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Identification of force directions created by dynamic events experienced in the international air freight distribution environment

William Enderle Jr

Identification of force directions created by dynamic events experienced in the International air freight distribution environment

by

William R. Enderle Jr.

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1999

Department of Packaging Science
College of Applied Science and Technology
Rochester Institute of Technology
Rochester, New York

CERTIFICATE OF APPROVAL

M. S. DEGREE THESIS

The M.S. degree of William R. Enderle Jr.
has been reviewed and approved by
the thesis committee as satisfactory
for the thesis requirements for the
Master of Science Degree

____
Dan Goodwin Ph.D.

____
Karen Proctor

____
Tom Feigel

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Identification of force directions created by dynamic events experienced in the International air freight distribution environment

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William R. Enderle Jr.

Identification of Force Directions Created by Dynamic Events Experienced in the International Air Freight Distribution Environment

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Abstract

By linking actual hazards experienced in the field to pre shipment packaging test protocols, the development of a robust packaging specification is developed. This study evaluated the international air freight distribution environment for shipment between the United States and the Netherlands. Utilizing an Environmental Data Recorder, the data identified that different events, other than the normally expected drops and impacts, were experienced. Based on force direction, magnitude and waveform analysis, the data identified that the product is being tossed as it is transported. The results of this study will provide data to enable the creation of a pre-shipment packaging test protocol that accounts for these new environmental forces.

Dedication

I would like to dedicate this work to my devoted wife and best friend who, without her help, encouragement and support, this work could not have been completed.

I love you.

Acknowledgements

I would like to thank Terrie Allen, Manager of the Packaging Competency Center, at the Document Company, Xerox for providing guidance and the opportunity to conduct this study. In addition, I want to thank my Thesis committee members, Dan Goodwin and Karen Proctor from the Department of Packaging Science at the Rochester Institute of Technology for their guidance and patience. Lastly, I want to thank Tom Feigel from the Document Company, Xerox for his support in the execution of this study.

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1.0 Introduction

In today's business environment, corporations are looking for speed in the delivery of products to the customer. To enable this objective, packaging is playing an increasingly important role. The globalization of business places a high demand for products to be shipped down the road as well as around the world. This change in how products are distributed has resulted in the Packaging Engineer slowly losing control of the environment in which products are shipped. To regain control, engineers need to comprehend the distribution environment and design packaging which protects products in any environment in which they are shipped. Packaging needs to be developed for direct channel distribution, which is defined as shipments direct from the manufacturing location to the point of sale.

As products are developed and distributed to customers with increasing speed, companies are broadening the use of air transport to get their products to customers. In 1999, the number of companies sending goods overseas will reach 1.2 million, triple the number of just five years ago.[1] By using contract-shipping companies that specialize in the delivery of products internationally, further control of the distribution channels is lost. As Packaging Engineers, an understanding of this environment needs to be grasped. Due to these changes, it is becoming harder to use a standard set of guidelines to aid in pre shipment packaging testing. The development of lab protocols based on fact need to be defined.

As was noted, corporations are increasingly becoming global. To meet customer requirements, there is a need to airship products from manufacturing locations around the world. This is primarily during the initial product launch, when filling the product pipeline.

1.1 Current State

Xerox is shipping several of its products from their manufacturing location in Webster, New York to our European Logistic Center (ELC) in Venray Holland. To meet the needs of customers, a percentage of Xerox products need to use Freight Forwarders to ship products to Europe. Due to a significant level of damage generated in the airfreight environment, sometimes reaching 30% of a product shipment, it is clear that our existing performance test specification does not adequately cover this environment.

1.2 Purpose

By measuring the international airfreight distribution environment, accurate readings can be recorded that will help develop a standardized pre-shipment test method to test for this distribution arena. To measure this environment, recordings of actual events need to be taken. An event is any inputted force that exceeds the threshold level defined in the data recorder. Once the events are measured and recorded, a method to identify the type of event needs to be established. "By developing a method of analyzing environmental data, more accurately, better test parameters can be defined,

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[1] Richard Decker "Scary Sailing: Insuring international shipments"

for simulating those events, during the package cushioning design process".[2] To identify what is happening in the distribution environment, identification of different input data will need to be demonstrated. Identification of the different types of events in the airfreight environment requires a complete understanding of the distribution environment. When a product is air shipped, it will experience several types of handling through its journey to the end customer. The identification of these handling steps will enable the development of a pre test protocol to accurately recreate the event in the laboratory. Once all the handling steps are accounted for, laboratory tests can be developed where event profiles are established. An event profile is a collection of data displaying similar characteristics. Through the creation of laboratory tests, as well as using a Data Saver, a signature for each event is generated. This signature will be used to identify events recorded when an actual product is shipped, by air, from Webster, NY to the Xerox ELC located in Venray Holland.

1.3 Objective

Several studies have been conducted that measured the ground freight distribution environment.[3] [4] One area that has been overlooked is the global airfreight distribution environment. The objective of this study is to measure this environment and identify handling hazards that are being experienced. Once these hazards are measured and understood, the development of a pre shipment packaging protocol will be developed to aid Packaging Engineers in designing and testing products and packaging. These

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[2] Dan Goodwin " Accuracy in the testing protocol for measured drop heights in the distribution environment"

[3] J.N. Daniels, R. T. Sanders "New approaches to defining the Distribution Environment"

[4] Stephen Pierce, Dennis E. Young "Package Handling in less than Truck Load Shipments: Focused simulation measurement and test development."

test protocols will close the gap between simulated testing hazards and will provide "real world" testing situations to enable the development of robust packaging.

2.0 Literature Review

The measuring of actual field data has been conducted for many years. However, the method in which the measurements have been taken has changed. In reviewing documentation surrounding this subject, it reveals the necessity to conduct this type of investigation. To provide background on environmental measurements, an understanding of the types hazards, materials, applicable standards, measurement equipment, and distribution carriers will need to be reviewed.

2.1 Hazards

Within any distribution environment, there are particular hazards that will be identified. Hazards can be classified into three categories: environmental hazards, physical hazards and miscellaneous hazards.[5] Environmental hazards are considered in terms of temperature, humidity or changes in atmospheric pressure. Physical hazards consist of drops, impacts, vibration, and compression to name a few. Miscellaneous hazards are more difficult to identify, however they would include infestation and pilferage.

2.2 Materials

In designing a product's package, several factors need to be accounted for. Cost, durability, and product protection are just a few of these factors. Corrugated fiberboard and lumber pallets are discussed in detail since they will be used on the

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[5] Friedman Walter F & Kipnees, Jerome J. Distribution Packaging

product package used in this study. This will be clarified later in equipment identification.

2.2.1 Corrugated Fiberboard

Corrugated fiberboard, or "cardboard" as it is generally called, is the workhorse of the packaging industry. In the early 20th century, corrugated fiberboard replaced wooden crates as the primary form of shipping containers. Today, the US domestic market for corrugated will consume 350 billion ft^2 (31 billion m^2) or 3.5 million truckloads of corrugated board[6].

Corrugated fiberboard is constructed from two different types of materials: the liner and the medium. The liner consists of the flat outer surfaces of the corrugated board, and the medium is the "fluted" internal component. The flutes supply rigidity to the board which imparts strength with minimal weight and density.[7] The mixing of different weight liners and mediums will provide different performance characteristics.

Corrugated fiberboard can be broken down into several different classifications. The three classifications are single wall, double wall, and triple wall corrugated. Single wall corrugated is a constructed from two liners and a medium. Single wall corrugated is a general-purpose material used for shipping and storing products smaller products. The corrugated board is designated by the type of medium that is

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[6] Brody, Aaron L & Kenneth S. Marsh. The Wiley Encyclopedia of Packaging Technology
[7] Brody, Aaron L & Kenneth S. Marsh. The Wiley Encyclopedia of Packaging Technology

used in the board. There are three common types of single wall corrugated: A flute, B flute and C flute. The difference in fluting is the size of the flute. Double wall corrugated is constructed of three liners and two mediums. This type of corrugated is used when enhanced stacking strength is required or when additional cushioning is needed. Standard types of double wall include BC flute, AC flute and AA flute, with BC flute being the most common double wall corrugated type. Triple wall corrugated is constructed from four liners and three mediums. Triple wall corrugated is used when stacking very heavy objects and when increased product protection is required. Triple wall corrugated can be any combination of A, B, or C flutes. Common types of triple wall are BCC and AAA.

As discussed, corrugated fiberboard has many different applications.

1. Product protection
2. Product containment
3. Stacking
4. Cushioning
5. Blocking and bracing
6. Separation

Depending on the application, the correct type (single, double, or triple wall) corrugated needs to specified.

The two methods currently used to specify corrugated fiberboard are the Edge Crush Test (ECT) and the Mullen burst test. The ECT identifies the edge compression resistance of the test sample. The Mullen test method grades corrugated fiberboard by bursting strength in pounds per square inch. This test measures the resistance of the board to puncturing. The Mullen test is the most common and universally accepted method to specify corrugated board. [8] The Mullen specification will be used to designate board type for this study.

In this study two types of corrugated board are used: 500# BC flute double wall corrugated and 275# BC flute double wall corrugated. The application for this material is primarily protection from external objects and stacking of other objects on top of the packaged unit. The 500# BC flute double wall corrugated is used to provide stacking strength and allow other product to be stacked on top of the shipping container. The 275# BC flute cap seals the top of the tube and prevents contaminants from getting into the container. In addition, the cap provides a flat surface on the top of the package, facilitating the stacking of products on top.

2.2.2 Pallets

Pallets are low profile devices, which allow product and parts to be stacked or staged for movement within a production environment or for delivery to the customer. Pallets are produced in different styles, and constructed from many different materials such as wood, plastic, and corrugated. Pallets are designed to enable the efficient movement of product via mechanical devices.

Generally, pallets can be classified into two different styles; slotted deck and solid deck. The first pallet type is the slotted deck pallet or Grocery Manufacturers Association (GMA) pallet. GMA pallets are the most common type of pallets. Often called grocery pallets, they measure 48" long by 40" wide with notched stringers to

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[8] Friedman, Walter F Distribution Packaging.

allow side as well as front entry.[9] The second style is the solid deck pallet, and are generally used for shipping heavier products or manufactured goods. Solid deck pallets have a completely solid deck, providing a good surface to secure brackets to as well as a solid surface to support an overpack corrugated tube if needed. Solid deck pallets tend to be used for international shipment of equipment because of their durability. Since the shipment of product in this study will be overseas and outside of our direct control during shipment, solid deck wood pallet is used.

2.3 Standards

Currently, there are three recognized approaches to performance testing.[10]

1. Integrity testing - Tests the performance of the product and package as they work
2. General simulation - Seeks to simulate motions and events of distribution, along with the effects of distribution.
3. Focused simulation - Ties laboratory test intensities to the actual levels of measured field conditions.

These three approaches cover the broad spectrum of packaging testing that is currently being conducted.

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[9] Environmental Protection Agency, "Notices for the CPG II and RMAN II final designation" Federal Register Notices

2.3.1 Integrity Testing

Integrity testing is an approach that will test the packaging, as well as the product, to similar hazards that may be experienced in the field. The objective of integrity testing is to avoid damage through the mechanism of product and package strength.[11] Since this testing combines the strength of both the product and packaging, a thorough knowledge of the distribution environment is not necessary.

2.3.2 General Simulation

General simulation is an approach where knowledge about the distribution is applied to the product and packaging. This method tries to simulate distribution effects and identify how they affect the product. General simulation typically uses defined test specifications where specific test levels and intensities are identified. Depending on the hazards of the environment, the engineer defines the level of testing for each product tested.

Today, a majority of the packaging testing conducted is general simulation testing. This type of testing, however, does not cover all hazards within a particular environment. Specifications such as the American Society for Testing and Materials (ASTM) D-4169 - Standard Practice for performance testing of shipping containers and systems, [12] and the International Safe Transit Association (ISTA) integrity test procedure 1B, are two methods available for general simulation. To enhance the testing specifications for a particular environment, carriers, such as United Parcel

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[10] Denis Young "Simulation Technology Improves Package Performance Testing"
[11] Denis Young "Simulation Technology Improves Package Performance Testing"

Service (UPS) and Federal Express (FedEx) have defined their own specifications based on their shipping environment.

General simulation is a test for individuals that do not have a large knowledge about the product's shipping environment. General simulation procedures provide a uniform basis of evaluation that can be tested in a laboratory setting.

2.3.3 Focused Simulation

Focused simulation ties laboratory test intensities to levels measured under field conditions.[13] Per the flaws inherent in integrity and general simulation testing, focused simulation is needed for the following reasons:

1. All distribution environments are not the same
2. Intensities differ depending on where the product is shipped to as well as how the product will be shipped there.
3. Focused simulation enhances existing laboratory test data by bringing it closer to real life events.

Focus simulation is used to identify a specific portion of a distribution environment, and to develop pre shipment test protocols based on the results. These protocols are inherently robust in that they simulate actual field measurements. This information provides an analytical tool that can be used in the development of product packaging. With a better understanding of the environment, and the testing to simulate it, cost-effective packaging can be developed.

