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THE DEVELOPMENT OF A METHOD FOR DERIVING THE CORRELATION BETWEEN FREE FALL AND SHOCK MACHINE DROP HEIGHT BASED ON EQUIVALENT VELOCITY CHANGE

presented by

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THE DEVELOPMENT OF A METHOD FOR DERIVING THE CORRELATION BETWEEN FREE FALL AND SHOCK MACHINE DROP HEIGHT BASED ON EQUIVALENT VELOCITY CHANGE

By

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ABSTRACT

THE DEVELOPMENT OF A METHOD FOR DERIVING THE CORRELATION BETWEEN FREE FALL AND SHOCK MACHINE DROP HEIGHT BASED ON EQUIVALENT VELOCITY CHANGE

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The purpose of this research is to derive the correlation between free fall and shock machine drop height based on equivalent velocity change. The velocity change of free fall drops have never been measured precisely due to the unavailability of accurate instrumentation. Therefore, a trigger device was developed for use in conjunction with a waveform analyzer in the measurement of velocity change. The drop height correlation, the descriptions of the operation and components of the device are presented.

The measuring system was used to obtain the data of velocity change in free fall drops performed with drop tester. The velocity change of shock machine drop was acquired through the usage of an shock machine system. The data were then analyzed and the correlation of drop height for the equivalent velocity change between free fall and shock machine was derived.

To my parents, Uncle and Aunt.

ACKNOWLEDGMENTS

I wish to express my sincere appreciation for the guidance and support given in this research by Dr. James W. Goff, Professor, School of Packaging, Michigan State University.

I am indebted to Dr. Diana Twede, Assistant professor, School of Packaging, for arranging the necessary financial assistance during my research and serving as one of my committee members. I also extend my appreciation for the assistance offered by the other members of my committee, Dr. Paul Singh, Assistant Professor, School of Packaging, and Dr. Richard F. Gonzalez, Professor of Management at Michigan State University.

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INTRODUCTION

Mechanical damage is a common occurrence during distribution of packaged articles. During material handling operations, packages are often dropped, thrown, kicked and otherwise abused. They are also subjected to a variety of vehicle-induced impacts: starting, stopping, jolting, and other violent actions (1). However, it is generally agreed that, the most severe shocks likely to be encountered in shipping result from handling operation (2,3). These shocks result from dropping the package onto a floor, dock or platform. It is also known that the shocks of the largest amplitude occur when a package lands flat on a non-resilient horizontal surface (4).

In order to reduce the incidence of mechanical failures of packaged articles, it is necessary to design packages to protect products from impacts, especially from flat drops since this kind of drop produce the most severe shock.

In the design of protective packages, a major consideration is the physical environments which the packages will encounter. The most common way of specifying the environment is in terms of the probable height of free-fall drop (5).

It is important to realize that the most relevant concept for characterizing an impact is its velocity change: since shock is a sudden change in velocity, and velocity change has been found to be an accurate way to characterize a large class of shock motions for engineering applications (6). In modern packaging laboratories, state-of-the-art shock testing equipment has been used to simulate shocks which damage products in physical distribution. With a shock machine, however, there exists a fundamental problem: the lack of knowledge concerning the correlation between a shock machine drop height and an actual free fall drop height. Without understanding this correlation, any results obtained in shock testing are difficult to explain.

Since drop height is one of the key factors that determines velocity change, it is reasonable to correlate shock machine drop height with free fall drop height based on the equivalent velocity change. Although modern shock machine has the capability to measure the velocity change it generates, free-fall velocity change has never been measured precisely, due to the fact that there was no existing instrument to perform this measurement. Therefore, a system for accurately measuring free-fall drop velocity change was developed as part of this research.

The purpose of this research is to accurately determine the correlation between free fall drop height and shock machine drop height based on the equivalent velocity change of the shock. The previous work of Goff, et, al. (7) was used as a starting point. The following are the objectives of this research:

(1) To measure and correlate the velocity change of free-fall drop height and shock machine drop height. This correlation is expected to be about 2.8.

(2) To determine if cushioning inside the package affects the correlation.

LITERATURE REVIEW

Although much research has been done on the subject of shock testing, it was only after the presentation of Newton's theory (8) that velocity change was widely considered as one of the key elements in describing a product fragility. The purpose of this chapter is to review the historical development of this concept.

In 1945, Mindlin (9) initiated the scientific approach to the Packaging Dynamics by investigating the dynamics of package cushioning. He conceptualized packages as a linear spring-mass system representing an element of the packed article which is susceptible to damage. He derived mathematical models to predict the maximum acceleration of the packaged article and the form of the acceleration-time relation. He also studied the potentially damaging effect of acceleration on the packaged article.

In 1954, Kornhauser (10) proposed the damage "sensitivity" curve. Again, a mass-spring system was used to model a shock-resistant structure. When the mass-spring system is subjected to acceleration-time pulses of varying amplitude and duration, it was found that the minimum shock values required to damage the system followed a curve. He called it the "sensitivity curve" which is defined by the velocity change and average acceleration of the shock pulse. Kornhauser began to appreciate the dependence of "damage" upon both velocity change and average acceleration. Later, in 1964, he applied the concept of the "sensitivity curve" to the study of both structure (steel, aluminum) and biological (mice, human) tolerance to shock (11). He plotted out the damage-sensitivity curves for the structure of steel, mice and the human body. The experimental data on human impact strength (supine position) showed that the criteria for damage are 20 g and 960 in/sec velocity change, both of which must be exceeded concurrently for damage to occur to a well-supported human in the supine position.

In 1965, Pendered (12) further developed the concept of damage-sensitivity as a means of indicating the fragility of an item.

In 1965, Newton (8) established fragility assessment theory and its test procedures, in which he introduced the concept of the Damage Boundary Curve. The concept implied that the fragility of a product could be characterized by a damage boundary, using the peak faired maximum acceleration and the velocity change of damaging shock pulse. Newton stated that damage would not occur unless both velocity change and peak faired acceleration of a shock pulse reached certain values. Here, velocity change was presented as one of the key elements of the concept.

In 1969 Goff and Pierce (13) presented a workable procedure to determine the damage boundary for several different items to be packaged. Damage boundary plots were developed for such products as television sets, refrigerators, alarm clocks, typewriters and several other products. It was shown that the determination of damage boundaries is both possible and practical.

In 1977, ASTM (14) presented the completed procedure for the development of the damage boundary curve as in ASTM D 3332-77, "Standard Test Methods for Mechanical-Shock Fragility of Products, Using Shock Machines". The shock-pulse velocity change, in addition to shock pulse shape and shock-pulse maximum-faired acceleration, was included as one of the three parameters of the shock pulse required to determine the fragility of a product.

In 1978, Cesari (15) studied the injury mechanisms of automobile side impact. Two tests were conducted in this study. The first test was carried out by allowing a car striking a stationary one with an angle of 75 degree at 40.5 kph impact speed, and the second test was conducted the same except that the impact speed was 49.7 kph. The velocity change of different parts of cars and of dummies were measured in the tests conducted. Here, the velocity change was used as the major parameter to indicate the severity of auto side impact.

In 1976 Goff, Chatman, Imashimizu and Collins (7) investigated the correlation of free-fall drop height and shock machine drop height for equivalent velocity change. The velocity change of both machine drop and free-fall drop was analyzed by the pulse weighing method (Appendix A). The relationship between velocity change and drop height was represented by hand plotted curves, and no cushion was used. A correlation of 2.8 between shock machine height and free-fall height was estimated by comparing the curve slopes.

As described above, the velocity change has been widely recognized as one of the basic elements in shock analysis. However, due to the previous unavailability of accurate instrumentation, the actual velocity change of free fall drop has never been measured, and thus the true correlation between shock machine height and free fall height had, until this research, remained unknown.

RESEARCH DESIGN

In order to achieve the goal of this study, the tests are designed to obtain accurate test data. The description of sophisticated test instrumentation used is presented in this chapter. The descriptions of test material, test procedure, and statistical design of the study are also addressed.

TEST INSTRUMENTATION

A programmable shock machine system and a free-fall drop tester were the two major instruments employed to generate and measure the shock pulse. In addition, during the testing a special trigger device was developed to serve as an interface between the drop tester and the waveform analyzer which is part of programmable shock machine system. Descriptions of these instruments follows.

(1) Programmable shock machine system

An MTS 846.36 shock test system was used for these tests. The system was designed to have the capability to perform a wide range of shock tests. It consists of three essential parts: the shock machine itself, an MTS model 466.10 waveform analyzer, and a TEXTRONIX 2213A 60 mhz oscilloscope.

The test is performed by dropping the shock table onto a plastic programmer which consists of eight cylindrical plastic rods made of high strength thermoplastic material. These plastic rods are spaced to distribute the shock load evenly into the underside of the table. This plastic programmer produces half sine shock pulses with a duration of two milliseconds. This is a simulation of shocks encountered in free fall drop environments. A 3/16" thick sheet of high density felt is placed between the plastic programmer and the impacted underside of the shock table to smooth the onset of the pulses. The felt reduces the excitation of high frequency ringing or noise at the start of pulse.

The microprocessor-based MTS Model 466.10 Waveform Analyzer is a device that samples an analog waveform, converts the sample values to a digital format, and determines the values of pertinent points along the waveform. It then presents the resulting data, such as change in velocity, in digital form on two multi-purpose displays.

The TEKTRONIX 2213A Oscilloscope is a dual-channel instrument that can be used to provide the visual feature of shock pulses. It features a bright, sharply defined trace on an 80 by 100 mm cathode ray tube (crt). Its range system supplies calibrated deflection factors from 2 mV per division to 5 V per division. The horizontal range provides calibrated sweep speeds from 0.5 sec per division to 50 ns per division.

(2) Free Fall Drop Tester

The LANSMONT model PDT 56E Precision Drop Tester was also employed in these tests. This machine is designed to comply with ASTM D-775 Test Standard. It is equipped with a drop leaf pneumatic actuation system which prevents package rotation and insures repeatable results. A high velocity pneumatic system accelerates the drop leaf vertically downward at greater than the gravity. True vertical motion is obtained by means of two precision guides. The package is dropped on a 46" x 36" x 0.5" steel plate which is mounted in concrete.

(3) Trigger device

The waveform analyzer on the MTS shock machine system was also used to transfer the shock pulse into useful data. However, a trigger signal was required to initiate the analyzer an instant before impact. The MTS shock machine system uses a trigger flag and an optical sensor to generate this trigger signal. This signal consists of two short pulses with a duration of 0.15 ms separated by a time delay of from 0.417 ms to 41.7 ms. Both the trigger flag and the optical sensor are designed to be used only in the shock machine system.

In order to make the waveform analyzer measure a shock pulse generated by the free-fall drop tester, it was necessary to develop a device. Therefore, as a significant part of this research, a device was developed to generate the required trigger signal (Appendix 2).

TEST MATERIAL

The test package (Figure 1) consisted of four components: an instrumented wooden block, a piece of cushioning material placed on both the top and bottom of the block, and this assembly is packed into an outer corrugated paperboard container.

(1) Instrumented wooden block

A 10 pounds and 16 oz, 8 inches x 8 inches x 8 inches wooden block constructed of maple dieboard was used throughout the testing. Four aluminum rods, each weighing 1 pound and 15 oz with length of 6 1/8 inches and diameter of 1 7/8 inches, were bolted into the block to simulate a heavy product which has total weight of 12 pounds and 1 oz. Four foam rods, each weighs 5/16 pound with length of 5 1/8 inches and diameter of 1 7/8 inches, were bolted in the block to simulate a light product which has total weight of 12 1/8 pounds. The block is instrumented with a KISTLER model 818 accelerometer mounted in its center to pick up the shock signals. The accelerometer has sensitivity of 10 millivolts per g.

(2) Cushioning material

Two types of cushioning material, Ethafoam* 220 with density of 2.2 pounds per cubic feet and Ethafoam HS 45 with density of 3.8 pounds per cubic feet, were chosen to be the media between wooden block and outer container. The cushion thickness variables were 1 inch and 2 inches. All cushion blocks used have same bearing area of 8 inches x 8 inches.

(3) Outer container

The containers were regular slotted containers made of 200-pound C-flute corrugated paperboard. Due to two variables of cushion thickness, two different dimensions of

* Ethafoam is a registered trade name of the Dow chemical Company for its polyethylene foam cushioning material

boxes were used, the inner dimensions are, 8 inches x 8 inches x 10 inches and 8 inches x 8 inches x 12 inches.

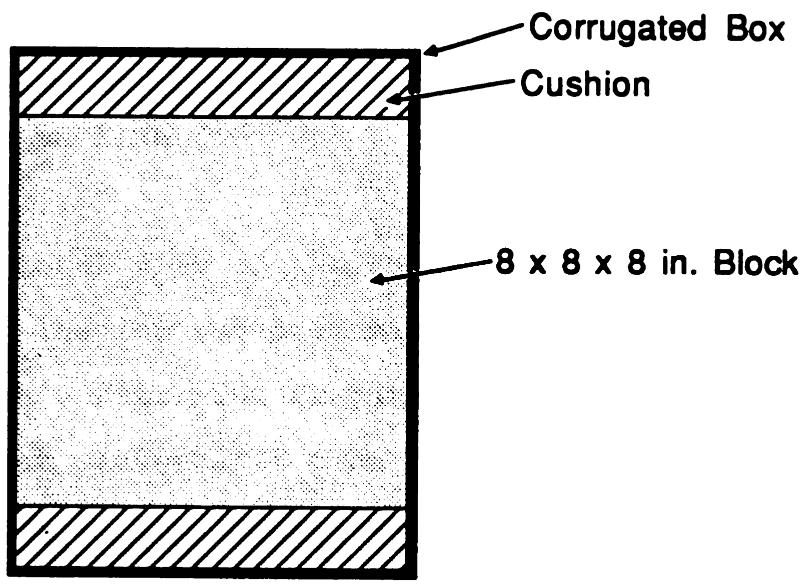


Figure 1. The complete test package

TEST PROCEDURE

The test consisted of two parts. (1) The shock machine test was designed to measure the velocity change of shock pulses produced at each -shock machine drop height. (2) The free-fall drop test was designed to measure the velocity change of shock pulse produced at each free-fall drop height. There was at least a one minute pause between each drop to allow for cushion recovery.

(1) Shock machine

The total view of the shock machine system is shown in figure 2. The instrumented package was placed on the shock table with a restraint fixture which does not contact the package but prevents it from falling off of the shock machine table. The machine was dropped five times at each height from 8" to 24" at increments of 1". The same cushion material was used throughout the test sequence. The shock signal that the test specimen received was measured by a accelerometer inside of wooden block. The signal was then sent to the waveform analyzer and oscilloscope via a KISTLER model 587 PIEZOTRON coupler.

