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MEASUREMENT OF THE UNITED PARCEL SERVICE GROUND SHIPPING ENVIRONMENT FOR LARGE AND HEAVY PACKAGES (UP TO 150 POUNDS)

presented by

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MEASUREMENT OF THE UNITED PARCEL SERVICE GROUND SHIPPING ENVIRONMENT FOR LARGE AND HEAVY PACKAGES (UP TO 150 POUNDS)

By

Zachary Grant Hays

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ABSTRACT

MEASUREMENT OF THE UPS GROUND SHIPPING ENVIRONMENT FOR LARGE AND HEAVY PACKAGES (UP TO 150 POUNDS)

By

Zachary Grant Hays

This study evaluated the UPS Ground shipping environment for large and heavy packages weighing up to 150 pounds. Four packages, identified as A, B, C, and D, (with A and B identical) were fitted with triaxial data recorders. The recorded data was processed to determine the equivalent drop height and velocity change of the impacts. The four packages originated from East Lansing, MI and were shipped the equivalent of 24 one-way trips via UPS Ground Service to destinations in Sunnyvale, CA, Duluth, GA, and Rochester, NY. Packages A and B weighed 46 pounds each, and received 370 drops greater than 3.0 inches and 274 impacts greater than 72.2 in./s. Resulting in an average of 8 drops and 7 impacts per shipment with 95% of the total drops occurring below 34 inches and 95% of the impacts below 210 in./s. Package C, weighing 72 pounds, encountered 173 drops and 147 impacts, 95% of the drops occurred below 32 inches and 95% of the impacts were below 180 in./s. It averaged 7 drops and 5 impacts per shipment. Package D, a palletized package weighing 140 pounds, was subjected to 112 drops and 91 impacts, averaging 5 drops and 3 impacts per shipment. Of the 112 drops, 95% were below a height of 22 inches and 95% of the impacts occurred below 220 in./s. The dominant impact surface of all four packages was an edge with approximately 50% of all the recorded events.

Dedicated To My Family, For All Their Support

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1.0 INTRODUCTION

Recently, the commercial shipping industry in the United States has become an extremely competitive business. What was once an industry dominated by the federal government's vision of package transit, there are now dozens of shipping options for individuals as well as for businesses. Private companies compete very successfully in the shipping industry, frequently offering customers better service and faster delivery than the federal solution to parcel delivery. In today's consumer and business worlds, individuals demand prompt guaranteed service at competitive prices. To accomplish these demands, new distribution systems have been created, and consequently, new logistical problems have evolved. Distribution systems are constantly evaluated and revised in order to expedite shipping deadlines and to ensure overall package protection. These newer distribution systems are composed of quite complex networks that focus on maximizing consumer convenience, while concurrently minimizing overall consumer cost.

The greatest competitor of the United States Postal Service is United Parcel Service (UPS), a private company driven to satisfy the ever changing needs of its customers. UPS has consistently been the front-runner of the shipping industry. Having been named America's most admired mail, package, and freight delivery company for the fifteenth consecutive year by *Fortune*® magazine (Fortune, 1997). Founded in 1907 under the name American Messenger Company, the company shipped solely in the Seattle, Washington area. (UPS, 1998). The company purchased its first delivery vehicles, the Model T Ford, in 1913, sparking a new concentration on consolidated delivery service. After several mergers, United Parcel Service was established in 1919 and relocated its home offices to Oakland, California. The major revolution for UPS came in the 1953 when the company acquired common carrier service authorization for the United Sates in order to compete more directly with the U.S. Postal Service. This initiative enabled UPS to serve all points within and between every state in the U.S. In 1975, UPS became the first private company to serve every address within the 48 contiguous United States, and its first international operation was established in Ontario, Canada. By the late 1980's UPS had developed into an international company serving over 185 countries worldwide (UPS, 1997). Despite all of the initiatives to introduce overnight and international flight shipments UPS has remained rooted in the ground shipping business. Today, UPS employs over 157,000 vehicles to transport shipments for its customers, and maintains 1,713 operating facilities around the world (UPS, 1998).

One of the most reliable forms of shipment for UPS is the UPS Ground Service. In an independent study conducted by Consumer Reports magazine, UPS Ground shipments reached their intended destinations on time with a success rate of 78%, compared to that of the U.S. Postal Service with only 72% for the same category of shipments (Consumer Reports, 1998).

1.1 UPS GROUND SHIPMENT SYSTEM

Similar to its many other parcel delivery services, UPS Ground shipment is based on a "Hub-and-Spoke" system. Originally created by UPS engineers in order to confront the problem of broad delivery areas while still maintaining fast and predictable transit times, this system has become the industry standard for ground and express delivery operations. The major UPS sorting facilities - "Hubs" - serve as the package exchange points for volumes of parcels moving to a broad area. The hubs are designed to sort tens of thousands of packages per hour permitting the quick exchange and redirection of parcels. Each hub is in turn connected to a number of operating centers - "Spokes" - which serve as the home base for the individual delivery vehicles. These vehicles provide all pickup and delivery service within a specified geographic area serving each spoke. The boundaries of the operating centers are contiguous to one another so that all addresses are covered. Next-day ground delivery occurs routinely between all operating center areas that are connected to the same hub, making it possible for shipments to reach their destinations up to 400 miles away.

The system works as follows: A route driver picks up a package from the customer and returns to the regional operating center. The package is then put aboard a tractor-trailer ("Feeder") that departs for the major hub later that day. At the major hub, the customer's package, as well as the many others, are unloaded and put through a "sort" at the hub. This major hub receives and sorts all the packages shipped from the connected operating centers. Typically, packages heavier than 50-70 pounds are handled on separate conveying equipment as part of the sorting process in the hubs. The package is then sorted into the feeder that originated from the final destination's hub. After the sort has been completed, the feeder bound for the package's ultimate destination departs for its operating center. When the package reaches the operating center, it is promptly loaded onto a delivery vehicle that serves the end customer's address and the parcel is delivered. For ground shipments covering vast distances, the packages move from hub to hub before reaching the operating center in the end delivery area (UPS, 1997). The distribution system for UPS Ground shipments is a tremendously complex system designed to facilitate the sorting of potentially millions of packages a day. Guaranteeing the correct destination and promptness in delivery with minimal damage or errors is a continuous logistical challenge.

It is an inevitable fact of shipping that damage to parcels in distribution systems will occur. The packages are continually subjected to various hazards that may literally destroy the shipping containers or worse yet, the internal product. Along with assorted drops, impacts and compressive forces, the packages also fall victim to climatic and pressure changes as well as vibration hazards from the delivery vehicles in transit.

Although common, one of the most severe hazards in the ground shipping environment are shocks. These shocks to the package result from impacts with stationary objects in the sorting facilities or even other packages in transit. Many studies have focused on determining the underlying causes of the shocks and vibrations that parcels are subjected to during transportation. Shipping damage is usually separated into two categories, the handling environment and the in-transit environment. Damage from the handling environment is primarily the result of loading and unloading operation, or the stacking, lifting and conveying of the packages. In the case of heavier packages, similar to those used in this study, the packages may often be tipped end over end in order to position them within the pick-up/delivery vehicles. In-transit damage, however, is due to the performance of the shipping vehicle and varies widely in severity with the overall shipping distance and the ground transportation surface.

One particular study designed to monitor the dynamics of individual packages in the sorting and handling environment conducted by Ostrem and Goodshall (1979), showed that most packages receive numerous shocks while passing through the distribution system. The data collected suggested the occurrence of low-level drops was significantly larger than that of higher-level drops. Further, it was determined that unitized loads or larger and heavier packages experienced drops from significantly lower heights. The data also indicated that over half of the recorded impacts typically occurred on the bottom face of the packages.

In a related study by Weigel (1996) the overnight shipping environment was evaluated for both corrugated and plywood shipping containers. The data was collected by using drop height recorders and was evaluated to determine the drop height and impact velocity change of each dynamic event measured during the test shipments. The shock environment was analyzed in terms of the number of shocks experienced and the level of the shocks as measured by the drop height, as well as the velocity change for the events classified as impacts. It was found that almost twice as many dynamic events occurred for the corrugated containers and were more severe than those experienced by the plywood containers. Which would suggest that overall package weight was indeed a factor in estimating the amount and level of shocks to a package in transit.

Another study conducted by Singh and Voss (1992), explored the effect of package size and weight in the handling of shipments sent via UPS. The weights of the test packages ranged from 20 to 45 pounds and a maximum drop height of 77.8 inches was recorded from the 150 one-way test shipments. It was also found that the maximum lateral impacts encountered exhibited a velocity change of 250 in./s. The data indicated that 99.5% of the drops encountered occurred below 27.5 inches and 99.5% of the lateral impacts had a velocity change less than 165 in./s. for the UPS shipping environment. One of the conclusions from this study, however, was that package size did not significantly affect the drop height, and weight was a significant factor only for the smaller lightweight packages used in the study.

Although the UPS Ground shipping environment has remained consistent in nature, there have been dramatic increases in package quantities within the distribution system. By focusing on minimizing damage to both package and product, it has become important to identify and characterize the dynamics of this transportation mode to assist in the design and testing of more effective packaging methods.

1.2 OBJECTIVES

The following objectives were proposed for this study:

A. To measure the dynamics of the ground shipping environment for large and heavy packages (up to 150 pounds) shipped by UPS within the United States.

B. To develop a test protocol to test packages of similar nature for the UPS Ground shipping environment.

2.0 EXPERIMENTAL DESIGN

This study was proposed to evaluate the ground shipping environment for large and heavy packages up to 150 pounds, within the UPS distribution system. In order to achieve these goals, test shipments were designed to obtain and collect dynamic data that could be used to develop laboratory test methods to simulate the characteristics of this shipping environment. The accumulated data will then be proposed for the creation of a laboratory test standard for similar shipping conditions. This is of particular interest in that such a test may obviate test shipments for the purpose of determining the associated drop height and shock impacts for packages of this classification. A detailed description of the testing instrumentation and packaging materials and methods employed is presented later in this chapter.

Of the various methods that can be utilized to document and measure dynamic events that parcels experience during a typical distribution cycle, the most effective is a triaxial recorder. Unlike the more simple single-drop recorders that only record impacts above a pre-set threshold, triaxial recorders give the user an exact time and severity level of the impacts as they occur. Since the single-drop mechanisms only indicate if the impact has occurred and not the severity beyond the specified threshold, they are greatly restricted in their applications to this particular type of study. The more sophisticated recorders, like the ones used in this study, measure and record impacts in the three axes of the package. These types of data recorders measure all impacts and save the acceleration-time history of the dynamic event. The impact pulses can then be used to estimate the actual drop height and impact orientation as well as the velocity change of each axis associated with the recorded impacts.

2.1 TEST INSTRUMENTATION AND PACKAGES

The triaxial data recorder used for this study was the "SAVER" - Shock and Vibration Environment Recorder, manufactured by Dallas Instruments a division of the Lansmont Company. This triaxial accelerometer unit is particularly useful in the evaluation of the shock and/or vibration environment of an existing package or potential prototype packaging system within a given distribution system.

The battery powered SAVER unit is small enough to be placed in virtually any size package. The device stores the impacts that the internal triaxial accelerometers sense in their order of occurrence and saves the acceleration-time history of the individual events. The SAVER also interprets the impact orientation from the triggered events, which indicates to the user not only the impact's severity, but the surfaces involved in the event as well.

For the transportation tests, there were a total of four packages involved. Two of the packages, A and B, were identical in size and weight. Package C was both heavier and larger than the first two packages, and package D was a palletized package, which weighed the most. The following table contains the approximate size and weight of the four packages and the SAVER units used in the study, the weight of the SAVER units are included in the individual package weights.

TABLE 1. Package/SAVER Weights and Sizes

Package	Weight	Size
A	48.2 lbs. (21.87 kg)	34.75 x 19.50 x 8.75 in (0.88 x 0.50 x 0.22 m)
B	48.2 lbs. (21.87 kg)	34.75 x 19.50 x 8.75 in (0.88 x 0.50 x 0.22 m)
C	74.2 lbs. (33.67 kg)	47.00 x 30.00 x 10.50 in (1.19 x 0.76 x 0.27 m)
D	142.2 lbs. (64.52 kg)	31.75 x 23.25 x 15.50 in (0.81 x 0.59 x 0.39 m)
SAVER	2.2 lbs. (1.00 kg)	4.90 x 3.80 x 2.20 in (0.125 x 0.097 x 0.056 m)

The four packages used for the test shipments consisted of varying components. Packages A and B each contained a set of four wooden folding chairs, which served as the weight for the shipment. See Figures 1 and 2. The SAVER's were mounted on wooden blocks measuring 7.00 x 6.00 x 0.75 inches (0.18 x 0.15 x 0.02 meters) and positioned as close to the geometric center of the packages as possible. In packages A and B, they were located in the lower portion of the chairs, below the legs, with the X-axis of the SAVER in line with the orientation of the shipping labels. See Figure 3. The SAVER's were surrounded by a polyethylene static shielding pouch for protection from electrostatic discharge buildups as well as loose particles and were then encased with several polyethylene cushions. For package C, the weight was supplied by an

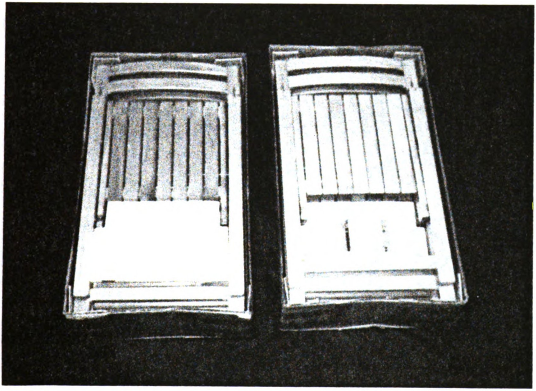

Figure 1. Package Configuration for Packages A and B

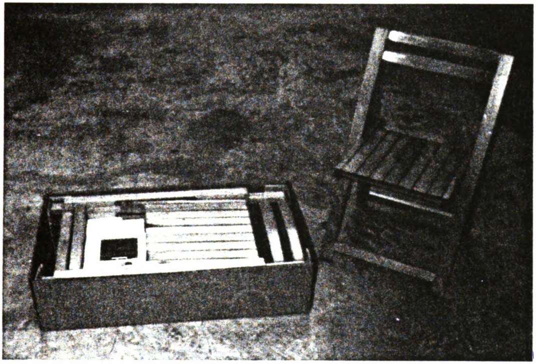

Figure 2. Product Display and SAVER Placement for Packages A and B

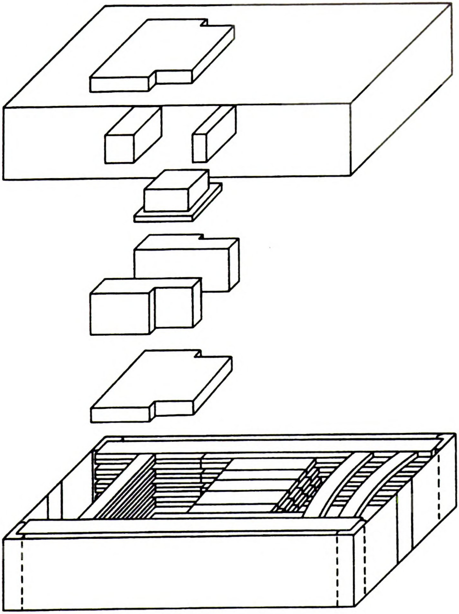

Figure 3. SAVER and Cushion Placement for Packages A and B

exercise machine. Because of the bulk of the apparatus, the position of the SAVER was restricted to slightly above, in the Y-axis, the geometric center of the package. Again, for impact surface identification purposes, the X-axis of the SAVER was in line with the shipping labels. Similarly, the SAVER was mounted onto the same wooden blocks as packages A and B and was surrounded by a polyethylene pouch and polyethylene cushions. See Figures 4-7. Packages A, B, and C were supplied by the QVC home-shopping network. Package D was a palletized dummy package supplied by the Eastman Kodak Company. For this package, the Saver was positioned in the exact geometric center of the package. The SAVER was protected in a polyethylene pouch and mounted onto a wooden box, which contained the ballast weight. Polyethylene cushions were used to isolate the wooden box from the exterior corrugated package. Refer to Figures 8-10.

Although the SAVER units are durable by design, the cushions were included to prevent damage to the instrumentation as well as from structural damages or abrasions when exposed to the severe shocks in the distribution environment. The polyethylene pouches serve to prevent static discharges during handling, as these may be potentially harmful the SAVER units. All of the exterior shipping boxes were constructed from single-wall C-flute corrugated board.

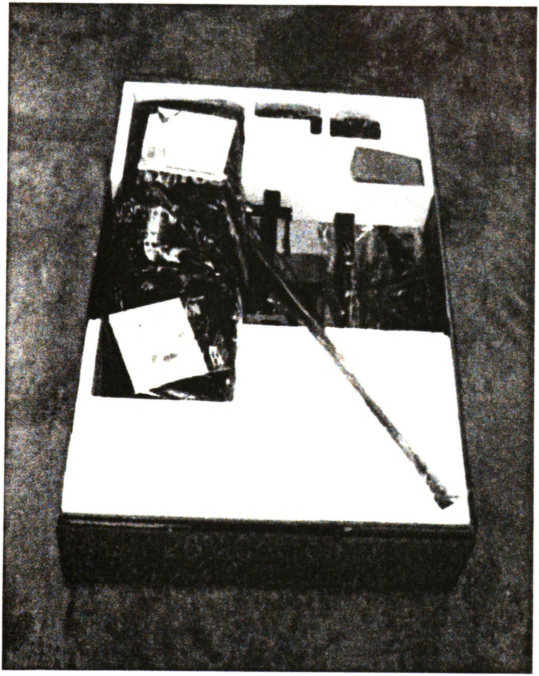

Figure 4. Package Configuration for Package C

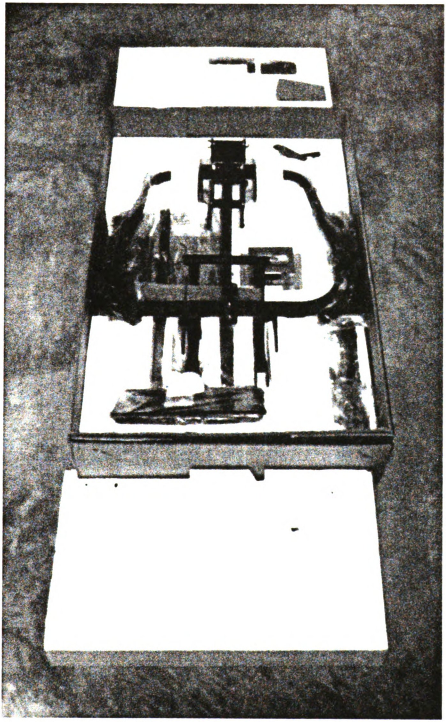

Figure 5. Product Display and SAVER Placement for Package C

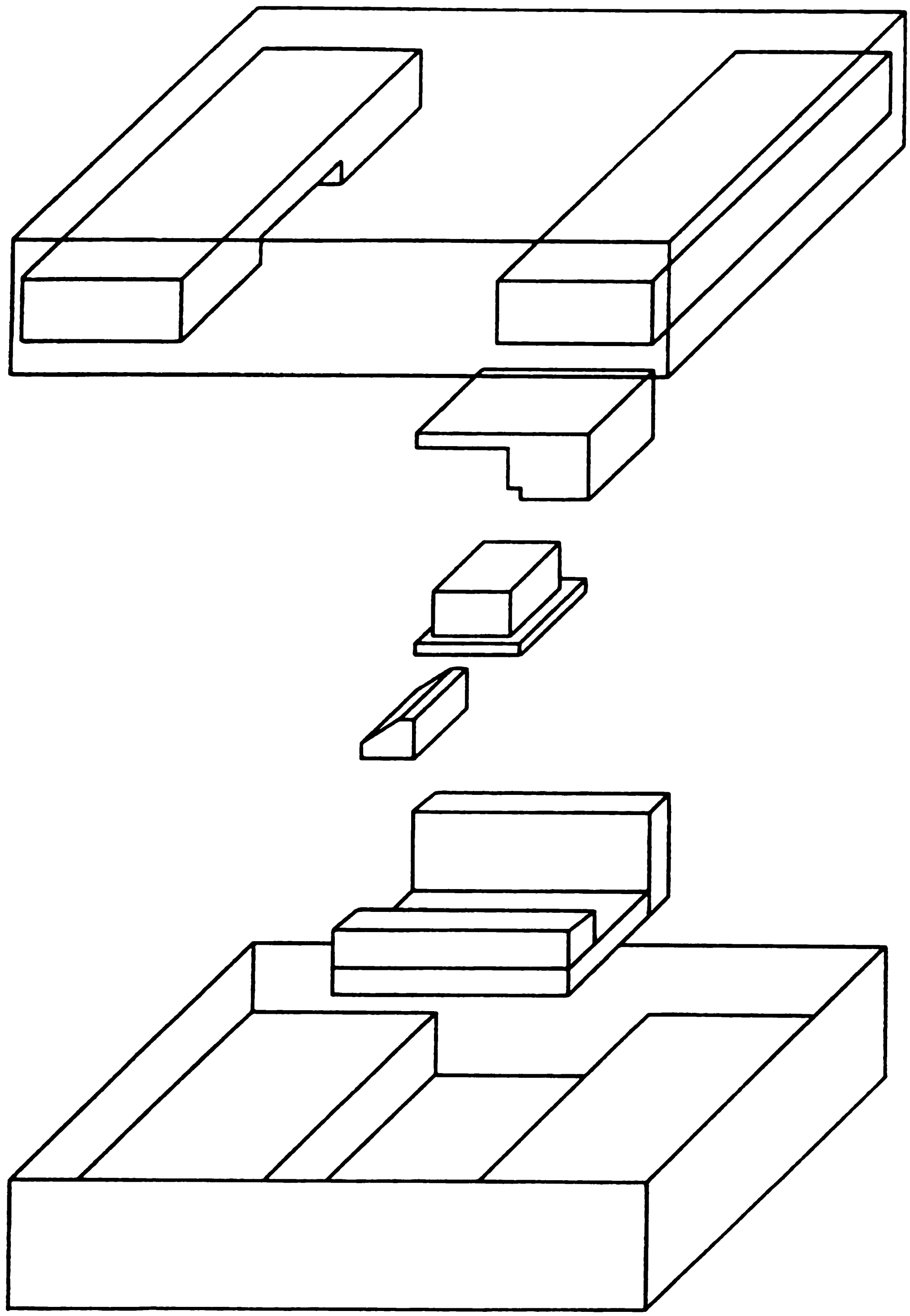

Figure 6. SAVER and Cushion Placement for Package C

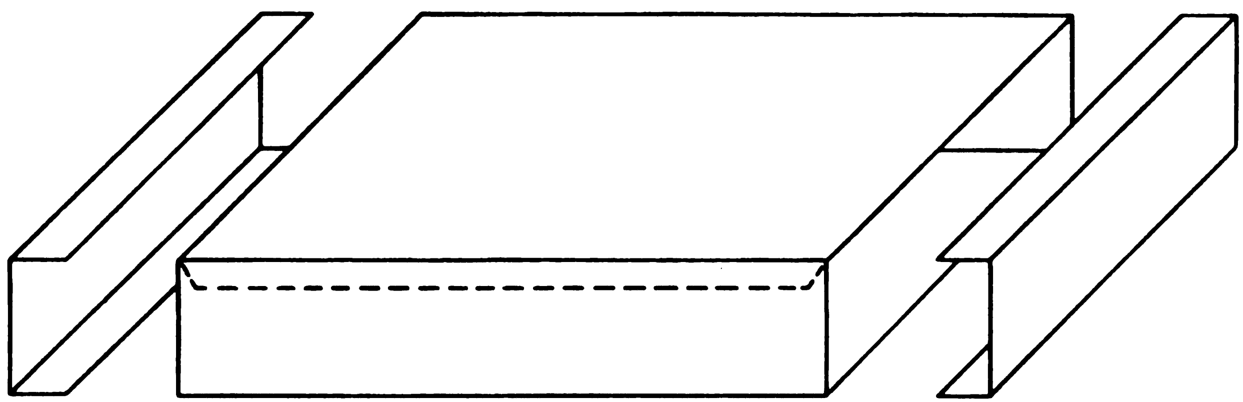

Figure 7. Exterior Shipping Unit for Package C

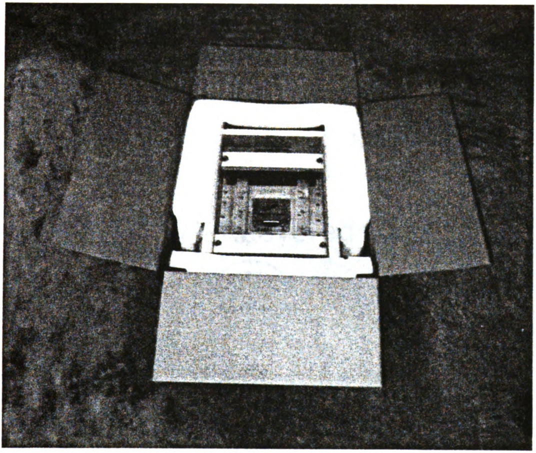

Figure 8. Display and SAVER Placement for Package D

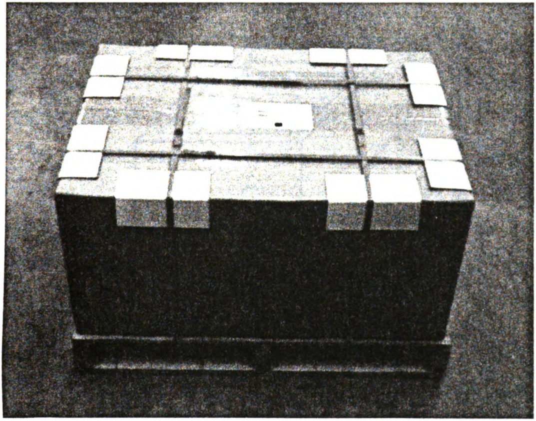

Figure 9. Exterior Shipping Unit for Package D

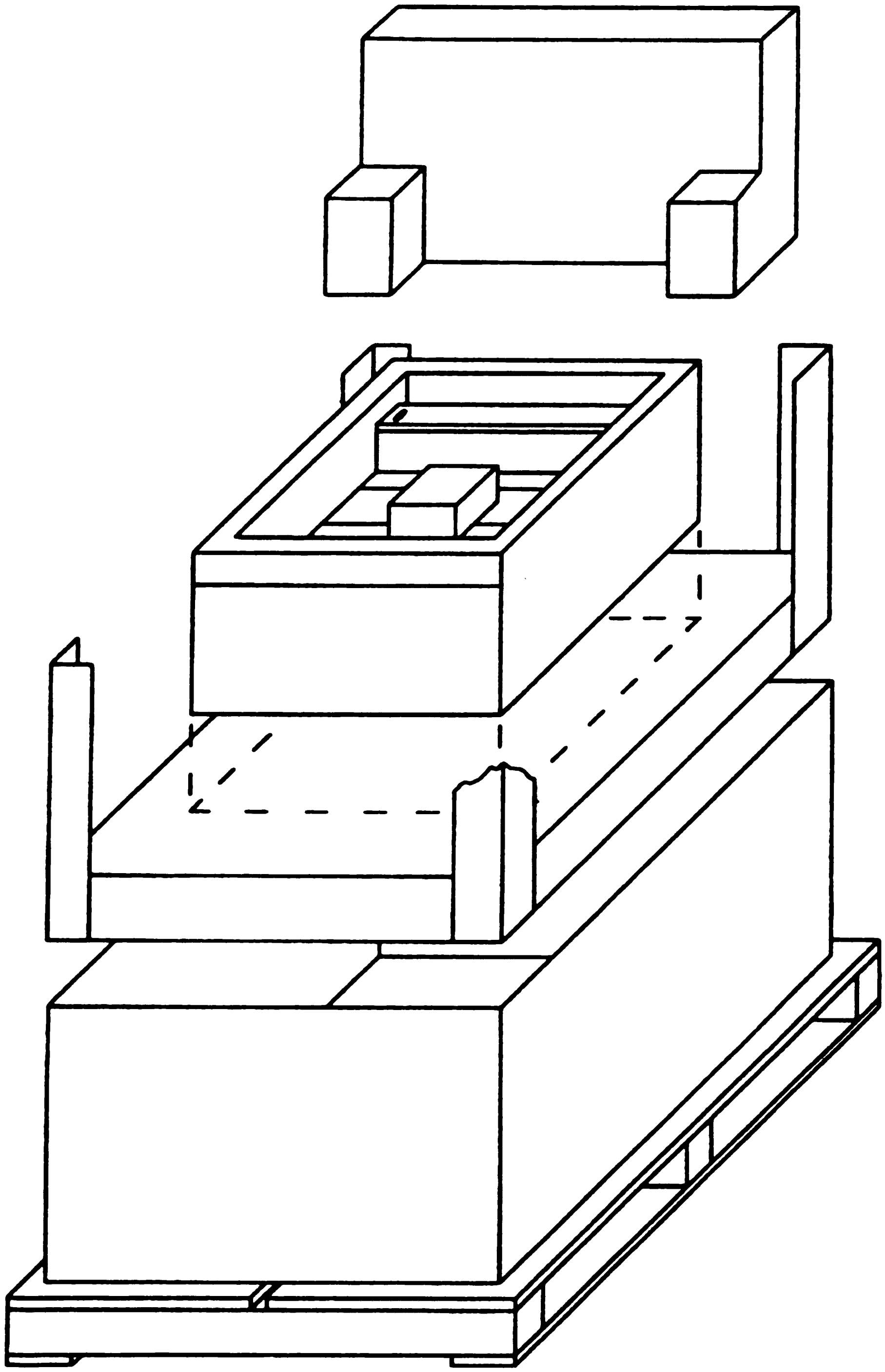

Figure 10. SAVER and Cushion Placement for Package D

2.2 SAVER OPERATION

This section provides a brief review of the SAVER operation and also describes the parameters used to program the devices and to analyze the collected data. The SAVER unit utilizes an internal triaxial accelerometer and includes an extra port for an additional external accelerometer. The unit also includes four programmable charge amplifiers, four gain stages, and four low-pass filters. There are also two 8-channel multiplexers, an analog-to-digital converter, and a temperature/humidity port. The unit is powered by four C-cell alkaline batteries, which are used to store the recorded data. However, there is also an internal memory back-up battery capable of storing recorded data for up to one year after the life of the exhausted or removed external batteries.

All SAVER parameters, as well as communication and data analysis are performed by a host computer with the installed Microsoft Windows™ -based "SaverWare" software. The accompanying program is used to set the data collection parameters, retrieve the collected data, and analyze the individual results. "SaverWare" utilizes the concept of system gateways, by selecting one of the standard gateways the automated instrument setup process is activated. The user may also select a "User Defined" option in which all of the SAVER's setup parameters can be adjusted separately. The setup parameters can be saved and loaded for analyses of additional similar shipments. The versatility of instrument setup makes the SAVER an ideal drop/shock analysis tool for users of all skill levels.

In order to fully understand the operation and application of the SAVER, it is helpful to know the basics of the system architecture and functions, both hardware and firmware/software.

Hardware

The SAVER contains a single analog-to-digital (A/D) converter, with its input connected to two 8-channel multiplexers (MUX's). One multiplexer is assigned to the 8 "dynamic" (rapidly changing signals) waveform channels, and the other is assigned to the 8 "static" (slowly changing signals) channels. Dynamic (waveform) channels 1-4 have built-in charge amplifiers, gain stages, and filters, which allow piezoelectric (charge-type) accelerometers to be connected directly. The standard SAVER incorporates an internal triaxial accelerometer, which is connected internally to channels 1-3. Leaving channel 4 available for an external accelerometer. The unit is also available for use without the internal accelerometer, in which case, all 4 channels (1-4) are available for the direct connection of external piezoelectric accelerometers.

Optional dynamic channels 5-8 have straight connections to the multiplexer and from the output of the multiplexer to the A/D converter. The SAVER unit can be configured (by the manufacturer) for the direct (DC) 0-5 volt input of the A/D, or a decoupling capacitor and resistor can be installed to change the input to ± 2.5 volts alternating current (AC). These channels may be configured to measure acceleration or nearly any other parameter since the transducers and signal conditioning are all external to the SAVER.

Optional accelerometer/cable setups are available for channels 1-4, and optional accelerometer/coupler/cable setups are also available for channels 5-8. The latter configuration has battery-powered couples with a 6-day battery life and allows many other possible configurations.

