MICHIGAN STATE UNIVERSITY LIBRARIES
3 1293 00802 4337

LIBRARY
Michigan State
University

This is to certify that the

thesis entitled

THE EFFECT OF OUTER PACKAGE

ON SHOCK ABSORBING CHARACTERISTICS

presented by

TAKESHI INAGAKI

has been accepted towards fulfillment
of the requirements for

M.S. degree in PACKAGING

Dr. James W. Goff
Major professor

Date April 3, 1987

O-7639

MSU is an Affirmative Action/Equal Opportunity Institution

May 10
18

MSU
LIBRARIES

RETURNING MATERIALS:
Place in book drop to
remove this checkout from
your record. FINES will
be charged if book is
returned after the date
stamped below.

May 10, 1993
18

THE EFFECT OF OUTER PACKAGE
ON SHOCK ABSORBING CHARACTERISTICS

By

Takeshi Inagaki

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

School of Packaging

1987

ABSTRACT

THE EFFECT OF OUTER PACKAGE ON SHOCK ABSORBING CHARACTERISTICS

By

Takeshi Inagaki

This study investigated the effect of an outer container on the shock transmissibility in a cushioned packaging system.

Three factors, trapped air, box side panel friction and the corrugated paperboard, which were thought to influence the dynamic performance of the cushioning system were studied.

Five different product-cushion-package configurations, three of which provided each of the individual factors acting alone, one which provided all of the factors acting together and one without any of the factors, were used to study the effects.

A regular slotted container was used as the outer package, and the cushioning material was 2.2 pcf polyethylene foam. The simulated product was a rigid wood block.

It was found that each factor had an effect on the shock transmitted to the product individually, and collectively they caused a decrease in the peak acceleration and an increase in the shock pulse duration seen by the product.

To Nobuko, Naoko and Saki

ACKNOWLEDGEMENTS

The writer wishes to express his sincere appreciation for the guidance and support given in this research by Dr. James W. Goff, professor, School of Packaging, Michigan State University.

He also wishes to extend his appreciation for the assistance with experimental work given by Fanfu Li, graduate student, for the assistance with material preparation given by Alan B. Adams, specialist and for the special assistance with choosing committee members given by Diana Twede, senior research assistant, School of Packaging, Michigan State University.

Finally, he wishes to express his special appreciation for the support given by TOSHIBA CORPORATION in Japan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

w	Weight of Mass
k	Spring Rate of Linear Cushion
h	Height of Drop
x	Displacement of Mass
G_m	The Absolute magnitude of The Maximum Acceleration
τ	Pulse Duration
g	Gravitational Acceleration
k_1	Spring Rate of Spring 1
k_2	Spring Rate of Spring 2
k_e	Equivalent Spring Rate
k_f	Spring Rate of Cushion with Friction
d_0	Maximum Deflection of x if Initial Spring Rate were maintained
F	A Friction Force
ΔV	Velocity Change
ΔX	Peak displacement Experienced by An Accelerometer during Impact

INTRODUCTION

Protecting products from damage due to distribution hazards is a major function of packaging (1).

The most commonly used product-package system for relatively fragile products is composed of product,cushion and an outer package as shown in Figure 1.

While both static forces and dynamic forces can be exerted on the product-package system, most damage results from the dynamic forces which result from handling. The most effective way to prevent shock damage is to provide a cushion between the product and the outer package. Much research has been done on the dynamic performance of the product-package system. Some of the research papers are concerned with the dynamic performance of each element, and others cover the dynamic performance of the entire system.

Mindlin (2) explained the dynamics of package cushioning by using the mathematical models. In his paper, the outer package was assumed to be rigid. Newton (3) established a fragility assessment theory and test procedures. Goff and Pierce (4) developed a fragility testing procedure for products.

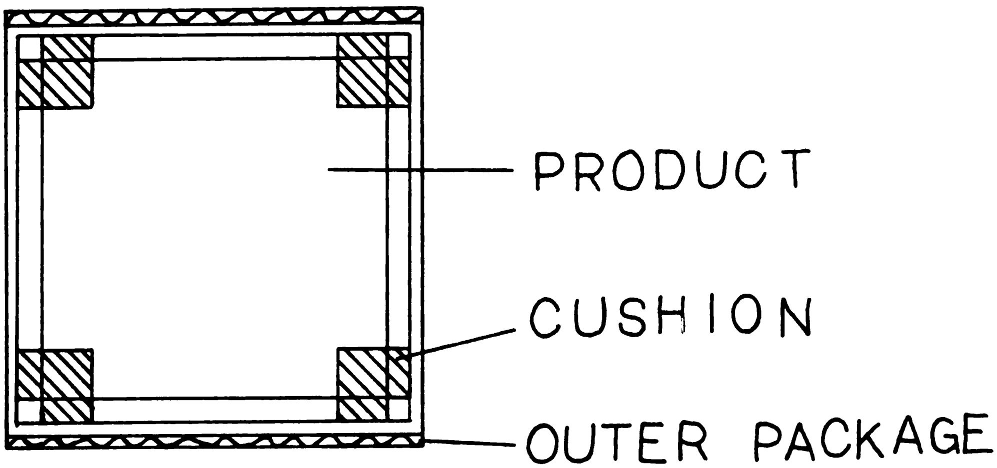


Figure 1. Elements of Product-Package System

Testing techniques for assessing the dynamic behavior of cushioning material have been established (5,6). A method of designing packages has been developed (7).

Some research relating to the cushion-outer package relationship has been done by individuals in the School of Packaging at Michigan State University.

Palmreuter (8) derived cushion curves for different kinds of built-up corrugated material. McCall (9) investigated the shocks which cause the corrugated board itself to become damaged. From his observations, he found that a large number of package drops will result in a collapse of the flute structure, and subsequent shocks will be amplified. Willson (10) tested relative energy absorption properties of free and enclosed cushions and found that the enclosed cushion is definitely stiffer. In his tests, he used rubberized hair cushions and plywood enclosures. The cushion was put between two 12 inch square platens, and static forces and dynamic forces were exerted on it in both free and enclosed conditions. Goff and Blake (11) compared shock level values measured in an 8" x 8" x 8" dummy wooden block with an 8" x 8" cushion area at the bottom using two sizes of regular slotted containers having dimensions, 8" x 8" x 8" and 8 1/4" x 8 1/4" x 8 1/4". They reported that the shock level values predicted from cushion curves of the test package having inside dimensions of 8 1/4" x 8 1/4" x 8 1/4" were closer to the actual shock level values.

McGinnis (12) followed Willson. He tested cushion performance with different amounts of lateral restraint. He used expanded bead polystyrene and bonded animal hair as cushioning materials and boxes made from A-flute corrugated board as the enclosure. In his paper, he suggested that the greatest effect of lateral restraint on a package cushion is the restriction of air movement in and around the cushion during dynamic shocks. On the other hand, Mindlin (2) mathematically derived the influence of friction developed by rubbing against the side and end pads in a package on acceleration and displacement.

In order to clarify the effect of the outer package on shock absorbing characteristics, it is required to combine their concepts investigated in the previous work, test the prduct-package system as closely to the actual situation as possible and evaluate the test results. No work of this kind is reported in the literature. The concern of each of the previous researches was a single aspect of the product-package system. Only Newton (3) addressed the effect of the outer package.

Based on the above discussion, the following three factors can be considered in a flat drop situation as the major factors which influence the effect of the outer package on shock transmissibility.

[1] air trapped inside the outer package

[2] side panel friction of the outer package

[3] corrugated flaps (box bottom) of the outer package

The following three effects which are derived from the three factors can be considered as shown in Figure 2.

[1] air trap effect

[2] side panel effect

[3] corrugated board effect

Consequently, the purposes of this research are

[1] to determine if these effects exist.

[2] to determine the extent to which each effect influences the shock transmissibility in an actual product-package system.

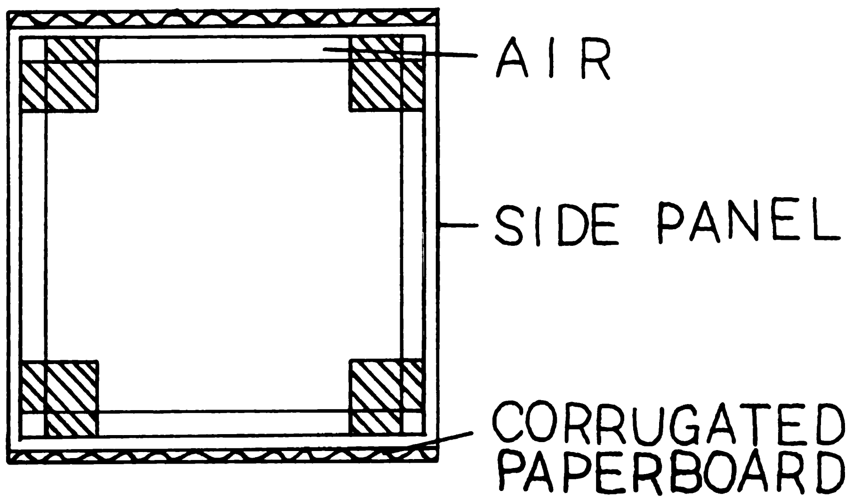


Figure 2. Major Factors Influencing
Outer Package's Shock Transmissibility

EVALUATION OF OUTER PACKAGE PERFORMANCE

In a product-package system composed of product, cushion and an outer package, each element dissipates a part of shock energy.

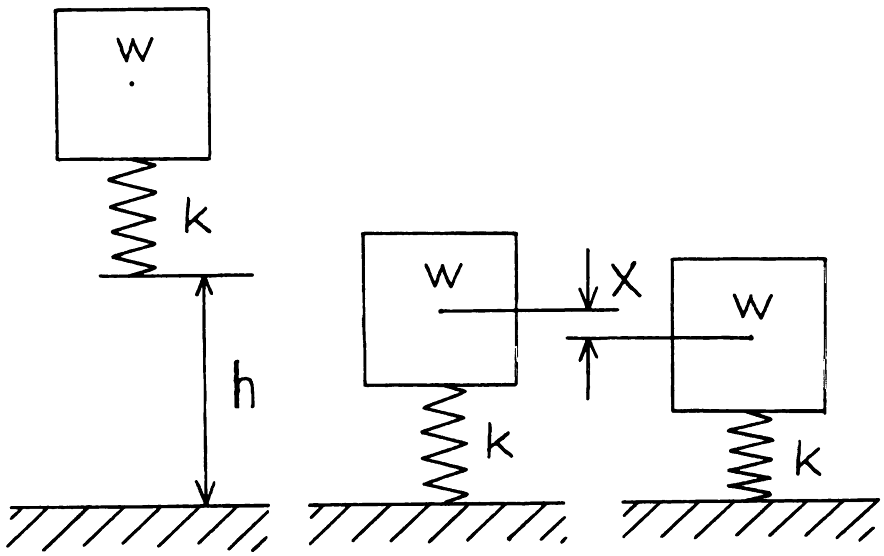
An instrumented wood block was used as the product. Because the block is very rigid when compared with the cushion and the outer package, it is considered that the total shock energy is absorbed by the cushion and the outer package.

In an elementary spring mass model under free fall situation, as shown in Figure 3, the absolute magnitude of the maximum acceleration, Gm, and pulse duration, τ, of the transmitted shock pulse through the product-package system are derived as follows.

$$Gm = \sqrt{\frac{2hk}{w}}$$

$$\tau = \frac{\pi}{\sqrt{\frac{kg}{w}}}$$

In this situation, the combination of springs can be considered. When two springs are placed in parallel, as shown in Figure 4, the equivalent spring rate increases, which results in increasing Gm and decreasing τ.



(a)

Free Fall
at a Drop Height h

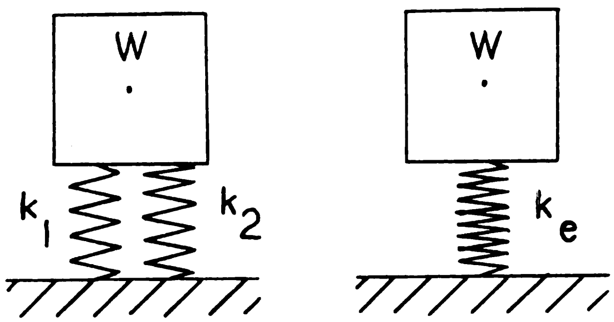
(b)

Spring in Contact
with the Floor

(c)

Spring Deformation

Figure 3. Elementary Spring Mass Model



Equivalent Spring Rate

$$k_e = k_1 + k_2$$

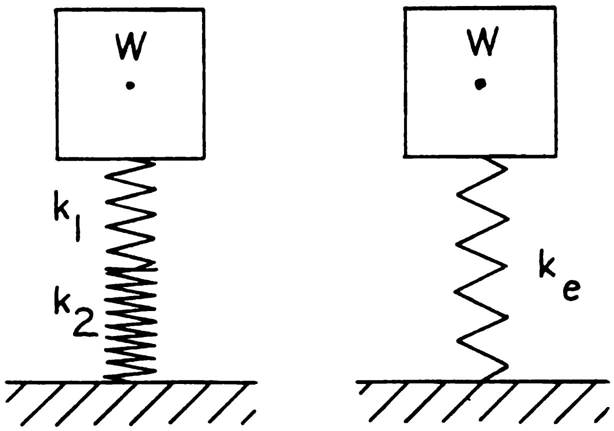
Figure 4. Two Springs Acting in Parallel

When the springs are placed in series, as shown in Figure 5, the equivalent spring rate decreases, which results in decreasing Gm and increasing τ(13). In addition, Mindlin (2) shows that the maximum acceleration is reduced by the addition of dry friction for the same maximum displacement. Mindlin also shows that this may be done by decreasing the spring rate in the cushioning with friction to

$$k_f = k - \frac{2F}{d_0}$$

$$d_0 = \sqrt{\frac{2wh}{k}}$$

Considering the above, the conclusion can be reached that each factor influences the effective total spring rate of the whole product-package system. As a result, both Gm and τ will be changed. Actually, free fall shock pulses are different from this model. However, since the first few peaks are very close to this linear undamped model, the approach described can be used.



Equivalent Spring Rate

$$k_e = \frac{k_1 k_2}{k_1 + k_2}$$

Figure 5. Two Springs Acting in Series

In this paper, the following evaluation criteria were used.

[1] When Gm increases, and τ decreases, the effect exists.

It acts by increasing the effective spring rate of the cushion.

[2] When Gm decreases, and τ increases, the effect exists.

It acts by reducing the effective spring rate of the cushion.

[3] Otherwise, no significant effect exists.

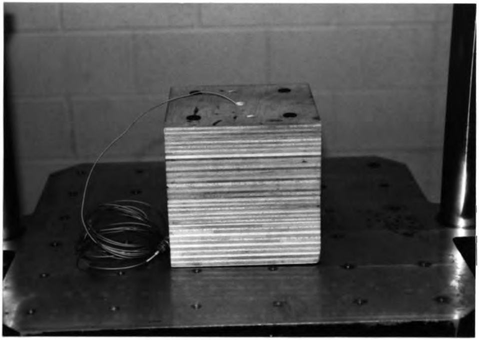
TEST MATERIALS

Materials used in the tests consist of the following.

1. An instrumented wood block as the product
2. Polyethylene foam as the cushion
3 200 pound C-flute corrugated paperboard as the outer package

[1] An instrunented wood block

An instrumented wood block was used as the product. This block was constructed of maple dieboard. The layers were glued together. A KISTLER Model 818 accelerometer was amounted in the center of the block to pick up shock signals. Steel weights, Aluminum weights, and Bolt-nuts weights was bolted individually to change the static loadings. The built-up dimensions of the instrumented wood block were 8" x 8" x 8" (Figures 6, 7, 8, 9, 10).



Dimensions : 8" x 8" x 8"

Weight : 10 9/16 lbs

Figure 6. Instrumented Wood Block

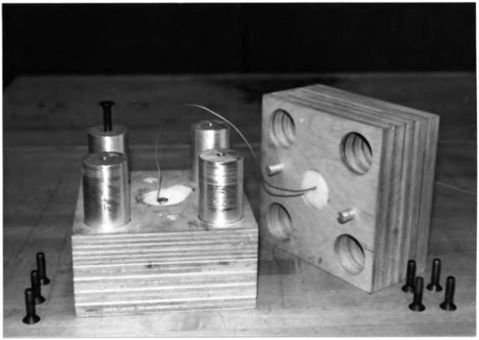
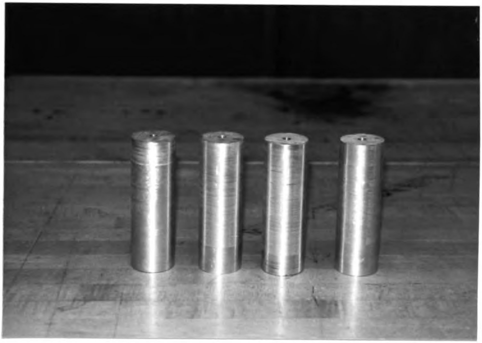


Figure 7. Structure of Instrumented Wood Block

Dimensions : 1 7/8" diameter, 6 1/8" long

Weight : 5 2/16 lbs/each

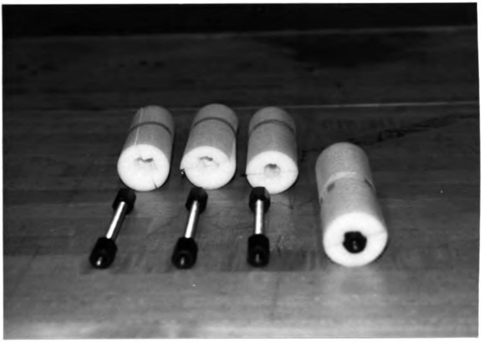
Figure 8. Steel Weight



Dimensions : 1 7/8" diameter, 6 1/8" long

Weight : 1 15/16 lbs/each

Figure 9. Aluminum Weight



Dimension : 5 1/8" long

Weight : 5/16 lbs/each

Figure 10. Bolt-Nuts Weight

[2] Polyethylene foam

ETHAFOAM 220* brand polyethylene foam (2.2 pcf) was used as the cushion. Three different shapes of cushion, type A cushion, type B cushion and type C cushion, were cut with a band saw and a table saw so that each cushion had the same one inch thickness. Each type of cushion provides the same bearing area of 16 square inches per face (Figures 11, 12, 13, 14, 15, 16).

[3] corrugated paperboard blank

200 pound C-flute corrugated paperboard blanks were cut with the sample making machine in the School of Packaging. The blanks were preconditioned at 73 degrees fahrenheit and 35 % relative humidity. When the blank was built up, the box had inside dimensions of 10" x 10" x 10" (Figure 17).