(2) Free-fall drop test

The total view of the drop tester is shown in figure 3. The package is dropped as flat as possible. Each test was replicated five times at each drop height from 20" to 50" at increments of 2". The test procedure is similar to the shock machine test procedure except that the waveform analyzer was initiated by the trigger device developed for this research. Figure 9 shows a shock pulse generated in a 30" free-fall drop.

STATISTICAL DESIGN

Two steps of statistical analysis were taken in this research. First, the correlation between drop height and velocity change of each sequence drop for both drop tester and shock machine was investigated. Second, the correlation between drop tester and shock machine drop height was derived through studying their predicted drop heights based on the same amount of velocity change at each level. MSTAT, a statistical computing program, was used to analyze the data in this research.

Figure 2. The total view of the shock machine system

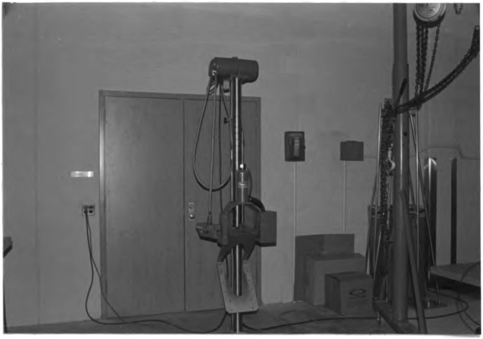


Figure 3. The total view of the drop tester

DATA ANALYSIS AND RESULTS

The physical law of gravitation shows that the drop height can expressed as a function of the impact velocity:

$$h = v^2/2g \tag{1}$$

Where h = the drop height

v = impact velocity

g = the gravitational constant

In addition, the rebound velocity is described as a function of the impact velocity:

$$v_r = e \times v \tag{2}$$

Where e = the value of the coefficient of restitution.

The velocity change is defined as the sum of the absolute values of the impact and rebound velocities:

$$V = v + v_r = (1+e)v \tag{3}$$

Where V = the velocity change

It is reasonable to deduct that the drop height can be expressed as a function of velocity change. The following mathematical model is then established:

$$h = f(V^2) = aV^2 + bV + c \qquad (4)$$

Where a, b, and c are the coefficients.

By actually calculating with the experiment data, it was found that the coefficient a was not significant. The equation was then simplified as follow:

$$h = f(V) = bV + c \qquad (5)$$

$$\text{or} \quad V = f(h) = mh + n \qquad (6)$$

$$\text{where} \quad m = 1/b$$

$$n = 1/c$$

The V is the average value of velocity change corresponding to each drop height. Since there are 8 simulated product configurations, 8 equations were built for both shock machine and drop tester by testing data (Appendix E). Following are the results of calculation.

Table 1. formulas for calculating the correlation between velocity change and drop height for shock machine and free fall drop tester

configuration	formula	correlation	probability
f111	V=108.8+4.632h	0.998	0.000
m111	V=91.59+9.866h	0.999	0.000
f112	V=122.2+4.333h	0.994	0.000
m112	V=89.44+9.438h	0.999	0.000
f121	V=106.3+4.285h	0.999	0.000
m121	V=88.09+9.433h	0.999	0.000
f122	V=107.9+4.323h	0.998	0.000
m122	V=101.5+8.635h	0.999	0.000
f212	V=108.6+4.348h	0.998	0.000
m212	V=105.9+9.096h	0.999	0.000
f211	V=119.1+4.275h	0.998	0.000
m211	V=111.7+9.072h	0.995	0.000
f222	V=118.8+3.960h	0.998	0.000
m222	V=108.3+8.510h	0.999	0.000
f221	V=103.8+4.247h	0.998	0.000
m221	V=95.49+8.973h	1.000	0.000

where first figure represents the type of drop

f = free fall m = shock machine

second figure represents the type of product weight

1 = heavy weight 2 = light weight

third figure represents the type of cushion

1 = ethafoam 220 2 = ethafoam HS-45

forth figure represents the thickness of cushion

1 = 1" 2 = 2"

Based on above equations, 6 velocity change values of 200, 220, 240, 260, 280, 300 were chosen for correlating shock machine and free fall drop heights. These two drop heights were then compared to obtain the correlation between them for each configuration

Table 2. correlation of drop height between shock machine and drop tester based on equivalent velocity change.

configuration	formula	correlation	probability
111	H=2.14+0.459h	0.999	0.000
112	H=3.46+0.459h	1.000	0.000
121	H=1.90+0.455h	0.999	0.000
122	H=0.95+0.497h	0.999	0.000
212	H=0.29+0.478h	1.000	0.000
211	H=1.15+0.458h	0.999	0.000
222	H=1.23+0.465h	1.000	0.000
221	H=1.04+0.470h	0.998	0.000

Where H = the drop height of shock machine

h = the drop height of drop tester

Above equations show that a strong correlation between the drop heights exists in 8 out of 8 cases, with the probability of null hypothesis 0 and the correlation coefficient close to 1, regardless of the variable of cushion type, cushion thickness and product weight used in the research.

Finally, a general equation is derived by comparing the expected shock machine drop height to every corresponding free fall drop height. As shown in (7)

$$H = 1.31 + 0.474h \qquad (7)$$

The above equation has the correlation coefficient of 0.984 and probability of null hypothesis of 0. This implies that free fall drop height can be represented by shock machine drop height with high confidence..

CONCLUSIONS

The correlation between shock machine and free fall drop height for each simulated product configuration was first derived separately based on the equivalent velocity change each of them received. Then a general formula was formed to represent the correlation with consideration of effect of all configurations. It can be seen that both hypothesis 1 and hypothesis 2 were correct in this research.

The research consisted of developing a device for triggering accurate measurement of free fall shock pulses. This device equipped the drop tester with a sophisticated analyzing instrument makes the tester more useful. The testing procedure developed to measure the free fall drop signal could be a valuable reference for setting industrial testing standards.

During testing, it was observed that the testing data could be affected by the time between drops and the flatness of the drop. The longer the time, the smaller the value of velocity change and acceleration. The closer to a perfect flat drop, the larger the value of velocity change and acceleration. When using a free fall drop tester, it is impossible to control rotational motions during the free fall. With a shock machine drop, this factor does not exist since the product can be placed flat on the shock table and remain flat through the impact. This is an advantage that a shock machine has over a free fall drop tester.

It is important to realize that different shock machines may generate different velocity change at the same drop height. Therefore, a calibration table of the shock machine used is presented in appendix C.

It should also be noted that since this investigation of the correlation was based on a simulated product configuration, the number of variables were limited. In order to extend the application value of this research, more work needs to be done to verify this correlation. Three possible research methods were proposed.

The first is to study the effect of the product/cushion/box configuration on the shock pulse. Whether the cushion material is placed inside of the box or on the impact surface could make big differences in the testing results. The existence of the corrugated box should also be studied since corrugated board acts as a type of cushion.

The second area for future research is in the effect of cushion fatigue since cushion material could be permanently deformed after certain a number of drops.

Third, the type of impact surface on the free fall drop tester should also be studied since steel surfaces rarely exist in any distribution environment. Perhaps the surface should be designed to match the expected surfaces such as wood or cement.

Based on this research, it can be seen that there does exist a correlation between shock machine drop height and free fall drop height. Once the correlation is defined, the estimated free fall drop height (Appendix D) in a distribution environment can be converted to shock machine drop height. However, this research addressed only the correlation of velocity change, since velocity change has been found to correlate with actual damage.

APPENDICES

APPENDIX A

PULSE WEIGHING METHOD FOR VELOCITY CHANGE

This method can be used to estimate the velocity change of shock pulse since velocity change is represented by the area under shock pulse. The shock pulse from oscilloscope screen is first photocopied to a known density piece of paper, and then the paper is cut into the size of the shock pulse whose weight will be determined. By dividing the weight by the sheet density of the paper, we obtained the shock pulse area which can be converted into velocity change.

The formula for calculation is as follow:

$$V = (C \times W \times M \times D)/(UA \times SD)$$

Where V = The velocity change of shock pulse (in/sec)

C = Conversion factor (386.4 in/sec/gram)

W = The weight of shock pulse shape paper (gram)

M = Magnitude per unit division (g's)

D = Duration per unit division (sec)

UA = the unit area of paper (in^2)

SD = The sheet density of paper ($gram/in^2$)

In 1976 Goff used this method to measure the area under the shock pulse in order to study the correlation between shock machine drop height and free fall drop height. He intended to compare the drop heights based on the equivalent velocity change that bare shock table generated with that induced by a drop tester on a bare surface. It was found that the shock pulse obtained was difficult to be analyzed. The cushion was then placed on the table to smooth out pulse. The relationship between velocity change and drop height was represented by the curve (Figure 4). The coefficient of 2.8 between shock machine drop height and free-fall drop height was obtained by analyzing the curve slopes as shown in figure 5.

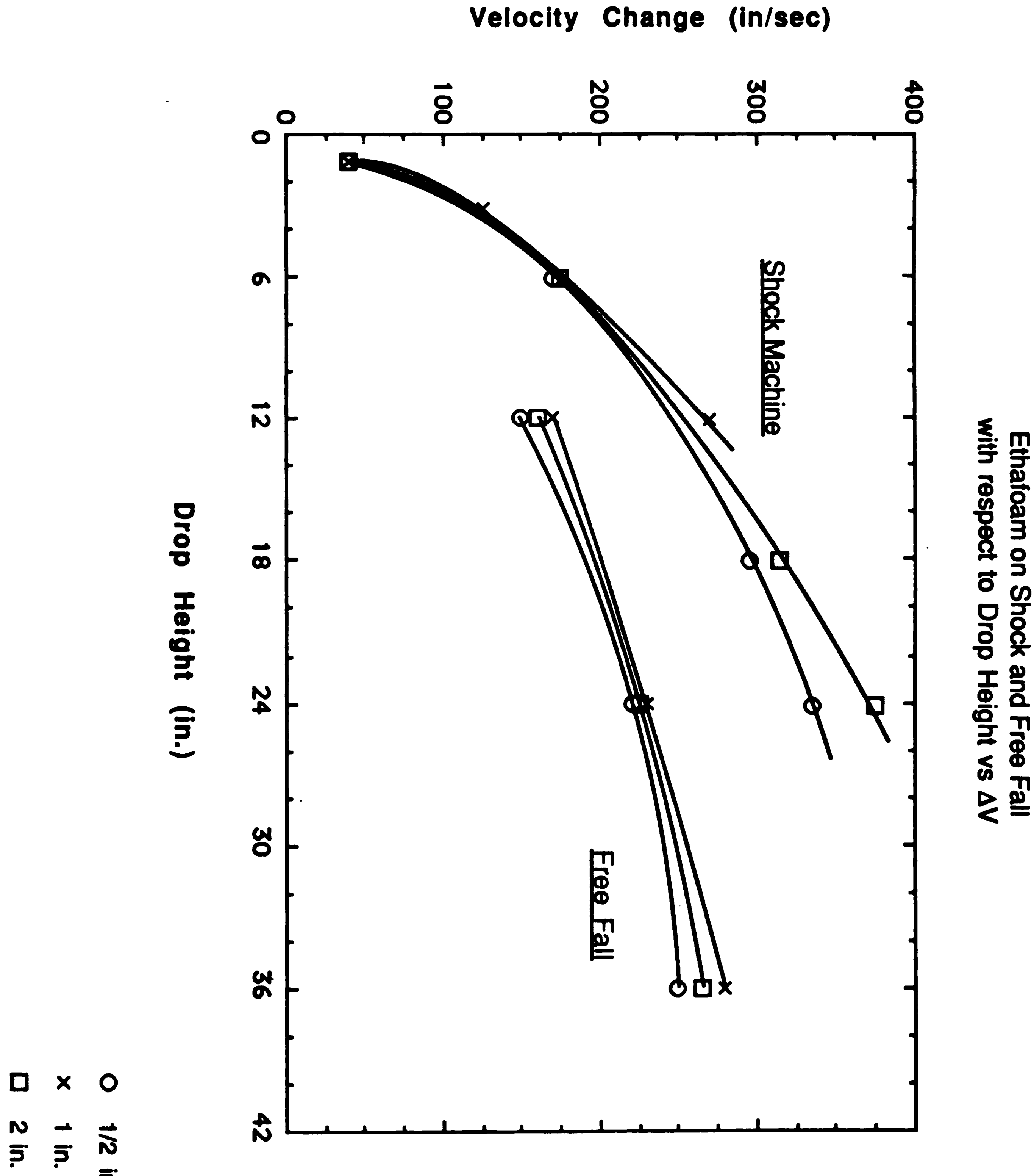


Figure 4. The relationship between
drop height and velocity change

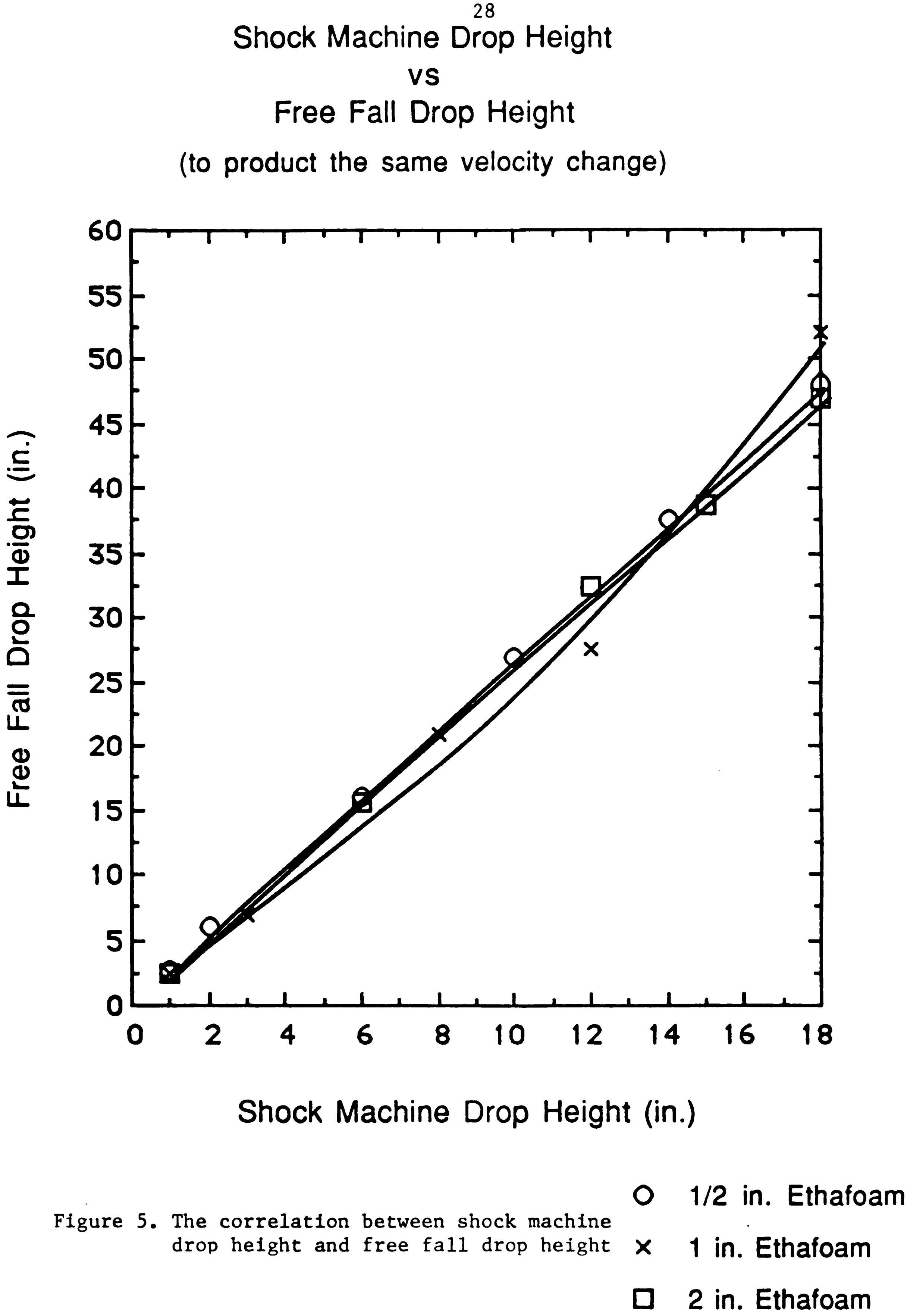


Figure 5. The correlation between shock machine drop height and free fall drop height