Two of the static channels are assigned to the *internal* temperature/ humidity sensor, and two more are assigned to the optional *external* temperature/humidity sensor. One pair of static channels is needed for internal circuit voltage measurements, leaving the optional channels available for any type of measurement. These channels exhibit the same multiplexer-to-A/D connection as described above. As such, they can be either 0-5 volts DC coupled, or ± 2.5 volts AC coupled.

The microcontroller unit (MCU) controls the basic configuration of the SAVER; the A/D and MUX's, the communications port, the real-time clock (for the time- and date-stamping of data, and other timekeeping functions), the internal and external triggering operations, the indicator LED, and the static RAM memory array.

Four C-size alkaline cells power the SAVER. They are connected in a series-parallel arrangement such that the nominal output voltage from the battery pack is 3 volts of direct current (VDC). The LED on the face of the SAVER flashes on initial system power-up to indicate the condition of the main battery. There is also a separate memory back-up battery, which retains data in memory for typically one year after the main batteries are removed or exhausted.

Firmware/Software

Dynamic (Waveform) and Static Channels

The SAVER is an example of a "sampled" data system, in that it takes periodic readings from its input signals, digitizes the data, and stores it in electronic memory. Readings may be taken as fast as thousands of times per second, or as slowly as once every 12 hours. Data is taken whenever pre-programmed "trigger" conditions are met. The trigger condition may be based on signal levels, combinations of signals, elapsed time intervals, or external events. The SAVER defines two basic types of data, which are treated differently. "Dynamic" data is that which changes rapidly with time; an example would be accelerations due to shock and vibration. In order to characterize dynamic data, many samples must be taken at a rapid rate - so that the waveform, or the time signature, of the data may be determined. "Static" data, on the other hand, is ascertained by only one sample per channel (examples would be temperature and humidity, where single readings are sufficient to determine the present values). When the pre-programmed trigger conditions are met, the SAVER typically takes a large number of high-speed samples of the active waveform channels, but only samples the active static channels.

Memory Partitioning

The Saver divides its memory into two partitions, a "Time Triggered" partition and a "Signal Triggered" partition, and data is stored according to the trigger conditions, which caused them to be taken. The amount of Time Triggered events to be sampled is easily determined from the total trip length, the programmed time interval, and the number of active channels. Signal Triggered data, however, is not as easily controlled. For example, if a threshold is set too low, a large amount of Signal Triggered data may be created very quickly. Without memory partitioning, this data would overrun the Time Triggered data, and the entire measurement project might be degraded or ruined. Memory partitioning eliminates this problem; each type of data is confined to its own partition, and cannot corrupt the other partition.

Nearly all of the SAVER's setup parameters - active channels, sampling rate, number of samples, memory mode, etc. may be set differently in the two different memory partitions. This provides enormous flexibility for setting up special measurements and meeting special experimental requirements. The user may determine the amount of total memory assigned to each partition.

Memory Modes

The objective of a measurement program is generally to obtain data from the entire trip. Because the amount of data cannot be precisely controlled, some allowance must be made for exceeding the capacity of available instrumented memory. The SAVER has three different, selectable ways of treating data when the memory partition becomes full. The first, called "Stop when Full", simply ignores any additional data taken. "Wrap and Overwrite when Full" replaces the oldest event with the most recently taken event. Finally, "Max Overwrite Min when Full", replaces an event already in memory with just-taken data, provided the just-taken event is larger than an event previously recorded. Individual channels may be included or excluded from the "Max" mode calculations, and memory modes may be set differently in the two partitions.

Triggering

The SAVER takes data whenever "trigger" conditions are met. Often, this is as simple as exceeding either a threshold level or when time interval has elapsed. The SAVER also has the capability of triggering from more complex conditions: individual channels may be included or excluded from the triggering equation; asymmetrical thresholds (different for + and - signals) may be set for each channel, triggering may be set to occur if the data is outside the thresholds or between the thresholds, and single channels or groups of channels may be combined with Boolean operations (AND, OR, NOT, etc.) for triggering purposes.

Ranges and Filters

Dynamic channels 1-4 are designed for the measurement of acceleration and as such have charge amplifiers with programmable ranges and filters. Acceleration levels may be selected from 5G full-scale to 200G full-scale, and may be different for different channels. This programmability of ranges and filters means that the SAVER can be set to measure a wide variety of signals - shock, vibration, and other dynamic events - without any changes of hardware or basic configuration.

"Gateways"

SaverWare introduces the concept of software "Gateways", application-specific dialogs that automate instrument setup, which are linked to the corresponding analyses. By entering one of the Gateways (shock, vibration, drop height, etc.), a user can configure the instrument by simply answering several data analysis questions. Once the data is taken and uploaded to a host computer, the Gateway directs a number of automatic analyses specifically tailored to the data type. A "User Defined" Gateway allows complete access to all of SAVER's setup capabilities, for special measurement situations and advanced or extended applications.

2.3 ZERO-G DROP HEIGHT CALCULATION

The SAVER and accompanying "SaverWare" software incorporate a proprietary algorithm to determine the drop height and drop type. In order to calculate these values per individual drop/impact, the algorithm analyzes the "Zero-G" time and the characteristics of the impact as well as the pre-impact data. However, the user is not restricted to the use of this algorithm for determining drop height and is free to override the automatic analysis. The analysis of the Zero-G drop height calculation includes the duration of free fall, which is measured by sensing the difference of the SAVER between a motionless state (Zero-G) and a free fall (around 1G), or a shock state (which can be up to several G's). The free fall duration is defined as the onset of the Zero-G state of the recorder and the moment of impact. Using this known quantity, which is specific to each individual event, the free fall drop height can be calculated using the following relationship:

$$h_z = \frac{1}{2}gt^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2-1)$$

Where: h_z = free fall drop height, expressed in inches

g = acceleration due to gravity, 386.4 in./s.^{2}

t = free fall duration, expressed in seconds

2.4 INTERPRETATION OF DROP HEIGHT ZERO-G DATA

Because the computer calculation of drop height is not infallible, the user has the freedom to override the automatic analysis. To do so requires a general understanding of what the "Event Analysis" data means and the principles involved.

The Event Analysis read-out for a Free-fall drop appears as a relatively flat, straight line before the release. When the package (with the SAVER inside) begins to fall, the data rises by at least several tenths of a G. The steepness of this rise depends upon the quickness of the release. The data remains essentially at this new level (sloping downward slightly) until impact. The drop time is taken from release to impact and drop height is calculated using the drop time.

The Event Analysis for an Impact - Not a Drop also appears as a relatively flat, straight line all the way until the moment of impact. Since there was no release and no drop (typically, the package was stationary and something hit it), the pre-impact data remains flat.

Event Analysis for Tosses is the most difficult type of event to assess. Tosses may involve both horizontal and vertical motion, as in the case of a package tumbling around in transit or sorting. The data appears as an initial rise during the toss, peaking at the moment the package is released. The package continues to travel upward for some period of time to its maximum height, during which the data resembles that due to a free-fall drop. The time period of the toss and the continued upward motion is subtracted from the apparent free-fall time resulting in the actual free-fall time. Drop height is then calculated from this actual free-fall time. (Dallas Instruments, 1998)

2.5 INSTRUMENT CONFIGURATION AND CALIBRATION

Calibration of the SAVER units was performed by Lansmont prior to the beginning of the study. Additionally, in order to test the reliability of the recorded data and the orientation of the impacts, several tests were performed in the laboratory. The packages were dropped from a known height onto a specified face and then compared to the data obtained from the SAVER's analysis of the impact. The results validated the accuracy of the reported drop heights and the impact faces. Refer to Figure 11 for the SAVER parameters used in the test shipments.

2.6 CHANNEL AND AXIS IDENTIFICATION

The typical SAVER unit has an internal triaxial accelerometer connected to dynamic (waveform) channels 1, 2, and 3. For ease of impact orientation identification these channels are also designated as X, Y, and Z respectively. The orientation of these axes is indicated on the unit's casing and is identified in Figure 12.

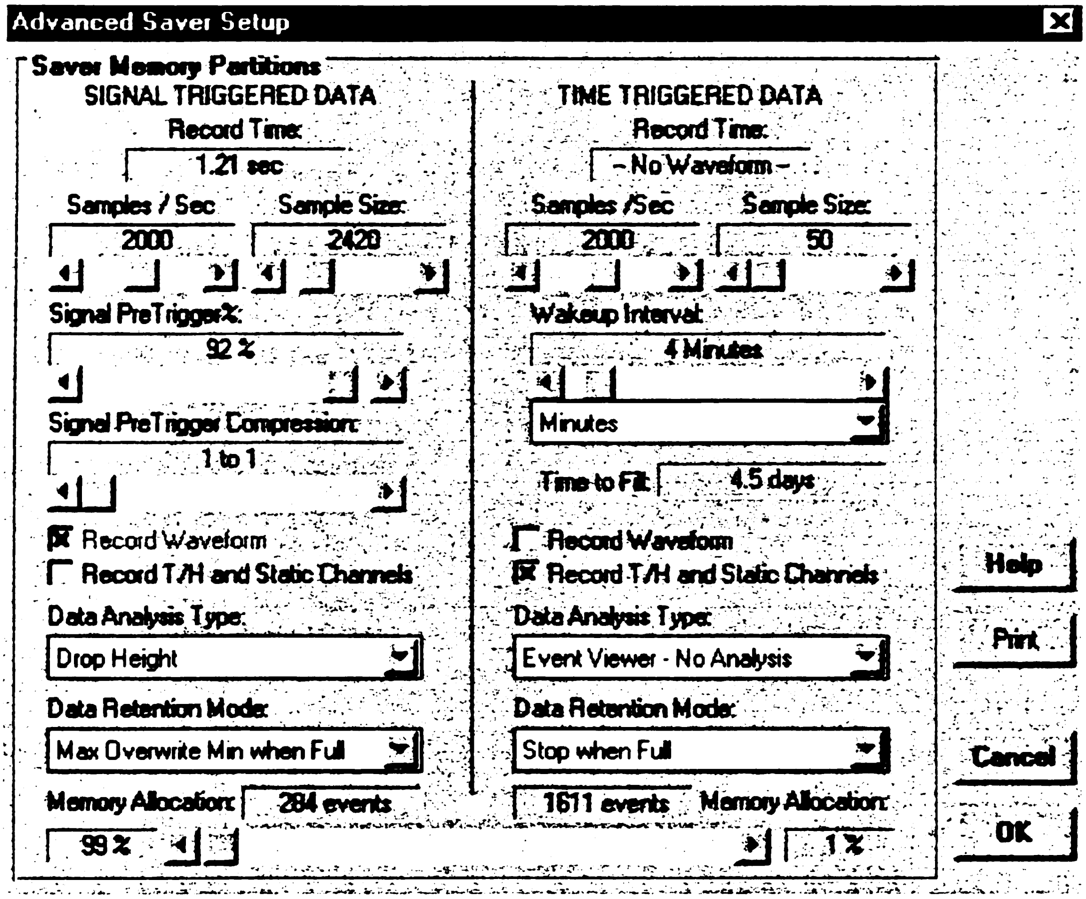

Figure 11. SAVER Testing Parameters

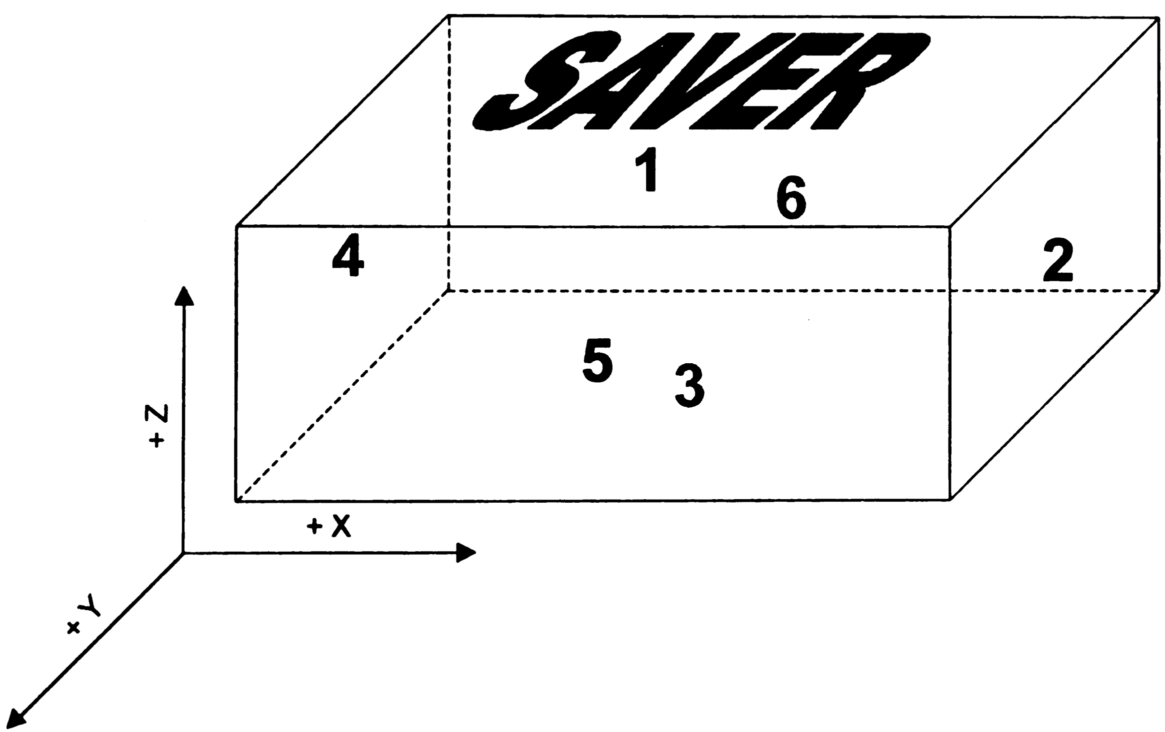

Figure 12. SAVER Triaxial Orientation

2.7 DATA COLLECTION

The intent of this study was to measure the shock impact levels in terms of drop height and impact velocity change of the UPS Ground shipping environment. The data was collected and analyzed for round-trip shipments but is presented as series of one way shipments. For the study, the shipping labels were kept in the same orientation as face 1 of the SAVER units to assist in the identification of the impact surfaces. The orientation of the box faces is based on the American Society for Testing and Materials (ASTM) standard D5176 and also on the placement of the shipping labels. Because there were no manufacturer's joints on most of the packages (or in the case of the palletized package D, there were two manufacturers joints) face 1 was identified as the face with the shipping label. From this orientation, face 3 is the opposite side (bottom) of the package, with faces 2 and 4 corresponding to the right and left sides respectively. The front was identified as face 5 and the opposite side (back) was face 6. For package orientations please refer to Figures 13-15.

Three round-trip destinations were chosen to represent varying distances throughout the United States. Refer to Figure 16 for a detailed map of the destinations as well as the hubs and spokes involved in the test shipments. The following round-trip shipments were performed:

Trip #1: East Lansing, MI - Sunnyvale, CA
Trip #2: East Lansing, MI - Sunnyvale, CA
Trip #3: East Lansing, MI - Sunnyvale, CA
Trip #4: East Lansing, MI - Sunnyvale, CA

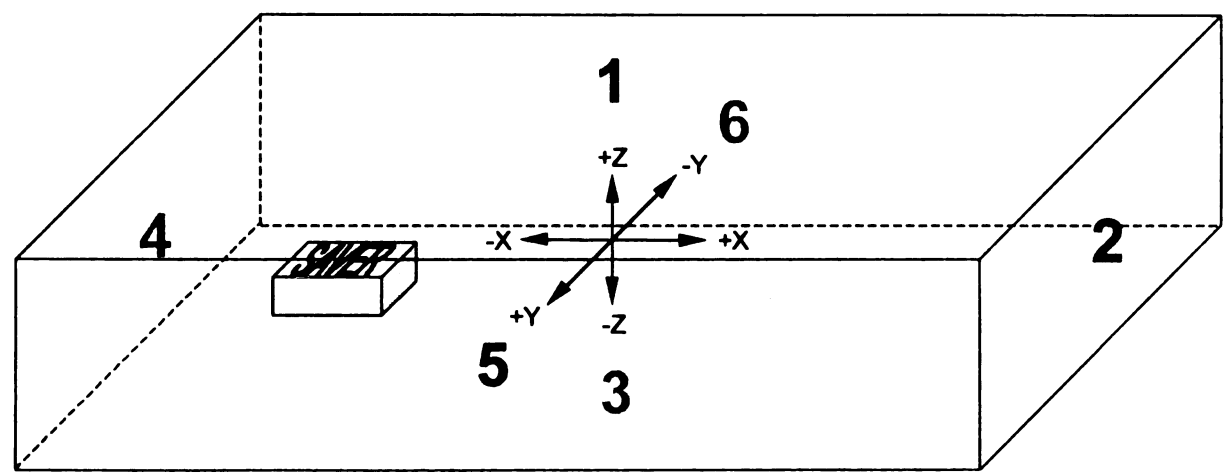

Figure 13. Face Orientation for Packages A and B

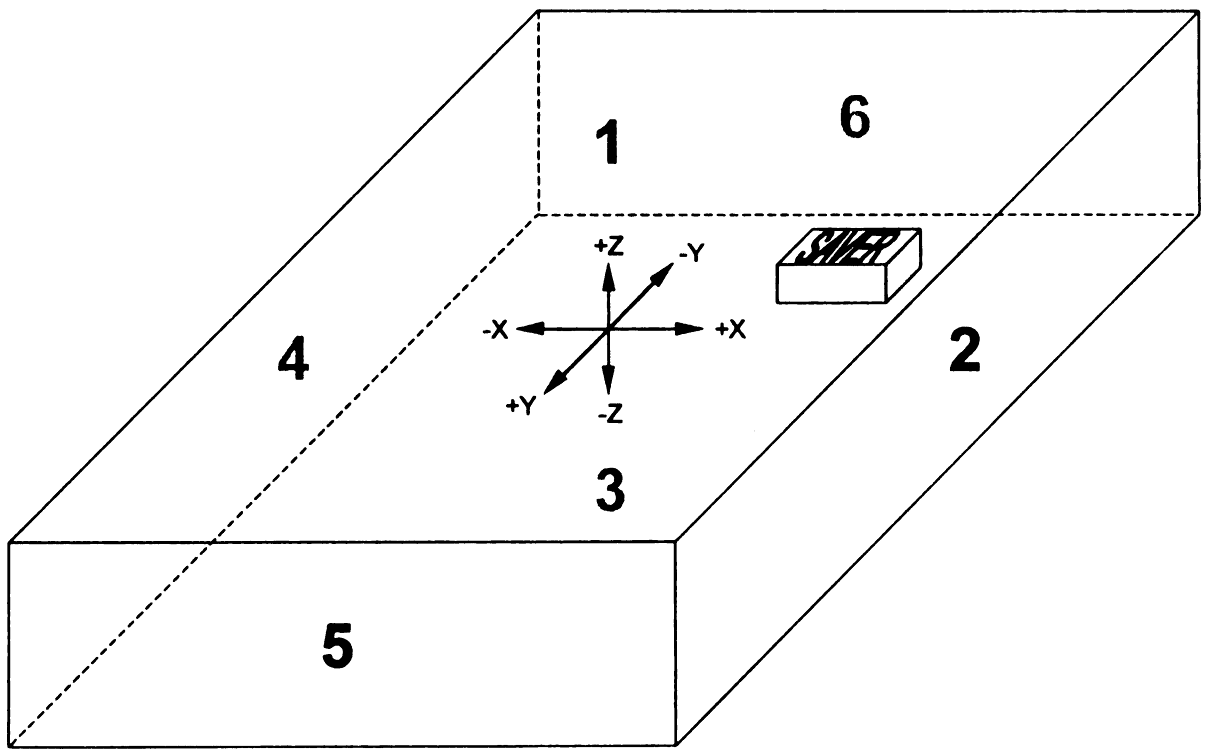

Figure 14. Face Orientation for Package C

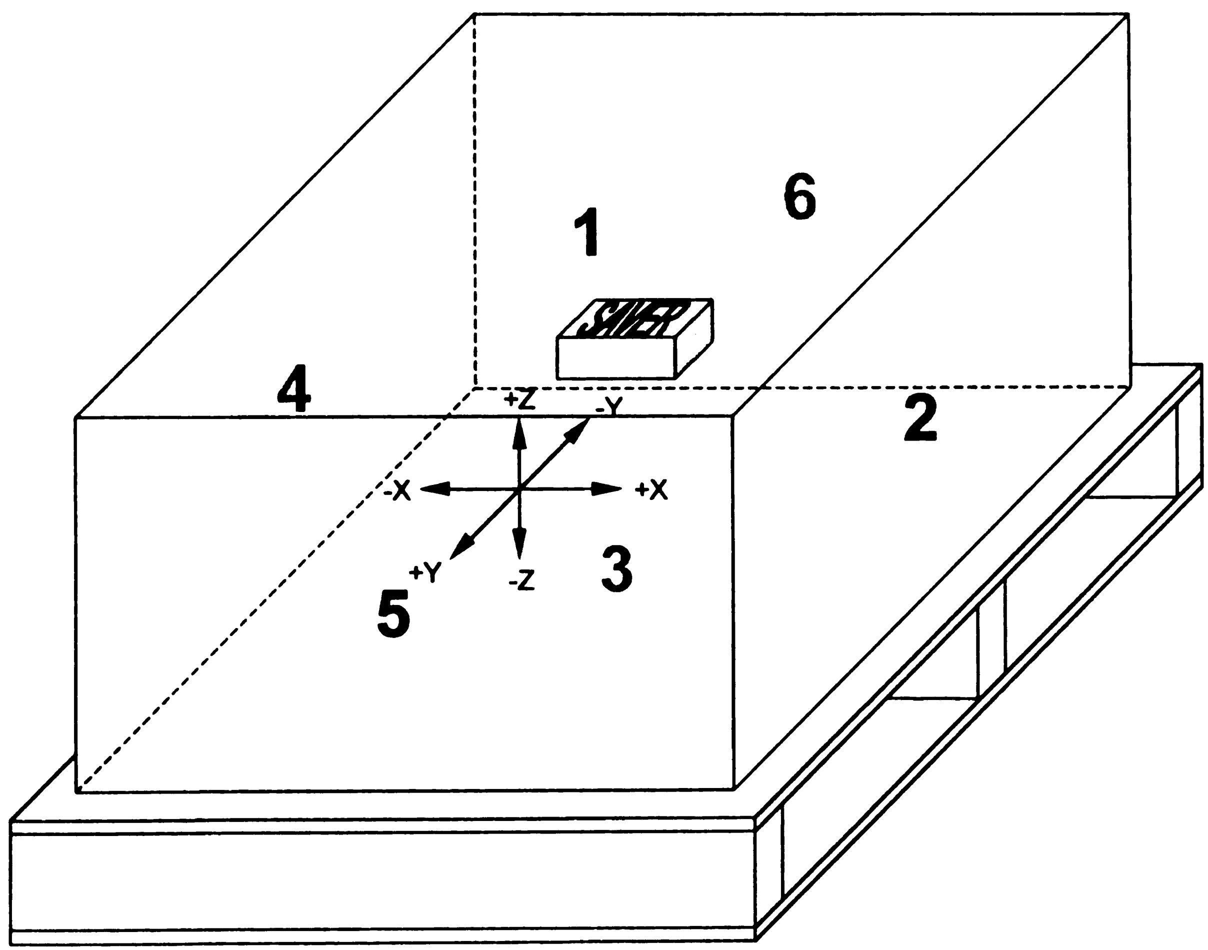

Figure 15. Face Orientation for Package D

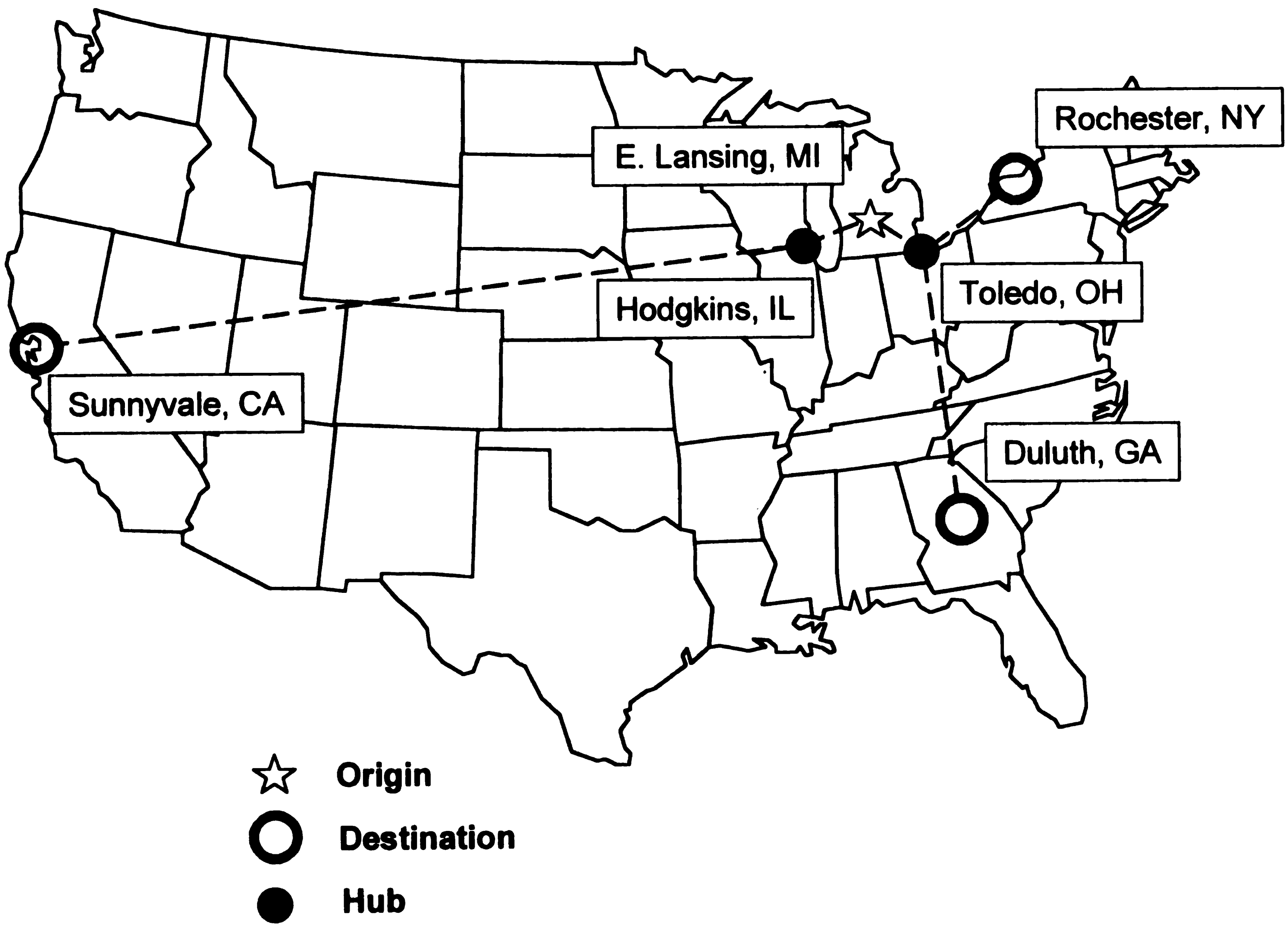

Figure 16. UPS Ground Destinations and Hubs in the U.S.

Trip #5: East Lansing, MI - Duluth, GA
Trip #6: East Lansing, MI - Duluth, GA
Trip #7: East Lansing, MI - Duluth, GA
Trip #8: East Lansing, MI - Duluth, GA

Trip #9: East Lansing, MI - Rochester, NY
Trip #10: East Lansing, MI - Rochester, NY
Trip #11: East Lansing, MI - Rochester, NY
Trip #12: East Lansing, MI - Rochester, NY

The four packages, (A through D) were all shipped from each destination on the same day, and were shipped back to East Lansing, MI together. All of the test shipments originated in East Lansing, MI and multiple shipments to each destination were performed in order to increase the reliability of the collected data. Four round-trips were made to each of the three destinations for a total of 48 one-way trips for packages A and B (24 apiece) and 24 one-way trips for both package C and package D.

For the shipments to Sunnyvale, CA, the packages passed through hubs in Lansing, MI, Hodgkins, IL, and finally San Bruno, CA before reaching the operating center in San Francisco, CA. The shipments to Duluth, GA began in the Lansing, MI hub, were transferred to the Toledo, OH hub, then to the Atlanta, GA hub, and finally the Roswell, GA spoke. The Rochester, NY shipments also passed through Toledo, OH, then were sent to the Buffalo, NY hub and finally the Rochester, NY spoke. Figure 17 shows the flow path of the test shipments through the UPS Ground shipping distribution system.

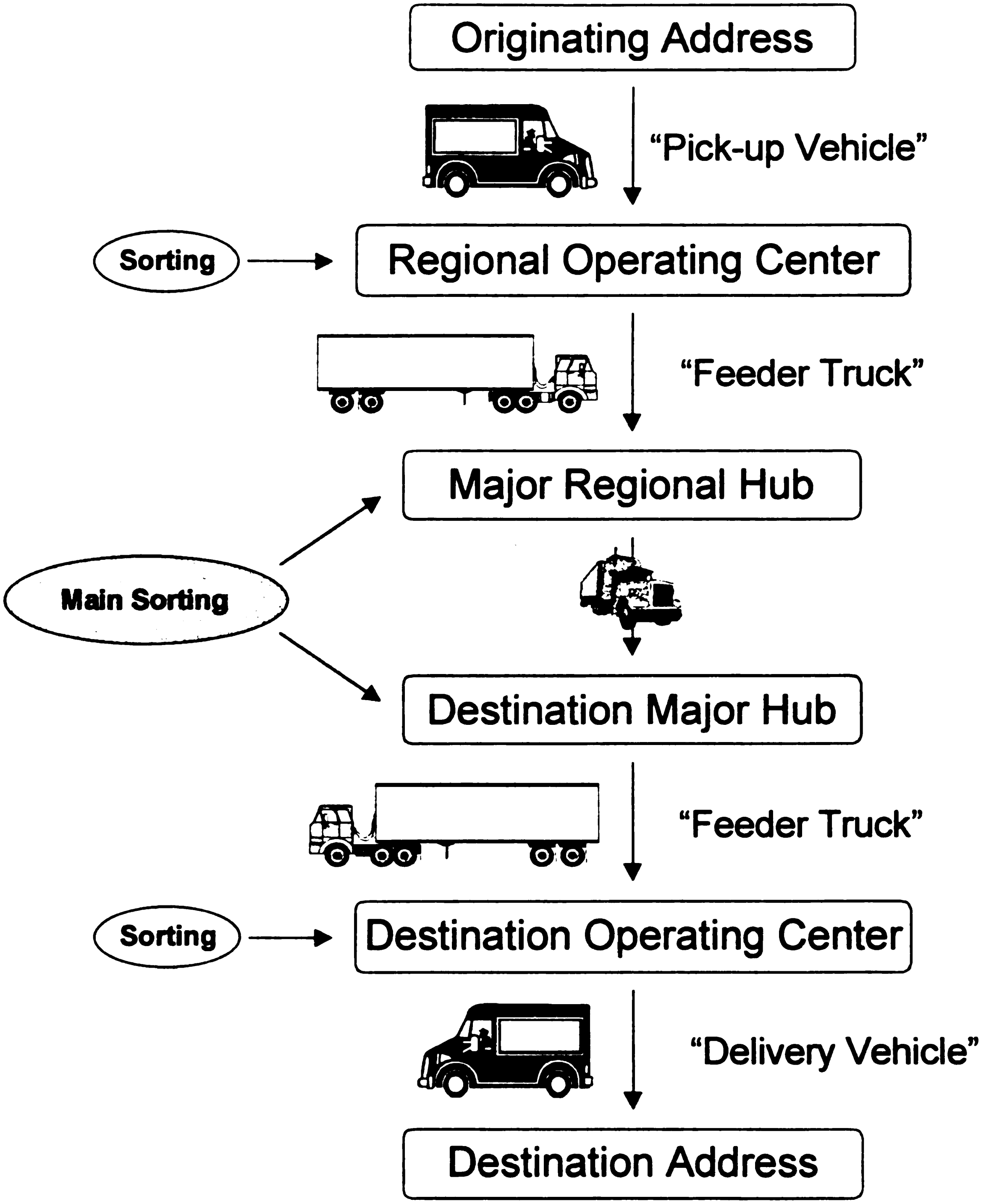

Figure 17. Overview of the UPS Ground Shipping Environment

3.0 DATA AND RESULTS

The acquired impact data from the SAVER units was uploaded into the computer and analyzed using the SaverWare analysis software version 1.33. The data was then processed by the software program and displayed in a spreadsheet format, separating the "Summary Events" from those that were not significant enough to register on the triaxial accelerometers (Non-Summary Events). The calculated drop heights from the summary events were further reduced to include only those impacts exhibiting a drop height of 3.00 inches (0.07 m) or higher. Since the recommended maximum weight limit by the Occupational Safety and Health Administration (OSHA) for manually handling packages is 40 pounds, it is very unlikely that any of the test packages would be tossed. Therefore, the only impacts interpreted by the SAVER units were classified as either "Free-Fall Drops" or "Impact-Not a Drop".

