PACKAGED-PRODUCT LABORATORY TESTING TO CONTROL DISTRIBUTION DAMAGE, PACKAGING COSTS, AND ENVIRONMENTAL IMPACTS

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PRESHIPMENT TESTING

Preshipment testing of packaged-product designs is an accepted practice for many organizations. Such testing, conducted in a laboratory under controlled conditions, allows evaluation of the ability to withstand distribution hazards prior to making actual large-scale shipments. Using this approach, both products and packages can be optimized and problems avoided at low cost and in an efficient manner. Yet such testing is often misunderstood – either given more or less credibility than warranted – with a resultant loss of effectiveness and with many opportunities and benefits going unrecognized.

Much of the misunderstanding can be attributed to the fact that "Packaged-Product Laboratory Testing" is not just a single entity, but a suite of various approaches used to support different objectives and situations. If there is a mis-match between what information a particular test protocol can deliver and what is expected or desired, incorrect conclusions can be drawn and inappropriate actions taken. It is therefore important to understand the various testing approaches, what can be expected from them, and how they should be applied.

The most obvious function of a protective package is to reduce or eliminate the damage of goods in distribution. In general, higher levels of protection mean higher packaging costs and complexity. But in a global and highly competitive market, cost and environmental concerns seem to dictate *less* packaging and therefore *less* protection. What's the proper balance, and how is it achieved? Appropriate laboratory testing of packaged-products can help find the answers.

THE TESTING HIERARCHY FROM SIMPLE TO COMPLEX

Testing protocols can be placed into three primary categories: *Non-Simulation Testing*, which challenges the strength and robustness of the product-package combination without necessarily attempting to replicate actual transport occurrences; *General Simulation*, which is designed to broadly model the damage-producing forces and conditions of the transport environment; and *Focused Simulation*, which bases laboratory tests, intensities, and conditions on actual field-measured hazards and levels. These test types form a hierarchy of cost, complexity, and effectiveness.

Non-Simulation Testing

This is the simplest and lowest-cost approach to package performance evaluation. In its most basic form, it typically requires only free-fall drops and fixed-displacement vibration, using equipment similar to that shown in Figure 1. Usually there are no temperature/humidity or other atmospheric tests, and no compression loading. Little or no consideration is given to product or package configuration, construction, value, shipment quantities, etc., and the same protocols are used without regard to transportation modes and distribution means. Test levels, for the tests conducted, tend to be of "worst-case" severity and are not correlated to real-world occurrences. Good examples of non-simulation tests are the International Safe Transit Association (ISTA) 1-Series Procedures.

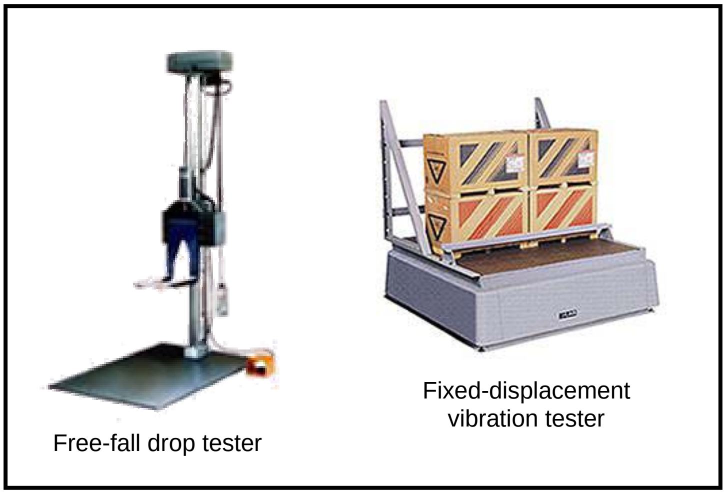

Figure 1 Typical equipment used for basic non-simulation testing

Packaging standards from many organizations include protocols which could be categorized as non-simulation. A number of the leading worldwide carriers include these types of tests in their recommendations and requirements. So there is no question that the basic approaches are used widely and successfully. The primary advantage is that the equipment is simple and relatively low-cost, and the tests are easy to perform.