APPENDIX B

Trigger Device

The operation of the trigger device is described by a system block diagram, as shown in Figure B1. The basic component in this device is an integrated circuit of type NE558N quad timer. Figure B2 is the top view of this circuit. This timing circuit is capable of producing accurate time delays. The delay time is determined by the resistor and capacitor network, and can be calculated by the following equation:

$$T = 1.1 \times R \times C$$

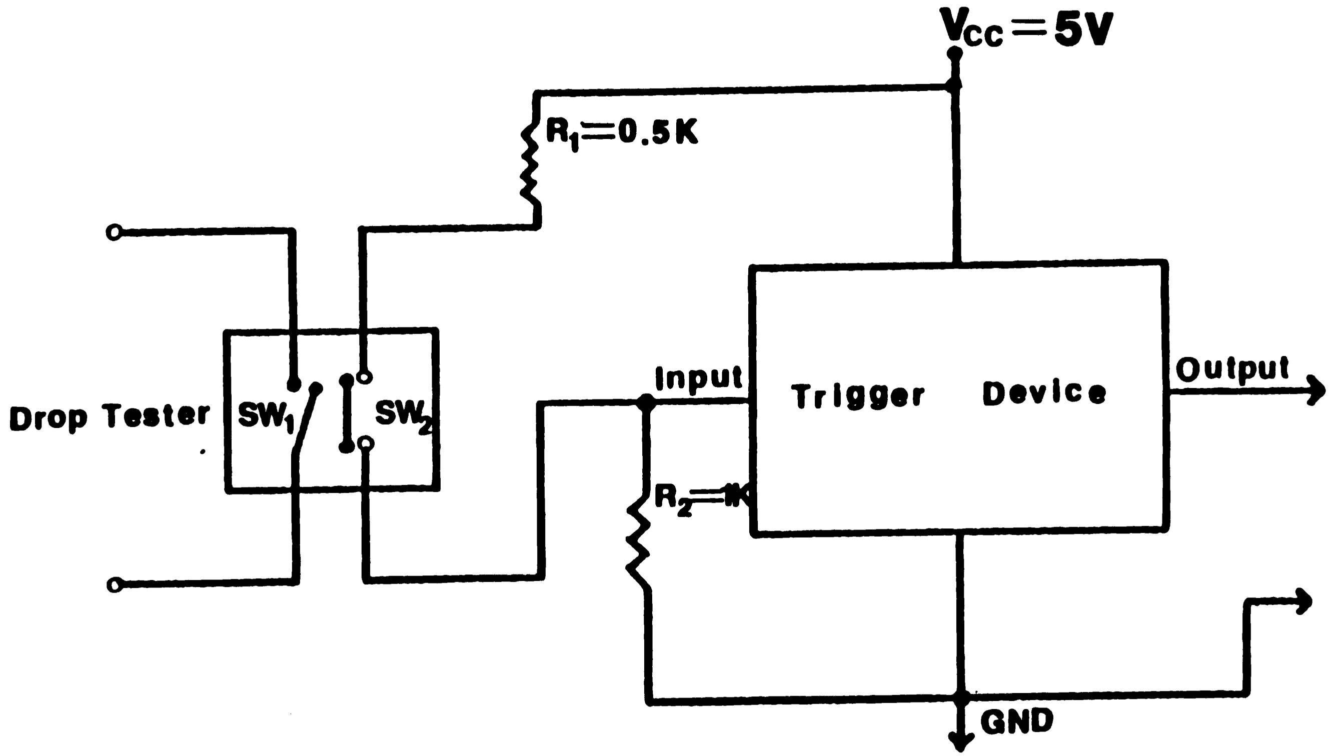
Where T = delay time (second)

R = resistance (ohm)

C = capacitance (farad)

Figure B3 shows the programmable sequence of the device. The NE558N is configured as four timers, T_1, T_2, T_3, T_4. The delay time of T_1 timer range, from 0.33 seconds to 0.55 seconds, is determined by a potentiometer R_1 and a capacitor C_1. This delay time is the time required for a package to free fall from 20" to 50". Each of the T_3 and T_4 timer is designed to produce a pulse with a duration of 0.15 ms. These two pulses are separated by a time delay range from 0.385 ms to 38.5 ms generated by R_2-C_2. Figure B4 is the timing diagram. In addition, a logic circuit of type

SN54LS32N with logic function of "OR" is used in conjunction with the IC to finalize the output signal, so that for every high-to-low signal, the trigger device generates a pair of pulses. Figure B5 is the top view of this logic circuit.



SW1 = Normally Open
SW2 = Normally Close

Figure B1: Operation of The Trigger Device

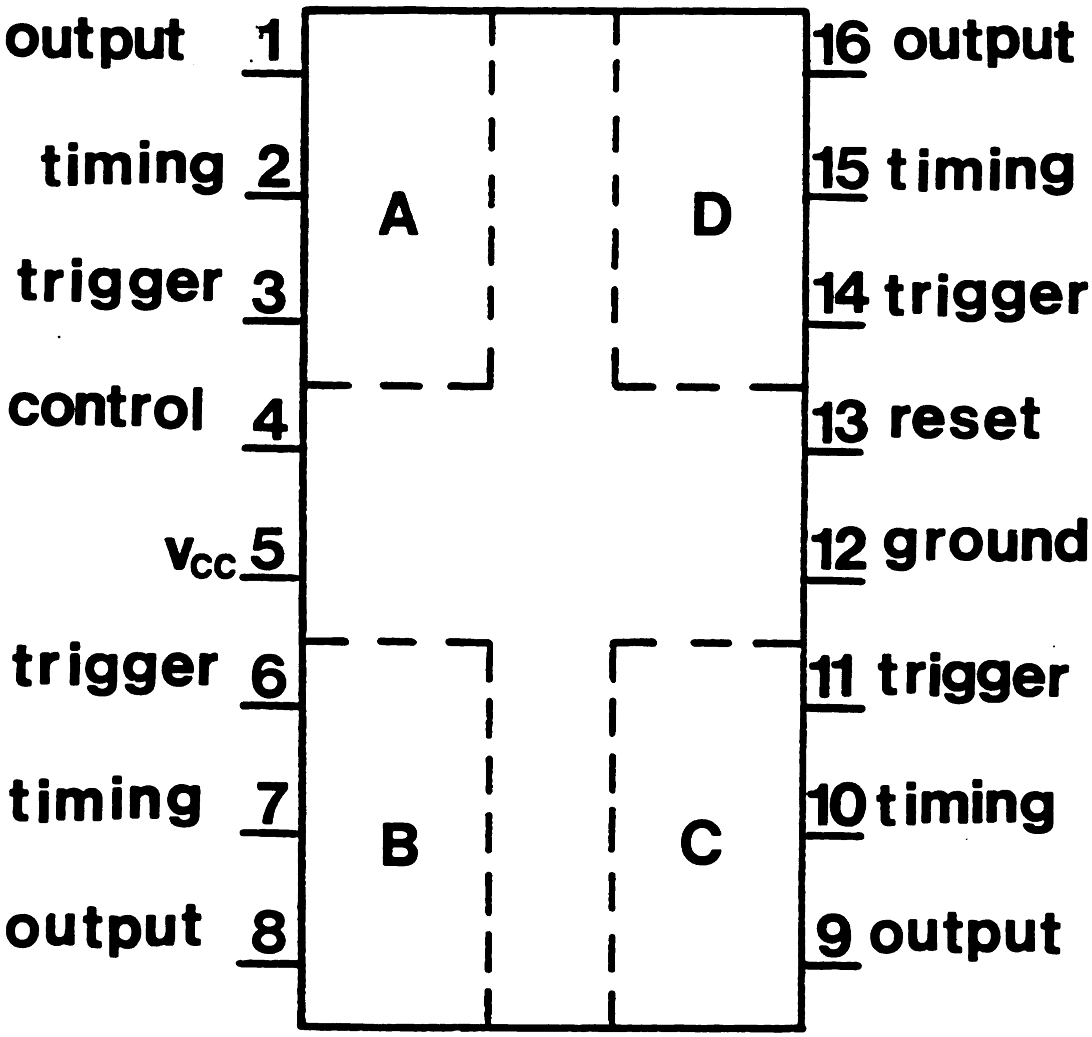
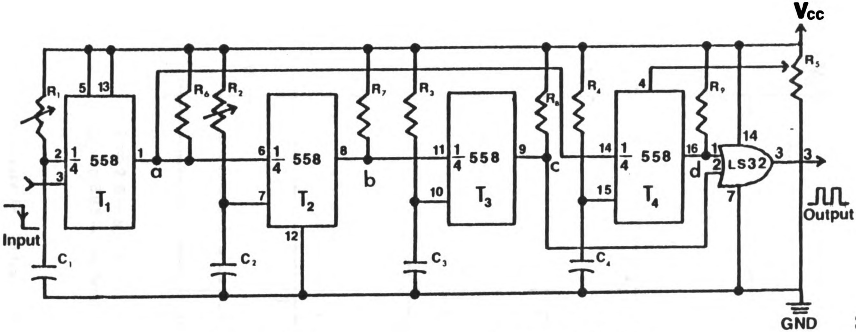


