Introduction

Package testing, more accurately referred to as package performance testing, is a logical step in package design. Developing empirical data on a packaged item’s susceptibility to damage from a transportation environment, including handling and en route storage, can enable a company to properly design and package their product.

Factors

A shipper should carry out a several-step process that results in a product/package set that is the best blend of protection and economy. As a start, define the transportation environment; this can be quite daunting for such an apparently simple task. Many variables need consideration, such as:

• Mode(s) of transportation: Each mode exposes cargo to a different set of exposures, whether it is the motions of an ocean-going vessel in a seaway or the ruts and bumps caused when switching the mode from a railcar to a truck.

• Shipment routing: In a perfect world, cargo moves nonstop from origin to destination, but we know this is clearly not the case. The typical transport system operates within a hub-and-spoke environment, with shipments combined in major hubs and then fanned-out from there. In a recent study, it was found that during the average 600-mile trip by truck, a shipment will be physically-handled between ten and twelve times. Thus, cargo could be stored for a long time period awaiting transfer/transshipment.

• Climatic conditions: Obviously, it is critical to understand climate conditions during transit of temperature-sensitive goods, but it can also be a factor for other cargo. Rain and humidity can wreak havoc on corrugated cartons, which translates as a significant loss of structural and stacking strength. Moisture in any form might damage the actual contents.

• Conditions at the landing port, during discharge and at the final destination: While shippers may have sophisticated cargo-handling equipment, even specifically designed for the product, this does not mean that the same capability will be available everywhere the cargo goes.

After mapping the scope and dynamics of the anticipated transit, shippers must accurately assess the fragility of the product. [For in-depth coverage of this topic, please reference the ARC Marine bulletin, “Cushioning & Cushioning Materials”]. Fragility, or resistance to shock, is the greatest amount of force an item can withstand without being damaged. This attribute, often expressed in G-force, represents the maximum acceleration/deceleration an item can withstand during impact divided by the known force of gravity. The more fragile an item, the lower the G-force level.

While there is no real substitute for quantitative analysis, this can be an expensive exercise and may be impractical to test, until destruction of a high-value or one-of-a-kind piece. Fortunately, in many cases, ample data exists to allow for a very educated guess.

Products can be categorized in six (6) classes, based on their fragility (see Table I, below):

Table I: Fragility Categorization Table

<table>
<thead>
<tr>
<th>Fragility Category</th>
<th>G-Force Range</th>
<th>Fragility Category Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extremely Fragile</td>
<td>15-25 G</td>
<td>Delicate mechanical equipment (e.g., an altimeter)</td>
</tr>
<tr>
<td>Very delicate</td>
<td>25-40 G</td>
<td>Medical diagnostic instruments (e.g., an x-ray machine)</td>
</tr>
<tr>
<td>Delicate</td>
<td>40-80 G</td>
<td>Hard disk drives and printers</td>
</tr>
<tr>
<td>Moderately Delicate</td>
<td>60-85 G</td>
<td>Hard disk drives and audio/video receiver</td>
</tr>
<tr>
<td>Moderately Rugged</td>
<td>85-115 G</td>
<td>Major appliances; some furniture</td>
</tr>
<tr>
<td>Rugged</td>
<td>115 G+</td>
<td>Machine tools</td>
</tr>
</tbody>
</table>

Tim Donney
Global Head of Marine Risk Engineering
Tel: +1 212 524-7848
tim.donney@agcs.allianz.com
www.agcs.allianz.com
After determining the fragility of the product, the shipper should critically look at their product and try to optimize its ruggedness (e.g., changing the cabinetry of a console from pressboard to sheet metal or from sheet metal to a heavier-gauge steel). Also, internal components can be bolted-in or, if shearing may occur, then removed and packed separately in another shipping container.

The next step is to evaluate the packaging and cushioning material. Once the transportation environment and the product’s fragility are known, including the redesign/retrofitting of the product, it is time to ponder both the interior and exterior packaging. Packaging manufacturers have a wealth of data to use to establish the best individual parts for the final package.

Next, the shipper must design a package. There are a variety of materials to choose from and a number of combinations. The previous steps, if done properly, should point the shipper to the right mix. The goal is not only to have the final package protect the shipment in transit, but also to have a package be both cost-effective and environmentally-friendly— or at least neutral.

Once the shipper has selected the package, the last step is to test it. Testing just the product or the package alone is not enough, since it is the packaged product that will be handled, stored and transported. There are a number of pre-shipment test procedures designed to help determine the likelihood of safe arrival of the package-product. The tests, using specialized equipment, simulate the shocks and stresses encountered during the transport cycle. The International Safe Transit Association (ISTA) has published a standardized program of testing and certification. The current issue of Pre-shipment Test Procedures is dated January 2008. The protocol consists of performance testing, a more logical approach to theoretical estimates or potentially costly trial-and-error.

The tests are to be completed in the following sequence:
1. Climatic Conditioning test
2. Static Compression test
3. Vibration
4. Impact (Drop and Shock)
5. (Second) Vibration
6. Tip/Tip-Over Test *

This sequence will be explained in more detail below.