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[12] ASTM D 4169 – Standard practice for performance testing of shipping containers and systems

2.4 Equipment

The ability to measure the distribution environment in which products are shipped is important. With new equipment being developed to measure this environment, understanding the data collection device and its capabilities will enable the proper data to be collected and analyzed. A Dallas Instruments Data Saver, a commonly used Environmental Data Recorder (EDR), is used for measuring and quantifying various environments associated with the packaging and transportation of products. The Data Saver is but one of several instruments that can be used to record environmental data. Early EDR devices were large and heavy, limiting the capable range of the instrument. Over the last 12 years, the space utilization metric (size times weight metric) has steadily decreased.[14] The Data Saver, for this project is 39 cu. in. weighing 2.2 pounds; yielding a space utilization metric of 90.1. (See Appendix A for specifications) Comparing this to an EDR from 1987, there has been a 93% decrease in EDR size.[14] Along with the decrease in overall size, the total data throughput, total power consumption, storage density, and throughput density have all been optimized to develop equipment that is more powerful and efficient than equipment of only a few years ago. As technology improves, the capabilities of Data Savers will also improve. Data Savers will become even smaller and lighter, provide greater storage capacity, and possibly enable the access of data remotely.

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[13] Denis Young "Simulation Technology Improves Package Performance Testing"
[14] Greg Hoshal "Environmental data recording: current and future"

The Data Saver used in this study is a remotely operated environmental recording device. The Data Saver is capable of recording product drop heights, environmental conditions (temperature and humidity) and product acceleration. This recorded data is stored on an internal microprocessor for uploading to a computer when the Data Saver is recovered. The Data Saver records two types of data or events. Dynamic data are events that change with time due to a drop or impact. The result is a waveform that can be measured and analyzed. Static data is recorded by one channel and is represented by temperature or humidity, where only a single reading is necessary. In addition to the identification of the impact locations, the Data Saver identifies the time of the handling event. With this feature, handling events can be tracked back to a particular location during product shipment. With the help of our carrier, product location will be monitored to identify the location of the test unit throughout the distribution cycle. This information will be used to identify specific points during the products delivery for correlation with the data once the machine is returned.

2.5 Carriers

As products are moved from one location to another, the product may encounter several different carriers along the way. Internal material handlers, or carriers, will be used to ship manufactured packaged/products internally. From the internal carriers, the product can be picked up by a common carrier that may deliver the product to an express carrier who ships the product to the final destination or customer. This is but one example of how a product is shipped. The difficulty is in deciding how to protect the product in this overall environment.

As corporations continue to globalize, ever-changing requirements are generated to get product from the manufacturer to the customer. Most corporations do not have the distribution infrastructure to ship their products on a global basis cost effectively. Because of this, many companies have been formed that specialize in shipping products throughout the world. These companies can be classified into two categories: parcel shippers such as UPS and FedEx, and freight forwarders. Parcel shippers, or express carriers, carry lighter weight packages and transport the packages to the customer either overnight or within a couple of days. These packages are generally unpalletized and weigh less than 100 pounds. The express carrier is set-up to handle a large volume of product in a short period. UPS has set-up a cross-docking operation where 2.0 million packages are handled every day.[15] Freight forwarders, on the other hand, can ship any type of product, regardless of size and weight. Generally freight forwarders handle palletized products and unitize the products into shippable loads. Depending on timing and location, freight forwarders transport product by land, sea or air. Because of this, Xerox utilizes freight forwarders to ship products to specific global distribution sites they have established.

To control shipping costs, Xerox has contracted with AEI Global Logistics Incorporated, the largest U.S. based international freight forwarder, to transport international shipments. AEI has capabilities to ship products using ground transportation, ocean forwarding, and air transport. This latter method has been identified as a concern relative to the shipment of Xerox products. This concern stems from the damage generated on products shipped in this environment. To

[15] Gary Forger "UPS starts world's premier cross-docking operation"

understanding how AEI moves our products, we have mapped their international airfreight distribution channels to identify the different transfer points within their logistic system. For product shipments from Webster, NY to Venray Holland, all AEI airfreight shipment handoffs have been identified. (figure 1) Per the data collection, we will be able to model their international airfreight distribution environment in our lab. By working in conjunction with AEI, we were able to use their logistics information system, or LOGIS™, to track and monitor our shipments through their entire system. From pick up to final delivery, AEI is capable of identifing the product location at any point during transport.

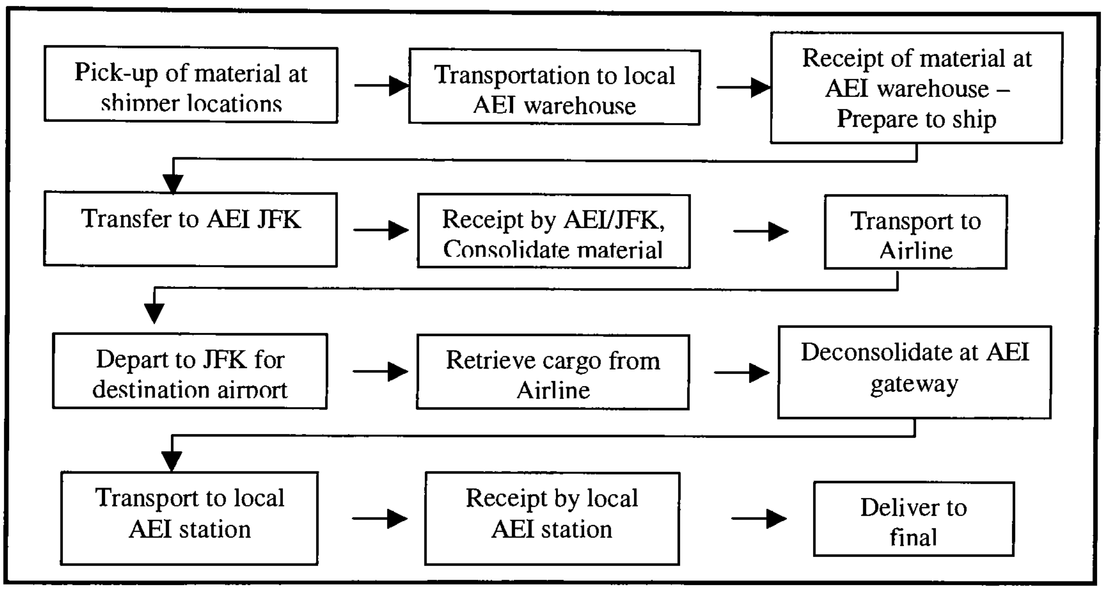

Figure 1. Flow chart defining the International Airfreight Distribution environment product handoffs

During this study, AEI coordinated all air shipments to and from our European Logistics Center (ELC). Additionally, they provided all customs clearances to speed the delivery of the product to its final destination. To avoid paying duty on the test unit being shipped, an ATA Carnet was generated. An ATA Carnet is documentation indicating the product being shipped will not remain in the country of destination and will be returned to the original shipping destination. This aided in clearing customs and eliminated the need to pay duty on the product shipped.

3.0 Methodology

Three main areas needed to be defined for this study: test machine identification, product packaging design and test equipment.

3.1 Machine Identification:

To determine the appropriate test machine, it was necessary to take a comprehensive look at the machines experiencing damage in the airfreight environment. Based on actual field data, it was identified that mid-volume machines were experiencing damage when shipped in the international airfreight environment. With this data, the machine type could be determined. Data regarding the mid-volume family of products such as, product type, size, weight, and number of installs expected in 1999, were collected. This data is listed in the Table 1. From this data, the test machine was chosen.

Table 1. Mid-Volume Machines installs, size, and weights

Product	1999 Installs (expected)	Machine Size		Machine Pkg Weight		% of total Installs
		Inches	mm	Kg	Pounds	
5365	4,217	59x32.6x53.5	1499x828x1359	445	979	10.1%
5345	256	59x31.5x59	1500x800x1500	349	768	0.6%
5355	2,107	59x31.5x59	1500x800x1500	349	768	5.1%
5065	176	61x30x46	1549x672x1168	332	730	0.4%
5052	0	50x30.3x50	1250x770x1250	249	548	0.0%
5053	2,021	50x30.3x50	1250x770x1250	249	548	4.9%
5050	0	47.5x30.3x46.5	1206x770x1180	244	537	0.0%
5350	0	46x30.4x50	1160x772x1265	225	495	0.0%
5343C	82	31.5x30.4x50	795x772x1265	225	495	0.2%
5352C	1,172	46x30.4x50	1160x772x1265	225	495	2.8%
5665	2,436	45x39x49	1143x991x1245	222	488	5.9%
5340	0	31.5x30.4x50	795x772x1265	208	458	0.0%
255ST	2,601	33.75x30.5x52	857x771x1320	179.5	395	6.3%
255DC	7,231	33.75x30.5x52	857x771x1320	179.5	395	17.4%
265ST	8,537	33.75x30.5x52	857x771x1320	179.5	395	20.5%
265DC	10,137	33.75x30.5x52	857x771x1320	179.5	395	24.4%
255LP (NP)	200	33.75x30.5x45	857x771x1143	159	350	0.5%
265LP (NP)	300	33.75x30.5x45	857x771x1143	159	350	0.7%
5337	74	31.5x30.5x50	795x772x1265	117	257	0.2%

From the data, mid volume product machines were broken down into weight classes, and the total number of machines installed vs. product weight was identified. After collecting this data, a machine that best represented the types of mid-volume products shipped by Xerox was chosen. (Figure 2) Based on the data, a Xerox 265DC was chosen as the machine to be used to measure the air shipment environment. The Xerox 265DC machine is 33.75"x 30.5"x 52" in size and weighs 395 pounds.

3.2 Package Design:

The Xerox 265DC is shipped on a solid deck lumber shipping pallet. The pallet size is 33.75" long by 30.5" wide and 4.75" tall. The machine is attached to the pallet by using 2, 3mm cold rolled steel formed "Z" brackets wich attach to mounting pins built into the 265DC frame. (Figure 3). Once the machine is mounted to the pallet, a 3mil low-density polyethylene bag is placed over the machine. The entire unit is then stretch wrapped using a 65 gauge stretch film used to secure the paper drawers and the document handler. Following the stretch wrapping, a 500# BC flute corrugated tube is placed over the machine and covered with a 275# BC flute corrugated top cap. The tube and cap are secured to the pallet using 2, .5 inch nylon straps, friction welded together. (Figure 4).

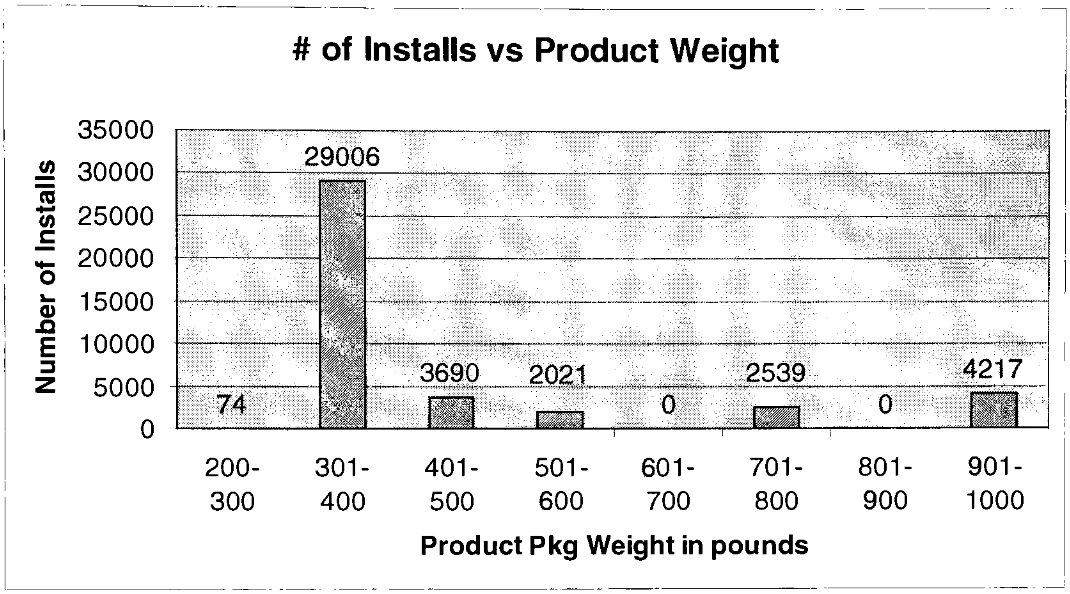

Figure 2. Graph of the number of product installs vs. the product weight within the mid volume product family of Xerox products

