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CORRELATION BETWEEN TRANSPORTATION TIME
AND VIBRATION TABLE TIME

By

Deanna Joyce Fell

A THESIS

ABSTRACT

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AND VIBRATION TABLE TIME

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Vibration due to shipment is a major cause of product damage. Vibration tables are used in laboratories to recreate transportation environments. From a packaging perspective, this device can aid in determining the packaging required for proper protection in some known distribution channel. An assumption of many investigators is that the vibration table is a time-saving device. If this assumption is correct, what then is the correlation between transportation time and vibration table time? Determining such a correlation was the focus of this research. In this experiment, cereal was used because damage, defined here to be settling of the contents, could easily be gauged over time. An Environmental Data Recorder (EDR) was used to record the vibration generated by an automotive mode of transportation. A Power Spectral Density (PSD) plot generated by the EDR was used to recreate the ride on the vibration table. It was found that for the product and road used, about one-third of the actual transportation time was required to cause the same amount of settling on the vibration table.

To God, I give all the glory for giving me the ability to do this thesis.

To my husband, Heath, I dedicate this work. Thank you for all of the support and patience these last two years.

To my best friend, and twin, Delana I don't think I could have survived without you. You're next!

Also, to my parents Jim and Brenda. Without you I could not have made it. Thank you, thank you.

ACKNOWLEDGMENTS

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

In the past few years, measuring the dynamics of the distribution environment has become a common practice for almost every major manufacturer in the United States [3]. Packaging engineers are continually studying the levels of shock and vibration in their distribution cycles. Although shock levels play an important role in determining the proper packaging for some products, this research was geared only at studying the vibration levels. It is the transportation environment that is characterized by vibration and the handling environment by shock. More specifically, random vibration was studied here. The intent of such field studies is to use the data from the actual transportation environment to develop laboratory testing environments which simulate the distribution environment.

Vibration tables can be used in the laboratory to simulate the transportation environment which a package/product system may encounter. Vibration tables, or shakers as they are sometimes called, can simulate different modes of transportation such as automotive or rail. For this study, only the automotive mode of transportation was used.

Although expensive, a vibration table could be used to simulate a particular roadtrip in a much shorter time than conducting the vibration analysis in an actual transportation environment such as a truck. It is easy to see how the vibration table could be beneficial in terms of being a time-saving device. It is of no surprise to any investigator that the two most limiting factors of an experiment are time and money. For many engineering professionals, the cost of a vibration table could be justified if it were shown to be a method of saving time.

The purpose of using the vibration table, from a packaging perspective is to determine how much packaging is necessary to protect the product for some specific trip. The determination of the correct amount, or kind, of packaging will vary depending on the standards of the packager. In most cases, the packaging professional will have their company's standards of quality by which they need to adhere. In other words, a product's damage criteria will be set by the manufacturer of the product. For this study, a product was chosen so that damage to the product could easily be assessed over time. Cereal was selected because it is damaged in distribution by breaking up and settling. Vibration can be attributed as the primary reason for such settling. The displacement of the cereal over time was decided to be the criteria by which the damage would be gauged for this experiment. The cereal was purchased from a local grocer. Because the product was purchased, it was assumed that it had already been through a distribution channel and had already settled. Therefore, it may be reasonable to assume that further settling may be minimal. It is also important to note that the damage criteria was determined by the investigator, and in no way reflects the damage

criteria set by the manufacturer.

Furthermore, it can be noted that there are several sources of dynamic excitation which must be taken into consideration. The first would be caused by the mode of transportation, or vehicle. The second source of excitation of interest here was the dynamic input caused by the pavement roughness. Therefore, the findings of this research are only applicable for the test conditions given. The method used, however, can be applied to different types of transportation and roads. There is one other significant factor to consider and that is the product. There are numerous types product and each has a distinct mode of failure or criteria by which it is rendered damaged.

One general problem with simulation which has been noted for many years and still remains a problem is that simulating the vibration which occurs in the actual distribution environment cannot be done exactly [2]. Basically, it is virtually impossible to re-create the vibrations in the exact same manner that they were produced in the actual transportation cycle. Developing a laboratory testing environment which identically mimics the actual transportation environment is extremely complex.

In this investigation, an Environmental Data Recorder (EDR) was used to record the vibration in the truck as a result of traveling primarily over expressways [10]. The road chosen for travel was one which was under construction. Rough road surfaces generate higher acceleration levels which was the reason such a road surface was used [1]. Also, the rear of the truck has been shown to have the highest acceleration levels [1]. For this reason the EDR and the package/product system were

acceleration levels [1]. For this reason the EDR and the package/product system were positioned in the rear of the truck. The EDR was basically a sensor/recording device for shock and vibration. Recalling that the transportation environment is characterized by vibration and the handling environment by shock, this device was used as a means of recording the vibration. The EDR was a battery-powered device which has a built in tri-axial accelerometer [8]. The Dyna Max software was used to take the data recorded by the EDR and generate a Power Spectral Density (PSD) plot [10]. The use of the PSD plot, in this case, is to send information to the random vibration controller to vibrate the vibration table. This controller is an electronic device which produces many pure sine waves in combination. The PSD signals the controller how the sine waves can be mixed together in the proper frequencies and amplitudes to recreate the random vibration from the actual transportation environment. The PSD is this re-creation that was used to drive the vibration table. It is actually a statistical representation of the random vibration occurring in the truck. The PSD is a plot of Power Density (PD) versus frequency.

In most instances the PSD plot is given in a line graph form which is indicated in Figure 1 by the dotted line. The line graph was the form which was plotted by the DynaMax software. Figure 1 also indicates the PSD plot in bar graph form by the solid line. It is important to understand that the graph actually represents a statistical picture of the random vibration. At any frequency, the PD is the square of the standard deviation of a random sampling of acceleration values taken from a 1 Hz bandwidth tuner set to that frequency [1].

Because different analyzers can have different bandwidths, RMS G^2 must be divided by the bandwidth so it does not have any influence on the PD results. All of this was done internally by the EDR software. For example, in Figure 1 the bandwidth is 1 Hz so every RMS G^2 would be divided by 1 Hz to get PD. Despite the sophistication of this method, there are still hurdles to overcome when using PSD plots to control a vibration table. One of the problems serves as the focus of this research.

Figure 1. PSD Plot in Bar Graph Form
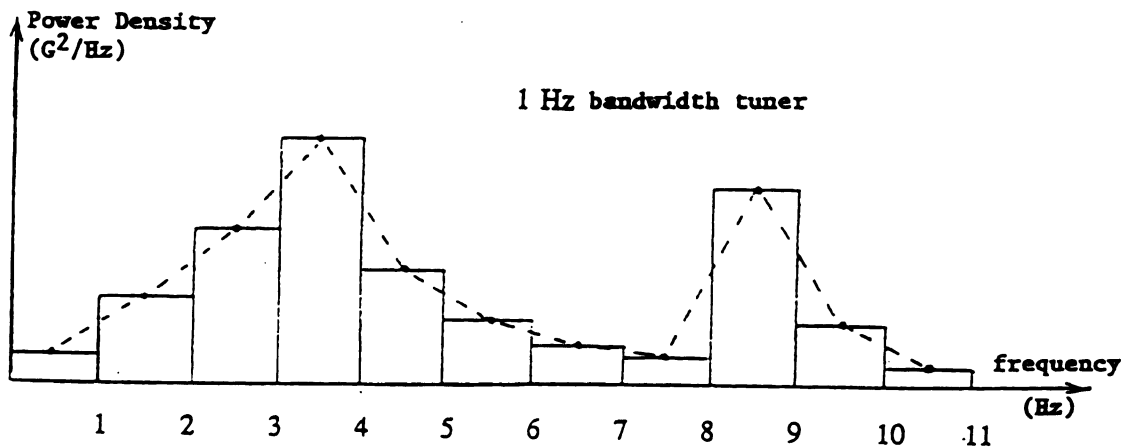
The objective of this research was to determine if there could be some correlation made between the time it takes to conduct the experiment on the road and the time it takes to conduct it on the vibration table. One hypothesis is that there is a one to one ratio which would indicate that the vibration table does not necessarily save

time. Another hypothesis is that this correlation is dependent on the product, the mode of transportation, and the route of transportation. Therefore, a product was chosen where the damage could be determined easily. The mode of travel was a ten foot rental truck. The route of travel was kept constant throughout the experiment and is discussed later.

The American Standard for Testing Methods (ASTM) designation D-4728-87 was used as a guide in using the vibration equipment. The problem with using this as a guideline is stated in section 10.2 of the procedure. It states to "conduct the random vibration test for the length of time stated in the applicable specification, if any, of for a predetermined period, or until a predetermined amount of damage may be detected. The test may be stopped momentarily to inspect for damage"[5]. This suggests that there is no specific correlation between table time and the road time. In ASTM D-4169 it is recommended to use a 180 minute duration for performing the random vibration test to simulate transportation [4]. Since many engineers use these standards for their testing purposes, one must question how they determine the length of time. The uncertainty explained here served as a motivation for conducting this research.

CHAPTER 2

EXPERIMENTAL DESIGN / MATERIALS

2.1 Product/Package System Under Investigation

For this study two types of cereal were used as the test specimens. Twenty-four, twenty ounce cartons of flake cereal were used. Also, twenty-four, twenty ounce cartons of a bran cereal were used. In all, there were forty-eight cartons. All of the cereal was purchased from Meijers grocery in Lansing, Michigan.

A corrugated container which would normally be used for shipping purposes was also obtained from the Meijers store. The dimensions of the box were 24" x 15 3/4" x 15 1/4". The shipping container held twenty four of the cartons of cereal at one time, twelve cartons on the bottom layer, and twelve on the top layer.

Prior to conducting the experiment, all of the cartons of cereal were opened. The inner liner containing the product was also opened. The level to which the cereal had previously settled was traced on the inside of the inner liner using a black marker. This was done for all forty eight cartons.

In the first phase of the experiment, which will be referred to as the actual transportation environment, the 24 cartons of cereal were labeled using a two letter code indicative of the sequence in which the cartons were removed from the corrugated

container. This code included the layer, top or bottom, in which the carton was positioned. The code also had a number which indicated which trip the carton was removed. There were four trips total.