In analyzing the velocity change of the impacts, the data was presented for both the summary events and the non-summary events. Although the non-summary events were not significant enough for analysis and consideration in the suggested test plan they are presented in Appendix D. The registered drop heights and impact velocity changes were then analyzed in order to determine the average values experienced for those impacts that were recorded by the SAVER's. Although all of the shipments are unique trials and there can be no separate similarities or inferences drawn from them, the data has been presented by destination merely for the sake of interest. All of the conclusions drawn from this study were based on the total shipments and are not intended to specify any relationship with shipping distance.

During the course of this study there were many instances when the test packages were damaged upon returning to the School of Packaging. While none of the damaged packages were reused for the study, evidence of some of the typical hazards encountered can be found in Appendix A.

Table 2 shows the amount and level of the dynamic events of all the round trip shipments for the three selected destinations. The recorded drops have been summarized to indicate the number of drops per round trip shipment as well as the maximum, minimum, and average drops heights for each roundtrip shipment to the three destinations. The data from the individual shipments is then further summarized to display the total amount of drops per destination and additionally, the total drops experienced by each package type for all three shipping destinations combined. Since packages A and B contain identical products and exhibit identical packaging methods, the accumulated data for the two packages have been combined and analyzed as 48 one-way shipments rather than as two sets of 24 one-way shipments like packages C and D. The data in Table 3 has been presented as round trip shipments as well as the corresponding one-way shipments in order to portray the data as possible one-way shipments from vendor to customer. Consequently, the average drops per shipment have been calculated as an average for both roundtrip shipments and one-way shipments. The average drop height for each package type has been calculated from the actual raw recorded drop heights and not by simply

TABLE 2. Summary of All Recorded Drops

Package	Destination	Trip #	Number of Drops	MAX (in.)	MIN (in.)	AVG (in.)	S.D.
A and B	Sunnyvale, CA	1	24	26.02	3.12	8.79	7.47
		2	30	33.76	3.04	10.55	9.12
		3	30	36.14	3.09	11.37	10.56
		4	39	27.97	3.12	9.69	8.15
		Subtotal	**123**	**36.14**	**3.04**	**10.13**	**8.78**
	Duluth, GA	1	41	42.86	3.09	11.22	9.49
		2	34	42.50	3.12	10.15	9.30
		3	21	100.15	3.14	11.76	20.64
		4	45	62.99	3.07	10.74	12.18
		Subtotal	**141**	**100.15**	**3.07**	**10.89**	**12.40**
	Rochester, NY	1	28	34.32	3.22	10.52	8.86
		2	33	83.90	3.55	17.32	16.91
		3	26	67.37	3.17	14.68	14.23
		4	19	37.23	3.07	12.11	9.13
		Subtotal	**106**	**83.90**	**3.07**	**13.94**	**13.32**
Total			**370**	**100.15**	**3.04**	**11.51**	**11.71**
C	Sunnyvale, CA	1	12	43.96	3.76	12.08	11.74
		2	7	13.62	3.50	6.47	3.37
		3	18	35.72	3.27	11.34	10.26
		4	14	51.94	3.17	15.24	17.13
		Subtotal	**51**	**51.94**	**3.17**	**11.28**	**12.29**
	Duluth, GA	1	15	24.28	3.42	11.48	7.10
		2	19	33.03	3.02	9.35	8.06
		3	10	23.00	3.37	9.93	6.11
		4	32	48.59	3.42	12.40	9.73
		Subtotal	**76**	**48.59**	**3.02**	**10.79**	**8.39**
	Rochester, NY	1	9	42.95	3.37	12.83	13.00
		2	18	35.06	3.65	12.34	7.96
		3	9	31.69	3.27	11.63	9.21
		4	10	26.38	3.44	9.22	6.96
		Subtotal	**46**	**42.95**	**3.27**	**11.51**	**8.97**
Total			**173**	**51.94**	**3.02**	**11.49**	**9.79**
D	Sunnyvale, CA	1	7	15.80	3.09	8.94	4.86
		2	14	26.16	3.22	9.55	7.93
		3	14	17.91	3.07	6.98	4.94
		4	14	33.27	4.58	12.10	7.84
		Subtotal	**49**	**33.27**	**3.07**	**9.39**	**6.86**
	Duluth, GA	1	8	14.40	3.95	8.61	3.43
		2	16	25.53	3.07	12.10	4.43
		3	5	38.43	3.37	18.57	15.14
		4	11	15.04	3.24	7.90	3.99
		Subtotal	**40**	**38.43**	**3.07**	**11.80**	**7.92**
	Rochester, NY	1	7	17.04	7.09	11.96	3.45

TABLE 2. (cont'd)

Package	Destination	Trip #	Number of Drops	MAX (in.)	MIN (in.)	AVG (in.)	S.D.
D (con't)	Rochester, NY	2	8	21.94	3.68	9.79	5.94
		3	4	14.45	8.72	11.49	2.34
		4	4	10.94	3.71	7.00	3.57
		Subtotal	**23**	**21.94**	**3.68**	**10.06**	**4.49**
Total			**112**	**38.43**	**3.07**	**10.19**	**6.85**

*Note: The average drop height and standard deviation of the drop height calculated for the Subtotal and Total summaries was determined from the raw data (Appendix B).

TABLE 3. Summary of Recorded Drops For All Shipments

Destination	Package(s)	Maximum (in.)	Minimum (in.)	Average (in.)	Standard Deviation	Total Drops	Average Drops per Round Trip	Average Drops per Shipment
Sunnyvale, CA	A and B	36.14	3.04	10.13	8.78	123	15	8
	C	51.94	3.17	11.28	12.29	51	13	6
	D	33.27	3.07	9.39	6.86	49	12	6
Duluth, GA	A and B	100.15	3.07	10.89	12.40	141	18	9
	C	48.59	3.02	10.79	8.39	76	19	10
	D	38.43	3.07	11.80	7.92	40	10	5
Rochester, NY	A and B	83.90	3.07	13.94	13.32	106	13	7
	C	42.95	3.27	11.51	8.97	46	12	6
	D	21.94	3.68	10.06	4.49	23	6	3
All Shipments	**A and B**	**100.15**	**3.04**	**11.51**	**11.71**	**370**	**15**	**8**
	C	**51.94**	**3.02**	**11.49**	**9.79**	**173**	**14**	**7**
	D	**38.43**	**3.07**	**10.19**	**6.85**	**112**	**9**	**5**

*Note: The average drop height and standard deviation of the drop height calculated for summary of all shipments was determined from the raw data and not from the previously summarized data.

averaging the average values previously calculated in Table 2. These averages as well as the maximum and minimum drop heights for each package are presented in Table 3. The raw data used to determine the average drop height can be found in Appendix B; Tables B1, B2, and B3.

For packages A and B there was a combined total of 370 recorded dynamic events for the 48 one-way shipments, with an associated average of 8 drops per shipment. Package C recorded 173 dynamic events for all three destinations combined and had an average of 7 drops per shipment. Finally, package D experienced 112 dynamic events averaging only 5 drops per shipment. It was found that packages A and B had a maximum drop height of 100.15 inches and an average drop height of 11.51 inches. Package C had a maximum drop height of 51.94 inches and an average drop height of 11.49 inches for the 173 recorded events. Package D had a maximum drop height of 38.43 inches with an average drop height of 10.19 inches for the 112 recorded dynamic events.

The drop height information as well as the velocity change data, presented later in the chapter, is particularly useful in developing laboratory simulation tests in accordance with ASTM package testing methods. Drop height testing up to 95% of the maximum drop height experienced per package type is largely regarded as a standard test level used by the packaging industry in the development of simulated laboratory testing procedures.

The cumulative number of drop occurrences expressed as a percent was plotted against the associated drop height for each of the three package types.

These levels as well as the actual number of drops corresponding to each drop height are shown in Table 4. The accompanying Figure 18, is a histogram which shows the number of drops occurring at a given drop height for all three package types. The data presented in Figure 19 shows that 95% of the drops occur below 34, 32, and 22 inches for packages A and B, package C, and package D respectively.

The dynamic events were also analyzed in order to examine the impact orientation of the drops and the combined faces involved in the recorded drops. Table 5 shows the drop orientation frequency of the recorded events for all three destinations and indicates the total number of drops experienced by each package type on a given round trip. In addition, this table shows the number of drops occurring on a face, edge, or corner and the frequency of each orientation. For all three package types, the most common impact surface was on an edge. Packages A and B had 52.16% of the 370 recorded drops impacting on an edge. Package C experienced 56.65% of the 173 recorded drops resulting on an edge impact, and 51.79% of the 112 recorded drops for package D were edge impacts. The second most common impact surface was a face impact, with 35.68% of the total impacts experienced by packages A and B, 42.20% of the recorded impacts for package C, and 28.57% of the impacts for package D. Lastly, corner impacts with only 12.16%, 1.16%, and 19.64% of the total recorded impacts for packages A and B, package C, and package D respectively. Since there are 6 faces, 8 corners and 12 edges for a total of 26 possible impact surfaces, it can be statistically predicted that 46% (12 edges ÷ 26 surfaces) of the

TABLE 4. Cumulative Percent as a Function of Drop Height for All Shipments

Drops (in.)	Packages A and B		Package C		Package D	
	Cumulative Percent	Number	Cumulative Percent	Number	Cumulative Percent	Number
0	0	0	0	0	0	0
2	19.19%	71	19.65%	34	16.07%	18
4	39.19%	74	33.53%	24	33.93%	20
6	55.95%	62	49.13%	27	45.54%	13
8	63.78%	29	62.43%	23	57.14%	13
10	71.62%	29	67.05%	8	74.11%	19
12	76.49%	18	73.41%	11	78.57%	5
14	80.81%	16	78.61%	9	83.93%	6
16	82.16%	5	84.39%	10	87.50%	4
18	84.32%	8	85.55%	2	90.18%	3
20	86.49%	8	87.86%	4	94.64%	5
22	88.65%	8	89.02%	2	95.54%	1
24	90.81%	8	91.91%	5	96.43%	1
26	92.16%	5	92.49%	1	97.32%	1
28	92.97%	3	93.06%	1	97.32%	0
30	93.51%	2	94.80%	3	98.21%	1
32	94.86%	5	95.38%	1	99.11%	1
34	95.41%	2	97.11%	3	99.11%	0
36	97.03%	6	97.11%	0	99.11%	0
38	97.84%	3	97.11%	0	100.00%	1
40	97.84%	0	97.11%	0		
42	98.38%	2	98.27%	2		
44	98.38%	0	98.27%	0		
46	98.38%	0	98.27%	0		
48	98.38%	0	98.84%	1		
50	98.38%	0	100.00%	2		
52	98.38%	0				
54	98.38%	0				
56	98.92%	2				
58	98.92%	0				
60	98.92%	0				
62	99.19%	1				
64	99.19%	0				
66	99.46%	1				
68	99.46%	0				
70	99.46%	0				
72	99.46%	0				
74	99.46%	0				
76	99.46%	0				
78	99.46%	0				
80	99.46%	0				
82	99.73%	1				
84	99.73%	0				

TABLE 4. (cont'd)

Drops (in.)	Packages A and B		Package C		Package D	
	Cumulative Percent	Number	Cumulative Percent	Number	Cumulative Percent	Number
86	99.73%	0				
88	99.73%	0				
90	99.73%	0				
92	99.73%	0				
94	99.73%	0				
96	99.73%	0				
98	99.73%	0				
100	100.00%	1				
Total Drops:		370		173		112

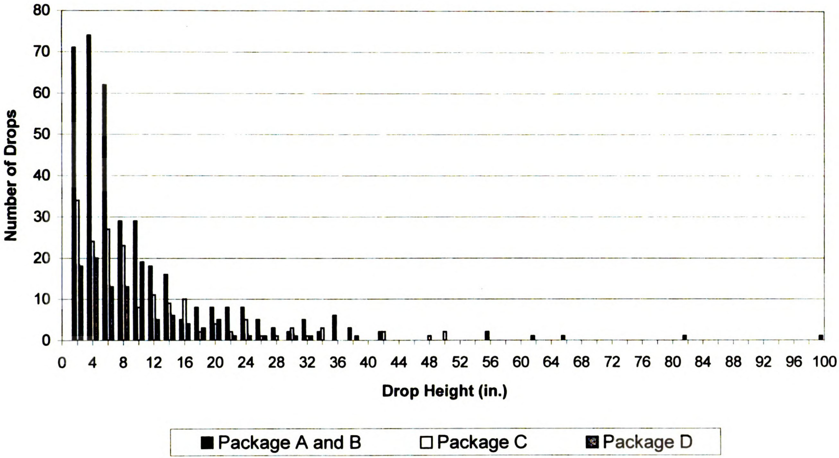

Figure 18. Number of Drops versus Drop Height for All Shipments

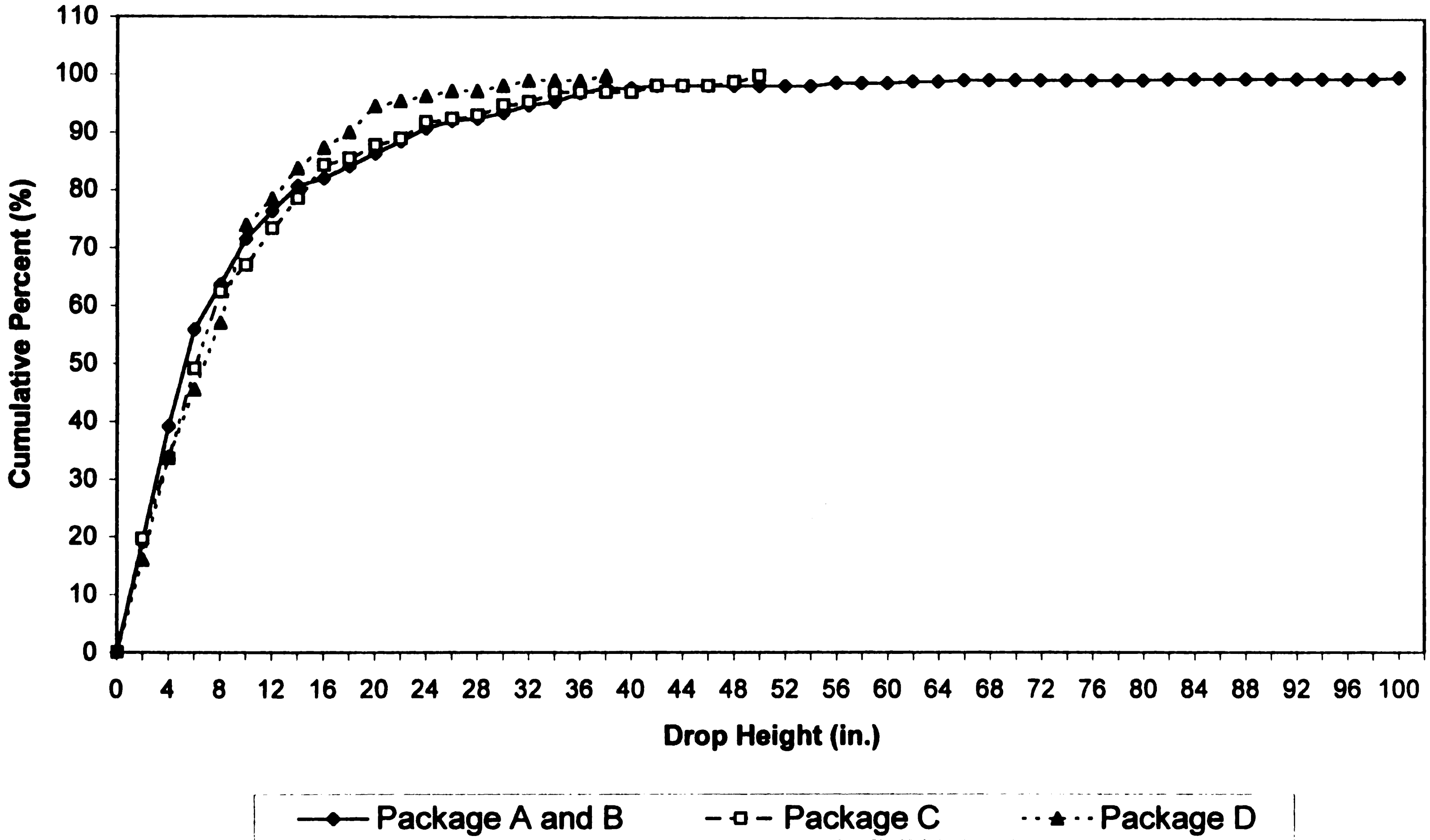

Figure 19. Cumulative Percent versus Drop Height for All Shipments

TABLE 5. Drop Orientation Frequency for All Shipments

Package	Destination	Trip #	Drops	Impact Orientation and Number		
				Face	Edge	Corner
A and B	Sunnyvale, CA	1	24	9	13	2
		2	30	12	16	2
		3	30	17	11	2
		4	39	15	17	7
	Subtotal		**123**	**53**	**57**	**13**
	Impact Frequency			**43.09%**	**46.34%**	**10.57%**
	Duluth, GA	1	41	16	18	7
		2	34	11	17	6
		3	21	7	12	2
		4	45	11	30	4
	Subtotal		**141**	**45**	**77**	**19**
	Impact Frequency			**31.91%**	**54.61%**	**13.48%**
	Rochester, NY	1	28	7	18	3
		2	33	11	17	5
		3	26	8	16	2
		4	19	8	8	3
	Subtotal		**106**	**34**	**59**	**13**
	Impact Frequency			**32.08%**	**55.66%**	**12.26%**
Total			**370**	**132**	**193**	**45**
Overall Impact Frequency				**35.68%**	**52.16%**	**12.16%**
C	Sunnyvale, CA	1	12	4	8	0
		2	7	2	5	0
		3	18	5	13	0
		4	14	6	8	0
	Subtotal		**51**	**17**	**34**	**0**
	Impact Frequency			**33.33%**	**66.67%**	**0.00%**
	Duluth, GA	1	15	5	10	0
		2	19	12	5	2
		3	10	4	6	0
		4	32	15	17	0
	Subtotal		**76**	**36**	**38**	**2**
	Impact Frequency			**47.37%**	**50.00%**	**2.63%**
	Rochester, NY	1	9	5	4	0
		2	18	5	13	0
		3	9	6	3	0
		4	10	4	6	0
	Subtotal		**46**	**20**	**26**	**0**
	Impact Frequency			**43.48%**	**56.52%**	**0.00%**
Total			**173**	**73**	**98**	**2**
Overall Impact Frequency				**42.20%**	**56.65%**	**1.16%**
D	Sunnyvale, CA	1	7	2	4	1
		2	14	5	6	3

TABLE 5. (cont'd)

Package	Destination	Trip #	Drops	Impact Orientation and Number		
				Face	Edge	Corner
D (con't)	Sunnyvale, CA	3	14	5	8	1
		4	14	3	6	5
	Subtotal		**49**	**15**	**24**	**10**
	Impact Frequency			**30.61%**	**48.98%**	**20.41%**
	Duluth, GA	1	8	1	7	0
		2	16	8	6	2
		3	5	2	2	1
		4	11	3	4	4
	Subtotal		**40**	**14**	**19**	**7**
	Impact Frequency			**35.00%**	**47.50%**	**17.50%**
	Rochester, NY	1	7	0	6	1
		2	8	2	4	2
		3	4	1	2	1
		4	4	0	3	1
	Subtotal		**23**	**3**	**15**	**5**
	Impact Frequency			**13.04%**	**65.22%**	**21.74%**
Total			**112**	**32**	**58**	**22**
Overall Impact Frequency				**28.57%**	**51.79%**	**19.64%**

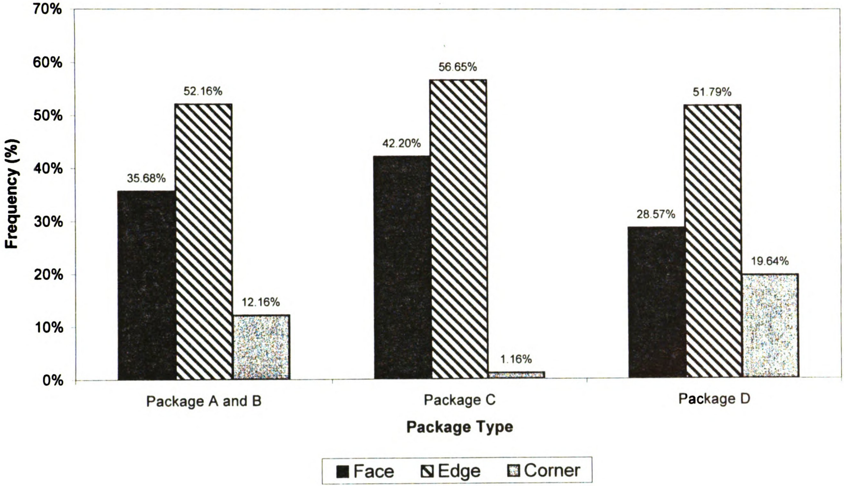

Figure 20. Distribution of Impact Orientation for All Shipments

drops will occur on an edge, 31% (8 corners ÷ 26 surfaces) will occur on a corner, and 23% (6 faces ÷ 26 surfaces) will occur on a face. The data collected for the surfaces of the impacts support this statistical relationship which justifies that the highest frequency of drops occurred on an edge. The impact orientation frequencies are displayed graphically in Figure 20.

Table 6 expands on the impact orientation to include the faces involved in each dynamic event registered by the SAVER units. The discrepancy between the total number of recorded impacts in Table 6 and the total drops presented in the previous tables can be attributed to the fact that many of the impacts involved more than one face (as in edge or corner drops) and were displayed in Table 6 as a summary of all faces involved. For packages A and B, the most frequent face involved in an impact was face 3 (the bottom face) with 31.70% of the recorded drops. Likewise, package D had most of the impacts involving face 3 as well, with 28.97% of the drops. Most of the drops experienced by package C, however, were found to involve face 6 (the back face) with 26.91% of the total recorded drops. This variance can be attributed to the size and shape of package C and the fact that the most conventional package orientation during shipment was either on its side or an end rather than on the bottom face which was the largest surface. The results presented in Table 6 as well as the breakdown of the faces involved in the drops are displayed graphically in Figure 21.

By applying the previous condition of including only drop heights greater than 3.00 inches, a similar restriction for analyzing the velocity change data can

TABLE 6. Number and Frequency of Impact Occurrences per Package Face for All Shipments

Package	Destination	Round Trip #	Number of Impacts	Number and Frequencies of occurences per surface 1	2	3	4	5	6
A and B	Sunnyvale, CA	1	41	1	5	10	7	8	10
		2	50	1	4	19	13	5	8
		3	45	0	13	12	7	3	10
		4	70	3	5	15	13	13	21
	Subtotal		**206**	**5**	**27**	**56**	**40**	**29**	**49**
	Impact Frequency			**2.43%**	**13.11%**	**27.18%**	**19.42%**	**14.08%**	**23.79%**
	Duluth, GA	1	73	3	6	24	19	13	8
		2	63	3	5	23	14	8	10
		3	37	1	2	13	8	7	6
		4	83	3	9	25	17	19	10
	Subtotal		**256**	**10**	**22**	**85**	**58**	**47**	**34**
	Impact Frequency			**3.91%**	**8.59%**	**33.20%**	**22.66%**	**18.36%**	**13.28%**
	Rochester, NY	1	52	0	7	17	11	11	6
		2	60	0	8	22	16	6	8
		3	46	0	9	16	11	5	5
		4	33	1	2	11	11	4	4
	Subtotal		**191**	**1**	**26**	**66**	**49**	**26**	**23**
	Impact Frequency			**0.52%**	**13.61%**	**34.55%**	**25.65%**	**13.61%**	**12.04%**
Total			**653**	**16**	**75**	**207**	**147**	**102**	**106**
Impact Frequency				**2.45%**	**11.49%**	**31.70%**	**22.51%**	**15.62%**	**16.23%**
C	Sunnyvale, CA	1	20	1	2	3	7	2	5
		2	12	0	3	0	3	2	4
		3	31	0	7	0	10	6	8
		4	22	0	4	0	8	3	7
	Subtotal		**85**	**1**	**16**	**3**	**28**	**13**	**24**
	Impact Frequency			**1.18%**	**18.82%**	**3.53%**	**32.94%**	**15.29%**	**28.24%**
	Duluth, GA	1	25	3	6	1	5	5	5
		2	28	11	3	3	3	6	2
		3	16	0	5	0	4	1	6
		4	49	0	18	0	9	10	12
	Subtotal		**118**	**14**	**32**	**4**	**21**	**22**	**25**
	Impact Frequency			**11.86%**	**27.12%**	**3.39%**	**17.80%**	**18.64%**	**21.19%**
	Rochester, NY	1	13	0	2	0	4	3	4
		2	31	0	10	0	7	3	11
		3	12	0	3	0	4	1	4
		4	16	0	3	0	5	2	6
	Subtotal		**72**	**0**	**18**	**0**	**20**	**9**	**25**
	Impact Frequency			**0.00%**	**25.00%**	**0.00%**	**27.78%**	**12.50%**	**34.72%**
Total			**275**	**15**	**66**	**7**	**69**	**44**	**74**
Impact Frequency				**5.45%**	**24.00%**	**2.55%**	**25.09%**	**16.00%**	**26.91%**

TABLE 6. (cont'd)

Package	Destination	Round Trip #	Number of Impacts	Number and Frequencies of occurences per surface					
				1	2	3	4	5	6
D	Sunnyvale, CA	1	13	1	3	4	1	3	1
		2	26	1	3	8	2	4	8
		3	24	1	1	11	4	1	6
		4	30	3	3	9	7	7	1
	Subtotal		**93**	**6**	**10**	**32**	**14**	**15**	**16**
	Impact Frequency			**6.45%**	**10.75%**	**34.41%**	**15.05%**	**16.13%**	**17.20%**
	Duluth, GA	1	15	2	1	4	2	1	5
		2	26	3	3	6	5	5	4
		3	9	3	1	2	0	2	1
		4	23	1	4	5	4	3	6
	Subtotal		**73**	**9**	**9**	**17**	**11**	**11**	**16**
	Impact Frequency			**12.33%**	**12.33%**	**23.29%**	**15.07%**	**15.07%**	**21.92%**
	Rochester, NY	1	15	1	2	3	3	2	4
		2	16	1	2	5	2	1	5
		3	8	2	2	1	0	2	1
		4	9	0	1	4	0	3	1
	Subtotal		**48**	**4**	**7**	**13**	**5**	**8**	**11**
	Impact Frequency			**8.33%**	**14.58%**	**27.08%**	**10.42%**	**16.67%**	**22.92%**
Total			**214**	**19**	**26**	**62**	**30**	**34**	**43**
Impact Frequency				**8.88%**	**12.15%**	**28.97%**	**14.02%**	**15.89%**	**20.09%**

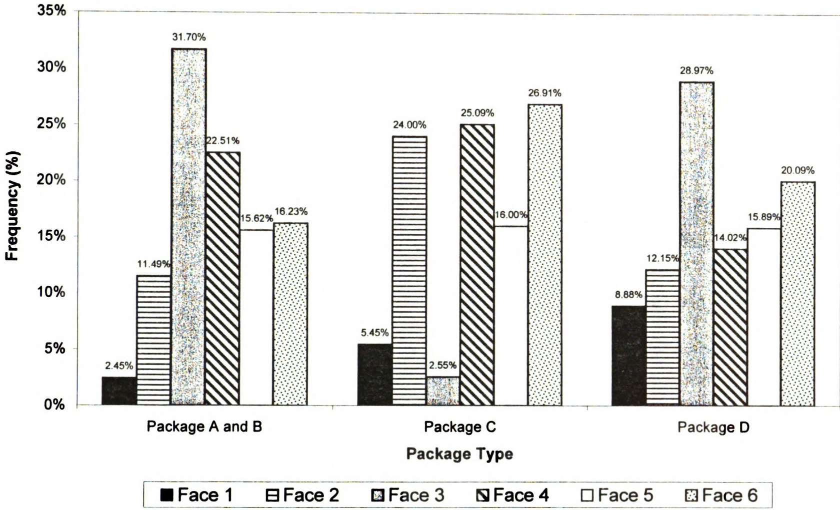

Figure 21. Distribution of Impact Faces for All Shipments

be derived. The justification is as follows and can be expressed using the following equation:

$$\Delta v = (1+e)\sqrt{2gh} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (3-1)$$

Where: v = the change in velocity in in./s.

e = the coefficient of restitution, in this case 0.5

g = the acceleration due to gravity, 386.4 in./s.^{2}

h = the drop height in inches

An average value of 0.5 was chosen to represent the coefficient of restitution in order to evaluate the data for an average cushion type. By inserting the drop height restriction of 3.00 inches into the previous equation, the cut off level for the velocity change can be calculated as follows:

$$\Delta v = (1+0.5)\sqrt{(2 \cdot 386.4 \cdot 3.00)}$$

$$= 72.22 \text{ in./s.}$$

Similar to drop height of the impacts, it is also important to analyze the velocity change of the impacts recorded by the SAVER units. The data has been limited to velocity changes greater than the aforementioned 72.22 in./s. in that they correspond to the previous requirement of drop heights greater than 3.00 inches. Also, the smaller values for impact velocity change are very difficult to re-create through testing on a shock table.

Table 7 presents the summary of the velocity changes experienced by the three different package types. The data is further summarized to indicate the maximum, minimum, and average velocity change as well as the associated standard deviation per impact face for each destination. The velocity change data has been presented as a separate summary for all three destinations with an additional summary of all three destinations combined (Table 8). It should, however, be noted that there can be no practical correlation between the distance of the shipments with the number and severity of impact velocity changes in that all shipments are considered unique. Table 7 also shows the number of impacts that each face experiences for the total shipments. The difference in the amount of impacts versus the previously presented drops (Table 2) lies in the fact that some of the calculated velocity changes that were significant enough to be measured (those greater than 72.22 in./s.) may correspond to actual drop heights less than the 3.00 inch cut-off for the first set of data or involve more than one face in the impact. Table 8 presents the velocity change data including the maximum, minimum, average and standard deviation of the events per package face involved. The table also includes data relating to the average number of impacts experienced per round trip as well as the average number of impacts per one way shipment.