* Trademark of The Dow Chemical Company

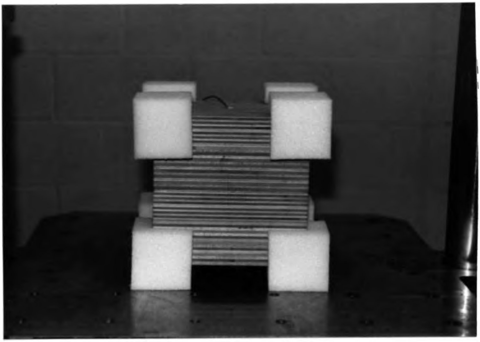


Figure 11. Type A Cushion

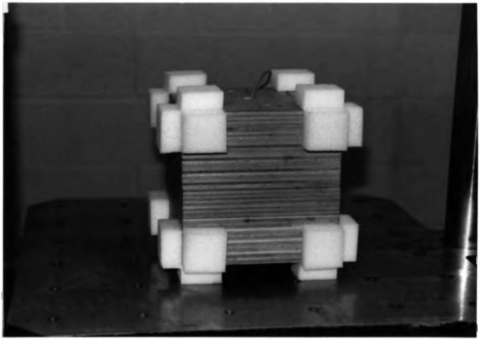


Figure 12. Type B Cushion

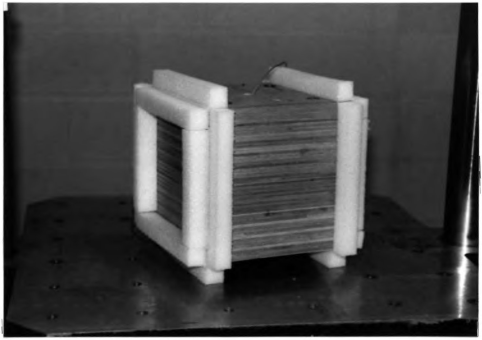


Figure 13. Type C Cushion

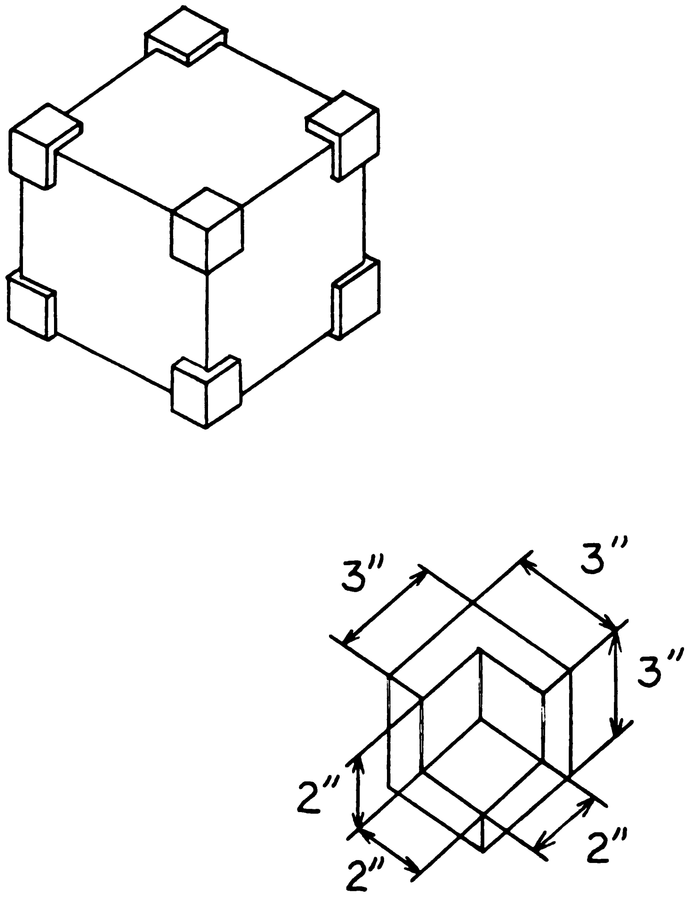


Figure 14. Dimensions of Type A Cushion

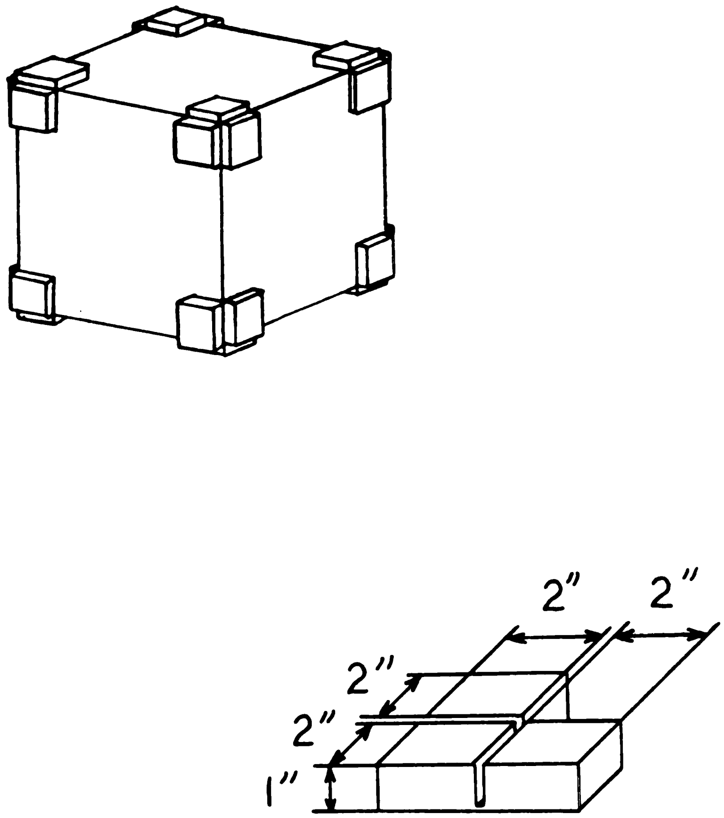


Figure 15. Dimensions of Type B Cushion

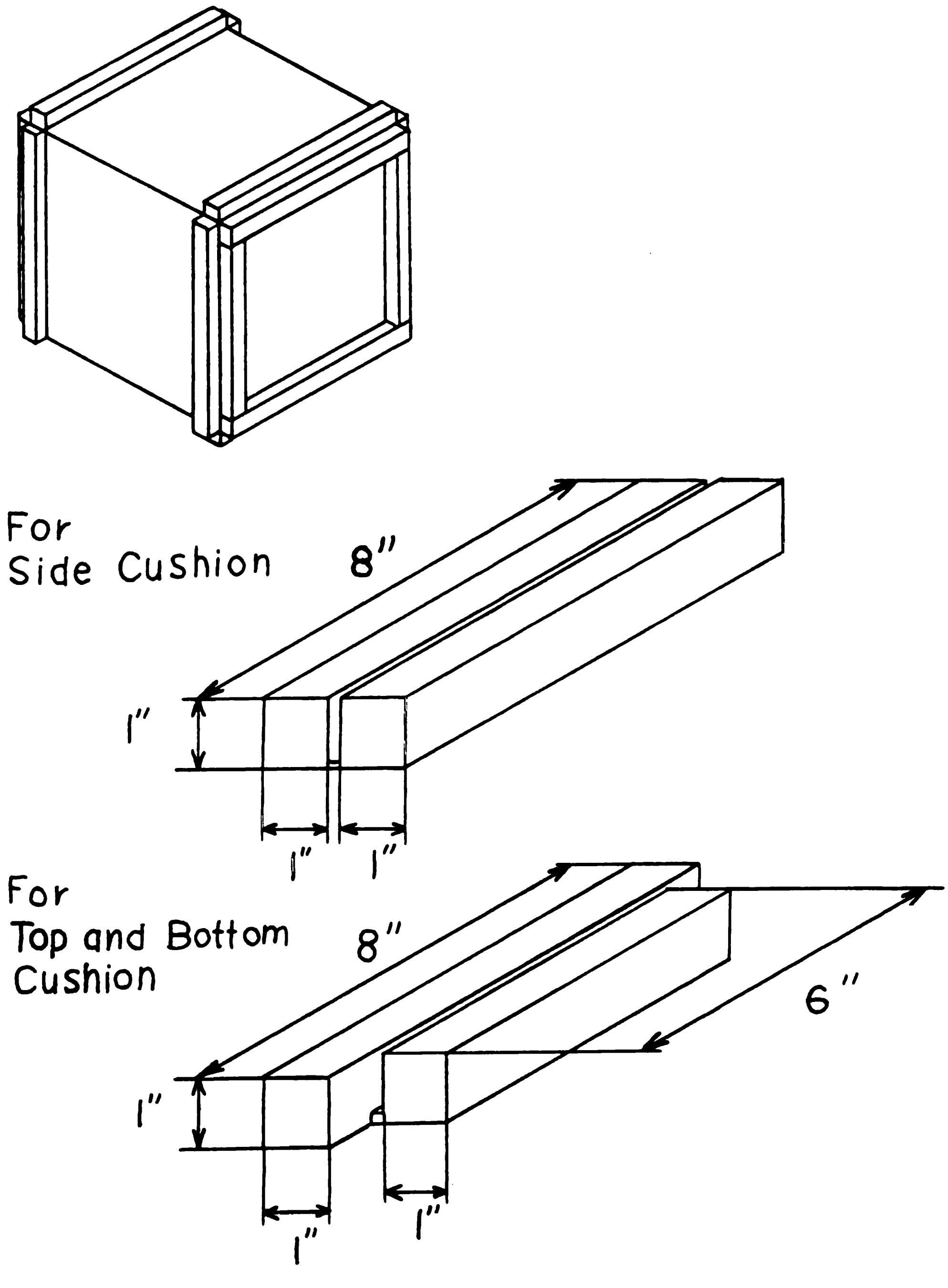
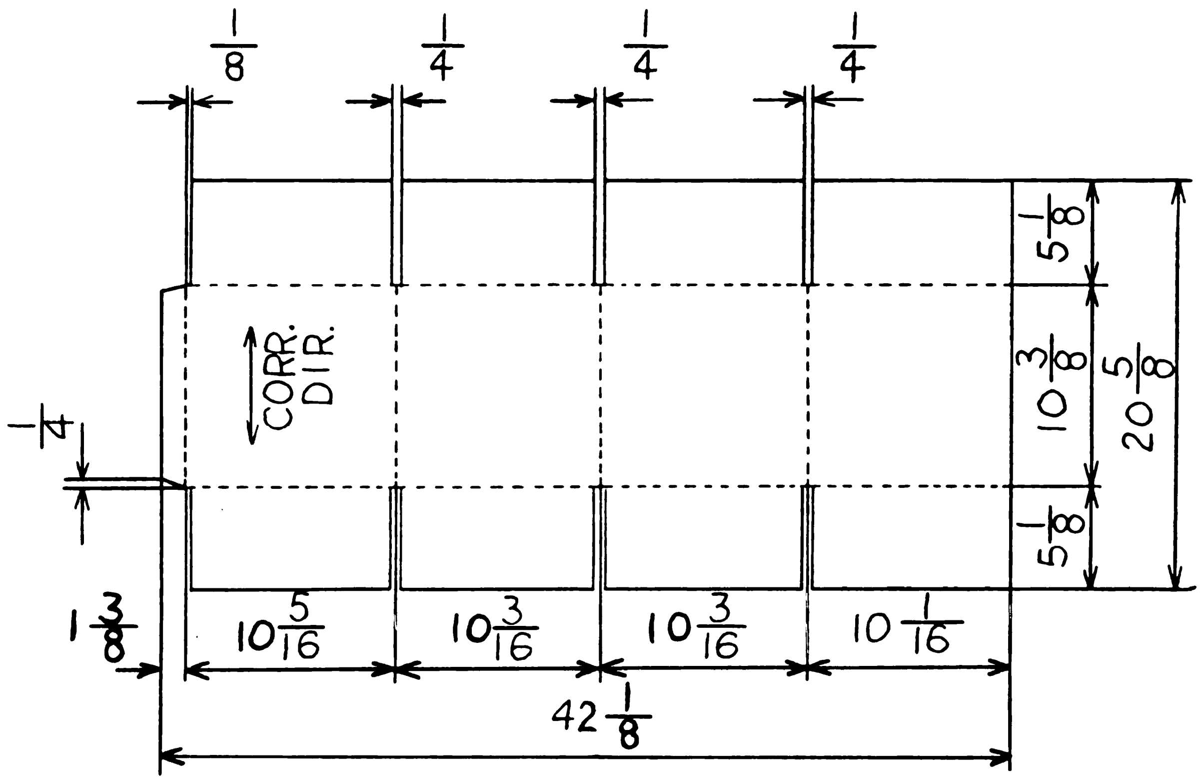


Figure 16. Dimensions of Type C Cushion



unit : inches

Figure 17. Dimensions of Corrugated Paperboard Blank

FIVE PRODUCT-PACKAGE TEST SPECIMENS

In order to detect each effect of the outer package, the following five product-package test specimens were made.

[1] no effect specimen

[2] air trap effect specimen

[3] side panel effect specimen

[4] corrugated board effect specimen

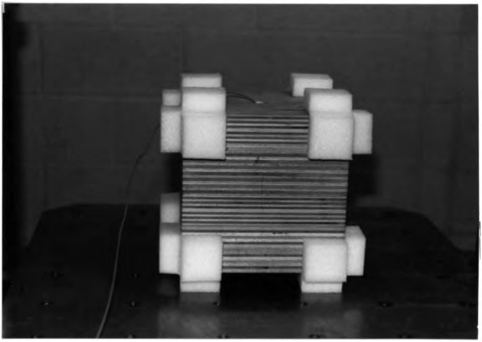
[5] all effects specimen

[1] no effect specimen

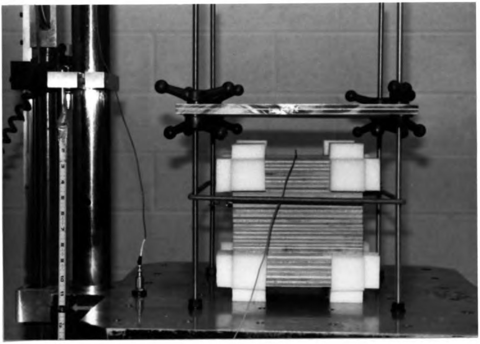
Cushioning material was attached to the instrumented wood block with double faced tape (Figure 18).

[2] air trap effect specimen

Cushioning material was attached to the instrumented wood block with double faced tape. Mobil 70 gauge LLDPE stretch film was wrapped horizontally and vertically at 0 % elongation around the wood block with cushion. The end and edge of the film was sealed with pressure sensitive tape (Figure 19).

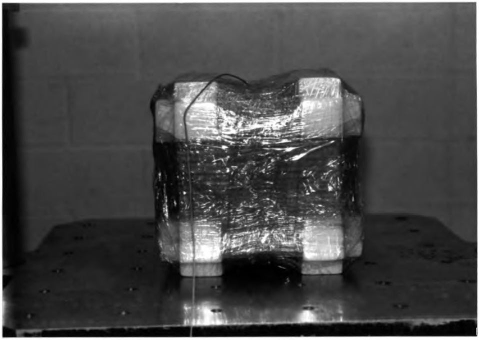


AFTER MAKING

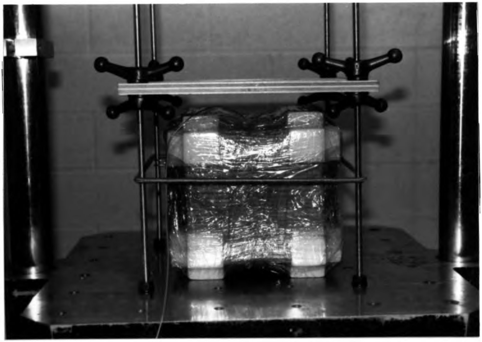


READY TO DROP

Figure 18. No Effect Specimen (type B cushion)



AFTER MAKING



READY TO DROP

Figure 19. Air Trap Effect Specimen (type B cushion)

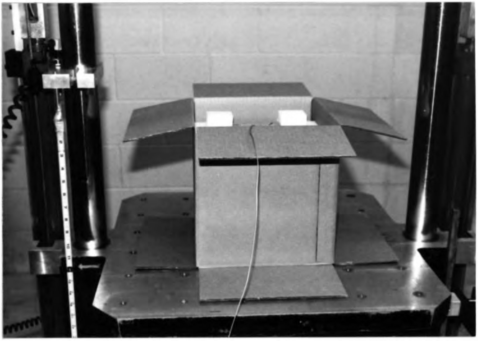
[3] side panel effect specimen

Cushioning material was attached to the instrumented wood block with double faced tape. The manufacturer's joint of the blank was glued on the outside of the box with hot melt adhensive. The wood block with cushion was placed in the outer package. Both top and bottom flaps were kept open (Figure 20).

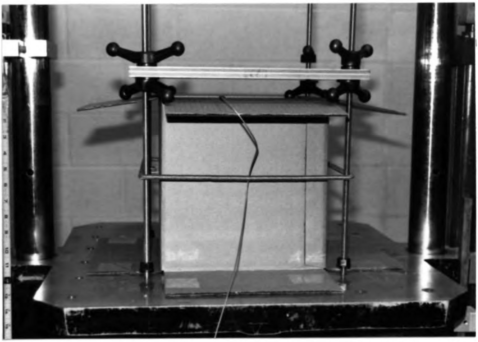
[4] corrugated board effect specimen

Cushioning material was attached to the instrumented wood block with double faced tape. The manufacturer's joint of the blank was glued on the outside of the box with hot melt adhensive, and bottom flaps were sealed with pressure sensitive tape.

The wood block with cushion was inserted into the box. Side corners were cut along the vertical scores with a cutter. The inside and outside flaps of the bottom were secured to each other with pressure sensitive tape. The contact area of the cushion was marked with a pencil to keep the contact area the same as in the other tests (Figure 21).

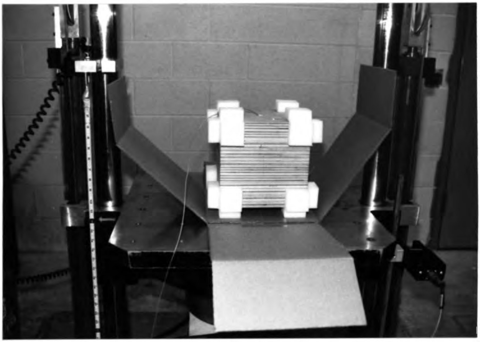


AFTER MAKING

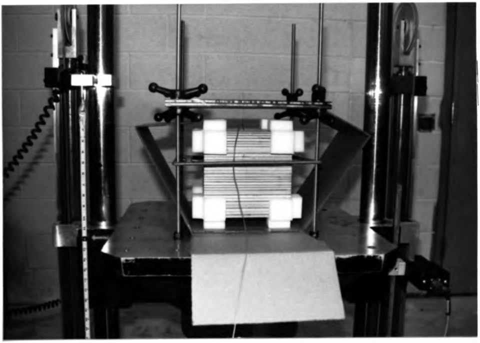


READY TO DROP

Figure 20. Side Panel Effect Specimen (type B cushion)



AFTER MAKING

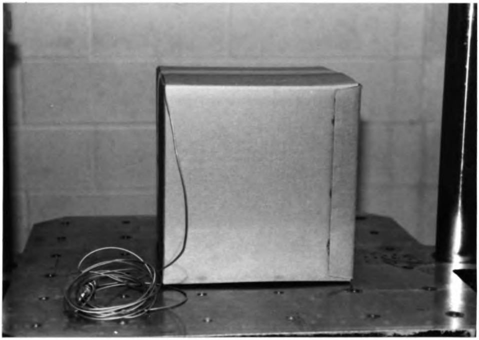


READY TO DROP

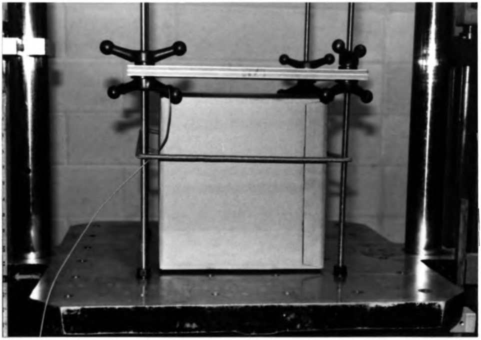
Figure 21. Corrugated Board Effect Specimen (type B cushion)

[5] all effects specimen

Cushioning material was attached to the instrumented wood block with double faced tape. The manufacturer's joint of the blank was glued on the outside of the box with hot melt adhesive, and bottom flaps was sealed with pressure sensitive tape. The wood block with cushion was inserted into the box, and top flaps were sealed with pressure sensitive tape (Figure 22).



AFTER MAKING



READY TO DROP

Figure 22. All Effects Specimen (type B cushion)

TEST INSTRUMENTATION

The instrumentation used for measuring and recording the shock pulses consisted of the following.

[1] MTS IMPAC II 2424 shock test machine

[2] MTS velocity sensor

[3] KISTLER Model 587D piezotron couplers

[4] MTS 466.10 wave analyzer

[5] TEXTRONIX 2213A 60 mhz oscilloscope

[6] HEWLETT PACKARD 7470A plotter

[7] KISTLER Model 815A1 accelerometer

[8] KISTLER Model 818 accelerometer

A block diagram of instrumentation is shown in Figures 23 and 24.

The two accelerometers were connected to the couplers, which serve as a power supply for the internal amplifier of the accelerometers. The KISTLER Model 815A1 accelerometer was used for picking up the shock pulses generated on the shock table, and the KISTLER Model 818 instrumented in the wood block was used for those transmitted through the each test specimen. The couplers were connected to the wave analyzer.

Figure 23. Total View of Test Instrumentation

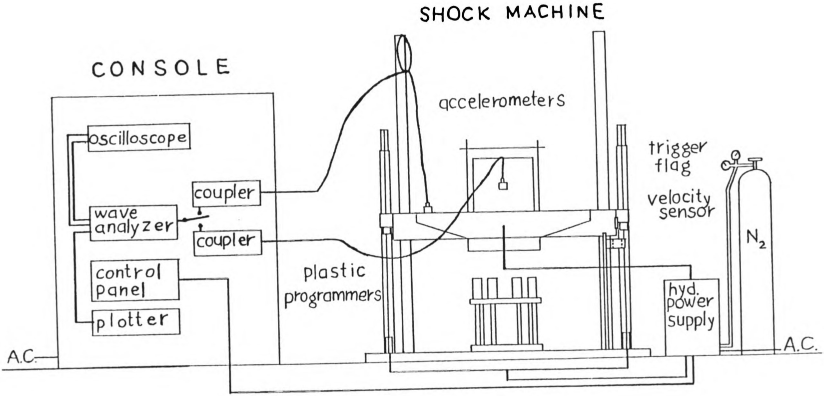


Figure 24. Shock Pulse Measuring System Diagram

The velocity sensor was also connected to the wave analyzer. This velocity sensor and one inch wide trigger flag secured to the shock table make a trigger pulse, which initiates the shock recording process. The wave analyzer converts analog signals to digital signals and calculates waveform parameters, that is, ΔV, peak g, pulse duration, ΔX and impact velocity. Plastic programmers were used through the tests. They consist of eight cylindrical plastic pads which produce two millisecond half-sine shock pulses for simulation of shocks encountered in a free fall drop environment. Since the velocity sensor passes the trigger flag slightly earlier than the time the shock table hits the plastic programmers, measured impact velocity values are not actual impact velocity values which the test specimens had, but they are considered to be close to the actual values (APPENDIX A). The oscilloscope provides a visual plot of a shock pulse, and the plotter draws a shock pulse on a sheet.

A compressed nitrogen gas cylinder and a hydraulic power supply are used for raising the shock table before impact and for activating the brake system to catch the rebounding shock table after impact. The control panel is used for operating the hydraulic power supply.

TEST PROCEDURE

Testing consisted of two parts, Part I tests and Part II tests. Part I tests were conducted before Part II tests.

Part I tests were designed to study the three effects of the outer package and the effects of cushion shape and static loading.

Part II tests were designed to analyze the data by a paired comparison based on the Part I test results.

In Part I tests, 45 different specimens were tested. Each specimen has a different cushion shape and a different static loading as shown in Table 1. Each test specimen had six drops at a 12 inch drop height. At the 2nd and 6th drops, the input shock pulses to the test specimens were recorded by the accelerometer secured to the shock table. At the 1st, 3rd, 4th, and 5th drops, the transmitted shock pulses were recorded by the accelerometer in the instrumented wood block.

Table 1. Test Specimens In Part I Tests

specimen	cushion shape	static loading [psi]
no effect specimens	type A cushion	.77 1.16 1.95
	type B cushion	.77 1.16 1.95
	type C cushion	.77 1.16 1.95
air trap effect specimens	type A cushion	.77 1.16 1.95
	type B cushion	.77 1.16 1.95
	type C cushion	.77 1.16 1.95
side panel effect specimens	type A cushion	.77 1.16 1.95
	type B cushion	.77 1.16 1.95
	type C cushion	.77 1.16 1.95

Table 1 (cont'd.). 45 Test Specimens In Part I Tests

specimen	cushion shape	static loading [psi]
corrugated board effect specimens	type A cushion	.77 1.16 1.95
	type B cushion	.77 1.16 1.95
	type C cushion	.77 1.16 1.95
all effects specimens	type A cushion	.77 1.16 1.95
	type B cushion	.77 1.16 1.95
	type C cushion	.77 1.16 1.95

Based on the Part I test results, type B cushions were used in Part II tests. A static loading of 1.16 psi was chosen because it is within the preferred operating region of the cushioning curve (14).

Twenty five specimens composed of five no-effect specimens, five air trap-effect specimens, five side panel-effect specimens, five corrugated board-effect specimens and five all-effects specimens, were tested. All the specimens were assigned to five blocks (groups) so that each block has five different effect specimens. Tests were conducted according to the block number, and the test order in the block was determined randomly. Table 2 shows the test order. A paired comparison analysis was applied to the test data in the block.

Each test specimen had six drops at a 12 inch drop height. During the 1st to 5th drop, the transmitted shock pulses were recorded by the accelerometer in the instrumented wood block. Since the difference between input shock pulses at the 2nd drop and 6th drop in Part I tests was slight, only the 6th drop was used to measure the input shock pulse in Part II tests. The input shock pulses were recorded by the accelerometer secured on the shock table. Input shock pulses and the transmitted 1st and 5th drop shock pulses were plotted on the data sheets (APPENDIX B).

Table 2. Test Specimens In Part II Tests

block	specimen	cushion shape	static loading [psi]	test order
	all effects specimen			1
	corrugated board effect specimen			2
1	no effect specimen	type B cushion	1.16	3
	side panel effect specimen			4
	air trap effect specimen			5
	side panel effect specimen			6
	corrugated board effect specimen			7
2	no effect specimen	type B cushion	1.16	8
	air trap effect specimen			9
	all effects specimen			10
	air trap effect specimen			11
	no effect specimen			12
3	corrugated boadr effect specimen	type B cushion	1.16	13
	all effects specimen			14
	side panel effect specimen			15

Table 2 (cont'd.). Test Specimens In Part II Tests

block	specimen	cushion shape	static loading [psi]	test order
	corrugated board effect specimen			16
	all effects specimen			17
4	no effect specimen	type B cushion	1.16	18
	air trap effect specimen			19
	side panel effect specimen			20
	all effects specimen			21
	air trap effect specimen			22
5	corrugated board effect specimen	type B cushion	1.16	23
	side panel effect specimen			24
	no effect specimen			25

Tests were conducted at 73 degrees Fahrenheit and 50 % relative humidity. Each test specimen was made before the test and placed on the shock table. Only the bottom flaps of the side panel-effect specimens were secured to the shock table with pressure sensitive tape. The support was composed of a plywood panel, 4 steel rods, nuts and rubber band and set on the shock table to prevent the test specimens from dropping off the shock table. The plywood panel has a 6 1/4" diameter hole in the center and was set 1 1/2" above the test specimens (Figure 25). The position of the velocity sensor was not changed during the tests.