Figure B2. Top Viw of NE558N Quad Timer

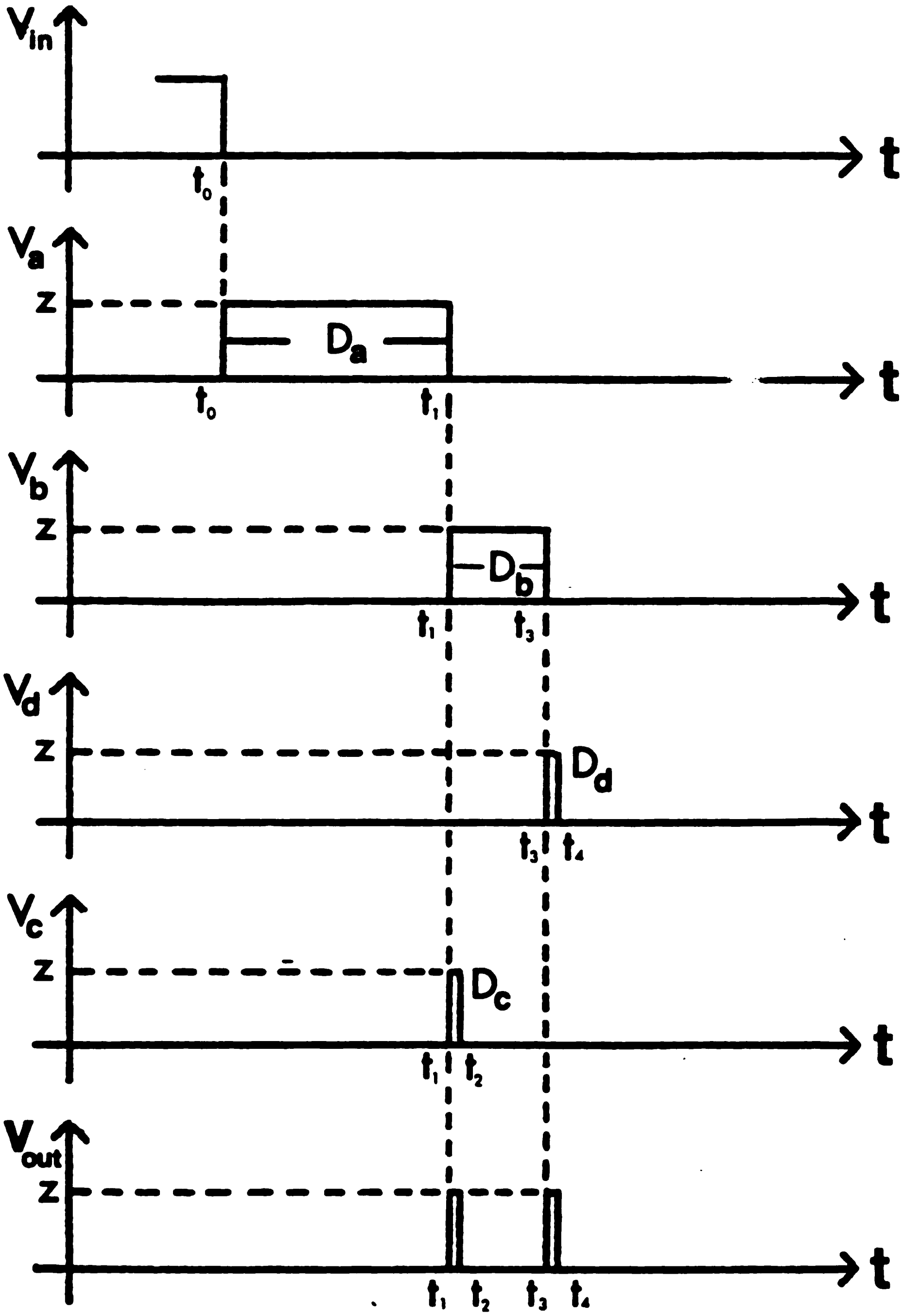


$R_1 = 3 - 5 M\Omega$ $R_2 = 3.5 - 350 K\Omega$

$R_3 = R_4 = 1.4 K\Omega$ $R_5 = 10 K\Omega$

$R_6 = R_7 = R_8 = R_9 = 3 K\Omega$ $C_1 = C_2 = C_3 = C_4 = 0.1 uF$

Figure B3. Programmable Sequence



$Z = 2.5 - 5.0$ V $\quad D_a = 0.33 - 0.55$ Sec

$D_b = 0.385 - 38.5$ms $\quad D_d = D_c = 150$ ms

Figure B4. Timing Diagram

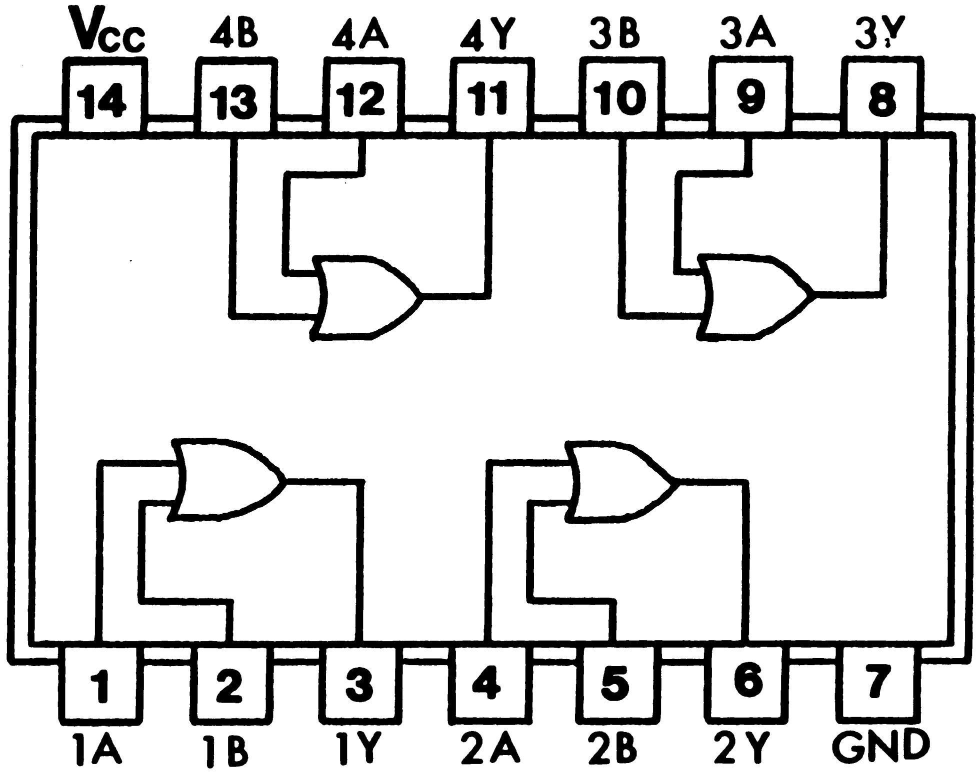


Figure B5. Top View of Logic Circuit

APPENDIX C

SHOCK MACHINE CALIBRATION VALUES

2 ms Half-Sine Programmers (Bare Table)

Drop Height (in)	V (in/sec)	G (g's)
4	83	186
5	94	212
6	102	238
7	110	256
8	117	274
9	123	291
10	130	307
11	135	320
12	141	334
13	147	349
14	153	359
15	157	371
16	165	385
17	170	394
18	174	402
19	180	412
20	184	422
21	190	436
22	194	445
23	200	453
24	204	465

APPENDIX D

HANDLING ENVIRONMENT

The most common way of specifying the handling environment is in terms of free-fall drops. Ostrem's (2) study on the common carrier environment found that the drop height is generally related to the product's weight or size. It is noticed that as the package becomes larger, the expected drop height decreases, due to the fact that the more cumbersome a package becomes the less likely it is to be dropped from a great height. A reference chart was then generated to reflect typical drop heights for products of various weight.

Typical Drop Height

Package Weight (pounds)	Greatest Dimension (inches)	Drop Height (inches)
0-20	48	42
20-50	36	36
50-100	48	24
100-150	60	21
150-200	60	18
200+	72	12

APPENDIX E

(H: Drop Height. V: Velocity Change. G: Acceleration Level. D: Shock Duration. X: Displacement)

1. Test Data in Free Fall Drop

Table 1. Aluminum weight with 1" thick ethafoam 220 (natural frequency = 45 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
20	193.7	67.3	11.63	0.33
	197.6	70.7	11.4	0.35
	200.4	73.2	11.71	0.41
	201.6	74.3	11.78	0.38
	200.0	73.8	11.77	0.38
Average	198.66	71.9	11.77	0.37
22	208.1	76.7	11.67	0.41
	209.4	77.9	11.51	0.39
	211.5	79.1	11.48	0.39
	211.2	79.6	11.82	0.38
	209.9	76.6	11.59	0.41
Average	210.12	77.98	11.59	0.39
24	219.9	85.7	11.44	0.32
	215.3	80.4	12.01	0.35
	218.6	84.6	11.75	0.35
	217.4	82.1	11.94	0.35
	218.1	83.3	12.05	0.35
Average	217.86	83.22	11.84	0.34
26	226.6	85	12.13	0.35
	224.6	85.0	12.13	0.35
	226.6	83.1	12.44	0.35
	224.3	84.0	12.28	0.35

	226.6	82.9	12.67	0.36
Average	226.14	84.14	12.33	0.35
28	237.8	93.9	12.09	0.35
	238.6	94.8	12.13	0.35
	238.2	95.1	12.17	0.35
	238.7	95.9	11.98	0.35
	239.8	97.4	12.01	0.35
Average	238.62	95.42	12.08	0.35
30	249.8	104.4	11.82	0.33
	248	100.9	11.9	0.34
	248.8	99.5	11.98	0.34
	245.0	99.6	11.86	0.34
	249.0	98.5	12.05	0.34
Average	248.12	100.56	11.92	0.34
32	260.9	108	11.78	0.34
	260.7	107.5	11.71	0.33
	260.9	109.9	11.63	0.34
	259.1	109.1	11.4	0.34
	258.6	107.7	11.59	0.34
Average	260.04	108.44	11.62	0.34
34	270.6	115.7	11.4	0.33
	271.4	117.3	11.4	0.34
	271.2	117.3	11.4	0.34
	270.2	117.3	11.24	0.33
	271.8	116.9	11.28	0.34
Average	271.04	116.9	11.34	0.34
36	276.9	123.1	11.05	0.32
	278.2	124	11.24	0.33
	280.9	124.4	11.17	0.33
	278.7	124	10.9	0.33
	278.5	123	11.17	0.32
Average	278.64	123.7	11.106	0.32
38	287.6	131.3	10.59	0.32
	288	133.4	10.82	0.32
	288	132.5	10.78	0.32
	288.5	133.3	10.67	0.32
	289	132.5	10.71	0.32
Average	288.22	132.6	10.71	0.32
40	297.1	142.6	10.59	0.31
	295.4	138.3	10.55	0.31

	296.6	143	10.51	0.31
	297.1	141.9	10.47	0.31
	295.5	139	10.59	0.31
Average	296.34	140.96	10.52	0.31
42	304.6	151.9	10.4	0.31
	304.3	147.7	10.32	0.31
	304	148.9	10.32	0.31
	303.8	149.7	10.36	0.30
	301.7	145	10.28	0.30
Average	303.18	148.64	10.34	0.30
44	310.8	152.3	10.09	0.30
	311.1	154.7	10.13	0.31
	312.1	158.2	10.13	0.31
	312.8	157.9	10.2	0.3
	313.8	158.2	10.05	0.32
Average	312.12	156.26	10.12	0.31
46	322.1	172.1	9.86	0.31
	321.8	167.6	10.05	0.31
	321.6	168.5	9.94	0.31
	323.3	169.5	10.01	0.31
	321.8	171.1	9.74	0.31
Average	322.12	169.76	9.92	0.31
48	325.7	174.6	9.67	0.31
	327.4	178.9	9.63	0.31
	329.8	179.3	9.63	0.31
	330	182.4	9.78	0.30
	330.3	178.1	9.67	0.31
Average	328.64	178.66	9.67	0.31
50	336.3	190.6	9.28	0.31
	334.9	182.8	9.74	0.31
	333.1	179.3	9.78	0.31
	334.5	182.8	9.7	0.30
	337.7	188.7	9.43	0.30
Average	335.3	184.84	9.58	0.28

Table 2. Aluminum weight with 2" thick ethafoam 220
(natural frequency = 38 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
20	199.1	63.9	12.86	0.34
	201.7	63.3	13.25	0.39
	203.0	63.3	13.52	0.39
	202.3	61.3	13.9	0.40
	201.8	61.8	13.86	0.38
Average	201.58	62.72	13.47	0.38
22	211.0	65.3	14.02	0.37
	212.6	65.9	14.13	0.38
	214.0	65.4	14.21	0.37
	215.5	65.6	14.44	0.39
	214.0	65.6	14.44	0.38
Average	213.43	65.56	14.25	0.38
24	223.3	68.2	14.48	0.37
	223.9	68.0	14.56	0.38
	222.8	67.1	14.67	0.39
	224.9	66.6	14.67	0.39
	223.9	67.7	14.79	0.39
Average	223.76	67.52	14.79	0.38
26	235.2	71.3	14.67	0.38
	234.3	70.3	14.75	0.38
	235.4	70.5	14.56	0.38
	236.6	70.1	14.9	0.38
	236.0	69.3	14.83	0.38
Average	235.5	70.3	14.74	0.38
28	246.4	72.8	14.94	0.38
	245.4	71.7	15.73	0.40
	245.9	71.3	15.1	0.37
	244.1	71.3	15.52	0.42
	246.9	71.7	15.44	0.40
Average	245.74	71.76	15.44	0.40
30	254.4	74.9	15.29	0.39
	255.6	74.7	15.17	0.37
	256.6	74.7	15.1	0.37
	258.7	74.9	15.17	0.36
	255.2	74.0	15.48	0.39

Average	256.1	74.64	15.24	0.39
32	263.3	76.3	15.63	0.38
	266.2	77.56	15.48	0.37
	264.5	77.1	15.60	0.38
	256.3	77.3	15.44	0.37
	263.8	76.2	15.43	0.37
Average	264.62	76.88	15.52	0.37
34	271.5	78.7	15.41	0.37
	272.4	77.5	15.83	0.38
	273.3	78.7	15.79	0.38
	273.4	79.4	15.63	0.38
	272.2	78.4	15.75	0.38
Average	272.56	78.54	15.69	0.38
36	278.6	80.7	15.79	0.37
	281.1	82.9	15.36	0.36
	282.9	82.2	15.4	0.37
	282.2	82.0	15.56	0.37
	280.6	82.9	15.44	0.38
Average	281.08	82.14	15.51	0.37
38	286.9	84.2	15.44	0.37
	286.7	84.2	15.6	0.37
	285.9	82.9	15.75	0.38
	288.5	84.5	15.44	0.36
	290.3	84.3	15.53	0.37
Average	287.66	84.3	15.53	0.37
40	295.1	87.6	15.52	0.36
	294.8	84.5	15.67	0.38
	295.3	85.7	15.75	0.39
	296.8	86.4	15.71	0.37
	298.4	86.4	15.75	0.37
Average	296.08	86.12	15.68	0.37
42	303.1	90.3	15.4	0.36
	299,4	87.7	15.71	0.36
	303.7	89.9	15.63	0.37
	305.2	90.1	15.67	0.38
	304.8	90.0	15.71	0.37
Average	303.24	89.6	15.62	0.37
44	311.7	92.6	15.52	0.36
	312.6	92.6	15.56	0.36
	311.6	92.5	15.67	0.36
	310.4	92.7	15.63	0.38

	312.5	92.7	15.63	0.38
Average	311.76	92.62	15.6	0.37
46	317.4	95.7	15.48	0.37
	319.0	94.8	15.33	0.38
	317.7	95.0	15.13	0.38
	318.5	93.8	15.63	0.37
	319.7	93.8	15.75	0.38
Average	318.46	94.62	15.56	0.38
48	322.8	96.1	15.48	0.39
	326.9	97.3	15.63	0.38
	325.8	97.3	15.56	0.39
	324.1	96.9	15.56	0.39
	324.7	97.3	15.60	0.39
Average	324.86	96.98	15.57	0.39
50	333.5	100.5	15.63	0.38
	337.3	102.2	15.44	0.38
	336.0	102.1	15.48	0.38
	336.7	103.1	15.29	0.39
	333.1	102.5	15.4	0.37
Average	335.32	102.08	15.45	0.38

Table 3. Aluminum weight with 1" thick ethafoam HS-45
(natural frequency = 58 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
20	185.1	89.2	8.55	0.25
	187.8	89.2	8.82	0.25
	189.5	90.0	8.97	0.25
	190.5	90.3	9.01	0.27
	191.4	91.3	9.01	0.25
Average	188.86	90.0	8.87	0.25
22	198.8	92.7	9.09	0.27
	197.5	88.6	9.26	0.27
	197.6	88.6	9.67	0.29
	196.8	89.9	9.51	0.29
	198.3	91.0	9.79	0.30

Average	197.8	90.16	9.53	0.28
24	208.1	93.7	9.67	0.27
	209.7	95.9	9.63	0.27
	211.0	97.1	9.67	0.29
	210.2	93.9	10.05	0.29
	209.5	93.9	10.05	0.31
Average	209.7	95.48	9.74	0.29
26	216.6	99.8	9.7	0.31
	218.5	98.6	9.59	0.30
	220.7	99.2	9.97	0.29
	221.0	102.6	9.94	0.29
	220.3	99.7	10.09	0.30
Average	218.82	99.98	9.86	0.30
28	226.5	103.3	10.17	0.31
	226.3	104.4	10.28	0.31
	225.5	106.3	10.32	0.32
	227.5	106.8	10.09	0.30
	229.1	104.1	10.28	0.29
Average	226.98	105	10.2	0.31
30	234.4	105.5	10.28	0.31
	238.2	109.0	10.05	0.29
	236.1	109.1	10.28	0.29
	236.1	111.3	10.17	0.30
	239.3	110.2	9.86	0.32
Average	236.8	109.2	10.13	0.30
32	243.5	114.4	10.4	0.30
	247.8	115.7	10.90	0.28
	247.0	114.6	10.20	0.30
	243.7	114.6	10.44	0.30
	242.5	117.8	10.01	0.31
Average	244.2	115.42	10.39	0.30
34	252.8	121.7	10.09	0.30
	252.0	123.9	9.55	0.29
	256.8	122.8	10.01	0.28
	256.9	124.1	10.01	0.28
	256.8	119.5	10.01	0.28
Average	255.06	122.4	9.93	0.28
36	261.1	126.3	9.47	0.30
	259.4	127.4	10.24	0.30
	260.2	127.7	10.20	0.30
	259.4	125.4	10.01	0.29