General Simulation

General simulation is an attempt to realistically model the damage-producing elements of transportation and distribution in the laboratory, using broad-based depictions of the intensities, conditions, and sequences. Test levels and other parameters are contained within the testing protocols, corresponding to generalizations drawn from diverse compilations, industry consensus, calculation, and "conventional wisdom". Requirements typically include varying drop heights, additional types of impacts, compression based on generalized top loads and stack heights, simple shaped random vibration which broadly simulates actual vehicle motions, atmospheric conditioning, and combined hazards such as compression and vibration simultaneously. Tests are tailored to some extent based on package type and construction, and some degree of consideration is given to product value and shipment quantities. Different basic modes of transportation are taken into account (including multi-mode situations), and a generalized attempt is made to put the lab tests into a sequence similar to that expected during actual distribution.

Compared with non-simulation testing, general simulation typically requires more types and sophistication of test equipment, as shown in Figure 2. This means an increased investment in both testing machines and facilities. Since there are more variables to be considered, configuration of test plans typically requires more planning, and general simulation tests are more extensive and time-consuming to run. Good examples of general simulation tests are the ISTA 3-Series Procedures.

The benefit of these increased costs and efforts is a comprehensive and representative simulation of the transportation/distribution environment. No major typical hazard is omitted, and the intensities and conditions are reasonably correlated to real-world occurrences. As will be discussed below, this type of testing can be effectively used in packaged-product optimization programs.

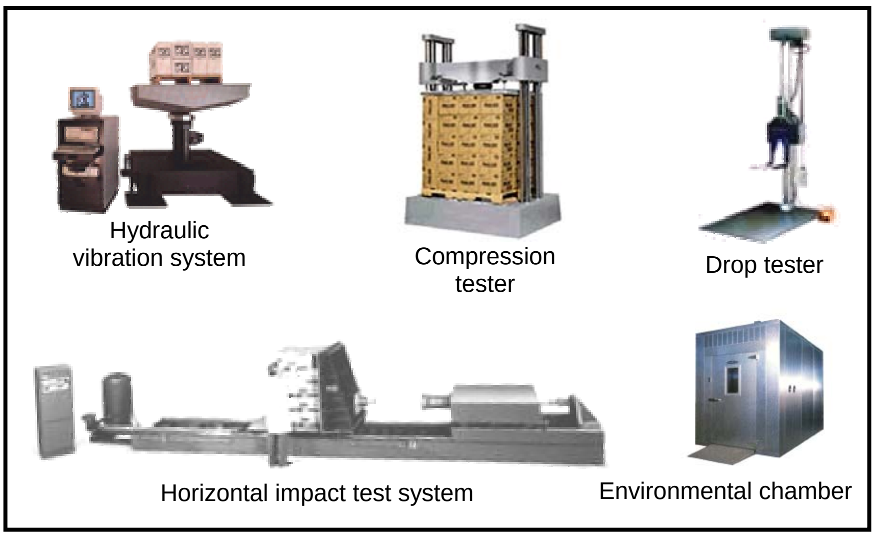

Figure 2 Range of equipment required for general simulation tests

Focused Simulation

The focused simulation approach is to observe and measure particular field situations in detail, then translate those hazards, intensities, sequences, and conditions into test protocols specific to the packaged-products and their distributions being considered. Test levels and other parameters are not contained within the testing protocols; in fact, there aren't protocols per se, only guidelines and recommendations about how to construct them. This is demanding, but the payoff is creation of laboratory tests with the best potential for correlation to actual transportation/distribution. The ISTA 5-Series are focused simulation guides.

Accurate and meaningful field measurements are made possible by the current availability of small, self-contained electronic field data recorders (Figure 3). These instruments, often the size of a paperback book or smaller, are able to record both static and dynamic information in such a way as to facilitate the required analyses.