The cumulative number of occurrences expressed in percent was plotted against the impact velocity change recorded for all three package types. For this analysis, impact data for faces 2 and 4 were combined to represent impacts along the X-axis. Likewise, faces 5 and 6 were combined to represent impacts

TABLE 7. Summary of Velocity Change for All Summary Events

Package	Destination	Impact Face	Number of Impacts	MAX (in./s.)	MIN (in./s.)	AVG (in./s.)	S.D.
A and B	Sunnyvale, CA	1	2	196.47	93.19	144.83	73.02
		2	12	211.47	73.15	135.67	50.80
		3	22	167.67	72.76	96.47	24.74
		4	9	222.72	79.50	133.87	51.53
		5	12	268.72	77.99	117.85	51.51
		6	23	169.22	73.45	105.69	28.36
		Subtotal	**80**	**268.72**	**72.76**		
	Duluth, GA	1	3	99.68	74.05	82.96	14.49
		2	13	182.16	73.87	110.05	33.88
		3	51	214.87	72.36	105.44	33.81
		4	18	195.61	74.21	133.67	43.10
		5	13	211.50	72.30	111.22	43.02
		6	7	220.39	80.89	132.26	52.15
		Subtotal	**105**	**220.39**	**73.82**		
	Rochester, NY	1	0	-	-	-	-
		2	9	203.40	74.30	127.85	49.35
		3	48	246.17	72.71	111.86	36.84
		4	19	242.41	91.58	152.97	48.79
		5	6	125.13	74.81	91.88	20.77
		6	7	170.94	73.17	107.24	38.61
		Subtotal	**89**	**242.41**	**72.71**		
Total			**274**	**268.72**	**72.71**		
C	Sunnyvale, CA	1	0	-	-	-	-
		2	8	164.64	73.05	105.35	37.66
		3	1	105.10	105.10	105.10	-
		4	14	200.01	72.84	115.08	37.57
		5	6	116.24	83.52	103.39	14.93
		6	10	135.38	81.01	98.15	19.68
		Subtotal	**39**	**200.01**	**72.84**		
	Duluth, GA	1	6	163.61	75.30	96.93	34.01
		2	19	183.88	73.61	107.78	31.22
		3	3	101.37	72.43	86.24	14.51
		4	9	140.87	74.92	95.04	21.69
		5	18	193.71	74.60	119.07	42.06
		6	13	167.09	73.46	101.33	28.38
		Subtotal	**68**	**193.71**	**72.43**		
	Rochester, NY	1	0	-	-	-	-
		2	4	134.81	80.58	101.01	23.53
		3	0	-	-	-	-
		4	11	169.65	75.15	111.51	36.49
		5	9	197.28	72.91	102.48	38.44
		6	16	214.66	73.52	115.98	37.42

TABLE 7. (cont'd)

Package	Destination	Impact Face	Number of Impacts	MAX (in./s.)	MIN (in./s.)	AVG (in./s.)	S.D.
C (con't)	Rochester, NY	**Subtotal**	**40**	**214.66**	**72.91**		
Total			**147**	**214.66**	**72.43**		
D	Sunnyvale, CA	1	3	131.46	96.44	111.06	18.21
		2	2	93.39	91.81	92.60	1.12
		3	12	191.97	73.24	108.85	39.97
		4	5	124.69	78.02	90.84	19.25
		5	7	152.74	75.50	116.98	29.62
		6	8	162.53	75.19	112.46	33.29
		Subtotal	**37**	**191.97**	**73.24**		
	Duluth, GA	1	3	228.82	74.32	131.65	84.60
		2	4	102.92	77.36	88.83	10.95
		3	9	142.95	77.00	96.03	19.46
		4	5	132.39	79.62	96.14	21.08
		5	7	194.75	86.29	127.95	41.26
		6	7	143.41	75.51	105.12	27.12
		Subtotal	**35**	**228.82**	**74.32**		
	Rochester, NY	1	2	82.69	81.78	82.24	0.64
		2	3	126.95	101.02	117.33	14.20
		3	7	172.12	73.15	103.68	35.53
		4	1	123.93	123.93	123.93	-
		5	3	165.51	85.86	126.18	39.83
		6	3	157.59	95.86	125.85	30.90
		Subtotal	**19**	**172.12**	**73.15**		
Total			**91**	**228.82**	**73.15**		

TABLE 8. Summary of All Impacts for All Summary Events

Destination	Package(s)	Impact Face	Maximum (in./s.)	Minimum (in./s.)	Average (in./s.)	Standard Deviation	Total Impacts	Average Impacts per Round Trip	Average Impacts per Shipment
Sunnyvale, CA	A and B	1	196.47	93.19	144.83	73.02	2	0	0
		2	211.47	73.15	135.67	50.80	12	2	1
		3	167.67	72.76	96.47	24.74	22	3	1
		4	222.72	79.50	133.87	51.53	9	1	1
		5	268.72	77.99	117.85	51.51	12	2	1
		6	169.22	73.45	105.69	28.36	23	3	1
	C	1	-	-	-	-	0	0	0
		2	164.64	73.05	105.35	37.66	8	2	1
		3	105.10	105.10	105.10	-	1	0	0
		4	200.01	72.84	115.08	37.57	14	4	2
		5	116.24	83.52	103.39	14.93	6	2	1
		6	135.38	81.01	98.15	19.68	10	3	1
	D	1	131.46	96.44	111.06	18.21	3	1	0
		2	93.39	91.81	92.60	1.12	2	1	0
		3	191.97	73.24	108.85	39.97	12	3	2
		4	124.69	78.02	90.84	19.25	5	1	1
		5	152.74	75.50	116.98	29.62	7	2	1
		6	162.53	75.19	112.46	33.29	8	2	1
Duluth, GA	A and B	1	99.68	74.05	82.96	14.49	3	0	0
		2	182.16	73.87	110.05	33.88	13	2	1
		3	214.87	72.36	105.44	33.81	51	6	3
		4	195.61	74.21	133.67	43.10	18	2	1
		5	211.50	72.30	111.22	43.02	13	2	1
		6	220.39	80.89	132.26	52.15	7	1	0
	C	1	163.61	75.30	96.93	34.01	6	2	1
		2	183.88	73.61	107.78	31.22	19	5	2

TABLE 8. (cont'd)

Destination	Package(s)	Impact Face	Maximum (in./s.)	Minimum (in./s.)	Average (in./s.)	Standard Deviation	Total Impacts	Average Impacts per Round Trip	Average Impacts per Shipment
Duluth, GA (con't)	C	3	101.37	72.43	86.24	14.51	3	1	0
		4	140.87	74.92	95.04	21.69	9	2	1
		5	193.71	74.60	119.07	42.06	18	5	2
		6	167.09	73.46	101.33	28.38	13	3	2
	D	1	228.82	74.32	131.65	84.60	3	1	0
		2	102.92	77.36	88.83	10.95	4	1	1
		3	142.95	77.00	96.03	19.46	9	2	1
		4	132.39	79.62	96.14	21.08	5	1	1
		5	194.75	86.29	127.95	41.26	7	2	1
		6	143.41	75.51	105.12	27.12	7	2	1
Rochester, NY	A and B	1	-	-	-	-	0	0	0
		2	203.40	74.30	127.85	49.35	9	1	1
		3	246.17	72.71	111.86	36.84	48	6	3
		4	242.41	91.58	152.97	48.79	19	2	1
		5	125.13	74.81	91.88	20.77	6	1	0
		6	170.94	73.17	107.24	38.61	7	1	0
	C	1	-	-	-	-	0	0	0
		2	134.81	80.58	101.01	23.53	4	1	1
		3	-	-	-	-	0	0	0
		4	169.65	75.15	111.51	36.49	11	3	1
		5	197.28	72.91	102.48	38.44	9	2	1
		6	214.66	73.52	115.98	37.42	16	4	2
	D	1	82.69	81.78	82.24	0.64	2	1	0
		2	126.95	101.02	117.33	14.2	3	1	0
		3	172.12	73.15	103.68	35.53	7	2	1
		4	123.93	123.93	123.93	-	1	0	0

TABLE 8. (cont'd)

Destination	Package(s)	Impact Face	Maximum (in./s.)	Minimum (in./s.)	Average (in./s.)	Standard Deviation	Total Impacts	Average Impacts per Round Trip	Average Impacts per Shipment
Rochester, NY (con't)	D	5	165.51	85.86	126.18	39.83	3	1	0
		6	157.59	95.86	125.85	30.90	3	1	0
All Shipments	**A and B**	**1**	**196.46**	**74.05**	**107.71**	**50.86**	**5**	**0**	**0**
		2	**211.47**	**73.15**	**123.80**	**44.75**	**34**	**1**	**1**
		3	**246.17**	**72.36**	**106.36**	**33.84**	**121**	**5**	**3**
		4	**242.41**	**74.21**	**141.86**	**47.09**	**46**	**2**	**1**
		5	**268.72**	**72.30**	**110.04**	**43.31**	**31**	**1**	**1**
		6	**222.39**	**73.17**	**111.01**	**36.08**	**37**	**2**	**1**
	Totals		**268.72**	**72.30**	**-**	**-**	**274**	**11**	**7**
	C	**1**	**163.61**	**75.30**	**96.93**	**34.01**	**6**	**1**	**0**
		2	**183.88**	**73.05**	**106.28**	**31.25**	**31**	**3**	**1**
		3	**105.10**	**72.43**	**90.96**	**15.14**	**4**	**0**	**0**
		4	**200.01**	**72.84**	**108.62**	**33.83**	**34**	**3**	**1**
		5	**197.28**	**72.91**	**111.69**	**37.57**	**33**	**3**	**1**
		6	**214.66**	**73.46**	**106.52**	**31.05**	**39**	**3**	**2**
	Totals		**214.66**	**72.43**	**-**	**-**	**147**	**13**	**5**
	D	**1**	**228.82**	**74.32**	**111.58**	**50.58**	**8**	**1**	**0**
		2	**126.95**	**77.36**	**99.17**	**16.84**	**9**	**1**	**0**
		3	**191.97**	**73.15**	**103.43**	**32.79**	**28**	**2**	**1**
		4	**132.39**	**78.02**	**96.26**	**20.43**	**11**	**1**	**0**
		5	**194.75**	**75.50**	**123.12**	**34.56**	**17**	**1**	**1**
		6	**162.53**	**75.19**	**111.84**	**29.69**	**18**	**2**	**1**
	Totals		**228.82**	**73.15**	**-**	**-**	**91**	**8**	**3**

*Note: The average velocity change and standard deviation of the velocity change calculated for the summary of all impacts was determined from the raw data and not from the previously summarized data.

along the Y-axis. The four faces are combined in this arrangement because the packages can be easily tested on either face to the recommended 95% of the maximum impact velocity change. Faces 1 and 3 remained isolated and were consequently analyzed separately because they are unique faces: being the top and bottom of the package respectively. Because of the shipping label placement, it is naturally assumed that the face bearing the label (top) would receive far less impacts than the side directly opposite it (bottom). The impact levels as well as the actual number of impacts recorded are shown in Table 9. The accompanying Figures 22-24 are histograms, which show the number of impacts occurring over a given range of velocity change. The data in Figures 25-27 show that 95% of the of the maximum velocity changes experienced by packages A and B occurred below 180 in./s. for face 1, 160 in./s. for face 3, 210 in./s. for faces 2 & 4, and below 170 in./s. for faces 5 & 6 combined. Package C experienced the 95% level below 160 in./s. for face 1, 100 in./s. for face 3, 160 in./s. for faces 2 & 4 and below 180 in./s. for faces 5 & 6. Package D was below 95% of the maximum velocity change at 220 in./s. for face 1, 170 in./s. for face 3, 120 in./s. for faces 2 & 4, and 170 in./s. as well for faces 5 & 6.

Similarly, the velocity changes of the dynamic events were again analyzed to examine the impact orientation and the combined faces involved. Table 10 shows the drop orientation frequency of the recorded events for all three package types to the three destinations. The data indicates the number of drops experienced by each package type as face/edge/corner impacts on a given

TABLE 9. Cumulative Percent as a Function of Velocity Change for All Summary Events

Package	Δv (in./s.)	Involved Impact Faces							
		1		3		2 and 4		5 and 6	
		Cumulative Percent	Impact #'s	Cumulative Percent	Impact #'s	Cumulative Percent	Impact #'s	Cumulative Percent	Impact #'s
A and B	70	40.00%	2	24.79%	30	11.25%	9	23.53%	16
	80	40.00%	0	41.32%	20	18.75%	6	36.76%	9
	90	80.00%	2	54.55%	16	31.25%	10	51.47%	10
	100	80.00%	0	67.77%	16	40.00%	7	63.24%	8
	110	80.00%	0	74.38%	8	45.00%	4	72.06%	6
	120	80.00%	0	79.34%	6	55.00%	8	77.94%	4
	130	80.00%	0	85.12%	7	61.25%	5	80.88%	2
	140	80.00%	0	88.43%	4	67.50%	5	85.29%	3
	150	80.00%	0	92.56%	5	70.00%	2	88.24%	2
	160	80.00%	0	95.87%	4	73.75%	3	91.18%	2
	170	80.00%	0	95.87%	0	77.50%	3	95.59%	3
	180	100.00%	1	95.87%	0	81.25%	3	95.59%	0
	190			97.52%	2	90.00%	7	95.59%	0
	200			98.35%	1	93.75%	3	95.59%	0
	210			99.17%	1	95.00%	1	97.06%	1
	220			99.17%	0	97.50%	2	98.53%	1
	230			99.17%	0	97.50%	0	98.53%	0
	240			100.00%	1	100.00%	2	98.53%	0
	250							98.53%	0
	260							100.00%	1
Total Drops:			5		121		80		68
C	70	50.00%	3	25.00%	1	23.08%	15	22.22%	16
	80	66.67%	1	50.00%	1	40.00%	11	41.67%	14
	90	66.67%	0	50.00%	0	53.85%	9	51.39%	7
	100	83.33%	1	100.00%	2	63.08%	6	59.72%	6
	110	83.33%	0			69.23%	4	68.06%	6
	120	83.33%	0			73.85%	3	76.39%	6
	130	83.33%	0			83.08%	6	83.33%	5
	140	83.33%	0			87.69%	3	86.11%	2
	150	83.33%	0			87.69%	0	91.67%	4
	160	100.00%	1			96.92%	6	94.44%	2
	170					96.92%	0	94.44%	0
	180					98.46%	1	95.83%	1
	190					98.46%	0	98.61%	2
	200					100.00%	1	98.61%	0
	210							100.00%	1
Total Drops:			6		4		65		72
D	70	12.50%	1	21.43%	6	15.00%	3	8.57%	3
	80	37.50%	2	42.86%	6	45.00%	6	28.57%	7
	90	62.50%	2	71.43%	8	65.00%	4	37.14%	3

TABLE 9. (cont'd)

Package	Δv (in./s.)	Involved Impact Faces							
		1		3		2 and 4		5 and 6	
		Cumulative Percent	Impact #'s	Cumulative Percent	Impact #'s	Cumulative Percent	Impact #'s	Cumulative Percent	Impact #'s
D (con't)	100	75.00%	1	75.00%	1	75.00%	2	51.43%	5
	110	75.00%	0	78.57%	1	75.00%	0	54.29%	1
	120	75.00%	0	78.57%	0	95.00%	4	62.86%	3
	130	87.50%	1	82.14%	1	100.00%	1	74.29%	4
	140	87.50%	0	85.71%	1			80.00%	2
	150	87.50%	0	89.29%	1			88.57%	3
	160	87.50%	0	92.86%	1			94.29%	2
	170	87.50%	0	96.43%	1			97.14%	1
	180	87.50%	0	96.43%	0			97.14%	0
	190	87.50%	0	100.00%	1			100.00%	1
	200	87.50%	0						
	210	87.50%	0						
	220	100.00%	1						
Total Drops:			8		28		20		35

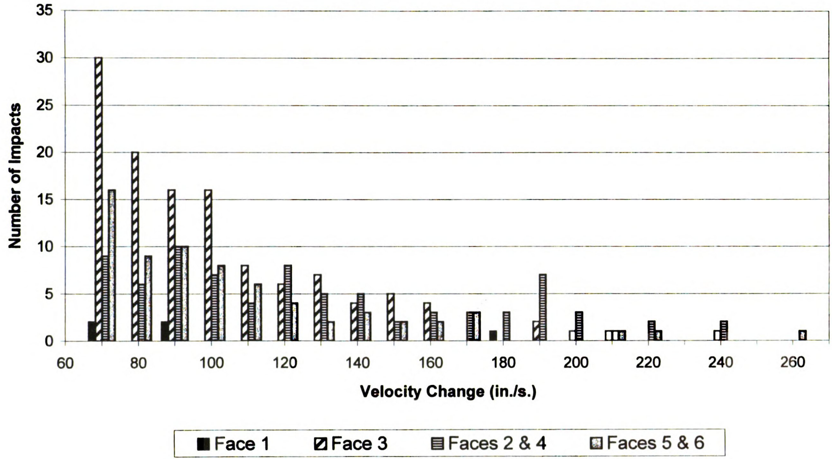

Figure 22. Number of Impacts versus Velocity Change for Packages A and B

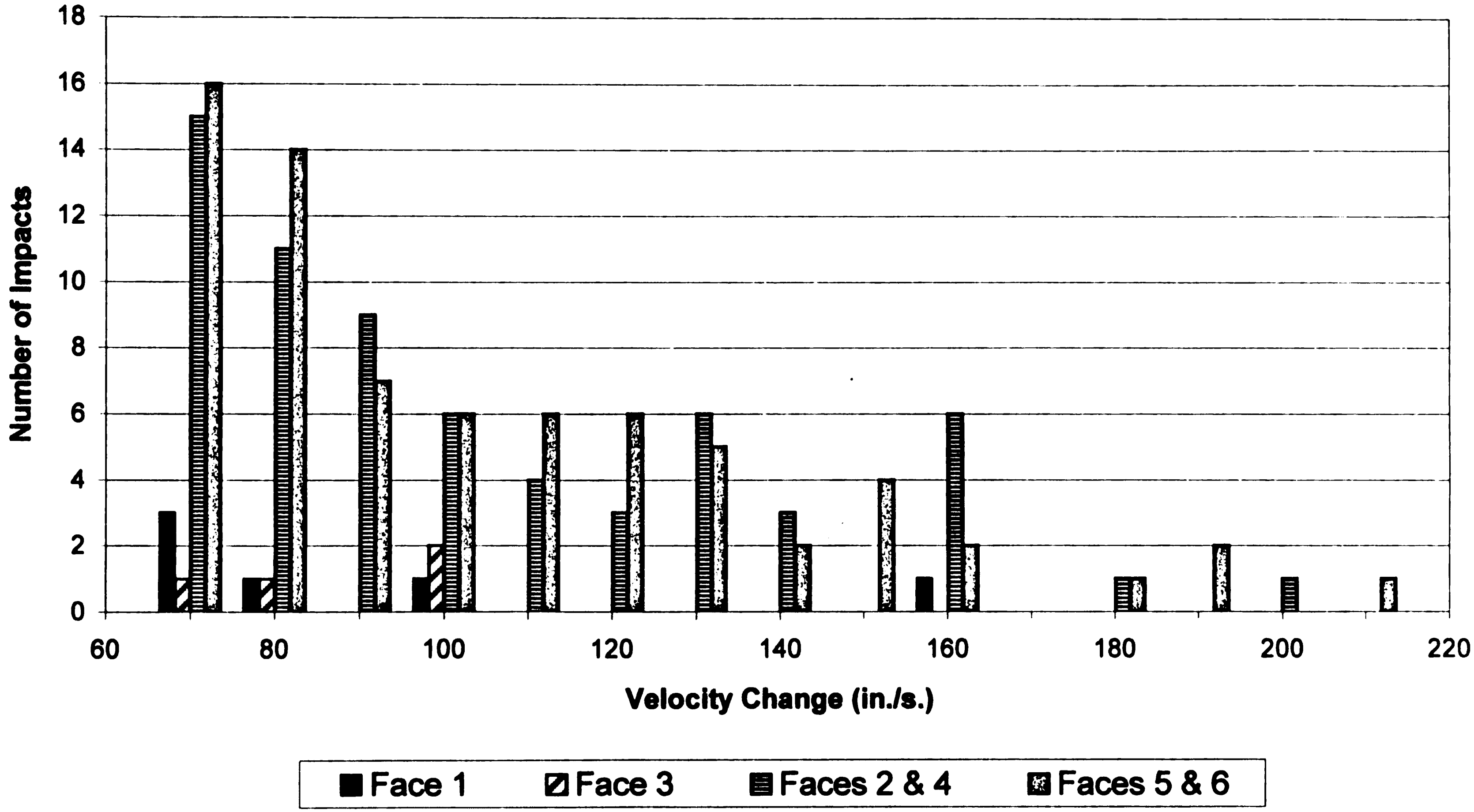

Figure 23. Number of Impacts versus Velocity Change for Package C

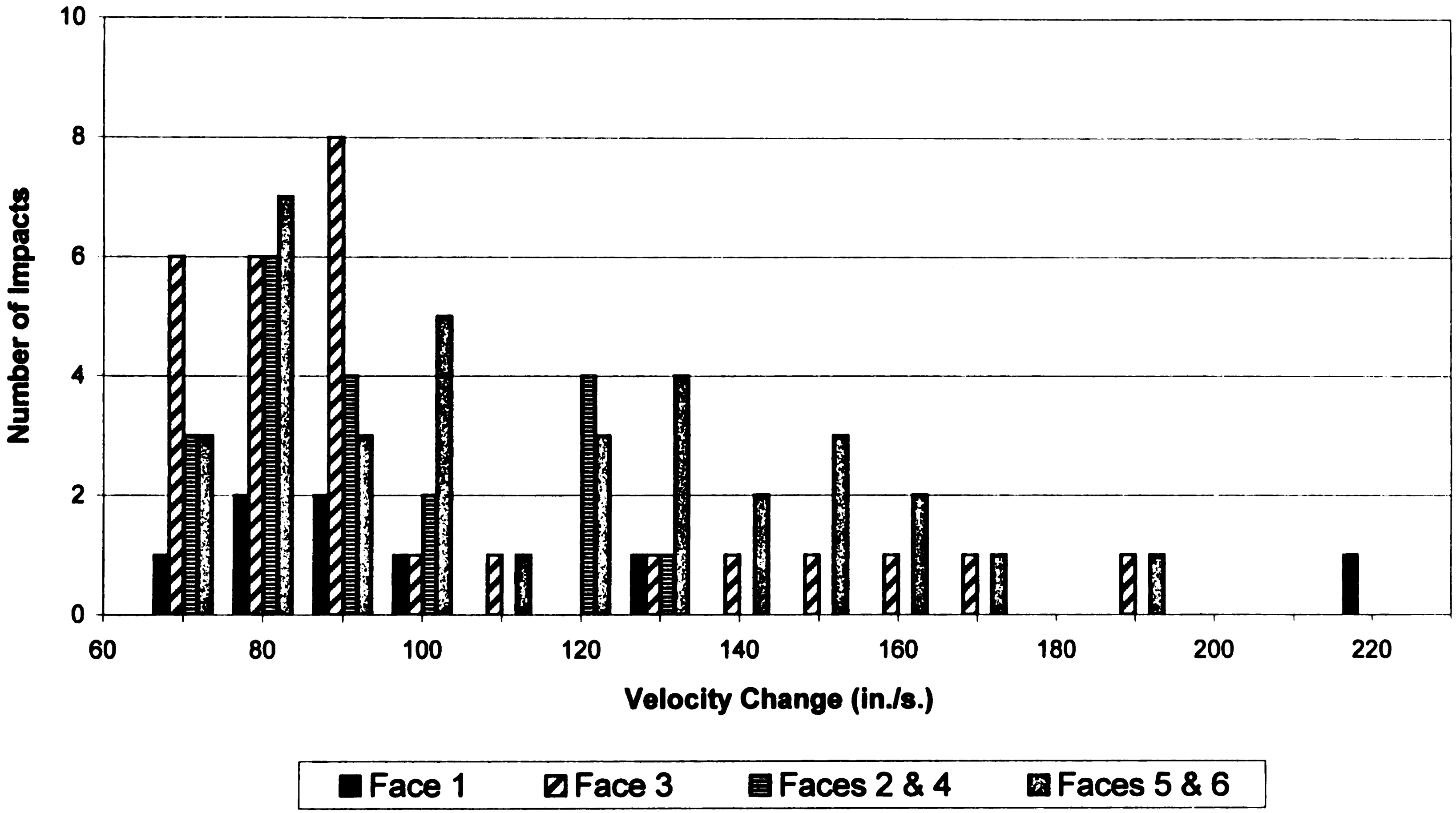

Figure 24. Number of Impacts versus Velocity Change for Package D

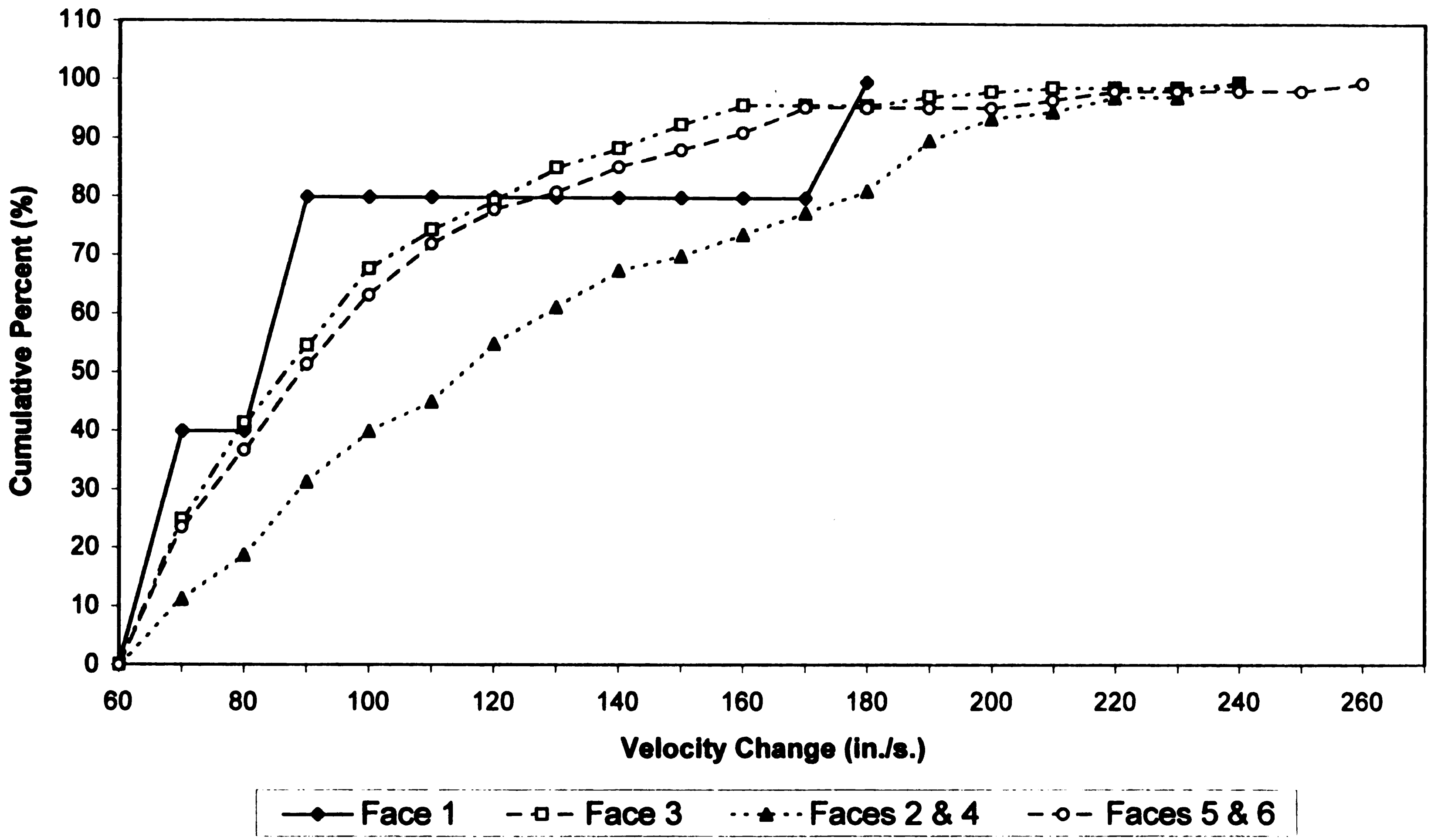

Figure 25. Cumulative Percent versus Impact Velocity Change of All Summary Events for Packages A and B

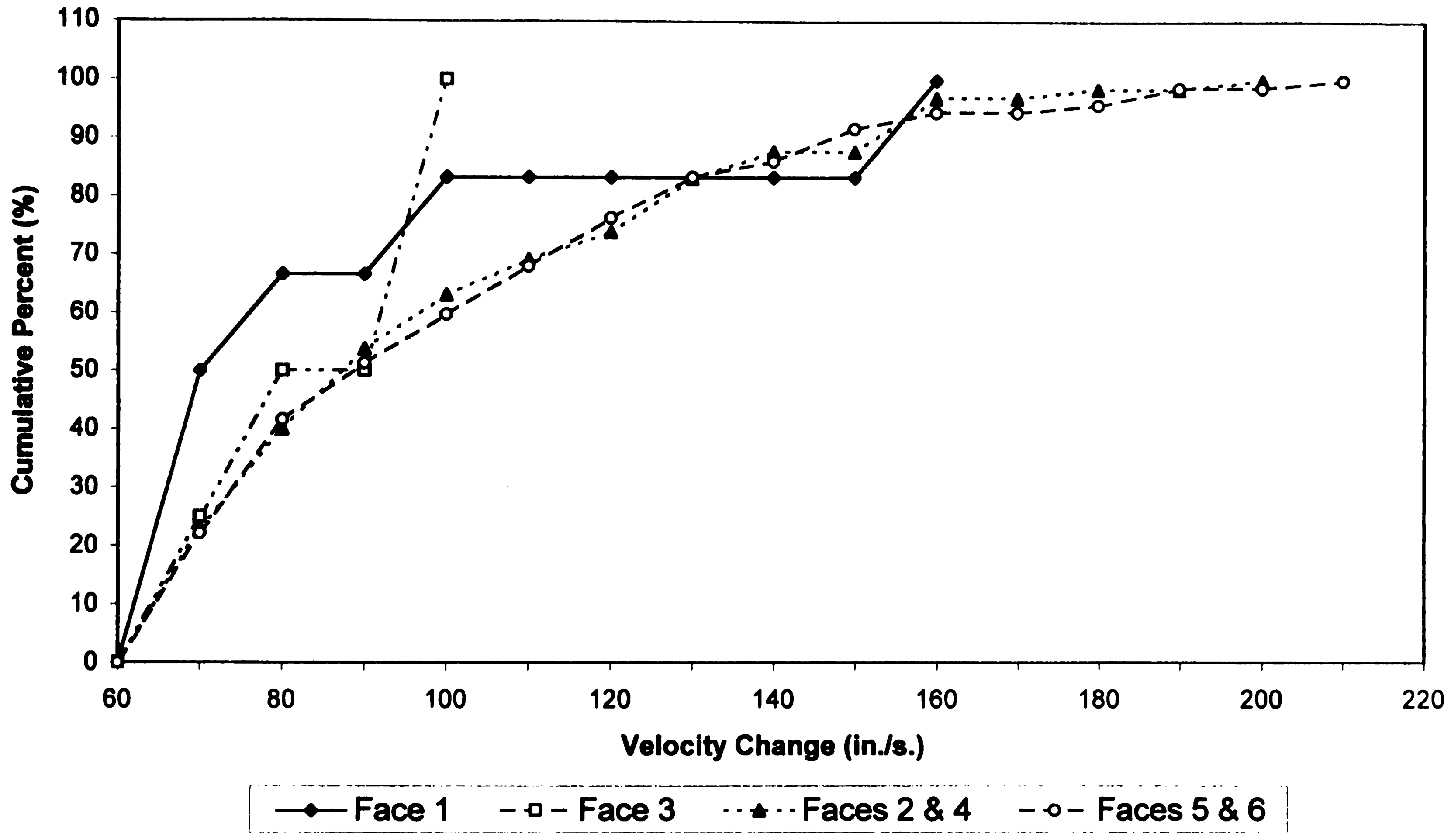

Figure 26. Cumulative Percent versus Impact Velocity Change of All Summary Events for Package C

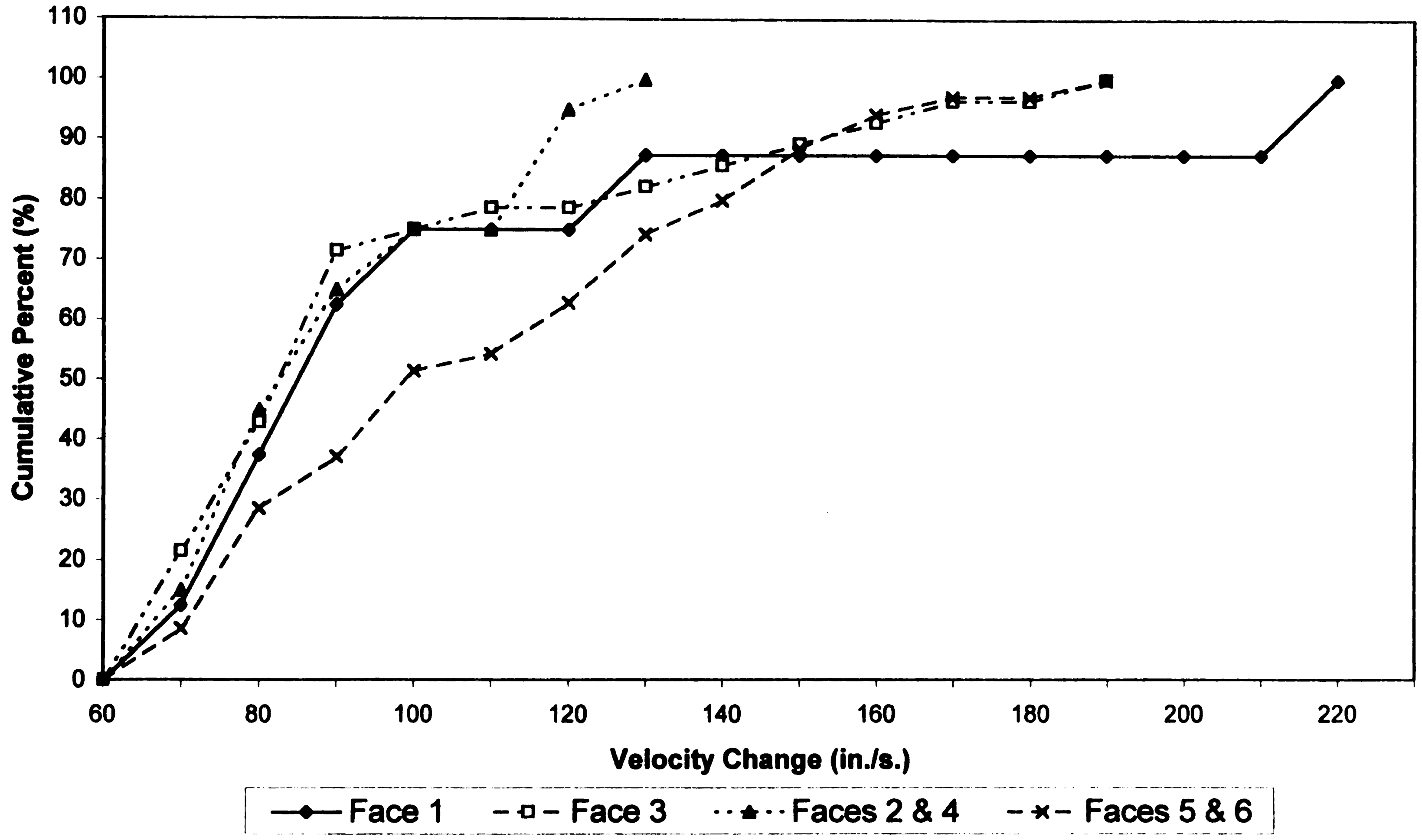

Figure 27. Cumulative Percent versus Impact Velocity Change of All Summary Events for Package D

round trip and the orientation frequency of each type of impact. It was found that for all three package types, the most common impact surface was an edge impact. Again, the statistical analysis of the possible impact surfaces yields the following predictions, 46% of the impacts will occur on an edge, 31% on a corner, and 23% on a face. Packages A and B encountered 50.81% of the 248 recorded drops impacting an edge. Of the 126 recorded impacts for package C, 61.90% of them were edge impacts as well. Package D experienced 55.00% of the 80 recorded impacts occurring on an edge. The second most common impact surface for the three package types was a face impact, with 37.10% of the total impacts for packages A and B, 36.51% of the recorded impacts for package C, and 23.75% of the recorded impacts for package D. Finally, packages A and B experienced only 12.10% of the total recorded impacts on a corner, package C received a meager 1.59% of its impacts on a corner, and package D experienced almost as many corner impacts as edge impacts with 21.25% of the total impacts occurring on a corner. For several of the data points, there was more than one face involved in the impacts. The raw data displayed in Appendix C shows those events and the total faces registered per impact. Packages A and B had 24 events with more than one face involved in the impacts. Package C had 21 impacts that registered in more than one face, and package D had 11 events that occurred on more than one face. These differences are included in Table 10 and are consequently carried over into the data displayed in Table 11. Figure 28 displays the percentage of impact surfaces graphically.