	262.7	125.4	10.13	0.29
Average	260.56	126.44	101.01	0.29
38	271.2	132.4	9.32	0.27
	268.1	129.5	9.95	0.30
	266.8	127.4	9.90	0.30
	258.0	130.2	9.94	0.27
	271.6	131.2	9.94	0.27
Average	267.14	130.12	9.64	0.29
40	278.1	137.1	9.74	0.28
	282.5	146.2	9.55	0.27
	273.0	132.7	9.44	0.30
	281.8	142.8	9.63	0.35
	281.4	142.7	9.40	0.26
Average	279.36	140.3	9.54	0.29
42	287.2	140.6	9.59	0.28
	290.2	150.9	9.40	0.26
	288.5	149.7	9.51	0.27
	290.4	148.8	9.47	0.28
	290.1	148.24	9.34	0.29
Average	289.28	148.24	9.48	0.28
44	294.3	153.8	9.09	0.27
	297.0	159.2	9.01	0.26
	295.4	157.2	9.29	0.29
	292.5	158.5	9.13	0.29
	293.7	150.0	9.28	0.30
Average	294.58	155.14	9.12	0.28
46	303.0	161.7	8.86	0.29
	305.7	163.0	9.20	0.25
	306.3	169.6	9.20	0.27
	299.6	164.2	8.93	0.30
	302.4	161.4	9.09	0.28
Average	303.4	164.04	9.06	0.28
48	309.7	173.0	8.90	0.27
	310.3	169.9	8.93	0.28
	314.1	173.3	9.05	0.27
	310.7	175.3	8.86	0.27
	312.6	164.1	9.16	0.28
Average	311.48	171.12	8.89	0.27
50	315.5	179.3	8.86	0.27
	310.4	173.1	8.82	0.29

	316.2	177.0	8.97	0.26
	321.0	174.6	9.01	0.26
	319.3	173.9	8.78	0.26
Average	316.48	175.7	8.89	0.28

Table 4. Aluminum weight with 2' thick ethafoam HS-45
(natural frequency = 55 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
20	183.6	90.3	8.78	0.22
	185.8	83.2	9.82	0.24
	189.4	86.4	9.90	0.25
	190.8	84.7	10.17	0.26
	191.5	80.9	10.32	0.27
	192.3	80.0	10.44	0.29
Average	188.9	84.25	9.91	0.26
22	198.3	79.4	10.59	0.31
	201.6	81.1	10.74	0.30
	201.5	79.4	10.94	0.31
	211.0	76.8	10.94	0.30
	199.7	76.8	11.01	0.30
Average	202.42	79.2	10.84	0.31
24	208.9	79.2	11.17	0.28
	208.4	78.7	11.55	0.33
	211.2	79.1	11.51	0.29
	211.0	79.1	11.67	0.30
	212.3	78.5	11.51	0.30
Average	210.36	79.02	11.48	0.30
26	220.6	81.4	11.78	0.29
	219.9	80.3	11.78	0.30
	221.2	80.3	11.78	0.29
	221.0	79.7	11.82	0.30
	223.2	80.3	11.67	0.29
Average	221.18	80.4	11.77	0.29
28	230.7	82.0	11.71	0.29
	231.1	82.6	11.82	0.30
	229.4	82.0	12.21	0.31

	228.6	80.9	12.32	0.32
	227.7	80.3	12.44	0.33
Average	229.5	81.56	12.1	0.31
30	236.1	82.6	12.09	0.33
	239.7	83.8	12.4	0.30
	239.0	82.0	12.25	0.30
	241.2	83.2	12.40	0.30
	240.8	83.8	12.28	0.31
Average	239.36	83.08	12.28	0.31
32	249.2	86.1	12.71	0.29
	248.6	87.3	12.55	0.31
	247.8	86.1	12.67	0.31
	248.9	87.3	12.44	0.31
	250.7	86.7	12.67	0.30
Average	249	86.7	12.61	0.30
34	259.0	89.6	12.63	0.30
	257.5	88.5	12.71	0.31
	255.7	85.0	12.90	0.29
	256.6	88.5	12.63	0.31
	256.1	87.9	12.75	0.32
Average	256.98	87.9	12.72	0.31
36	261.8	89.6	12.71	0.32
	265.7	90.2	12.86	0.30
	265.8	91.4	12.96	0.30
	267.4	90.8	12.94	0.30
	266.3	90.8	12.90	0.32
Average	265.4	90.56	12.87	0.31
38	271.2	92.0	13.13	0.32
	273.7	92.0	13.09	0.31
	274.5	93.2	12.90	0.31
	276.4	93.6	13.21	0.30
	277.6	93.7	13.17	0.30
Average	274.7	92.9	13.1	0.31
40	283.5	96.7	13.13	0.30
	282.7	96.7	13.17	0.31
	280.8	94.9	13.17	0.33
	282.2	95.5	13.21	0.32
	281.9	95.5	13.09	0.33
Average	282.22	95.86	13.15	0.32
42	292.0	98.4	13.25	0.30

	291.8	99.0	13.25	0.30
	292.0	99.0	13.36	0.31
	289.6	97.9	13.40	0.32
	286.1	95.5	13.59	0.35
Average	290.3	97.96	13.37	0.32
44	296.7	100.2	13.13	0.32
	299.2	100.8	13.13	0.32
	299.9	102.0	13.32	0.30
	299.3	100.8	13.40	0.31
	293.9	97.9	13.86	0.35
Average	297.8	100.34	13.42	0.32
46	303.1	102.0	13.44	0.32
	303.6	103.1	13.32	0.33
	303.2	102.5	13.25	0.33
	306.8	102.5	13.44	0.32
	308.4	103.1	13.52	0.31
Average	305.02	102.64	13.39	0.32
48	312.0	106.5	13.44	0.32
	314.1	108.4	13.32	0.31
	311.4	106.1	13.36	0.34
	309.0	103.7	13.71	0.35
	314.2	106.1	13.32	0.32
Average	312.14	106.16	13.43	0.31
50	322.7	110.7	13.44	0.31
	323.2	109.6	13.32	0.30
	322.1	109.6	13.40	0.32
	323.3	110.2	13.40	0.39
	318.8	107.8	13.44	0.34
Average	322.02	109.58	13.4	0.33

Table 5. Aluminum weight with 2" thick ethafoam 220
(natural frequency = 49)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
20	192.1	77.4	10.13	0.28

	191.2	76.2	10.47	0.31
	190.8	75.1	10.55	0.33
	190.6	75.1	10.59	0.32
	187.8	73.8	11.17	0.34
Average	190.5	75.52	10.58	0.32
22	201.9	79.5	10.51	0.31
	203.5	79.3	10.74	0.32
	204.5	78.6	10.74	0.32
	203.4	77.4	11.07	0.33
	203.5	77.1	10.94	0.33
Average	203.36	78.38	10.77	0.32
24	211.0	79.4	11.13	0.34
	212.9	80.4	11.01	0.32
	214.5	81.8	11.05	0.32
	215.0	80.9	11.17	0.32
	213.6	79.3	11.28	0.33
Average	213.4	80.36	11.13	0.33
26	224.0	84.0	11.9	0.32
	223.6	82.0	11.36	0.33
	220.6	78.2	11.63	0.33
	218.9	78.1	11.82	0.34
	219.2	78.1	11.71	0.34
Average	221.26	80.08	11.68	0.33
28	231.1	86.3	11.51	0.32
	233.7	86.7	11.40	0.31
	234.9	85.5	11.77	0.30
	233.2	84.4	11.78	0.32
	231.0	79.7	11.94	0.33
Average	232.78	84.52	11.67	0.32
30	237.4	84.0	12.13	0.33
	239.1	84.4	11.90	0.32
	242.1	85.5	11.82	0.32
	242.8	87.5	11.94	0.31
	243.4	87.9	12.01	0.33
Average	240.96	85.86	11.96	0.32
32	251.6	91.1	12.01	0.30
	249.6	87.9	12.28	0.32
	249.2	87.7	12.36	0.32
	247.9	87.9	12.63	0.33
	244.8	85.5	12.32	0.33
Average	248.62	88.02	12.32	0.32

34	257.0	91.4	12.32	0.31
	259.0	91.3	12.21	0.30
	261.4	91.1	12.36	0.30
	261.7	90.2	12.55	0.30
	254.9	85.5	12.98	0.32
Average	258.8	89.9	12.48	0.32
36	258.3	88.6	12.67	0.30
	262.8	89.1	12.59	0.31
	264.8	88.9	12.67	0.31
	268.0	91.4	12.75	0.30
	260.8	87.6	12.94	0.32
Average	262.94	89.12	12.72	0.31
38	272.9	92.0	12.86	0.31
	277.3	92.6	12.81	0.31
	278.2	93.7	13.09	0.30
	271.0	90.3	13.09	0.33
	269.3	90.3	12.98	0.32
Average	273.74	91.92	12.98	0.32
40	282.0	94.9	13.17	0.31
	284.6	95.8	13.05	0.31
	286.6	102.7	13.36	0.29
	286.4	94.9	13.21	0.29
	283.6	92.6	13.4	0.31
Average	284.64	96.18	13.24	0.30
42	295.1	94.6	13.40	0.31
	297.1	96.1	13.44	0.40
	294.2	100.0	13.13	0.32
	296.3	102.2	13.55	0.31
	290.8	98.1	13.58	0.31
Average	294.7	98.2	13.42	0.33
44	297.9	103.1	13.67	0.31
	300.5	104.3	13.59	0.30
	303.4	104.9	13.52	0.29
	300.8	104.3	13.67	0.30
	303.6	105.2	13.82	0.29
Average	301.24	104.36	13.65	0.30
46	308.6	108.7	13.75	0.30
	307.1	108.1	13.98	0.31
	307.7	107.7	13.94	0.31
	310.9	106.6	13.75	0.29
	310.1	108.3	13.98	0.30

Average	308.88	107.88	13.88	0.30
48	316.9	113.7	13.94	0.29
	313.8	112.5	14.06	0.31
	315.5	112.1	14.09	0.30
	316.3	112.2	13.94	0.30
	317.0	110.2	13.79	0.30
Average	315.9	112.14	13.96	0.30
50	321.2	114.8	14.06	0.30
	322.7	114.8	14.13	0.30
	319.0	112.5	14.25	0.31
	321.1	112.5	13.86	0.32
	318.1	114.8	14.25	0.33
Average	320.4	113.88	14.11	0.31

Table 6. Aluminum wieght with 1" thick ethafoam 220
(natural frequency = 52)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
20	196.6	91.4	9.05	0.26
	196.6	89.6	9.40	0.28
	198.9	91.5	9.40	0.27
	202.5	93.9	9.32	0.27
	202.9	92.4	9.43	0.27
Average	199.5	91.76	9.32	0.27
22	207.9	93.3	9.7	0.29
	210.9	95.8	9.59	0.28
	211.1	94.7	9.74	0.30
	212.5	95.8	9.67	0.28
	214.1	97.3	9.67	0.28
Average	211.3	95.38	9.67	0.28
24	224.0	102.0	9.59	0.27
	225.4	103.2	9.55	0.27
	225.4	102.0	9.70	0.27
	224.7	102.0	9.7	0.27
	225.2	102.0	9.78	0.30

Average	224.94	102.24	9.66	0.27
26	228.1	102.0	9.97	0.30
	232.0	105.1	9.82	0.25
	230.4	102.7	9.97	0.29
	233.8	106.2	9.82	0.28
	234.5	105.0	9.97	0.28
Average	231.76	104.2	9.91	0.28
28	241.8	109.0	9.94	0.29
	239.5	103.9	10.05	0.28
	237.7	102.8	10.17	0.29
	237.7	104.3	10.24	0.31
	236.0	103.0	10.28	0.31
Average	238.54	104.6	10.14	0.30
30	245.6	108.7	10.13	0.31
	248.9	112.1	10.17	0.29
	249.9	113.2	10.09	0.29
	249.9	113.2	9.94	0.29
	246.5	110.2	10.13	0.30
Average	248.16	109.74	10.09	0.30
32	252.1	111.3	10.32	0.32
	254.2	113.2	10.28	0.30
	255.8	115.6	10.13	0.29
	259.5	118.2	12.05	0.29
	257.4	116.3	10.09	0.32
Average	255.8	114.92	10.17	0.30
34	260.1	118.4	10.09	0.31
	262.8	120.7	10.01	0.30
	262.6	121.5	10.05	0.31
	262.9	120.7	9.97	0.30
	268.2	124.3	10.05	0.30
Average	263.32	121.12	10.03	0.30
36	275.7	130.1	9.74	0.29
	272.3	128.8	9.90	0.30
	273.2	128.9	9.94	0.30
	276.4	131.2	9.82	0.29
	278.0	132.4	9.86	0.29
Average	275.12	130.28	9.85	0.29
38	282.5	136.8	9.63	0.29
	281.7	136.8	9.82	0.29
	283.8	137.2	9.82	0.29

	285.6	138.3	9.67	0.29
	287.2	139.5	9.70	0.29
Average	284.16	137.54	9.73	0.29
40	290.3	143.0	9.63	0.29
	291.6	143.0	9.74	0.29
	291.6	144.0	9.67	0.28
	295.3	146.5	9.59	0.28
	296.6	148.4	9.59	0.28
Average	293.08	144.98	9.64	0.28
42	301.2	152.3	9.36	0.28
	298.8	151.2	9.43	0.29
	298.4	151.2	9.43	0.29
	298.6	150.0	9.43	0.29
	299.0	150.0	9.55	0.29
Average	299.2	150.94	9.37	0.29
44	306.3	155.9	9.24	0.28
	310.2	160.5	9.28	0.28
	310.0	159.4	9.24	0.28
	308.2	158.9	9.24	0.28
	305.2	157.3	9.28	0.29
Average	308.0	158.4	9.25	0.29
46	314.4	164.1	9.13	0.28
	314.3	164.4	9.16	0.27
	316.9	168.3	9.16	0.28
	318.3	168.8	9.13	0.28
	318.2	169.6	9.13	0.28
Average	316.42	167.04	9.14	0.28
48	323.1	172.0	8.97	0.30
	321.9	172.3	8.97	0.27
	322.6	172.3	8.93	0.72
	319.8	171.6	8.97	0.27
	320.9	170.7	9.01	0.28
Average	321.66	171.78	8.97	0.28
50	327.9	175.8	8.86	0.27
	333.7	183.7	8.93	0.27
	329.2	179.3	8.86	0.27
	326.3	179.1	8.86	0.27
	327.7	177.7	8.86	0.28
Average	329.0	179.12	8.87	0.27