The second phase of the experiment was simulation of the trip on the vibration table. In this phase, four cartons of cereal were removed after each predetermined interval of time. After the settling was measured, the cartons were placed back into the container. The cartons of cereal were labelled in the same manner as in the first phase.

2.2 Equipment

In order to create an actual transportation environment, a ten foot truck was rented through Michigan State University and Kildee Kar Kare, 2649 Grand River, Okemos, MI 48864.

The device used to record the vibration data from the transportation environment was an Environmental Data Recorder. Specifically, the EDR was an EDR-3-10, S/N 0401, +/- 10G FS Range, with an RS-232 Interface cable. This equipment was leased from Instrumented Sensor Technology, Inc., 4704 Moore Street, Okemos, MI 48864. Other equipment leased from IST included magnetic brackets used to mount the EDR to the steel floor of the truck and the Dyna Max Module DM-3 software used to interpret the recorded vibration and generate a PSD plot. Wood beams were used to brace the shipping container in the moving truck. Metal brackets were used for support on the vibration table.

Lansmont Corporation's Vibration Table and System Station were used to

simulate the transportation environment encountered by the EDR in the truck. The

System Station was a computer which was simply programmed by touching the monitor

[11]. The System Station was used to drive the vibration table.

CHAPTER 3

EXPERIMENTAL PROCEDURES

3.1 Experimental Design

It was the opinion of this investigator prior to the test that neither the type of cereal nor the orientation of the package in the shipping container would have any significant effect on the amount of settling. Nevertheless, when designing this experiment, it was very important to make certain that the test would not be biased in any way. In order to test this hypothesis, two types of cereal were used. There were also two positions in the shipping container that the cartons could set. When taking the measurements, care was taken to do so in a manner that neither of these factors could be said to have any influence on the conclusion of the experiment. Statistically speaking, the experiment was designed so that the factors were not confounded. An example of confounding a factor would be if the six measurements of settling from the first run were all taken from cartons on the top layer and the second set of measurements were taken from the cartons positioned on the bottom of the shipping container. At the conclusion of the experiment one must then ask if the orientation of the package had any influence on the settling. As this example illustrates, this is the reason for careful planning and designing of the experiment. For the actual

transportation phase of this study, six cartons of cereal were removed after each trip.

The patterns in which the cereal was removed is illustrated in Table 1 and Table 2.

Table 1.   Pattern of Removing Cereal from Shipping Container
            in the Actual Transportation TRIPS 1 and 3.

Package	Cereal Type	Package Orientation
1	bran	top
2	bran	top
3	bran	bottom
4	flake	top
5	flake	top
6	flake	bottom

Table 2.   Pattern of Removing Cereal from Shipping Container
            in the Actual Transportation TRIPS 2 and 4.

Package	Cereal Type	Package Orientation
1	bran	top
2	bran	bottom
3	bran	bottom
4	flake	top
5	flake	bottom
6	flake	bottom

The data collection for the simulated transportation environment was conducted in much the same way as previously explained for the actual transportation data. The difference was that only four cartons of cereal were removed and inspected for damage rather than six. Of these four cartons of cereal, two were flake cereal and two were bran cereal. Also, two of the four cartons were from the top and two from the bottom of the shipping container.

In addition, all of the measurements for the actual transportation were done on the same day and the weather conditions were fair all day. The measurements for the simulated transportation were also taken on the same day. Therefore, time, weather or driving conditions were not considered factors in this experiment.

3.2 Programming the Environmental Data Recorder

An EDR was used to record the vibration in the rear of the truck for the actual transportation environment. Prior to mounting the EDR in the rear of the truck, it had to be programmed. The Dyna Max software, which was also leased by IST, Inc., was used to do the programming. Several parameters needed to be adjusted before use. Such programming is referred to as setting the Recording Control Parameters (RCPs) in the manual provided by the manufacturer. The RCPs had to be carefully determined to assure that a representation of the entire trip was recorded. It is the user's responsibility to be sure that the memory capabilities of the recording device was not exceeded. This particular EDR had a memory of 3550 KBytes.

The route of transportation chosen was sixty-six miles in length. The maximum

length of time to complete one trip was estimated to be eighty-five minutes. Taking

into consideration the time it would take to complete the trip, an engineer of IST was

consulted to aid in determining how the RCPs were programmed [7]. Not all of the

parameters had to be changed. The most important were those which determined the

length of recording time (the time to complete the trip). Essentially, a simple

calculation was used to determine three of the parameters. These parameters included

the event length, dead time, and the number of events. Equation 1 was used to

determine these parameters.

Recording Time = Events(Dead Time + Event Length)   (1)

Because the trip would take an estimated 85 minutes, the parameters were selected by

trial and error in order to maximize the length of recording time. The Event Length

was the time (seconds) that the EDR would record an event and the Dead Time was the

time (seconds) that the EDR would shut off between recordings. The Events was the

number of events that the EDR was capable of recording. The maximum number of

events was given as 850 by an engineer of IST,Inc [7]. As indicated in the EDR

Manual provided by IST, the EDR had to be set in the overwrite recording mode in

order to construct a PSD [9]. This means that the device will automatically begin

recording over the start of its memory when the length of recording time has been

exceeded. Consequently, it was imperative to use a length of time believed to be the

maximum to complete one trip while at the same time taking into consideration that

excess time would be a waste of recording space. The trigger level is the lowest G-

level that will be recorded. The RCPs were programmed as indicated in Table 3. The

memory required for recording the information is shown in Table 4. As indicated in Table 5, two of the RCPs were changed from their initial setting as shown in Table 3. The Dead Time and Event Length were switched. The reason for doing this was to determine if these parameters had any significant influence on the PSD plots generated in each of the trips. The parameters which were changed are highlighted in each table. Table 6 shows the memory requirements of the EDR for the RCPs shown in Table 5.

Table 3. Recording Control Parameters TRIP1

PARAMETER	PROGRAMMING
Accelerometer Sample Rate	1024 samples/second
Trigger Level	0.1 G
Trigger Duration Thresh	0.0391 seconds
Pre-Trigger Length	512 (0.5) seconds
Post-Trigger Length	512 (0.5) seconds
Accelerometer Input Selection	internal
Recording Mode	overwrite
Number of Events	850 events
Dead Time After Event	4 seconds
Event Length	2 seconds

Table 4. Memory Requirements TRIP 1

Acceleration Data	3410.8 KBytes
Temperature Data	0.3 KBytes
Total Required Memory	3343.1 kBytes

Table 5. Recording Control Parameters TRIP2

PARAMETER	PROGRAMMING
Accelerometer Sample Rate	1024 samples/second
Trigger Level	0.1 G
Trigger Duration Thresh	0.0391 seconds
Pre-Trigger Length	512 (0.5) seconds
Post-Trigger Length	512 (0.5) seconds
Accelerometer Input Selection	internal
Recording Mode	overwrite
Number of Events	850 events
Dead Time After Event	2 seconds
Event Length	4 seconds

Table 6. Memory Requirements TRIP 2

Acceleration Data	3441.2 KBytes
Temperature Data	0.3 KBytes
Total Required Memory	3343.1 kBytes

3.3 The Actual Transportation Environment

The intention of this portion of the study was to re-create the actual

transportation environment as near to the real one as possible. Cereal is generally

distributed via a semi-trailer mode of transportation and so a ten foot truck was used to

re-create the actual transportation environment. Primarily because of financial

restraints, a larger truck was not used. The corrugated container with the twenty-four,

twenty ounce cartons of cereal was placed in the rear of the rental truck. The

corrugated container was secured in place using two wooden beams. The two beams

were placed horizontally across the width of the truck on either side of the corrugated

container.

The EDR was mounted in the truck with the aid of magnets. The EDR was

mounted at the rear of the truck as near to the shipping container as possible. The

reason for placing the EDR near the container was to record the same ride that the

product experienced. The path which was driven for each of the four trips was

identical and is explained in detail below:

-Started at the Packaging building's loading dock.

-Turned left, or west, onto Wilson Road.

-Turned left, or south, onto Harrison Road.

-Turned right, or west, onto Trowbridge Road.

-Entered the U.S. 127 South expressway.

-Took Interstate 96 West for approximately 20 miles to the Portland Exit. At the exit turned right, then left into the McDonald's parking lot.

-From the parking lot, turned right onto to the road and then entered the I-96 East expressway by turning left.

-Took I-96 East toU.S.127 North.

-Exited U.S. 127 North at the Trowbridge Road exit.

-Turned left, or north, onto Harrison Road.

-Turned right, or east, onto Wilson Road.

-Returned to the Packaging building.

This entire trip was sixty-six miles in length. This path was chosen because the expressway, for the most part, was under construction. All of the driving occurred on Friday, October 7, 1994.

After each trip, six cartons of cereal were removed from the corrugated container to be inspected for damage and then returned to the container before the next trip. The damage criteria will be discussed in section five of this chapter.