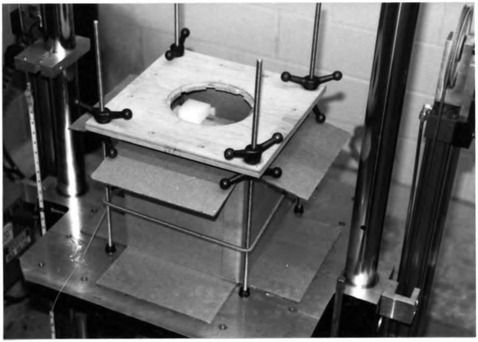


Figure 25. Support on The Shock Table

TEST DATA IN PART I TESTS

Table 3. Test Data in Part I Tests

3-1 Test Data for No Effect Specimen with Type A Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact velocity [in/sec]	Remark
1st	225.4	80.3	13.52	.24	74.2	
2nd	152.2	375.0	1.77	.04	74.7	input shock
3rd	242.0	117.8	11.44	.27	74.8	
4th	243.0	126.0	10.90	.27	74.8	
5th	244.8	130.7	10.55	.27	74.9	
6th	155.3	375.6	1.77	.05	75.2	input shock

3-2 Test Data for Air Trap Effect Specimen with Type A Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	213.6	68.0	13.71	.22	73.9	
2nd	152.7	357.0	1.77	.05	74.6	input shock
3rd	235.5	113.2	11.36	.26	74.8	
4th	236.4	123.0	10.67	.25	74.9	
5th	244.2	131.2	10.46	.27	75.2	
6th	150.9	369.1	1.73	.04	75.1	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-3 Test Data for Side Panel Effect Specimen with Type A Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	207.3	65.0	13.67	.22	73.6	
2nd	152.7	372.8	1.77	.06	73.9	input shock
3rd	230.5	97.9	12.59	.27	74.3	
4th	235.8	106.6	12.13	.27	74.4	
5th	238.3	114.8	11.75	.28	74.5	
6th	153.9	375.0	1.81	.05	74.7	input shock

3-4 Test Data for Corrugated Board Effect Specimen with Type A Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	213.2	63.2	14.86	.24	73.5	
2nd	150.9	369.1	1.73	.04	74.5	input shock
3rd	231.0	87.9	13.63	.29	74.6	
4th	231.9	90.2	13.44	.29	74.7	
5th	236.9	104.2	13.05	.35	74.7	
6th	150.7	369.1	1.77	.04	74.6	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-5 Test Data for All Effects Specimen with Type A Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	202.8	58.0	14.44	.22	74.0	
2nd	151.6	369.1	1.77	.05	74.1	input shock
3rd	220.5	80.3	13.52	.27	74.1	
4th	223.7	84.4	13.48	.28	74.3	
5th	225.3	88.4	13.18	.29	74.3	
6th	154.8	375.0	1.77	.05	74.3	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-6 Test Data for No Effect Specimen with Type A Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	218.1	80.9	14.40	.31	73.3	
2nd	229.3	114.8	11.55	.34	74.8	
3rd	231.1	121.9	11.24	.33	74.4	
4th	231.6	126.0	10.86	.33	73.4	
5th	235.3	133.6	10.40	.33	74.2	
6th	146.3	351.6	1.77	.05	74.2	input shock

3-7 Test Data for Air Trap Effect Specimen with Type A Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	220.5	99.6	12.55	.30	76.6	
2nd	154.5	380.9	1.77	.04	78.6	input shock
3rd	242.8	190.9	7.55	.31	79.1	
4th	243.9	207.3	7.09	.31	79.2	
5th	243.7	215.3	6.78	.30	79.3	
6th	156.9	386.7	1.77	.05	79.4	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-8 Test Data for Side Panel Effect Specimen with Type A Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	202.7	65.6	14.71	.27	74.0	
2nd	215.7	99.6	12.44	.30	73.4	
3rd	218.0	116.0	11.36	.31	73.2	
4th	220.8	121.3	11.28	.31	73.8	
5th	219.9	127.7	10.28	.32	73.7	

3-9 Test Data for Corrugated Board Effect Specimen with Type A Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	213.3	64.5	16.17	.32	75.3	
2nd	215.9	96.1	13.48	.34	73.9	
3rd	217.2	142.8	10.17	.36	74.6	
4th	221.4	156.4	9.43	.36	74.7	
5th	223.1	166.4	9.05	.36	74.9	
6th	145.3	357.4	1.77	.05	75.2	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-10 Test Data for All Effects Specimen with Type A Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	193.6	51.0	16.40	.28	75.4	
2nd	205.5	66.2	15.21	.33	75.3	
3rd	213.4	96.9	12.71	.33	75.3	
4th	216.1	130.7	10.67	.35	75.1	
5th	215.2	138.3	10.20	.34	75.0	

Table 3 (cont'd.). Test Data in Part I Tests

3-11 Test Data for No Effect Specimen with Type A Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	213.2	113.1	11.48	.38	76.8	
2nd	155.3	386.7	1.73	.04	77.7	input shock
3rd	197.0	222.0	4.81	.21	78.2	
4th	201.7	243.2	4.66	.20	77.8	
5th	202.6	252.3	4.47	.19	77.8	
6th	158.4	389.7	1.73	.05	78.2	input shock

3-12 Test Data for Air Trap Effect Specimen with Type A Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	215.9	126.6	10.20	.36	76.3	
2nd	158.8	386.7	1.77	.05	77.6	input shock
3rd	174.1	215.7	3.58	.18	78.1	
4th	172.6	230.6	3.39	.17	78.1	
5th	173.1	244.8	3.27	.16	78.1	
6th	158.8	392.6	1.77	.05	78.3	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-13 Test Data for Side Panel Effect Specimen with Type A Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	225.8	138.9	10.20	.40	79.2	
2nd	158.6	392.6	1.77	.04	79.1	input shock
3rd	185.9	246.8	3.70	.19	79.1	
4th	188.5	268.3	3.58	.17	78.9	
5th	191.9	276.2	3.62	.17	78.7	
6th	158.5	392.6	1.77	.05	78.7	input shock

3-14 Test Data for Corrugated Board Effect Specimen with Type A Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	198.1	98.4	13.55	.40	77.3	
2nd	159.4	386.7	1.77	.05	78.3	input shock
3rd	175.9	188.0	4.70	.23	78.4	
4th	182.4	217.7	4.58	.21	78.3	
5th	181.7	228.9	3.85	.19	78.3	
6th	156.5	387.5	1.73	.04	79.0	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-15 Test Data for All Effects Specimen with Type A Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	196.0	90.2	14.06	.41	78.3	
2nd	161.0	398.4	1.77	.04	79.4	input shock
3rd	166.1	193.7	4.39	.22	79.5	
4th	180.1	200.1	4.51	.22	79.5	
5th	180.0	204.4	4.16	.21	79.5	
6th	163.0	400.3	1.77	.05	79.6	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-16 Test Data for No Effect Specimen with Type B Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	222.7	78.5	14.17	.27	74.3	
2nd	153.0	375.0	1.77	.04	74.9	input shock
3rd	242.2	131.2	10.67	.29	74.8	
4th	245.1	143.6	9.82	.29	74.9	
5th	246.3	149.4	9.63	.29	74.8	
6th	154.2	375.0	1.81	.04	74.8	input shock

3-17 Test Data for Air Trap Effect Specimen with Type B Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	222.5	82.0	13.90	.28	73.6	
2nd	150.0	369.1	1.77	.04	74.3	input shock
3rd	239.0	128.3	10.86	.29	74.2	
4th	241.6	140.6	9.82	.29	74.4	
5th	243.6	145.9	9.67	.29	74.5	
6th	151.8	372.1	1.81	.06	74.6	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-18 Test Data for Side Panel Effect Specimen with Type B Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	213.8	71.5	14.33	.27	74.2	
2nd	150.1	363.3	1.77	.04	75.1	input shock
3rd	234.0	120.1	11.36	.29	75.1	
4th	237.2	131.8	10.71	.29	75.1	
5th	239.0	137.1	10.55	.29	75.1	
6th	153.6	375.0	1.81	.04	75.0	input shock

3-19 Test Data for Corrugated Board Effect Specimen with Type B Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	212.5	60.9	15.90	.27	73.8	
2nd	153.4	369.1	1.77	.05	74.6	input shock
3rd	231.6	92.0	13.75	.32	74.8	
4th	235.5	107.8	12.36	.33	75.0	
5th	236.6	128.9	11.17	.33	74.9	
6th	150.8	369.1	1.77	.04	75.0	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-20 Test Data for All Effects Specimen with Type B Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	215.6	65.6	15.75	.30	74.3	
2nd	151.3	375.0	1.77	.04	75.3	input shock
3rd	234.2	98.4	13.67	.33	75.3	
4th	237.4	114.3	12.44	.33	75.4	
5th	237.8	133.6	11.17	.34	75.3	
6th	153.4	369.1	1.77	.05	75.2	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-21 Test Data for No Effect Specimen with Type B Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	219.1	110.7	12.52	.31	75.2	
2nd	156.8	380.9	1.77	.05	77.1	input shock
3rd	209.3	221.7	5.39	.25	77.8	
4th	208.6	251.9	4.77	.22	78.3	
5th	207.9	263.3	4.54	.20	78.1	
6th	159.0	386.7	1.81	.05	77.9	input shock

3-22 Test Data for Air Trap Effect Specimen with Type B Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	223.1	116.6	12.36	.33	76.7	
2nd	155.8	380.9	1.81	.05	77.7	input shock
3rd	235.6	196.1	7.05	.31	79.0	
4th	229.7	210.5	6.32	.29	78.8	
5th	224.1	221.5	5.78	.27	79.0	
6th	161.3	386.7	1.77	.05	79.1	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-23 Test Data for Side Panel Effect Specimen with Type B Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	236.1	128.1	10.94	.36	77.0	
2nd	155.8	380.9	1.77	.04	78.0	input shock
3rd	244.8	185.9	7.93	.34	78.0	
4th	243.0	194.7	7.47	.33	78.3	
5th	239.1	201.6	7.01	.32	78.4	
6th	153.5	380.9	1.73	.04	78.4	input shock

3-24 Test Data for Corrugated Board Effect Specimen with Type B Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	208.2	65.8	16.33	.36	75.5	
2nd	151.8	375.0	1.77	.04	76.7	input shock
3rd	191.9	170.0	6.70	.31	77.7	
4th	198.0	183.0	6.55	.30	77.8	
5th	200.0	177.1	6.66	.31	77.6	
6th	159.8	386.0	1.81	.06	78.3	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-25 Test Data for All Effects Specimen with Type B Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	214.5	70.3	15.79	.36	76.9	
2nd	155.1	380.9	1.77	.04	78.5	input shock
3rd	181.2	183.9	5.55	.27	79.0	
4th	188.9	192.0	5.47	.27	79.4	
5th	194.6	205.7	5.39	.26	79.5	
6th	160.7	392.6	1.81	.05	79.3	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-26 Test Data for No Effect Specimen with Type B Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	169.2	171.5	5.04	.23	76.2	
2nd	158.2	386.7	1.77	.04	77.0	input shock
3rd	194.8	268.8	3.23	.15	77.3	
4th	194.4	262.9	3.20	.15	77.2	
5th	195.4	280.4	3.08	.14	77.4	
6th	156.1	386.7	1.77	.04	77.6	input shock

3-27 Test Data for Air Trap Effect Specimen with Type B Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	165.7	152.5	5.70	.26	75.7	
2nd	158.1	380.9	1.81	.05	76.4	input shock
3rd	178.1	262.8	3.12	.15	77.2	
4th	184.1	289.6	3.04	.14	77.3	
5th	187.1	305.3	2.93	.13	77.6	
6th	155.7	381.2	1.73	.05	77.8	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-28 Test Data for Side Panel Effect Specimen with Type B Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	165.8	161.6	5.12	.25	76.2	
2nd	155.0	375.0	1.77	.05	76.3	input shock
3rd	188.3	239.0	4.27	.18	75.9	
4th	182.6	236.3	4.35	.17	74.2	
5th	187.6	238.3	4.31	.17	74.8	
6th	153.1	369.1	1.77	.04	74.7	input shock

3-29 Test Data for Corrugated Board Effect Specimen with Type B Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	188.6	110.6	12.05	.42	74.2	
2nd	156.4	380.9	1.73	.05	75.5	input shock
3rd	174.0	192.1	4.31	.21	76.1	
4th	180.3	254.5	3.66	.17	76.5	
5th	185.8	270.0	3.58	.17	76.7	
6th	157.9	385.6	1.77	.05	77.5	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-30 Test Data for All Effects Specimen with Type B Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	196.5	117.8	11.09	.42	76.6	
2nd	159.6	386.7	1.77	.05	77.7	input shock
3rd	185.1	201.2	5.01	.22	78.1	
4th	178.0	239.0	3.81	.18	77.9	
5th	184.7	249.7	3.85	.19	78.0	
6th	160.0	392.6	1.77	.05	78.3	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-31 Test Data for No Effect Specimen with Type C Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	215.7	71.5	14.25	.26	74.0	
2nd	153.0	376.1	1.81	.05	75.3	input shock
3rd	239.4	130.1	10.55	.29	75.5	
4th	241.2	140.6	9.82	.29	75.4	
5th	242.0	145.3	9.55	.29	75.2	
6th	154.0	375.0	1.77	.04	75.2	input shock

3-32 Test Data for Air Trap Effect Specimen with Type C Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	212.3	70.9	13.82	.24	73.7	
2nd	152.7	369.1	1.77	.04	74.4	input shock
3rd	233.4	124.2	10.82	.27	74.6	
4th	236.2	133.6	10.36	.27	74.9	
5th	238.1	141.8	9.82	.27	75.0	
6th	152.6	375.0	1.77	.04	75.1	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-33 Test Data for Side Panel Effect Specimen with Type C Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	225.2	93.7	13.29	.30	73.9	
2nd	153.0	375.0	1.77	.04	74.8	input shock
3rd	241.7	133.6	11.36	.31	75.3	
4th	241.6	135.3	11.17	.31	75.4	
5th	243.4	141.8	10.90	.30	75.3	
6th	152.9	375.0	1.77	.04	75.3	input shock

3-34 Test Data for Corrugated Board Effect Specimen with Type C Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	212.5	60.9	15.98	.28	73.6	
2nd	150.6	363.3	1.81	.05	74.5	input shock
3rd	231.9	97.3	13.48	.32	74.9	
4th	234.9	107.8	12.71	.33	74.9	
5th	235.3	117.8	11.98	.33	75.0	
6th	151.9	375.0	1.81	.04	74.9	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-35 Test Data for All Effects Specimen with Type C Cushion at .77 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	202.4	55.1	15.63	.26	74.5	
2nd	154.9	379.8	1.81	.05	75.6	input shock
3rd	223.1	91.4	12.94	.30	75.7	
4th	226.3	100.8	12.32	.30	75.7	
5th	228.7	109.0	12.01	.30	75.8	
6th	155.6	380.9	1.77	.05	75.7	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-36 Test Data for No Effect Specimen with Type C Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	238.4	133.0	10.74	.38	76.4	
2nd	160.8	392.6	1.77	.05	77.9	input shock
3rd	223.7	187.1	6.74	.30	78.3	
4th	227.0	195.5	6.55	.30	77.9	
5th	223.5	198.6	6.32	.28	77.9	
6th	159.0	386.7	1.77	.05	78.1	input shock

3-37 Test Data for Air Trap Effect Specimen with Type C Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	240.6	149.4	9.59	.37	78.4	
2nd	161.2	392.6	1.77	.05	78.6	input shock
3rd	213.9	198.9	6.24	.28	78.6	
4th	212.7	208.7	5.89	.26	78.4	
5th	213.3	227.3	5.43	.25	78.6	
6th	157.1	386.7	1.77	.04	78.5	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-38 Test Data for Side Panel Effect Specimen with Type C Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	228.9	124.2	11.75	.33	80.1	
2nd	160.0	398.4	1.77	.05	79.8	input shock
3rd	194.5	216.7	5.01	.24	79.8	
4th	197.8	237.2	4.74	.22	79.8	
5th	200.4	251.3	4.62	.21	79.6	
6th	161.5	392.6	1.81	.05	79.4	input shock

3-39 Test Data for Corrugated Board Effect Specimen with Type C Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	219.2	115.1	13.59	.36	78.8	
2nd	160.0	390.8	1.81	.05	78.0	input shock
3rd	191.0	178.5	6.20	.29	78.2	
4th	190.5	201.2	5.35	.25	78.3	
5th	193.4	203.7	5.35	.25	78.4	
6th	158.4	386.7	1.77	.05	78.2	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-40 Test Data for All Effects Specimen with Type C Cushion at 1.16 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	207.7	65.1	15.90	.35	79.0	
2nd	159.3	386.7	1.77	.05	79.2	input shock
3rd	219.1	176.2	8.05	.36	79.1	
4th	174.9	174.7	5.62	.28	79.1	
5th	174.8	184.7	5.16	.26	79.0	
6th	157.3	382.3	1.77	.05	78.9	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-41 Test Data for No Effect Specimen with Type C Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	181.4	167.2	5.55	.27	79.6	
2nd	158.8	404.3	1.73	.04	79.5	input shock
3rd	204.0	251.9	4.27	.19	79.5	
4th	205.4	248.5	4.16	.18	79.5	
5th	208.3	246.9	4.27	.19	79.3	
6th	156.4	386.7	1.73	.05	79.0	input shock

3-42 Test Data for Air Trap Effect Specimen with Type C Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	176.7	154.8	5.89	.26	74.0	
2nd	148.4	357.4	1.77	.04	74.8	input shock
3rd	184.7	228.2	4.00	.19	75.4	
4th	187.5	253.1	3.85	.18	75.8	
5th	187.9	259.4	3.85	.18	75.7	
6th	152.6	369.1	1.77	.05	76.1	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-43 Test Data for Side Panel Effect Specimen with Type C Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	218.3	133.0	9.40	.42	79.4	
2nd	150.9	375.0	1.73	.05	78.6	input shock
3rd	190.8	181.2	5.24	.24	77.0	
4th	194.2	199.6	5.04	.23	76.7	
5th	194.4	212.5	4.93	.20	76.7	
6th	153.1	372.4	1.77	.05	77.1	input shock

3-44 Test Data for Corrugated Board Effect Specimen with Type C Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	189.2	130.4	8.90	.47	79.7	
2nd	156.6	386.7	1.73	.04	79.6	input shock
3rd	180.9	197.8	4.47	.22	79.6	
4th	183.0	213.4	4.12	.21	79.3	
5th	185.0	220.9	3.97	.20	79.4	
6th	158.7	392.6	1.73	.05	79.4	input shock

Table 3 (cont'd.). Test Data in Part I Tests

3-45 Test Data for All Effects Specimen with Type C Cushion at 1.95 psi

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	197.5	118.2	10.28	.46	78.5	
2nd	154.2	380.9	1.73	.05	78.6	input shock
3rd	181.8	207.1	4.85	.22	79.1	
4th	178.9	210.6	4.08	.20	79.2	
5th	179.7	216.9	3.93	.20	79.1	
6th	157.2	386.7	1.77	.04	79.5	input shock

DATA ANALYSIS IN PART I TESTS

Measured peak gs and pulse durations are shown in Figures 26 to 34. To see the trend of difference between the no-effect specimen and the other-effect specimens on peak g and pulse duration, Table 4 was made.

It was observed that impact velocity changed slightly drop by drop. Slight setting error of drop height, changing friction between the shock table and steel rods of the shock machine and tolerance of the measuring device can be considered to be the major factors for the change.

In comparing the difference between the no-effect specimen and the other-effect specimens on peak g and pulse duration, the test data for which the impact velocity exceeded the impact velocity for the no-effect specimens by ±1.5 in/sec was omitted from the analysis. The values ±1.5 in/sec are based on the tolerance of the velocity sensor, which measures the impact velocity.

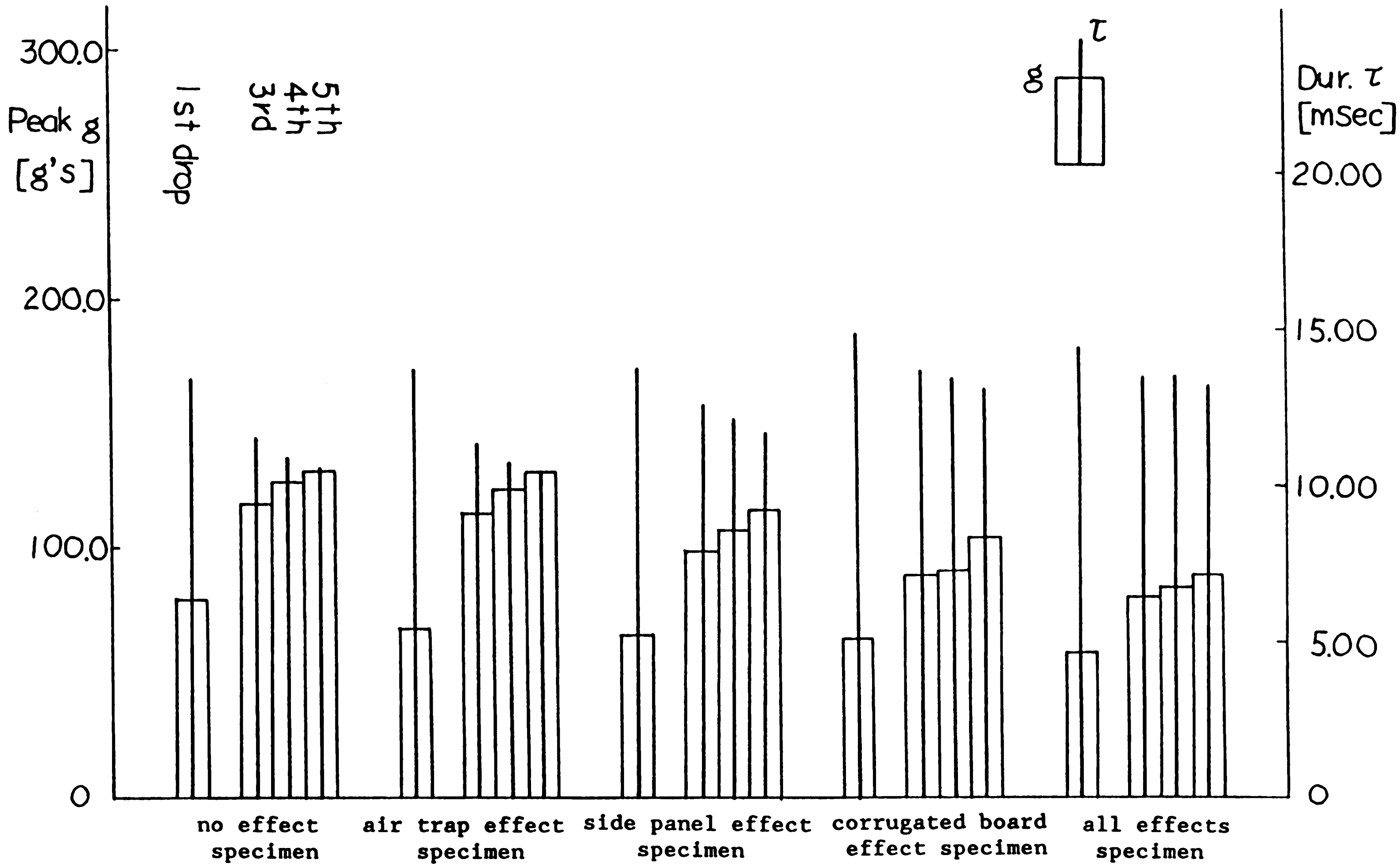


Figure 26. Peak g and Pulse Duration τ (type A cushion, .77 psi)