Table 7. Foam weight with 2" thick ethafoam HS-45
(natural frequency = 57 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
20	195.0	92.6	8.78	0.26
	195.3	93.6	8.74	0.25
	191.5	89.1	8.93	0.27
	194.1	91.4	8.86	0.27
	195.1	91.4	8.90	0.27
Average	194.2	91.62	8.84	0.26
22	200.8	92.3	9.20	0.29
	204.4	95.7	8.97	0.27
	206.0	95.7	9.01	0.25
	205.0	93.7	9.09	0.27
	204.1	94.5	9.16	0.27
Average	204.06	94.38	9.09	0.27
24	208.7	95.8	9.28	0.30
	210.3	97.1	9.28	0.29
	212.1	97.3	9.28	0.29
	212.5	98.0	9.24	0.29
	213.7	97.3	9.20	0.29
Average	211.46	97.1	9.26	0.29
26	220.0	102.0	9.20	0.29
	224.8	103.1	9.05	0.25
	224.1	102.0	9.28	0.27
	221.7	100.6	9.40	0.28
	224.9	101.7	9.28	0.26
Average	223.1	101.88	9.24	0.27
28	227.0	102.8	9.59	0.30
	232.8	103.9	9.40	0.28
	231.8	104.0	9.40	0.27
	232.7	104.3	9.40	0.26
	229.1	102.0	9.63	0.29
Average	230.28	103.4	9.48	0.29
30	239.2	106.5	9.47	0.27

	238.4	105.6	9.59	0.29
	238.7	105.0	9.74	0.29
	241.4	105.0	9.67	0.26
	242.7	104.3	9.7	0.26
Average	240.08	105.26	9.63	0.26
32	248.7	106.6	9.82	0.27
	248.8	107.8	9.82	0.27
	248.3	106.6	9.86	0.28
	249.6	107.5	9.94	0.27
	249.4	107.5	10.05	0.28
Average	248.96	107.2	9.9	0.27
34	257.3	110.2	9.97	0.26
	258.7	111.3	10.01	0.26
	258.4	110.9	9.97	0.26
	256.7	109.0	10.05	0.28
	256.4	109.0	10.05	0.29
Average	257.5	100.08	10.01	0.27
36	260.3	111.0	10.20	0.29
	261.0	109.7	10.28	0.30
	262.6	111.3	10.28	0.30
	264.1	111.3	10.17	0.28
	262.7	111.3	10.13	0.28
Average	262.14	110.92	10.21	0.29
38	267.7	113.7	10.40	0.30
	264.8	110.2	10.63	0.32
	269.0	112.1	10.44	0.30
	272.4	113.7	10.32	0.28
	272.7	111.3	10.40	0.28
Average	269.32	112.2	10.44	0.29
40	275.5	114.4	10.59	0.31
	276.4	113.7	10.51	0.30
	278.1	116.0	10.51	0.31
	279.1	116.0	10.47	0.30
	279.6	116.0	10.47	0.30
Average	277.74	115.22	10.51	0.30
42	286.8	120.3	10.42	0.27
	285.5	118.1	10.51	0.28
	284.0	114.8	10.74	0.29
	285.2	118.4	10.59	0.30
	281.9	114.4	10.86	0.32
Average	284.68	115.94	10.62	0.29

44	293.1	118.4	10.67	0.28
	293.2	118.1	10.67	0.27
	290.7	118.1	10.71	0.28
	291.7	116.9	10.90	0.29
	291.4	116.7	10.97	0.30
Average	292.02	117.64	10.784	0.28
46	297.2	119.5	10.86	0.30
	299.9	120.3	10.82	0.29
	299.8	120.7	10.82	0.29
	301.9	119.5	10.74	0.27
	299.8	118.4	10.86	0.29
Average	299.72	119.68	10.82	0.29
48	304.9	122.6	11.05	0.30
	307.4	124.1	10.94	0.29
	308.8	120.7	10.90	0.27
	309.0	121.9	11.05	0.28
	309.0	122.6	10.94	0.28
Average	307.82	122.38	10.98	0.28
50	313.4	125.4	10.97	0.30
	315.4	126.1	11.01	0.28
	315.6	126.6	11.01	0.29
	315.5	123.9	11.13	0.28
	314.5	125.1	11.01	0.29
Average	314.88	125.42	11.03	0.29

Table 8. Foam weight with 1" thick ehtafoam HS-45
(natural frequency = 71 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
20	181.9	119.5	6.51	0.22
	183.0	118.4	6.66	0.23
	183.1	114.1	7.20	0.25
	183.1	109.9	7.43	0.26
	185.1	111.3	7.09	0.24
Average	182.84	114.64	6.98	0.24

22	188.1	111.3	7.51	0.27
	197.2	114.8	6.97	0.23
	195.9	115.9	7.32	0.25
	193.5	113.4	7.47	0.27
	186.9	106.1	7.93	0.28
Average	192.32	116.08	7.44	0.26
24	203.3	120.1	7.35	0.26
	207.9	122.6	7.16	0.23
	209.1	119.6	7.39	0.22
	209.9	118.9	7.39	0.23
	208.8	118.4	7.51	0.24
Average	207.8	119.92	7.36	0.24
26	211.2	116.6	7.97	0.27
	214.7	119.5	7.78	0.26
	219.3	123.0	7.55	0.23
	219.3	122.5	7.62	0.23
	218.1	120.7	7.70	0.24
Average	216.52	120.46	7.53	0.25
28	222.6	122.3	7.97	0.27
	223.8	121.9	7.97	0.26
	227.9	125.4	7.74	0.23
	228.2	124.8	7.82	0.23
	224.2	121.9	8.13	0.26
Average	25.34	123.26	7.93	0.25
30	232.4	127.7	8.01	0.25
	231.7	123.6	8.13	0.25
	231.0	123.6	8.13	0.26
	232.9	126.0	8.05	0.25
	233.5	127.4	8.13	0.26
Average	232.3	125.66	8.09	0.25
32	241.3	132.4	8.09	0.25
	241.6	127.7	8.28	0.24
	241.4	130.7	8.16	0.25
	242.1	131.8	8.16	0.26
	241.3	131.2	8.20	0.26
Average	241.54	130.76	8.18	0.25
34	248.5	135.3	8.20	0.26
	251.9	135.3	8.13	0.24
	253.5	138.0	8.09	0.24
	252.5	137.5	8.13	0.25
	252.1	135.3	8.32	0.25

Average	251.66	136.32	8.17	0.25
36	254.1	136.5	8.28	0.28
	258.9	141.8	8.16	0.26
	261.3	142.8	8.13	0.25
	260.7	141.6	8.25	0.25
	261.5	141.2	8.28	0.24
Average	259.3	140.78	8.22	0.26
38	266.1	144.1	8.24	0.25
	265.4	143.6	8.24	0.27
	268.8	145.3	8.16	0.25
	268.3	145.9	8.20	0.26
	269.6	143.0	8.32	0.24
Average	267.74	144.38	8.23	0.25
40	276.2	148.5	8.32	0.24
	275.2	148.2	8.28	0.25
	274.0	148.0	8.24	0.26
	273.2	145.9	8.39	0.26
	275.7	147.7	8.39	0.25
Average	274.86	147.66	8.32	0.25
42	282.8	153.5	8.36	0.25
	283.2	154.7	8.36	0.24
	280.5	153.4	8.28	0.25
	280.0	154.7	8.28	0.27
	282.2	153.2	8.28	0.26
Average	281.74	153.9	8.31	0.25
44	290.9	158.8	8.39	0.25
	288.6	158.6	8.28	0.25
	289.2	158.2	8.39	0.26
	288.1	158.2	8.36	0.27
	289.0	158.8	8.36	0.26
Average	289.16	158.52	8.36	0.26
46	293.4	161.7	8.39	0.27
	299.2	168.8	8.20	0.25
	297.9	167.0	8.43	0.25
	298.1	167.0	8.32	0.25
	297.0	166.1	8.39	0.26
Average	297.12	166.12	8.35	0.26
48	303.4	179.9	8.28	0.25
	305.9	174.6	8.39	0.26
	306.1	172.3	8.28	0.25
	304.0	171.7	8.39	0.26

	306.2	177.1	8.32	0.26
Average	305.12	173.82	8.37	0.26
50	314.5	179.9	8.28	0.25
	314.1	183.5	8.09	0.26
	316.6	179.3	8.28	0.25
	313.6	182.8	8.28	0.26
	315.5	182.4	8.20	0.25
Average	314.86	181.58	8.27	0.25

2. Test Data in Shock Machine Drop

Table 1. Aluminum weight with 1" thick ethafoam 220
(natural frequency = 45 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
9	178.7	70.9	10.78	0.18
	179.2	70.9	10.82	0.17
	179.2	70.9	10.82	0.17
	179.4	70.9	10.90	0.18
	179.9	70.9	10.82	0.18
Average	179.28	70.9	10.7	0.18
10	195.1	77.9	10.82	0.20
	195.6	77.6	10.85	0.20
	195.8	77.8	10.94	0.20
	196.1	77.9	10.86	0.20
	196.2	77.9	10.86	0.20
Average	195.76	77.82	10.87	0.20
11	200.6	80.6	10.96	0.21
	200.5	80.3	10.94	0.21
	199.6	79.7	11.09	0.21
	195.5	78.5	11.17	0.21
	198.2	77.9	11.21	0.21
Average	198.88	79.4	11.06	0.21
12	208.5	83.8	11.09	0.23

	207.3	83.2	11.05	0.23
	207.8	82.6	11.9	0.23
	209.6	84.4	11.05	0.23
	210.0	85.0	10.97	0.23
Average	208.64	83.8	11.05	0.23
13	218.3	89.6	10.9	0.25
	219.1	90.9	10.94	0.25
	221.8	90.2	11.05	0.26
	221.9	91.4	10.94	0.25
Average	220.78	90.58	10.95	0.25
14	231.7	97.3	10.78	0.26
	231.6	97.3	10.78	0.26
	230.1	94.3	10.90	0.26
	229.3	94.3	10.94	0.26
	230.2	94.3	11.01	0.27
Average	230.58	95.38	10.90	0.26
15	238.1	101.2	10.78	0.28
	239.8	102.5	10.57	0.28
	238.9	100.8	10.82	0.28
	238.1	100.2	10.86	0.28
Average	238.72	101.22	10.80	0.28
16	246.8	107.8	10.59	0.29
	249.9	109.3	10.63	0.30
	251.6	110.1	10.63	0.30
	252.2	110.2	10.63	0.30
	252.6	110.2	10.59	0.29
Average	250.62	109.52	10.61	0.30
17	260.0	116.7	10.44	0.30
	260.8	117.0	10.44	0.33
	261.4	117.2	10.36	0.31
	262.8	119.2	10.32	0.31
	262.6	118.9	10.32	0.30
Average	261.52	117.8	10.38	0.30
18	268.6	123.0	10.28	0.31
	270.2	125.0	10.17	0.32
	270.6	125.4	10.17	0.31
	271.7	126.0	10.17	0.31
	271.4	126.1	10.17	0.31
Average	270.54	125.1	10.18	0.31
19	278.8	131.2	9.97	0.32

	281.2	134.2	10.01	0.32
	280.9	134.3	9.97	0.32
	281.3	134.8	9.94	0.32
	281.9	135.9	9.85	0.32
Average	280.82	134.08	9.97	0.32
20	289.6	142.2	9.63	0.33
	290.1	141.8	9.74	0.33
	290.0	141.8	9.67	0.33
	290.7	143.7	9.63	0.33
	291.2	143.0	9.70	0.33
Average	290.32	142.5	9.67	0.33
21	297.5	148.8	9.63	0.34
	299.0	150.3	9.55	0.34
	299.4	150.0	9.51	0.34
	300.0	151.2	9.51	0.34
	299.7	151.2	9.51	0.34
Average	299.12	150.3	9.54	0.34
22	306.6	158.6	9.36	0.34
	307.7	160.5	9.28	0.35
	307.9	160.4	9.32	0.35
	308.5	161.1	9.28	0.35
	308.5	161.4	9.24	0.35
Average	307.84	160.4	9.30	0.35
23	314.7	168.8	9.09	0.35
	315.9	168.5	9.20	0.36
	316.8	171.1	9.09	0.36
	318.1	172.3	9.05	0.35
	318.0	172.0	9.09	0.35
Average	316.7	170.54	9.10	0.35
24	323.3	178.1	8.90	0.36
	325.5	181.6	8.93	0.36
	325.7	181.6	8.90	0.36
	326.3	182.8	8.90	0.36
	326.5	184.0	8.78	0.36
Average	325.25	181.62	8.88	0.36

Table 2. Aluminum weight with 2" thick ehtafoam 220
(natural frequency = 45 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
8	153.9	53.9	10.59	0.13
	160.1	56.3	11.05	0.14
	162.1	56.5	11.28	0.15
	163.4	56.5	11.59	0.15
	163.2	56.5	11.75	0.16
Average	160.54	55.94	11.25	0.15
9	172.7	58.9	11.90	0.17
	172.7	58.6	12.01	0.17
	172.8	58.4	12.21	0.18
	173.4	58.6	12.21	0.18
	173.5	57.7	12.32	0.18
Average	173.02	58.2	12.13	0.18
10	182.4	60.8	12.44	0.20
	183.4	60.9	12.52	0.20
	183.5	60.8	12.63	0.20
	184.1	60.8	12.75	0.20
	184.1	60.9	12.75	0.20
Average	183.5	60.84	12.62	0.20
11	192.8	63.6	12.71	0.22
	193.4	63.6	12.75	0.22
	193.8	63.6	12.78	0.22
	194.1	63.6	12.90	0.22
	194.1	63.6	12.94	0.22
Average	193.64	63.6	12.82	0.22
12	202.0	66.6	13.02	0.23
	203.5	66.9	13.09	0.23
	204.4	66.9	13.13	0.24
	204.2	66.8	13.09	0.24
	204.6	67.1	13.17	0.24
Average	203.74	66.86	13.10	0.23
13	212.4	69.6	13.25	0.25
	212.4	69.6	13.36	0.26
	213.4	69.6	13.36	0.26
	213.9	70.3	13.25	0.26
	214.0	70.3	13.36	0.26
Average	213.22	69.88	13.32	0.25