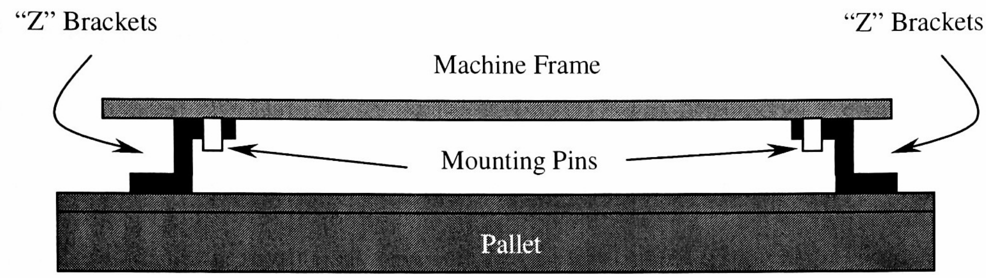

Figure 3. DC265 Machine / pallet mounting configuration

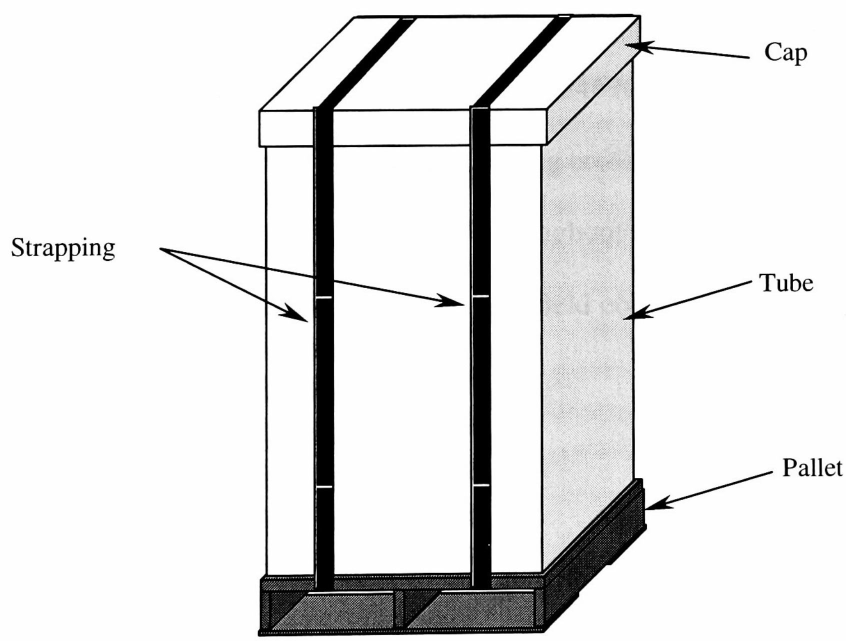

Figure 4. DC265 overpack packaged Configuration

3.3 Test Equipment:

3.3.1 Field Recording Equipment

A Dallas Instruments Data Saver serial #0440-012 was utilized in the recovery of data from the field as well as the data from the laboratory testing. For all testing conducted, the Data Saver unit was secured to the center of the base plate of the 265DC machine using 4, 3/16 #10 machine screws with nylon inserted nuts to prevent loosening during testing. (Figure 5).

3.3.2 Lab Equipment

A Lansmont precision drop tester model F, serial# L-1085MJ, with a 1000 pound capacity was used to perform controlled drops in the Xerox Packaging Engineering lab. A “big Joe” forktruck model# PDI-20-T8, serial# 346964 was used to simulate pallet marshaling and movement of the product during cross docking and load unitization. To ensure consistent data collection throughout the study, and to enable the ability to compare laboratory-collected data and field collected data, the existing packaging design was utilized.

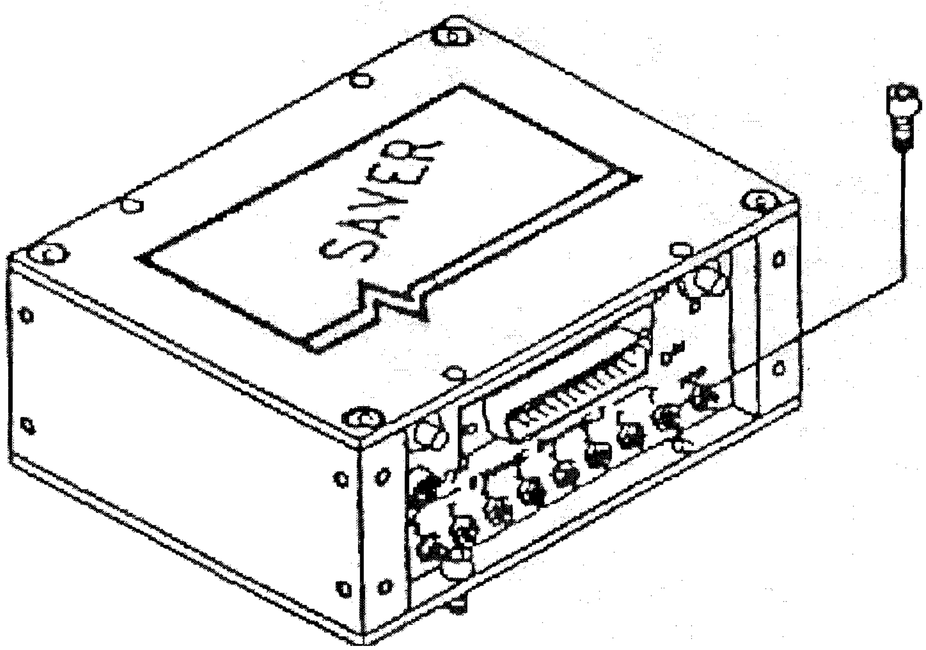

Figure 5. Dallas Instruments Data saver Unit

4.0 Lab Data Collection

In setting up the data collection for the lab testing, the 265DC machine was packaged using the packaging identified in figures 3 and 4. The Data Saver was set to record data per the process identified in Appendix A. In each test, the event was recorded and processed using the Data Saver software. Through the utilization of the zero-g algorithm within the Data Saver software, a vector resultant magnitude (VRM) signal, measured in g's, was identified[16]. In the laboratory testing, the VRM signature generated was used as a comparison against actual field data. In addition to the VRM signature, measured drop heights and impact forces, measured in g's, were recorded. The data was used to compare differences between different handling hazards experienced in the international airfreight distribution environment. All laboratory test data is located in Appendix B.

4.1 Drop testing

4.1.1 Flat Drops:

Using the precision drop tester at the Xerox Packaging Lab, following the procedure outlined in Appendix A, a flat drop test was conducted from 6 inches on the packaged DC265 machine. This test procedure follows the Xerox test specification MN2-810.13 Rev 12.[17] Five drops from the specified height were performed using the set-up identified in figure 6a. Using the Data Saver, the data was recorded and

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[16] "Instruction Manual for the Saver – Shock and Vibration Environmental Recorder"
[17] Xerox MN2-810.13, rev 12,

downloaded per the process outlined in Appendix A. The data was then compared to the actual drop height.

4.1.2 Edge Drops

Using the precision drop tester at the Xerox Packaging Engineering Lab and following MN2-810.13, Five drops to each edge were conducted using the set-up identified in figure 6b. Using the Data Saver, the data was recorded and downloaded. From this data, g's and drop height results were tabulated and compared to the actual drop height.

4.1.3 Corner Drops

Using the precision drop tester at the Xerox Packaging Engineering Lab, a corner drop test from a handling side waw conducted following the set up in figure 6c. Five drops from 6 inches were conducted. Using the Data Saver, the data was recorded and downloaded. From this data, g's and drop height results were tabulated and compared to the actual drop height.

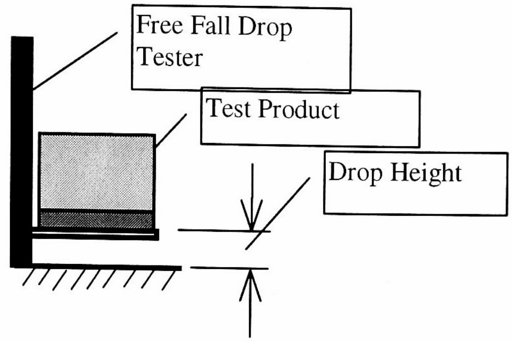

Figure 6a. Palletized flat shock test setup

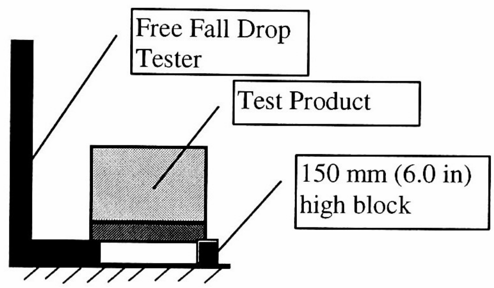

Figure 6b. Palletized Edge Drop test Set up

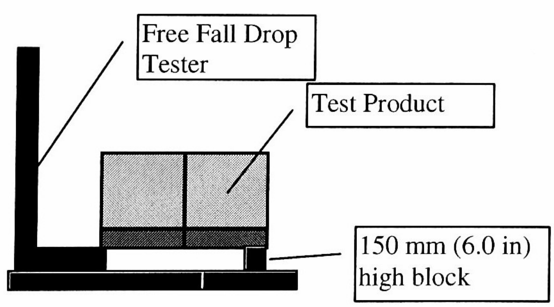

Figure 6c. Palletized Corner Drop test Set up

4.2 Warehouse Data Collection

To capture all expected handling hazards the test product will experience, we subjected the DC265 test machine to warehouse handling. Simulated forktruck handing was conducted in a controlled setting to record the type of event product experiences during shipment. Three different types of testing were conducted; Fork drops, pallet marshaling where the test unit is impacted into another product, and pallet marshaling where another product is impacted into the test product. All the downloaded data from the Data Saver is located in Appendix B.

4.2.1 Fork Drops:

In a controlled setting, a "Big Joe" forktruck model# PDI-20-T8, serial# 346964, lowered the test machine equipped to record events simulating un-stacking of products. The lowering of the test machine was unimpeded. This simulated a "controlled" drop, not a free fall drop. The test machine was lowered from the height of a packaged machine, 45 inches, and five controlled drops performed. The data was recorded on the Data Saver, then downloaded for evaluation

To simulate movement of product within a warehouse and loading and unloading of transportation devices, pallet marshaling was simulated. Pallet marshaling is described as an impact of pallets as they are pushed or impacted on the warehouse floor. There were two types of pallet marshaling events recorded. The first was a product on a forktruck striking a stationary product on the floor. The second was the stationary object being struck by an object on the forktruck.

4.2.2 Pallet Marshaling (Striking)

In the laboratory setting, the forktruck pushed the test machine at full speed into another pallet with a simulated weight that was the same as the test unit. This procedure was conducted five times. The data was recorded on the Data Saver, then downloaded for evaluation.

4.2.3 Pallet Marshaling: (Struck)

In a controlled setting, the forktruck pushed a pallet at full speed with a simulated weight, into the test machine. This procedure was conducted five times. The data was recorded on the Data Saver, then downloaded for evaluation.

5.0 Field Data Collection

To collect data in the field, it was necessary to have an understanding of the product-shipping environment. By using remote recording devices it was possible, to precisely identify the mode of transit and the type of handling experienced. In addition, a device that could yield data that are more accurate was fundamentally necessary to build confidence in the results.[18]

5.1 Product Shipping Environment

A packaged product containing a Data Saver was shipped, by air, from the Xerox manufacturing facility in Webster, New York to the Xerox European Logistics Center (ELC) in Venray Holland. From the ELC, the product was turned around and shipped back to the Packaging Engineering Lab in Webster, New York. During this shipment, the Data Saver recorded actual dynamic events that the machine experienced. With each full trip, we collected two sets of data from the international airfreight shipping and distribution environment. Once the data was collected and stored, the test machine was repacked, with the Data Saver, and shipped back through the system. Four trips were conducted. This data was compared against the data generated in the laboratory testing to identify the type of event the machine experienced. Additionally, the number of different events and magnitude of the event was identified.

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[18] J.N. Daniels, R. T. Sanders "New approaches to defining the Distribution Environment"

5.2 Data Collection / Set Up[19]

In setting up the Data Saver, it was necessary to adjust the settings within the Data Saver to ensure that the Signal trigger, time triggers, and overall memory allocations were appropriately partitioned in order to collect data. Table 1 and table 2 indicate the Data Saver Set-up for all testing. Data Saver set-ups for the field testing phase were critical, since temperature and humidity data were collected to add to our knowledge base. Although temperature and humidity were not a factor in this study, the collection of this data was "free" and can be used in other areas of our business.

5.3 Channel and Axis Identification:

In reviewing the placement of the Data Saver unit, the orientation of the device needed to be noted. The Data Saver unit is equipped with a tri-axel accelerometer that indicate the direction of forces experienced by the unit. The triaxial accelerometers are connected to dynamic waveform channels and are indicated as channels 1, 2, & 3. The channels can also be identified as the X, Y, & Z-axis respectively. Additionally, in recording shock and drop heights, the Data Saver identifies the impact or force locations as the front, back, right, etc. side of the Data Saver unit. To identify the correct impact or force locations, the front was designated as is the side of the Data Saver where the host communication connector was located and the top was identified by the Data Saver Logo. (Figure 7). Because the impact location was identified, accurate readings could be taken on how the Data Saver unit and product were handled in the field.

