Effects of High Altitude on Package Integrity

This study investigated the effect of high altitude shipments (feeder aircraft and truck shipments over mountain passes) on package integrity. In the past two years,the FAA has documented an increase of package failures with hazardous materials in air shipments. This study, funded by FAA and DOT, presents some of the findings of the effects of low pressure, vibration, and temperature on package performance.

S. Paul Singh
Professor
Michigan State University

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S. Paul Singh, Professor
Gary J. Burgess, Professor
Jagjit Singh, Research Assistant

School of Packaging
Michigan State University
East Lansing MI 48824

ABSTRACT:

This paper discusses the impact of high altitude shipments on package integrity. High altitude shipments are encountered when trucks travel over high mountain passes or when cargo and feeder aircraft transport packages in non-pressurized holds. Both these types of transport methods will result in severe changes in pressure and temperature conditions as compared to packages being transported close to sea-level. The testing of packages under these conditions is critical since package integrity may be compromised. Most shipping tests are performed in test labs that do not account for pressure changes.

INTRODUCTION:

This study investigated the effect of high altitude shipments on various forms of packaging systems including liquid hazardous materials. Packaged products transported via the feeder aircraft network (UPS, FedEx, and USPS) are liable to experience altitudes as high as 19,000 feet. Packages transported on ground may experience altitudes as high as 12,000 feet when shipped over mountain passes. When exposed to these conditions, products and/or packaging systems may be adversely affected by the changes in the environment. The Federal Aviation Administration has observed an increase in number of package failures of hazardous materials in commercial and cargo aircraft over the past three years (Singh and Burgess, 2001).

Existing test methods recommended by ASTM, DOT or ICAO do not truly represent the combined effects of pressure, temperature and vibration when simulating these conditions for package evaluation. The first phase of this study was to develop a new test method that can replicate the physical and climatic conditions that packages undergo during these shipments. The existing pressure differential methods recommended in ASTM and DOT may not truly replicate these conditions and often lead to validating packages that have problems in real life shipments.

Several types of commercially available, UN certified hazardous material packages were obtained from US manufacturers. Using the test protocols developed, different packages specified for liquids were tested. Results show the effect of closure, liner, and bottle finish on the package integrity.

Package Types Tested:

The information on package description is provided by the supplier of the various packages and is available on their web site (Labelmaster Inc.). The samples of these packages were procured by Michigan State University.

HMS-08: Consists of a PVC plasticoated glass bottle and a plastic lid with a flat liner. The lid is sealed with PP tape and placed inside a PP bag, which is sealed with a nylon tie. The bag is wrapped in a vermiculite pad and placed inside a steel canister. This canister is then placed inside a double-wall fiberboard insert. The whole setup is contained inside another PP bag and sealed with a nylon tie before being boxed and sealed inside a double-wall fiberboard carton.

UN950PPT: Consists of a PE bottle and cap (with flat liner), which is sealed with PP tape and placed in a fiberboard insert. This setup after being placed inside a PP bag and closed with a nylon tie is then placed inside a fiberboard box and sealed.

UN950GPT: Consists of glass bottle and a plastic cap with a flat liner, which is sealed with PP tape and then placed in a XEBEC pouch with ziplock. The setup is then placed in a fiberboard box and sealed

UN16FFPS: Consists of a glass bottle and plastic cap with a PE cone liner. The bottle is sealed with PP tape and placed inside two PS end caps at the top and bottom. This setup

after being placed inside a PP bag and closed with a nylon tie is then placed inside a fiberboard box and sealed.

UN32FFPS: Consists of a glass bottle and plastic cap with a PE cone liner. The bottle is sealed with PP tape and placed inside an enclosure made of two molded PS pieces. This setup after being placed inside a PP bag and closed with a nylon tie is then placed inside a fiberboard box and sealed.