As previously discussed, the PSD plots for the first two trips were generated by the EDR. The PSD plots for TRIP 1 and TRIP 2 are shown in Figure 2 and Figure 3, respectively. Immediately following the first run, the EDR was switched to standby mode. In this standby mode, all of the data from the trip was preserved and could not be over written. The EDR was connected directly to a computer and the data information uploaded as directed in the Dyna Max User Operating Manual.
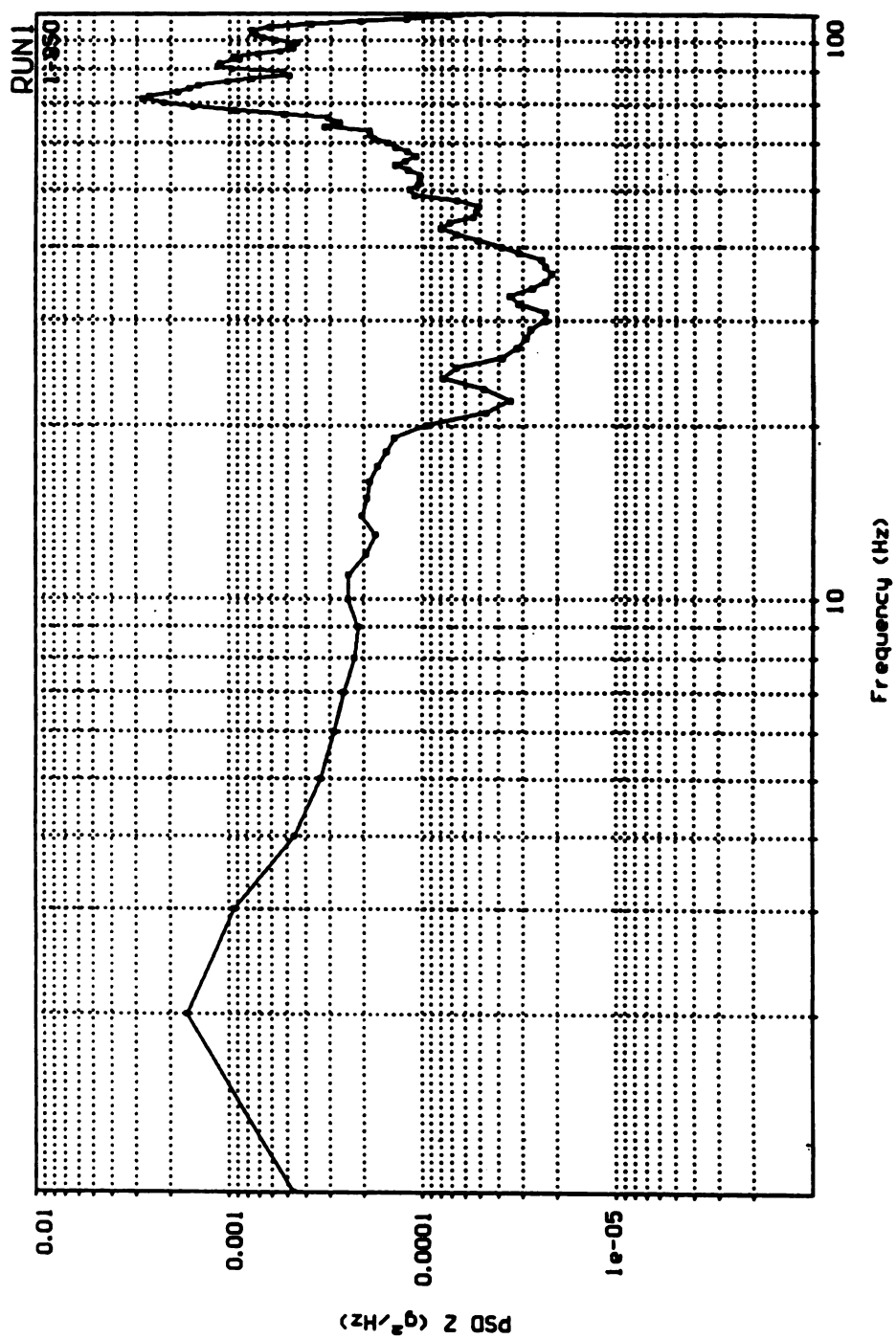
Figure 2. PSD Plot of TRIP 1
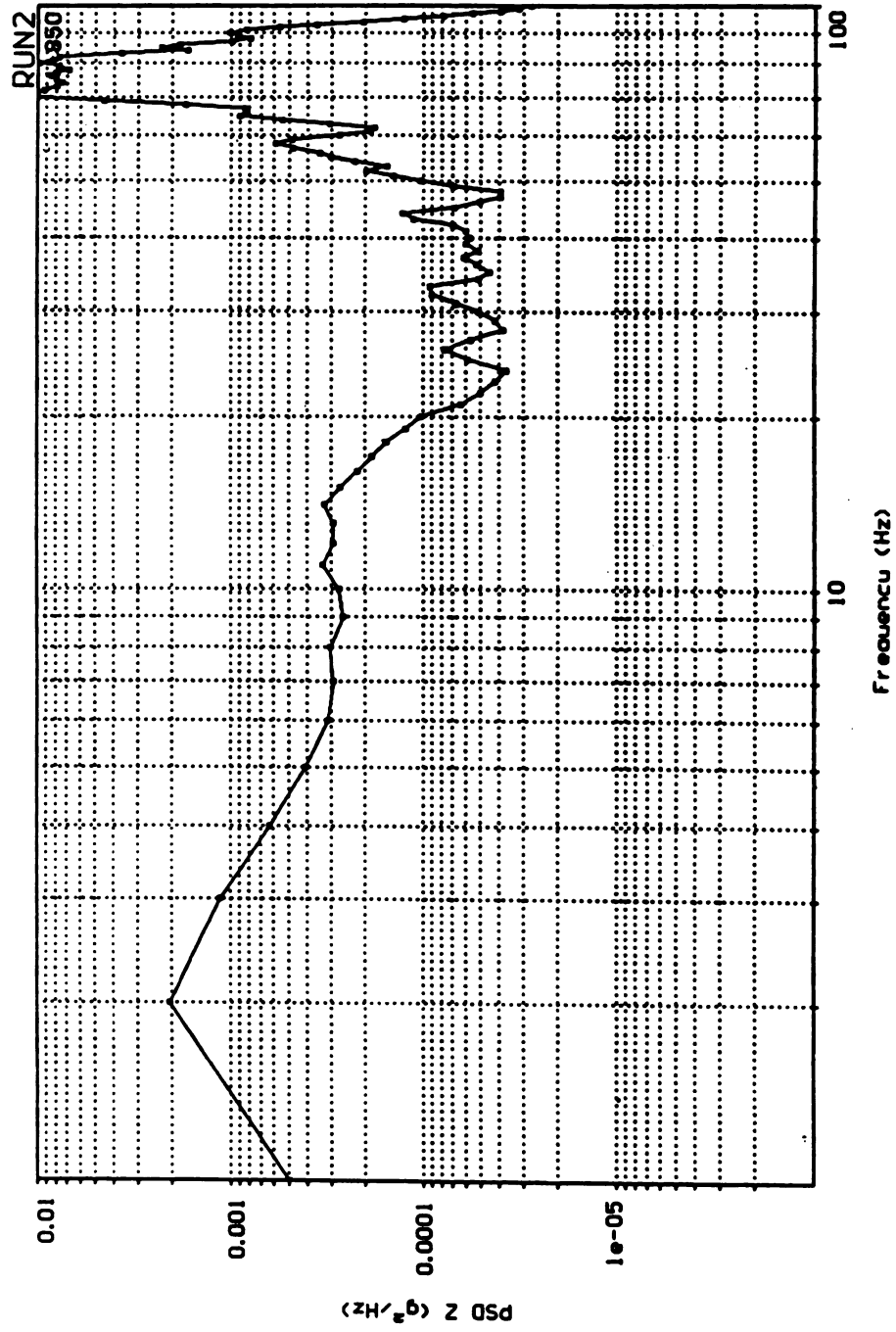
Figure 3. PSD Plot of TRIP 2

3.4 The Simulated Transportation Environment

The vibration table was used in the laboratory to simulate the ride recorded by the EDR on the ten foot truck. Power density and frequency data had to be retrieved from the PSD plot in order to program the vibration table. This was accomplished by using the Dyna Max software and the PSD plot from TRIP 2 to determine the Power Density (G^2/Hz) values for the first fifty frequencies. Although there was not a significant difference between the two PSD plots generated in the Actual Transportation Environment, the PSD from TRIP 2 did have slightly higher PD values than in TRIP 1. For this reason, the PSD values from TRIP 2 were used to program the vibration table for the Simulated Environment. The frequencies used were from 1 Hz to 49 Hz in increments of 1Hz. Table 7 represents the data that was used to program the vibration table. The data was entered into the Touch Test Vibration System Station manually. The raw data from the EDR can be found in Appendix A.

Again, the test specimens under investigation were packaged as intended for shipment. Twenty-four cartons of cereal, not the same as previously tested, were packaged into the same corrugated container as used in the actual transportation environment. Restraining devices were attached to the vibration table to prevent the corrugated container from moving freely. This method of restraint was used to mimic the wooden beams used in the truck to secure the container.

Table 7. PSD Data Used to Program the Vibration Table

FREQUENCY (Hz)	POWER DENSITY (G^2/ Hz)
1	0.000469
2	0.001680
3	0.000946
4	0.000464
5	0.000338
6	0.000288
7	0.000255
8	0.000226
9	0.000216
10	0.000241
11	0.000242
12	0.000196
13	0.000174
14	0.000207
15	0.000193
16	0.000187
17	0.000171
18	0.000153
19	0.000140
20	0.000096
21	0.000047
22	0.000035
23	0.000048
24	0.000078
25	0.000067
26	0.000039
27	0.000033
28	0.000029
29	0.000028
30	0.000023
31	0.000023
32	0.000032
33	0.000036
34	0.000027
35	0.000023
36	0.000022
37	0.000023
38	0.000024
39	0.000032
40	0.000039
41	0.000051
42	0.000066
43	0.000080
44	0.000072
45	0.000055
46	0.000053
47	0.000051
48	0.000066
49	0.000110

According to ASTM D-4728-87, the random vibration test can be stopped at predetermined times to inspect for damage [5]. For this investigation the predetermined interval of time was ten minutes. Because the entire length of the actual trip was 335 minutes, ten minutes was thought to be appropriate.

After each trial, which will be defined as each ten minute interval, the vibration table was stopped and four cartons of cereal were removed and inspected for damage. Of these cartons, two were from the top layer and two were from the bottom layer. Also, two of the cartons were flake cereal and two were bran cereal. These cartons of cereal were inspected for damage and placed back into the container to keep the organization of the package intact. This test was continued until the amount of settling was near that of the worst condition measured in the actual transportation portion of this study.

