet- polyethylene, polypropylene	1,2,3,4,6,7
Honeycomb pads, die cuts	2
Honeycomb pads, die cuts- pre-crushed	1,2
Loose fill- EPS, paper, molded pulp, starch	3
Molded pulp forms	1,2
Paper- single ply	3
Paper- tissue	4
Plastic films, bags	4,6
Polyethylene foam- fabricated or molded	1,2,6,7
Polypropylene foam- fabricated or molded	1,2,6,7
Polystyrene expanded beads (EPS)- fabricated or molded	1,2,6,7
Polyurethane foam-in-place	1,2,3,7
Polyurethane foam- pre-molded or fabricated	1,2,4,6,7
Suspension packs- plastic film/corrugated	1,2,4,6
Vapor corrosion inhibitors (VCI)	5

A wide variety of materials and forms are available for interior packaging and most of them will perform more than one of the above functions. Use of reliable engineering data is preferred to assure optimum material performance. When selecting cushioning, bracing, or void fills the packer should use care to avoid over-loading as that may adversely affect its protection capabilities. For Type 2 or 3 freight packages, overfilling the container slightly with void fill material before closing will assure the item is held in place; excessive overfill should be avoided to prevent container distortion and/or damage. Use industry approved lab test procedures to determine how well a Type 1 package will perform in distribution.

When enclosing several items within a freight package system, special care should be taken to protect them from contact with each other as well as external forces. Heavy freight items should not be packaged with fragile items unless extreme care is taken to separate these items from each other.

Some items may require specialized interior packaging materials, such as absorptive materials for liquids in case of spill, or dry ice for temperature control. Other special requirements such as shielding from electromagnetic forces should be implemented inside a primary container within the shipping container.

Temperature Controlled Packaging

In shipments by land, ocean and airfreight carriers, significant extremes of temperatures may be encountered that could be harmful to some freight package contents. The shipper should rely on packaging to protect the contents since most general transport conveyances cannot guarantee an optimal transit environment.

A wide variety of insulation materials are available for those products requiring protection against these temperature extremes. These materials are typically used with some type phase-change material such as refrigerant gel packs or dry ice.

For guidance on the range of temperatures that may be encountered on air shipments of 24, 48 or 72 hour duration, refer to ISTA 7D Procedure for Thermal Controlled Transport Packaging for Parcel Delivery System Shipment (see ISTA (International Safe Transit Association) listing under Standards in the References and Resources section.)

It is highly recommended that any temperature controlled package design be validated by laboratory testing according to industry standards. Application of the ISTA 5B Focused Simulation Guide is strongly recommended for temperature sensitive products of high value or where liability of damage is significant.

Testing in the Laboratory prior to Shipment

Pre-shipment testing in a laboratory is the best way to determine if a freight package item is adequately protected against hazards encountered during shipping and handling. Such testing is particularly appropriate for pre-engineered Type 1 packages.

Lab testing can also be useful in developing a general approach to Type 2 freight packaging. However, due to the random nature of Type 2 packaging, testing will not provide the same positive assurance as seen with Type 1 freight package testing.

Shock, vibration and compression are major reoccurring forces present in all shipping modes, including the freight environment; damage will occur unless items are properly packaged to protect against these forces. Temperature and humidity extremes are naturally occurring conditions that will also contribute to package failure in the freight environment. At a minimum, lab tests should assess all of these potential causes of damage.

ASTM International (American Society for Testing and Materials) and the International Safe Transit Association (ISTA) are the principal sources for freight methods of laboratory testing, including minimum equipment requirements. Among the test methods recommended for freight shipments are drop, incline impact, random vibration, repetitive shock (loose load) vibration, machine compression, constant load compression and stability

tests as necessary. ASTM International and ISTA also provide conditioning practices for temperature and humidity.

When tests are conducted in a sequence similar to that expected in actual shipments, the practice is called performance testing or general simulation. Copies of testing methods and performance test procedures are available from ASTM International, ISTA and the National Motor Freight Traffic Association (NMFTA). Some freight or LTL carriers specify these procedures as the minimum requirements for packaging.

It is strongly recommended that Type 1 freight packages should be pre-shipment tested using one of the following procedures:

ISTA 3E atmospheric preconditioning, incline or horizontal impact test, rotational edge test, compression test, random vibration test, rotational edge test.

ASTM D4169 Distribution Cycles 4 through 12

ASTM D4169 Distribution Cycle 3- atmospheric conditioning, compression test, loose-load vibration test, random vibration test, drop test.