TABLE 10. Impact Orientation Frequency for All Summary Events

Package	Destination	Trip #	Impacts	Impact Orientation and Number		
				Face	Edge	Corner
A and B	Sunnyvale, CA	1	14	6	6	2
		2	17	8	8	1
		3	17	7	8	2
		4	28	11	13	4
	Subtotal		**76**	**32**	**35**	**9**
	Impact Frequency			**42.11%**	**46.05%**	**11.84%**
	Duluth, GA	1	29	11	13	5
		2	22	5	14	3
		3	18	8	8	2
		4	22	5	14	3
	Subtotal		**91**	**29**	**49**	**13**
	Impact Frequency			**31.87%**	**53.85%**	**14.29%**
	Rochester, NY	1	19	7	11	1
		2	27	10	13	4
		3	22	7	13	2
		4	13	7	5	1
	Subtotal		**81**	**31**	**42**	**8**
	Impact Frequency			**38.27%**	**51.85%**	**9.88%**
Total			**248**	**92**	**126**	**30**
Overall Impact Frequency				**37.10%**	**50.81%**	**12.10%**
C	Sunnyvale, CA	1	10	4	6	0
		2	2	1	1	0
		3	9	3	6	0
		4	10	4	6	0
	Subtotal		**31**	**12**	**19**	**0**
	Impact Frequency			**38.71%**	**61.29%**	**0.00%**
	Duluth, GA	1	12	4	8	0
		2	15	7	6	2
		3	8	3	5	0
		4	25	9	16	0
	Subtotal		**60**	**23**	**35**	**2**
	Impact Frequency			**38.33%**	**58.33%**	**3.33%**
	Rochester, NY	1	5	2	3	0
		2	16	3	13	0
		3	6	3	3	0
		4	8	3	5	0
	Subtotal		**35**	**11**	**24**	**0**
	Impact Frequency			**31.43%**	**68.57%**	**0.00%**
Total			**126**	**46**	**78**	**2**
Overall Impact Frequency				**36.51%**	**61.90%**	**1.59%**
D	Sunnyvale, CA	1	5	2	2	1
		2	8	2	3	3

TABLE 10. (cont'd)

Package	Destination	Trip #	Impacts	Impact Orientation and Number		
				Face	Edge	Corner
D (con't)	Sunnyvale, CA	3	7	1	5	1
		4	10	3	4	3
	Subtotal		**30**	**8**	**14**	**8**
	Impact Frequency			**26.67%**	**46.67%**	**26.67%**
	Duluth, GA	1	7	0	7	0
		2	12	6	5	1
		3	5	2	2	1
		4	7	1	3	3
	Subtotal		**31**	**9**	**17**	**5**
	Impact Frequency			**29.03%**	**54.84%**	**16.13%**
	Rochester, NY	1	6	0	5	1
		2	6	1	3	2
		3	4	1	2	1
		4	3	0	3	0
	Subtotal		**19**	**2**	**13**	**4**
	Impact Frequency			**10.53%**	**68.42%**	**21.05%**
Total			**80**	**19**	**44**	**17**
Overall Impact Frequency				**23.75%**	**55.00%**	**21.25%**

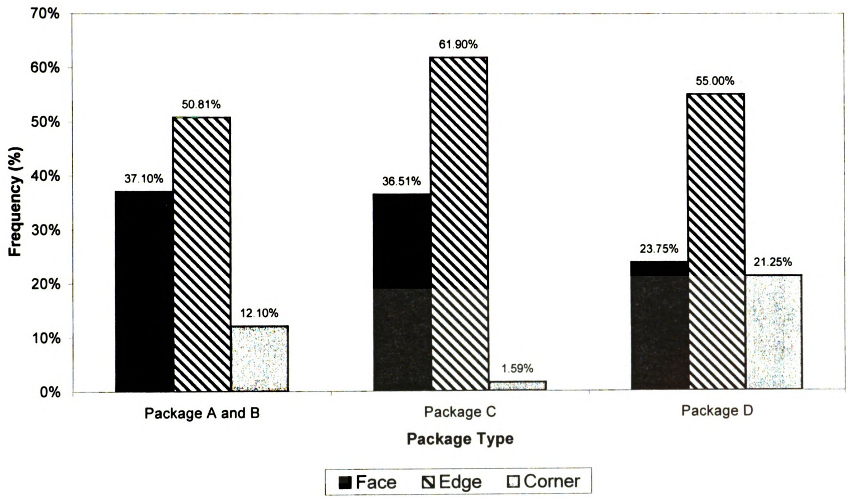

Figure 28. Distribution of Impact Orientation for All Summary Events

Table 11 continues the impact orientation analysis to include the individual faces involved in each dynamic event as summarized by velocity change. Of the impacts recorded for packages A and B, the most frequent face involved in an impact was face 3 (the bottom face) with 29.95% of the recorded impacts. Package D also had the majority of impacts involving face 3 with 24.84% of the total impacts. Package C, again experienced the majority of its impacts involving face 6 (the back face) with 26.24% of the total recorded impacts. Due to the dimensions of package C, the most conventional placement of the package was not on face 3, the largest face. It was consequently positioned on a side to better conform to the shipping standards of the UPS Ground shipping environment. For the velocity change analysis, there is also a difference between the number of impacts observed in Table 11 and those previously presented in Tables 7-10. Which can be attributed to the fact that many of the impacts involved more than one face (edge or corner drops) and were displayed in Table 11 as a summary of all faces involved. The results presented in Table 11 as well as the breakdown of the faces involved in the impacts are displayed graphically in Figure 29.

TABLE 11. Number and Frequency of Impact Occurrences per Package Face of All Summary Events

Package	Destination	Round Trip #	Number of Impacts	Number and Frequencies of occurences per surface 1	2	3	4	5	6
A and B	Sunnyvale, CA	1	24	1	4	4	3	5	7
		2	27	1	2	8	7	4	5
		3	29	0	7	7	4	3	8
		4	49	2	3	8	12	8	16
	Subtotal		**129**	**4**	**16**	**27**	**26**	**20**	**36**
	Impact Frequency			**3.10%**	**12.40%**	**20.93%**	**20.16%**	**15.50%**	**27.91%**
	Duluth, GA	1	52	2	4	17	14	9	6
		2	42	2	4	14	10	5	7
		3	30	1	3	11	7	4	4
		4	42	2	3	15	10	10	2
	Subtotal		**166**	**7**	**14**	**57**	**41**	**28**	**19**
	Impact Frequency			**4.22%**	**8.43%**	**34.34%**	**24.70%**	**16.87%**	**11.45%**
	Rochester, NY	1	32	0	6	10	6	6	4
		2	48	0	7	17	13	4	7
		3	39	0	7	14	9	5	4
		4	20	1	2	5	7	2	3
	Subtotal		**139**	**1**	**22**	**46**	**35**	**17**	**18**
	Impact Frequency			**0.72%**	**15.83%**	**33.09%**	**25.18%**	**12.23%**	**12.95%**
Total			**434**	**12**	**52**	**130**	**102**	**65**	**73**
Overall Impact Frequency				**2.76%**	**11.98%**	**29.95%**	**23.50%**	**14.98%**	**16.82%**
C	Sunnyvale, CA	1	16	1	2	1	6	2	4
		2	3	0	0	0	1	0	2
		3	15	0	4	0	5	2	4
		4	16	0	4	0	6	3	3
	Subtotal		**50**	**1**	**10**	**1**	**18**	**7**	**13**
	Impact Frequency			**2.27%**	**22.73%**	**2.27%**	**40.91%**	**15.91%**	**29.55%**
	Duluth, GA	1	20	2	5	1	3	5	4
		2	25	8	3	3	3	6	2
		3	13	0	5	0	2	2	4
		4	41	0	15	0	6	11	9
	Subtotal		**99**	**10**	**28**	**4**	**14**	**24**	**19**
	Impact Frequency			**10.10%**	**28.28%**	**4.04%**	**14.14%**	**24.24%**	**19.19%**
	Rochester, NY	1	8	0	2	0	2	1	3
		2	29	0	8	0	7	5	9
		3	9	0	0	0	4	1	4
		4	13	0	2	0	4	2	5
	Subtotal		**59**	**0**	**12**	**0**	**17**	**9**	**21**
	Impact Frequency			**0.00%**	**20.34%**	**0.00%**	**28.81%**	**15.25%**	**35.59%**
Total			**208**	**11**	**50**	**5**	**49**	**40**	**53**
Overall Impact Frequency				**5.45%**	**24.75%**	**2.48%**	**24.26%**	**19.80%**	**26.24%**

TABLE 11. (cont'd)

Package	Destination	Round Trip #	Number of Impacts	Number and Frequencies of occurences per surface					
				1	2	3	4	5	6
D	Sunnyvale, CA	1	9	1	2	2	0	3	1
		2	17	1	2	5	2	3	4
		3	14	1	0	4	3	1	5
		4	20	3	2	5	4	5	1
	Subtotal		**60**	**6**	**6**	**16**	**9**	**12**	**11**
	Impact Frequency			**10.34%**	**10.34%**	**27.59%**	**15.52%**	**20.69%**	**18.97%**
	Duluth, GA	1	14	2	2	3	1	1	5
		2	19	2	2	3	4	5	3
		3	9	3	1	2	0	2	1
		4	16	1	3	3	3	2	4
	Subtotal		**58**	**8**	**8**	**11**	**8**	**10**	**13**
	Impact Frequency			**13.79%**	**13.79%**	**18.97%**	**13.79%**	**17.24%**	**22.41%**
	Rochester, NY	1	13	1	2	3	2	1	4
		2	13	1	2	4	1	1	4
		3	8	2	2	1	0	2	1
		4	6	0	0	3	0	2	1
	Subtotal		**40**	**4**	**6**	**11**	**3**	**6**	**10**
	Impact Frequency			**10.81%**	**16.22%**	**29.73%**	**8.11%**	**16.22%**	**27.03%**
Total			**158**	**18**	**20**	**38**	**20**	**28**	**34**
Overall Impact Frequency				**11.76%**	**13.07%**	**24.84%**	**13.07%**	**18.30%**	**22.22%**

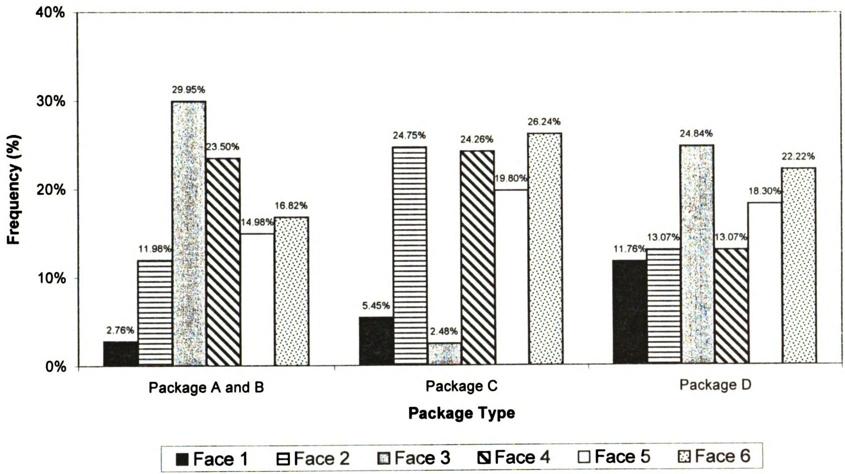

Figure 29. Distribution of Impact Occurrences per Package Face for All Summary Events

4.0 CONCLUSIONS

1. Packages A and B received a total of 370 drops for all the shipments combined with an average drop height of 11.5 inches. Package C experienced 173 drops with an average drop height of 11.5 inches. Package D received the fewest amounts of drops with 112 for all shipments and an average drop height on 10.2 inches.

2. For all shipments, packages A and B experienced most drops, 52.2%, occurring on an edge. Similarly, 56.7% of the total drops for package C occurred on an edge. Package D also experienced the most impacts on an edge with 51.8% of the total recorded drops. The data supports the assumed probability distribution that most of the drops will occur on an edge. There are 6 faces, 8 corners and 12 edges for a total of 26 possible impact surfaces. Since 12 of the 26 surfaces are edges, it is reasonable that approximately 50% of the total drops would occur on an edge.

3. It was evidenced that the large and heavy packages utilized in this study saw higher drop heights than the conventional test methods suggested in both ASTM D4169 and in the International Safe Transit Association (ISTA) Project 1A. It was also observed that these large and heavy packages shipped by the small parcel environment received more severe handling

resulting in cases of significant damage to the exterior shipping package. Examples of some of the typical shipping damage are displayed in Appendix A.

4. Based on the results of this investigation, a test protocol has been developed to test packages for the UPS Ground shipping environment for large and heavy packages. The package test sequence that has also been defined should be followed using the appropriate suggestions.

5.0 TEST PROTOCOL

Packages A and B

Drop Height Data:

Average Number of Drops per Round Trip: 15

Average Number of Drops per One Way Trip: 8

From Tables 3 and 5, the following impact orientation predictions can be made:

Predicted Number of Face Drops per One Way Trip: 0.36 x 8 = 3

Predicted Number of Edge Drops per One Way Trip: 0.52 x 8 = 4

Predicted Number of Corner Drops per One Way Trip: 0.12 x 8 = 1

Using Table 4 and Figure 19, measure at the 95% drop height level to determine the severity level of the drop height. For packages A and B, a free fall drop height of 34 inches will be used.

Velocity Change Data:

Average Number of Impacts per Round Trip: 11

Average Number of Impacts per One Way Trip: 7

From Tables 8 and 10, the following impact orientation predictions can be made:

Predicted Number of Face Impacts per One Way Trip: 0.37 x 7 = 3

Predicted Number of Edge Impacts per One Way Trip: 0.51 x 7 = 4

Predicted Number of Corner Impacts per One Way Trip: 0.12 x 7 = 1*

*Note: Due to the constraints of typical impact testing machines, corner impacts will not be evaluated.

Using Table 9 and Figure 25, measure at the 95% velocity change level to determine the severity level of the impact. For packages A and B, a velocity change of 180 in./s. for face 1, 160 in./s. for face 3, 210 in./s. for faces 2 and 4, and 170 in./s. for faces 5 and 6 will be used.

Package C

Drop Height Data:

Average Number of Drops per Round Trip: 14

Average Number of Drops per One Way Trip: 7

From Tables 3 and 5, the following impact orientation predictions can be made:

Predicted Number of Face Drops per One Way Trip: 0.42 x 7 = 3

Predicted Number of Edge Drops per One Way Trip: 0.57 x 7 = 4

Predicted Number of Corner Drops per One Way Trip: 0.01 x 7 = 1*

*Note: Even though mathematically the corner drop is not necessary, it is recommended.

Using Table 4 and Figure 19, measure at the 95% drop height level to determine the severity level of the drop height. For package C, a free fall drop height of 32 inches will be used.

Velocity Change Data:

Average Number of Impacts per Round Trip: 13

Average Number of Impacts per One Way Trip: 5

From Tables 8 and 10, the following impact orientation predictions can be made:

Predicted Number of Face Impacts per One Way Trip: 0.37 x 5 = 2

Predicted Number of Edge Impacts per One Way Trip: 0.62 x 5 = 3

Predicted Number of Corner Impacts per One Way Trip: 0.02 x 5 = 1*

*Note: Due to the constraints of typical impact testing machines, corner impacts will not be evaluated.

Using Table 9 and Figure 26, measure at the 95% velocity change level to determine the severity level of the impact. For package C, a velocity change of 160 in./s. for face 1, 100 in./s. for face 3, 160 in./s. for faces 2 and 4, and 180 in./s. for faces 5 and 6 will be used.

Package D

Drop Height Data:

Average Number of Drops per Round Trip: 9

Average Number of Drops per One Way Trip: 5

From Tables 3 and 5, the following impact orientation predictions can be made:

Predicted Number of Face Drops per One Way Trip: 0.29 x 5 = 1

Predicted Number of Edge Drops per One Way Trip: 0.52 x 5 = 3

Predicted Number of Corner Drops per One Way Trip: 0.20 x 5 = 1

Using Table 4 and Figure 19, measure at the 95% drop height level to determine the severity level of the drop height. For package D, a free fall drop height of 22 inches will be used.

Velocity Change Data:

Average Number of Impacts per Round Trip: 8

Average Number of Impacts per One Way Trip: 3

From Tables 8 and 10, the following impact orientation predictions can be made:

Predicted Number of Face Impacts per One Way Trip: 0.24 x 3 = 1

Predicted Number of Edge Impacts per One Way Trip: 0.55 x 3 = 2

Predicted Number of Corner Impacts per One Way Trip: 0.21 x 3 = 1*

*Note: Due to the constraints of typical impact testing machines, corner impacts will not be evaluated.

Using Table 9 and Figure 27, measure at the 95% velocity change level to determine the severity level of the impact. For package D, a velocity change of 220 in./s. for face 1, 170 in./s. for face 3, 120 in./s. for faces 2 and 4, and 170 in./s. for faces 5 and 6 will be used.

6.0 TEST SEQUENCE

Packages A and B

1. Perform 8 drops from a height of 34 inches. The orientation of the drop is determined from Table 6 and Figure 21.
   - 3 drops on randomly selected flat faces, preferably 2 on the bottom face and 1 on a side face, either face 2 or 4.
   - 4 drops on randomly selected edges, preferably 2 bottom edges, 2-3 or 3-4 and 3-5 or 3-6, and 2 side edges, 2-5 or 2-6 and 4-5 or 4-6.
   - 1 drop on a randomly selected corner, preferably a bottom corner, 3-4-6.

2. Perform 7 impacts with the designated impact velocity changes expressed in inches per second (in./s.). The orientation of the impacts is determined from Table 11 and Figure 29.
   - 3 impacts on randomly selected flat faces, preferably 1 on face 3 with an impact velocity change of 160 in./s., 1 on either face 2 or 4 with an impact velocity change of 210 in./s., and 1 on either face 5 or 6 with an impact velocity change of 170 in./s.
   - 4 impacts on randomly selected edges, preferably 1 on edge 2-3 or 3-4 with a velocity change of 210 in./s., 1 on edge 3-5 or 3-6 with an impact velocity change of 170 in./s., 2 on edges 2-5 or

2-6 and edges 4-5 and 4-6 with an impact velocity change of 210 in./s.

Package C

1. Perform 7 drops from a height of 32 inches. The orientation of the drop is determined from Table 6 and Figure 21.
   - 3 drops on randomly selected flat faces, preferably 1 on the bottom face and 2 on side faces, face 2 or 4 and face 5 or 6.
   - 4 drops on randomly selected edges, preferably 2 bottom edges, 2-3 or 3-4 and 3-5 or 3-6, and 2 side edges, 2-5 or 2-6 and 4-5 or 4-6.
   - 1 drop on a randomly selected corner, preferably a bottom corner, 3-4-6.

2. Perform 5 impacts with the designated impact velocity changes expressed in in./s. The orientation of the impacts is determined from Table 11 and Figure 29.
   - 2 impacts on randomly selected flat faces, preferably 1 on either face 2 or 4 with an impact velocity change of 160 in./s., and 1 on either face 5 or 6 with an impact velocity change of 180 in./s.
   - 3 impacts on randomly selected edges, preferably 1 on edge 2-3 or 3-4 with a velocity change of 160 in./s., 1 on edge 3-5 or

3-6 with an impact velocity change of 180 in./s., and 1 on edge 2-5 or 2-6 with an impact velocity change of 180 in./s.

Package D

1. Perform 5 drops from a height of 22 inches. The orientation of the drop is determined from Table 6 and Figure 21.
   - 1 drop on a randomly selected flat face, preferably the bottom face.
   - 3 drops on any 2 bottom edges, preferably 2-3 or 3-4 and 3-5 or 3-6, and 1 on a side edge, 2-5 or 2-6 and 4-5 or 4-6.
   - 1 drop on a randomly selected corner, preferably a bottom corner, 3-4-6.

2. Perform 3 impacts with the designated impact velocity changes expressed in in./s. The orientation of the impacts is determined from Table 11 and Figure 29.
   - 1 impact on randomly selected flat faces, preferably 1 on face 3 with an impact velocity change of 170 in./s.
   - 2 impacts on randomly selected edges, preferably 1 on edge 2-3 or 3-4 with a velocity change of 170 in./s. and 1 on edge 3-5 or 3-6 with an impact velocity change of 170 in./s.

APPENDICES

APPENDIX A

Samples of Damaged Packages

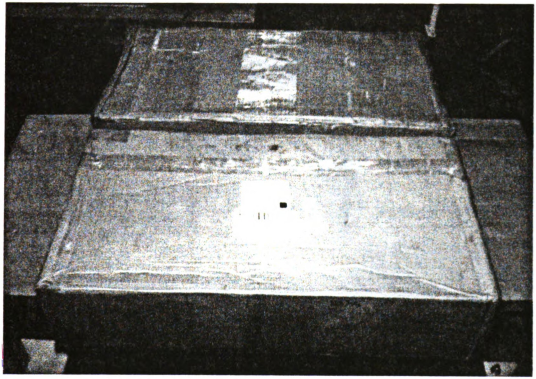

Figure A1. Shipping Damage to Edges of Packages A and B

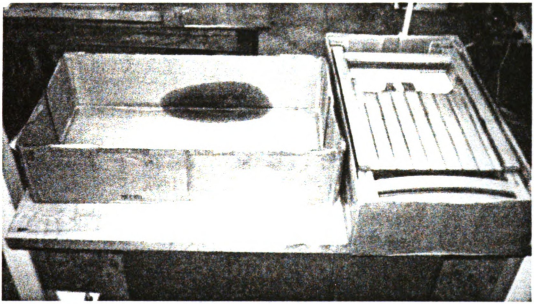

Figure A2. Oil Spill Damage to Package A

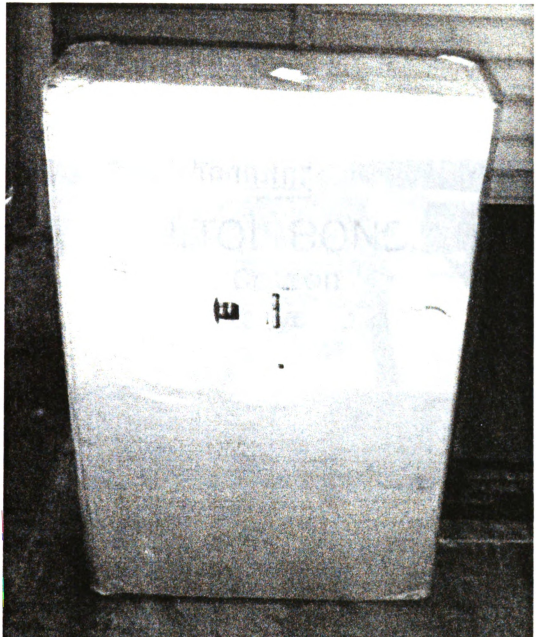

Figure A3. Damage to Face 1 of Package C

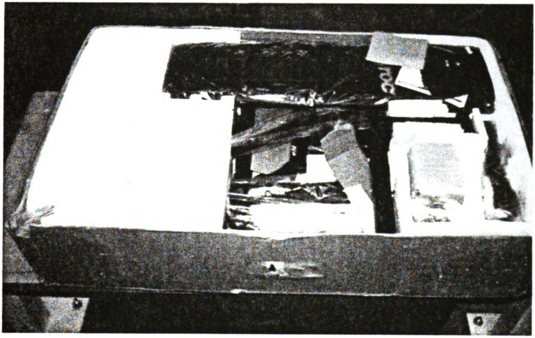

Figure A4. Interior Damage to Package C

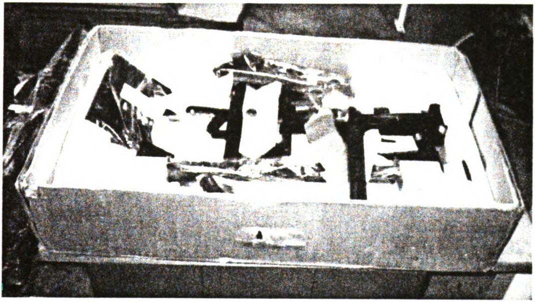

Figure A5. Interior Damage to Package C (without top cushions)

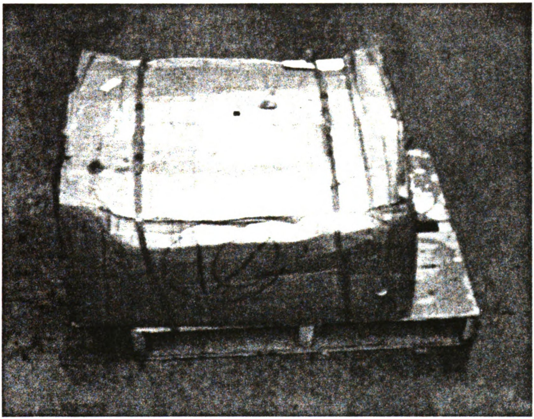

Figure A6. State of Returned Package D

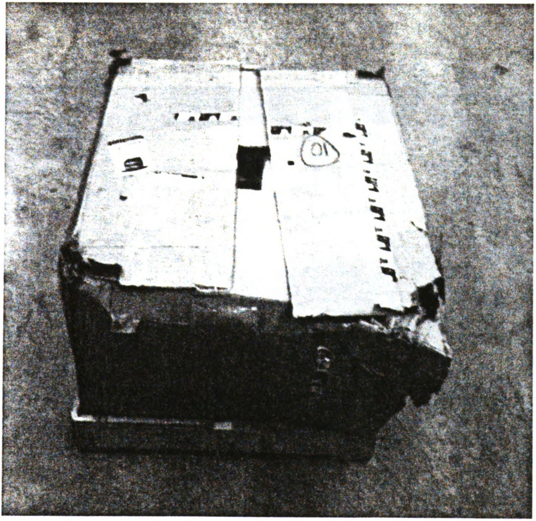

Figure A7. Shipping Damage to Package D

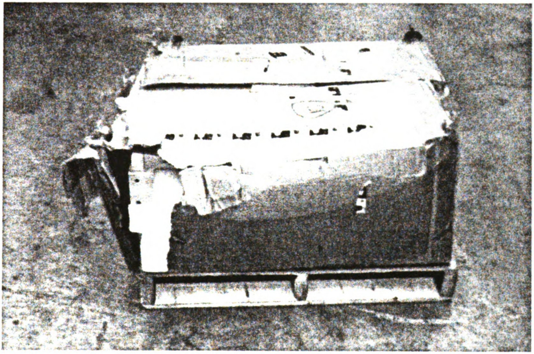

Figure A8. Shipping Damage to Package D (side view)

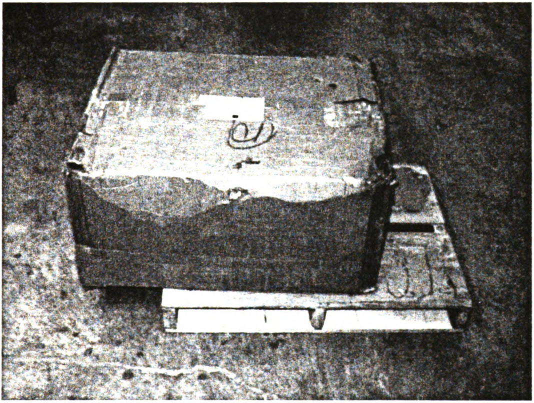

Figure A9. Package D Not Attached to the Pallet

APPENDIX B

Individual Drop Heights
for All Shipments

TABLE B1. Individual Drop Events greater than 3.00 inches for Shipments to Sunnyvale, CA

Round Trip #	Event #	Package Drop Heights (in)			
		A	B	C	D
1	1	4.32	4.35	7.57	11.69
	2	19.78	3.44	5.32	8.24
	3	3.27	3.12	10.58	15.80
	4	5.32	7.54	4.76	6.90
	5	4.92	7.35	14.61	3.57
	6	4.17	3.37	43.96	3.09
	7	14.88	7.16	9.48	13.31
	8	3.87	-	6.61	-
	9	10.26	-	25.74	-
	10	6.65	-	8.81	-
	11	6.51	-	3.76	-
	12	25.18	-	3.81	-
	13	5.49	-	-	-
	14	26.02	-	-	-
	15	3.22	-	-	-
	16	5.92	-	-	-
	17	24.90	-	-	-
	MAX	**26.02**	**7.54**	**43.96**	**15.80**
	MIN	**3.22**	**3.12**	**3.76**	**3.09**
	AVG	**10.28**	**5.19**	**12.08**	**8.94**
	STD. DEV.	**8.41**	**2.06**	**11.74**	**4.86**
2	1	8.68	3.68	3.50	26.16
	2	21.81	3.22	5.55	5.85
	3	3.19	5.13	4.76	19.60
	4	24.55	7.73	6.05	18.39
	5	3.79	3.50	13.62	3.65
	6	3.04	19.29	4.55	4.49
	7	10.85	8.60	7.27	3.39
	8	7.88	10.04	-	4.32
	9	8.24	4.20	-	3.22
	10	33.76	5.65	-	5.42
	11	5.23	7.50	-	3.84
	12	8.16	3.50	-	7.54
	13	10.94	4.85	-	20.66
	14	4.49	30.07	-	7.23
	15	32.95	-	-	-
	16	11.98	-	-	-
	MAX	**33.76**	**30.07**	**13.62**	**26.16**
	MIN	**3.04**	**3.22**	**3.50**	**3.22**
	AVG	**12.47**	**8.35**	**6.47**	**9.55**
	STD. DEV.	**10.16**	**7.53**	**3.37**	**7.93**