14	222.6	72.7	13.48	0.27
	223.0	72.7	13.44	0.27
	223.6	73.1	13.44	0.27
	223.8	73.1	13.44	0.28
	224.2	73.1	13.51	0.28
Average	223.24	72.94	13.46	0.27
15	231.0	75.4	13.44	0.29
	231.6	75.0	13.55	0.29
	232.5	75.4	13.55	0.29
	232.8	75.4	13.59	0.29
	232.3	75.1	13.71	0.29
Average	232.04	75.26	13.57	0.29
16	241.5	78.8	13.63	0.31
	241.7	78.7	13.67	0.31
	242.2	78.5	13.71	0.31
	242.2	78.5	13.75	0.31
	242.3	78.7	13.79	0.31
Average	241.94	78.6	13.71	0.31
17	251.0	82.0	13.75	0.32
	251.8	81.3	13.82	0.33
	251.4	81.3	13.98	0.33
	251.8	81.3	13.94	0.32
	252.2	82.0	13.90	0.33
Average	251.64	81.58	13.88	0.33
18	259.9	84.8	13.90	0.34
	260.7	84.8	13.94	0.34
	260.7	83.6	13.94	0.34
	261.8	84.8	13.98	0.34
	261.1	83.6	14.02	0.34
Average	260.84	84.32	13.96	0.34
19	268.1	87.2	13.86	0.36
	269.8	87.9	13.90	0.36
	271.4	88.3	13.94	0.36
	270.6	88.0	13.94	0.36
	271.3	88.3	13.94	0.36
Average	270.24	87.99	13.92	0.36
20	277.2	90.4	13.90	0.37
	278.2	90.7	13.98	0.37
	279.3	91.8	13.94	0.37
	279.4	91.7	13.98	0.38
	279.2	91.6	14.02	0.37

Average	278.66	91.24	13.96	0.37
21	285.1	93.9	14.02	0.38
	286.6	94.2	14.06	0.38
	287.8	95.2	13.98	0.39
	288.3	95.4	13.97	0.39
	289.5	95.4	13.98	0.39
Average	287.46	94.82	14.0	0.39
22	294.8	97.4	14.06	0.40
	295.9	97.7	14.06	0.41
	296.5	97.7	14.13	0.41
	297.2	98.6	14.02	0.40
	297.8	98.9	13.98	0.41
Average	296.4	98.06	14.05	0.41
23	303.5	99.0	14.44	0.42
	303.9	101.5	14.25	0.42
	305.2	100.2	14.40	0.43
	307.0	101.4	14.48	0.43
	304.8	99.6	14.29	0.43
Average	304.88	100.34	14.34	0.43
24	310.8	103.7	14.25	0.44
	312.5	104.9	14.29	0.44
	313.0	104.9	14.25	0.44
	312.7	104.3	14.36	0.44
	313.4	104.6	14.25	0.44
Average	312.48	104.48	14.28	0.44

Table 3. Aluminum weight with 1" thick ethafoam HS_45
(natural frequency = 65)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
8	156.9	98.0	6.89	0.10
	160.4	89.1	7.20	0.10
	162.8	96.3	7.74	0.11
	158.2	78.5	8.01	0.11

	155.7	74.1	8.39	0.12
Average	158.8	85.4	7.65	0.11
9	169.5	84.4	8.36	0.14
	169.7	84.0	8.39	0.14
	170.1	84.4	8.39	0.14
	170.7	84.7	8.39	0.14
	170.5	84.2	8.39	0.14
Average	170.1	84.3	8.38	0.14
10	180.4	88.8	8.55	0.15
	181.8	88.6	8.59	0.15
	183.0	87.9	8.63	0.16
	181.3	87.1	8.63	0.16
	182.0	86.9	8.59	0.16
Average	181.7	87.9	8.60	0.16
11	192.1	91.7	8.82	0.17
	192.2	91.6	8.82	0.17
	192.6	91.0	8.86	0.17
	193.4	90.2	8.90	0.17
	194.3	90.2	8.90	0.17
Average	192.92	90.9	8.85	0.17
12	200.3	94.2	8.86	0.18
	202.6	94.2	9.01	0.18
	203.1	94.8	9.05	0.19
	203.2	93.9	8.97	0.18
	203.4	93.7	9.01	0.19
Average	202.5	94.2	8.98	0.18
13	212.2	98.4	9.05	0.20
	212.2	98.9	9.09	0.20
	212.3	98.5	9.09	0.20
	212.5	99.2	9.13	0.20
	214.8	100.3	9.20	0.20
Average	212.78	99.96	9.11	0.20
14	220.9	104.3	9.16	0.21
	220.9	103.6	9.20	0.21
	222.7	103.1	9.20	0.21
	222.4	104.3	9.20	0.21
	220.3	100.8	9.36	0.21
Average	221.44	103.2	9.25	0.21
15	228.0	105.9	9.43	0.22
	228.7	106.6	9.36	0.22

	229.2	107.1	9.32	0.22
	231.3	109.3	9.32	0.23
	232.6	109.0	9.36	0.23
Average	229.96	105.9	9.34	0.22
16	239.9	111.3	9.43	0.24
	240.9	114.6	9.32	0.24
	241.4	114.6	9.28	0.24
	242.3	114.7	9.40	0.24
	243.4	115.6	9.32	0.24
Average	241.58	115.0	9.35	0.24
17	247.3	119.0	9.36	0.24
	250.9	121.4	9.32	0.25
	250.8	120.7	9.28	0.25
	250.8	120.7	9.32	0.25
	252.0	120.7	9.32	0.25
Average	250.34	120.0	93.3	0.25
18	258.5	126.1	9.28	0.26
	260.8	127.7	9.28	0.26
	258.6	124.2	9.40	0.26
	258.6	125.8	9.32	0.26
	261.7	128.5	9.36	0.26
Average	259.64	126.5	9.33	0.26
19	266.7	131.2	9.20	0.27
	267.9	133.7	9.16	0.27
	270.2	133.9	9.20	0.27
	269.7	134.6	9.16	0.27
	271.4	135.2	9.20	0.27
Average	269.14	133.7	9.18	0.27
20	276.0	138.3	9.20	0.28
	279.9	140.6	9.13	0.28
	279.4	141.5	9.16	0.28
	278.7	140.6	9.13	0.28
	277.2	138.4	9.28	0.28
Average	278.24	140.0	9.18	0.28
21	286.4	146.2	9.09	0.29
	287.9	148.8	9.09	0.29
	286.4	145.0	9.20	0.29
	286.7	148.1	9.09	0.29
	287.9	148.4	9.09	0.29
Average	287.06	147.3	9.11	0.29

22	291.9	151.7	9.05	0.30
	293.8	152.8	9.01	0.29
	297.3	155.9	9.01	0.30
	295.5	154.0	9.01	0.30
	297.3	154.4	9.01	0.30
Average	295.16	153.8	9.02	0.30
23	300.6	158.1	9.01	0.31
	301.5	160.1	8.86	0.31
	303.4	157.8	9.05	0.31
	303.2	162.5	8.86	0.31
	304.3	162.9	8.90	0.31
Average	302.6	160.3	8.90	0.31
24	308.2	168.1	8.78	0.31
	308.9	165.7	8.82	0.31
	309.0	166.1	8.86	0.31
	310.5	168.3	8.82	0.31
	308.7	167.4	8.90	0.32
Average	309.06	167.1	8.84	0.31

Table 4. Aluminum weight with 2" thick ethafoam HS-45
(natural frequency = 53 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
8	166.1	71.5	9.36	0.13
	166.9	72.1	9.36	0.13
	165.0	70.9	9.36	0.13
	166.2	72.1	9.36	0.13
	166.9	72.1	9.36	0.13
Average	166.22	71.74	9.36	0.13
9	176.1	75.6	9.55	0.14
	176.6	75.6	9.47	0.14
	177.4	75.6	9.51	0.14
	177.3	75.6	9.51	0.14
	177.0	75.6	9.55	0.14
Average	176.88	75.6	9.52	0.14
10	185.7	78.6	9.55	0.15

	187.6	78.5	9.74	0.15
	187.7	78.5	9.74	0.16
	188.0	77.9	9.78	0.16
	187.6	77.9	9.78	0.16
Average	187.32	78.28	9.72	0.16
11	195.4	80.3	9.85	0.17
	196.4	80.3	9.97	0.17
	197.0	80.3	9.94	0.17
	197.2	80.3	10.01	0.17
	197.0	79.7	10.05	0.17
Average	196.6	80.18	9.96	0.17
12	204.6	82.0	10.20	0.18
	205.7	82.0	10.20	0.18
	205.2	81.4	10.32	0.18
	205.9	81.4	10.32	0.18
	207.0	81.7	10.32	0.20
Average	205.68	81.7	10.27	0.18
13	212.2	82.7	10.40	0.20
	216.2	83.8	10.55	0.21
	215.7	83.5	10.55	0.20
	216.4	83.2	10.59	0.20
	216.4	83.2	10.63	0.20
Average	215.38	83.28	10.54	0.20
14	222.7	85.0	10.74	0.21
	223.1	85.5	10.78	0.22
	223.1	85.0	10.82	0.22
	223.6	85.0	10.86	0.22
	225.4	85.4	10.86	0.24
Average	223.58	85.2	10.81	0.22
15	228.9	86.8	10.90	0.23
	233.9	87.9	10.90	0.23
	234.2	88.2	11.01	0.23
	234.3	87.9	11.09	0.24
	234.9	87.9	11.13	0.24
Average	233.4	87.74	11.25	0.24

16	240.4	89.6	11.17	0.25
	242.2	91.1	11.17	0.25
	242.9	90.8	11.21	0.25
	244.1	91.3	11.21	0.25
	244.9	91.7	11.24	0.25
Average	242.9	90.76	11.25	0.25
17	249.0	93.2	11.28	0.26
	250.5	93.7	11.28	0.26
	250.9	93.7	11.28	0.26
	251.5	93.7	11.32	0.26
	251.7	93.7	11.32	0.26
Average	250.72	93.6	11.30	0.26
18	257.8	96.7	11.36	0.27
	259.3	97.3	11.36	0 27
	259.6	97.3	11.36	0.28
	260.0	97.9	11.36	0.28
	260.5	97.9	11.40	0.28
Average	259.44	97.42	11.38	0.28
19	264.7	100.0	11.36	0.28
	266.2	99.0	11.48	0.29
	265.7	99.6	11.36	0.29
	267.1	100.3	11.40	0.29
	267.0	99.6	11.36	0.29
Average	266.14	99.7	11.39	0.29
20	272.4	102.0	11.51	0.30
	273.5	102.7	11.55	0.30
	274.4	102.7	11.59	0.30
	274.1	102.7	11.59	0.30
	274.3	102.5	11.59	0.30
Average	273.74	102.5	11.57	0.30
21	280.8	105.3	11.59	0.32
	282.1	106.5	11.55	0.32
	283.1	105.8	11.59	0.32
	283.5	106.3	11.59	0.32
	283.0	106.3	11.59	0.32
Average	282.5	106.04	11.58	0.32
22	288.2	108.3	11.59	0.33
	289.7	109.3	11.59	0.33
	291.1	108.3	11.75	0.33
	293.0	110.2	11.67	0.33
	293.2	110.2	11.67	0.33

Average	291.04	109.26	11.65	0.33
23	297.3	112.5	11.63	0.34
	299.3	113.2	11.67	0.34
	300.0	113.4	11.67	0.34
	299.0	112.5	11.71	0.34
	299.0	112.5	11.71	0.34
Average	298.92	112.82	11.68	0.34
24	303.3	114.8	11.71	0.35
	304.4	114.8	11.71	0.35
	304.1	114.8	11.67	0.35
	304.4	114.8	11.71	0.35
	304.4	115.0	11.75	0.36
Average	304.12	114.82	11.71	0.35

Table 5. Foam weight with 2" thick ethafoam 220
(natural frequency = 55 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
8	171.1	75.3	8.82	0.12
	172.2	74.4	8.97	0.12
	172.9	74.4	9.13	0.12
	174.5	74.7	9.24	0.12
	175.9	73.8	9.36	0.13
Average	173.32	74.5	9.11	0.12
9	189.9	72.0	10.31	0.15
	188.2	72.1	10.32	0.15
	189.4	72.1	10.44	0.16
	188.8	72.1	10.40	0.15
	187.7	71.5	10.40	0.15
Average	188.8	71.96	10.37	0.15
10	193.8	78.5	9.78	0.19
	193.5	77.3	9.90	0.15
	196.4	76.7	10.09	0.20
	197.9	76.2	10.20	0.16

	197.6	75.6	10.24	0.16
Average	195.84	76.86	10.04	0.17
11	225.9	77.9	10.47	0.17
	207.6	77.9	10.71	0.18
	208.7	77.9	10.71	0.18
	206,4	76.2	10.74	0.18
	208.4	76.8	10.78	0.18
Average	207.4	77.34	10.68	0.18
12	216.2	78.7	10.86	0.19
	216.7	78.7	10.90	0.19
	217.1	79.1	10.97	0.19
	217.2	78.5	11.05	0.20
	216.8	78.5	11.05	0.20
Average	216.8	79.1	10.97	0.19
13	224.8	80.9	11.09	0.21
	226.3	80.9	11.17	0.21
	227.3	80.7	11.32	0.21
	226.0	80.4	11.28	0.22
	228.1	80.9	11.32	0.21
Average	226.5	80.76	11.24	0.21
14	234.4	82.1	11.44	0.23
	235.5	82.9	11.40	0.22
	235.3	82.0	11.51	0.23
	232.5	82.0	11.32	0.32
	231.8	81.4	11.40	0.23
Average	233.9	82.0	11.41	0.23
15	240.6	84.4	11.55	0.24
	241.0	84.5	11.63	0.24
	242.7	83.8	11.71	0.24
	240.6	84.2	11.59	0.23
	242.1	84.1	11.69	0.23
Average	241.32	84.2	11.63	0.23
16	247.2	87.3	11.55	0.25
	249.0	87.3	11.71	0.26
	252.4	88.1	11.78	0.26
	250.8	87.6	11.82	0.26
	254.9	87.9	11.90	0.27
Average	250.86	87.52	11.75	0.26
17	260.1	89.5	12.01	0.28
	267.0	91.5	12.25	0.28