UNHWS16: Consists of a wide mouth glass bottle and plastic cap with a flat liner. The bottle is sealed with PP tape and placed inside two PS end caps at the top and bottom and a central PS body piece. This setup after being placed inside a PP bag and closed with a nylon tie is then placed inside a fiberboard box and sealed.

UN1M: Consists of a steel pail with rust inhibiting lining and a steel drum fitting (cap) with a rubber gasket. The opening is not at the geometric center. The container is placed between two double-wall fiberboard end caps. This setup after being placed inside a PP bag and closed with a nylon tie is then placed inside a double-wall fiberboard box and sealed.

UN32NPVB: Consists of wide mouth Nalgene PE bottle and a liner less plastic cap, which is sealed with PP tape and then placed in a XEBEC pouch with ziplock. The setup is then placed in a fiberboard box and sealed.

HMSP-32N: Consists of four Nalgene PE bottle with liner less plastic caps. These are completely enclosed in a three-piece (two end pieces and a center-body piece) PS setup. This setup after being placed inside a PP bag and closed with a nylon tie is then placed inside a double-wall fiberboard box and sealed.

UN32PPS: Consists of a PE bottle and a cap with a cone liner, which is sealed with PP tape and placed in a fiberboard insert. A PS end piece is placed on the top end of the bottle. This setup after being placed inside a PP bag and closed with a nylon tie is then placed inside a fiberboard box and sealed.

UN4FFPS: Consists of a glass bottle and plastic cap with a PE cone liner. The bottle is sealed with PP tape and placed inside two PS end caps at the top and bottom and a central PS body piece. This setup after being placed inside a PP bag and closed with a nylon tie is then placed inside a fiberboard box and sealed.

UAC32FPS: Consists of a glass bottle and plastic cap (with PE cone liner). The bottle is sealed with PP tape and placed in a double-wall fiberboard insert and between two double-wall fiberboard end cushions. This setup after being placed inside a PP bag and closed with a nylon tie is then placed inside a double-wall fiberboard box and sealed.

UN32FAPS: Consists of a glass bottle and plastic cap with a PE cone liner. The bottle is sealed with PP tape and placed inside an enclosure made of two molded PS pieces. This setup after being placed inside a PP bag and closed with a nylon tie is then placed inside a fiberboard box and sealed.

KMP32UN4: Consists of four steel cans and lids with epoxy phenolic lining and welded side seams. The cans are sealed with plastic securing rings and placed within two EPS end caps. The setup is then placed in a fiberboard box and the box is sealed.

KM1000DF: Consists of a 24 gauge steel pail with rust inhibiting lining and a steel drum fitting (cap) with a rubber gasket. The opening is not at the geometric center. This is shipped without an outer fiberboard box.

KM1080: Consists of a 24 gauge steel pail with epoxy phenolic lining and a steel drum fitting (cap) with a rubber gasket. The opening (Rieke spout) is at the geometric center. This is shipped without an outer fiberboard box.

KTMGASUN: Consists of a 24 gauge steel pail with epoxy phenolic lining and a steel drum fitting (cap) with a rubber gasket. The opening (Rieke spout) is at the geometric center. The pail is placed in a double-wall fiberboard insert. This setup after being placed inside a PP bag and closed with a nylon tie is then placed inside a double-wall fiberboard box and sealed.

HINF630: Consists of four 10ml drawtubes, which have friction rubber closures. These are placed in a preformed cushioned encasing with a cushion top. The cushion is then placed within an aluminum canister with a screw on aluminum lid. This setup after being sealed in a ziplock PP bag is placed inside an enclosure made of two molded PS pieces and then put in a fiberboard box and sealed.

TEST METHODS AND RESULTS:

The tests were performed in two different phases. The Phase I test methods and results are briefly discussed in this section. The Phase II tests are currently being performed. These include additional tests including torque measurements on closures, cap misalignment, and dimensional tolerances. Some of these results will be presented at the conference program.