TABLE B1. (cont'd)

Trip #	Event #	Package Drop Heights (in)			
		A	B	C	D
3	1	3.71	11.79	10.53	16.36
	2	19.23	10.04	7.96	4.09
	3	34.81	29.84	17.50	11.08
	4	36.14	23.73	3.57	4.17
	5	11.41	32.32	17.85	3.60
	6	6.76	4.52	18.63	9.14
	7	26.81	11.55	3.63	3.07
	8	4.29	4.38	14.35	4.82
	9	3.60	5.82	35.14	17.91
	10	3.95	6.09	3.73	8.04
	11	3.55	7.27	3.27	3.44
	12	3.81	3.47	35.72	4.15
	13	7.54	3.09	4.12	3.71
	14	5.42	3.17	8.28	4.20
	15	-	7.84	3.55	-
	16	-	5.23	6.65	-
	17	-	-	3.65	-
	18	-	-	5.95	-
	MAX	**36.14**	**32.32**	**35.72**	**17.91**
	MIN	**3.55**	**3.09**	**3.27**	**3.07**
	AVG	**12.22**	**10.63**	**11.34**	**6.98**
	STD. DEV.	**11.98**	**9.47**	**10.26**	**4.94**
4	1	4.12	9.56	28.79	8.32
	2	13.11	6.19	14.35	5.98
	3	5.45	3.52	6.33	33.27
	4	13.21	37.83	8.52	21.23
	5	4.06	12.61	4.67	7.81
	6	27.97	6.36	3.17	13.26
	7	9.31	25.88	4.55	4.58
	8	5.92	14.77	51.94	18.99
	9	10.49	5.13	4.88	11.74
	10	8.89	3.14	20.72	7.73
	11	23.87	19.29	3.63	5.32
	12	5.26	3.32	51.44	7.31
	13	23.20	7.73	5.85	13.21
	14	-	3.12	4.46	10.71
	15	-	3.63	-	-
	16	-	4.03	-	-
	17	-	3.34	-	-
	18	-	3.14	-	-
	19	-	3.60	-	-
	20	-	6.36	-	-
	21	-	6.12	-	-
	22	-	7.20	-	-
	23	-	6.16	-	-

TABLE B1. (cont'd)

Trip #	Event #	Package Drop Heights (in)			
		A	B	C	D
4 (con't)	24	-	5.49	-	-
	25	-	10.71	-	-
	26	-	4.79	-	-
	MAX	**27.97**	**37.83**	**51.94**	**33.27**
	MIN	**4.06**	**3.12**	**3.17**	**4.58**
	AVG	**11.91**	**8.58**	**15.24**	**12.10**
	STD. DEV.	**8.13**	**8.09**	**17.13**	**7.84**
OVERALL	**MAX**	**36.14**	**37.83**	**51.94**	**33.27**
	MIN	**3.04**	**3.09**	**3.17**	**3.07**
	AVG	**11.67**	**8.67**	**11.92**	**9.46**
	STD. DEV.	**9.56**	**7.92**	**12.29**	**6.86**

TABLE B2. Individual Drop Events greater than 3.00 inches for Shipments to Duluth, GA

Trip #	Event #	Package Drop Heights (in)			
		A	B	C	D
1	1	7.69	3.09	24.28	6.61
	2	3.37	7.42	10.04	3.95
	3	9.87	10.22	3.55	8.24
	4	20.85	3.98	3.98	10.22
	5	7.23	42.86	10.71	8.48
	6	5.10	11.50	4.70	11.69
	7	4.32	3.24	24.21	5.32
	8	10.26	10.90	3.42	14.40
	9	4.76	5.45	17.39	-
	10	4.98	4.29	16.42	-
	11	14.50	17.33	13.77	-
	12	12.22	6.76	6.94	-
	13	7.31	7.31	17.33	-
	14	29.69	9.44	7.96	-
	15	32.00	6.22	7.46	-
	16	22.73	12.76	-	-
	17	3.98	4.88	-	-
	18	-	11.93	-	-
	19	-	8.48	-	-
	20	-	39.12	-	-
	21	-	7.05	-	-
	22	-	9.14	-	-
	23	-	5.68	-	-
	24	-	10.13	-	-
	MAX	**32.00**	**42.86**	**24.28**	**14.40**
	MIN	**3.37**	**3.09**	**3.42**	**3.95**
	AVG	**11.82**	**10.80**	**11.48**	**8.61**
	STD. DEV.	**9.12**	**9.91**	**7.10**	**3.43**
2	1	23.60	15.53	7.81	5.98
	2	9.65	4.52	9.78	5.42
	3	7.65	10.26	33.03	25.53
	4	4.32	3.52	13.11	20.09
	5	6.36	6.90	3.47	17.62
	6	3.12	5.85	3.02	23.87
	7	3.98	3.32	6.51	3.07
	8	4.92	6.36	3.14	9.01
	9	9.69	10.49	3.07	21.81
	10	9.65	36.06	3.14	11.08
	11	10.62	26.02	3.34	10.13
	12	13.98	5.07	4.98	4.23
	13	-	3.44	14.29	3.63
	14	-	6.22	4.55	11.60
	15	-	3.63	9.18	9.39
	16	-	8.48	8.08	11.08

TABLE B2. (cont'd)

Trip #	Event #	Package Drop Heights (in)			
		A	B	C	D
2 (con't)	17	-	17.56	13.26	-
	18	-	3.12	25.81	-
	19	-	3.81	8.16	-
	20	-	11.36	-	-
	21	-	42.50	-	-
	22	-	3.47	-	-
	MAX	**23.60**	**42.50**	**33.03**	**25.53**
	MIN	**3.12**	**3.12**	**3.02**	**3.07**
	AVG	**8.96**	**10.80**	**9.35**	**12.10**
	STD. DEV.	**5.63**	**10.86**	**8.06**	**7.43**
3	1	4.49	3.87	12.12	30.68
	2	14.77	3.22	12.76	8.64
	3	4.17	10.99	8.36	3.37
	4	100.15	7.16	3.52	38.43
	5	3.32	3.79	9.52	11.74
	6	3.37	3.14	23.00	-
	7	9.61	9.52	3.37	-
	8	4.70	8.64	15.09	-
	9	7.88	4.43	7.31	-
	10	11.17	13.01	4.23	-
	11	-	15.64	-	-
	MAX	**100.15**	**15.64**	**23.00**	**38.43**
	MIN	**3.32**	**3.14**	**3.37**	**3.37**
	AVG	**16.36**	**7.58**	**9.93**	**18.57**
	STD. DEV.	**29.69**	**4.33**	**6.11**	**15.14**
4	1	5.20	4.15	7.57	15.04
	2	6.19	11.46	3.73	7.88
	3	6.29	7.35	17.97	3.24
	4	3.14	14.66	48.59	6.40
	5	5.82	56.02	3.68	4.41
	6	4.35	7.23	31.07	4.73
	7	4.88	4.95	7.31	10.04
	8	6.09	8.89	30.30	13.41
	9	9.87	3.55	7.38	3.44
	10	3.37	9.74	20.79	10.62
	11	5.29	3.39	10.71	7.69
	12	62.99	15.36	9.27	-
	13	3.81	21.88	3.42	-
	14	5.75	3.07	8.32	-
	15	3.71	3.55	11.79	-
	16	6.36	9.18	5.36	-
	17	6.40	21.81	4.35	-
	18	5.13	13.82	12.61	-
	19	26.88	-	17.97	-

TABLE B2. (cont'd)

Trip #	Event #	Package Drop Heights (in)			
		A	B	C	D
4 (con't)	20	6.33	-	8.89	-
	21	4.03	-	17.80	-
	22	16.87	-	6.40	-
	23	5.72	-	3.90	-
	24	4.03	-	3.79	-
	25	13.93	-	9.01	-
	26	23.00	-	6.58	-
	27	7.96	-	4.23	-
	28	-	-	12.46	-
	29	-	-	16.93	-
	30	-	-	14.40	-
	31	-	-	15.09	-
	32	-	-	15.04	-
	MAX	**62.99**	**56.02**	**48.59**	**15.04**
	MIN	**3.14**	**3.07**	**3.42**	**3.24**
	AVG	**9.76**	**12.23**	**12.40**	**7.90**
	STD. DEV.	**12.14**	**12.43**	**9.73**	**3.99**
OVERALL	**MAX**	**100.15**	**56.02**	**48.59**	**38.43**
	MIN	**3.12**	**3.07**	**3.02**	**3.07**
	AVG	**11.14**	**10.67**	**11.13**	**11.06**
	STD. DEV.	**14.49**	**10.20**	**8.39**	**7.92**

TABLE B3. Individual Drop Events greater than 3.00 inches for Shipments to Rochester, NY

Trip #	Event #	Package Drop Heights (in)			
		A	B	C	D
1	1	6.72	13.41	13.62	7.09
	2	3.50	5.72	5.36	9.91
	3	3.22	3.50	7.57	11.22
	4	4.03	6.40	7.31	9.65
	5	6.02	29.84	24.21	17.04
	6	7.01	6.19	7.09	14.56
	7	7.61	32.24	42.95	14.24
	8	12.81	7.09	3.37	-
	9	34.32	13.06	3.98	-
	10	15.69	5.52	-	-
	11	3.98	6.19	-	-
	12	-	23.46	-	-
	13	-	7.54	-	-
	14	-	10.85	-	-
	15	-	3.65	-	-
	16	-	9.87	-	-
	17	-	5.10	-	-
	MAX	**34.32**	**32.24**	**42.95**	**17.04**
	MIN	**3.22**	**3.50**	**3.37**	**7.09**
	AVG	**9.54**	**11.15**	**12.83**	**11.96**
	STD. DEV.	**9.11**	**8.91**	**13.00**	**3.45**
2	1	9.96	23.60	8.93	3.68
	2	13.01	3.55	10.58	6.97
	3	56.23	24.90	21.81	10.00
	4	20.28	12.27	16.36	12.96
	5	83.90	11.46	3.79	6.54
	6	7.46	9.39	5.29	4.41
	7	15.58	24.97	3.65	21.94
	8	8.24	15.47	9.74	11.83
	9	4.35	4.85	12.66	-
	10	5.52	20.66	7.73	-
	11	14.61	6.05	22.93	-
	12	38.95	5.98	8.08	-
	13	4.55	36.64	8.89	-
	14	3.95	3.84	18.27	-
	15	15.64	20.47	12.07	-
	16	6.22	30.14	35.06	-
	17	8.97	-	9.39	-
	18	-	-	6.97	-
	MAX	**83.90**	**36.64**	**35.06**	**21.94**
	MIN	**3.95**	**3.55**	**3.65**	**3.68**
	AVG	**18.67**	**15.89**	**12.34**	**9.79**
	STD. DEV.	**21.65**	**10.30**	**7.96**	**5.94**

TABLE B3. (cont'd)

Trip #	Event #	Package Drop Heights (in)			
		A	B	C	D
3	1	67.37	7.05	21.94	8.72
	2	6.47	16.53	31.69	11.46
	3	19.97	5.52	8.64	11.31
	4	19.60	9.06	7.38	14.45
	5	38.69	6.29	6.90	-
	6	5.16	12.17	7.50	-
	7	5.95	24.35	5.88	-
	8	10.04	3.73	3.27	-
	9	12.03	36.56	11.46	-
	10	15.53	3.50	-	-
	11	-	10.67	-	-
	12	-	5.75	-	-
	13	-	5.23	-	-
	14	-	15.36	-	-
	15	-	15.86	-	-
	16	-	3.17	-	-
	MAX	**.67.37**	**36.56**	**31.69**	**14.45**
	MIN	**5.16**	**3.17**	**3.27**	**8.72**
	AVG	**20.08**	**11.30**	**11.63**	**11.49**
	STD. DEV.	**19.37**	**8.97**	**9.21**	**2.34**
4	1	3.07	25.25	15.36	9.10
	2	19.66	10.22	7.88	10.94
	3	5.13	3.79	3.71	4.26
	4	6.26	6.61	5.78	3.71
	5	12.32	5.58	8.04	-
	6	9.35	37.23	26.38	-
	7	17.45	21.49	4.32	-
	8	12.32	-	9.01	-
	9	5.16	-	8.28	-
	10	3.29	-	3.44	-
	11	19.23	-	-	-
	12	6.65	-	-	-
	MAX	**19.66**	**37.23**	**26.38**	**10.94**
	MIN	**3.07**	**3.79**	**3.44**	**3.71**
	AVG	**9.99**	**15.74**	**9.22**	**7.00**
	STD. DEV	**6.11**	**12.55**	**6.96**	**3.57**
OVERALL	**MAX**	**83.90**	**37.23**	**42.95**	**21.94**
	MIN	**3.07**	**3.17**	**3.27**	**3.68**
	AVG	**14.86**	**13.12**	**11.62**	**10.26**
	STD. DEV.	**16.43**	**9.82**	**8.97**	**4.49**

APPENDIX C

Individual Velocity Changes
for All Summary Events

TABLE C1. Individual Velocity Changes for All Summary Events for Shipments to Sunnyvale, CA

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
A	1	1	-	-	-	-	-	80.96	Corner - 3,4,6
		2	-	142.39	-	98.96	-	-	Corner - 1,2,6
		3	-	-	-	104.13	-	-	Flat - 6
		4	-	-	93.25	-	-	-	Edge - 4,5
		5	-	111.37	-	-	-	-	Flat - 2
		6	-	-	-	-	-	72.76	Edge - 3,5
		7	-	-	77.99	-	-	-	Edge - 2,5
		8	-	-	-	-	-	97.92	Edge - 3,6
		9	-	-	268.72	-	-	-	Flat - 5
		10	-	-	-	114.56	-	-	Edge - 4,6
	2	1	-	-	-	-	-	135.90	Edge - 3,4
		2	79.50	-	-	165.67	-	-	Edge - 4,6
		3	134.66	-	-	-	-	-	Flat - 4
		4	-	-	-	-	93.19	-	Flat - 1
		5	-	-	-	-	-	135.20	Flat - 3
		6	-	-	-	145.49	-	-	Edge - 4,6
		7	-	-	80.48	-	-	-	Edge - 3,5
		8	-	-	110.35	-	-	-	Flat - 5
		9	-	211.47	-	-	-	-	Edge - 2,6
		10	-	-	-	-	-	167.67	Flat - 3
	3	1	-	82.40	-	-	-	-	Edge - 2,6
		2	-	-	133.49	-	-	-	Edge - 4,5
		3	-	126.85	-	-	-	-	Corner - 2,3,5
		4	-	-	-	169.22	-	-	Edge - 4,6
		5	-	172.57	-	-	-	-	Flat - 2
		6	-	-	-	-	-	103.79	Flat - 3
		7	-	198.56	-	-	-	-	Flat - 2
	4	1	-	-	-	-	-	75.33	Corner - 3,4,6
		2	105.09	-	-	-	-	-	Edge - 4,5
		3	-	-	119.58	-	-	-	Flat - 5
		4	127.24	-	-	-	-	-	Edge - 4,5
		5	-	-	-	-	-	81.91	Edge - 3,6
		6	-	-	-	-	-	80.94	Edge - 3,4
		7	-	-	-	-	-	124.07	Edge - 3,5
		8	-	-	-	155.91	-	-	Flat - 6
		9	-	-	113.60	-	-	-	Edge - 2,5
		10	-	-	91.57	-	-	-	Edge - 4,5
		MAX	**134.66**	**211.47**	**268.72**	**169.22**	**93.19**	**167.67**	
		MIN	**79.50**	**82.40**	**77.99**	**98.96**	**93.19**	**72.76**	
		AVG	**111.62**	**149.37**	**121.00**	**136.28**	**93.19**	**105.13**	
		S.D.	**24.83**	**47.08**	**58.39**	**29.77**	**-**	**31.34**	

TABLE C1. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
B	1	1	-	-	-	102.31	-	-	Flat - 6
		2	-	81.69	-	-	-	-	Edge - 2,6
		3	-	-	81.92	-	-	-	Flat - 5
		4	-	-	-	-	-	104.96	Flat - 3
	2	1	-	-	-	-	-	93.06	Edge - 3,5
		2	80.48	-	-	-	-	-	Corner - 3,4,6
		3	160.75	-	-	-	-	-	Edge - 4,5
		4	-	-	-	-	-	80.22	Edge - 3,6
		5	-	-	-	-	-	78.49	Flat - 3
		6	-	76.89	-	-	-	-	Flat - 2
		7	222.72	-	-	-	-	-	Flat - 4
	3	1	-	-	-	101.59	-	-	Flat - 6
		2	-	162.19	-	-	-	-	Flat - 2
		3	-	188.51	-	93.14	-	-	Edge - 2,6
		4	-	-	-	-	-	109.78	Flat - 3
		5	200.07	-	137.45	-	-	-	Edge - 4,5
		6	-	-	-	-	-	91.55	Corner - 2,3,6
		7	-	-	-	-	-	78.66	Edge - 3,4
		8	-	-	-	-	-	75.23	Edge - 3,6
		9	-	-	-	-	-	94.45	Edge - 3,6
		10	-	-	-	77.26	-	-	Flat - 6
	4	1	94.34	-	-	-	-	-	Edge - 4,5
		2	-	-	-	-	196.47	-	Corner - 1,2,6
		3	-	-	-	-	-	77.42	Flat - 3
		4	-	-	-	-	-	82.17	Edge - 3,4
		5	-	73.15	-	-	-	-	Flat - 2
		6	-	-	-	80.02	-	-	Corner - 3,4,6
		7	-	-	105.75	-	-	-	Flat - 5
		8	-	-	-	107.89	-	-	Flat - 6
		9	-	-	-	84.77	-	-	Edge - 4,6
		10	-	-	-	73.45	-	-	Edge - 4,6
		11	-	-	-	90.36	-	-	Flat - 6
		12	-	-	-	88.60	-	-	Corner - 3,4,6
		13	-	-	-	73.69	-	-	Flat - 6
		14	-	-	-	78.00	-	-	Edge - 4,6
		15	-	-	-	107.67	-	-	Edge - 1,6
		16	-	-	-	102.18	-	-	Flat - 6
		17	-	-	-	121.31	-	-	Flat - 6
		18	-	-	-	94.71	-	-	Flat - 6
		MAX	**222.72**	**188.51**	**137.45**	**121.31**	**196.47**	**109.78**	
		MIN	**80.48**	**73.15**	**81.92**	**73.45**	**196.47**	**75.23**	
		AVG	**151.67**	**116.49**	**108.37**	**92.31**	**196.47**	**87.82**	

TABLE C1. (cont'd)

Package	Trip #	Event #	+Δv_x (in./s.) Face 4	-Δv_x (in./s.) Face 2	+Δv_y (in./s.) Face 5	-Δv_y (in./s.) Face 6	+Δv_z (in./s.) Face 1	-Δv_z (in./s.) Face 3	Impact Orientation
B (con't)	4	**S.D.**	**62.90**	**54.62**	**27.86**	**14.07**	-	**11.78**	
C	1	1	-	74.59	-	-	-	-	Edge - 2,5
		2	-	-	-	83.80	-	-	Edge - 4,6
		3	-	-	-	92.85	-	-	Edge - 1,6
		4	76.23	-	-	-	-	-	Flat - 4
		5	167.62	-	-	-	-	-	Edge - 4,6.
		6	200.01	-	-	-	-	-	Flat - 4
		7	-	75.62	-	114.19	-	-	Edge - 2,6
		8	-	-	-	-	-	105.10	Flat - 3
		9	81.50	-	116.24	-	-	-	Edge - 4,5
		10	89.96	-	-	-	-	-	Flat - 4
	2	1	81.52	-	-	-	-	-	Edge - 4,6
		2	-	-	-	84.00	-	-	Flat - 6
	3	1	-	-	-	81.87	-	-	Edge - 2,6
		2	-	-	99.72	-	-	-	Edge - 4,5
		3	132.22	-	-	-	-	-	Edge - 4,6
		4	130.94	-	83.52	-	-	-	Edge - 4,5
		5	119.83	-	-	135.38	-	-	Edge - 4,6
		6	-	94.71	-	-	-	-	Flat - 2
		7	118.48	-	-	81.67	-	-	Edge - 4,6
		8	-	149.97	-	120.97	-	-	Flat - 2
		9	-	73.05	-	-	-	-	Flat - 2
	4	1	81.14	-	116.23	-	-	-	Edge - 4,5
		2	-	-	88.63	-	-	-	Edge - 4,5
		3	134.59	-	-	-	-	-	Flat - 4
		4	-	-	-	81.01	-	-	Edge - 4,6
		5	72.84	-	-	-	-	-	Edge - 4,6
		6	-	78.34	-	-	-	-	Flat - 2
		7	124.17	-	-	105.77	-	-	Edge - 4,6
		8	-	-	115.98	-	-	-	Edge - 2,5
		9	-	131.89	-	-	-	-	Flat - 2
		10	-	164.64	-	-	-	-	Flat - 2
		MAX	**200.01**	**164.64**	**116.24**	**135.38**	-	**105.10**	
		MIN	**72.84**	**73.05**	**83.52**	**81.01**	-	**105.10**	
		AVG	**115.08**	**105.35**	**103.39**	**98.15**	-	**105.10**	
		S.D.	**37.57**	**37.66**	**14.93**	**19.68**	-	-	
D	1	1	-	-	-	-	-	95.23	Flat - 3
		2	-	-	152.74	-	-	-	Flat - 5
		3	-	-	103.10	-	-	-	Corner - 1,2,5
		4	-	-	-	-	-	73.24	Edge - 3,6

TABLE C1. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
D (con't)	1	5	-	91.81	86.24	-	-	-	Edge - 2,5
	2	1	-	-	-	95.74	-	79.29	Corner - 2,3,6
		2	-	-	-	-	-	78.18	Edge - 3,5
		3	87.76	-	-	162.53	-	-	Corner - 3,4,6
		4	124.69	-	-	-	-	-	Edge - 1,4
		5	-	-	-	85.46	-	-	Flat - 6
		6	-	-	-	75.19	-	-	Flat - 6
		7	-	-	75.50	-	-	-	Corner - 2,3,5
		8	-	-	145.56	-	-	-	Edge - 3,5
	3	1	-	-	-	151.19	-	-	Edge - 4,6
		2	82.80	-	-	131.20	-	-	Edge - 4,6
		3	-	-	-	-	-	89.48	Edge - 3,6
		4	80.93	-	-	81.18	-	-	Corner - 3,4,6
		5	-	-	-	-	131.46	-	Edge - 1,6
		6	-	-	-	-	-	114.45	Edge - 3,5
		7	-	-	-	-	-	80.87	Flat - 3
	4	1	-	-	-	-	-	93.08	Flat - 3
		2	-	-	-	-	-	191.97	Edge - 3,4
		3	-	-	-	-	96.44	-	Flat - 1
		4	-	-	121.74	-	-	-	Corner - 1,2,5
		5	-	-	-	-	105.29	-	Corner - 1,4,5
		6	-	93.39	-	-	-	152.16	Edge - 2,3
		7	-	-	133.97	-	-	-	Flat - 5
		8	-	-	-	-	-	88.71	Edge - 3,5
		9	78.02	-	-	-	-	169.48	Corner - 3,4,5
		10	-	-	-	117.17	-	-	Edge - 4,6
		MAX	**124.69**	**93.39**	**152.74**	**162.53**	**131.46**	**191.97**	
		MIN	**78.02**	**91.81**	**75.50**	**75.19**	**96.44**	**73.24**	
		AVG	**90.84**	**92.60**	**116.98**	**112.46**	**111.06**	**108.85**	
		S.D.	**19.25**	**1.12**	**29.62**	**33.29**	**18.21**	**39.97**	
OVERALL		**MAX**	**222.72**	**211.47**	**268.72**	**169.22**	**196.47**	**191.97**	
		MIN	**72.84**	**73.05**	**75.50**	**73.45**	**93.19**	**72.76**	
		AVG	**116.79**	**120.73**	**114.13**	**105.17**	**124.57**	**100.96**	
		S.D.	**41.77**	**46.02**	**38.99**	**27.33**	**42.91**	**30.50**	

TABLE C2. Individual Velocity Changes for All Summary Events for Shipments to Duluth, GA

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
A	1	1	-	84.34	-	-	-	-	Edge - 2,5
		2	-	-	-	-	-	76.37	Corner - 3,4,6
		3	-	-	-	-	-	156.33	Edge - 3,4
		4	-	-	-	-	-	95.82	Edge - 3,6
		5	-	-	-	-	-	96.79	Flat - 3
		6	-	-	-	80.89	-	-	Corner - 3,4,6
		7	-	-	73.82	-	-	105.77	Corner - 3,4,5
		8	-	-	-	-	-	77.14	Corner - 3,4,6
		9	-	-	-	-	-	83.91	Edge - 3,4
		10	-	-	-	-	-	133.40	Flat - 3
		11	163.06	-	-	-	-	-	Edge - 4,5
		12	191.39	-	-	-	-	-	Flat - 4
	2	1	99.28	-	-	-	-	-	Corner - 3,4,5
		2	-	120.90	-	-	-	-	Edge - 2,6
		3	74.39	-	-	-	-	-	Flat - 4
		4	-	98.24	-	-	-	-	Edge - 2,5
		5	-	-	-	-	-	75.68	Flat - 3
		6	-	-	-	-	-	76.89	Edge - 3,6
		7	-	-	-	-	-	73.93	Edge - 3,4
		8	-	114.51	-	-	-	-	Corner - 2,3,6
		9	-	-	-	-	-	74.95	Edge - 3,6
		10	-	-	-	-	-	113.83	Flat - 3
	3	1	124.94	-	-	-	-	94.19	Edge - 3,4
		2	-	74.28	-	-	-	-	Edge - 2,3
		3	-	107.57	-	-	-	85.08	Edge - 2,5
		4	-	-	-	141.19	-	-	Edge - 3,6
		5	192.06	-	171.14	-	-	129.82	Edge - 4,5
		6	-	171.29	-	-	-	-	Flat - 2
		7	-	-	-	-	-	144.91	Flat - 3
		8	-	-	-	-	-	90.67	Edge - 3,5
		9	-	-	-	93.47	-	79.74	Corner - 3,4,6
		10	127.88	-	-	-	-	-	Flat - 4
		11	-	-	-	220.39	-	88.23	Flat - 3
	4	1	-	-	-	-	-	110.33	Flat - 3
		2	-	-	-	-	-	152.84	Edge - 3,4
		3	-	-	-	-	-	75.19	Edge - 3,4
		4	104.31	-	151.29	-	-	-	Edge - 4,5
		5	-	-	-	-	-	118.11	Edge - 3,4
		6	-	-	78.48	-	-	-	Flat - 5
		7	-	-	-	-	-	90.27	Flat - 3
		8	-	-	-	-	-	82.94	Edge - 3,4

TABLE C2. (cont'd)

Package	Trip #	Event #	+Δv_x (in./s.) Face 4	-Δv_x (in./s.) Face 2	+Δv_y (in./s.) Face 5	-Δv_y (in./s.) Face 6	+Δv_z (in./s.) Face 1	-Δv_z (in./s.) Face 3	Impact Orientation
A (con't)	4	9	-	-	-	122.14	-	-	Edge - 1,6
		10	-	96.44	211.50	-	-	-	Edge - 2,5
		MAX	**192.06**	**171.29**	**211.50**	**220.39**	**-**	**156.33**	
		MIN	**74.39**	**74.28**	**73.82**	**80.89**	**-**	**73.93**	
		AVG	**134.66**	**108.45**	**137.25**	**131.62**	**-**	**99.35**	
		S.D.	**43.53**	**29.61**	**59.87**	**54.98**	**-**	**25.56**	
B	1	1	-	-	-	-	-	120.25	Edge - 3,5
		2	-	-	-	-	-	89.44	Edge - 3,5
		3	186.04	-	78.66	-	-	-	Edge - 4,5
		4	-	-	-	-	-	85.54	Edge - 3,4
		5	-	-	95.15	-	-	-	Flat - 5
		6	-	-	97.21	-	-	-	Flat - 5
		7	-	94.01	-	-	-	-	Flat - 2
		8	-	86.22	-	-	-	-	Edge - 2,6
		9	-	-	-	-	74.05	-	Flat - 1
		10	-	126.78	-	-	-	-	Flat - 2
		11	-	-	-	-	-	129.42	Flat - 3
		12	-	-	-	-	-	109.91	Edge - 3,4
		13	74.21	-	-	-	-	-	Edge - 3,4
		14	148.55	-	-	-	-	-	Edge - 4,6
		15	-	-	-	-	-	214.87	Flat - 3
		16	-	-	-	-	-	110.38	Flat - 3
		17	-	-	116.97	-	-	-	Corner - 1,4,5
	2	1	-	-	-	87.94	-	-	Corner - 1,4,6
		2	-	73.87	-	-	-	-	Edge - 2,6
		3	-	-	-	-	75.15	-	Edge - 1,5
		4	-	-	-	-	-	102.99	Flat - 3
		5	-	-	-	-	-	78.10	Edge - 3,6
		6	-	-	-	-	-	199.58	Edge - 3,4
		7	193.49	-	97.14	-	-	-	Edge - 4,5
		8	-	-	-	-	-	72.36	Edge - 3,5
		9	-	-	-	-	-	88.45	Edge - 3,4
		10	-	-	-	-	-	107.04	Edge - 3,4
		11	-	-	-	-	-	109.93	Edge - 3,4
		12	195.61	-	-	-	-	-	Flat - 4
	3	1	-	-	-	-	-	76.10	Corner - 3,4,5
		2	-	-	-	-	-	145.59	Flat - 3
		3	97.49	-	-	-	-	-	Edge - 4,6
		4	-	-	-	-	-	76.81	Flat - 3
		5	-	-	-	-	99.68	-	Flat - 1
		6	-	-	-	179.79	-	-	Flat - 6
		7	123.35	-	-	-	-	73.15	Edge - 3,4

TABLE C2. (cont'd)

Package	Trip #	Event #	+Δv_x (in./s.) Face 4	-Δv_x (in./s.) Face 2	+Δv_y (in./s.) Face 5	-Δv_y (in./s.) Face 6	+Δv_z (in./s.) Face 1	-Δv_z (in./s.) Face 3	Impact Orientation
B	4	1	-	-	-	-	-	103.71	Corner - 3,4,5
		2	-	-	72.30	-	-	-	Edge - 2,5
		3	-	-	-	-	-	203.16	Edge - 3,4
		4	-	-	-	-	-	114.95	Edge - 3,5
		5	-	-	-	-	-	84.00	Edge - 3,4
		6	-	-	78.49	-	-	106.45	Edge - 3,5
		7	-	-	-	-	-	76.43	Flat - 3
		8	-	182.16	-	-	-	-	Edge - 2,5
		9	109.45	-	-	-	-	-	Flat - 4
		10	-	-	-	-	-	115.72	Edge - 3,6
		11	109.28	-	-	-	-	-	Corner - 3,4,5
		12	91.36	-	123.72	-	-	-	Corner - 1,4,5
		MAX	**195.61**	**182.16**	**123.72**	**179.79**	**99.68**	**214.87**	
		MIN	**74.21**	**73.87**	**72.30**	**87.94**	**74.05**	**72.36**	
		AVG	**132.88**	**112.61**	**94.96**	**133.87**	**82.96**	**111.77**	
		S.D.	**45.09**	**43.53**	**18.41**	**64.95**	**14.49**	**40.24**	
C	1	1	-	-	-	126.67	-	-	Edge - 2,6
		2	-	-	-	98.09	-	-	Edge - 4,6
		3	-	94.01	-	-	-	-	Flat - 2
		4	-	105.83	-	-	-	-	Edge - 1,2
		5	-	76.49	-	-	-	-	Edge - 2,3
		6	-	-	128.17	-	-	-	Edge - 2,5
		7	-	-	-	167.09	-	-	Flat - 6
		8	-	-	193.71	-	-	-	Edge - 1,5
		9	-	-	123.41	-	-	-	Flat - 5
		10	-	74.44	-	-	-	-	Flat - 5
		11	140.87	-	-	-	-	-	Edge - 4,6
		12	78.46	-	-	-	-	-	Edge - 4,5
	2	1	-	-	-	-	-	101.37	Edge - 3,6
		2	82.22	-	81.78	-	-	-	Corner - 1,4,5
		3	79.51	-	182.25	-	-	-	Edge - 4,5
		4	-	-	-	-	100.87	-	Flat - 1
		5	-	-	-	-	75.30	-	Flat - 1
		6	-	-	-	-	77.80	-	Edge - 1,5
		7	-	-	-	-	77.51	-	Flat - 1
		8	-	-	-	-	86.46	-	Flat - 1
		9	-	-	132.05	-	-	-	Edge - 1,5
		10	-	-	-	-	-	72.43	Corner - 2,3,6
		11	-	-	-	-	163.61	-	Flat - 1
		12	-	-	-	-	-	84.93	Flat - 3
		13	104.53	-	-	-	-	-	Edge - 4,5
		14	-	87.97	155.19	-	-	-	Edge - 2,5
		15	-	83.04	-	-	-	-	Flat - 2