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[19] Instruction Manual for the Saver – "Shock and Vibration Environmental Recorder"

Table 2. Data Saver Memory Partitions

Signal Triggered Data		**Time Triggered Data**	
Record Time	720 msec	Record Time	No Waveform
Samples / Second	2000	Samples / Second	2000
Sample Size	900	Sample Size	50
Signal Pre Trigger	30%	Wake-up interval	59 minutes
Signal Pre-trigger Compression	3:1	Time to fill	132.1 Days
Record Waveform	Checked	Record T/H and static Channels	Checked
Data Analysis Type	Drop Height	Data Analysis Type	Event Viewer – No analysis
Data Retention Mode	Stop When Full	Data Retention Mode	Stop When Full
Memory Allocation	758 Events (98%)	Memory Allocation	3223 Events (2%)

Table 3. Channel Maps

Channels to sample / Signal Trigger	1 – 3
Samples / Second	2000
Channels to sample / Timer Trigger	1 – 3
Samples / Second	2000
Full Scale	100 g's
Filter Frequency	780 Hz

Channel Information				
Active in Signal Partition	Active in Timer Partition	Channel Description	Full Scale	Primary Trigger Group
>>->	>>->	Channel 1	100g's	Above 10 G's or Below –10 G's
>>->	>>->	Channel 2	100g's	Above 10 G's or Below –10 G's
>>->	>>->	Channel 3	100g's	Above 10 G's or Below –10 G's

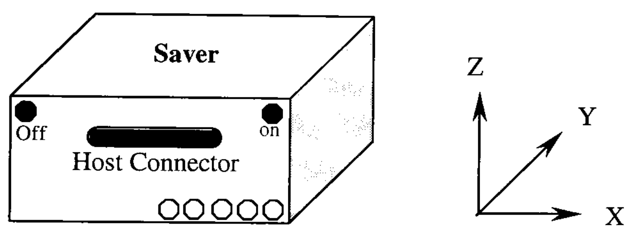


Figure 7. Saver Orientation

6.0 Data Analysis

The data collected and analyzed by the Data Saver identified the different types of events experienced by the product. Each event recorded by the Data Saver is catalogued into four different categories: Flat drop, impact, tossed up, or unknown. Events classified as flat drop or tossed up, the Data Saver analyzes the three waveforms generated by the tri-axial accelerometer using a proprietary algorithm to calculate a drop height. This algorithm records the time that the Data Saver senses "zero-G" and determines the event type. In an event where there is no "zero-G" time recorded, and there is no input prior to the actual event, the Data Saver records the event as an impact. When the Data Saver analysis is unable to classify the event into a specific format, the event is labeled as unknown.

Four round trip shipments were conducted for this study. During the initial Data Saver set-up, the Data Saver unit was set to record only the events in excess of 15G's. With this set-up, the Data Saver recorded only 6 events. For the second, third, and forth trips, the Data Saver set-up was modified to capture events in excess of 10G's. This change captured significantly more data on the subsequent trips. On trip 2, the Data Saver recorded 56 events; trip 3 the Data Saver recorded 49 events, and on trip 4 the Data Saver recorded 18 events. This change in Data Saver set-up identified that a significant portion of the events recorded were less than 15G's. However, the identification of the magnitude of each recorded event is only part of the equation. The direction of each event needed to be identified to understand how the packaged machine received impacts in the field.

Through further analysis of the data, the axis of greatest acceleration for each event was identified and reviewed. The analysis identified that the majority of the events recorded by the Data Saver occurred in the z-axis direction. (see table 4). This indicates that the test machine was subjected to greater forces in the vertical direction or on the top or bottom of the machine packaging. Through visual inspection of the packaging at the end of each trip, it was identified that the machine was never dropped on its top. Understanding this, the recorded data were generated via impacts on the base of the pallet and transmitted to the machine.

Now understanding where the forces are generated, the entire population of data was analyzed. Table 5 identifies the summary statistics for the z-axis data for the individual trips. In reviewing the summary statistics, it showed consistencies between populations. The means for all the trips were within 5.5G's with the largest mean taken from the first trip and the lowest mean from trip two. Similarly, the medians from all four trips are within 6.5G's of each other. Following the same method, z-axis data from all trips were combined and the summary statistics were calculated. (see Table 6).

Table 4. Number of recorded events identified by axis of highest acceleration

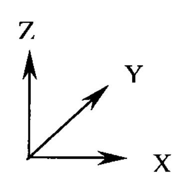
Number of Events Trip #1			Number of events Trip #2	
X Axis	2		X Axis	4
Y Axis	0		Y Axis	0
Z Axis	4		Z Axis	52
66.6% of events occurred in the z-axis			**91.1% of events occurred in the z-axis**	
Number of Events Trip #3			Number of Events Trip #4	
X Axis	4		X Axis	2
Y Axis	0		Y Axis	1
Z Axis	45		Z Axis	15
91.8% of events occurred in the z-axis			**83.3% of events occurred in the z-axis**	

Table 5. Individual Summary Statistics for the z-axis on all Trips measured in G's

Trip 1			**Trip 2**	
Mean	19.308		Mean	13.840
Median	18.900		Median	12.755
Standard deviation	3.549		Standard deviation	4.127
Minimum	15.520		Minimum	10.030
Maximum	23.910		Maximum	26.970
Range	8.390		Range	16.940
Variance	12.594		Variance	17.029
Trip 3			**Trip 4**	
Mean	14.331		Mean	17.339
Median	12.420		Median	13.190
Standard deviation	5.710		Standard deviation	9.266
Minimum	10.140		Minimum	10.080
Maximum	36.730		Maximum	45.830
Range	26.590		Range	35.750
Variance	32.602		Variance	85.863

Table 6. Summary Statistics for cumulative z-axis data (Trips 1-4)

Mean	14.290
Median	12.750
Standard deviation	5.730
Minimum	5.890
Maximum	45.830
Range	39.940
Variance	32.838



Similar results can be seen with means and medians within the same range as the individual populations. Based on this data, the data were tested to identify if the populations were normally distributed. Histograms were plotted for each trips' data, as well as the cumulative z-axis data and a p-value was identified for each population. For each trip and the cumulative z-axis data, it was determined that the data were not normally distributed. See Appendix B for histograms and normalcy test information. The population that best fit a normally distributed population was trip 4, with a p-value of 0.262. All the other distributions had p-values of .000.

From the analysis of the magnitude of the data collected in this study, it can be seen that during each trip through the international airfreight distribution environment, the package was subjected to similar forces and impacts.

Understanding the direction of the recorded forces leads toward what is causing the event. By reviewing the Data Saver data, the event type is identified providing additional information on the type of events experienced. Table 7 shows the total number of recorded events broken down into specific event types. With the knowledge that a significant number of events occurred in the z-axis, we could correlate this data with the event types. The data shows that 116 events caused recordings to be taken in the z-axis. Within the data, the Data Saver recorded 14 events identified as a flat top impacts. Since this was recorded in the z-axis direction, this data were included in the analysis.

Table 7. Event location vs Number of recorded events

Event Location	Number of Events	% of Total
Flat - Bottom	43	33%
Edge - Bottom Front	25	19%
Flat - Top	14	11%
Edge - Top Back	7	5%
Edge - Bottom Left	6	5%
Corner - Bottom Front Left	5	4%
Flat - Right	4	3%
Edge - Bottom Back	3	2%
Edge - Front Bottom	3	2%
Edge - Right Bottom	3	2%
Corner - Front Bottom Left	2	2%
Edge - Top Front	2	2%
Edge - Top Left	2	2%
Corner - Bottom Left Front	1	1%
Corner - Bottom Right Front	1	1%
Corner - Left Front Bottom	1	1%
Corner - Left Back Top	1	1%
Corner - Right Back Top	1	1%
Corner - Right Bottom Front	1	1%
Corner - Top Left Back	1	1%
Edge - Bottom Right	1	1%
Edge - Left Front	1	1%
Flat - Left	1	1%

As there were no x-axis events surrounding pallet marshaling, investigation of the data was needed to identify the unknown drop types recorded by the Data Saver. Based on previous research completed by Goodwin and Goyal (March 1997), the unknown VRM waveforms can be compared to a known event signature and be reclassified. However, depending on the environment and the complexity of the event inputs, the type of event may not be determined by looking at the event signature alone.

To identify the handling event, the individual VRM for the unknown drop types were reviewed. This analysis showed that for the unknown drop types there is a resemblance to a toss VRM signature. Figure 8a identifies a known toss VRM signature and Figure 8b is a recorded VRM signature identified as an unknown drop type. By reviewing the individual trip data, the number of drop types identified as unknown are identified. Table 9 identifies the drop type data for the individual trips and cumulative data set.

Table 9. Number of recorded drop types per trip

Drop types: Trip #1		**Drop Types: Trip #2**	
Flat Drops	0	Flat Drops	0
Tossed up	2	Tossed up	12
Impact not a Drop	1	Impact not a Drop	8
Unknown	3	Unknown	36
50.0% of drop types identified as unknown		**64.2% of drop types identified as unknown**	
Drop Types: Trip #3		**Drop Types: Trip #4**	
Flat Drops	0	Flat Drops	0
Tossed up	4	Tossed up	2
Impact not a Drop	2	Impact not a Drop	5
Unknown	43	Unknown	11
87.7% of drop types identified as unknown		**61.1% of drop types identified as unknown**	

Drop Types: Cumulative Data

Drop Type	**# recorded**	**Percentage**
Flat Drops	0	0%
Tossed up	20	15.5%
Impact not a Drop	16	12.4%
Unknown	93	72.1%

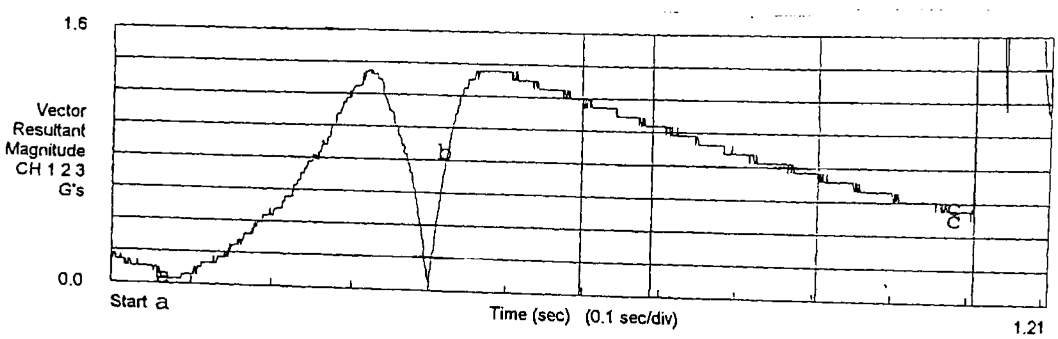


Figure 8a. Known toss VRM signature

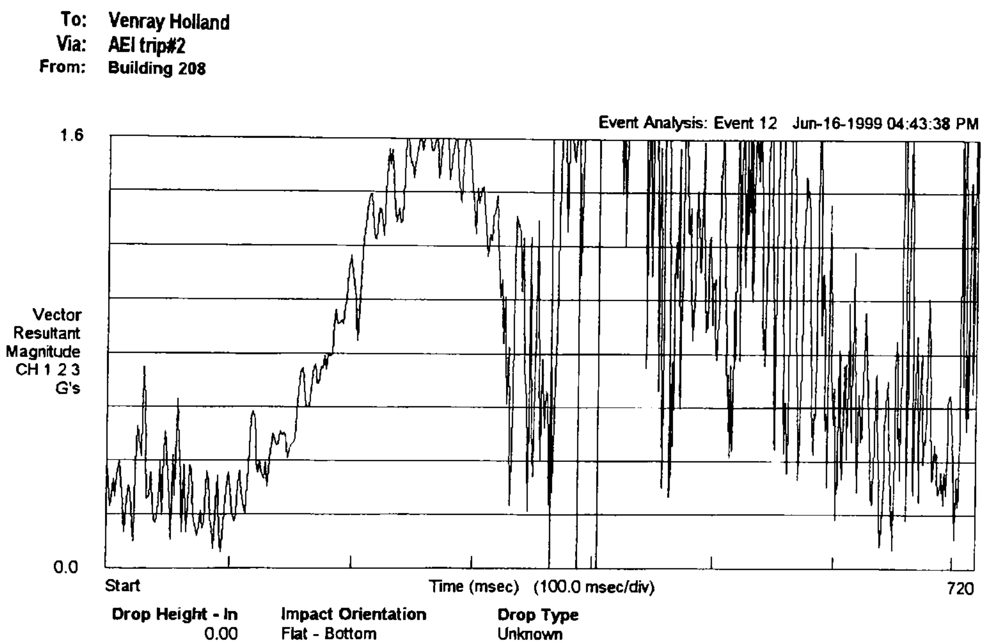


Figure 8b. Data Saver Unknown drop type

7.0 Observations / Conclusions

The data showed that 89.9% (116 out of 129) of all recorded events occurred in the z-axis. This indicates that the events were being generated from actual drops or other types of handling in the z-direction as indicated by the Data Saver. Since the palletized product was moved and handled by forktrucks, this type of handling hazard needs to be focused on. Handling via forktrucks was anticipated, however, the expected outcome was to see events associated with pallet marshaling. Based on our lab testing, pallet marshaling would have generated an event in the x-axis. As the data indicated, only 9.3% (12 out of 129) of the recorded events were in the x-axis. (The remaining .77% (1 event) occurred in the y-axis.) With such a small percentage of the total number of recorded events occurring in the x-axis direction, other types of inputs needed to be generated by the forktruck. These findings were significant in that it indicates that a new type of handling phenomena is experienced in the field. This also indicates that traditional test protocols identified earlier did not account for these phenomena

The data supports this observation in that there were 19 instances where an actual drop height was recorded. Of the 19-recoreded drop heights, the largest drop height was 3.52" with a flat bottom orientation, and a tossed-up drop type. Additionally, every recorded event with a measurable drop height had the characteristic of a toss-up. This led toward the idea that the international airfreight distribution environment subjects products to a large number of tosses instead of the traditional impacts and drops normally tested for. Additionally, recorded drop types classified as "unknown" matched the same VRM waveform characteristic of a toss drop type. Of the total data collected, 87.6% of all the recorded data are classified with a drop type of unknown or toss.