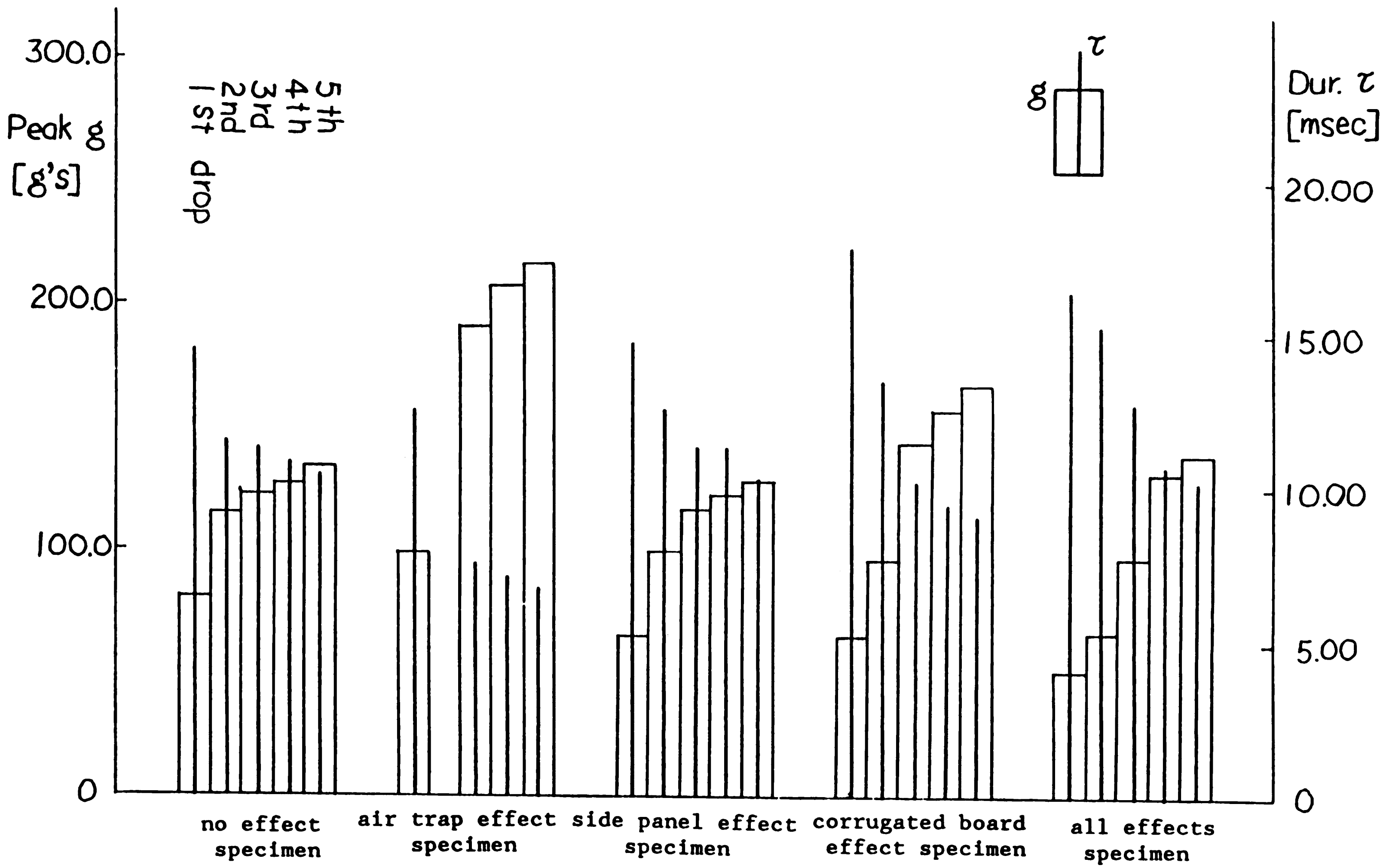


Figure 27. Peak g and Pulse Duration τ (type A cushion, 1.16 psi)

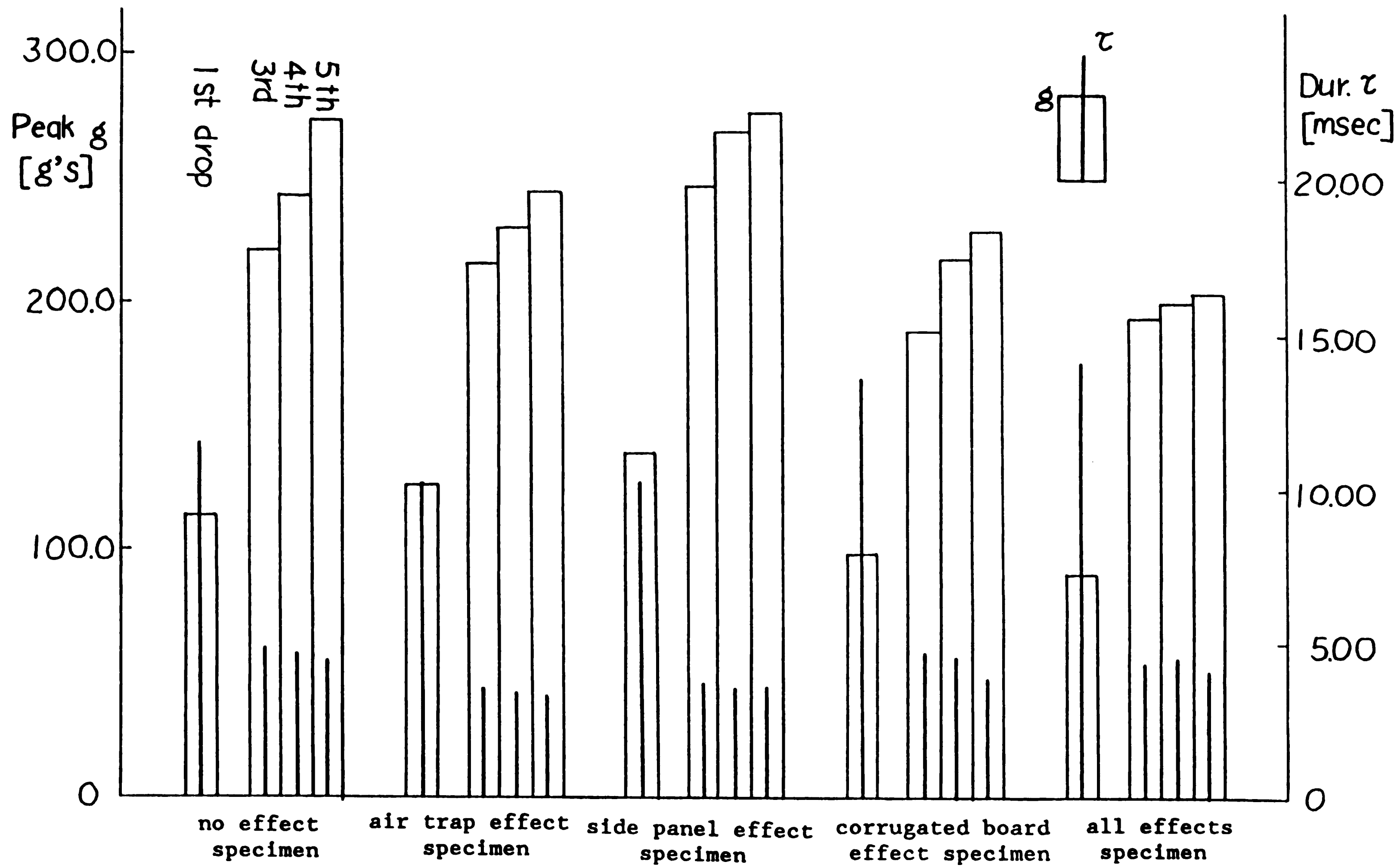


Figure 28. Peak g and Pulse Duration τ (type A cushion, 1.95 psi)

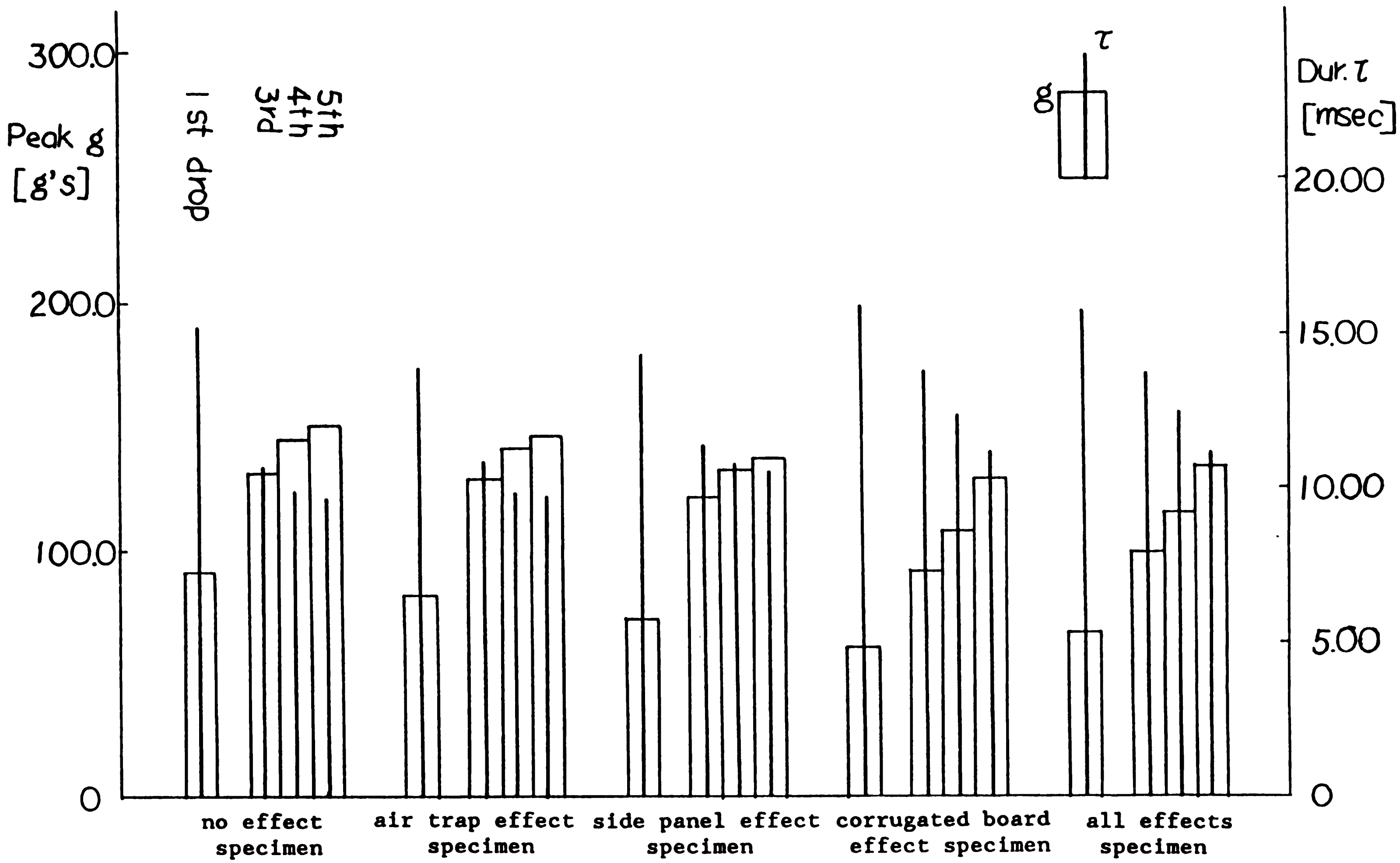


Figure 29. Peak g and Pulse Duration τ (type B cushion, .77 psi)

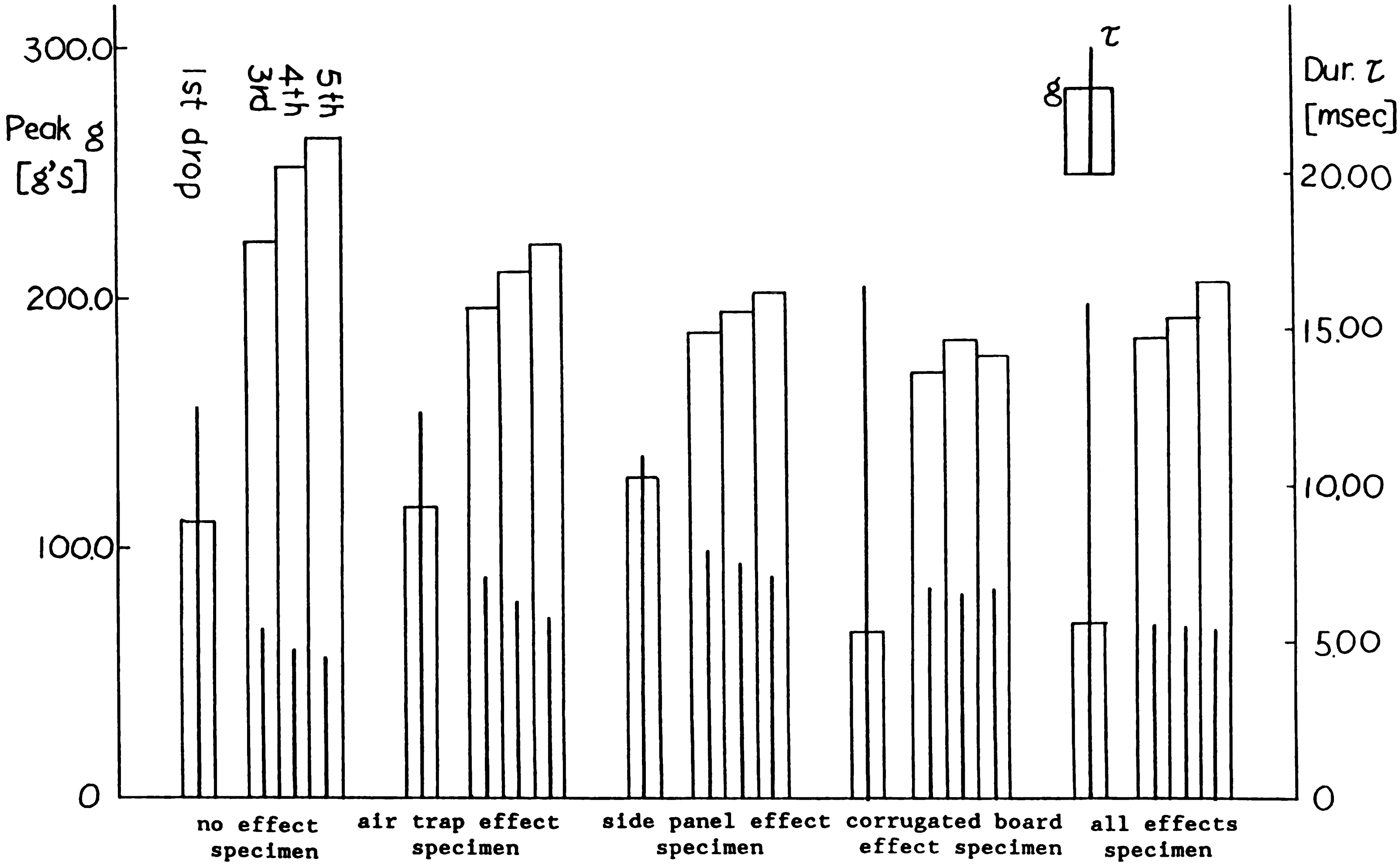


Figure 30. Peak g and Pulse Duration τ (type B cushion, 1.16 psi)

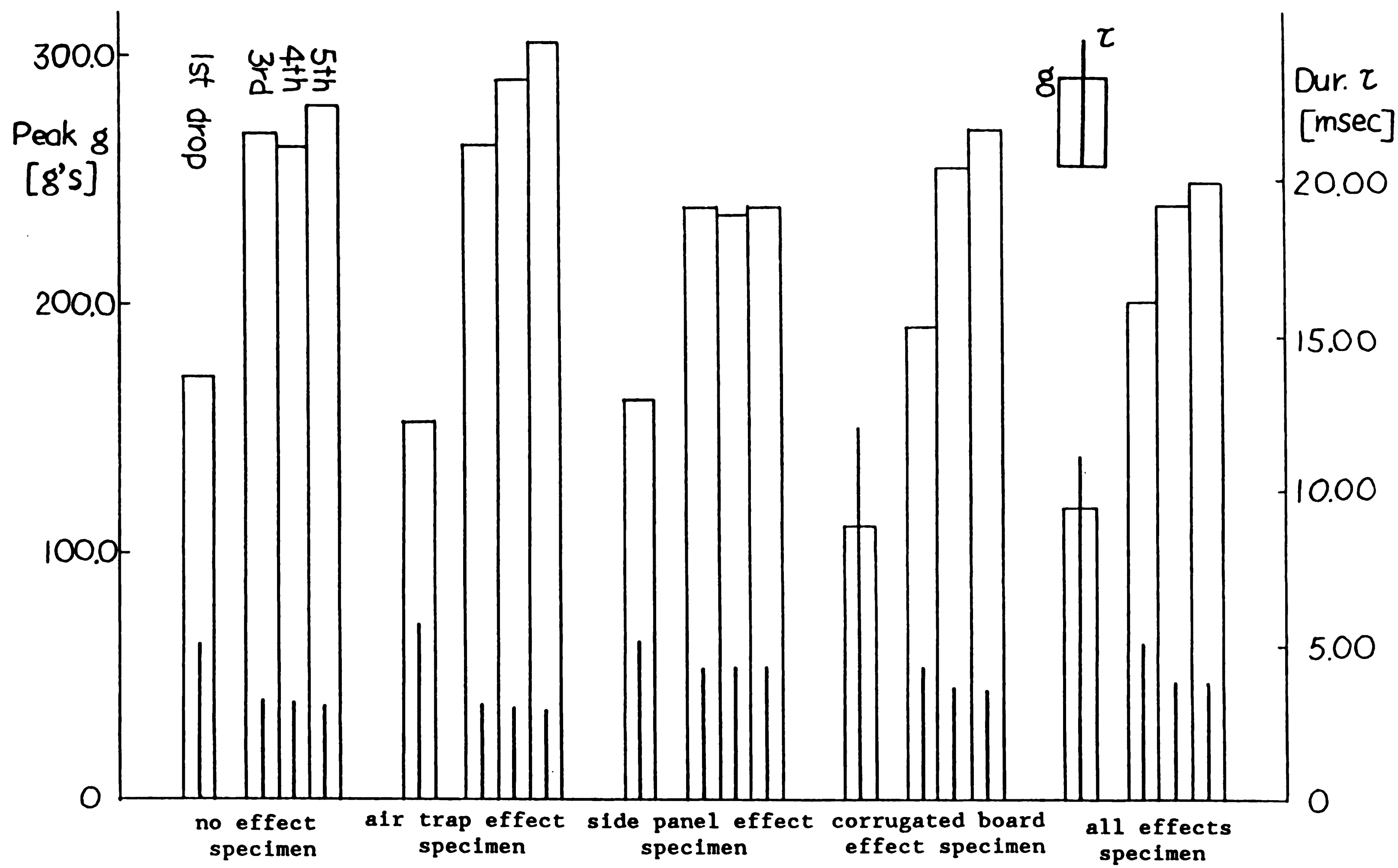


Figure 31. Peak g and Pulse Duration τ (type B cushion, 1.95 psi)

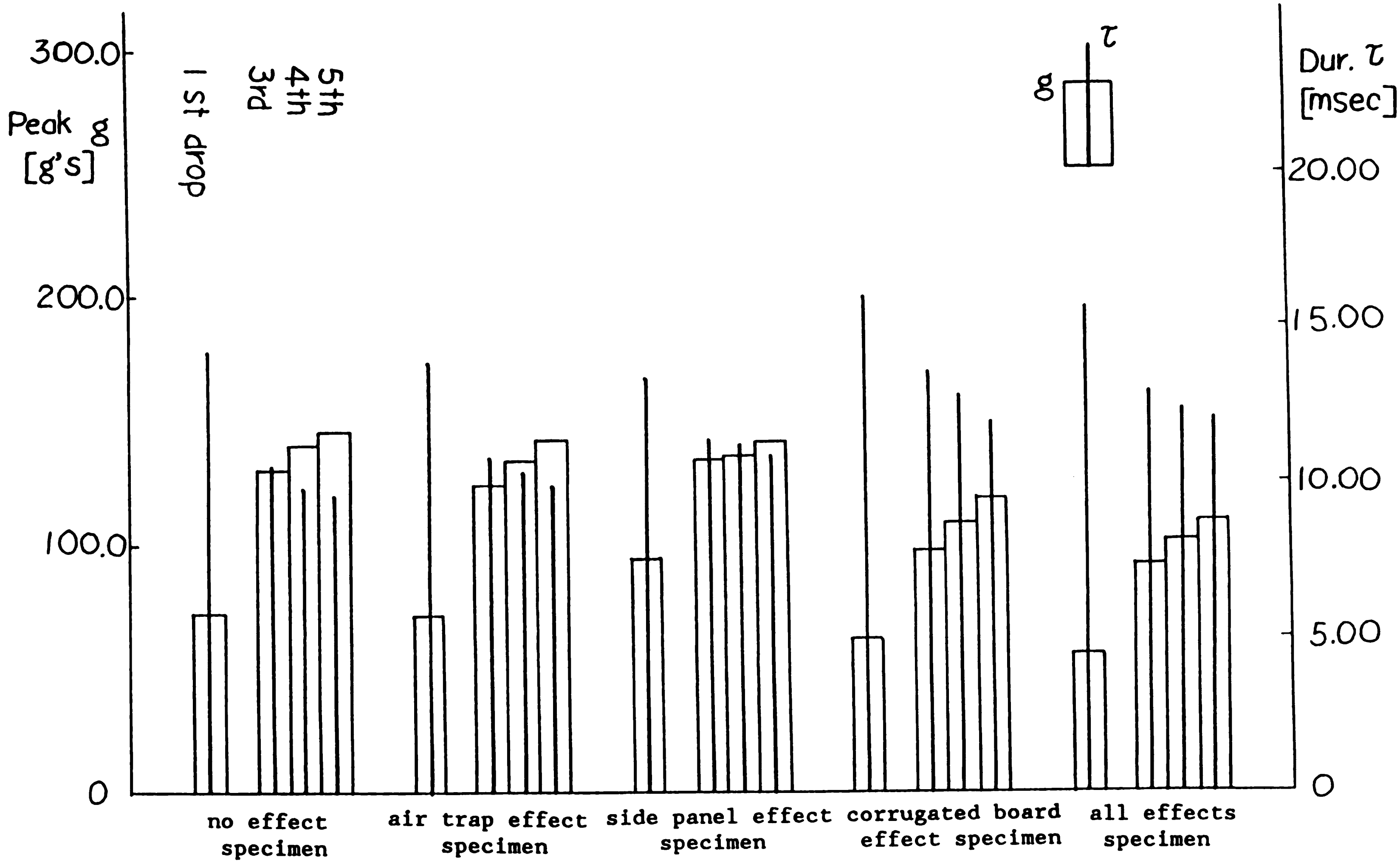


Figure 32. Peak g and Pulse Duration τ (type C cushion, .77 psi)

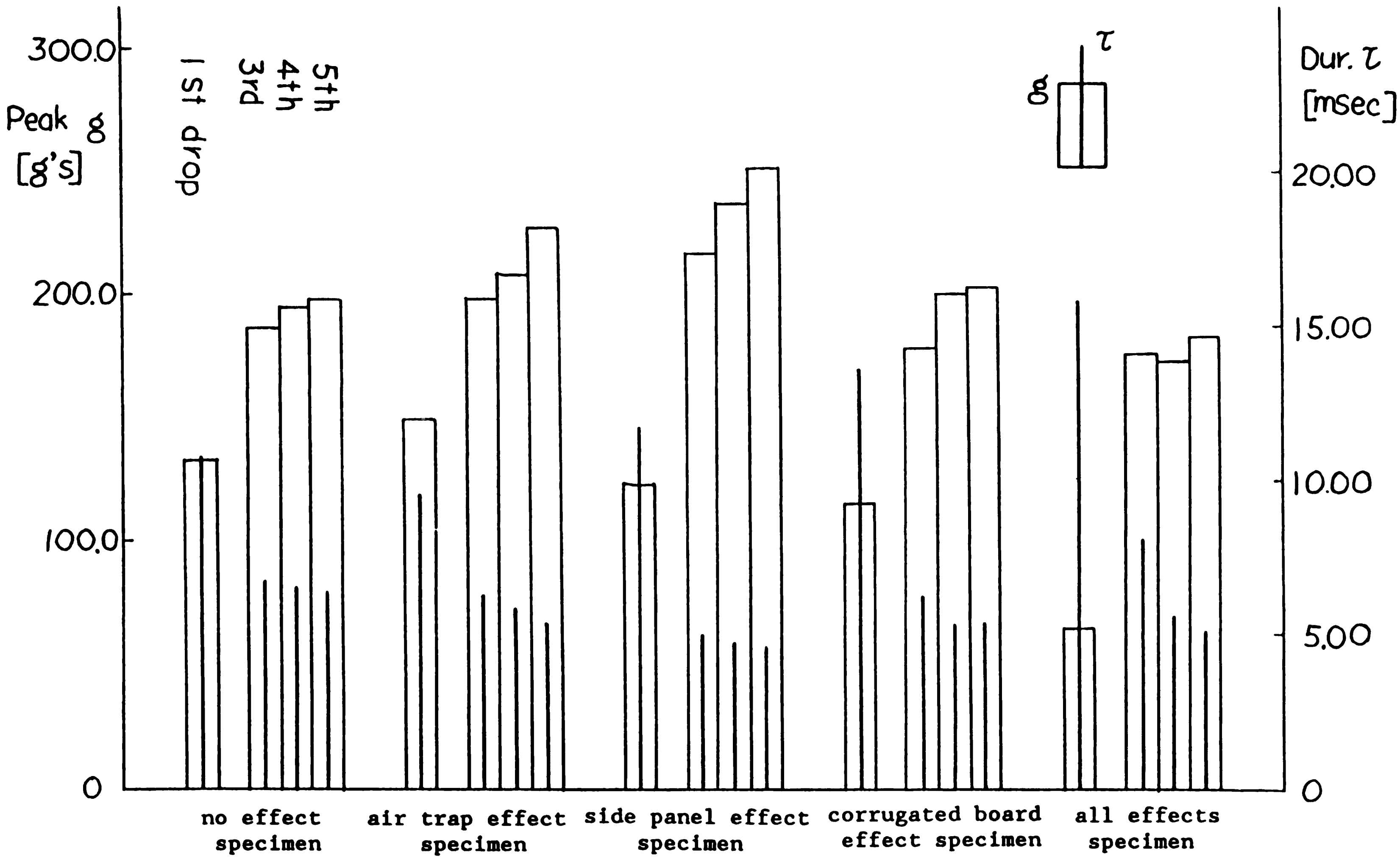


Figure 33. Peak g and Pulse Duration τ (type C cushion, 1.16 psi)