	263.6	90.2	12.13	0.28
	264.0	91.1	12.05	0.28
	262.0	90.0	12.05	0.28
Average	263.4	90.46	12.09	0.28
18	267.2	93.2	11.98	0.29
	271.4	93.5	12.09	0.30
	270.1	93.6	12.09	0.29
	270.1	93.7	11.98	0.30
	270.2	92.6	12.17	0.30
Average	269.8	92.32	12.06	0.30
19	278.0	96.4	12.17	0.31
	280.2	96.1	12.17	0.31
	279.9	96.8	12.13	0.31
	279.6	97.6	12.3	0.31
	281.7	97.4	12.13	0.32
Average	279.9	96.86	12.15	0.31
20	289.5	100.8	12.25	0.32
	290.1	100.8	12.32	0.33
	290.2	100.6	12.36	0.32
	293.4	100.8	12.36	0.33
	288.4	100.3	12.28	0.32
Average	290.32	100.66	12.26	0.32
21	294.9	101.4	12.28	0.34
	294.8	103 1	12.17	0.33
	299.6	103.9	12.36	0.34
	299.6	104.3	12.40	0.34
	300.4	104.3	12.43	0.35
Average	297.9	103.4	12.33	0.34
22	303.6	105.6	12.32	0.35
	307.4	106.6	12.28	0.35
	305.6	106.9	12.36	0.35
	306.6	106.6	12.32	0.35
	307.6	107.8	12.36	0.35
Average	306.04	106.7	12.33	0.35
23	314.1	110.0	12.40	0.36
	310.7	108.0	12.48	0.36
	313.4	109.4	12.44	0.36
	311.4	110.2	12.36	0.34
	312.3	109.0	12.36	0.36
Average	312.38	109.3	12.41	0.36

24	317.1	112.9	12.25	0.36
	321.5	112.8	12.40	0.37
	323.4	113.2	12.44	0.37
	322.9	113.6	12.52	0.38
	321.9	113.2	12.48	0.38
Average	321.36	113.14	12.42	0.37

Table 6. Foam weight with 1" thick ethafoam 220
(natural frequency = 62 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
8	164.9	85.5	7.78	0.11
	172.2	85.0	8.24	0.12
	174.4	82.6	8.43	0.13
	176.4	85.0	8.51	0.13
	178.4	84.4	8.59	0.13
Average	173.26	85.1	8.31	0.12
9	189.0	90.8	8.66	0.13
	187.4	89.7	8.74	0.14
	188.4	90.0	8.74	0.15
	190.5	91.1	8.78	0.15
	189.0	89.1	8.86	0.14
Average	188.86	90.32	8.76	0.14
10	200.4	96.7	8.86	0.16
	202.3	97.9	8.93	0.16
	201.9	96.1	8.97	0.16
	202.7	97.3	8.93	0.16
	202.4	96.1	8.97	0.16
Average	201.94	96.8	8.93	0.16
11	213.8	102.5	8.97	0.17
	214.9	102.5	9.05	0.17
	215.6	103.7	9.05	0.17
	216.0	103.7	9.05	0.17
	216.4	103.7	9.09	0.17
Average	215.34	103.22	9.04	0.17
12	224.9	107.2	9.05	0.18
	226.7	108.4	9.05	0.19

	225.8	106.1	9.16	0.18
	227.1	108.4	9.09	0.18
	227.0	107.2	9.16	0.19
Average	226.3	107.46	9.102	0.18
13	235.4	113.1	9.13	0.20
	237.2	114.3	9.13	0.20
	235.8	111.9	9.20	0.19
	236.5	111.9	9.20	0.20
	237.7	114.3	9.13	0.20
Average	236.52	113.1	9.16	0.20
14	244.2	118.1	9.09	0.21
	244.2	116.3	9.32	0.21
	244.8	117.8	9.24	0.21
	243.6	116.6	9.24	0.21
	244.1	117.2	9.20	0.21
Average	244.18	117.2	9.22	0.21
15	253.8	124.6	9.16	0.22
	255.2	123.6	9.16	0.23
	254.9	123.6	9.16	0.22
	251.6	120.9	9.32	0.23
	251.9	120.0.	9.32	0.23
Average	253.48	122.54	9.22	0.23
16	256.9	124.6	9.24	0.23
	259.6	125.9	9.36	0.24
	258.4	124.6	9.36	0.24
	256.4	120.8	9.43	0.24
	253.8	116.2	9.55	0.24
Average	257.02	122.42	9.39	0.24
17	261.9	123.3	9.47	0.25
	263.3	124.4	9.51	0.25
	263.3	125.2	9.43	0.25
	262.9	122.9	9.51	0.25
	263.6	125.5	9.43	0.26
Average	262.9	124.3	9.47	0.25
18	270.9	130.4	9.40	0.26
	273.4	133.6	9.24	0.27
	273.1	133.7	9.28	0.27
	273.9	133.9	9.28	0.26
	274.5	134.7	9.32	0.27
Average	273.16	133.26	9.304	0.27

19	282.3	140.6	9.24	0.27
	283.4	141.9	9.24	0.27
	283.6	142.1	9.20	0.27
	283.9	142.8	9.20	0.27
	284.2	142.8	9.05	0.27
Average	283.48	142.04	9.19	0.27
20	291.1	147.5	9.01	0.28
	291.6	147.9	8.90	0.28
	293.5	149.0	8.93	0.28
	292.9	149.1	8.90	0.28
	292.5	147.5	8.97	0.28
Average	292.32	148.2	8.94	0.28
21	300.0	155.7	8.78	0.29
	301.7	156.9	8.78	0.29
	301.9	157.0	8.82	0.29
	302.5	157.3	8.86	0.29
	303.2	157.3	8.82	0.29
Average	301.86	156.84	8.812	0.29
22	310.0	162.9	8.78	0.30
	312.8	163.8	8.86	0.30
	310.4	162.0	8.86	0.30
	308.7	156.1	8.93	0.30
	310.7	160.7	8.90	0.31
Average	310.52	161.1	8.87	0.30
23	316.5	166.3	8.70	0.31
	318.1	166.7	8.82	0.31
	319.1	169.0	8.70	0.31
	319.9	170.2	8.63	0.31
	320.2	171.1	8.78	0.31
Average	318.76	168.66	8.73	0.31
24	326.3	176.1	8.63	0.32
	328.2	178.4	8.63	0.32
	329.1	179.3	8.59	0.32
	328.4	179.6	8.59	0.32
	329.5	180.8	8.55	0.32
Average	327.7	178.84	8.60	0.32

Table 7. Foam weight with 2" thick ethafoam HS-45

(natural frequency = 96 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
8	167.5	138.6	5.21	0.10
	170.7	126.8	5.47	0.10
	172.0	124.5	5.58	0.10
	172.6	123.7	5.66	0.10
	174.0	124.5	5.70	0.11
Average	171.36	127.6	5.48	0.10
9	183.1	127.1	5.85	0.12
	183.1	127.5	5.97	0.12
	184.7	127.7	6.05	0.13
	184.3	126.0	6.01	0.12
	184.1	123.6	6.12	0.12
Average	183.86	126.58	6.00	0.12
10	192.1	129.5	6.12	0.12
	190.2	128.3	6.12	0.12
	193.1	128.9	6.20	0.13
	192.1	127.1	6.32	0.13
	192.5	126.0	6.39	0.13
Average	192.0	127.96	6.23	0.13
11	200.5	130.5	6.47	0.13
	201.9	128.9	6.47	0.13
	203.4	128.3	6.66	0.14
	204.0	128.0	6.78	0.14
	202.4	126.6	6.78	0.14
Average	202.44	128.46	6.63	0.14
12	212.3	130.7	6.85	0.15
	213.0	130.1	6.89	0.15
	212.5	128.9	6.93	0.15
	213.8	128.3	6.97	0.15
	212.7	127.7	6.97	0.15
Average	212.86	129.14	6.92	0.15
13	220.9	132.1	7.01	0.15
	220.4	130.5	7.09	0.15
	219.1	129.1	7.09	0.15
	218.9	128.9	7.09	0.15
	221.0	128.9	7.12	0.16
Average	220.06	129.9	7.08	0.15

14	229.2	133.6	7.20	0.16
	230.0	132.4	7.24	0.17
	229.4	131.2	7.28	0.16
	230.5	130.7	7.35	0.16
	229.0	130.1	7.35	0.16
Average	229.62	131.6	7.35	0.16
15	235.7	131.7	7.32	0.17
	236.3	132.7	7.43	0.17
	238.4	130.5	7.66	0.18
	239.1	130.4	7.70	0.18
	238.4	129.5	7.70	0.18
Average	237.58	130.96	7.56	0.18
16	244.7	133.0	7.74	0.18
	247.3	132.7	7.78	0.19
	246.9	131.5	7.78	0.18
	247.6	130.1	7.89	0.19
	246.2	130.4	7.86	0.19
Average	246.54	131.54	7.81	0.19
17	253.5	132.4	7.93	0.19
	254.9	132.2	7.89	0.19
	255.2	132.6	7.89	0.19
	255.4	132.7	7.89	0.19
	255.6	132.6	7.93	0.19
Average	254.92	132.46	7.906	0.19
18	261.9	135.5	7.97	0.20
	262.8	134.9	8.01	0.20
	262.4	133.3	8.05	0.20
	261.9	130.8	8.24	0.20
	263.8	131.2	8.36	0.21
Average	262.56	133.14	8.13	0.20
19	269.3	135.5	8.32	0.21
	272.3	135.9	8.36	0.22
	272.4	134.8	8.43	0.22
	271.4	133.4	8.39	0.22
	272.0	132.4	8.47	0.22
Average	271.48	134.4	8.39	0.22
20	277.5	135.5	8.55	0.22
	278.5	133 9	8.47	0.22
	279.4	135.6	8.51	0.23
	279.6	135.1	8.55	0.23

	279.2	134.3	8.59	0.23
Average	278.84	134.88	8.53	0.23
21	284.5	136.1	8.63	0.23
	286.1	136.6	8.63	0.24
	287.5	137.0	8.70	0.24
	288.5	136.8	8.74	0.24
	288.2	136.8	8.74	0.24
Average	286.96	136.66	8.69	0.24
22	293.0	139.0	8.74	0.24
	295.0	140.0	8.82	0.25
	295.0	139.6	8.78	0.25
	295.6	138.9	8.82	0.25
	295.1	138.7	8.82	0.25
Average	294.74	139.24	8.80	0.25
23	301.0	141.0	8.86	0.26
	303.1	141.8	8.90	0.26
	302.2	141.1	8.93	0.26
	303.3	141.6	8.90	0.26
	304.6	141.8	8.93	0.26
Average	302.84	141.48	8.90	0.26
24	305.9	141.8	8.93	0.26
	309.3	144.1	8.97	0.27
	308.8	143.3	9.01	0.27
	309.7	141.8	9.05	0.27
	307.6	141.1	9.05	0.27
Average	308.26	142.42	8.99	0.27

Table 8. Foam weight with 1" thick ehtafoam HS-45
(natural frequency = 91 Hz)

H [in]	V [in/sec]	G [g's]	D [ms]	X [in]
8	160.4	149.7	4.85	0.08
	164.6	134.2	5.24	0.09
	166.7	128.9	5.70	0.09
	164.7	123.6	5.85	0.09
	168.0	123.0	5.97	0.09

Average	164.88	133.5	5.72	0.09
9	177.2	126.6	6.05	0.10
	176.9	123.0	6.12	0.10
	178.2	121.3	6.20	0.10
	176.7	119.2	6.24	0.10
	177.2	120.0	6.28	0.10
Average	177.24	122.0	6.14	
10	186.9	121.9	6.39	0.11
	187.4	120.7	6.43	0.11
	187.5	120.7	6.43	0.11
	187.1	120.6	6.43	0.11
	188.8	120.7	6.51	0.11
Average	187.54	120.9	6.44	0.11
11	196.8	125.4	6.58	0.12
	197.3	124.2	6.82	0.12
	195.2	122.2	7.01	0.12
	186.5	118.4	7.09	0.12
	190.1	107.2	7.39	0.13
Average	193.18	119.5	6.98	0.12
12	201.4	116.0	7.09	0.15
	203.1	120.1	7.01	0.15
	203 0	120.1	7.01	0.15
	203.3	120.1	7.05	0.15
	204.1	120.5	7.09	0.15
Average	202.98	119.4	7.05	0.15
13	213.3	127.1	7.05	0.16
	214.4	127.1	7.05	0.16
	214.2	126.6	7.12	0.16
	213.1	124.8	7.12	0.16
	213.5	126.0	7.12	0.16
Average	213.7	126.3	7.92	0.16
14	221.6	131.2	7.12	0.16
	222.1	130.7	7.12	0.17
	224.7	131.8	7.20	0.17
	224.9	131.8	7.32	0.17
	224.6	130.7	7.47	0.17
Average	223.58	131.2	7.25	0.17
15	230.3	132.9	7.51	0.18
	229.2	129.5	7.78	0.18
	228.8	128.3	7.82	0.18
	226.7	123.0	7.93	0.19

	228.7	127.1	7.70	0.19
Average	228.74	128.2	7.75	0.18
16	236.8	134.8	7.59	0.20
	238.4	136.5	7.55	0.20
	239.5	135.9	7.62	0.20
	240.9	137.1	7.62	0.20
	240.9	137.7	7.62	0.20
Average	239.3	136.4	7.60	0.20
17	246.5	141.2	7.51	0.21
	247.8	142.4	7.59	0.21
	248.6	143.6	7.55	0.21
	248.5	143.0	7.59	0.21
	248.4	142.4	7.55	0.21
Average	247.96	142.5	7.56	0.21
18	254.2	147.1	7.55	0.21
	256.1	148.2	7.55	0.22
	256.2	147.7	7.55	0.22
	256.9	148.2	7.59	0.22
	257.1	148.2	7.55	0.22
Average	256.1	147.9	7.56	0.22
19	263.1	152.6	7.55	0.23
	265.3	154.8	7.55	0.23
	265.1	153.7	7.62	0.23
	264.7	152.9	7.62	0.23
	266.5	155.0	7.62	0.23
Average	264.94	153.8	7.59	0.23
20	272.6	158.0	7.59	0.23
	274.6	160.5	7.55	0.23
	276.8	161.3	7.62	0.24
	276.3	161.2	7.62	0.24
	278.1	162.9	7.62	0.24
Average	275.68	160.8	7.60	0.24
21	281.8	163.9	7.55	0.24
	284.7	166.6	7.62	0.24
	284.7	167.7	7.55	0.25
	285.1	169.0	7.59	0.25
	283.8	166.4	7.62	0.24
Average	284.02	166.7	7.59	0.24
22	292.0	173.0	7.59	0.25
	295.0	177.8	7.55	0.25

	294.2	175.8	7.59	0.25
	295.2	176.7	7.59	0.25
	296.1	177.8	7.59	0.25
Average	294.46	176.2	7.58	0.25
23	299.1	180.5	7.59	0.26
	302.1	184.0	7.51	0.26
	301.7	182.3	7.59	0.26
	302.3	182.8	7.59	0.26
	301.6	181.5	7.59	0.26
Average	301.36	182.2	7.57	0.26
24	308.1	188.7	7.51	0.26
	310.0	191.0	7.51	0.26
	311.1	192.2	7.51	0.27
	311.0	191.0	7.51	0.27
	311.5	191.0	7.51	0.27
Average	310.3	190.8	7.51	0.27

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