Within the international airfreight distribution environment there are many areas where a drop type of toss can identified. When shipped by a truck, light loads can bounce when the truck hits a bump. A toss can also be attributed to the product bouncing on the forks of a forktruck when moved with-in the warehouse. This bouncing can be attributed to several factors. The bouncing can be generated when the forktruck is going over a bump or a seam in the warehouse floor or when the forktruck is loading the truck for transport and travels over the dock leveling plate. This phenomenon can also be experienced when the air cargo lift plate is brought into position. The air cargo lift plate is a hydraulic lift used to move product to be loaded onto a plane. If the lift stops abruptly, the product will experience the sensation of a toss. Another cause of a toss drop type is an individually shipped product in the back of a truck. If the truck hits a bump in the road the product will experience a toss phenomenon.

The data from this study showed that 72.1% of all the recorded drop types were identified as "unknown". This could identify a deficiency within the Data Saver software. In previous studies, the Data Saver had been used for measuring the parcel distribution environment using smaller unpalletized products. In this study, our product was large and palletized. A factor in generating the large number of "unknown" drop types may be linked to how the Data Saver was mounted to the product. In being physically attached to the base pan of the machine, it becomes part of a large mechanical system. With-in this mechanical system, the product itself could have generated noise that was recorded by the Data Saver. This additional Environmental noise and the actual recordable event, can combine to generate a VRM waveform that is unrecognizable to the Data Saver software.

In protecting products shipped in the international airfreight distribution environment, it is critical that the type of hazards with-in the environment be identified. With the knowledge that a dynamic event is being experienced, which has not been historically accounted for, further studies can be conducted to further identify where and when they occur.

8.0 Recommendations / Next Steps

8.1 Recommendations

With the identification a new type of field event, further studies are needed to expand the knowledge in this area. Three studies that will support the scope of this study are as follows:

1. Specifically measure toss drop type events generated in the field. Part of this study will include measurement of the magnitude and the specifics on how the events occur.
2. Correlate the findings of this study with larger products, greater than 395 pounds, shipped through the international airfreight distribution environment.
3. Conduct a similar study by changing the destination location. Areas of interest include the Far East, South America, and East to West Coast shipments. By conducting this study, the data will be correlated to see if there are differences in shipping environments depending on geographic locations.

In addition to studying the environment, the use of the Data Saver as a recording instrument should be re-evaluated. For larger palletized products, updated analytical software may need to be developed to account for the noise generated in a highly complex mechanical system. By accounting for the noise that is generated, drop types will be accurately recorded allowing for easier data analysis.

Since there is limited information regarding studies in the area of pallet marshaling, conduct further research in this area is warranted to see if there are overlaps in the types of data collected. Using the data collected in this study will grow the knowledge surrounding a limited number of marshaling studies, and provide a foundation for additional studies in the future.

8.2 Next Steps

By using the data generated from this study, the next step is to develop a laboratory test that will simulate the field measurements recorded in this analysis. The development of a new test method will bring the currently used test methods closer in line to actual field levels. Additionally, further field measurements will provide greater knowledge in this area. By using the field data magnitudes collected from this study, and updating the standard test protocols currently in use, we can bring our performance testing closer to a focused simulation approach.

Appendix – A
Data Saver Specifications

Envelope Size	4.9 x 3.8 x 2.2 inches (125 x 97 x 56 mm)
Volume	39 cu. Inches (639 cu. Cm.)
Cast Material	6061-T6 Aluminum, Anodized
Weight	2.2 lbs (1 kg)
Mounting	Mounting Bars Recommended Holes for #8 screws Magnetic Mounts Optional
Data Conversion	
Resolution, Bits	12 (4095 Counts)
Dynamic Range	62 db typical
Number of Channels	16 total 14 user channels 2 system channels
Internal Accelerometers (standard)	Triaxial, Piezoelectric
Accelerometer Ranges	5, 10, 20, 50, 100, 200 Full Scale
Accelerometer Channels Filters	Nominal 20 Hz. – 2800 Hz.
Accelerometer Channel Filter Characteristics	2-Pole, Low Pass, Bessel
Accelerometer Channel Frequency Response	0.4 Hz. (near d.c.) to filter Max
Typical Accelerometer Channel Accuracy	± 5% with norminal variations in temperature and Frequency
Built in Temperature and RH Transducers	Standard
Relative Humidity Measurement Range	0 – 100% @ 25 °C
Temperature Measurement Accuracy	±0.5 °C
Humidity Measurement Accuracy	2% at 25 °C
Voltage-Input Channels Range	0 to 5 volts DC or ±2.5 Volts AC
Maximum Sample Rate	1800 to 7200 Sam./Sec/channel Depending on # of Active Chnls.
Memory (standard)	1Mb Static RAM (4Mb optional)
Memory Modes	Fill/Stop, wrap, Max.
Memory Partitioning (Program Selectable)	Separated Between Signal and time triggered
Triggering	Threshold (Signal Trigging) Asymmetrical +/- each Chnl.

Process to configure Data Saver

1. Connect the Data Saver unit to the computers parallel port with the provided cable. Press the "ON" button the right side of the Data Saver unit.

2. Using the SaverWare software provided by Dallas Instruments, Select the "Talk to Instrument" button in the SaverWare window.

3. In the next window, press the "Check Status" button. Check the battery voltage and make sure that the voltage is greater than 2.5 volts. If the voltage is less than 2.5 Volts, replace the batteries. Hit "OK" to exit this window, and hit "hang up to get back to the initial SaverWare window.

4. Press the "Setup Gateways" button

5. In the Setup Gateways window, press the "Drop Height" button

6. In the Saver-Instrument Selection window, select the Saver unit serial number for the machine that is being used. (In this study Saver #0440-012 is used)

7. The Drop Height Recorder – Gateway Setup box will appear on the screen

8. The "Drop Height Recorder" settings should be as Follows

Maximum Drop Height:	24"
Drop Height Resolution:	Medium
Estimated Trip Length	30 Days

9. Hit "OK" and edit the trip text to document the trip set-up.

10. In the Setup Gateways window, hit the "Edit Channels" button

11. Setup the Saver unit per Table #3 – Channel Maps. Hit "OK" to go back to the Setup Gateways window

12. In the Setup Gateways window, hit the "Advanced Setup" button

13. Setup the Saver unit per Table #2 – Saver Memory Partitions. Hit "OK" to go back to the Setup Gateways window.

14. Hit the "Send Setup to Saver" to download the set up to the Saver unit.

15. Hit the "Exit Setup" button. Press the "OFF" button on the saver unit and disconnect the parallel port connector.

Process to download data from the Data Saver

1. Connect the Data Saver unit to the computers parallel port with the provided cable. Press the "ON" button the right side of the Data Saver unit.

2. Using the SaverWare software provided by Dallas Instruments, Select the "Talk to Instrument" button in the SaverWare window.

3. Press the "Read Back Data" button in the Instrument Communication Window. The Data Saver unit will download the data to the computer. In the Instrument data window that comes up requesting to "Process the Instrument Data Now", press "NO"

4. A file Save As screen will come up. Save the data to a location on the hard drive. The file will be saved as a *.Di1 file

5. Press the "hang up" button to exit the Saver Communication window

Process to use The Lansmont precision drop tester model F, Serial# L-1085MJ, with a 1000 pound capacity

1. On the controller handset, press the red power button. The button will light indicating there is power to the machine

2. Remove the safety bar from the drop tester column

3. Place the test specimen onto the lift area in from of the drop tester

4. On the controller handset, press the up arrow and raise the platform up until it contacts the test specimen.

5. Ensure the test specimen is positioned correctly on the lift platform, then raise to the appropriate height.

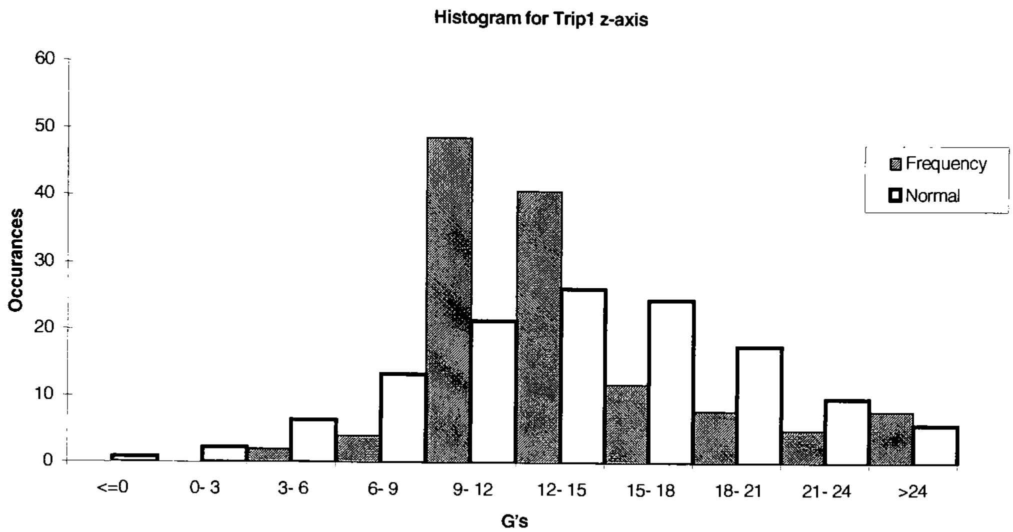
6. Press and hold the "ARM" button on the controller, then press the "DROP" button to drop the specimin.

7. On the controller handset, press the down arrow and lower the platform releases latch until it contacts the platform.

8. Press the "RESET" button to reengage the release latch for the next drop

APPENDIX B

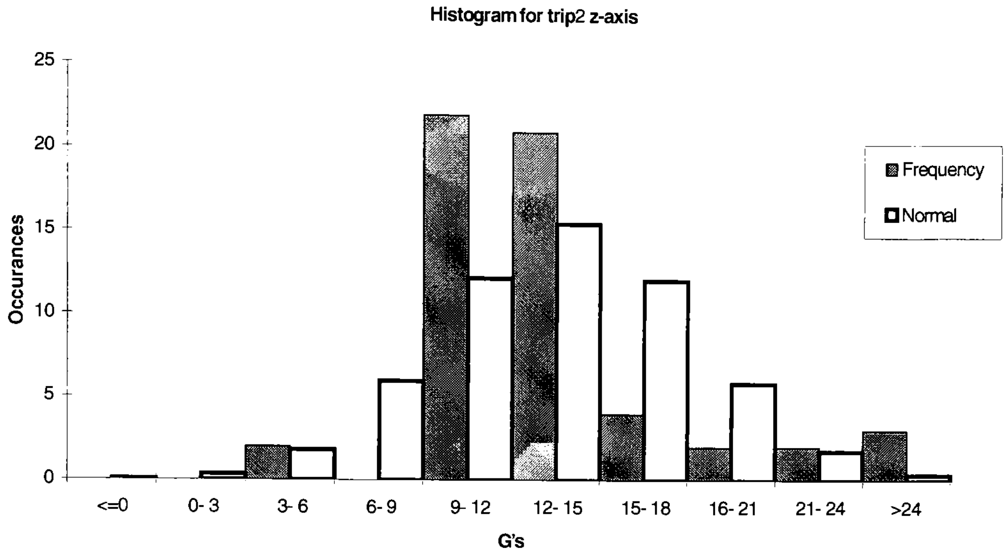
Appendix – B
Data Saver Recorded data z-axis trip #1



Frequency table and normal test for Trip1 – z-axis

Upper limit	Category	Frequency	Normal	Distance measure		***Test of normal fit***	
0	<=0	0	0.815	0.815		Chi-square statistic	71.108
3	0- 3	0	2.333	2.333		p-value	0.000
6	3- 6	2	6.396	3.022			
9	6- 9	4	13.411	6.604			
12	9- 12	49	21.510	35.132			
15	12- 15	41	26.391	8.087			
18	15- 18	12	24.771	6.584			
21	18- 21	8	17.786	5.384			
24	21- 24	5	9.769	2.328			
	>24	8	5.817	0.819			