ISTA 1B/2B vibration test, drop test. In addition a compression test is conducted prior to the vibration and drop tests. Conduct either a constant load test or utilize a compression test machine to simulate floor loading of the package with a load density of about 10 lb/cu.ft. on top of the box, measured to a 9-foot high stack height in a carrier vehicle. The constant load test should be conducted for one hour on each of three mutually perpendicular faces, with a constant static load of approximately 400 pounds per square foot (based on a design safety factor of 5 to compensate for time, humidity, and handling effects). The compression machine test should also be conducted on each of three mutually perpendicular faces, loading each briefly to a maximum load that is equivalent to approximately 550 pounds per square foot of package face (based on a design safety factor of 7 to compensate for time, humidity, and handling effects).

ISTA 3B (currently in development as of 3/1/2007) for packages defined as freight.

NMFC Rule 180- stacked random vibration test, impact tests, (and handling tests for unitized loads)

It is also encouraged to test freight packages having unique properties or characteristics, using one of the following procedures:

ISTA 2D (formerly ISTA 1J): for packages that are large and flat
ISTA 2E (formerly ISTA 1K): for packages that are long and narrow

Trial shipments via the freight carrier(s) of choice are strongly recommended following successful laboratory testing. Ideally, tests should include multiple freight shipments to each of several destinations. Freight packages may be opened and inspected on arrival or they may be returned unopened to the point of origin for inspection. If damage occurs, an analysis of trial shipment results compared to lab test results may be necessary to determine

the cause of the damage. Such damage in trial shipments may indicate a need to increase intensity of one or more lab tests, depending on type of damage incurred, and/or the addition of different types of appropriate tests.

ISTA will provide certification of successful laboratory testing if the tests are performed **(1)** in accordance with a current ISTA Test Procedure or Project (or ASTM D4169), **(2)** in an ISTA-Certified laboratory, and **(3)** for a company or organization (manufacturer, shipper, etc.) who is an ISTA member. In order to determine pass/fail, documented acceptance criteria for both package and contents must be provided to the laboratory prior to testing. (Certification is also available to NMFTA members who pass the appropriate test for their particular product)

Labeling and Marking

All freight shipping containers must be labeled or marked with routing information, including consignee and consignor addresses. This information must be legible, easily understood, and durable to better ensure that the package ultimately reaches the intended consignee. The carrier may also require other routing labels and information. The ideal placement of shipping labels for freight shipments is on the vertical sides of the shipping container while in its desired orientation. Visible freight package weight information is recommended to be marked near the top of each vertical side orientation of the individual freight shipment to assist the forklift handler in proper stacking to avoid heavy on light shipments.

Identification of contents on the exterior of the container is not required by carriers, however such identification may be a requirement of the consignee for subsequent identification in storage. When marking content's identification on containers, use a coded system to preclude theft or pilferage of valuable or highly desirable items.

If package contents require a warning such as *Electromagnetic* or *ESD sensitive,* a label or marking should be placed on at least the two largest faces of the shipping container. If the container requires special considerations in handling, consult industry standards "Pictorial Markings for the Handling of Goods" published by ASTM (D5445) and ISO (780). Keep in mind that some carriers may disclaim any guarantee to honor orientation labels.

References and Resources

Published articles

- Rule 180 - NMFTA – National Motor Freight Traffic Association
- "Guide to Packaging for Small Parcel Shipments", IoPP, Transport Packaging Committee, 2002
- "Measurement of UPS Ground Shipping Environment for Large & Heavy Packages", Paul Singh, Michigan State University, ISTACON 2000 proceedings, ISTA

Books

- "Corrugated Shipping Containers: An Engineering Approach", George G. Maltenfort, IoPP Bookstore, www.iopp.org
- "Transport Packaging", Alfred H. McKinlay, IoPP Bookstore, www.iopp.org

Standards

- "Annual Book of ASTM Standards", Volume 15.09, ASTM International, 100 Barr Harbor Drive, W. Conshohocken, PA 19428-2959, tel. 610-832-9585, www.astm.org
- "Pre-shipment Test Procedures and Projects", ISTA, 1400 Abbott Road, Suite 310, East Lansing, MI 48823-1900, tel. 517-333-3437, www.ista.org
- ISO Standards, available from American National Standards Institute (ANSI), 25 West 43rd Street, New York, NY 10036, tel. 212-642-4900, www.ansi.org
- "National Motor Freight Classification", available from National Motor Freight Traffic Association, 1001 North Fairfax St. Suite 600, Alexandria, VA 22314-1503, www.nmfta.org, tel. 703-838-1810

Testing Laboratories

"Certified Testing Laboratories", ISTA, www.ista.org

Consultants

"Directory of Packaging Consultants", IoPP, www.iopp.org