TABLE C2. (cont'd)

Package	Trip #	Event #	+Δv_x (in./s.) Face 4	-Δv_x (in./s.) Face 2	+Δv_y (in./s.) Face 5	-Δv_y (in./s.) Face 6	+Δv_z (in./s.) Face 1	-Δv_z (in./s.) Face 3	Impact Orientation
C (con't)	3	1	-	-	-	79.25	-	-	Edge - 2,6
		2	-	-	-	134.90	-	-	Edge - 4,6
		3	-	89.55	-	-	-	-	Flat - 2
		4	-	101.03	-	-	-	-	Flat - 2
		5	-	-	168.36	-	-	-	Edge - 2,5
		6	-	-	-	83.79	-	-	Edge - 4,6
		7	-	-	-	75.49	-	-	Edge - 2,6
		8	-	-	74.60	-	-	-	Flat - 5
	4	1	-	-	77.18	-	-	-	Edge - 2,5
		2	-	-	76.51	-	-	-	Edge - 2,5
		3	-	-	77.44	-	-	-	Edge - 2,5
		4	-	162.23	77.85	-	-	-	Edge - 2,5
		5	115.19	-	-	-	-	-	Flat - 4
		6	-	121.96	-	-	-	-	Flat - 6
		7	-	138.74	74.60	-	-	-	Edge - 2,5
		8	-	104.94	155.57	-	-	-	Edge - 2,5
		9	-	124.49	-	81.69	-	-	Edge - 2,6
		10	86.19	-	-	-	-	-	Edge - 4,6
		11	-	73.61	-	-	-	-	Edge - 2,5
		12	-	95.10	-	-	-	-	Edge - 2,6
		13	-	-	-	101.32	-	-	Edge - 2,6
		14	-	142.06	-	-	-	-	Flat - 2
		15	-	114.19	146.57	-	-	-	Edge - 2,5
		16	-	-	-	101.22	-	-	Flat - 6
		17	-	-	-	118.36	-	-	Flat - 6
		18	-	-	-	73.46	-	-	Edge - 2,6
		19	-	-	78.46	-	-	-	Edge - 4,5
		20	-	-	-	75.97	-	-	Edge - 4,6
		21	93.45	-	-	-	-	-	Flat - 4
		22	-	183.88	-	-	-	-	Flat - 2
		23	74.92	-	-	-	-	-	Flat - 4
		24	-	-	139.56	-	-	-	Flat - 5
		25	-	74.17	-	-	-	-	Edge - 2,5
		MAX	**140.87**	**183.88**	**193.71**	**167.09**	**163.61**	**101.37**	
		MIN	**74.92**	**73.61**	**74.60**	**73.46**	**75.30**	**72.43**	
		AVG	**95.04**	**107.78**	**119.07**	**101.33**	**96.93**	**86.24**	
		S.D.	**21.69**	**31.22**	**42.06**	**28.38**	**34.01**	**14.51**	
D	1	1	-	-	-	-	-	77.00	Edge - 3,6
		2	-	-	-	-	-	78.36	Edge - 3,5
		3	-	83.88	-	-	-	-	Edge - 1,2
		4	79.62	-	-	-	-	-	Edge - 4,6
		5	-	-	-	108.37	-	-	Edge - 1,6
		6	-	-	-	-	-	103.98	Edge - 3,6

TABLE C2. (cont'd)

Package	Trip #	Event #	+Δv_x (in./s.) Face 4	-Δv_x (in./s.) Face 2	+Δv_y (in./s.) Face 5	-Δv_y (in./s.) Face 6	+Δv_z (in./s.) Face 1	-Δv_z (in./s.) Face 3	Impact Orientation
D (con't)	1	7	-	-	-	85.85	-	-	Edge - 2,6
	2	1	85.89	-	-	-	-	-	Flat - 4
		2	-	-	-	137.87	-	-	Corner - 1,2,6
		3	-	-	194.75	-	-	-	Flat - 5
		4	-	-	-	-	-	90.97	Flat - 3
		5	95.94	-	-	-	91.81	-	Flat - 4
		6	-	-	-	80.31	-	91.37	Edge - 3,6
		7	132.39	-	-	-	74.32	-	Edge - 1,4
		8	-	-	173.27	-	-	-	Flat - 5
		9	-	-	-	-	-	90.06	Edge - 3,6
		10	-	-	95.26	-	-	-	Flat - 5
		11	-	-	132.09	-	-	-	Edge - 4,5
		12	-	-	106.41	-	-	-	Edge - 2,5
	3	1	-	-	107.61	-	-	-	Edge - 1,5
		2	-	-	-	-	-	142.95	Flat - 3
		3	-	-	-	-	-	93.21	Edge - 3,6
		4	-	-	-	-	228.82	-	Flat - 1
		5	-	-	86.29	-	-	-	Corner - 1,2,5
	4	1	-	-	-	104.53	-	-	Flat - 6
		2	-	102.92	-	-	-	-	Edge - 1,2
		3	-	-	-	75.51	-	-	Edge - 4,6
		4	-	91.15	-	-	-	-	Corner - 2,3,5
		5	86.87	-	-	143.41	-	-	Edge - 4,6
		6	-	77.36	-	-	-	-	Corner - 2,3,5
		7	-	-	-	-	-	96.33	Corner - 3,4,6
		MAX	**132.39**	**102.92**	**194.75**	**143.41**	**228.82**	**142.95**	
		MIN	**79.62**	**77.36**	**86.29**	**75.51**	**74.32**	**77.00**	
		AVG	**96.14**	**88.83**	**127.95**	**105.12**	**131.65**	**96.03**	
		S.D.	**21.08**	**10.95**	**41.26**	**27.12**	**84.60**	**19.46**	
OVERALL		**MAX**	**195.61**	**183.88**	**211.50**	**220.39**	**228.82**	**214.87**	
		MIN	**74.21**	**73.61**	**72.30**	**73.46**	**74.05**	**72.36**	
		AVG	**116.94**	**106.49**	**118.02**	**110.33**	**102.12**	**103.18**	
		S.D.	**39.61**	**30.76**	**41.53**	**36.69**	**47.10**	**31.67**	

TABLE C3. Individual Velocity Changes for All Summary Events for Shipments to Rochester, NY

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
A	1	1	-	-	-	-	-	89.42	Corner - 3,4,5
		2	-	-	-	-	-	81.66	Flat - 3
		3	-	-	109.66	-	-	-	Edge - 2,5
		4	-	-	-	-	-	84.78	Edge - 3,5
		5	242.41	-	-	-	-	-	Flat - 4
		6	-	-	-	-	-	150.49	Flat - 3
	2	1	133.00	-	-	-	-	-	Edge - 4,5
		2	-	-	-	73.17	-	-	Edge - 4,6
		3	174.84	-	-	-	-	-	Edge - 4,5
		4	-	-	-	-	-	102.85	Edge - 2,3
		5	242.01	-	-	-	-	-	Flat - 4
		6	-	-	-	-	-	157.05	Flat - 3
		7	-	-	-	-	-	116.56	Flat - 3
		8	-	-	-	-	-	92.46	Edge - 3,4
		9	197.59	-	-	-	-	-	Flat - 4
		10	140.56	-	-	-	-	-	Edge - 4,6
		11	-	-	-	79.99	-	106.99	Corner - 3,4,6
		12	-	-	-	-	-	91.65	Flat - 3
		13	-	149.08	-	-	-	-	Flat - 2
	3	1	-	195.39	-	-	-	-	Edge - 2,6
		2	-	-	-	-	-	89.01	Flat - 3
		3	-	-	-	-	-	139.88	Corner - 3,4,6
		4	-	74.52	-	-	-	-	Edge - 2,5
		5	135.78	-	-	-	-	-	Flat - 4
		6	-	-	-	-	-	78.85	Flat - 3
		7	-	-	-	-	-	145.40	Edge - 3,4
		8	-	-	-	-	-	89.19	Edge - 2,3
		9	-	-	-	-	-	80.97	Edge - 2,3
		10	146.44	-	-	85.31	-	-	Edge - 4,6
		11	-	-	-	-	-	107.79	Edge - 3,5
		12	130.21	-	-	-	-	-	Flat - 4
	4	1	-	89.18	-	-	-	-	Flat - 2
		2	-	203.40	-	-	-	-	Flat - 2
		3	-	-	74.81	-	-	-	Edge - 4,5
		4	-	-	-	-	-	75.29	Edge - 3,4
		5	-	-	-	119.65	-	-	Flat - 6
		6	96.01	-	-	-	-	85.87	Edge - 3,4
		7	-	-	-	-	-	167.01	Flat - 3
		8	-	-	-	144.91	-	-	Edge - 4,6
		MAX	**242.41**	**203.40**	**109.66**	**144.91**	**-**	**167.01**	
		MIN	**96.01**	**74.52**	**74.81**	**73.17**	**-**	**75.29**	

TABLE C3. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
A (con't)		**AVG**	**163.89**	**142.31**	**92.24**	**100.61**	**-**	**106.66**	
		S.D.	**49.28**	**59.19**	**24.64**	**30.57**	**-**	**29.12**	
B	1	1	-	-	-	-	-	134.45	Flat - 3
		2	-	-	-	-	-	79.25	Edge - 2,3
		3	-	74.30	-	-	-	-	Edge - 2,6
		4	-	-	-	-	-	75.42	Edge - 2,3
		5	226.87	-	-	-	-	-	Flat - 4
		6	-	-	-	-	-	191.57	Edge - 3,6
		7	104.67	-	78.36	-	-	-	Edge - 4,5
		8	-	-	-	-	-	138.60	Flat - 3
		9	91.58	-	-	-	-	-	Edge - 4,6
		10	102.72	-	-	-	-	-	Edge - 4,6
		11	-	97.81	-	-	-	-	Edge - 2,5
		12	-	-	-	-	-	94.01	Edge - 2,3
		13	-	-	76.55	-	-	-	Flat - 5
	2	1	-	-	-	-	-	168.50	Corner - 3,4,5
		2	-	116.26	-	-	-	-	Flat - 2
		3	-	-	-	-	-	95.03	Flat - 3
		4	-	-	-	-	-	150.37	Edge - 2,3
		5	123.10	-	-	76.74	-	-	Edge - 4,6
		6	-	-	-	-	-	246.17	Edge - 2,3
		7	-	-	-	-	-	101.23	Flat - 3
		8	-	-	-	-	-	108.75	Edge - 3,6
		9	-	-	-	-	-	94.24	Corner - 3,4,5
		10	-	-	-	-	-	79.33	Edge - 3,4
		11	-	-	-	-	-	161.01	Edge - 2,3
		12	-	-	-	-	-	75.65	Edge - 3,4
		13	-	-	-	-	-	99.30	Flat - 6
		14	-	-	-	-	-	123.40	Corner - 2,3,6
	3	1	-	150.72	-	-	-	-	Flat - 2
		2	-	-	-	-	-	75.84	Edge - 2,3
		3	-	-	-	-	-	137.29	Edge - 3,5
		4	-	-	-	-	-	124.97	Edge - 3,4
		5	-	-	-	-	-	114.88	Edge - 3,4
		6	114.52	-	-	170.94	-	-	Edge - 4,6
		7	-	-	-	-	-	91.77	Flat - 3
		8	-	-	-	-	-	73.90	Edge - 3,5
		9	-	-	-	-	-	104.00	Corner - 2,3,5
		10	159.18	-	-	-	-	72.71	Flat - 4
	4	1	208.05	-	-	-	-	-	Flat - 4
		2	-	-	-	-	-	75.17	Corner - 3,4,6

TABLE C3. (cont'd)

Package	Trip #	Event #	+Δv_x (in./s.)	-Δv_x (in./s.)	+Δv_y (in./s.)	-Δv_y (in./s.)	+Δv_z (in./s.)	-Δv_z (in./s.)	Impact Orientation
			Face 4	Face 2	Face 5	Face 6	Face 1	Face 3	
B (con't)	4	3	-	-	125.13	-	-	-	Edge - 1,5
		4	-	-	-	-	-	149.34	Flat - 3
		5	136.86	-	86.78	-	-	-	Flat - 4
		MAX	**226.87**	**150.72**	**125.13**	**170.94**	-	**246.17**	
		MIN	**91.58**	**74.30**	**76.55**	**76.74**	-	**72.71**	
		AVG	**140.84**	**109.77**	**91.71**	**123.84**	-	**115.58**	
		S.D.	**48.04**	**32.25**	**22.72**	**66.61**	-	**41.61**	
C	1	1	-	80.58	-	-	-	-	Flat - 2
		2	-	-	85.30	-	-	-	Flat - 5
		3	101.25	-	-	-	-	-	Edge - 4,6
		4	169.65	-	-	151.13	-	-	Edge - 4,6
		5	-	-	-	74.74	-	-	Edge - 2,6
	2	1	-	-	94.21	-	-	-	Edge - 2,5
		2	-	-	-	121.46	-	-	Edge - 2,6
		3	-	-	197.28	-	-	-	Edge - 2,5
		4	97.21	-	-	-	-	-	Edge - 4,6
		5	-	-	79.99	-	-	-	Edge - 4,5
		6	-	-	-	84.77	-	-	Edge - 2,6
		7	75.15	-	72.91	-	-	-	Edge - 4,5
		8	-	-	89.06	-	-	-	Edge - 4,5
		9	-	96.72	-	-	-	-	Flat - 2
		10	-	-	-	146.87	-	-	Edge - 2,6
		11	92.21	-	-	-	-	-	Edge - 4,6
		12	-	-	-	139.94	-	-	Edge - 2,6
		13	-	134.81	-	-	-	-	Flat - 2
		14	160.58	-	-	73.52	-	-	Edge - 4,6
		15	-	-	-	105.22	-	-	Flat - 6
		16	86.60	-	-	-	-	-	Edge - 4,6
	3	1	-	-	116.91	-	-	-	Edge - 4,5
		2	-	-	-	214.66	-	-	Flat - 6
		3	105.24	-	-	-	-	-	Flat - 4
		4	-	-	-	96.89	-	-	Edge - 4,6
		5	94.97	-	-	91.65	-	-	Edge - 4,6
		6	-	-	-	151.27	-	-	Flat - 6
	4	1	-	91.94	-	-	-	-	Flat - 2
		2	-	-	-	97.69	-	-	Edge - 4,6
		3	75.15	-	-	-	-	-	Edge - 4,6
		4	-	-	109.69	-	-	-	Edge - 2,5
		5	168.65	-	-	81.86	-	-	Edge - 4,6
		6	-	-	-	120.58	-	-	Flat - 6
		7	-	-	-	103.36	-	-	Edge - 4,6

TABLE C3. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
C (con't)	4	8	-	-	76.96	-	-	-	Flat - 5
		MAX	**169.65**	**134.81**	**197.28**	**214.66**	**-**	**-**	
		MIN	**75.15**	**80.58**	**72.91**	**73.52**	**-**	**-**	
		AVG	**111.51**	**101.01**	**102.48**	**115.98**	**-**	**-**	
		S.D.	**36.49**	**23.53**	**38.44**	**37.42**	**-**	**-**	
D	1	1	-	-	85.86	-	-	-	Corner - 2,3,5
		2	123.93	-	-	-	-	-	Edge - 4,6
		3	-	-	-	157.59	-	-	Edge - 1,6
		4	-	-	-	-	-	172.12	Edge - 3,4
		5	-	-	-	-	-	94.61	Edge - 3,6
		6	-	124.02	-	-	-	-	Edge - 2,6
	2	1	-	-	-	-	-	81.11	Edge - 3,6
		2	-	101.02	-	-	-	-	Flat - 2
		3	-	-	-	124.11	-	-	Edge - 3,6
		4	-	-	-	95.86	-	-	Corner - 3,4,6
		5	-	-	-	-	-	131.58	Corner - 2,3,6
		6	-	-	-	-	82.69	-	Edge - 1,5
	3	1	-	-	-	-	81.78	-	Edge - 1,5
		2	-	126.95	-	-	-	-	Flat - 2
		3	-	-	127.16	-	-	-	Corner - 1,2,5
		4	-	-		-	-	87.98	Edge - 3,6
	4	1	-	-	-	-	-	85.18	Edge - 3,6
		2	-	-	165.51	-	-	-	Edge - 3,5
		3	-	-	-	-	-	73.15	Edge - 3,5
		MAX	**123.93**	**126.95**	**165.51**	**157.59**	**82.69**	**172.12**	
		MIN	**123.93**	**101.02**	**85.86**	**95.86**	**81.78**	**73.15**	
		AVG	**123.93**	**117.33**	**126.18**	**125.85**	**82.24**	**103.68**	
		S.D.	**-**	**14.20**	**39.83**	**30.90**	**0.64**	**35.53**	
OVERALL		**MAX**	**242.41**	**203.40**	**197.28**	**214.66**	**82.69**	**246.17**	
		MIN	**75.15**	**74.30**	**72.91**	**73.17**	**81.78**	**72.71**	
		AVG	**137.32**	**119.17**	**102.90**	**114.76**	**82.24**	**110.82**	
		S.D.	**47.72**	**39.63**	**33.88**	**36.14**	**0.64**	**36.46**	

APPENDIX D

Individual Velocity Changes for All Non-Summary Events

TABLE D1. Individual Velocity Changes for All Non-Summary Events for Shipments to Sunnyvale, CA

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
A	1	1	-	-	-	86.18	-	-	Flat - 6
		2	-	-	-	106.90	-	-	Edge - 4,6
		3	-	-	133.75	-	-	-	Flat - 5
		4	-	-	75.77	-	-	-	Edge - 1,5
		5	-	-	-	-	-	93.40	Flat - 3
		6	-	-	-	-	91.59	-	Edge - 1,4
		7	-	-	-	-	-	186.47	Edge - 3,5
		8	-	-	-	98.70	-	-	Edge - 4,6
		9	-	-	125.66	-	-	-	Flat - 5
		10	-	-	-	-	-	111.32	Flat - 3
	2	1	-	-	-	-	-	98.38	Edge - 3,5
		2	-	-	100.92	-	-	-	Flat - 5
		3	-	-	-	134.20	-	-	Edge - 4,6
		4	181.93	-	-	91.33	-	-	Edge - 4,6
		5	-	111.18	-	-	-	-	Edge - 2,5
		6	-	-	107.03	-	-	-	Flat - 5
		7	-	-	113.15	-	-	-	Edge - 4,5
		8	-	-	92.42	-	-	-	Flat - 5
		9	-	-	-	96.78	-	-	Flat - 6
	3	1	-	-	-	93.11	-	-	Flat - 6
		2	-	-	103.77	-	-	-	Edge - 2,5
		3	-	-	-	-	-	74.24	Edge - 3,6
		4	-	-	-	-	-	112.36	Flat - 3
		5	-	-	-	122.45	-	-	Edge - 4,6
		6	-	-	-	135.37	-	-	Edge - 4,6
		7	-	-	216.87	-	-	-	Edge - 4,5
		8	-	-	-	85.79	-	-	Corner - 3,4,6
		9	-	105.85	-	-	-	-	Corner - 2,3,5
		10	-	-	-	-	-	74.95	Flat - 3
		11	82.00	-	-	-	-	-	Corner - 3,4,5
		12	-	-	-	-	-	115.62	Flat - 3
		13	-	-	104.87	-	-	-	Edge - 3,5
		14	-	-	110.76	-	-	-	Edge - 4,5
		15	-	-	-	139.30	-	-	Edge - 4,6
	4	1	87.69	-	-	-	-	-	Edge - 3,4
		2	-	-	-	-	-	111.66	Edge - 3,6
		3	-	-	-	105.03	-	-	Flat - 6
		4	-	102.08	-	-	-	-	Edge - 2,5
		5	-	-	-	168.72	-	-	Corner - 1,2,6
		6	-	-	83.86	-	-	-	Corner - 1,2,5
		7	-	-	-	132.77	-	-	Flat - 6

TABLE D1. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
A (con't)	4	8	84.07	-	-	158.72	-	-	Corner - 3,4,6
		9	-	-	-	118.92	-	-	Edge - 4,6
		10	-	-	-	-	-	107.92	Edge - 3,5
		11	-	-	-	-	-	86.17	Edge - 3,5
		12	-	91.69	-	-	-	-	Edge - 2,5
		13	-	151.08	-	-	-	-	Flat - 2
		14	-	-	-	-	-	90.58	Edge - 3,6
		15	-	-	-	98.66	-	-	Flat - 6
		16	-	-	-	105.86	-	-	Flat - 6
		17	-	-	-	-	98.76	-	Edge - 1,4
		18	74.63	-	-	-	-	-	Corner - 1,4,5
		MAX	**181.93**	**151.08**	**216.87**	**168.72**	**98.76**	**186.47**	
		MIN	**74.63**	**91.69**	**75.77**	**85.79**	**91.59**	**74.24**	
		AVG	**102.06**	**112.38**	**114.07**	**115.49**	**95.18**	**105.26**	
		S.D.	**44.90**	**22.78**	**36.13**	**24.72**	**5.07**	**29.37**	
B	1	1	-	-	-	-	-	98.51	Flat - 3
		2	-	230.89	-	-	-	-	Flat - 2
		3	-	-	-	105.56	-	-	Edge - 4,6
		4	-	114.03	-	-	-	-	Edge - 2,6
		5	-	-	-	-	-	112.55	Flat - 3
		6	-	-	100.67	-	-	-	Edge - 4,5
		7	-	186.38	-	103.38	-	-	Edge - 2,6
		8	-	-	-	-	-	113.59	Edge - 3,5
		9	-	-	82.99	-	-	-	Edge - 2,5
		10	-	-	-	-	-	86.66	Flat - 3
		11	-	-	-	-	-	72.47	Edge - 3,6
	2	1	-	-	109.71	-	-	-	Edge - 3,5
		2	-	-	-	156.66	-	-	Edge - 4,6
		3	-	-	-	119.75	-	-	Edge - 4,6
		4	-	-	-	-	-	149.90	Flat - 3
		5	-	-	84.85	-	-	-	Edge - 2,5
		6	-	-	-	-	-	150.60	Flat - 3
		7	-	-	-	-	-	72.67	Edge - 3,6
		8	72.49	-	-	-	-	-	Flat - 4
		9	-	-	-	-	-	82.57	Flat - 3
		10	-	-	-	-	-	105.13	Corner - 3,4,5
		11	-	-	129.75	-	-	-	Flat - 5
		12	-	-	120.56	-	-	-	Flat - 5
		13	93.21	-	-	-	-	-	Flat - 4
	3	1	-	-	-	-	-	104.18	Edge - 3,5
		2	-	-	-	-	-	186.26	Flat - 3
		3	-	-	105.76	-	-	-	Edge - 3,5

TABLE D1. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
B (con't)	3	4	-	-	116.32	-	-	-	Flat - 5
		5	-	-	-	123.13	-	-	Corner - 1,4,6
		6	-	-	104.73	-	-	-	Flat - 5
		7	-	-	-	-	-	85.75	Edge - 3,4
		8	-	-	-	-	-	96.66	Corner - 3,4,5
		9	-	-	-	-	-	77.96	Corner - 3,4,6
		10	-	-	127.61	-	-	-	Flat - 5
		11	-	-	119.56	-	-	-	Edge - 3,5
		12	-	-	-	-	-	74.59	Edge - 3,5
		13	-	-	-	-	-	75.46	Edge - 3,5
	4	1	-	-	-	-	-	119.80	Edge - 3,5
		2	-	-	-	95.96	-	-	Edge - 3,6
		3	-	-	99.12	-	-	-	Edge - 2,5
		4	-	-	105.47	-	-	-	Flat - 5
		5	-	-	-	-	120.40	-	Flat - 1
		6	-	-	-	-	-	99.70	Flat - 3
		7	-	-	-	-	-	87.22	Flat - 3
		8	-	120.50	-	97.60	-	-	Flat - 2
		9	-	-	-	-	-	77.97	Edge - 3,5
		10	-	73.89	-	-	-	-	Flat - 2
		11	-	-	205.78	-	-	-	Edge - 1,5
		12	-	-	-	121.46	-	-	Edge - 1,6
		13	-	-	-	-	-	101.18	Corner - 3,4,5
		14	-	-	122.98	-	-	-	Flat - 5
		15	-	-	-	129.40	-	-	Edge - 4,6
		16	-	-	-	76.63	-	-	Edge - 4,6
		17	-	-	-	-	-	103.48	Edge - 3,5
		18	-	-	-	-	-	141.20	Edge - 3,4
		MAX	**93.21**	**230.89**	**205.78**	**156.66**	**120.40**	**186.26**	
		MIN	**72.49**	**73.89**	**82.99**	**76.63**	**120.40**	**72.47**	
		AVG	**82.85**	**145.14**	**115.72**	**112.95**	**120.40**	**103.17**	
		S.D.	**14.65**	**62.66**	**28.57**	**22.09**	**-**	**28.99**	
C	1	1	-	-	-	-	-	82.06	Corner - 3,4,6
		2	77.87	-	-	-	-	-	Flat - 4
		3	-	156.43	77.47	-	-	-	Edge - 2,5
		4	100.67	-	-	-	-	-	Flat - 4
		5	-	-	-	-	93.62	-	Flat - 1
		6	-	-	73.96	-	-	-	Edge - 2,5
		7	-	-	-	156.16	-	-	Edge - 4,6
		8	-	-	72.32	-	-	-	Flat - 4
		9	-	123.05	-	82.87	-	-	Edge - 2,6
		10	-	-	-	-	-	81.17	Flat - 3
		11	-	75.35	-	-	-	-	Edge - 2,6

TABLE D1. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
C (con't)	2	1	-	-	-	96.58	-	-	Edge - 2,6
		2	92.17	-	-	-	-	-	Edge - 4,5
		3	-	80.01	-	-	-	-	Flat - 2
		4	-	-	85.70	-	-	-	Flat - 5
		5	-	-	77.98	-	-	-	Edge - 4,5
		6	-	116.90	-	-	-	-	Flat - 2
		7	-	-	151.83	-	-	-	Edge - 4,5
		8	85.65	-	-	-	-	-	Flat - 4
		9	-	-	156.57	-	-	-	Flat - 5
		10	112.77	-	73.33	-	-	-	Edge - 4,5
		11	-	101.30	-	-	-	-	Edge - 2,5
		12	-	-	114.49	-	-	-	Flat - 5
		13	-	-	77.01	-	-	-	Flat - 5
	3	1	74.23	-	-	-	-	-	Edge - 4,5
		2	-	-	-	129.46	-	-	Edge - 4,6
		3	80.25	-	-	-	-	-	Edge - 4,6
		4	108.51	-	-	-	-	-	Edge - 4,5
		5	-	125.17	-	-	-	-	Flat - 2
		6	-	-	-	81.41	-	-	Edge - 2,6
		7	-	92.62	-	-	-	-	Flat - 2
		8	-	-	88.15	-	-	-	Edge - 2,5
		9	131.5	-	-	126.64	-	-	Edge - 4,6
		10	-	96.90	-	-	-	-	Edge - 2,5
		11	-	-	119.91	-	-	-	Flat - 5
		12	76.23	-	-	-	-	-	Flat - 4
		13	112.22	-	-	-	-	-	Edge - 4,6
		14	78.47	-	-	-	-	-	Flat - 4
		15	-	79.76	94.44	-	-	-	Edge - 2,5
		16	-	119.51	-	-	-	-	Edge - 2,5
		17	-	75.59	-	-	-	-	Flat - 2
		18	-	100.41	-	-	-	-	Edge - 2,6
		19	106.01	-	78.03	-	-	-	Edge - 4,5
	4	1	-	84.13	-	-	-	-	Flat - 2
		2	-	-	121.16	-	-	-	Edge - 2,5
		3	160.00	-	-	-	-	-	Flat - 4
		4	135.08	-	-	-	-	-	Edge - 4,5
		5	-	87.12	-	-	-	-	Flat - 2
		6	-	-	143.36	-	-	-	Flat - 5
		7	-	132.39	-	-	-	-	Flat - 2
		8	-	-	88.12	-	-	-	Edge - 4,5
		9	151.11	-	-	-	-	-	Edge - 4,6
		10	152.12	-	-	88.73	-	-	Edge - 4,6
		11	-	130.10	-	-	-	-	Flat - 2

TABLE D1. (cont'd)

Package	Trip #	Event #	+ Δv_x (in./s.) Face 4	− Δv_x (in./s.) Face 2	+ Δv_y (in./s.) Face 5	− Δv_y (in./s.) Face 6	+ Δv_z (in./s.) Face 1	− Δv_z (in./s.) Face 3	Impact Orientation
C (con't)	4	12	-	-	111.07	-	-	-	Edge - 4,5
		13	-	108.55	-	-	-	-	Flat - 2
		14	-	81.51	-	-	-	-	Flat - 2
		15	-	-	117.77	-	-	-	Edge - 2,5
		16	150.72	-	-	100.83	-	-	Edge - 4,6
		17	143.73	-	-	116.00	-	-	Edge - 4,6
		18	-	-	122.22	-	-	-	Edge - 2,5
		19	-	115.45	-	-	-	-	Edge - 2,5
		20	97.18	-	79.79	-	-	-	Edge - 4,5
		21	-	-	137.07	-	-	-	Edge - 4,5
		22	-	92.93	-	-	-	-	Flat - 2
		23	96.30	-	-	103.78	-	-	Edge - 4,6
		24	130.52	-	90.12	-	-	-	Edge - 4,5
		25	74.30	-	-	-	-	-	Edge - 4,6
		MAX	**160.00**	**156.43**	**156.57**	**156.16**	**93.62**	**82.06**	
		MIN	**74.23**	**75.35**	**72.32**	**81.41**	**93.62**	**81.17**	
		AVG	**109.90**	**103.58**	**102.26**	**108.25**	**93.62**	**81.62**	
		S.D.	**28.81**	**22.25**	**27.13**	**23.81**	**-**	**0.63**	
D	1	1	-	-	-	-	122.80	-	Flat - 1
		2	-	-	-	-	-	125.39	Flat - 3
		3	-	-	-	-	-	84.82	Flat - 3
		4	-	-	-	93.63	-	-	Edge - 2,6
		5	-	-	-	-	83.56	-	Edge - 1,5
		6	-	-	-	-	-	73.44	Edge - 3,4
	2	1	-	-	-	-	97.98	-	Edge - 1,5
		2	103.20	-	-	-	-	-	Flat - 4
		3	-	-	-	-	-	83.97	Edge - 3,4
		4	-	-	-	73.12	-	-	Flat - 6
		5	-	-	163.93	-	-	162.53	Corner - 2,3,5
		6	-	-	-	-	77.53	-	Edge - 1,5
		7	-	-	-	-	111.54	-	Edge - 1,6
		8	74.73	-	-	-	-	90.40	Edge - 3,4
	3	1	-	83.89	-	-	-	-	Edge - 2,3
		2	-	-	-	88.53	-	-	Corner - 3,4,6
		3	-	-	-	-	110.67	-	Edge - 1,5
		4	-	-	-	-	-	83.60	Edge - 3,6
		5	-	-	-	-	92.83	-	Flat - 1
		6	-	-	-	-	-	89.55	Flat - 3
		7	130.08	-	-	-	-	114.24	Corner - 3,4,5
		8	-	-	-	-	-	74.28	Edge - 3,6
		9	-	-	-	-	-	86.42	Edge - 2,3
		10	-	-	-	-	129.45	-	Flat - 1