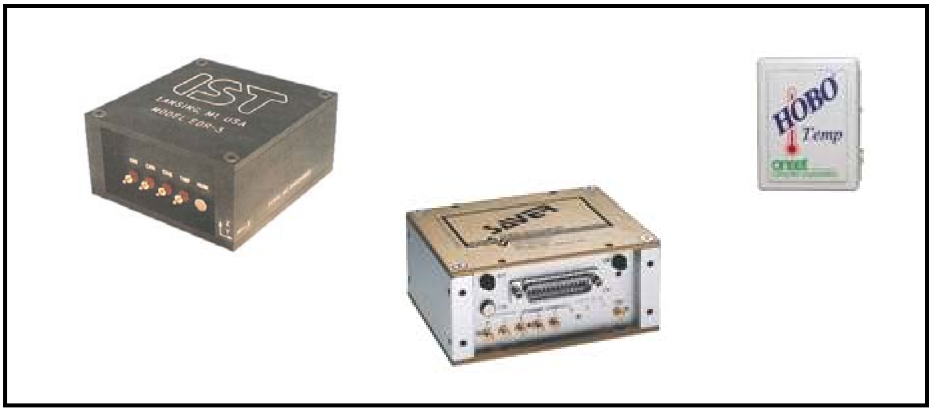

Figure 3 Examples of self-contained electronic field data recorders

Information from the recorders and from field observations must be translated into a lab testing protocol specific to the packaged-products and their distributions being considered. Data must be analyzed statistically and the tests based on sound use of the results. If there are variables and variations in the package, product, or system, it must be decided how to incorporate them into the protocol or whether to create separate protocols.

Other than the recorders, equipment required for focused simulation is essentially the same as for general simulation testing. To the casual observer, it might be difficult to distinguish a focused simulation test from a comprehensive general simulation test being run in the laboratory. But the difference would be in the details: the drop and impact test heights and velocities, orientations, and total numbers of impacts would be different; the vibration profiles and times, the compression loadings and times, the superimposed conditions, and other parameters would be different. A good general simulation test covers all the hazards, but focused simulation links the characteristics of those hazards to a particular type or class of packaged-product, and particular means and modes of distribution.

WHICH PROTOCOL TO USE?

Which protocol to use: non-simulation, general simulation, or focused simulation? Unfortunately, the tremendous range of products, goods, and commodities shipped, along with the complexity of routes and distribution systems, preclude a simple answer to that question. The more advanced tests can certainly lead to more accurate assessments of the ability of packaged-products to survive the transportation/-distribution environment, but it does not necessarily follow that all situations demand or warrant their use. Many factors must be considered: costs of product, packaging, and damage, product characteristics, distribution means, market issues, liability exposure, regulations, etc. Proper protocol selection achieves the optimum balance of all these factors for the particular situation.

Effectiveness of Non-Simulation Testing

For organizations where no preshipment testing is currently being conducted, institution of a non-simulation test program can be an enormous step forward. Almost any testing is better than no testing, and can serve to screen out at least basic product and package design problems. In cases where product fragility is not particularly an issue, non-simulation testing can often do a good job of assessing the package performance – its ability to withstand abuse and continue to properly contain and identify the product.

When simple non-simulation tests "work", defined as leading to the design of packaging which successfully protects products in large-scale shipping situations, they probably err on the side of over-protection and over-performance. This is because the rational response to a lack of information or lack of consideration of real-world situations is to configure "worst-case" test intensities, and this is the essential approach of non-simulation testing. Of course some hazards (compression, atmospheric) may not be covered, but perhaps in many instances it happens that severe tests of just a few types will compensate for tests that are omitted altogether. Regardless, if the specimens pass these severe tests, they are probably overly-robust, at least with respect to those types of inputs.