3.5 Damage Criteria

For this experiment, a product was chosen where damage criteria could be easily defined. Cereal settles during distribution. It is often noted by the manufacturer of the product, on a flap of the carton, that the product is sold by weight and not by volume to reflect this fact. Furthermore, such a statement usually indicates that some settling of the contents may occur during shipment and handling. For purposes of this investigation, the damage criteria was taken to be the amount of settling and was simply gauged by measuring the displacement of the cereal over time in the carton. Figure 4 helps to show how the settling of the cereal was measured. Prior to testing,

the outline of the cereal was traced using a marker. This line was not a horizontal one, but irregular as shown in Figure 4. The height of the cereal was measured prior to testing. This height was actually an average of the ten heights taken at the locations marked with an X in Figure 4. After testing, the height of the cereal was determined again. This height was also an average of ten heights. Settling was defined as the difference between the average height prior to testing and the average height after testing. The ruler used to measure was heights graduated in 1/16ths of an inch. Therefore, the error would be about 1/32nd of an inch.

Figure 4. Measuring of Settling of the Cereal
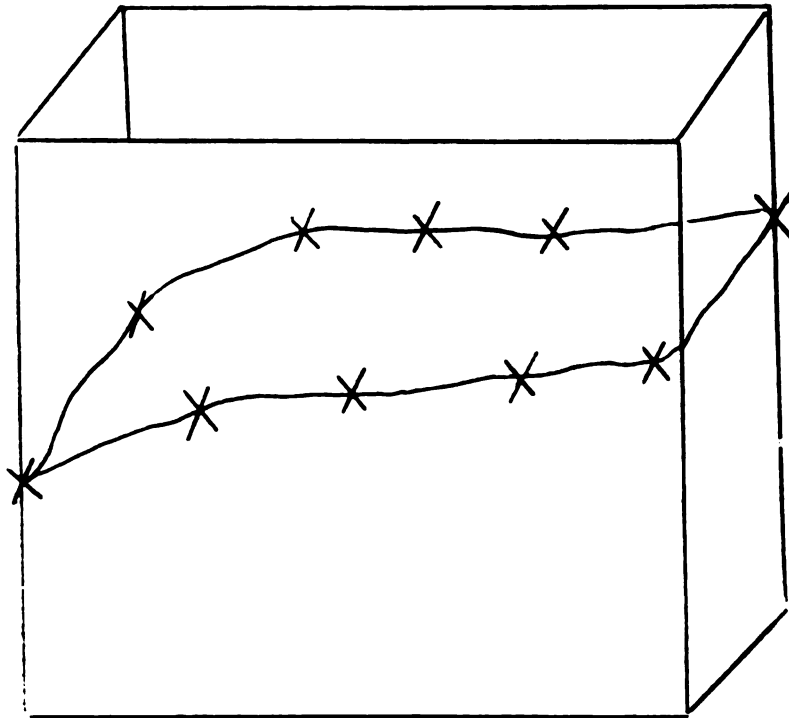
CHAPTER 4

DATA AND RESULTS

4.1 Data From the Actual Transportation Environment

Four of the same sixty-six mile trips were driven to re-create an actual

transportation environment for the cereal. After each trip, six cartons of cereal were

removed and the average amount of settling for each was determined. Ten

measurements of settling were taken for each carton of cereal to determine the

average. Again, settling was calculated by determining the average height of the cereal

prior to testing and subtracting from it the average height of the cereal after testing.

The average settling for each trip was calculated by computing the mean of the settling

for the six cartons of cereal.

Trip 1 took 82 minutes to complete. The speed of travel for Trip 1 was

determined to be an average of 48.29mph. The settling data for Trip 1 is shown in

Table 8. Table 9 shows the settling data for Trip 2. The second trip took 88 minutes

to complete for an average speed of 45mph. Table 10 contains the settling data for

Trip 3. The third trip took 81 minutes to complete for an average speed of 48.9mph.

Finally, the settling data for the fourth trip, Trip 4, can be found in Table 12. Trip 4

took 84 minutes to complete and the average speed was 47.14mph.

Table 8. Settling Data For Trip 1

Package	Cereal Type	Package Position	Average Settling (inch)
1	bran	top	0.24
2	bran	top	0.29
3	bran	bottom	0.26
4	flake	top	0.27
5	flake	top	0.34
6	flake	bottom	0.29
Average Settling For Trip 1 0.28 inches			

Table 9. Settling Data For Trip 2

Package	Cereal Type	Package Position	Average Settling (inch)
1	bran	top	0.51
2	bran	bottom	0.59
3	bran	bottom	0.42
4	flake	top	0.58
5	flake	bottom	0.44
6	flake	bottom	0.44
Average Settling For Trip 2 0.49 inches			

Table 10. Settling Data For Trip 3

Package	Cereal Type	Package Position	Average Settling (inch)
1	bran	top	0.62
2	bran	top	0.78
3	bran	bottom	0.69
4	flake	top	0.73
5	flake	top	0.78
6	flake	bottom	0.74
Average Settling For Trip 3 0.72 inches			

Table 11. Settling Data For Trip 4

Package	Cereal Type	Package Position	Average Settling (inch)
1	bran	top	0.76
2	bran	bottom	0.79
3	bran	bottom	0.74
4	flake	top	0.83
5	flake	bottom	0.73
6	flake	bottom	0.91
Average Settling For Trip 4 0.79 inches			

Figure 5 is a plot of the amount of settling of the cereal over time in the Actual

Transportation Environment. Each point is the average of six replications. Recall that

six cartons of cereal were removed and the amount of settling measured after each trip.

The four points on the plot represent the averages of settling from each trip.

Regression analysis was performed to find the slope of the line. The slope was found

to be 0.0024 inches/minute.

Figure 5. Actual Transportation Environment Settling Versus Time
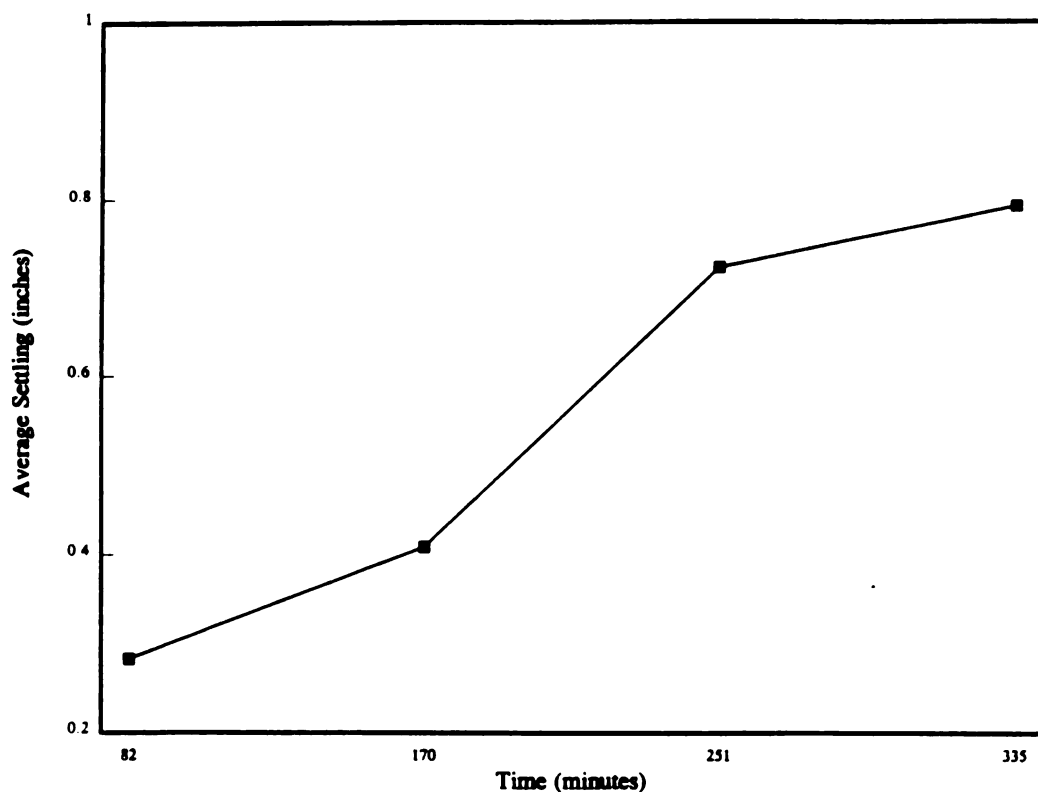
Recall that one expectation in this experiment was that neither the cereal type nor the orientation of the package in the corrugated container would have any significant influence on the amount of settling. In order to show how this factor affected the settling, the data for each trip has also been averaged for each cereal type (bran and flake) separately and for each position within the corrugated container (top or bottom). These averages for TRIPS 1, 2, 3 and 4 were tabulated and are shown in Tables 12, 13, 14 and 15, respectively. Furthermore, to compare the amount of settling over time for each of these factors, this data was also plotted. Figure 6 depicts the amount of settling versus time for bran cereal, for flake cereal, and for cartons in the top and bottom layers of the corrugated container. Using linear regression, the slopes of each of these graphs were determined and compared to the slope for Figure 5. All slopes were approximately 0.0024 inches/minute suggesting that neither the type of cereal nor the orientation of the carton had any influence on the settling of the product.