TABLE D1. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
D (con't)	3	11	129.05	-	-	-	103.04	-	Edge - 1,4
	4	1	-	-	-	-	-	78.03	Edge - 3,5
		2	-	-	-	92.61	-	-	Corner - 3,4,6
		3	-	-	-	-	-	80.43	Edge - 3,6
		4	-	-	124.15	-	86.75	-	Edge - 1,5
		5	132.44	-	-	-	144.88	-	Corner - 1,4,6
		6	-	-	-	-	76.54	-	Edge - 1,6
		7	-	-	-	-	-	92.74	Edge - 3,5
		8	-	-	-	-	75.79	-	Edge - 1,5
		9	-	-	-	-	-	86.23	Edge - 3,6
		10	-	-	-	-	-	82.66	Corner - 3,4,5
		11	-	-	-	-	-	72.76	Edge - 3,5
		12	-	-	-	-	-	85.52	Corner - 2,3,5
		13	-	-	-	-	108.34	-	Edge - 1,5
		14	-	-	-	-	-	157.04	Flat - 3
		15	-	-	-	-	-	83.24	Flat - 3
		MAX	**132.44**	**83.89**	**163.93**	**93.63**	**144.88**	**162.53**	
		MIN	**74.73**	**83.89**	**124.15**	**73.12**	**75.79**	**72.76**	
		AVG	**113.90**	**83.89**	**144.04**	**86.97**	**101.55**	**94.36**	
		S.D.	**24.92**	**-**	**28.13**	**9.49**	**21.19**	**25.68**	
OVERALL		**MAX**	**181.93**	**230.89**	**216.87**	**168.72**	**144.88**	**186.47**	
		MIN	**72.49**	**73.89**	**72.32**	**73.12**	**75.79**	**72.47**	
		AVG	**107.80**	**110.83**	**110.47**	**110.44**	**101.45**	**99.82**	
		S.D.	**30.06**	**33.80**	**30.41**	**23.65**	**19.34**	**27.54**	

TABLE D2. Individual Velocity Changes for All Non-Summary Events for Shipments to Duluth, GA

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
A	1	1	-	-	-	-	-	76.22	Edge - 3,4
		2	-	-	-	91.97	-	-	Edge - 3,6
		3	107.79	-	-	-	-	-	Corner - 1,4,5
		4	-	185.33	-	-	-	-	Flat - 2
		5	103.33	-	-	-	-	75.43	Corner - 3,4,5
		6	-	-	-	-	-	79.32	Edge - 3,4
		7	-	-	-	-	-	91.96	Edge - 3,5
		8	-	-	-	-	-	72.33	Flat - 3
		9	-	-	114.07	-	-	-	Edge - 4,5
		10	-	88.93	-	-	-	-	Flat - 2
		11	86.24	-	-	-	-	-	Flat - 4
	2	1	-	-	-	-	-	128.20	Edge - 3,4
		2	-	-	87.00	-	-	129.76	Edge - 3,5
		3	213.47	-	110.94	-	-	-	Edge - 4,5
		4	-	-	-	192.59	-	-	Flat - 6
		5	-	200.81	-	-	-	-	Flat - 2
	3	1	193.87	-	-	-	-	228.16	Edge - 3,6
		2	-	-	150.62	-	-	-	Flat - 5
		3	-	-	169.07	-	-	-	Flat - 5
		4	-	108.69	-	-	-	-	Flat - 2
		5	153.69	-	-	-	-	-	Corner - 1,4,5
		6	-	-	198.29	-	81.00	-	Edge - 1,5
		7	96.84	-	-	-	-	114.89	Flat - 5
		8	95.62	-	-	308.24	-	90.87	Corner - 3,4,6
		9	-	-	-	142.92	-	95.89	Edge - 3,4
	4	1	-	88.07	-	-	-	-	Edge - 2,5
		2	-	-	-	-	-	72.33	Edge - 3,6
		3	-	-	-	81.71	-	180.54	Flat - 3
		4	-	-	-	-	-	116.87	Edge - 3,5
		5	-	-	-	-	-	149.91	Edge - 3,4
		6	-	-	-	-	-	84.07	Edge - 3,4
		7	-	-	-	93.49	-	-	Corner - 1,2,6
		8	-	-	-	79.70	-	-	Flat - 6
		9	-	-	-	86.22	-	-	Edge - 3,6
		10	-	-	-	79.03	-	-	Flat - 6
		11	-	-	-	72.42	-	-	Flat - 6
		12	-	96.99	-	-	-	-	Flat - 2
		13	-	-	-	-	-	83.97	Edge - 3,5
		14	-	-	90.45	-	-	-	Corner - 3,4,5
		15	-	190.62	-	-	-	-	Edge - 2,5
		16	-	-	-	152.99	-	-	Edge - 4,6

TABLE D2. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
A (con't)	4	17	106.03	-	-	-	-	-	Flat - 4
		18	-	-	-	-	-	75.01	Edge - 3,5
		19	-	-	-	-	-	76.13	Corner - 3,4,6
		MAX	**213.47**	**200.81**	**198.29**	**308.24**	**81.00**	**228.16**	
		MIN	**86.24**	**88.07**	**87.00**	**72.42**	**81.00**	**72.33**	
		AVG	**128.54**	**137.06**	**131.49**	**125.57**	**81.00**	**106.41**	
		S.D.	**46.86**	**52.26**	**42.09**	**71.86**	**-**	**42.04**	
B	1	1	-	-	-	-	-	122.61	Corner - 3,4,5
		2	-	-	-	75.03	-	76.76	Corner - 3,4,6
		3	-	-	-	-	-	72.74	Edge - 3,4
		4	-	235.29	-	-	-	-	Flat - 2
		5	79.19	-	-	-	-	-	Flat - 3
		6	-	-	-	-	-	138.66	Flat - 3
		7	-	88.49	-	-	-	-	Flat - 2
		8	-	-	-	-	-	88.06	Edge - 3,4
		9	-	-	-	-	-	106.93	Flat - 3
		10	-	-	-	-	102.48	-	Flat - 1
		11	-	-	-	-	-	112.16	Flat - 3
		12	109.71	-	-	143.52	-	-	Edge - 4,6
		13	-	164.25	-	-	-	-	Edge - 2,6
		14	-	118.16	-	-	-	-	Edge - 2,6
	2	1	-	118.29	-	-	-	-	Edge - 2,6
		2	-	-	-	-	-	112.28	Flat - 3
		3	-	-	125.44	-	-	-	Edge - 4,5
		4	-	-	-	-	-	92.43	Flat - 3
		5	-	-	-	-	-	76.75	Edge - 3,4
		6	-	87.21	-	-	-	80.47	Edge - 2,3
		7	-	-	-	-	-	92.54	Edge - 3,6
		8	-	-	-	-	-	94.01	Edge - 3,4
	3	1	-	-	-	-	-	78.14	Edge - 3,4
		2	-	197.95	-	-	-	-	Flat - 2
		3	-	-	182.96	-	-	-	Flat - 5
		4	-	-	-	-	-	110.62	Edge - 3,5
		5	-	-	-	-	-	85.07	Flat - 3
		6	-	-	88.56	-	-	117.13	Corner - 3,4,5
		7	-	-	190.32	-	-	-	Flat - 5
		8	-	-	-	95.29	-	-	Corner - 3,4,6
		9	-	-	-	-	-	119.74	Edge - 2,3
		10	-	-	-	-	220.27	-	Edge - 1,4
		11	-	-	-	-	109.67	-	Edge - 1,5
		12	-	-	-	-	-	82.80	Edge - 2,3

TABLE D2. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
B (con't)	4	1	-	-	-	-	-	72.76	Edge - 3,6
		2	-	-	-	-	-	78.63	Flat - 3
		3	-	-	-	-	-	84.75	Flat - 3
		4	161.79	-	-	-	-	76.88	Edge - 3,4
		5	-	-	-	-	-	144.66	Edge - 3,4
		6	-	-	-	-	-	87.13	Edge - 3,6
		7	-	87.72	-	-	-	-	Flat - 2
		8	-	-	-	-	-	81.74	Flat - 3
		9	161.80	-	-	-	-	-	Edge - 4,6
		10	-	-	-	-	-	92.97	Flat - 3
		11	83.59	-	-	-	-	-	Flat - 4
		12	-	-	-	116.04	-	-	Edge - 4,6
		13	-	-	-	-	-	92.46	Edge - 3,4
		MAX	**161.80**	**235.29**	**190.32**	**143.52**	**220.27**	**144.66**	
		MIN	**79.19**	**87.21**	**88.56**	**75.03**	**102.48**	**72.74**	
		AVG	**119.22**	**137.17**	**146.82**	**107.47**	**144.14**	**95.42**	
		S.D.	**40.58**	**56.17**	**48.48**	**29.29**	**66.03**	**19.83**	
C	1	1	-	-	-	-	-	124.78	Edge - 2,3
		2	-	88.19	-	-	-	-	Flat - 2
		3	117.95	-	-	-	-	-	Edge - 4,6
		4	-	-	-	-	-	98.29	Flat - 3
		5	-	-	-	-	-	93.98	Edge - 2,3
		6	-	-	-	-	-	80.01	Corner - 3,4,6
		7	85.22	-	-	-	-	-	Edge - 1,4
		8	-	100.35	-	-	-	-	Flat - 2
		9	-	-	-	-	-	82.55	Edge - 2,3
		10	-	-	119.26	-	-	-	Edge - 1,5
		11	-	-	-	-	-	81.22	Flat - 3
		12	-	-	-	95.19	-	-	Flat - 6
		13	126.62	-	90.67	-	-	-	Corner - 1,4,5
		14	-	93.19	-	-	-	-	Flat - 2
		15	-	-	-	73.02	-	-	Flat - 2
		16	-	-	-	-	88.97	-	Flat - 1
		17	-	77.57	-	-	-	-	Flat - 2
		18	-	103.35	-	-	-	-	Edge - 1,2
		19	-	117.20	-	-	-	-	Flat - 2
		20	-	-	-	150.64	-	-	Flat - 6
	2	1	-	-	-	-	-	143.01	Flat - 3
		2	-	-	-	-	-	83.61	Edge - 3,4
		3	73.64	-	-	154.27	-	-	Edge - 3,6
		4	92.82	-	-	-	-	-	Edge - 4,6
		5	-	-	-	-	73.59	-	Flat - 1
		6	-	133.51	-	-	-	-	Flat - 2

TABLE D2. (cont'd)

Package	Trip #	Event #	+ Δv$_x$ (in./s.) Face 4	− Δv$_x$ (in./s.) Face 2	+ Δv$_y$ (in./s.) Face 5	− Δv$_y$ (in./s.) Face 6	+ Δv$_z$ (in./s.) Face 1	− Δv$_z$ (in./s.) Face 3	Impact Orientation
C (con't)	2	7	91.32	-	-	-	-	-	Corner - 1,4,6
		8	-	-	-	110.06	-	-	Edge - 4,6
		9	-	129.10	-	-	-	-	Flat - 2
		10	-	-	-	-	220.34	-	Edge - 1,4
		11	137.09	-	-	-	-	-	Edge - 4,5
		12	-	121.84	-	-	-	-	Flat - 2
		13	-	-	102.27	-	-	-	Edge - 4,5
		14	-	-	166.21	-	-	-	Edge - 2,5
		15	-	120.26	-	-	-	-	Flat - 2
		16	-	84.85	-	-	-	-	Flat - 2
	3	1	-	-	74.93	-	-	-	Flat - 5
		2	-	-	90.28	-	-	-	Edge - 2,5
		3	-	-	-	92.82	-	-	Egde - 2,6
		4	-	104.76	-	-	-	-	Flat - 2
		5	-	76.64	-	-	-	-	Flat - 2
		6	-	-	74.84	-	-	-	Edge - 4,5
		7	-	-	78.68	-	-	-	Flat - 5
		8	-	-	78.46	-	-	-	Flat - 5
		9	159.86	-	-	-	-	-	Edge - 4,6
		10	79.06	-	-	-	-	-	Edge - 4,6
		11	-	-	74.71	-	-	-	Edge - 2,5
		12	-	129.80	-	-	-	-	Edge - 2,5
		13	-	84.16	-	-	-	-	Edge - 2,5
		14	-	117.07	-	-	-	-	Flat - 2
		15	-	84.53	-	-	-	-	Edge - 2,5
		16	-	-	108.54	-	-	-	Flat - 5
		17	136.63	-	-	-	-	-	Edge - 4,6
		18	73.29	-	91.98	-	-	-	Edge - 4,5
		19	114.34	-	-	-	-	-	Edge - 4,6
		20	127.31	-	-	-	-	-	Edge - 4,6
		21	143.44	-	-	132.52	-	-	Edge - 4,6
	4	1	124.45	-	-	-	-	-	Flat - 4
		2	-	-	93.94	-	-	-	Edge - 4,5
		3	-	-	93.56	-	-	-	Edge - 2,5
		4	-	88.07	-	-	-	-	Edge - 2,6
		5	-	-	125.44	-	-	-	Flat - 5
		6	-	110.48	-	78.87	-	-	Edge - 2,6
		7	-	152.14	73.44	-	-	-	Edge - 2,5
		8	-	-	141.49	-	-	-	Flat - 5
		9	72.84	-	-	-	-	-	Flat - 4
		10	-	125.63	-	-	-	-	Flat - 2
		11	-	137.89	78.76	-	-	-	Flat - 2
		12	-	-	144.53	-	-	-	Flat - 5

TABLE D2. (cont'd)

Package	Trip #	Event #	+ Δv$_x$ (in./s.)	− Δv$_x$ (in./s.)	+ Δv$_y$ (in./s.)	− Δv$_y$ (in./s.)	+ Δv$_z$ (in./s.)	− Δv$_z$ (in./s.)	Impact Orientation
			Face 4	Face 2	Face 5	Face 6	Face 1	Face 3	
C (con't)	4	13	-	-	83.12	-	-	-	Flat - 2
		14	-	85.65	-	76.32	-	-	Edge - 2,6
		15	-	-	-	113.98	-	-	Flat - 6
		16	-	122.07	-	-	-	-	Edge - 2,5
		17	-	138.42	-	-	-	-	Flat - 2
		18	92.91	-	-	-	-	-	Flat - 4
		19	109.38	-	-	-	-	-	Flat - 4
		20	-	-	75.51	-	-	-	Edge - 2,5
		21	96.96	-	-	-	-	-	Flat - 4
		22	109.15	-	-	-	-	-	Edge - 4,6
		23	-	93.88	-	78.25	-	-	Edge - 2,6
		MAX	**159.86**	**152.14**	**166.21**	**154.27**	**220.34**	**143.01**	
		MIN	**72.84**	**76.64**	**73.44**	**73.02**	**73.59**	**80.01**	
		AVG	**108.21**	**108.48**	**98.12**	**105.09**	**127.63**	**98.43**	
		S.D.	**25.73**	**21.65**	**26.74**	**29.77**	**80.65**	**23.33**	
D	1	1	-	-	-	-	-	166.12	Flat - 3
		2	-	81.89	-	-	-	-	Edge - 2,6
		3	-	-	-	131.25	-	-	Flat - 6
		4	-	-	-	-	-	213.37	Flat - 3
		5	-	78.22	-	-	-	-	Corner - 2,3,5
	2	1	-	-	-	-	-	113.31	Edge - 3,6
		2	-	-	-	-	-	99.62	Flat - 3
		3	-	-	-	-	-	83.50	Edge - 3,5
		4	-	-	-	-	-	87.11	Edge - 3,5
		5	73.33	-	-	-	-	-	Flat - 4
		6	-	-	-	214.15	-	-	Edge - 4,6
		7	-	-	-	95.84	-	-	Edge - 2,6
	3	1	-	-	-	-	74.04	-	Edge - 1,6
		2	-	-	-	-	-	79.83	Flat - 3
		3	-	-	-	-	-	112.54	Flat - 3
		4	-	-	-	-	-	91.34	Edge - 3,4
		5	-	-	-	-	-	90.77	Edge - 3,6
		6	-	-	-	-	-	79.22	Edge - 3,6
		7	-	-	-	84.57	-	-	Flat - 6
	4	1	-	-	119.75	-	-	-	Edge - 2,5
		2	-	-	-	-	-	99.64	Edge - 3,6
		3	-	-	-	-	-	80.57	Edge - 2,3
		4	-	-	76.63	-	-	-	Flat - 5
		5	-	-	-	-	-	93.87	Flat - 3
		6	-	-	-	-	-	76.75	Edge - 3,6
		7	-	90.19	-	-	-	105.46	Flat - 3

TABLE D2. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.)	$-\Delta v_x$ (in./s.)	$+\Delta v_y$ (in./s.)	$-\Delta v_y$ (in./s.)	$+\Delta v_z$ (in./s.)	$-\Delta v_z$ (in./s.)	Impact Orientation
			Face 4	Face 2	Face 5	Face 6	Face 1	Face 3	
D (con't)	4	8	-	-	-	-	-	92.18	Flat - 3
		9	84.55	-	-	-	-	-	Flat - 4
		10	-	99.88	-	-	-	-	Edge - 1,2
		11	-	-	-	-	-	75.39	Edge - 3,5
		12	102.16	-	-	-	-	-	Edge - 4,5
		MAX	**102.16**	**99.88**	**119.75**	**214.15**	**74.04**	**213.37**	
		MIN	**73.33**	**78.22**	**76.63**	**84.57**	**74.04**	**75.39**	
		AVG	**86.68**	**87.55**	**98.19**	**131.45**	**74.04**	**102.26**	
		S.D.	**14.53**	**9.63**	**30.49**	**58.61**	**-**	**34.77**	
OVERALL		**MAX**	**213.47**	**235.29**	**198.29**	**308.24**	**220.34**	**228.16**	
		MIN	**72.87**	**76.64**	**73.44**	**72.42**	**73.59**	**72.33**	
		AVG	**112.90**	**116.17**	**110.73**	**116.43**	**121.30**	**100.30**	
		S.D.	**34.18**	**37.50**	**36.84**	**51.51**	**62.42**	**30.79**	

TABLE D3. Individual Velocity Changes for All Non-Summary Events for Shipments to Rochester, NY

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
A	1	1	206.21	-	-	-	-	-	Flat - 4
		2	-	-	-	-	-	116.93	Flat - 3
		3	-	-	-	-	-	86.04	Edge - 2,3
		4	-	-	-	-	-	81.87	Edge - 3,5
		5	-	-	-	-	-	190.79	Flat - 3
		6	-	97.58	-	-	-	-	Corner - 2,3,6
	2	1	-	-	-	-	-	97.55	Corner - 3,4,6
		2	-	-	-	-	-	101.68	Flat - 3
		3	-	-	-	-	-	125.63	Flat - 3
		4	80.27	-	-	-	-	-	Corner - 3,4,6
		5	-	-	105.05	-	-	-	Flat - 5
		6	-	-	-	-	-	85.19	Corner - 3,4,6
		7	-	-	-	-	-	90.09	Edge - 3,4
		8	-	-	-	-	-	76.63	Edge - 3,6
	3	1	-	-	-	-	-	79.93	Edge - 3,6
		2	-	176.12	-	-	-	-	Flat - 2
		3	-	-	-	-	153.45	-	Flat - 1
		4	-	-	-	-	105.79	-	Flat - 1
		5	-	-	-	-	81.78	-	Flat - 1
		6	-	-	-	-	-	83.43	Flat - 3
		7	-	-	-	-	-	76.82	Edge - 3,6
		8	-	-	-	-	-	120.49	Flat - 3
		9	-	-	-	-	-	146.18	Flat - 3
		10	-	-	-	-	-	82.39	Edge - 3,4
		11	-	-	-	-	-	92.47	Flat - 3
		12	-	-	-	-	-	72.33	Flat - 3
		13	-	129.71	-	-	-	-	Edge - 2,6
		14	86.48	-	-	-	-	103.44	Flat - 3
		15	-	-	-	-	-	77.15	Edge - 3,6
	4	1	-	-	-	89.60	-	109.62	Edge - 2,3
		2	-	-	-	-	-	83.79	Corner - 2,3,6
		3	-	-	-	-	-	82.19	Corner - 3,4,5
		4	-	-	-	85.48	-	-	Flat - 6
		5	-	-	195.17	-	-	-	Corner - 1,2,5
		6	-	-	-	121.23	-	-	Edge - 1,6
		7	-	-	-	-	-	188.32	Flat - 3
		8	-	113.90	-	85.06	-	-	Edge - 2,6
		9	-	182.41	-	-	-	-	Flat - 2
		10	-	-	-	-	89.68	-	Corner - 1,2,6
		11	-	-	-	-	-	88.14	Flat - 3
		12	-	98.33	-	-	-	-	Flat - 3

TABLE D3. (cont'd)

Package	Trip #	Event #	+ Δv_x (in./s.) Face 4	− Δv_x (in./s.) Face 2	+ Δv_y (in./s.) Face 5	− Δv_y (in./s.) Face 6	+ Δv_z (in./s.) Face 1	− Δv_z (in./s.) Face 3	Impact Orientation
A (con't)	4	13	-	92.52	-	-	-	-	Edge - 2,6
		14	-	75.10	-	-	-	-	Edge - 2.6
		MAX	**206.21**	**182.41**	**195.17**	**121.23**	**153.45**	**190.79**	
		MIN	**80.27**	**75.10**	**105.05**	**85.06**	**81.78**	**72.33**	
		AVG	**124.32**	**120.71**	**150.11**	**95.34**	**107.68**	**101.56**	
		S.D.	**70.99**	**39.49**	**63.72**	**17.38**	**32.11**	**32.00**	
B	1	1	-	-	-	-	-	95.56	Edge - 3,5
		2	-	-	-	-	-	88.29	Edge - 2,3
		3	-	-	95.22	-	-	-	Flat - 5
		4	-	-	72.64	-	-	167.95	Edge - 3,5
		5	88.51	-	-	-	-	155.25	Edge - 3,6
		6	-	-	-	-	-	80.56	Corner - 2,3,6
		7	-	-	-	-	-	98.67	Edge - 2,3
		8	-	-	-	-	-	87.01	Edge - 3,6
		9	170.33	-	153.56	-	-	-	Edge - 4,5
	2	1	-	151.22	-	-	-	-	Edge - 2,6
		2	-	-	-	-	-	117.90	Edge - 2,3
		3	-	-	-	-	-	79.02	Edge - 3,6
		4	103.56	-	-	156.03	-	-	Edge - 4,6
		5	-	-	-	-	-	100.45	Edge - 3,4
		6	-	-	-	-	-	73.17	Corner - 3,4,5
		7	-	-	-	-	-	88.01	Edge - 1,2
		8	-	-	-	-	-	85.84	Edge - 3,5
		9	-	-	-	-	-	112.97	Edge - 3,4
	3	1	-	-	-	-	89.26	-	Flat - 1
		2	-	-	-	-	-	89.10	Corner - 3,4,5
		3	-	-	-	-	-	81.72	Corner - 3,4,6
		4	-	169.33	-	124.01	-	-	Edge - 2,6
		5	-	-	-	-	-	88.87	Corner - 2,3,5
		6	-	-	-	-	-	98.43	Flat - 3
		7	102.82	-	-	-	-	-	Edge - 4,5
		8	-	-	-	-	-	77.80	Flat - 3
		9	-	94.15	-	-	-	-	Flat - 2
		10	-	-	-	-	-	81.75	Edge - 3,4
	4	1	-	-	121.86	-	-	116.24	Corner - 3,4,5
		2	-	-	-	-	-	118.64	Flat - 3
		3	-	-	-	-	-	94.25	Edge - 3,5
		4	-	-	73.34	-	-	-	Edge - 2,5
		5	-	-	-	-	-	106.65	Corner - 3,4,6
		6	-	-	-	87.93	-	-	Edge - 4,6
		7	-	-	-	-	-	123.45	Edge - 3,6

TABLE D3. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
B (con't)	4	8	-	-	-	-	-	77.94	Edge - 2,3
		9	-	178.70	-	-	-	-	Flat - 2
		10	-	-	-	150.99	-	-	Edge - 4,6
		11	-	-	-	-	-	115.60	Flat - 3
		12	-	-	80.81	-	-	-	Flat - 5
		MAX	**170.33**	**178.70**	**153.56**	**156.03**	**89.26**	**167.95**	
		MIN	**88.51**	**94.15**	**72.64**	**87.93**	**89.26**	**73.17**	
		AVG	**116.31**	**148.35**	**99.57**	**129.74**	**89.26**	**100.04**	
		S.D.	**36.68**	**37.89**	**32.24**	**31.22**	**-**	**22.99**	
C	1	1	-	105.12	-	-	-	-	Flat - 2
		2	-	-	-	116.08	-	-	Edge - 2,6
		3	94.17	-	-	-	-	-	Edge - 4,5
		4	134.40	-	-	170.16	-	-	Edge - 4,6
		5	-	-	132.94	-	-	-	Edge - 2,5
		6	131.24	-	-	-	-	-	Edge - 4,6
		7	-	80.74	-	-	-	-	Flat - 2
		8	-	116.86	-	-	-	-	Flat - 2
		9	-	-	80.96	-	-	-	Edge - 2,5
		10	115.11	-	-	-	-	-	Edge - 4,6
		11	-	-	-	115.13	-	-	Flat - 6
		12	-	-	-	-	98.74	-	Corner - 1,2,6
		13	85.35	-	-	-	-	-	Flat - 4
		14	-	-	92.94	-	-	-	Edge - 4,5
		15	138.45	-	-	-	-	-	Flat - 4
		16	72.55	-	-	-	-	-	Edge - 4,5
		17	87.89	-	-	-	-	-	Edge - 4,5
		18	173.02	-	-	-	-	-	Edge - 4,6
	2	1	-	101.19	-	-	-	-	Flat - 2
		2	-	-	-	248.70	-	-	Edge - 4,6
		3	-	-	-	-	-	91.12	Edge - 2,5
		4	-	-	99.64	-	-	-	Flat - 5
		5	-	-	94.33	-	-	-	Flat - 5
		6	-	119.69	-	-	-	-	Flat - 2
		7	-	-	-	109.45	-	-	Flat - 6
		8	-	-	-	104.95	-	-	Flat - 6
		9	73.47	-	-	-	-	-	Edge - 4,6
		10	-	129.82	-	-	-	-	Flat - 2
	3	1	-	-	-	132.89	-	-	Flat - 6
		2	161.43	-	-	80.04	-	-	Flat - 4
		3	-	72.48	-	-	-	-	Flat - 2
		4	154.37	-	-	-	-	-	Edge - 4,6
		5	77.04	-	-	-	-	-	Edge - 4,6

TABLE D3. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
C (con't)	3	6	-	85.40	-	-	-	-	Edge - 2,6
		7	-	114.62	-	-	-	-	Flat - 2
		8	141.20	-	-	-	-	-	Edge - 4,5
		9	-	-	-	91.93	-	-	Edge - 4,6
		10	98.93	-	-	-	-	-	Edge - 4,5
		11	-	127.93	-	-	-	-	Flat - 2
	4	1	-	-	-	87.09	-	-	Flat - 6
		2	-	-	-	144.19	-	-	Flat - 6
		3	-	119.25	-	-	-	-	Flat - 2
		4	-	92.34	-	-	-	-	Flat - 2
		5	-	87.64	-	-	-	-	Flat - 2
		6	-	93.72	-	-	-	-	Flat - 2
		7	-	107.39	-	-	-	-	Flat - 2
		8	-	-	82.17	-	-	-	Edge - 4,5
		9	-	80.30	-	-	-	-	Flat - 2
		10	96.71	-	-	72.92	-	-	Edge - 4,6
		11	74.24	-	80.39	-	-	-	Flat - 4
		12	-	-	-	128.83	-	-	Flat - 6
		MAX	**173.02**	**129.82**	**132.94**	**248.70**	**98.74**	**91.12**	
		MIN	**72.55**	**72.48**	**80.39**	**72.92**	**98.74**	**91.12**	
		AVG	**112.33**	**102.16**	**94.77**	**123.26**	**98.74**	**91.12**	
		S.D.	**33.63**	**18.10**	**18.44**	**46.40**	-	-	
D	1	1	-	-	-	-	-	79.92	Edge - 3,6
		2	-	-	-	-	93.66	-	Flat - 1
		3	-	-	-	-	-	73.09	Edge - 3,6
		4	-	-	153.11	-	-	-	Edge - 3,5
		5	-	-	104.83	-	-	-	Flat - 5
		6	-	-	-	-	-	75.45	Edge - 3,4
		7	-	82.17	-	-	-	-	Corner - 1,2,6
	2	1	-	-	-	-	-	82.63	Edge - 3,6
		2	-	-	-	-	-	86.34	Edge - 3,6
		3	-	-	-	-	-	85.87	Edge - 3,6
		4	-	-	-	-	78.14	-	Corner - 1,4,6
		5	-	-	-	-	73.73	-	Flat - 1
		6	-	-	-	-	-	92.77	Corner - 2,3,5
		7	-	-	-	-	-	94.39	Edge - 3,6
		8	-	76.87	-	-	-	-	Flat - 2
		9	-	-	-	-	-	85.07	Edge - 3,5
		10	159.31	-	-	-	-	-	Flat - 4
	3	1	-	127.18	-	-	-	-	Edge - 1,2
		2	-	-	-	-	-	75.18	Flat - 3

TABLE D3. (cont'd)

Package	Trip #	Event #	$+\Delta v_x$ (in./s.) Face 4	$-\Delta v_x$ (in./s.) Face 2	$+\Delta v_y$ (in./s.) Face 5	$-\Delta v_y$ (in./s.) Face 6	$+\Delta v_z$ (in./s.) Face 1	$-\Delta v_z$ (in./s.) Face 3	Impact Orientation
D (con't)	3	3	-	-	-	-	82.66	-	Edge - 1,6
		4	-	-	-	-	-	72.97	Corner - 3,4,6
		5	-	-	-	-	-	105.71	Edge - 3,6
		6	-	-	-	-	-	73.15	Edge - 3,6
		7	-	-	94.40	-	-	-	Edge - 2,5
		8	-	-	-	-	-	103.79	Corner - 2,3,5
	4	1	-	-	-	-	-	82.49	Edge - 3,6
		2	-	-	-	-	-	78.75	Corner - 3,4,6
		3	-	-	-	-	-	77.53	Edge - 3,5
		4	-	-	83.14	-	-	-	Flat - 5
		5	-	-	-	-	-	79.20	Edge - 3,6
		MAX	**159.31**	**127.18**	**153.11**	**-**	**93.66**	**105.71**	
		MIN	**159.31**	**76.87**	**83.14**	**-**	**73.73**	**72.97**	
		AVG	**159.31**	**95.41**	**108.87**	**-**	**82.05**	**83.57**	
		S.D.	**-**	**27.64**	**30.79**	**-**	**8.56**	**9.93**	
OVERALL		**MAX**	**206.21**	**182.41**	**195.17**	**248.70**	**153.45**	**190.79**	
		MIN	**72.55**	**72.48**	**72.64**	**72.92**	**73.73**	**72.33**	
		AVG	**116.28**	**112.25**	**105.08**	**119.18**	**94.69**	**96.28**	
		S.D.	**37.93**	**31.59**	**32.64**	**40.37**	**22.79**	**25.07**	

REFERENCES

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Consumer Reports. 1998. Mailing options test. December, Vol. 63, No. 12, 12-16.

Dallas Instruments. 1998. Instruction manual for SAVER - Shock and vibration environment recorder. Lansmont Corporation. Monterey, California.

Davis, Joyce E. 1997. Americans are more finicky than ever. *Fortune Magazine*, 3 February, Vol. 135, No. 2, 108.

Ostrem, F. E., and W. D. Goodshall. 1979. An assessment of the common carrier shipping environment. *Gen. Tech. Rep. FPL22*, Madison, Wisconsin: USDA, Forest Service, Forest Products Laboratory.

Singh, S. P. and T. Voss. 1992. Drop heights encountered in the U.P.S. small parcel environment in the United States. *Journal of Testing and Evaluation*, 20(5), 382-387.

United Parcel Service. 1997. Celebrating the past - A chronicle of the times. U.P.S. of America, Inc.

United Parcel Service. 1997. How UPS works: The hub and spoke. U.P.S. of America, Inc. March.

United Parcel Service. 1998. United Parcel Service fact sheet. U.P.S. of America, Inc. August.

Weigel, T. G. 1996. Handling differences between plywood and corrugated containers with and without fragile labels in overnight shipment. Masters thesis, Michigan State University.