When simple non-simulation tests do not work, it's probably because damage is caused by hazards for which a test was not included. For example, if damage is caused by compression during warehousing but there is no compression test, or by high humidity when all the tests are conducted at lab ambient conditions, the protocols' simplicity results in a major shortcoming. The tests are passed, but field performance is unsatisfactory – a sure sign that the tests are somehow improper for that situation.

Effectiveness of General Simulation

As might be expected, general simulation usually provides more and better data than non-simulation testing. When product/package values and shipping quantities (or both) are moderate-to-high, the economic and other benefits to be derived from a more thorough and accurate testing program can be readily justified. If product fragility is an issue, general simulation can often uncover hidden damage as it might occur in actual distribution.

General simulation works well when there is a good match between the actual transportation/distribution environment and the selected laboratory tests, sequences, and intensities. The ISTA 3-Series tests have shown good correlation with actual field performance in the U.S., Canada, Western Europe, and similar regions. Problems can arise, however, when there is not a good match. If a hazard is included in the tests but does not actually occur in the field, over-packaging can result. Test intensities which are too high relative to the actual transport environment can also lead to over-packaging. Conversely, omission of a unique hazard which actually does occur, or test intensities which are too low, can lead to excessive damage. There is growing evidence that correlation with the ISTA 3-Series and other general-simulation tests is not so good for Mexico, many parts of Asia, Eastern Europe, etc.

Effectiveness of Focused Simulation

Focused simulation is essentially the *creation* of that good match between real-world occurrences and laboratory tests. Properly researched and implemented, it has the possibility of producing laboratory testing protocols with excellent correlation to the actual transportation/distribution environment.

Of course, focused simulation is also the most demanding in terms of prior knowledge, test preparation, equipment and facilities, and test time/complexity. In its complete form, it is most appropriate for situations of high product value, where product liability or other issues require unmistakable demonstration of due diligence, or in scenarios where economics, environmental, regulatory, or other factors indicate and justify the using best possible approach.

There are situations in which focused simulation is the only viable approach to constructing preshipment testing protocols. If distribution structures and systems are known to be significantly different than what has been previously studied but there is no quantifying data, the only recourse is a focused simulation program. For example, important and growing markets may exist in developing countries, but a distribution infrastructure common to the U.S., Canada, Western Europe, and other developed regions is lacking. The result is significantly different static, dynamic, and atmospheric conditions than are simulated by any existing test protocol.

PRODUCT AND PACKAGE OPTIMIZATION

Passing a series of laboratory tests, even very realistic ones, does not necessarily lead to an optimized packaged-product. The tests only set baseline levels of performance and protection, but do not limit the maximums. For example, an excessively over-designed package might pass any and all tests, but that certainly doesn't make it a good package in terms of cost, environmental impact, and other factors. So a process is needed to insure that the tests are passed with *minimum appropriate margin* to avoid over-design, over-packaging, and waste. As a practical matter, package and product condition at the end of the tests is often an indication, at least qualitatively, of the amount of margin. To quantify the margin, test intensities can be incrementally increased until damage occurs. Or the traditional approach of "redesign if necessary until the tests are passed" might be modified to "if the tests are passed, redesign with less material/cost/performance and test again". In any event, it is a combination of careful design, proper tests, and thorough analysis which leads to the best, optimized package-product.

Non-simulation tests are poor tools for design optimization, even when passed with minimum margin. Because they do not well represent actual field exposure in either intensity or type, the tests cannot be readily shown to have good correlation to field performance. Non-simulation tests can perhaps be effective if coupled with a program of field monitoring and feedback after redesign, but the far better approach is to use tests which provide a good actual simulation of the distribution hazards.

General simulation tests can support well-optimized designs if there is good correlation to actual distribution conditions, and if they are passed with minimum margin. In some cases, general simulation may be augmented with specific focused simulation elements to accommodate unique hazards or conditions.

Focused simulation, when warranted, is the most powerful approach for optimizing designs due to its possibility of near-perfect correlation. Coupled with a rigorous program to ensure passage with minimum appropriate margin, it can help to meet even the most demanding requirements.