Table 12. Average Settling Per Trip For Bran Cereal

Trip	Average Settling (in)
1	0.26
2	0.51
3	0.70
4	0.77

Table 13. Average Settling Per Trip For Flake Cereal

Trip	Average Settling (in)
1	0.30
2	0.49
3	0.73
4	0.82

Table 14. Average Settling Per Trip For Cartons In Top Position

Trip	Average Settling (in)
1	0.29
2	0.54
3	0.73
4	0.79

Table 15. Average Settling Per Trip For Cartons In Bottom Position

Trip	Average Settling (in)
1	0.28
2	0.47
3	0.72
4	0.79

Figure 6. Settling Versus Time For Bran Cereal, Flake Cereal, Cartons In the Top
and Bottom Position
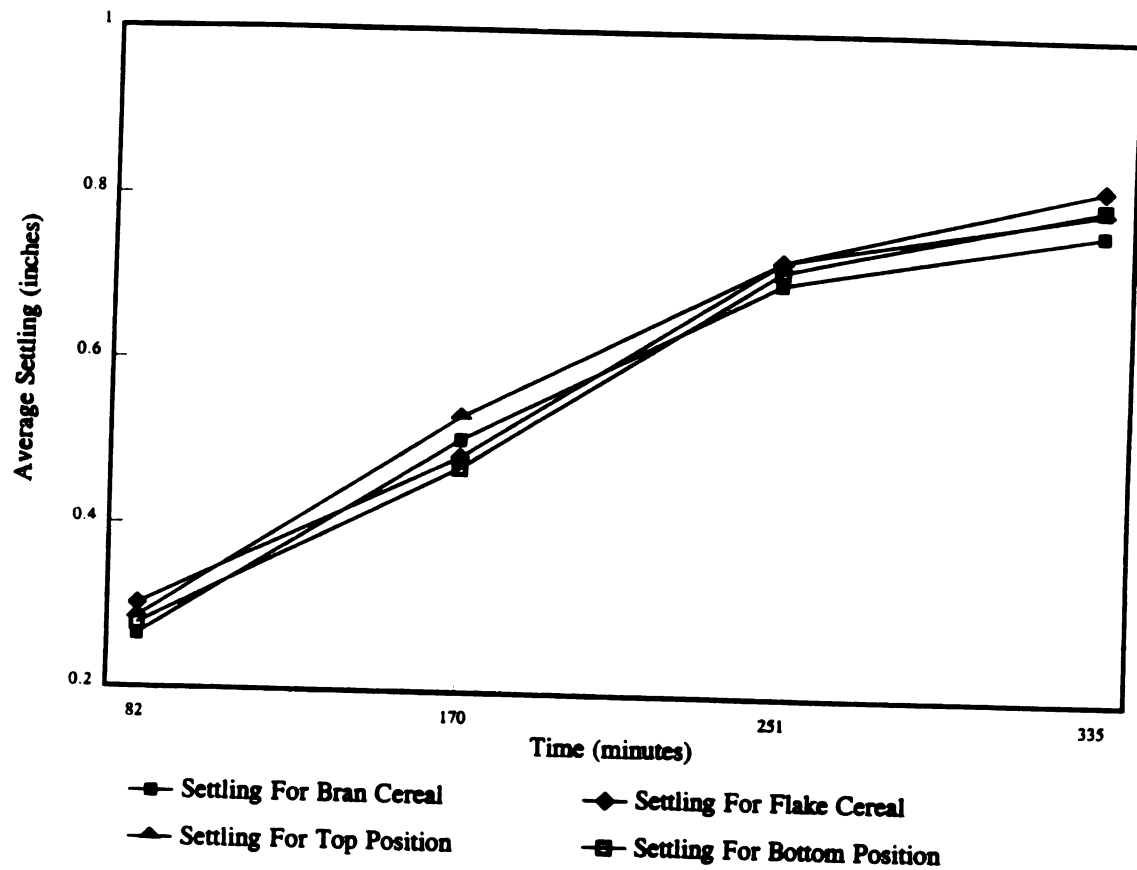
4.2 Data From the Simulated Transportation Environment

Table 16 represents the settling data for the cereal under the simulated conditions. As indicated in Table 16, the measurements were taken every ten minutes. After each ten minute interval, which will be referred to as a trial, four cartons of cereal were removed and the measurements of settling taken. Again the average amount of settling for each carton of cereal was determined by computing the mean of ten measurements. For each interval of time, or trial as it is referred to in Table 16, the average settling was computed for the four cartons of cereal.

After the first six trials, the settling for all twenty-four cartons had been measured once. For the remainder of the trials, sixteen cartons of cereal were re-examined for settling. It is important to note here that some error in the settling for trials 7, 8, 9 and 10 may be attributed to the fact that the cartons of cereal had been measured previously. Furthermore, the data indicates that a correlation can be made for the data from the first six trials of the test. However, the data from trials 7, 8, 9 and 10 seem to agree with the correlation of the data for the first six trials which suggests that the re-measuring of the data did not have a significant effect on the measurements.

Figure 7 is a plot of the displacement of cereal over time in the simulated transportation environment. Regression analysis was also performed to determine the slope of the line generated by the data in Table 16. The slope of the line was 0.007 inches/minute.

As in the Actual Transportation phase of this experiment, the data here was also

averaged according to the type of cereal (bran or flake) and the orientation which the carton was placed in the corrugated container (top or bottom). The data was separated in this manner to show if either of these factors had any influence on the settling of the cereal. For each trial, or each ten minute interval, the average amount of settling for the bran cereal is shown in Table 17. This data was plotted versus time in Figure 8. The average settling per trial for the flake cereal was computed and is shown in Table 12 and plotted in Figure 8. The average settling per trial for the cartons in the top and bottom positions are shown in Table 19 and Table 20, respectively. Figure 8 also charts the average settling over time for the cartons in the top and bottom positions, respectively. The slopes of the lines in Figure 8 where computed by linear regression and compared to the slope of the line in Figure 7. All slopes were approximately 0.007 inches/minute which suggests that none of the factors had any significant effect on the settling of the cereal.

Table 16. Settling Data From Simulated Environment

Trial	Time (minutes)	Package	Cereal Type	Package Orientation	Average Settling (inches)
1	10	1	bran	top	0.14
		2	flake	top	0.15
		3	bran	bottom	0.13
		4	flake	bottom	0.14
Average Settling For Trial 1 is 0.14 in					
2	20	1	bran	top	0.21
		2	flake	top	0.22
		3	bran	bottom	0.23
		4	flake	bottom	0.21
Average Settling For Trial 2 is 0.22 in					
3	30	1	bran	top	0.33
		2	flake	top	0.29
		3	bran	bottom	0.32
		4	flake	bottom	0.28
Average Settling For Trial 3 is 0.30 in					

Table 16. (cont'd)

Trial	Time (minutes)	Package	Cereal Type	Package Orientation	Average Settling (inches)
4	40	1	bran	top	0.35
		2	flake	top	0.38
		3	bran	bottom	0.39
		4	flake	bottom	0.33
Average Settling For Trial 4 is 0.36 in					
5	50	1	bran	top	0.39
		2	flake	top	0.43
		3	bran	bottom	0.39
		4	flake	bottom	0.43
Average Settling For Trial 5 is 0.41 in					
6	60	1	bran	top	0.53
		2	flake	top	0.51
		3	bran	bottom	0.51
		4	flake	bottom	0.47
Average Settling For Trial 6 is 0.51 in					

Table 16. (cont'd)

Trial	Time (minutes)	Package	Cereal Type	Package Orientation	Average Settling (inches)
7	70	1	bran	top	0.53
		2	bran	top	0.56
		3	flake	bottom	0.57
		4	flake	bottom	0.57
Average Settling For Trial 7 is 0.56 in					
8	80	1	bran	top	0.71
		2	bran	top	0.63
		3	flake	bottom	0.59
		4	flake	bottom	0.60
Average Settling For Trial 8 is 0.63 in					
9	90	1	bran	top	0.74
		2	bran	top	0.77
		3	flake	bottom	0.80
		4	flake	bottom	0.73
Average Settling For Trial 9 is 0.76 in					

Table 16. (cont'd)

Trial	Time (minutes)	Package	Cereal Type	Package Orientation	Average Settling (inches)
10	100	1	bran	top	0.80
		2	bran	top	0.77
		3	flake	bottom	0.76
		4	flake	bottom	0.84
Average Settling For Trial 10 is 0.79 in					

Figure 7. Settling Versus Time For the Simulated Environment
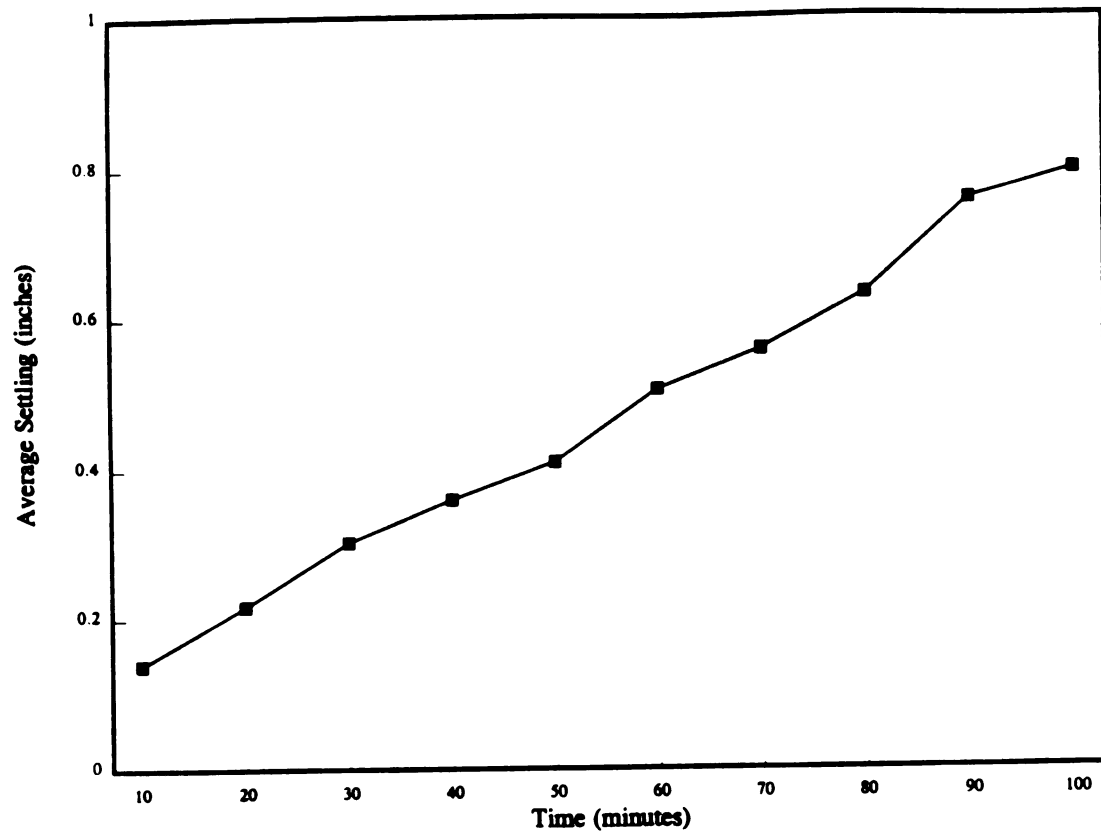
Table 17. Average Settling Per Trial For Bran Cereal