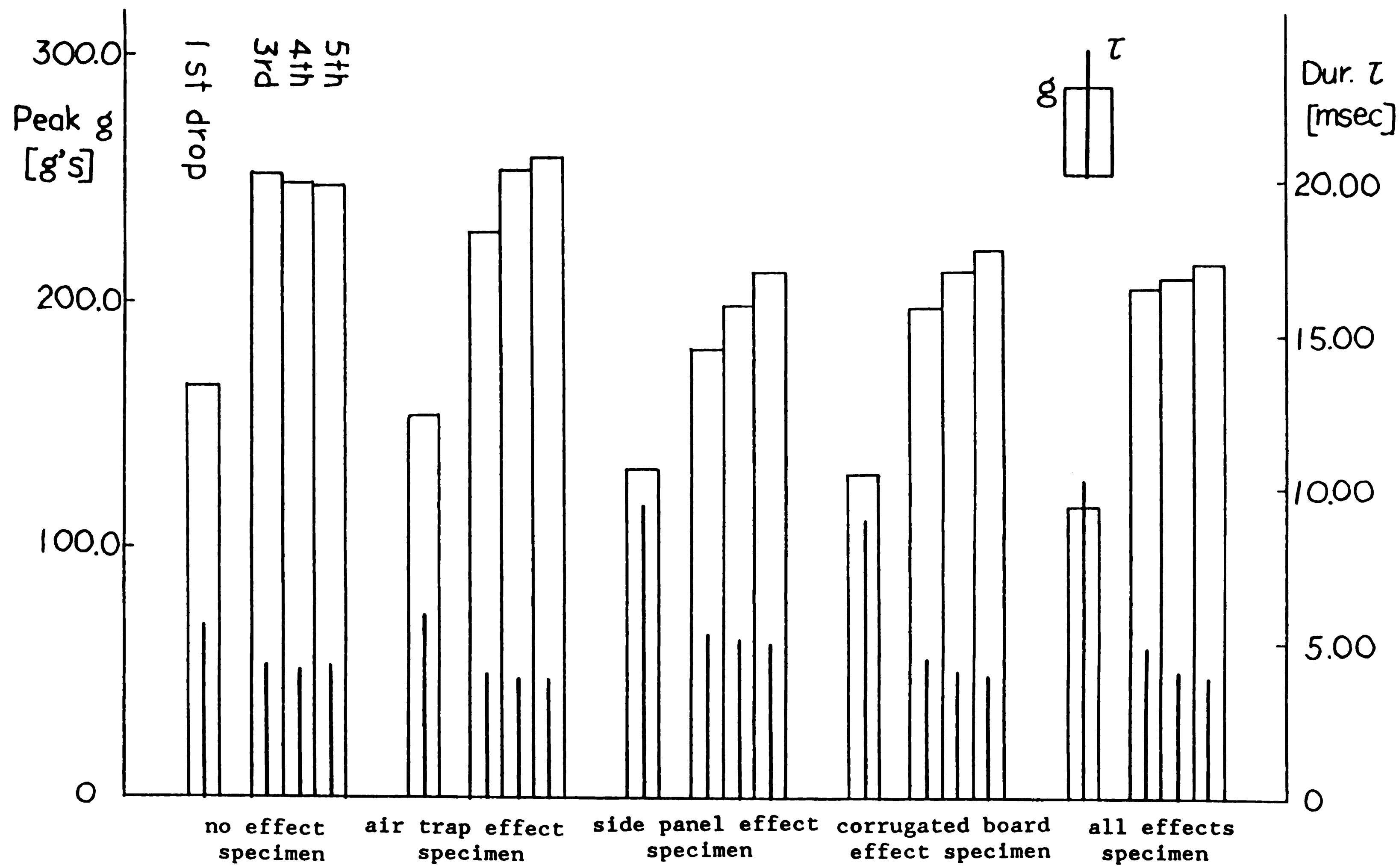


Figure 34. Peak g and Pulse Duration τ (type C cushion, 1.95 psi)

Table 4. Trend of Difference between No Effect Specimen and The Other Effect Specimens on Peak g and Pulse Duration τ

4-1 with Type A Cushion at .77 psi

		1st	3rd	4th	5th drop
air trap effect specimen	Peak g	-	-	-	+
	Dur. τ	+	-	-	-
	Impact velocity change	-.3	.0	+.1	+.3
side panel effect specimen	Peak g	-	-	-	-
	Dur. τ	+	+	+	+
	Impact velocity change	-.6	-.5	-.4	-.4
corrugated board effect specimen	Peak g	-	-	-	-
	Dur. τ	+	+	+	+
	Impact velocity change	-.7	-.2	-.1	-.2
all effects specimen	Peak g	-	-	-	-
	Dur. τ	+	+	+	+
	Impact velocity change	-.2	-.7	-.5	-.6

<Peak g and Pulse Duration τ>

+ Peak g or pulse duration τ value for the specimen increased compared with that for the no effect-specimen.

- Peak g or pulse duration τ value for the specimen decreased compared with that for the no effect-specimen.

= Peak g or pulse duration τ value for the specimen equalled to that for the no effect-specimen.

NA Not available

<Impact Velocity Change: unit [in/sec]>

+ Impact velocity value for the specimen increased compared with that for the no effect-specimen.

- Impact velocity value for the specimen decreased compared with that for the no effect-specimen.

Table 4 (cont'd.). **Trend of Difference between No Effect Specimen and The Other Effect Specimens on Peak g and Pulse Duration τ**

4-2 **with Type A Cushion at 1.16 psi**

		1st	3rd	4th	5th drop
air trap effect specimen	**Peak g**	NA	NA	NA	NA
	Dur. τ	NA	NA	NA	NA
	Impact velocity change	+3.3	+4.7	+5.8	+5.1
side panel effect specimen	**Peak g**	-	-	-	-
	Dur. τ	+	+	+	-
	Impact velocity change	+.7	-1.2	+.4	-.5
corrugated board effect specimen	**Peak g**	NA	+	+	+
	Dur. τ	NA	-	-	-
	Impact velocity change	+2.0	+.2	+1.3	+.7
all effects specimen	**Peak g**	NA	-	NA	+
	Dur. τ	NA	+	NA	-
	Impact velocity change	+2.1	+.9	+1.7	+.8

Table 4 (cont'd.). Trend of Difference between No Effect Specimen and The Other Effect Specimens on Peak g and Pulse Duration τ

4-3 with Type A Cushion at 1.95 psi

		1st	3rd	4th	5th drop
air trap effect specimen	Peak g	+	-	-	-
	Dur. τ	-	-	-	-
	Impact velocity change	-.5	-.1	+.3	+.3
side panel effect specimen	Peak g	NA	+	+	+
	Dur. τ	NA	-	-	-
	Impact celocity change	+2.4	+.9	+1.1	+.9
corrugated board effect specimen	Peak g	-	-	-	-
	Dur. τ	+	-	-	-
	Impact velocity change	+.5	+.2	+.5	+.5
all effects specimen	Peak g	-	-	NA	NA
	Dur. τ	+	-	NA	NA
	Impact velocity change	+1.5	+1.3	+1.7	+1.7

Table 4 (cont'd.). Trend of Difference between No Effect Specimen and The Other Effect Specimens on Peak g and Pulse Duration τ

4-4 with Type B Cushion at .77 psi

		1st	3rd	4th	5th drop
air trap effect specimen	Peak g	+	-	-	-
	Dur. τ	-	+	-	+
	Impact velocity change	-.7	-.2	-.5	-.3
side panel effect specimen	Peak g	-	-	-	-
	Dur. τ	+	+	+	+
	Impact velocity change	-.1	+.3	+.2	+.2
corrugated board effect specimen	Peak g	-	-	-	-
	Dur. τ	+	+	+	+
	Impact velocity change	-.5	.0	+.1	+.1
all effects specimen	Peak g	-	-	-	-
	Dur. τ	+	+	+	+
	Impact velocity change	.0	+.5	+.5	+.5

Table 4 (cont'd.). Trend of Difference between No Effect Specimen and The Other Effect Specimens on Peak g and Pulse Duration τ

4-5 with Type B Cushion at 1.16 psi

		1st	3rd	4th	5th drop
air trap effect specimen	Peak g	+	-	-	-
	Dur. τ	-	+	+	+
	Impact velocity change	+1.5	+.2	+.5	+.9
side panel effect specimen	Peak g	NA	-	-	-
	Dur. τ	NA	+	+	+
	Impact velocity change	+1.8	+.2	.0	+.3
corrugated board effect specimen	Peak g	-	-	-	-
	Dur. τ	+	+	+	+
	Impact velocity change	+.3	-.1	-.5	-.5
all effects specimen	Peak g	NA	-	-	-
	Dur. τ	NA	+	+	+
	Impact velocity change	+1.7	+1.2	+1.1	+1.4

Table 4 (cont'd.). Trend of Difference between No Effect Specimen and The Other Effect Specimens on Peak g and Pulse Duration τ

4-6 with Type B Cushion at 1.95 psi

		1st	3rd	4th	5th drop
air trap effect specimen	Peak g	-	-	+	+
	Dur. τ	+	-	-	-
	Impact velocity change	-.5	-.1	+.1	+.2
side panel effect specimen	Peak g	-	-	NA	NA
	Dur. τ	+	+	NA	NA
	Impact velocity change	.0	-1.4	-3.0	-2.6
corrugated board effect specimen	Peak g	NA	-	-	-
	Dur. τ	NA	+	+	+
	Impact velocity change	-2.0	-1.2	-.7	-.7
all effects specimen	Peak g	-	-	-	-
	Dur. τ	+	+	+	+
	Impact velocity change	+.4	+.8	+.7	+.6

Table 4 (cont'd.). Trend of Difference between No Effect Specimen and The Other Effect Specimens on Peak g and Pulse Duration τ

4-7 with Type C Cushion at .77 psi

		1st	3rd	4th	5th drop
air trap effect specimen	Peak g	-	-	-	-
	Dur. τ	-	+	+	+
	Impact velocity change	-.3	-.9	-.5	-.2
side panel effect specimen	Peak g	+	-	-	-
	Dur. τ	-	+	+	+
	Impact velocity change	-.1	-.2	.0	+.1
corrugated board effect specimen	Peak g	-	-	-	-
	Dur. τ	+	+	+	+
	Impact velocity change	-.4	-.6	-.5	-.2
all effects specimen	Peak g	-	-	-	-
	Dur. τ	+	+	+	+
	Impact velocity change	+.5	+.2	+.3	+.6

Table 4 (cont'd.). Trend of Difference between No Effect Specimen and The Other Effect Specimens on Peak g and Pulse Duration τ

4-8 with Type C Cushion at 1.16 psi

		1st	3rd	4th	5th drop
air trap effect specimen	Peak g	NA	+	+	+
	Dur. τ	NA	-	-	-
	Impact velocity change	+2.0	+.3	+.5	+.7
side panel effect specimen	Peak g	NA	+	NA	NA
	Dur. τ	NA	-	NA	NA
	Impact velocity change	+3.7	+1.5	+1.9	+1.7
corrugated board effect specimen	Peak g	NA	-	+	+
	Dur. τ	NA	-	-	-
	Impact velocity change	+2.4	-.1	+.4	+.5
all effects specimen	Peak g	NA	-	-	-
	Dur. τ	NA	+	-	-
	Impact velocity change	+2.6	+.8	+1.2	+1.1

Table 4 (cont'd). Trend of Difference between No Effect Specimen and The Other Effect Specimens on Peak g and Pulse Duration τ

4-9 with Type C Cushion at 1.95 psi

		1st	3rd	4th	5th drop
air trap effect specimen	Peak g	NA	NA	NA	NA
	Dur. τ	NA	NA	NA	NA
	Impact velocity change	-5.6	-4.1	-3.7	-3.6
side panel effect specimen	Peak g	-	NA	NA	NA
	Dur. τ	+	NA	NA	NA
	Impact velocity change	-.2	-2.5	-2.8	-2.6
corrugated board effect specimen	Peak g	-	-	-	-
	Dur. τ	+	+	-	-
	Impact velocity change	+.1	+.1	-.2	+.1
all effects specimen	Peak g	-	-	-	-
	Dur. τ	+	+	-	-
	Impact velocity change	-1.1	-.4	-.3	-.2

TEST RESULTS IN PART I TESTS

Peak g and pulse duration change with impact velocity, and the impact velocity changes drop by drop. This impact velocity difference should be taken into account when detecting the trend of differences between the no-effect specimen and the other-effect specimens.

Of the 115 drops analyzed, 20 drops resulted in increasing peak g and decreasing pulse duration. Seventeen of these 20 drops were conducted for the other-effect specimens at a higher impact velocity than the impact velocity for the no-effect specimens. Higher impact velocity results in a higher peak g. Therefore, the data for these drops can be considered to be affected by the higher impact velocity as well as by the effect of the outer package.

On the other hand, of the 115 drops analyzed, 76 drops resulted in decreasing peak g and increasing pulse duration. Thirty-four of these 76 drops were conducted for the other-effect specimens at a higher impact velocity than the impact velocity for the no-effect specimens. Therefore, the data for these drops can be considered to be affected only by the effect being investigated in the particular test. Classification of the 34 drops is shown in Table 5.

Table 5. Classification of The 34 Drops

Specimen		static loading [psi] .77	1.16	1.95	total
air trap	type A cushin	0	0	0	0
effect specimen	type B cushion	0	3	0	3
	type C cushion	0	0	0	0
side panel	type A cushin	0	2	0	2
effect specimen	type B cushion	3	2	0	5
	type C cushion	1	0	0	1
corrugated board	type A cushin	0	0	1	1
effect specimen	type B cushion	2	1	0	3
	type C cushion	0	0	2	2
all effects	type A cushin	0	1	1	2
specimen	type B cushion	3	3	4	10
	type C cushion	4	1	0	5

From the above, it is considered that all of the effects exist and tend to decrease peak g and increasing pulse duration.

Concerning the cushion type, it was not recognized that there was any significant difference between the three different shapes of cushion. However, it was observed that the test specimens with type B cushions showed the three effects of the outer package most clearly.

Concerning the static loadings, it was not recognized that there was any significant difference between the three static loadings with respect to the effects of the outer package.

Finally, it was recognized that the difference between the input shock pulse measured at the 2nd drop and that at the 6th drop was very slight.

TEST DATA IN PART II TESTS

Table 6. Test Data in Part II Tests

6-1 Test Data for All Effects Specimen with Type B Cushion at 1.16 psi

Block 1

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	210.3	68.0	16.02	.37	77.4	
2nd	217.9	168.0	8.20	.37	77.4	
3rd	183.9	191.5	5.81	.28	77.1	
4th	184.7	199.4	5.28	.25	77.6	
5th	186.9	210.3	5.08	.25	77.8	
6th	161.1	392.6	1.77	.05	78.0	input shock

6-2 Test Data for Corrugated Board Effect Specimen with Type B Cushion at 1.16 psi

Block 1

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	217.3	68.0	16.71	.36	77.3	
2nd	217.1	179.1	8.13	.37	77.5	
3rd	186.6	191.5	5.97	.28	77.6	
4th	193.3	198.9	5.89	.27	77.9	
5th	198.2	199.4	5.97	.27	78.0	
6th	158.8	392.6	1.77	.04	78.2	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-3 Test Data for No Effect Specimen with Type B Cushion at 1.16 psi

Block 1

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	233.2	124.2	12.36	.34	77.3	
2nd	239.2	190.5	7.47	.33	77.2	
3rd	214.6	212.3	5.89	.27	77.4	
4th	211.7	220.3	5.51	.25	77.7	
5th	213.3	241.2	5.12	.23	77.6	
6th	156.1	387.5	1.77	.04	77.6	input shock

6-4 Test Data for Side Panel Effect Specimen with Type B Cushion at 1.16 psi

Block 1

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	225.1	114.8	12.48	.33	75.5	
2nd	235.2	172.3	8.16	.33	76.2	
3rd	221.1	195.5	6.70	.31	76.4	
4th	203.3	206.8	5.55	.24	76.5	
5th	204.9	213.4	5.47	.24	76.2	
6th	157.8	380.9	1.81	.05	76.3	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-5 Test Data for Air Trap Effect Specimen with Type B Cushion at 1.16 psi

Block 1

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	229.5	119.5	12.40	.34	76.3	
2nd	236.4	177.5	7.93	.33	76.5	
3rd	217.8	216.0	5.89	.27	78.2	
4th	221.2	225.3	5.78	.27	78.1	
5th	216.8	232.3	5.39	.25	77.5	
6th	159.2	392.6	1.77	.05	77.4	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-6 Test Data for Side Panel Effect Specimen with Type B Cushion at 1.16 psi

Block 2

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	221.4	104.3	13.05	.33	75.2	
2nd	232.6	155.9	8.82	.33	75.6	
3rd	236.1	182.2	7.74	.33	75.9	
4th	230.6	194.3	7.05	.31	75.8	
5th	222.4	198.3	6.58	.30	75.7	
6th	153.2	375.0	1.77	.05	75.7	input shock

6-7 Test Data for Corrugated Board Effect Specimen with Type B Cushion at 1.16 psi

Block 2

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	203.6	57.4	17.64	.34	73.6	
2nd	216.9	140.0	10.40	.37	74.2	
3rd	211.4	169.1	8.16	.35	74.5	
4th	186.1	169.7	6.62	.30	74.9	
5th	186.1	176.3	6.32	.28	75.0	
6th	152.1	369.1	1.77	.04	75.3	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-8 Test Data for No Effect Specimen with Type B Cushion at 1.16 psi

Block 2

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	221.9	104.3	13.40	.33	73.9	
2nd	232.2	160.5	8.63	.33	74.4	
3rd	231.7	185.9	7.35	.32	74.3	
4th	229.9	195.1	7.01	.30	74.2	
5th	225.1	199.3	6.70	.29	74.2	
6th	153.5	369.1	1.81	.05	74.2	input shock

6-9 Test Data for Air Trap Effect Specimen with Type B Cushion at 1.16 psi

Block 2

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	221.3	103.1	13.29	.33	74.3	
2nd	229.4	154.1	8.82	.33	74.4	
3rd	232.3	178.6	7.78	.32	74.4	
4th	230.4	190.3	7.28	.30	74.4	
5th	231.0	196.6	7.09	.30	74.6	
6th	154.0	369.1	1.77	.05	74.7	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-10 Test Data for All Effects Specimen with Type B Cushion at 1.16 psi

Block 2

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	199.2	57.4	17.02	.34	73.2	
2nd	215.6	123.0	11.48	.37	74.6	
3rd	174.9	169.9	6.62	.30	74.4	
4th	178.5	173.3	6.35	.29	74.5	
5th	180.9	172.8	6.32	.28	74.3	
6th	152.3	363.3	1.73	.04	74.3	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-11 Test Data for Air Trap Effect Specimen with Type B Cushion at 1.16 psi

Block 3

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	214.5	92.6	13.67	.32	72.7	
2nd	225.5	138.3	9.63	.32	73.0	
3rd	229.8	165.2	8.24	.31	73.4	
4th	231.1	176.9	7.74	.31	73.5	
5th	231.1	186.1	7.35	.30	73.6	
6th	150.9	365.8	1.81	.04	73.8	input shock

6-12 Test Data for No Effect Specimen with Type B Cushion at 1.16 psi

Block 3

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	217.2	102.0	13.32	.33	72.8	
2nd	226.6	152.9	8.63	.33	72.9	
3rd	231.5	188.3	7.32	.31	73.8	
4th	222.8	195.6	6.70	.29	73.3	
5th	217.8	204.1	6.28	.27	73.5	
6th	152.0	363.3	1.77	.04	72.9	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-13 Test Data for Corrugated Board Effect Specimen with Type B Cushion at 1.16 psi

Block 3

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	201.7	55.1	17.56	.34	72.7	
2nd	213.6	126.6	10.94	.36	72.8	
3rd	215.1	158.0	8.78	.36	73.0	
4th	196.6	167.4	7.39	.32	73.0	
5th	194.6	169.6	7.09	.30	73.1	
6th	150.6	363.3	1.77	.04	73.2	input shock

6-14 Test Data for All Effects Specimen with Type B Cushion at 1.16 psi

Block 3

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	196.4	58.6	16.64	.34	72.6	
2nd	210.7	134.8	10.36	.35	73.0	
3rd	206.4	170.7	7.93	.34	73.3	
4th	180.7	171.3	6.32	.28	73.4	
5th	183.0	175.9	6.24	.27	73.7	
6th	151.3	357.4	1.77	.04	73.3	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-15 Test Data for Side Panel Effect Specimen with Type B Cushion at 1.16 psi

Block 3

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	212.5	96.1	13.48	.33	72.3	
2nd	222.2	142.4	9.05	.33	72.2	
3rd	224.4	161.7	8.32	.32	72.2	
4th	224.7	172.1	7.78	.32	72.0	
5th	224.7	181.8	7.47	.31	72.0	
6th	151.1	363.3	1.81	.04	71.9	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-16 Test Data for Corrugated board Effect Specimen with Type B Cushion at 1.16 psi

Block 4

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	200.1	58.6	17.06	.34	72.1	
2nd	212.3	114.3	11.63	.36	72.3	
3rd	212.8	159.2	8.90	.36	72.2	
4th	208.0	162.9	8.20	.35	72.5	
5th	188.0	163.7	7.05	.30	72.3	
6th	153.9	363.3	1.73	.05	72.6	input shock

6-17 Test Data for All Effects Specimen with Type B Cushion at 1.16 psi

Block 4

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	196.8	56.8	16.98	.33	72.6	
2nd	209.9	98.4	13.40	.35	72.6	
3rd	212.2	151.2	9.47	.35	72.5	
4th	209.8	161.8	8.20	.34	72.4	
5th	209.7	165.6	8.05	.33	72.4	
6th	151.8	353.8	1.73	.05	72.4	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-18 Test Data for No Effect Specimen with Type B Cushion at 1.16 psi

Block 4

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	211.2	85.5	14.36	.32	70.9	
2nd	218.6	126.0	10.01	.32	70.9	
3rd	222.9	144.1	9.20	.31	70.9	
4th	221.5	146.5	8.97	.31	70.6	
5th	223.3	151.8	8.86	.31	70.7	
6th	149.9	345.7	1.73	.04	70.2	input shock

6-19 Test Data for Air Trap Specimen with Type B Cushion at 1.16 psi

Block 4

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	201.9	75.6	14.98	.31	68.8	
2nd	215.1	112.5	11.01	.32	70.1	
3rd	217.6	130.1	9.74	.31	70.3	
4th	220.3	140.0	9.40	.31	70.3	
5th	219.6	143.6	9.01	.31	70.3	
6th	150.4	351.6	1.77	.05	70.6	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-20 Test Data for Dide Panel Effect Specimen with Type B Tushion at 1.16 psi

Block 4

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	201.1	73.2	15.10	.30	68.7	
2nd	213.0	107.8	11.17	.32	69.9	
3rd	217.0	123.6	10.09	.31	70.0	
4th	219.8	131.8	9.63	.31	70.0	
5th	221.2	138.9	9.36	.31	69.9	
6th	150.9	351.6	1.73	.05	70.0	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-21 Test Data for All Effects Specimen with Type B Cushion at 1.16 psi

Block 5

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	190.0	50.4	17.60	.33	70.3	
2nd	206.9	93.2	13.63	.35	70.7	
3rd	208.9	133.6	10.40	.35	70.7	
4th	210.8	148.2	9.28	.35	70.9	
5th	210.1	154.0	8.74	.34	70.7	
6th	151.9	357.4	1.81	.05	71.1	input shock

6-22 Test Data for Air Trap Effect Specimen with Type B Cushion at 1.16 psi

Block 5

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	200.6	74.4	14.98	.30	67.8	
2nd	208.7	106.1	11.32	.31	69.0	
3rd	212.1	123.1	10.17	.30	69.2	
4th	214.6	132.5	9.59	.30	69.2	
5th	219.4	143.6	9.13	.30	69.7	
6th	146.5	345.7	1.77	.04	69.4	input shock

Table 6 (cont'd.). Test Data in Part II Tests

6-23 Test Data for Corrugated Board Effect Specimen with Type B Cushion at 1.16 psi

Block 5

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	187.6	50.4	18.10	.32	67.8	
2nd	203.5	78.5	14.25	.35	69.6	
3rd	207.3	144.1	9.74	.36	70.1	
4th	206.7	153.9	8.90	.35	69.9	
5th	206.6	160.3	8.51	.34	70.2	
6th	147.5	351.6	1.73	.04	70.4	input shock

6-24 Test Data for Side Panel Effect Specimen with Type B Cushion at 1.16 psi

Block 5

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	195.4	68.0	15.40	.30	67.8	
2nd	210.5	102.0	12.48	.32	68.8	
3rd	211.9	118.4	10.24	.31	69.1	
4th	215.1	128.3	9.82	.31	69.5	
5th	215.8	132.4	9.63	.31	69.4	
6th	150.0	351.6	1.77	.05	69.7	input shock

Table 6 (cont'd). Test Data in Part II Tests

6-25 Test Data for No Effect Specimen with Type B Cushion at 1.16 psi

Block 5

Drop No.	ΔV [in/sec]	Peak g [g's]	Pulse Duration τ [msec]	ΔX [in]	Impact Velocity [in/sec]	Remark
1st	206.3	83.2	14.48	.32	69.3	
2nd	216.4	123.0	10.20	.32	69.7	
3rd	220.1	141.8	9.09	.31	69.8	
4th	220.8	148.8	8.86	.31	69.6	
5th	221.1	155.9	8.39	.31	69.8	
6th	144.5	345.7	1.73	.04	69.8	input shock

DATA ANALYSIS IN PART II TESTS

Measured peak gs and pulse durations are shown in Figures 35 to 39. A paired comparison analysis was applied to the peak g and pulse duration values in the five blocks. The significance of the levels of difference between the no-effect specimens and the other-effect specimens is shown in Table 7.