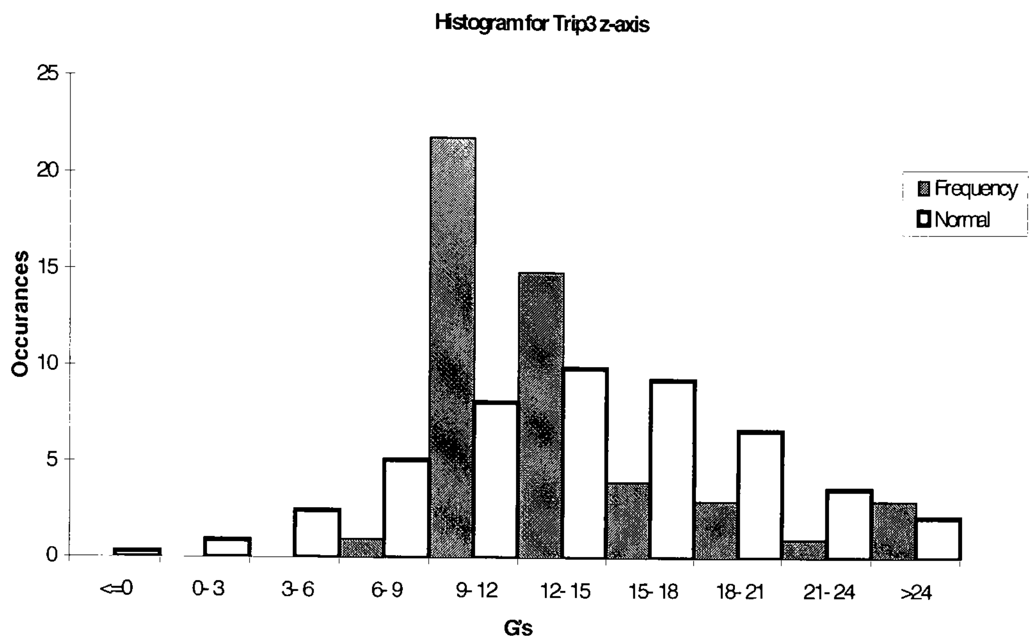
Recorded data z-axis trip #2



Frequency table and normal test for trip2 z-axis

Upper limit	Category	Frequency	Normal	Distance measure		***Test of normal fit***	
0	<=0	0	0.041	0.041		Chi-square statistic	43.395
3	0- 3	0	0.336	0.336		p-value	0.000
6	3- 6	2	1.804	0.021			
9	6- 9	0	5.982	5.982			
12	9- 12	22	12.248	7.765			
15	12- 15	21	15.498	1.953			
18	15- 18	4	12.122	5.442			
21	18- 21	2	5.859	2.542			
24	21- 24	2	1.749	0.036			
	>24	3	0.361	19.277			

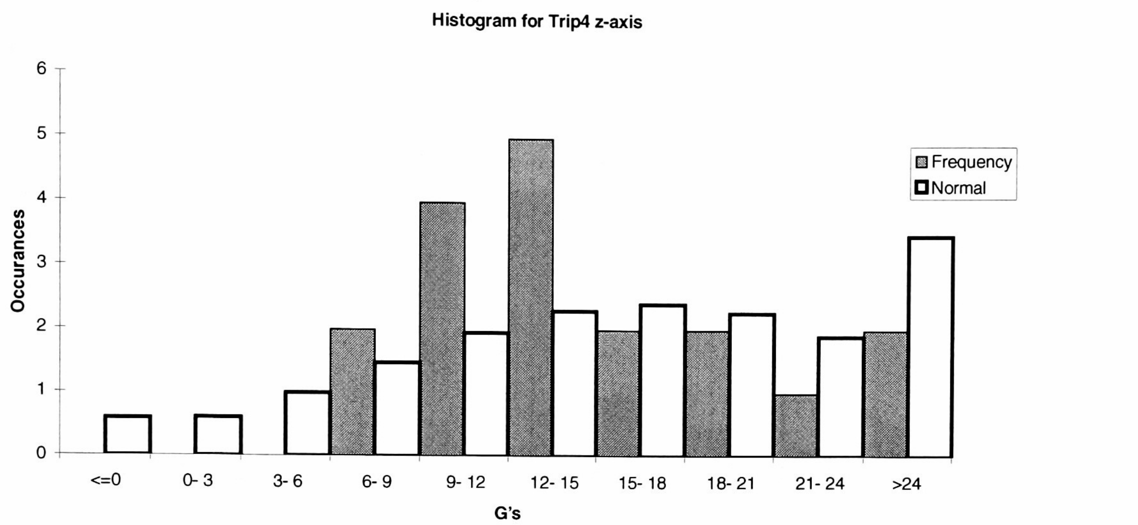
Recorded data z-axis trip #3



Frequency table and normal test for Trip3 z-axis

Upper limit	Category	Frequency	Normal	Distance measure		***Test of normal fit***	
0	<=0	0	0.319	0.319		Chi-square statistic	40.117
3	0- 3	0	0.904	0.904		p-value	0.000
6	3- 6	0	2.463	2.463			
9	6- 9	1	5.136	3.331			
12	9- 12	22	8.198	23.236			
15	12- 15	15	10.019	2.477			
18	15- 18	4	9.373	3.080			
21	18- 21	3	6.714	2.055			
24	21- 24	1	3.682	1.954			
	>24	3	2.191	0.299			

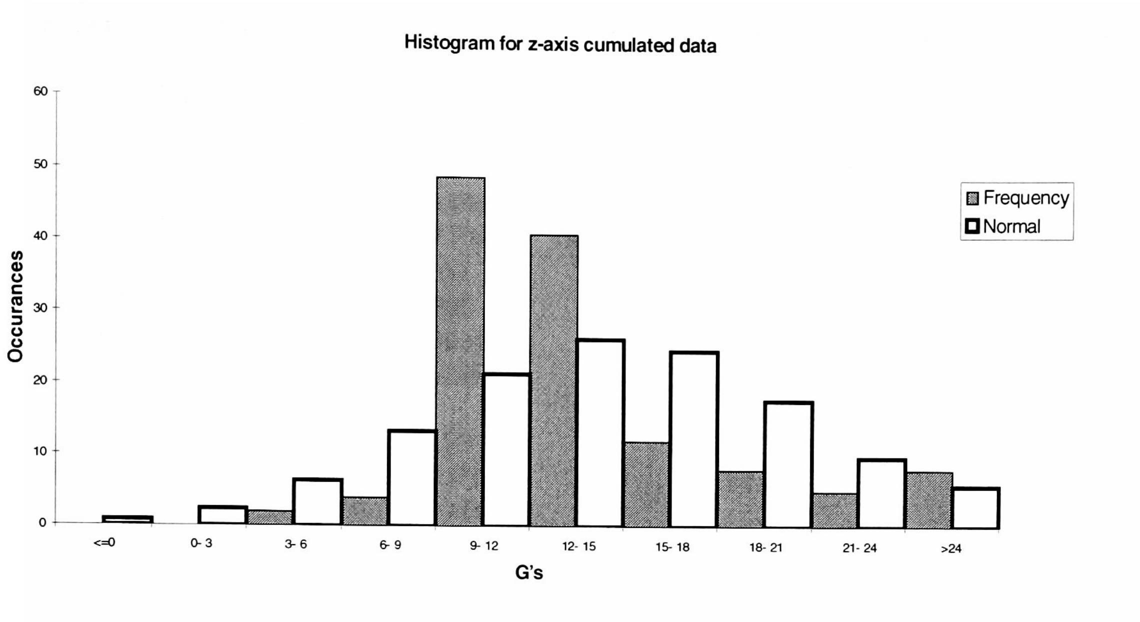
Recorded data z-axis trip #4



Frequency table and normal test for Trip4 z-axis

Upper limit	Category	Frequency	Normal	Distance measure		***Test of normal fit***	
0	<=0	0	0.593	0.593		Chi-square statistic	8.876
3	0- 3	0	0.607	0.607		p-value	0.262
6	3- 6	0	1.003	1.003			
9	6- 9	2	1.481	0.182			
12	9- 12	4	1.952	2.149			
15	12- 15	5	2.297	3.179			
18	15- 18	2	2.415	0.071			
21	18- 21	2	2.267	0.031			
24	21- 24	1	1.900	0.427			
	>24	2	3.484	0.632			

Cumulative z-axis Data – all trips



Frequency table and normal test for cumulative z-axis data

Upper limit	Category	Frequency	Normal	Distance measure		***Test of normal fit***	
0	<=0	0	0.815	0.815		Chi-square statistic	71.108
3	0- 3	0	2.333	2.333		p-value	0.000
6	3- 6	2	6.396	3.022			
9	6- 9	4	13.411	6.604			
12	9- 12	49	21.510	35.132			
15	12- 15	41	26.391	8.087			
18	15- 18	12	24.771	6.584			
21	18- 21	8	17.786	5.384			
24	21- 24	5	9.769	2.328			
	>24	8	5.817	0.819			

Laboratory test data

Drop Testing Flat Drops

Event	Date	Time	Summary	Drop Height - (In)	Impact Orientation
1	Feb-20-1999	01:00:10 PM	YES	6.26	Edge - Front Top
2	Feb-20-1999	01:03:43 PM	YES	6.33	Flat - Front
3	Feb-20-1999	01:12:40 PM	YES	6.4	Flat - Front
4	Feb-20-1999	01:15:15 PM	YES	6.4	Corner - Front Left Top
5	Feb-20-1999	01:16:18 PM	YES	6.12	Flat - Front
6	Feb-20-1999	01:17:52 PM	YES	6.26	Flat - Front

Actual Drop Height	6.00
Average Drop	6.295
Standard Deviation	0.10616
Average recorded G value	102.4367
Drop 1 Max G	92.93
Drop 2 Max G	110.09
Drop 3 Max G	110.09
Drop 4 Max G	81.33
Drop 5 Max G	110.09
Drop 6 Max G	110.09

Drop Testing Edge Drops

Right Edge

Event	Date	Time	Summary	Drop Height - (In)	Impact Orientation
1	Feb-20-1999	01:54:59 PM	YES	0	Edge - Bottom Front
2	Feb-20-1999	01:55:55 PM	YES	0.61	Flat - Front
3	Feb-20-1999	01:58:00 PM	YES	0	Flat - Front
4	Feb-20-1999	02:00:13 PM	YES	0	Flat - Front
5	Feb-20-1999	02:01:59 PM	YES	0	Flat - Bottom

Actual Drop Height	6.00
Average recorded Drop height	0.122
Average recorded G value	55.122
Drop 1 Max G	24.41
Drop 2 Max G	74.19
Drop 3 Max G	61.94
Drop 4 Max G	62.21
Drop 5 Max G	52.86

Drop Testing Edge Drops

Front Edge

Event	Date	Time	Summary	Drop Height - (In)	Impact Orientation
7	Feb-20-1999	02:05:20 PM	YES	0	Edge - Bottom Front
9	Feb-20-1999	02:06:22 PM	YES	0	Flat - Bottom
11	Feb-20-1999	02:09:24 PM	YES	0.13	Corner - Front Bottom Left
12	Feb-20-1999	02:11:30 PM	YES	0	Edge - Top Left
14	Feb-20-1999	02:12:58 PM	YES	0	Edge - Bottom Front

Actual Drop Height	6.00
Average recorded Drop height	0.026
Average recorded G value	29.204
Drop 1 Max G	25.88
Drop 2 Max G	43.81
Drop 3 Max G	23.15
Drop 4 Max G	21.85
Drop 5 Max G	31.33

Left Edge

Event	Date	Time	Summary	Drop Height - (In)	Impact Orientation
16	Feb-20-1999	02:15:12 PM	YES	0	Flat - Bottom
18	Feb-20-1999	02:17:47 PM	YES	0	Edge - Left Bottom
19	Feb-20-1999	02:19:02 PM	YES	1.36	Corner - Bottom Front Left
20	Feb-20-1999	02:20:49 PM	YES	0	Edge - Bottom Back
21	Feb-20-1999	02:22:01 PM	YES	1.3	Corner - Bottom Right Front

Actual Drop Height	6.00
Average recorded Drop height	0.532
Average recorded G value	33.468
Drop 1 Max G	34.71
Drop 2 Max G	25.56
Drop 3 Max G	46.48
Drop 4 Max G	29.75
Drop 5 Max G	30.84

Rear Edge

Event	Date	Time	Summary	Drop Height - (In)	Impact Orientation
23	Feb-20-1999	02:24:54 PM	YES	0	Flat - Top
24	Feb-20-1999	02:25:55 PM	YES	1.71	Flat - Bottom
25	Feb-20-1999	02:28:25 PM	YES	1.21	Flat - Bottom
26	Feb-20-1999	02:30:04 PM	YES	0	Flat - Top
27	Feb-20-1999	02:31:42 PM	YES	0	Flat - Bottom