Trial	Average Settling (in)
1	0.13
2	0.22
3	0.32
4	0.37
5	0.39
6	0.52
7	0.55
8	0.65
9	0.77
10	0.78

Table 18. Average Settling Per Trial For Flake Cereal

Trial	Average Settling (in)
1	0.14
2	0.21
3	0.30
4	0.35
5	0.43
6	0.49
7	0.57
8	0.61
9	0.75
10	0.81

Table 19. Average Settling Per Trial For Cartons In Top Position

Trial	Average Settling (in)
1	0.14
2	0.22
3	0.31
4	0.36
5	0.41
6	0.52
7	0.55
8	0.67
9	0.75
10	0.79

Table 20. Average Settling Per Trial For Cartons In Bottom Position

Trial	Average Settling (in)
1	0.14
2	0.22
3	0.29
4	0.36
5	0.41
6	0.49
7	0.57
8	0.59
9	0.76
10	0.80

Figure 8. Settling Versus Time For Bran Cereal, Flake Cereal, Cartons In the Top and Bottom Positions

Time (minutes)

—■— Settling For Bran Cereal   —◆— Settling For Flake Cereal

—▲— Settling For Top Position   —☐— Settling For Bottom Position
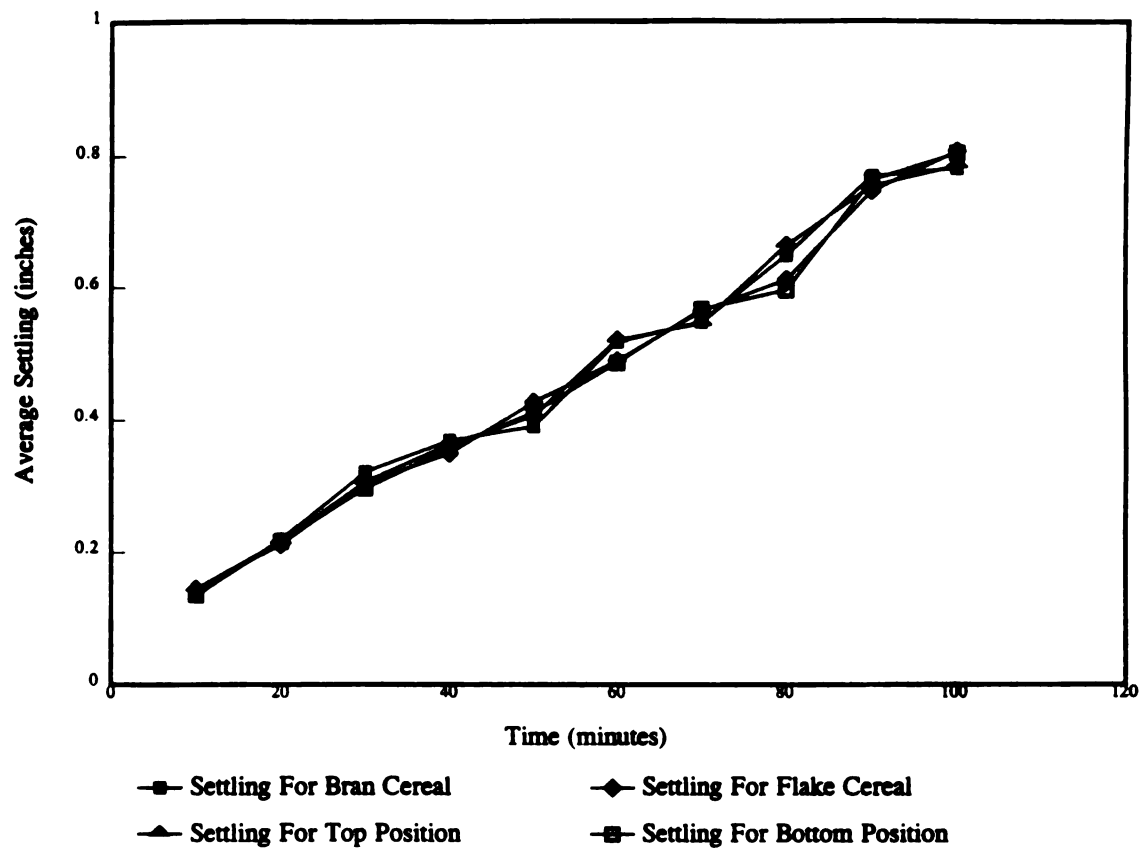
4.3 Correlating Road Time ToTable Time

As shown in the data for the Actual Transportation Environment and the Simulated Environment, neither the type of cereal nor the orientation of the package in the corrugated container proved to be a significant factor in the settling of the cereal. Therefore, the data used for correlation purposes was that which was not separated for these factors.

Figure 9 represents the correlation of the data between the Actual and Simulated environments. For this particular study, having a criteria such as settling makes determining the "damage" easy. The reason the line for the Actual Transportation Environment begins so late is because the first trip took 82 minutes to complete. Also, the data for this line is so infrequent because the points represent the data for each of the four trips.

For illustration purposes, if the correlation between table time and transportation time was known, one could use this information to gauge the damage. This could be an extremely valuable tool in determining the appropriate amount of time a package/product system should be on the vibration table for a known distribution time. For example, if the actual distribution time is 240 minutes then the amount of settling is approximately 0.6" and so the time necessary to re-create this amount of settling on the vibration table is approximately 80 minutes from Figure 9. It takes approximately 50 minutes on the vibration table and 135 minutes in the truck for the cereal to settle 0.4 inches. This graph shows that there is not a one to one relationship between transportation time and table time. The correlation is more like 2:1 to 3:1.

Based on the slopes in Figure 5 and Figure 7 obtained from regression analysis the

correlation suggested here for cereal is 0.007/0.0024 which is about 3 to 1.

Figure 9. Correlation of Actual and Simulated Data

— Settling in Simulated Environment   ◆ Settling in Actual Environment
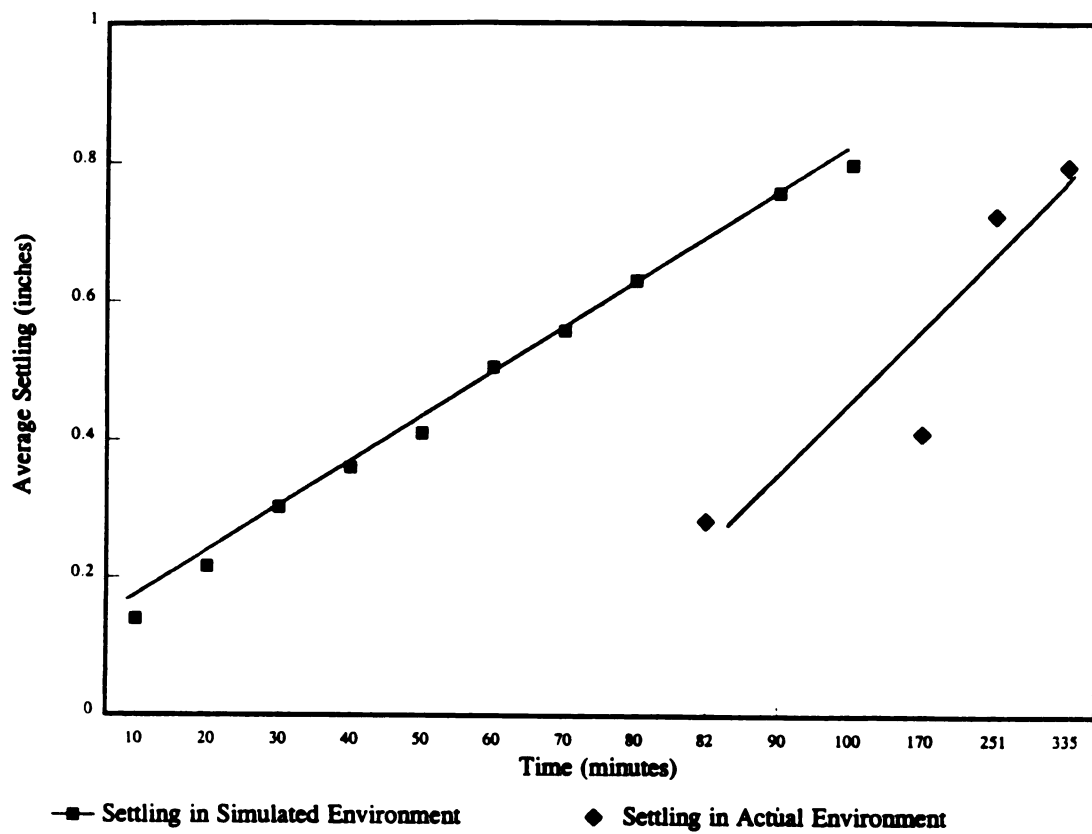
CHAPTER 5

SUMMARY AND CONCLUSIONS

The focus of this research was to determine if a correlation between vibration table time and actual transportation time could be found. As previously described, an EDR was used to record the vibration environment in a ten foot truck. Because the rear of the truck has been shown to have the highest acceleration levels, the EDR and the package/product system were positioned in he rear of the truck [1]. The Dyna Max software was used to plot the PSD from the actual transportation environment. The vibration table was able to simulate the transportation environment by entering the PSD data via the Touch Test Vibration System Station control panel. The method described here coincides which Method A, closed loop- automatic equalization, of the ASTM standard D-4728 for Random Vibration Testing of Shipping Containers [5].

The EDR was a dimple device to use. Programming the RCPs was , perhaps, one of the more difficult aspects of the experiment. Fortunately, changing the RCPs had little effect on the PSD plot. Recall that the times for the Event Length and the Dead Time were switched in TRIP 1 and TRIP 2. In TRIP 1 the Event Length was 2 seconds and the Dead Time was 4 seconds. In TRIP 2 the Event Length was changed to 4 seconds and the Dead Time to 2 seconds. Both of the plots were made on the

same scale for comparison purposes. When overlaying the two plots they were very similar between frequencies 1Hz and 50 Hz. The largest difference between the two graphs was approximately 0.0004 G^2/Hz which occurred at 2 Hz. There are other areas which appear to have larger discrepancies, but because the PSD plot is on a log-log scale, some of the differences appear large but are actually orders of magnitude less than that at 2 Hz.