In applying a paired comparison analysis, the drop data in which the impact velocity exceeded the impact velocity for the no-effect specimens by ±1.5 in/sec within the same block were omitted from the analysis. (APPENDIX C, D)

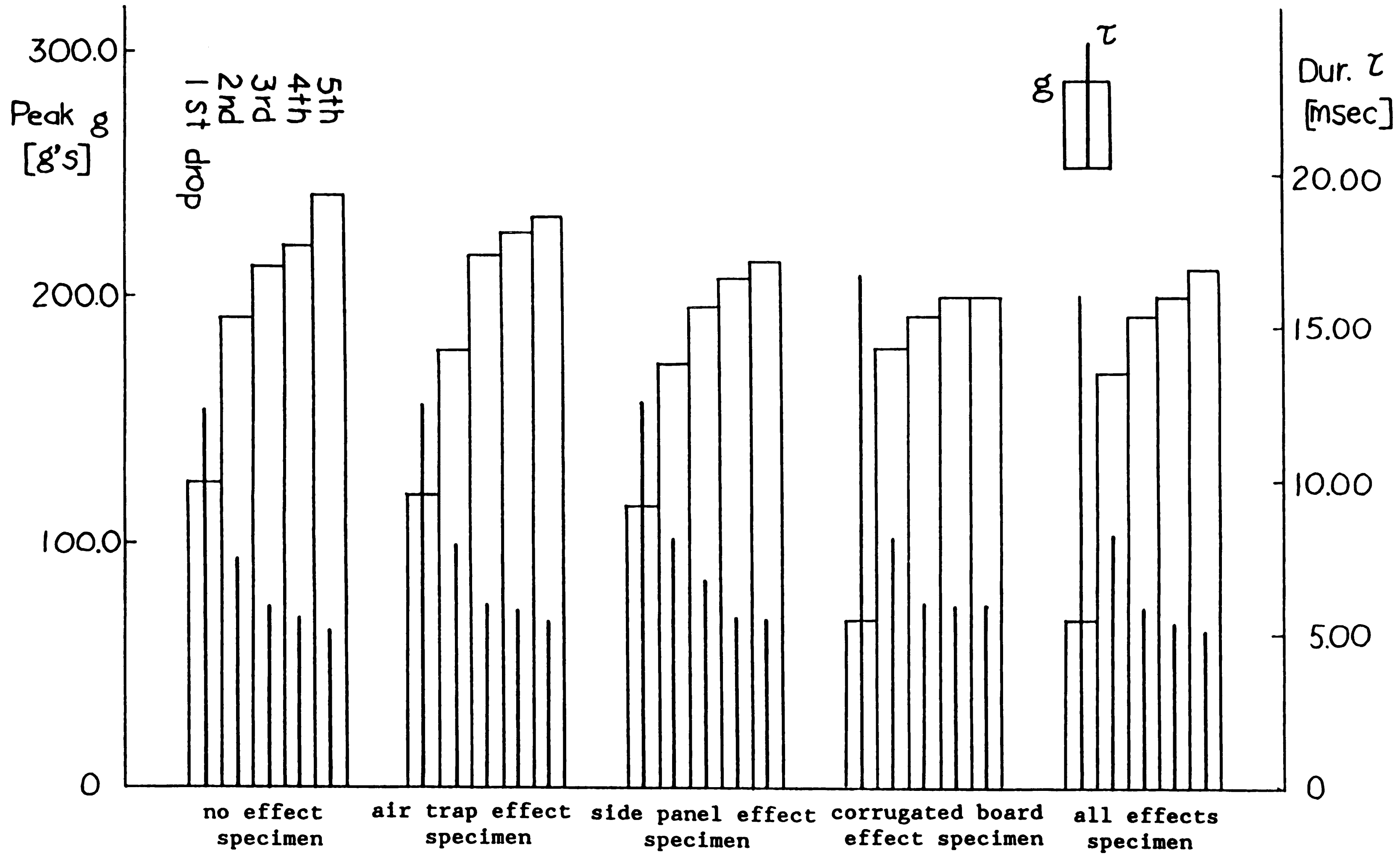


Figure 35. Peak g and Pulse Duration τ (block 1)

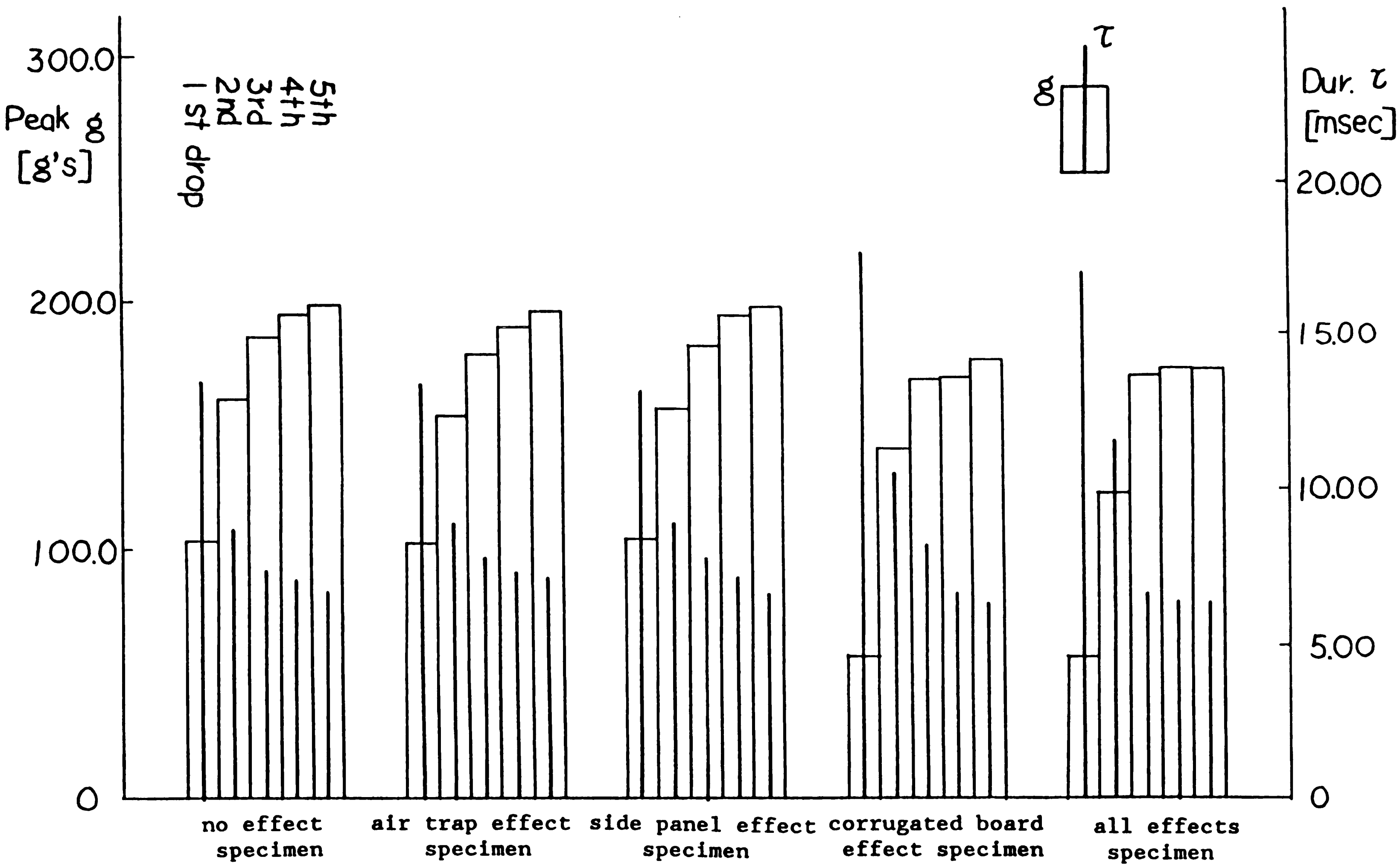


Figure 36. Peak g and Pulse Duration τ (block 2)

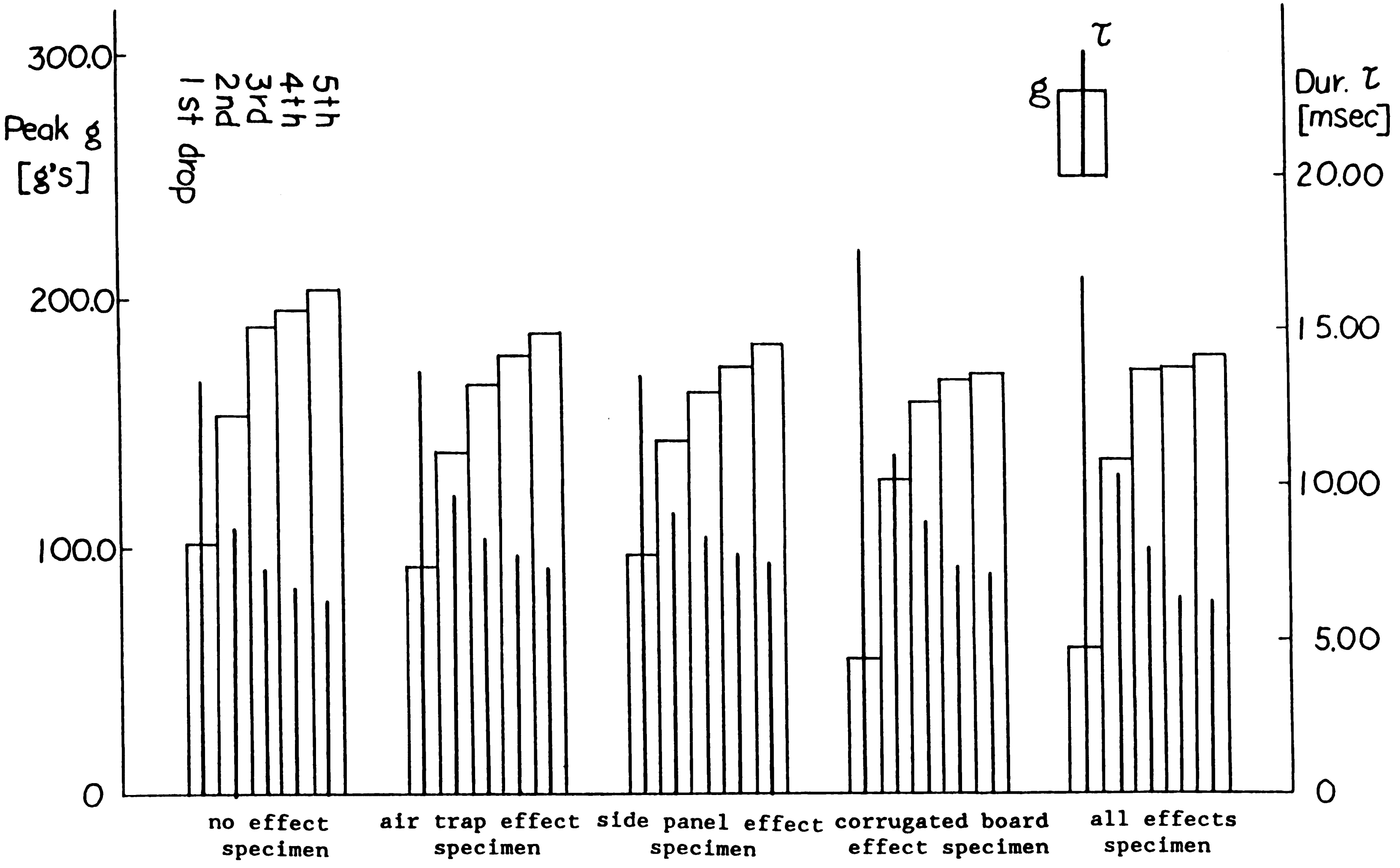


Figure 37. Peak g and Pulse Duration τ (block 3)

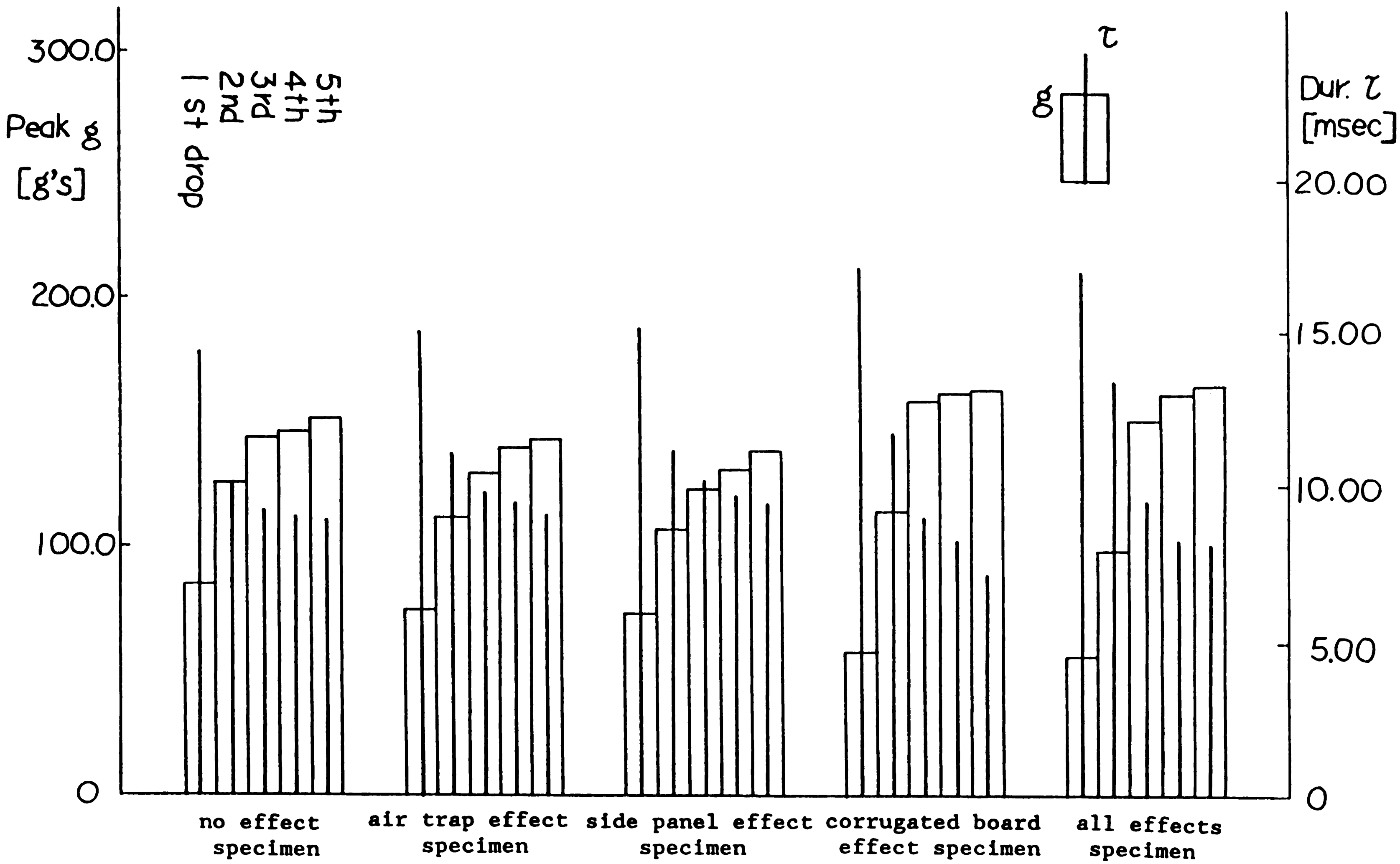


Figure 38. Peak g and Pulse Duration τ (block 4)

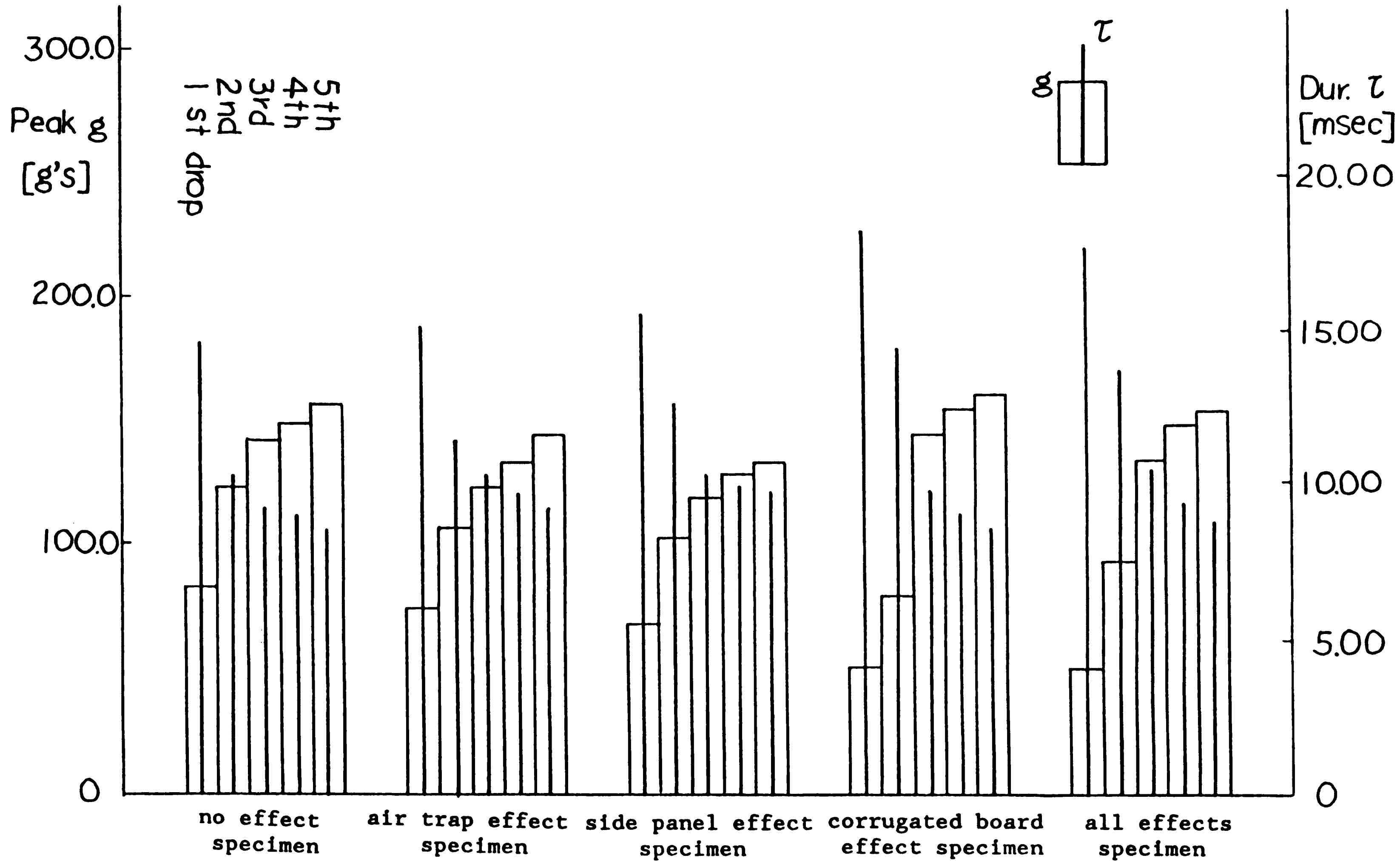


Figure 39. Peak g and Pulse Duration τ (block 5)

Table 7. Significance of The Levels of Difference between No Effect Specimen and The Other Effect Specimens on Peak g and Pulse Duration τ

		1st	2nd	3rd	4th	5th drop
		[g's] [msec]				
air trap effect specimen	Peak g	*	**	*	ns	**
	Est. of D.	-6	-13	-12	-8	-10
	Dur. τ	ns	**	*	*	*
	Est. of D.	.2	4.2	3.1	3.6	3.1
side panel effect specimen	Peak g	ns	*	**	**	*
	Est. of D.	-7	-3	-20	-18	-18
	Dur. τ	ns	*	**	*	*
	Est of D.	.2	1.0	1.0	.7	.6
corrugated board effect specimen	Peak g	**	**	ns	ns	ns
	Est. of D.	-42	-23	-10	-18	-24
	Dur. τ	**	*	ns	ns	ns
	Est. of D.	3.8	2.1	.5	.2	.4
all effects specimen	Peak g	**	**	**	*	*
	Est. of D.	-45	-27	-16	-17	-22
	Dur. τ	**	*	ns	ns	ns
	Est. of D.	3.4	2.2	.3	-.2	-.0

* Each effect results in decreasing peak g or increasing pulse duration τ at 5 % level of significance.

** Each effect results in decreasing peak g or increasing pulse duration τ at 1 % level of significance.

ns No significance at 5 % level of significance.