Actual Drop Height	6.00
Average recorded Drop height	0.584
Average recorded G value	26.614
Drop 1 Max G	20.65
Drop 2 Max G	24.25
Drop 3 Max G	29.54
Drop 4 Max G	25.12
Drop 5 Max G	33.51

Drop Testing Corner Drop Data

Left Rear

Event	Date	Time	Summary	Drop Height - (In)	Impact Orientation
1	Feb-20-1999	03:11:14 PM	YES	0	Flat - Top
2	Feb-20-1999	03:13:02 PM	YES	0	Flat - Bottom
3	Feb-20-1999	03:14:57 PM	YES	0	Flat - Top
4	Feb-20-1999	03:15:38 PM	YES	0	Flat - Bottom
5	Feb-20-1999	03:16:33 PM	YES	0	Flat - Bottom

Actual Drop Height		6.00
Average recorded Drop height		0
Average recorded G value		19.696
Drop 1 Max G	20.6	
Drop 2 Max G	21.91	
Drop 3 Max G	18.69	
Drop 4 Max G	18.64	
Drop 5 Max G	18.64	

Right Rear

Event	Date	Time	Summary	Drop Height - (In)	Impact Orientation
6	Feb-20-1999	03:18:21 PM	YES	0	Flat - Bottom
7	Feb-20-1999	03:19:02 PM	YES	0	Flat - Bottom
8	Feb-20-1999	03:20:40 PM	YES	0	Flat - Bottom
9	Feb-20-1999	03:21:31 PM	YES	0	Flat - Bottom
10	Feb-20-1999	03:23:19 PM	YES	0.87	Flat - Bottom

Actual Drop Height		6.00
Average recorded Drop height		0.174
Average recorded G value		27.596
Drop 1 Max G	27.36	
Drop 2 Max G	28.12	
Drop 3 Max G	32.42	
Drop 4 Max G	29.1	
Drop 5 Max G	20.98	

Drop Testing Corner Drop Data

Left Front

Event	Date	Time	Summary	Drop Height - (In)	Impact Orientation
11	Feb-20-1999	03:24:50 PM	YES	0.19	Flat - Top
12	Feb-20-1999	03:25:50 PM	YES	0.34	Flat - Top
13	Feb-20-1999	03:27:36 PM	YES	0	Flat - Top
14	Feb-20-1999	03:28:56 PM	YES	0	Edge - Front Top
15	Feb-20-1999	03:30:28 PM	YES	0	Corner - Bottom Left Front

Actual Drop Height		6.00
Average recorded Drop height		0.106
Average recorded G value		24.782
Drop 1 Max G	28.66	
Drop 2 Max G	29.37	
Drop 3 Max G	32.75	
Drop 4 Max G	20.16	
Drop 5 Max G	12.97	

Right Front

Event	Date	Time	Summary	Drop Height - (In)	Impact Orientation
16	Feb-20-1999	03:32:55 PM	YES	0	Edge - Top Back
17	Feb-20-1999	03:33:34 PM	YES	0	Edge - Front Bottom
18	Feb-20-1999	03:34:54 PM	YES	0	Edge - Top Back
19	Feb-20-1999	03:37:18 PM	YES	0	Flat - Front
20	Feb-20-1999	03:38:50 PM	YES	0	Flat - Bottom

Actual Drop Height		6.00
Average recorded Drop height		0
Average recorded G value		36.678
Drop 1 Max G	28.34	
Drop 2 Max G	45.43	
Drop 3 Max G	19.94	
Drop 4 Max G	69.35	
Drop 5 Max G	20.33	

Pallet Marshaling - Product being struck

Pallet Marshaling (struck)

Event	Date	Time	Summary	Drop Height - (In)	Impact Orientation
8	Feb-20-1999	04:28:32 PM	YES	0	Edge - Left Bottom
9	Feb-20-1999	04:28:54 PM	YES	0	Edge - Left Bottom
11	Feb-20-1999	04:29:11 PM	YES	0	Flat - Left
13	Feb-20-1999	04:29:28 PM	YES	0	Edge - Left Front
14	Feb-20-1999	04:29:47 PM	YES	0	Flat - Left

Average recorded G value		23.46
Direction of travel - Channel 1		
Impact 1	16.18	
Impact 2	27.35	
Impact 3	35.14	
Impact 4	16.78	
Impact 5	21.84	

Pallet Marshaling - Product striking

Pallet Marshaling (striking)

Event	Date	Time	Summary	Drop Height - (In)	Impact Orientation
1	Feb-20-1999	04:25:57 PM	YES	0	Corner - Back Left Top
2	Feb-20-1999	04:26:09 PM	YES	0	Flat - Left
4	Feb-20-1999	04:26:30 PM	YES	0	Flat - Bottom
5	Feb-20-1999	04:26:47 PM	YES	0	Edge - Bottom Front
6	Feb-20-1999	04:26:58 PM	YES	0	Edge - Left Bottom

Average recorded G value		5.56
Direction of travel - Channel 1		
Impact 1	5.34	
Impact 2	6.32	
Impact 3	3.81	
Impact 4	6.65	
Impact 5	5.67	

Appendix C

Trip #1 Data

Event	Date	Time	Summary	Drop Height (In)	Impact Orientation	Drop Type	Ch1 - G's	Ch2 - G's	Ch3 - G's	Impact Orientation
1	Apr-22-1999	03:37:27 PM	YES	0	Edge - Right Bottom	Impact-Not a Drop	-16.32	9	-11.77	Edge - Right Bottom
2	Apr-27-1999	03:31:44 PM	YES	0.53	Edge - Front Bottom	Tossed up	5.79	12.71	-15.52	Edge - Front Bottom
3	Apr-27-1999	03:45:59 PM	YES	0.73	Corner - Top Left Back	Tossed up	8.62	-15.38	-23.91	Corner - Top Left Back
4	May-03-1999	03:37:00 AM		0	Flat - Bottom	Unknown	-6.71	-5.89	-19.88	Flat - Bottom
5	May-17-1999	07:05:04 PM		0	Flat - Left	Unknown	21.89	10.03	8.06	Flat - Left
6	May-17-1999	09:53:30 PM		0	Flat - Top	Unknown	4.75	8.83	17.92	Flat - Top

Trip #2 Data

Event	Date	Time	Summary	Drop Height (In)	Impact Orientation	Drop Type	Ch1 - G's	Ch2 - G's	Ch3 - G's	Impact Orientation
1	Jun-07-1999	11:33:27 AM		0	Edge - Bottom Front	Unknown	3.05	-8.33	-12.42	Edge - Bottom Front
2	Jun-07-1999	05:04:05 PM		0	Flat - Bottom	Unknown	-3.7	4.47	-12.64	Flat - Bottom
3	Jun-07-1999	05:18:22 PM		0	Edge - Top Left	Unknown	4.79	10.19	15.09	Edge - Top Left
4	Jun-07-1999	05:19:57 PM		0	Edge - Bottom Front	Unknown	2.07	-5.56	-10.9	Edge - Bottom Front
5	Jun-07-1999	07:14:38 PM		0	Flat - Bottom	Unknown	9.81	-6.54	-25.12	Flat - Bottom
6	Jun-09-1999	03:12:37 AM		0	Flat - Top	Impact-Not a Drop	-8.44	-10.35	18.2	Flat - Top
7	Jun-09-1999	03:56:02 AM		0	Flat - Bottom	Impact-Not a Drop	-4.63	-10.84	24.58	Flat - Bottom
8	Jun-13-1999	03:35:17 PM		0	Flat - Right	Impact-Not a Drop	-11.22	-5.18	-5.99	Flat - Right
9	Jun-13-1999	06:10:17 PM	YES	0.05	Flat - Top	Tossed up	1.69	-1.53	10.03	Flat - Top
10	Jun-13-1999	08:01:19 PM	YES	0.14	Edge - Top Front	Tossed up	1.8	3	10.52	Edge - Top Front
11	Jun-13-1999	08:01:32 PM		0	Flat - Bottom	Impact-Not a Drop	7.63	-4.74	-14.01	Flat - Bottom
12	Jun-16-1999	04:43:38 PM		0	Flat - Bottom	Unknown	5.77	8.33	-16.24	Flat - Bottom
13	Jun-16-1999	04:43:39 PM		0	Edge - Bottom Front	Unknown	-5.61	-5.28	-10.74	Edge - Bottom Front
14	Jun-16-1999	07:07:52 PM		0	Flat - Top	Impact-Not a Drop	4.52	4.52	13.84	Flat - Top
15	Jun-22-1999	12:21:21 AM		0	Corner - Right Back Top	Impact-Not a Drop	-12.09	-6.7	-11.01	Corner - Right Back Top
16	Jun-22-1999	04:10:32 AM	YES	0.39	Flat - Right	Tossed up	-14.16	6.37	12.1	Flat - Right

Event	Date	Time	Summary	Drop Height (In)	Impact Orientation	Drop Type	Ch1 - G's	Ch2 - G's	Ch3 - G's	Impact Orientation
17	Jun-22-1999	11:12:06 PM		0	Flat - Bottom	Impact-Not a Drop	-2.56	-5.72	-20.82	Flat - Bottom
18	Jun-23-1999	01:34:12 AM		0	Flat - Right	Unknown	-10.89	4.41	-5.89	Flat - Right
19	Jun-23-1999	08:44:08 PM		0	Flat - Top	Unknown	5.28	-12.47	23.6	Flat - Top
20	Jun-24-1999	09:16:50 AM		0	Edge - Bottom Left	Unknown	6.7	5.99	-15.26	Edge - Bottom Left
21	Jun-24-1999	09:43:50 AM		0	Flat - Top	Unknown	3.05	3.21	10.63	Flat - Top
22	Jun-25-1999	03:02:45 AM		0	Edge - Bottom Front	Unknown	-3.92	6.48	-10.95	Edge - Bottom Front
23	Jun-25-1999	03:02:49 AM		0	Edge - Bottom Back	Unknown	-3.87	5.28	10.79	Edge - Bottom Back
24	Jun-26-1999	10:29:47 PM	YES	0.53	Edge - Top Front	Tossed up	13.51	-21.35	26.97	Edge - Top Front
25	Jun-26-1999	10:29:48 PM	YES	0.14	Flat - Bottom	Tossed up	6.92	10.13	-21.69	Flat - Bottom
26	Jun-26-1999	10:54:39 PM		0	Edge - Bottom Front	Unknown	3.92	7.41	11.39	Edge - Bottom Front
27	Jun-26-1999	10:57:10 PM		0	Flat - Top	Unknown	3.1	-6.32	11.06	Flat - Top
28	Jun-26-1999	10:57:29 PM		0	Edge - Bottom Right	Unknown	3.87	5.5	-10.41	Edge - Bottom Right
29	Jun-26-1999	11:06:53 PM	YES	0.03	Corner - Bottom Front Left	Tossed up	4.79	-6.59	-10.95	Corner - Bottom Front Left
30	Jun-26-1999	11:07:20 PM		0	Flat - Bottom	Unknown	3.43	-8.93	-13.02	Flat - Bottom
31	Jun-26-1999	11:07:56 PM		0	Edge - Bottom Front	Unknown	2.78	-6.92	-13.41	Edge - Bottom Front
32	Jun-27-1999	01:06:24 AM		0	Flat - Bottom	Unknown	1.85	-6.75	-14.88	Flat - Bottom
33	Jun-27-1999	01:13:42 AM		0	Edge - Front Bottom	Impact-Not a Drop	3.21	10.89	-13.3	Edge - Front Bottom
34	Jun-27-1999	01:17:14 AM		0	Corner - Bottom Front Left	Unknown	5.56	8.06	12.15	Corner - Bottom Front Left