It appeared that altering the Event Length and Dead Time parameters had no significant effect on the PSD plots. One explanation may be that the 2 second window of time in which the event was recorded was long enough.

The Touch Test Vibration System Station control panel was capable of receiving a total of fifty entries for the PSD plot. In this study, the PD values for only the first fifty frequencies, 1 Hz to 49 Hz, were determined using the Dyna Max software. For frequencies greater than 49 Hz the PSD plots from the Actual Transportation Environment show a graph with several peaks. These peaks may indicate that there was some other source of vibration than that produced from the road. This other influence of vibration could be from the flexing of the metal to which the EDR was magnetically fixed. If the PD values for every 2 Hz had been entered into the Touch Test Vibration System Station control panel, a PSD representative of the entire PSD from the Actual Transportation Environment would have been used. This means that the PD values for the frequencies 2 Hz to 100 Hz, in increments of 2 Hz, would have been determined. The reason for using the PD values for frequencies 1 Hz to 49 Hz was to avoid using the PD values at the higher frequencies which seemed more severe

than what actually happened in the truck. Again, these high PD values may be attributed to the flexing of the metal floor to which the magnets on the EDR were attached. Evidently, the Simulated Environment can in no way re-produce the exact vibration which occurred in the Transportation Environment. Also, it becomes evident that it is a very difficult task to determine what data to use from the Actual Transportation Environment in attempting to re-create it on the vibration table.

Product damage is the criteria that should be used to correlate Transportation Time to the Vibration Table Time. For this investigation a product was chosen where damage could be easily assessed. Measuring the settling, or displacement of the cereal, over time was a seemingly simple way to evaluate the damage for cereal. It is important to realize, however, that it is not always easy to define damage criteria for products.

Specifically, the findings of this research are as follows:

1.   The average settling for cereal is 0.0024 inches / minute for the Actual Transportation Environment.

2.   The average settling for cereal is 0.007 inches / minute for the Simulated Transportation Environment.

3.   Neither the type of cereal (bran or flake) nor the position of the carton in the shipping container (top or bottom) had any effect on the average settling of the cereal. This was true for both the Actual and Simulated Environments.

4.   Based on findings in 1 and 2 above, it took approximately one-third of the transportation time to simulate the same amount of settling on the vibration table for the product, mode of transportation, and route of transportation used in this study.

The findings of this research support the notion that the vibration table is a time-

saving device. In fact, the evidence in this study shows that the vibration table was capable of creating the same amount of damage as the actual transportation environment, in one-third of the time. Although justification for the vibration table is not necessary, it is interesting to note that if the findings of this research were applicable for all product/package systems and routes of automotive transportation, the vibration table would certainly be worth its cost.

Although there may be flaws with the techniques used in this experiment, the fact remains that the relationship between transportation time and vibration table time is not an equal one. It has become quite apparent that determining a correlation is an extremely complex task. There are literally hundreds, maybe thousands, of experiments which could be done to check the major finding of this research, that transportation time and vibration table time are not equal. Different products and routes of transportation could be used in further attempts to find some correlation. Also, different modes of transportation could be investigated. It would certainly be worthwhile to study other products. One idea would be to use a granular product such as salt, sugar, or flour and measure the amount of product breakup due to vibration. The amount of breakup could be measured using different size sieves. Another example of future work may include overlaying real time (G versus time) plots of actual versus vibration table and determine if a 3:1 relationship can also be found.

There are some questions which were raised in the process of doing this thesis which are not answered here but, perhaps, may be in the future. Since correlation between transportation time and vibration table time is not 1:1, is simulation on the

vibration table merely a matter of using less test time, or should PD levels be decreased? What are the effects of the random controller giving the table the same frequencies and same amplitudes but in a different order? Also, what effect does the PSD data have since the process of generating this data is one of averaging out the small vertical accelerations?

Needless to say, there are numerous options for packaging professionals and students to investigate in the world of vibration. Whether the product be a stereo component, computer, apples or cereal, the effects of vibration should always play a role in determining how the product should be protected.

As described in this thesis, the need for simulating the distribution environment is a tremendous one. The problem with simulation is determining the length of time the product needs to be on the vibration table to get comparable damage in reproducing the actual transportation environment. Simulating the actual environment incorrectly could have some harsh consequences. If the simulated environment is too severe, one may find that more packaging material than necessary is needed to protect the product and so packaging cost rises. The consequence of under-packaging can also be a costly one in terms of product damage.

The findings of this research in no way suggest that the vibration table time is, at all times, one-third of the actual transportation time but that these times are not equal. For the particular product, mode of transportation, and route of transportation in this study, this was certainly the case. The method outlined in this research is definitely applicable to other sets of conditions.

APPENDIX

APPENDIX - EDR DATA

EVENT	DATE MM-DD-YY	TIME HH-MM-SS	MEAN x G's	MEAN y G's	MEAN z G's	PEAK x G's	PEAK y G's	PEAK z G's
850	9-23-94	15-25-30	0.000	0.003	-0.002	0.165	0.039	0.298
310	9-23-94	14-28-59	0.038	0.005	-0.024	0.594	0.141	0.633
61	9-23-94	14-12-4	0.022	-0.012	-0.052	0.971	0.014	0.940
710	9-23-94	15-6-25	0.029	-0.002	-0.043	0.722	0.116	0.764
848	9-23-94	15-20-31	0.019	0.004	-0.026	0.646	0.090	0.660
70	9-23-94	14-12-32	0.050	0.002	-0.068	0.057	0.115	0.631
485	9-23-94	14-50-41	0.041	0.003	-0.067	0.544	0.090	0.711
538	9-23-94	14-56-4	0.053	-0.004	-0.052	0.417	0.090	0.710
118	9-23-94	14-16-56	0.079	-0.001	-0.033	0.543	0.090	0.684
300	9-23-94	14-27-57	0.032	0.005	-0.090	0.442	0.090	0.969
327	9-23-94	14-30-19	0.039	0.006	-0.074	0.468	0.116	0.762
78	9-23-94	14-13-12	0.041	-0.008	-0.053	0.517	0.141	0.760
443	9-23-94	14-47-51	0.019	0.014	-0.063	0.392	0.090	0.763
117	9-23-94	14-16-47	0.031	0.002	-0.047	0.644	0.141	0.942
475	9-23-94	14-49-55	0.053	0.010	-0.069	0.418	0.064	0.685
384	9-23-94	14-35-7	0.015	0.001	-0.067	0.468	0.090	0.839
100	9-23-94	14-14-39	0.056	0.008	-0.060	0.645	0.115	0.734
519	9-23-94	14-54-4	-0.016	-0.002	-0.073	0.444	0.090	0.711
374	9-23-94	14-34-38	0.032	0.003	-0.068	0.518	0.116	0.633
497	9-23-94	14-52-25	0.037	-0.002	-0.066	0.443	0.090	0.685
303	9-23-94	14-28-25	0.062	-0.003	-0.073	0.417	0.090	0.814
672	9-23-94	15-3-56	0.021	0.002	-0.061	0.618	0.090	0.816
352	9-23-94	14-32-39	0.031	-0.007	-0.062	0.720	0.640	0.788
436	9-23-94	14-47-14	0.037	0.005	-0.045	0.057	0.115	0.840
119	9-23-94	14-17-18	-0.032	0.002	-0.060	0.418	0.116	0.761
67	9-23-94	14-12-23	0.037	0.006	-0.042	0.569	0.116	1.069
425	9-23-94	14-46-33	0.103	0.002	-0.056	0.441	0.090	0.891
709	9-23-94	15-6-10	0.020	0.004	-0.114	0.468	0.116	0.944
714	9-23-94	15-6-38	0.037	0.000	-0.050	0.443	0.090	0.919
343	9-23-94	14-31-52	0.022	0.003	-0.057	0.367	0.116	0.839
82	9-23-94	14-13-25	0.037	-0.004	-0.047	0.367	0.090	0.812
524	9-23-94	14-54-46	0.039	0.000	-0.070	0.592	0.090	0.892
500	9-23-94	14-56-36	0.046	0.005	-0.043	0.722	0.090	0.685
28	9-23-94	14-52-40	0.029	0.005	-0.064	0.469	0.090	0.762
849	9-23-94	14-9-15	0.032	-0.003	-0.037	0.544	0.141	1.068
529	9-23-94	15-20-35	0.151	0.007	-0.061	0.693	0.167	0.893
555	9-23-94	14-55-5	0.021	0.008	-0.052	0.417	0.090	0.893
15	9-23-94	14-57-19	0.035	0.003	-0.083	0.949	0.142	0.711
341	9-23-94	14-5-59	0.098	-0.008	-0.065	0.693	0.064	1.016
829	9-23-94	14-31-46	0.027	0.002	-0.028	0.418	0.090	0.710
42	9-23-94	15-16-53	0.031	0.001	-0.063	0.444	0.142	0.970
532	9-23-94	14-10-49	0.034	-0.003	-0.058	0.718	0.167	1.095
691	9-23-94	14-55-36	0.029	0.008	-0.036	0.695	0.116	0.711
7	9-23-94	15-5-1	0.063	0.001	-0.028	0.444	0.116	0.712
349	9-23-94	14-5-34	0.146	-0.001	-0.061	0.417	0.166	0.888
675	9-23-94	14-32-20	0.041	0.001	-0.056	0.418	0.090	0.814
388	9-23-94	15-4-5	0.021	0.004	-0.060	0.518	0.116	0.660
476	9-23-94	14-35-20	0.036	0.001	-0.047	0.443	0.090	0.762
314	9-23-94	14-49-58	0.046	0.005	-0.054	0.444	0.090	0.970
537	9-23-94	14-29-27	0.011	0.003	-0.069	0.494	0.090	0.943
844	9-23-94	14-56-1	0.022	-0.002	-0.061	0.694	0.090	0.737
452	9-23-94	15-19-42	0.035	-0.001	-0.076	0.494	0.090	0.764
174	9-23-94	14-48-28	0.043	-0.001	-0.065	0.544	0.116	0.840
498	9-23-94	14-52-31	0.035	-0.003	-0.048	0.494	0.090	1.071
810	9-23-94	15-12-36	0.016	0.005	-0.100	0.564	0.116	0.763