*Note: a sixth test, the Tip/Tip-Over test is additional in this sequence for packages of more than 150 pounds, especially tall items over 48 inches high.}

### Table II: Climatic Conditioning Table

<table>
<thead>
<tr>
<th>Climate Type</th>
<th>Climatic Conditioning Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperate</td>
<td>Hold for 72 hours at 20 degrees C (68 degrees F) at around 85% relative humidity (rh)</td>
</tr>
<tr>
<td>Tropical Wet</td>
<td>Hold for 72 hours at 38 degrees C (100 degrees F) at around 90% rh</td>
</tr>
<tr>
<td>Tropical Dry</td>
<td>Hold for 72 hours at 38 degrees C (100 degrees F) at around 90% rh then another 6 hours at 60 degrees C (140 degrees F) at 30% rh.</td>
</tr>
<tr>
<td>Refrigerated</td>
<td>Hold for 72 hours at 5 degrees C (40 degrees F) at around 85% rh</td>
</tr>
</tbody>
</table>

### Table III: Static Compression Test Formula

\[
L = W \times \left( \frac{H-D}{D} \right) \times F
\]

Where:
- \( L \) = the Load the package-product must withstand
- \( W \) = the gross Weight of the package-product
- \( H \) = the stacking Height
- \( D \) = the overall Depth of the package-product
- \( F \) = compensating (safety) Factor

### 1. Climatic Conditioning

To test the package-product’s conditioning to the required temperature and humidity, it is best to store the test item at ambient conditions for approximately six (6) hours, then subject it to the situation that will most closely correspond to the environment it will likely encounter during transit: temperate, tropical wet or tropical dry climates. Perishable goods requiring controlled temperature should be refrigeration-tested. [See Table II, below]:

### 2. Static Compression Test

This test is designed to determine if the package-product can resist superimposed loads, likely to be encountered both in transit, during stowage in an intermodal container, rail car, truck or aircraft, or in static situations, (e.g., the height of stacking in a warehouse or cargo terminal). It is conducted using a device applying a load at 0.5 inch per minute and holding it over a period of time. The end test load should be consistent with the following formula (see Table III, below):

\[
L = W \times \left( \frac{H-D}{D} \right) \times F
\]
3. Vibration Test
This evaluation is used to check the package-product’s susceptibility to vibration frequency. This is conducted on a vibration, or “shake”, table. The device simulates the effects of vibratory impacts during transportation; the duration of the test is dependent on the cycles-per-minute frequency.

4. Impact Test
As already stated, this is actually a dual-purpose regimen, which includes both a drop and shock test component.

Drop-testing is a critical process for determining how or whether a package will respond to the rigors of handling, transit and, eventually, distribution. This test will help determine the effectiveness not just of the outer package but also cushioning and other interior protective material, closures, and other design features.

An effective drop-test device will reproduce handling and other impact events with precision. The weight of the package-product dictates the most likely drop-scenario, since, as the weight increases, more than one person will be manually carrying or lifting, or mechanical means such as pallet jacks, dolleys or lift trucks will be used.

Table IV is a rather generic chart detailing the weight/ freefall drop height parameters.

<table>
<thead>
<tr>
<th>Package-Product Weight</th>
<th>Drop Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-21 pounds</td>
<td>38 inches</td>
</tr>
<tr>
<td>21-41 pounds</td>
<td>32 inches</td>
</tr>
<tr>
<td>41-61 pounds</td>
<td>24 inches</td>
</tr>
<tr>
<td>61-100 pounds</td>
<td>20 inches</td>
</tr>
<tr>
<td>100+ pounds</td>
<td>12-16 inches</td>
</tr>
</tbody>
</table>

5. (Second) Vibration Test
The previous vibration test procedure is repeated with the equal amount of intensity and time duration (see Vibration Test, above).

After each of the above tests, both the package and the product are inspected. If the product is free of a predetermined degree of damage, and if the package affords reasonable protection to its contents, then the package-product “passes” the test.

6. Tip/Tip-over Test
For packages more than 150 pounds, especially tall items over 48 inches high, a tip test using an angle of 22 degrees should be conducted. If it fails this test, a tip-over test should be performed in those directions in which the tip test failed.
Conclusion

To summarize, it is important, before the shipper proceeds with the six-step process listed immediately above, that they complete the pre-testing procedures outlined at the top of this document. This will ensure that they achieve the best blend of package protection and economy.

The shipper should:

- Define the transportation environment
- Assess the fragility of the product
- Look at the product and try to optimize its ruggedness
- Evaluate the packaging and cushioning material
- Design a package
- Test it (using the six-step process)

Package testing can pay real and immediate dividends to a shipper, either in reduction in loss and damage to their products during shipment or in reduction in protective packaging costs or both. These quantitative measures have proved to be effective but only when they are tested based on realistic transport environment models according to accepted principles using suitable equipment and having the results interpreted by trained technicians.

One more important caveat: a package-product should be re-tested any time a substantive change is made to the package, product or the transportation process.

Sources

ASTM International
100 Barr Harbor Drive
P.O. Box C700
West Conshohocken, PA 19428-2959
610-832-9500 (phone)
[www.astm.org](http://www.astm.org)

International Safe Transit Association (ISTA)
1400 Abbott Road, Suite 310
East Lansing, MI 48823-1900
USA
517-333-3437 (phone)
517-333-3813 (fax)
[www.ista.org](http://www.ista.org)

Lansmont Corporation
Ryan Ranch Research Park, 17 Mandeville Court
Monterey, CA 93940-5745
800-526-7666/408-655-6600 (phone)
408-655-6606 (fax)
[www.lansmont.com](http://www.lansmont.com)