PHASE I (Simultaneous Pressure Differential & Vibration)
TEST PROCEDURE

- Packages were conditioned at 73.4 ± 3.6°F for a minimum of 24 hours before testing
- The primary containers were filled to the fill-level recommended and proper closure torque was applied
- Secondary packaging was applied, as if preparing for shipping, in accordance with the manufacturer’s instructions
- The test specimen was placed in the top-down position in the vacuum chamber and the vacuum chamber

was placed on an electro-hydraulic vibration table

- After sealing the vacuum chamber shut, the vacuum source is turned on and adjusted to a rate of 305 meters (1000 feet) per 30-60 seconds as recommended in the new proposed ASTM standard (ASTM, 2001)
- A pressure differential of 17.57 in.Hg (pressure equivalent of 14,000 feet) was achieved with a permissible error margin of ±5%
- While maintaining the pressure differential of 17.57 in. Hg, the vibration table was operated for 10 minutes using random mode simulation of a truck/air shipping environment (Assurance level II, ASTM D 4169).
- The chamber inlet valve was opened and the vacuum released at a rate of 305 meters (1000 feet) per 30-60 seconds
- The chamber cover was remove to retrieve the test specimen
- Any leakage observed was recorded

Figure 1 shows a description of the test setup. The samples are placed in the vacuum chamber and the chamber is placed on an electro-hydraulic vibration table.

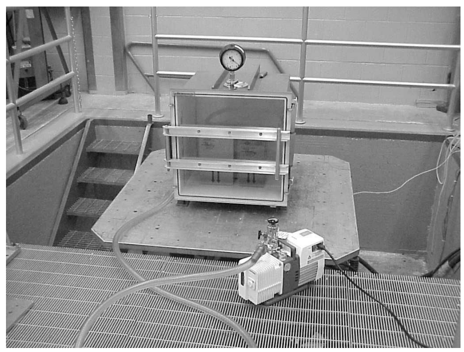

Figure 1: Experimental Setup for Phase I

RESULTS OF PHASE I:

The results of Phase I tests are listed in Table 1. Half the packages tested showed leaks after the test was completed.

TABLE 1: Test Results from Phase I

SKU	DESCRIPTION	LEAKED
HMS-08	Exemption (Poison Pack)	Yes
UN950PPT	Ground Only (950cc)	No
UN950GPT	Passenger Aircraft (950cc)	Yes
UN16FFPS	16oz (Flint)	No
UN32FFPS	Flint Bottle (Foam)	No
UNHWS16	16oz	Yes
UN1M	1 Gallon (Combo)	Yes
UN32NPVB	Passenger Air (32oz Poly-Pack)	No
HMSP-32N	Cargo Air ((4) 32oz)	No
UN32PPS	Ground Only (32oz)	Yes
UN4FFPS	4oz (Flint)	No

UAC32FPS	Flint Bottle (Corrugated)	No
UN32FAPS	32oz (Amber Bottle)	No
KMP32UN4	(4) Quart	Yes
KM1000DF	Closed Head 1 Gallon	Yes
KM1080	Rieke Spout	Yes
KTMGASUN	Gas Shipper	Yes
HINF630	Polyfoam Infectious Shipper	No

In addition Figures 2 and 3 show the types of different closures on the packages tested. Figure 2 shows the closures that leaked and Figure 3 shows the closures that did not leak.

Figure 2: Closures that showed leaks after tests

Figure 3: Closures that showed no leaks after tests

CONCLUSIONS:

Based on the results of this study, it is evident that a large number of existing DOT certified packages for liquids show leaks when simultaneously tested with low pressure and vibration representing the single parcel environment.

These results are similar to the results found by the Federal Aviation Authority in filed evaluations. This study is currently ongoing and additional results will be available in the coming year.

REFERENCES:

Singh, S.P., and G. Burgess, Effect of Vibration, Low Pressure and Temperature on Packages, Annual Report, Consortium of Distribution Packaging Research, Michigan State University, 2001

ASTM Task Group - Test Method for "Determining the Effects of High Altitude on Packaging Systems by Vacuum Method". ASTM, 2001