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RMS x G's	RMS y G's	RMS z G's	DUR x seconds	DUR y seconds	DUR z seconds	VEL x ft/sec	VEL y ft/sec	VEL z ft/sec	TEMP. F
0.030	0.013	0.054	0.008	0.007	0.008	-0.025	-0.005	0.044	84.100
0.166	0.038	0.196	0.012	0.010	0.008	0.027	0.027	-0.091	81.900
0.180	0.045	0.204	0.011	0.014	0.011	0.036	0.036	-0.188	79.600
0.171	0.040	0.208	0.012	0.014	0.010	-0.026	-0.026	-0.143	84.100
0.192	0.034	0.213	0.017	0.022	0.008	-0.030	-0.030	0.103	79.600
0.139	0.038	0.218	0.012	0.025	0.009	-0.053	-0.053	-0.103	83.000
0.132	0.028	0.223	0.012	0.008	0.008	-0.014	-0.014	-0.104	81.900
0.129	0.028	0.223	0.014	0.019	0.009	-0.029	-0.029	-0.103	80.700
0.141	0.031	0.225	0.012	0.023	0.009	-0.022	-0.022	-0.102	81.900
0.139	0.028	0.226	0.009	0.008	0.008	-0.013	-0.013	-0.133	81.900
0.139	0.035	0.226	0.012	0.041	0.007	0.047	1.047	-0.114	79.600
0.138	0.030	0.229	0.012	0.010	0.008	-0.025	-0.025	-0.100	83.000
0.132	0.031	0.230	0.009	0.019	0.008	-0.027	-0.027	-0.124	80.700
0.173	0.044	0.232	0.011	0.037	0.009	0.102	0.102	-0.192	83.000
0.123	0.027	0.233	0.010	0.008	0.011	-0.009	-0.009	-0.092	81.900
0.132	0.031	0.233	0.010	0.010	0.008	-0.015	-0.015	-0.131	83.000
0.162	0.033	0.233	0.013	0.049	0.009	0.079	0.079	-0.116	79.600
0.139	0.029	0.233	0.008	0.024	0.008	0.072	-0.030	-0.103	83.000
0.151	0.040	0.235	0.012	0.021	0.008	0.103	-0.032	-0.091	81.900
0.146	0.030	0.236	0.011	0.032	0.008	0.087	-0.042	0.092	83.000
0.162	0.034	0.237	0.010	0.021	0.008	0.130	-0.030	-0.011	81.900
0.146	0.031	0.240	0.010	0.011	0.009	-0.079	-0.017	-0.125	84.100
0.137	0.032	0.241	0.011	0.010	0.009	0.098	-0.015	-0.133	81.900
0.148	0.029	0.241	0.009	0.026	0.008	-0.072	-0.035	-0.128	83.000
0.139	0.024	0.242	0.009	0.010	0.008	-0.063	-0.011	-0.118	80.700
0.158	0.034	0.242	0.012	0.034	0.008	0.139	-0.053	-0.134	79.600
0.149	0.031	0.242	0.010	0.021	0.007	0.130	-0.037	0.124	81.900
0.158	0.039	0.242	0.013	0.021	0.009	-0.135	-0.029	-0.169	83.000
0.134	0.026	0.243	0.009	0.019	0.009	0.069	-0.021	-0.147	84.100
0.156	0.033	0.244	0.010	0.040	0.008	0.106	0.076	0.114	81.900
0.151	0.030	0.244	0.020	0.014	0.008	0.121	-0.023	-0.125	79.600
0.137	0.028	0.245	0.008	0.010	0.008	-0.078	-0.018	-0.124	83.000
0.140	0.028	0.245	0.009	0.019	0.008	-0.075	-0.021	-0.096	83.000
0.126	0.029	0.246	0.010	0.011	0.009	-0.039	-0.017	-0.116	81.900
0.153	0.038	0.247	0.020	0.020	0.008	-0.188	0.045	-0.161	78.400
0.163	0.043	0.247	0.008	0.010	0.008	0.262	-0.028	-0.121	84.100
0.146	0.028	0.249	0.009	0.030	0.008	0.089	-0.015	-0.121	84.100
0.157	0.041	0.249	0.006	0.004	0.008	-0.237	0.081	-0.106	83.000
0.133	0.026	0.250	0.021	0.009	0.008	0.271	-0.002	-0.071	78.500
0.129	0.027	0.250	0.025	0.014	0.005	0.071	-0.015	-0.198	81.900
0.234	0.410	0.250	0.010	0.011	0.009	0.234	0.032	-0.193	83.000
0.129	0.042	0.251	0.025	0.020	0.011	-0.130	0.035	-0.128	79.600
0.172	0.035	0.251	0.026	0.021	0.010	0.093	-0.035	-0.103	84.100
0.150	0.036	0.251	0.009	0.010	0.010	0.116	-0.034	-0.132	78.500
0.116	0.038	0.252	0.014	0.022	0.008	0.454	-0.033	-0.116	81.900
0.173	0.320	0.252	0.010	0.023	0.008	0.193	-0.034	-0.090	84.100
0.158	0.037	0.252	0.012	0.008	0.008	0.107	-0.040	-0.098	81.900
0.148	0.030	0.254	0.019	0.042	0.008	0.093	-0.011	-0.132	83.000
0.130	0.028	0.255	0.040	0.030	0.007	0.074	0.038	-0.142	81.900
0.134	0.031	0.255	0.015	0.009	0.008	0.106	-0.035	-0.107	83.000
0.137	0.026	0.255	0.013	0.011	0.007	0.072	-0.013	-0.112	84.100
0.148	0.026	0.255	0.011	0.019	0.008	0.081	0.014	-0.122	83.000
0.127	0.032	0.256	0.009	0.009	0.008	0.092	-0.023	-0.175	80.700
0.154	0.032	0.257	0.011	0.033	0.008	0.159	-0.016	-0.108	83.000
0.145	0.031	0.257	0.008	0.011	0.011	0.138	0.016	-0.180	83.000

MAX x G's	MAX y G's	MAX z G's	MIN x G's	MIN y G's	MIN z G's
0.114	0.013	0.298	-0.165	-0.039	-0.246
0.594	0.141	0.633	-0.468	-0.090	-0.633
0.542	0.141	0.554	-0.971	-0.115	-0.940
0.722	0.090	0.660	-0.444	-0.116	-0.764
0.646	0.090	0.660	-0.545	-0.090	-0.608
0.567	0.115	0.605	-0.340	-0.115	-0.631
0.544	0.090	0.711	-0.291	-0.090	-0.711
0.417	0.090	0.659	-0.291	-0.090	-0.710
0.543	0.090	0.555	-0.341	-0.090	-0.684
0.442	0.064	0.504	-0.471	-0.090	-0.969
0.367	0.116	0.529	-0.468	-0.141	-0.762
0.517	0.090	0.760	-0.416	-0.090	-0.760
0.392	0.090	0.659	-0.342	-0.090	-0.763
0.492	0.141	0.735	-0.644	-0.115	-0.942
0.418	0.064	0.504	-0.266	-0.064	-0.685
0.417	0.115	0.529	-0.367	-0.090	-0.839
0.492	0.064	0.580	-0.467	-0.090	-0.734
0.418	0.090	0.634	-0.392	-0.090	-0.711
0.468	0.090	0.607	-0.442	-0.116	-0.633
0.645	0.064	0.685	0.342	-0.090	-0.659
0.393	0.090	0.788	0.342	-0.090	-0.814
0.518	0.064	0.557	0.468	-0.090	-0.816
0.367	0.064	0.633	-0.444	-0.064	-0.788
0.341	0.115	0.530	-0.468	-0.012	-0.840
0.618	0.090	0.632	-0.443	-0.116	-0.761
0.720	0.116	0.940	-0.417	-0.116	-1.069
0.443	0.064	0.891	-0.542	-0.090	-0.839
0.418	0.116	0.659	-0.367	-0.116	-0.944
0.569	0.090	0.660	-0.570	-0.116	-0.919
0.441	0.090	0.839	-0.392	-0.090	-0.814
0.443	0.064	0.580	-0.366	-0.090	-0.812
0.418	0.064	0.685	-0.468	-0.090	-0.892
0.341	0.141	0.556	-0.443	-0.090	-0.685
0.491	0.142	0.684	-0.367	-0.090	-0.762
0.722	0.090	0.759	-0.592	-0.090	-1.068
0.469	0.142	0.660	-0.418	-0.167	-0.983
0.519	0.090	0.764	-0.367	-0.090	-0.893
0.693	0.064	0.634	-0.544	-0.090	-0.711
0.417	0.064	0.991	-0.340	-0.064	-1.016
0.949	0.142	0.555	-0.367	-0.090	-0.711
0.593	0.167	0.940	-0.620	-0.116	-0.970
0.418	0.090	0.582	-0.693	-0.115	-1.095
0.444	0.116	0.608	-0.392	-0.116	-0.711
0.718	0.115	0.836	-0.266	-0.116	-0.712
0.695	0.090	0.684	-0.340	-0.166	-0.888
0.444	0.116	0.608	-0.544	-0.090	-0.814
0.417	0.090	0.762	-0.393	-0.064	-0.660
0.418	0.090	0.840	-0.367	-0.090	-0.762
0.518	0.090	0.762	-0.367	-0.090	-0.970
0.443	0.064	0.737	-0.316	-0.064	-0.943
0.444	0.090	0.634	-0.392	-0.116	-0.737
0.494	0.090	0.685	-0.317	-0.090	-0.764
0.694	0.090	0.632	-0.342	-0.090	-0.840
0.494	0.090	0.659	-0.494	-0.116	-1.071
0.544	0.090	0.634	-0.418	-0.090	-0.763

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