TEST RESULTS IN PART II TESTS

As shown in Table 7, the air trap effect was recognized at the 2nd, 3rd and 5th drops at 1 %, 5 % and 5 % levels of significance. The side panel effect was recognized at the 2nd, 3rd, 4th and 5th drops at 5 %, 1 %, 5 % and 5 % levels of significance. The corrugated board effect was recognized at the 1st and 2nd drops at 1 % and 5 % levels of significance. At the other drops, it was observed that each effect tended to decrease peak g and increase pulse duration, but the level of significance was not determined.

It was observed that the corrugated board effect was larger than the air trap effect and the side panel effect at the 1st and 2nd drops. While the corrugated board effect is large at the 1st and 2nd drops, the air trap effect and the side panel effect are considered to be small at those drops. Since the shock absorbing characteristics of the cushion itself vary greately at those drops, the variability of the shock absorbing characteristics of the cushion is larger than that caused by the two effects.

On the other hand, it was observed that the corrugated board effect tended to decrease at the 3rd, 4th and 5th drops, while the air trap effect and the side panel effect did not change very much. In addition to this, the shock absorbing characteristics of the cushion itself still vary greatly at those drops, and those of the corrugated paperboard also vary drastically at those drops.

It was also observed that the all-effects specimens had the closest values to the corrugated board-effect specimens values.

CONCLUSIONS

Through Part I tests and Part II tests, it was found that the air trap effect, the side panel effect and the corrugated board effect of the outer package do exist. All of the effects act to decrease peak g and increase pulse duration.

However, each of the effects was different in magnitude. The corrugated board effect was the largest at the 1st and 2nd drops. It is considered that corrugated paperboard absorbs a large amount of shock energy at the 1st and 2nd drops, while the air trap effect and the side panel effect combine to absorb shock energy by relatively small amount.

On the other hand, while the corrugated board effect decreased at subsequent drops, that is, the 3rd, 4th and 5th drops, the air trap effect and the side panel effect took a more important role to decrease peak g and increase pulse duration. While the side panel effect acted at those drops equally with the corrugated board effect, the air trap effect was smaller. It was measurable, however.

APPENDICES

APPENDIX A

WAVEFORM PARAMETERS

Figure 40 shows an example of collected data and the waveform parameters measured in this research (15).

<Definition of The Parameters>

Trigger Pulse	Developed by the trigger flag through the velocity sensor.
Tv	The time required for the trigger flag to pass through the velocity sensor. Tv is used to calculate the impact velocity.
Zero g Reference	Calculated by wave analyzer routine. This value is used as 0 g level for g measurements.
Peak g	The most positive waveform peak value in the data field.
Pulse Duration τ	The time between T1 and T2. T1 is located at the point where the waveform crosses the .1 Peak g level prior to the Peak g point. T2 is located at the point where the waveform crosses the .1 Peak g level after the Peak g point.
ΔV	Integrated value of the waveform between points I and F. I is located at .4 τ prior to T1. F is located at .1 τ after T2.
ΔX	The peak displacement experienced by the accelerometer during impact.
Impact Velocity	Calculated from Tv by the waveform analyzer.

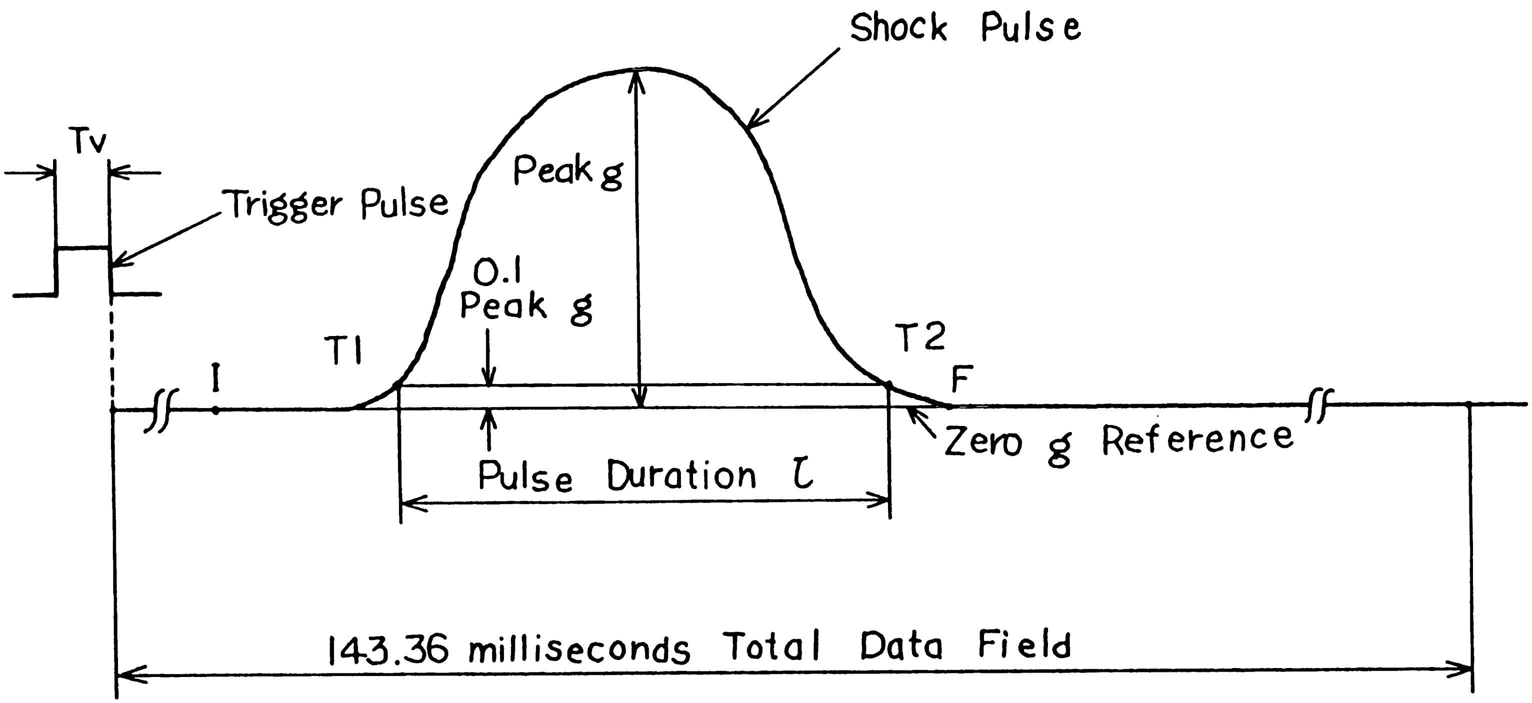


Figure 40. Sample Waveform and Waveform Parameters

APPENDIX B

PEAK TO PEAK DELAY TIME

In Part II tests, an input shock pulse and the transmitted 1st and 5th drop shock pulses were plotted on the same data sheet. From the plotted shock pulses, peak to peak delay time was calculated (Tables 8, 9). Shock pulses in Block 2 are shown in Figures 41 to 45. X s marked on the shock pulses denote the same data sampling point in the same total data field.

It was found that shock pulses at the 5th drops were transmitted earlier than those at the 1st drops, and the corrugated board-effect specimens and the all-effects specimens had almost equal longer delay times than the air trap-effect specimens and the side panel-effect specimens did.

Table 8. Peak to Peak Delay Time between Input Shock Pulse and Transmitted 1st Drop Shock Pulse with Type B Cushion at 1.16 psi

[msec]

Specimen	Block 1	Block 2	Block 3	Block 4	Block 5
no effect specimen	8.3	8.3	8.3	8.3	9.0
air trap effect specimen	8.3	8.3	8.3	9.3	9.0
side panel effect specimen	8.0	8.0	8.3	9.3	7.7
corrugated board effect specimen	10.0	10.0	10.0	9.7	10.3
all effects specimen	10.0	10.0	9.7	9.7	10.3

Table 9. Peak to Peak Delay Time between Input Shock Pulse and Transmitted 5th Drop Shock Pulse with Type B Cushion at 1.16 psi

[msec]

Specimen	Block 1	Block 2	Block 3	Block 4	Block 5
no effect specimen	6.3	6.7	6.7	7.0	7.0
air trap effect specimen	6.3	6.3	6.7	7.0	7.0
side panel effect specimen	6.3	6.7	6.7	7.3	5.7
corrugated board effect specimen	7.3	7.7	7.7	8.0	8.0
all effects specimen	7.3	7.7	7.7	7.7	8.0

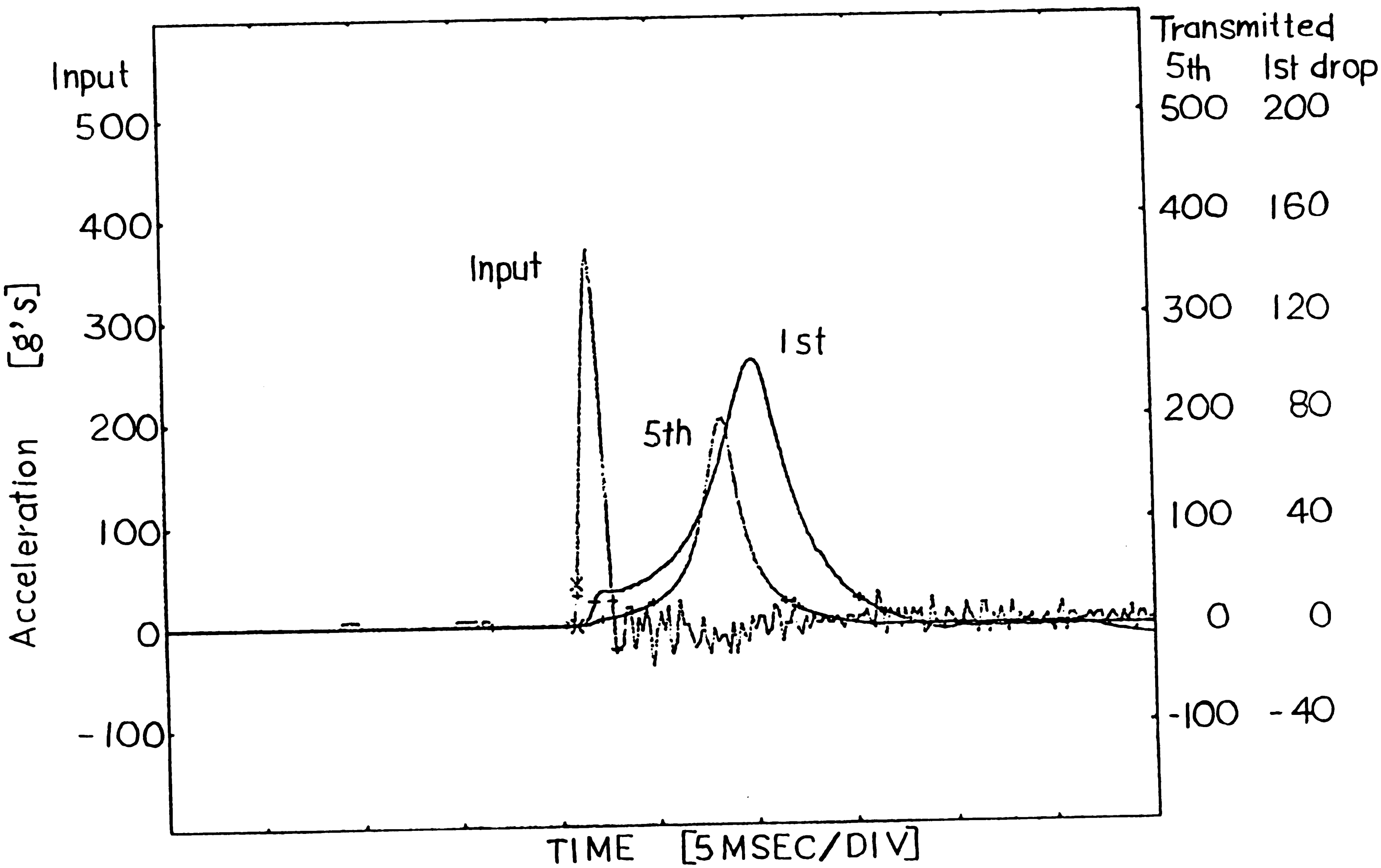


Figure 41. Shock Pulses in Block 2 (no effect specimen)

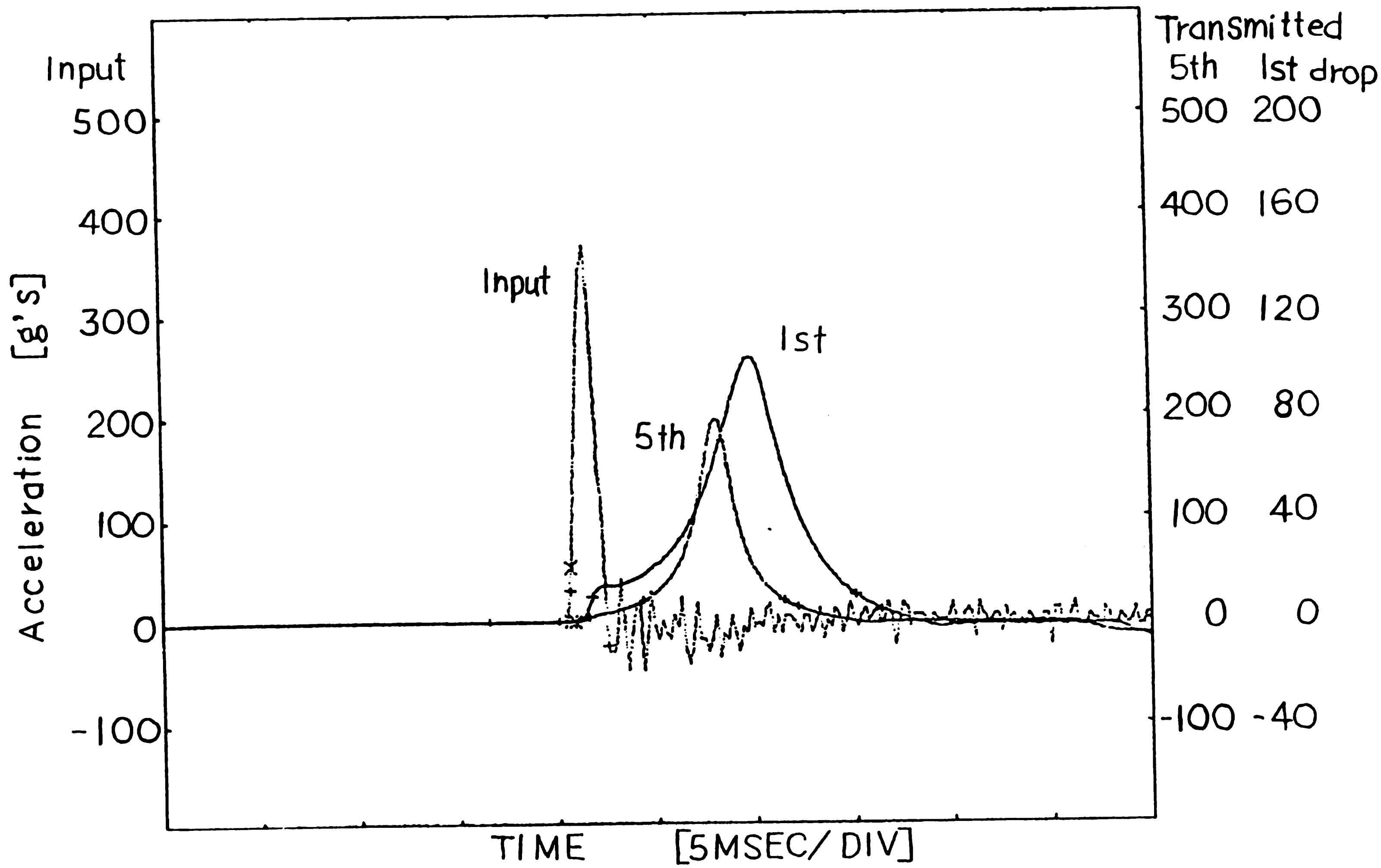


Figure 42. Shock Pulses in Block 2 (air trap effect specimen)

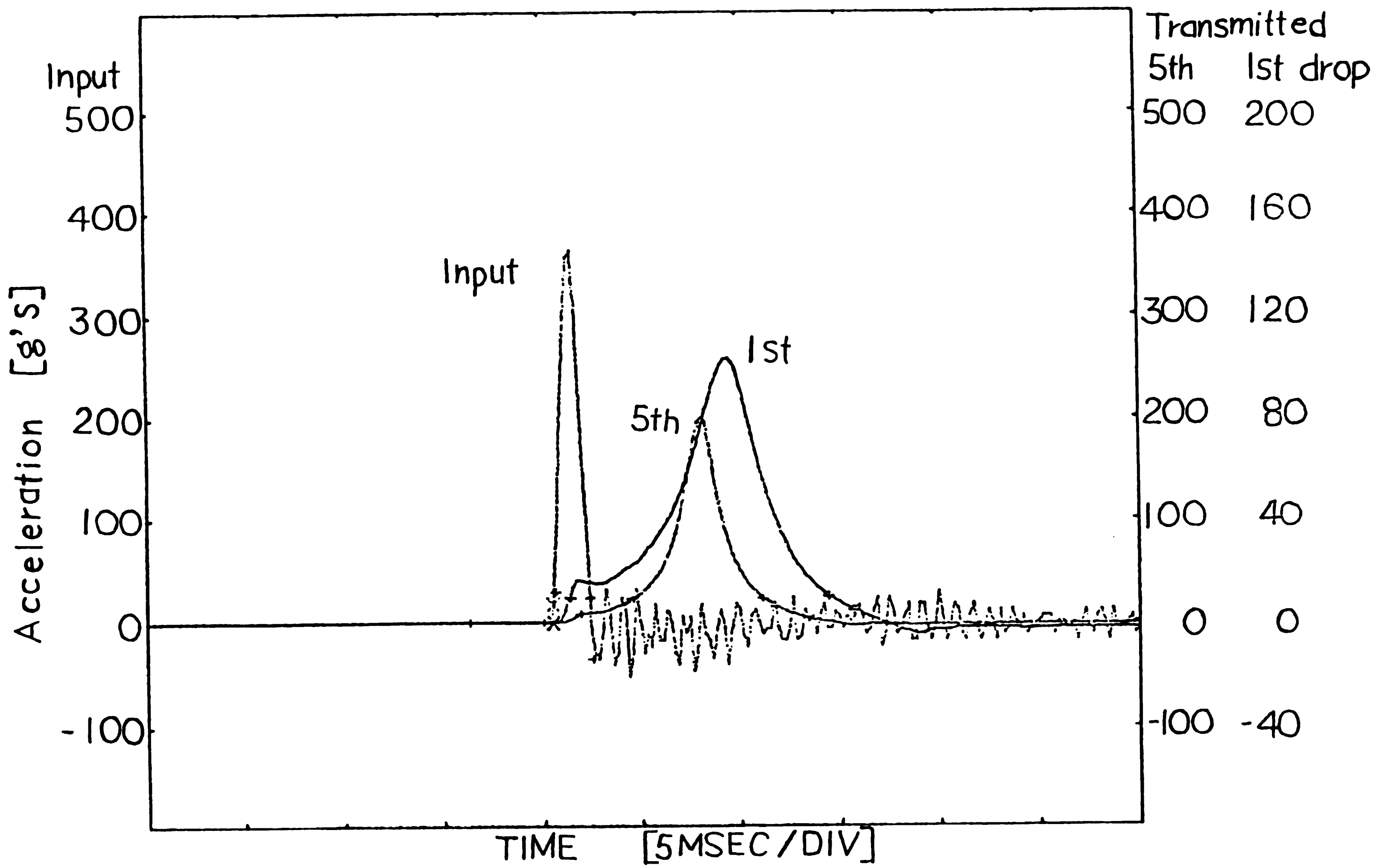


Figure 43. Shock Pulses in Block 2 (side panel effect specimen)

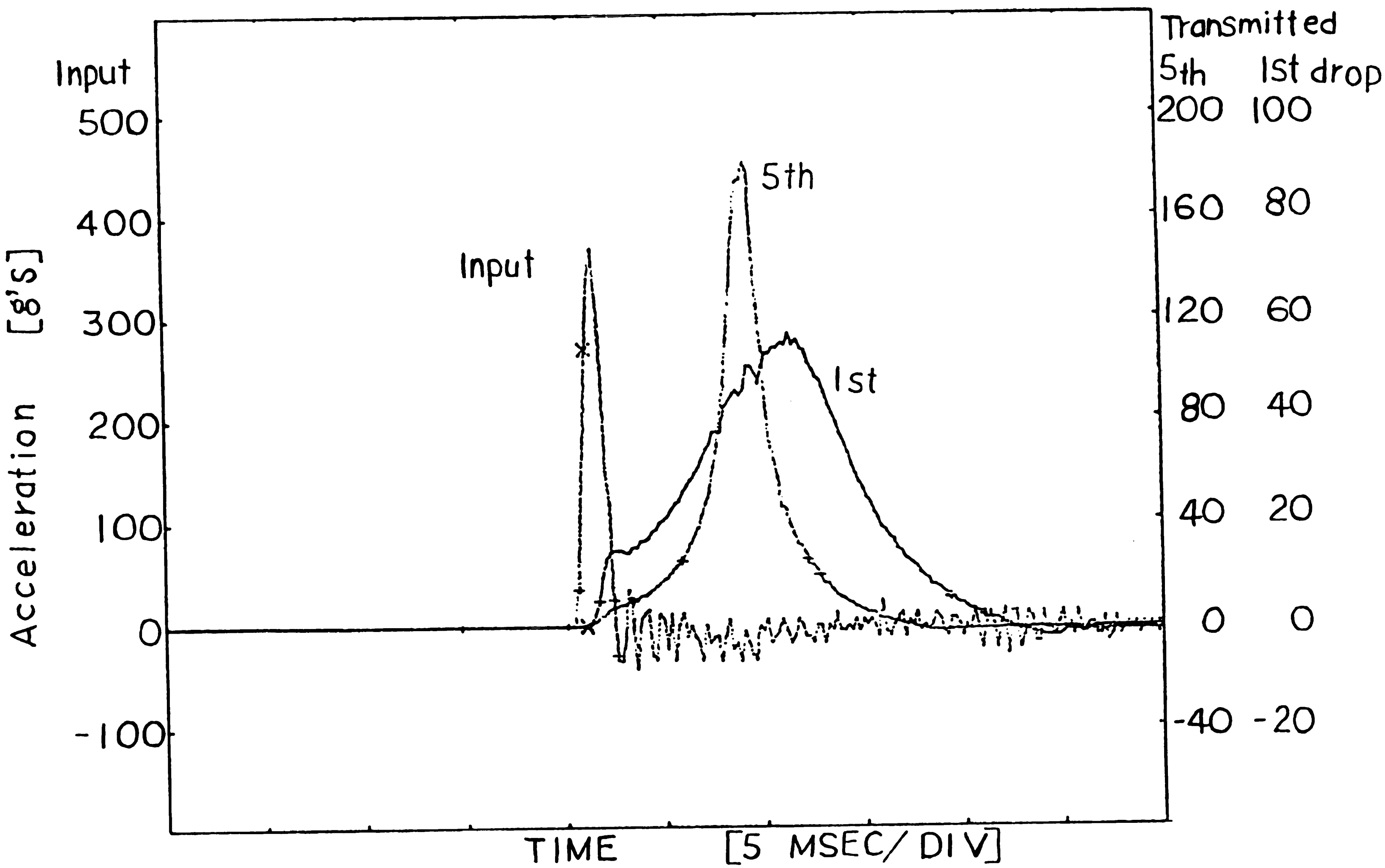


Figure 44. Shock Pulses in Block 2 (corrugated board effect specimen)