Event	Date	Time	Summary	Drop Height (In)	Impact Orientation	Drop Type	Ch1 - G's	Ch2 - G's	Ch3 - G's	Impact Orientation
35	Jun-27-1999	01:18:06 AM		0	Edge - Bottom Front	Unknown	4.96	9.15	-11.99	Edge - Bottom Front
36	Jun-27-1999	11:12:07 AM		0	Flat - Bottom	Unknown	-2.02	-5.07	-10.52	Flat - Bottom
37	Jun-27-1999	11:12:17 AM		0	Edge - Top Back	Unknown	2.34	8.55	14.93	Edge - Top Back
38	Jun-27-1999	11:41:02 AM		0	Flat - Bottom	Unknown	2.61	7.57	-13.62	Flat - Bottom
39	Jun-27-1999	11:46:17 AM	YES	0.07	Edge - Bottom Front	Tossed up	3.43	-8.12	-13.68	Edge - Bottom Front
40	Jun-27-1999	11:46:22 AM		0	Flat - Bottom	Unknown	2.72	7.79	-11.06	Flat - Bottom
41	Jun-27-1999	11:46:29 AM	YES	0.09	Flat - Bottom	Tossed up	2.61	3.92	-10.84	Flat - Bottom
42	Jun-27-1999	11:48:56 AM	YES	0.39	Flat - Top	Tossed up	-2.89	7.46	12.86	Flat - Top
43	Jun-27-1999	11:49:07 AM		0	Edge - Bottom Front	Unknown	3.76	6.65	-12.81	Edge - Bottom Front
44	Jun-27-1999	12:02:25 PM		0	Edge - Bottom Front	Unknown	5.39	7.68	-12.37	Edge - Bottom Front
45	Jun-27-1999	12:12:19 PM	YES	0.02	Edge - Top Back	Tossed up	-3.76	8.93	-14.11	Edge - Top Back
46	Jun-27-1999	12:12:24 PM		0	Edge - Bottom Front	Unknown	2.45	-5.5	-11.77	Edge - Bottom Front
47	Jun-27-1999	12:13:33 PM		0	Edge - Top Back	Unknown	3.1	-6.59	-10.74	Edge - Top Back
48	Jun-27-1999	12:13:34 PM		0	Edge - Bottom Front	Unknown	3.98	-8.82	-13.84	Edge - Bottom Front
49	Jun-27-1999	12:13:39 PM	YES	0.27	Edge - Bottom Left	Tossed up	-6.48	6.92	-15.75	Edge - Bottom Left
50	Jun-27-1999	12:13:42 PM		0	Edge - Bottom Front	Unknown	-2.45	7.57	-10.14	Edge - Bottom Front
51	Jun-27-1999	12:13:55 PM		0	Edge - Bottom Front	Unknown	2.51	10.79	-12.7	Edge - Bottom Front
52	Jun-27-1999	12:14:00 PM		0	Edge - Bottom Front	Unknown	1.96	9.53	-10.74	Edge - Bottom Front

Event	Date	Time	Summary	Drop Height (In)	Impact Orientation	Drop Type	Ch1 - G's	Ch2 - G's	Ch3 - G's	Impact Orientation
53	Jun-27-1999	12:14:07 PM	YES	0.04	Edge - Top Back	Tossed up	2.45	-8.5	14.33	Edge - Top Back
54	Jun-27-1999	12:14:12 PM		0	Edge - Bottom Front	Unknown	2.61	7.19	-14.71	Edge - Bottom Front
55	Jun-27-1999	12:14:22 PM		0	Edge - Bottom Front	Unknown	2.56	7.52	-10.08	Edge - Bottom Front
56	Jun-27-1999	06:03:32 PM		0	Flat - Bottom	Unknown	3.54	6.65	-10.46	Flat - Bottom

Trip #3 Data

Event	Date	Time	Summary	Drop Height (In)	Impact Orientation	Drop Type	Ch1 - G's	Ch2 - G's	Ch3 - G's	Impact Orientation
1	Jul-27-1999	02:09:12 PM		0	Flat - Bottom	Unknown	-4.36	-3.87	-11.17	Flat - Bottom
2	Jul-27-1999	02:14:38 PM		0	Edge - Top Left	Unknown	13.73	14.76	28.99	Edge - Top Left
3	Jul-27-1999	02:15:12 PM		0	Corner - Right Bottom Front	Impact-Not a Drop	-15.96	8.01	-11.88	Corner - Right Bottom Front
4	Jul-29-1999	04:50:04 AM		0	Flat - Bottom	Unknown	2.94	5.34	-11.12	Flat - Bottom
5	Jul-29-1999	04:50:46 AM		0	Edge - Bottom Front	Unknown	4.03	11.82	-17.55	Edge - Bottom Front
6	Jul-29-1999	05:08:44 AM		0	Flat - Bottom	Unknown	4.63	4.09	-10.14	Flat - Bottom
7	Jul-29-1999	03:33:48 PM		0	Flat - Bottom	Impact-Not a Drop	3.27	4.74	-11.88	Flat - Bottom
8	Jul-29-1999	03:33:50 PM		0	Flat - Top	Unknown	-2.61	3.38	10.46	Flat - Top
9	Jul-29-1999	06:05:52 PM		0	Flat - Right	Unknown	-42.82	-14.33	-23.38	Flat - Right
10	Jul-29-1999	08:33:25 PM	YES	3.52	Flat - Bottom	Tossed up	10.73	-9.91	-32.32	Flat - Bottom
11	Jul-29-1999	08:38:10 PM	YES	0.47	Flat - Bottom	Tossed up	17.49	-16.12	-36.73	Flat - Bottom
12	Jul-30-1999	07:07:32 AM		0	Edge - Bottom Back	Unknown	4.47	8.99	-20.27	Edge - Bottom Back
13	Jul-30-1999	01:28:04 PM		0	Flat - Top	Unknown	5.88	4.14	14.28	Flat - Top
14	Aug-03-1999	11:02:02 AM		0	Edge - Bottom Left	Unknown	6.48	-5.01	-11.83	Edge - Bottom Left
15	Aug-03-1999	11:16:38 AM		0	Corner - Bottom Front Left	Unknown	4.68	4.47	-13.3	Corner - Bottom Front Left
16	Aug-06-1999	08:07:59 PM		0	Edge - Bottom Front	Unknown	9.15	-7.46	-13.73	Edge - Bottom Front
17	Aug-07-1999	11:10:26 AM		0	Edge - Bottom Left	Unknown	-5.56	6.48	-14.66	Edge - Bottom Left
18	Aug-08-1999	03:39:54 AM		0	Edge - Bottom Left	Unknown	6.97	5.34	-12.42	Edge - Bottom Left
19	Aug-08-1999	03:42:56 AM		0	Flat - Bottom	Unknown	6.16	7.25	-14.5	Flat - Bottom
20	Aug-08-1999	03:43:35 AM		0	Flat - Bottom	Unknown	2.89	3.6	-12.21	Flat - Bottom
21	Aug-08-1999	03:45:16 AM		0	Flat - Bottom	Unknown	4.19	6.37	-12.21	Flat - Bottom

Event	Date	Time	Summary	Drop Height (In)	Impact Orientation	Drop Type	Ch1 - G's	Ch2 - G's	Ch3 - G's	Impact Orientation
22	Aug-08-1999	03:46:11 AM		0	Flat - Bottom	Unknown	5.07	6.97	-16.57	Flat - Bottom
23	Aug-08-1999	03:46:19 AM		0	Flat - Top	Unknown	2.94	3.38	10.79	Flat - Top
24	Aug-08-1999	03:46:36 AM		0	Corner - Front Bottom Left	Unknown	4.63	9.15	-10.41	Corner - Front Bottom Left
25	Aug-08-1999	03:46:43 AM		0	Edge - Bottom Front	Unknown	4.25	10.13	-13.79	Edge - Bottom Front
26	Aug-08-1999	03:51:12 AM		0	Flat - Bottom	Unknown	6.7	-3.87	-11.44	Flat - Bottom
27	Aug-08-1999	02:39:51 PM		0	Flat - Bottom	Unknown	3.21	6.37	-11.06	Flat - Bottom
28	Aug-08-1999	02:39:58 PM		0	Flat - Bottom	Unknown	5.99	10.3	-17.11	Flat - Bottom
29	Aug-08-1999	02:41:37 PM		0	Flat - Bottom	Unknown	-4.19	6.86	-12.75	Flat - Bottom
30	Aug-08-1999	02:42:19 PM		0	Flat - Bottom	Unknown	-4.09	-10.46	-14.22	Flat - Bottom
31	Aug-08-1999	02:42:41 PM		0	Flat - Bottom	Unknown	4.47	12.09	-16.46	Flat - Bottom
32	Aug-08-1999	02:43:53 PM		0	Edge - Bottom Front	Unknown	2.89	7.57	-13.19	Edge - Bottom Front
33	Aug-08-1999	02:45:09 PM	YES	0.02	Flat - Bottom	Tossed up	2.07	6.48	-13.68	Flat - Bottom
34	Aug-08-1999	02:47:13 PM		0	Flat - Top	Unknown	2.89	-4.96	13.19	Flat - Top
35	Aug-08-1999	02:47:34 PM	YES	0.19	Flat - Bottom	Tossed up	2.72	2.67	-10.35	Flat - Bottom
36	Aug-08-1999	03:01:05 PM		0	Edge - Bottom Front	Unknown	-4.63	4.9	-10.35	Edge - Bottom Front
37	Aug-09-1999	10:24:04 PM		0	Flat - Bottom	Unknown	8.61	-4.68	-19.56	Flat - Bottom
38	Aug-09-1999	10:24:07 PM		0	Edge - Left Front	Unknown	11.71	4.63	7.63	Edge - Left Front
39	Aug-09-1999	10:24:41 PM		0	Flat - Bottom	Unknown	3.43	6.92	-14.93	Flat - Bottom
40	Aug-09-1999	10:24:44 PM		0	Flat - Bottom	Unknown	3.92	3.32	-10.63	Flat - Bottom
41	Aug-09-1999	10:24:45 PM		0	Corner - Left Front Bottom	Unknown	15.03	9.37	10.3	Corner - Left Front Bottom
42	Aug-10-1999	12:36:56 AM		0	Edge - Bottom Front	Unknown	3.05	9.97	-11.17	Edge - Bottom Front
43	Aug-10-1999	12:47:51 AM		0	Flat - Bottom	Unknown	3.38	4.36	-11.06	Flat - Bottom
44	Aug-10-1999	07:50:02 AM		0	Flat - Bottom	Unknown	-1.91	-4.85	-11.12	Flat - Bottom
45	Aug-10-1999	08:02:16 AM		0	Corner - Bottom Front Left	Unknown	-4.63	5.77	-10.3	Corner - Bottom Front Left

Event	Date	Time	Summary	Drop Height (In)	Impact Orientation	Drop Type	Ch1 - G's	Ch2 - G's	Ch3 - G's	Impact Orientation
46	Aug-10-1999	08:03:06 AM		0	Corner - Front Bottom Left	Unknown	2.45	7.95	-10.41	Corner - Front Bottom Left
47	Aug-10-1999	08:04:10 AM		0	Edge - Bottom Front	Unknown	2.29	4.85	10.52	Edge - Bottom Front
48	Aug-10-1999	08:29:20 AM		0	Flat - Bottom	Unknown	-6.86	7.41	-19.94	Flat - Bottom
49	Aug-13-1999	02:10:52 PM		0	Edge - Front Bottom	Unknown	-4.58	9.91	-10.14	Edge - Front Bottom

Trip #4 data

Event	Date	Time	Summary	Drop Height (In)	Impact Orientation	Drop Type	Ch1 - G's	Ch2 - G's	Ch3 - G's	Impact Orientation
1	Aug-20-1999	09:49:21 AM		0	Flat - Top	Impact-Not a Drop	-5.72	-12.26	19.29	Flat - Top
2	Aug-20-1999	09:56:17 AM		0	Flat - Bottom	Impact-Not a Drop	-21.24	23.37	-45.83	Flat - Bottom
3	Aug-20-1999	09:56:22 AM		0	Edge - Top Back	Impact-Not a Drop	-6.92	12.15	12.75	Edge - Top Back
4	Aug-26-1999	04:56:47 AM		0	Flat - Bottom	Unknown	3.7	-6.48	-14.6	Flat - Bottom
5	Aug-26-1999	04:56:58 AM		0	Edge - Bottom Back	Unknown	6.86	-9.15	-18.85	Edge - Bottom Back
6	Aug-26-1999	04:57:12 AM		0	Edge - Top Back	Unknown	-3.1	-7.35	11.01	Edge - Top Back
7	Aug-26-1999	05:00:08 AM		0	Flat - Bottom	Unknown	5.45	5.01	-13.13	Flat - Bottom
8	Aug-27-1999	05:38:32 PM		0	Flat - Top	Unknown	-2.56	2.94	10.08	Flat - Top
9	Aug-30-1999	06:14:52 AM		0	Corner - Bottom Right Front	Unknown	10.57	10.19	-12.75	Corner - Bottom Right Front
10	Aug-30-1999	06:28:55 AM		0	Corner - Left Back Top	Unknown	15.14	16.83	16.68	Corner - Left Back Top
11	Aug-30-1999	06:48:52 AM		0	Edge - Top Back	Unknown	6.21	5.83	10.84	Edge - Top Back
12	Aug-31-1999	02:00:14 AM		0	Edge - Right Bottom	Impact-Not a Drop	-10.51	3.76	-8.28	Edge - Right Bottom
13	Sep-02-1999	02:43:40 AM		0	Edge - Right Bottom	Impact-Not a Drop	-12.53	-4.68	-8.77	Edge - Right Bottom
14	Sep-10-1999	12:24:25 AM	YES	0.13	Edge - Bottom Front	Tossed up	8.5	8.61	13.19	Edge - Bottom Front
15	Sep-11-1999	01:19:38 PM		0	Flat - Bottom	Unknown	2.72	3.27	-10.74	Flat - Bottom
16	Sep-11-1999	01:22:04 PM	YES	1.27	Corner - Bottom Front Left	Tossed up	8.33	10.3	-23.54	Corner - Bottom Front Left
17	Sep-11-1999	01:22:05 PM		0	Edge - Bottom Left	Unknown	18.3	18.85	-26.43	Edge - Bottom Left
18	Sep-11-1999	01:22:06 PM		0	Corner - Bottom Left Front	Unknown	6.26	-6.32	-17.06	Corner - Bottom Left Front

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