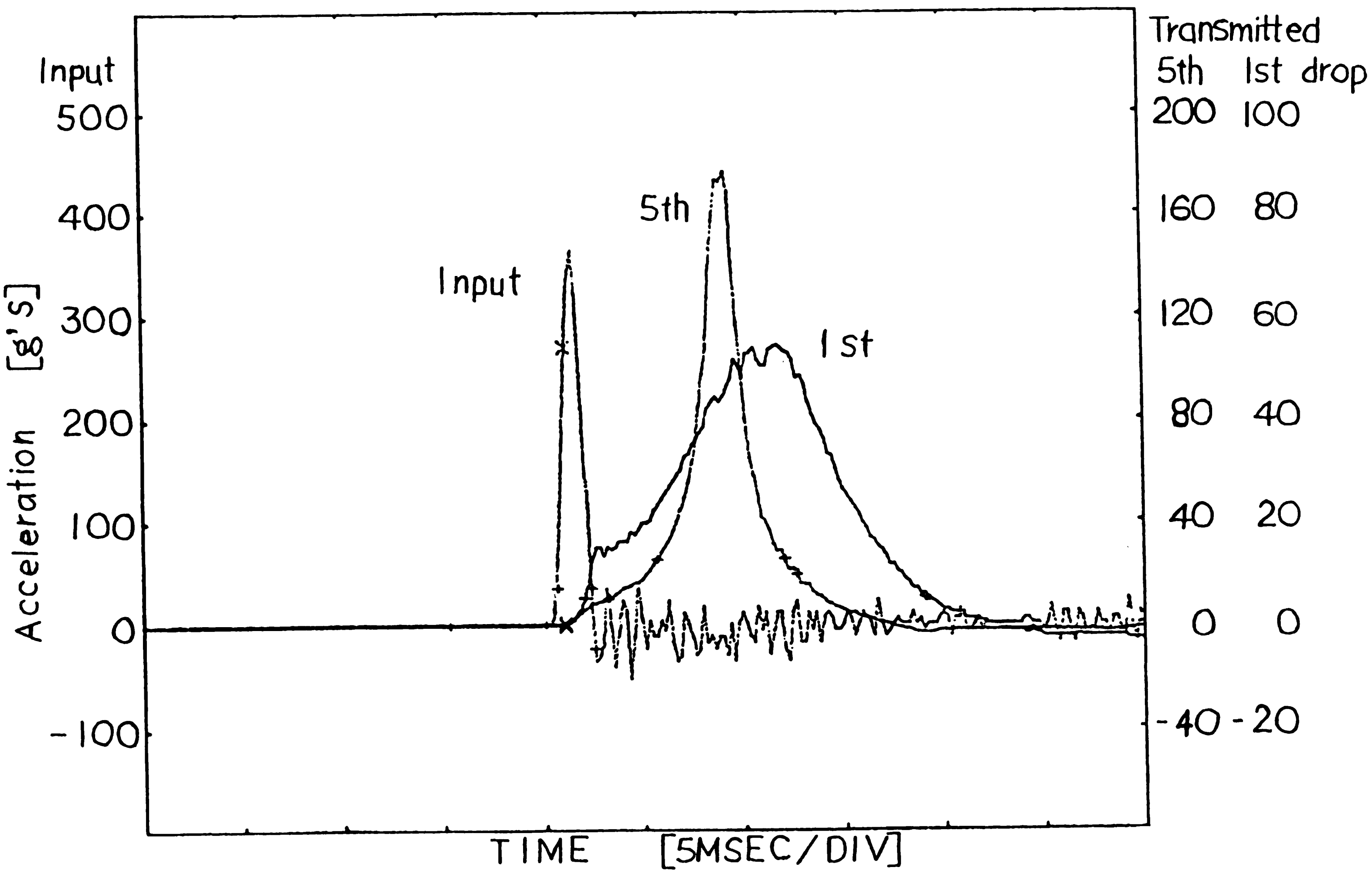


Figure 45. Shock Pulses in Block 2 (all effects specimen)

APPENDIX C

A PAIRED COMPARISON

X and Y denote the responses to treatment 1 (specimen 1) and treatment 2 (specimen 2) respectively. The structure of data for a paired comparison is the following (16).

Block	Treatment 1 (specimen 1)	Treatment 2 (specimen 2)	Difference
1	X_1	Y_1	$D_1 = X_1 - Y_1$
2	X_2	Y_2	$D_2 = X_2 - Y_2$
.	.	.	.
.	.	.	.
.	.	.	.
n	X_n	Y_n	$D_n = X_n - Y_n$

The paires (X_1, Y_1), (X_2, Y_2), ..., (X_n, Y_n) are independent.

Assume that the differences $D_i = X_i - Y_i$ are independent with a $N(\delta, \sigma_D)$ distribution. Summary statistics are the following.

$$\bar{D} = \sum_{i=1}^{n} D_i / n$$

$$S_D^2 = \sum_{i=1}^{n} (D_i - \bar{D})^2 / (n - 1)$$

From the test results in Part I tests, because the investigation was being made to determine if each effect decreases peak g and increases pulse duration, the parameter values under H_1 lie to one side of the range of values specified by H_0 as followed.

A test of H_0 ; $\delta = 0$ v.s. H_1 ; $\delta > 0$ is based on the following statistic.

$$t = \frac{\bar{D}}{S_D / \sqrt{n}} \quad , \text{d.f.} = n - 1$$

APPENDIX D

PAIRED COMPARISONS CALCULATION

Table 10. A Paired Comparison Calculation

10-1 A Paired Comparison on Peak g between Air Trap Effect Specimen and No Effect Specimen at 1st Drop

Block No.	air trap effect Peak g [g's]	no effect Peak g [g's]	Diff.	$\bar{D}$	S_D	t
1	119.5	124.2	-4.7			
2	103.1	104.3	-1.2			*
3	92.6	102.0	-9.4	-6.03	3.84	-3.14
4	--	85.5	--			
5	74.4	83.2	-8.8			

Table 10 (cont'd.). A Paired Comparison Calculation

10-2 A Paired Comparison on Peak g between Air Trap Effect Specimen and No Effect Specimen at 2nd Drop

Block No.	air trap effect Peak g [g's]	no effect Peak g [g's]	Diff.	$\bar{D}$	S_D	t
1	177.5	190.5	-13.0			
2	154.1	160.5	- 6.4			**
3	138.3	152.9	-14.6	-12.9	3.92	-7.35
4	112.5	126.0	-13.5			
5	106.1	123.0	-16.9			

10-3 A Paired Comparison on Peak g between Air Trap Effect Specimen and No Effect Specimen at 3rd Drop

Block No.	air trap effect Peak g [g's]	no effect Peak g [g's]	Diff.	$\bar{D}$	S_D	t
1	216.0	212.3	3.7			
2	178.6	185.9	- 7.3			*
3	165.2	188.3	-23.1	-11.9	10.5	-2.53
4	130.1	144.1	-14.0			
5	123.1	141.8	-18.7			

Table 10 (cont'd.). A Paired Comparison Calculation

10-4 A Paired Comparison on Peak g between Air Trap Effect Specimen and No Effect Specimen at 4th Drop

Block No.	air trap effect Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	225.3	220.3	5.0			
2	190.3	195.1	- 4.8			
3	176.9	195.6	-18.7	-8.26	9.55	-1.93
4	140.0	146.5	- 6.5			
5	132.5	148.8	-16.3			

10-5 A Paired Comparison on Peak g between Air Trap Effect Specimen and No Effect Specimen at 5th Drop

Block No.	air trap effect Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	232.3	241.2	- 8.9			
2	196.6	199.3	- 2.7			**
3	186.1	204.1	-18.0	-10.0	5.64	-3.97
4	143.6	151.8	- 8.2			
5	143.6	155.9	-12.3			

Table 10 (cont'd.). A Paired Comparison Calculation

10-6 A Paired Comparison on Pulse Duration τ between Air Trap Effect Specimen and No Effect Specimen at 1st Drop

Block No.	air trap effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	12.40	12.36	.04			
2	13.29	13.40	-.11			
3	13.67	13.32	.35	.195	.279	1.40
4	--	14.36	--			
5	14.98	14.48	.50			

10-7 A Paired Comparison on Pulse Duration τ between Air Trap Effect Specimen and No Effect Specimen at 2nd Drop

Block No.	air trap effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	7.93	7.47	.46			
2	8.82	8.63	.19			
3	9.63	8.63	1.00	.754	.406	4.15**
4	11.01	10.01	1.00			
5	11.32	10.20	1.12			

Table 10 (cont'd.). A Paired Comparison Calculation

10-8 A Paired Comparison on Pulse Duration τ between Air Trap Effect Specimen and No Effect Specimen at 3rd Drop

Block No.	air trap effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	5.89	5.89	.00			
2	7.78	7.35	.43			*
3	8.24	7.32	.92	.594	.426	3.12
4	9.74	9.20	.54			
5	10.17	9.09	1.08			

10-9 A Paired Comparison on Pulse Duration τ between Air Trap Effect Specimen and No Effect Specimen at 4th Drop

Block No.	air trap effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	5.78	5.51	.27			
2	7.28	7.01	.27			*
3	7.74	6.70	1.04	.548	.333	3.68
4	9.40	8.97	.43			
5	9.59	8.86	.73			

Table 10 (cont'd.). A Paired Comparison Calculation

10-10 A Paired Comparison on Pulse Duration τ between Air Trap Effect Specimen and No Effect Specimen at 5th Drop

Block No.	air trap effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	5.39	5.12	.27			
2	7.09	6.70	.39			*
3	7.35	6.28	1.07	.524	.377	3.11
4	9.01	8.86	.15			
5	9.13	8.39	.74			

Table 10 (cont'd.). A Paired Comparison Calculation

10-11 A Paired Comparison on Peak g between Side Panel Effect Specimen and No Effect Specimen at 1st Drop

Block No.	side panel effect Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	--	124.2	--			
2	104.3	104.3	.0			
3	96.1	102.0	- 5.9	-7.03	7.66	-.159
4	--	85.5	--			
5	68.0	83.2	-15.2			

10-12 A Paired Comparison on Peak g between Side Panel Effect Specimen and No Effect Specimen at 2nd Drop

Block No.	side panel effect Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	172.3	190.5	-18.2			
2	155.9	160.5	- 4.6			*
3	142.4	152.9	-10.5	-12.7	10.4	-2.72
4	107.8	126.0	-18.2			
5	102.0	123.0	-21.0			

Table 10 (cont'd.). A Paired Comparison Calculation

10-13 A Paired Comparison on Peak g between Side Panel Effect Specimen and No Effect Specimen at 3rd Drop

Block No.	side panel effect Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	199.5	212.3	-16.8			
2	--	185.9	--			**
3	--	188.3	--	-20.2	3.31	-10.6
4	123.6	144.1	-20.5			
5	118.4	141.8	-23.4			

10-14 A Paired Comparison on Peak g between Side Panel Effect Specimen and No Effect Specimen at 4th Drop

Block No.	side panel effect Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	206.8	220.3	-13.5			
2	--	195.1	--			**
3	172.1	195.6	-23.5	-18.1	4.75	-7.60
4	131.8	146.5	-14.7			
5	128.3	148.8	-20.5			

Table 10 (cont'd.). A Paired Comparison Calculation

10-15 A Paired Comparison on Peak g between Side Panel Effect Specimen and No Effect Specimen at 5th Drop

Block No.	side panel effect Peak g [g's]	no effect Peak g [g's]	Diff.	$\bar{D}$	S_D	t
1	213.4	241.2	-27.8			
2	198.3	199.3	- 1.0			*
3	181.8	204.1	-22.3	-17.5	10.7	-3.65
4	138.9	151.8	-12.9			
5	132.4	155.9	-23.5			

Table 10 (cont'd.). A Paired Comparison Calculation

10-16 A Paired Comparison on Pulse Duration τ between Side Panel Effect Specimen and No Effect Specimen at 1st Drop

Block No.	side panel effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	--	12.36	--			
2	13.05	13.40	-.35			
3	13.48	13.32	.16	.243	.639	.659
4	--	14.36	--			
5	15.40	14.48	.92			

10-17 A Paired Comparison on Pulse Duration τ between Side Panel Effect Specimen and No Effect Specimen at 2nd Drop

Block No.	side panel effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	8.16	7.47	.69			
2	8.82	8.63	.19			*
3	9.05	8.63	.42	.948	.828	2.56
4	11.17	10.01	1.16			
5	12.48	10.20	2.28			

Table 10 (cont'd.). A Paired Comparison Calculation

10-18 A Paired Comparison on Pulse Duration τ between Side Panel Effect Specimen and No Effect Specimen at 3rd Drop

Block No.	side panel effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	6.70	5.89	.81			
2	--	7.35	--			**
3	--	7.32	--	.950	.178	9.25
4	10.09	9.20	.89			
5	10.24	9.09	1.15			

10-19 A Paired Comparison on Pulse Duration τ between Side Panel Effect Specimen and No Effect Specimen at 4th Drop

Block No.	side panel effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	5.55	5.51	.04			
2	--	7.01	--			*
3	7.78	6.70	1.08	.685	.465	2.95
4	9.63	8.97	.66			
5	9.82	8.86	.96			

Table 10 (cont'd.). A Paired Comparison Calculation

10-20 A Paired Comparison on Pulse Duration τ between Side Panel Effect Specimen and No Effect Specimen at 5th Drop

Block No.	side panel effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	5.47	5.12	.35			
2	6.58	6.70	-.12			*
3	7.47	6.28	1.19	.632	.580	2.44
4	9.36	8.86	.50			
5	9.63	8.39	1.24			

Table 10 (cont'd.). A Paired Comparison Calculation

10-21 A Paired Comparison on Peak g between Corrugated Board Effect specimen and No Effect Specimen at 1st Drop

Block No.	corrugated board effect Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	68.0	124.2	-56.2			
2	57.4	104.3	-46.9			**
3	55.1	102.0	-46.9	-41.9	11.9	-7.91
4	58.6	85.5	-26.9			
5	50.4	83.2	-32.8			

10-22 A Paired Comparison on Peak g between Corrugated Board Effect Specimen and No Effect Specimen at 2nd Drop

Block No.	corrugated board effect Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	179.1	190.5	-11.4			
2	140.0	160.5	-20.5			**
3	126.6	152.9	-26.3	-22.9	13.6	-3.76
4	114.3	126.0	-11.7			
5	78.5	123.0	-44.5			

Table 10 (cont'd.). A Paired Comparison Calculation

10-23 A Paired Comparison on Peak g between Corrugated Board Effect Specimen and No Effect Specimen at 3rd Drop

Block No.	corrugated board effect Peak g	no effect Peak g	Diff.	$\bar{D}$	S_D	t
	[g's]					
1	191.5	212.3	-20.8			
2	169.1	185.9	-16.8			
3	158.0	188.3	-30.3	-10.1	18.4	-1.23
4	159.2	144.1	15.1			
5	144.1	141.8	2.3			

10-24 A Paired Comparison on Peak g between Corrugated Board Effect Specimen and No Effect Specimen at 4th Drop

Block No.	corrugated board effect Peak g	no effect Peak g	Diff.	$\bar{D}$	S_D	t
	[g's]					
1	198.9	220.3	-21.4			
2	169.7	195.1	-25.4			
3	167.4	195.6	-28.2	-17.5	15.3	-2.28
4	--	146.5	--			
5	153.9	148.8	5.1			

Table 10 (cont'd.). A Paired Comparison Calculation

10-25 A Paired Comparison on Peak g between Corrugated Board Effect Specimen and No Effect Specimen at 5th Drop

Block No.	corrugated board effect Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	199.4	241.2	-41.8			
2	176.3	199.3	-23.0			
3	169.6	204.1	-34.5	-23.7	20.3	-2.34
4	--	151.8	--			
5	160.3	155.9	4.4			

Table 10 (cont'd.). A Paired Comparison Calculation

10-26 A Paired Comparison on Pulse Duration τ between Corrugated Board Effect Specimen and No Effect Specimen at 1st Drop

Block No.	corrugated board effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	16.71	12.36	4.35			
2	17.64	13.40	4.24			**
3	17.56	13.32	4.24	3.83	.694	12.3
4	17.06	14.36	2.70			
5	18.10	14.48	3.62			

10-27 A Paired Comparison on Pulse Duration τ between Corrugated Board Effect Specimen and No Effect Specimen at 2nd Drop

Block No.	corrugated board effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	8.13	7.47	.66			
2	10.40	8.63	1.77			*
3	10.94	8.63	2.31	2.08	1.25	3.72
4	11.63	10.01	1.62			
5	14.25	10.20	4.05			

Table 10 (cont'd.). A Paired Comparison Calculation

10-28 A Paired Comparison on Pulse Duration τ between Corrugated Board Effect Specimen and No Effect Specimen at 3rd Drop

Block No.	corrugated board effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	5.97	5.89	.08			
2	8.16	7.35	.81			
3	8.78	7.32	1.46	.540	.680	1.78
4	8.90	9.20	-.30			
5	9.74	9.09	.65			

10-29 A Paired Comparison on Pulse Duration τ between Corrugated Board Effect Specimen and No Effect Specimen at 4th Drop

Block No.	corrugated board effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	5.89	5.51	.38			
2	6.62	7.01	-.39			
3	7.39	6.70	.69	.180	.464	.867
4	--	8.97	--			
5	8.90	8.86	.04			

Table 10 (cont'd.). A Paired Comparison Calculation

10-30 A Paired Comparison on Pulse Duration τ between Corrugated Board Effect Specimen and No Effect Specimen at 5th Drop

Block No.	corrugated board effect Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	5.97	5.12	.85			
2	6.32	6.70	-.38			
3	7.09	6.28	.81	.350	.591	1.18
4	--	8.86	--			
5	8.51	8.39	.12			

Table 10 (cont'd.). A Paired Comparison Calculation

10-31 A Paired Comparison on Peak g between All Effects Specimen and No Effect Specimen at 1st Drop

Block No.	all effects Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	68.0	124.2	-56.2			
2	57.4	104.3	-46.9			**
3	58.6	102.0	-43.4	-44.8	9.67	-9.27
4	--	85.5	--			
5	50.4	83.2	-32.8			

10-32 A Paired Comparison on Peak g between All Effects Specimen and No Effect Specimen at 2nd Drop

Block No.	all effects Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	168.0	190.5	-22.5			
2	123.0	160.5	-37.5			**
3	134.8	152.9	-18.1	-27.0	8.52	-6.33
4	--	126.0	--			
5	93.2	123.0	-29.8			

Table 10 (cont'd.). A Paired Comparison Calculation

10-33 A Paired Comparison on Peak g between All Effects Specimen and No Effect Specimen at 3rd Drop

Block No.	all effects Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	191.5	212.3	-20.8			
2	169.9	185.9	-16.0			**
3	170.7	188.3	-17.6	-15.7	5.35	-5.85
4	--	144.1	--			
5	133.6	141.8	- 8.2			

10-34 A Paired Comparison on Peak g between All Effects Specimen and No Effect Specimen at 4th Drop

Block No.	all effects Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	199.4	220.3	-20.9			
2	173.3	195.1	-21.8			*
3	171.3	195.6	-24.3	-16.9	10.96	-3.08
4	--	146.5	--			
5	148.2	148.8	- .60			

Table 10 (cont'd.). A Paired Comparison Calculation

10-35 A Paired Comparison on Peak g between All Effects Specimen and No Effect Specimen at 5th Drop

Block No.	all effects Peak g [g's]	no effect Peak g	Diff.	$\bar{D}$	S_D	t
1	210.3	241.2	-30.9			
2	172.8	199.3	-26.5			*
3	175.9	204.1	-28.2	-21.9	13.4	-3.26
4	--	151.8	--			
5	154.0	155.9	- 1.9			

Table 10 (cont'd.). A Paired Comparison Calculation

10-36 A Paired Comparison on Pulse Duration τ between All Effects Specimen and No Effect Specimen at 1st Drop

Block No.	all effects Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	16.02	12.36	3.66			
2	17.02	13.40	3.62			**
3	16.64	13.32	3.32	3.43	.256	26.8
4	--	14.36	--			
5	17.60	14.45	3.12			

10-37 A Paired Comparison on Pulse Duration τ between All Effects Specimen and No Effect Specimen at 2nd Drop

Block No.	all effects Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	8.20	7.47	.73			
2	11.48	8.63	2.85			*
3	10.36	8.63	1.73	2.19	1.20	3.64
4	--	10.01	--			
5	13.63	10.20	3.43			

Table 10 (cont'd.). A Paired Comparison Calculation

10-38 A Paired Comparison on Pulse Duration τ between All Effects Specimen and No effect Specimen at 3rd Drop

Block No.	all effects Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	5.81	5.89	-.08			
2	6.62	7.35	-.73			
3	7.93	7.32	.61	.278	.879	.631
4	--	9.20	--			
5	10.40	9.09	1.31			

10-39 A Paired Comparison on Pulse Duration τ between All Effects Specimen and No Effect Specimen at 4th Drop

Block No.	all effects Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	5.28	5.51	-.23			
2	6.35	7.01	-.66			
3	6.32	6.70	-.38	-.213	.458	-.928
4	--	8.97	--			
5	9.28	8.86	.42			

Table 10 (cont'd.). A Paired Comparison Calculation

10-40 A Paired Comparison on Pulse Duration τ between All Effects Specimen and No Effect Specimen at 5th Drop

Block No.	all effects Dur. τ [msec]	no effect Dur. τ [msec]	Diff.	$\bar{D}$	S_D	t
1	5.08	5.12	-.04			
2	6.32	6.70	-.38			
3	6.24	6.28	-.04	-.0275	.298	-.185
4	--	8.86	--			
5	8.74	8.39	.35			

* Significant at level 5 %

** Significant at level 1 %

BIBLIOGRAPHY

1. Goff, J.W. and Twede, D., 1984. "Functions of Intermediate Packages," School of Packaging, Michigan State University.

2. Mindlin, R.D., 1945. "Dynamics of Package Cushioning," Bell Telephone System Technical Journal, Vol. 24, pp. 353-461.

3. Newton, R.E., 1968. "Fragility Assessmnt Theory and Test Procedure." Monterey Research Laboratory, Monterey, California.

4. Goff, J.W. and Pierce, S.R., 1970. "A Fragility Assessment Theory and Test Procedure Demonstrated on Real Test Items." Technical Report No.18, Multi-sponsor Research Program, Project 1, Control of Damage in Shipment, School of Packaging, Michigan State University.

5. Stern, R.K., 1965. "Military standardization Handbook - Package Cushioning Design."MIL-HDBK-304, Department of Defence, Washington, D.C..

6. "Standard Test Method for Shock Absorbing Characteristics of Package Cushioning Materials," American Society For Testing And Materials D1596-78a, 1983.

7. "Five Step Packaging Development." MTS System Corporation, 1971.

8. Palmreuter, G.L., 1968. "An Evaluation of The Cushioning Properties of Corrugated Paperboard." M.S. Thesis, School of Packaging, Michigan State University.

9. McCall, D.G., 1969. "The Application of The Shock Spectrum Derived Damage Boundary Theory to The Evaluation of The Shock Transmissibility of Corrugated Board," M.S. Thesis, School of Packaging, Michigan State University.

10. Willson, K.S., 1958. "Relative Energy Absorption Properties of Free and Enclosed Cushions," M.S. Thesis, School of Packaging, Michigan State University.

11. Goff, J.W. and Blake, H.C., 1965. "Some Package Drop Tests Utilizing The Package Cushion Design Method," Technical Report No.8, Multi-sponsor Research Program, Project 1, Control of Damage in Shipment, School of Packaging, Michigan State University.

12. McGinnis, M.A., 1965. "A Study of The Transmissibility of Short Duration Shock Pulses by Package Cushioning Materials." M.S. Thesis, School of Packaging, Michigan State University.

13. Brandenburg,R.K. and Lee, J.L., 1985. "Fundamentals of Packaging Dynamics," MTS Systems Corporation, Minneapolis, Minnesota.

14. "Product Design Data for ETHAFOAM brand polyethylene foam," DOW CHEMICAL U.S.A., March 1985.

15. "Model 466.10 Waveform Analyzer," Hardware Product Mannual, MTS Systems Corporation.

16. Bhattacharyya, G.K. and Johnson, R.A., 1977. "Statical Concepts and Methods," John Wiley & Sons.

MICHIGAN STATE UNIV. LIBRARIES
31293008024337