A STUDY OF THE TRANSMISSIBILITY OF SHORT DURATION SHOCK PULSES BY PACKAGE CUSHIONING MATERIALS

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ABSTRACT

A STUDY OF THE TRANSMISSIBILITY OF SHORT DURATION SHOCK PULSES BY PACKAGE CUSHIONING MATERIALS

by Michael A. McGinnis

This study was undertaken in order to determine if a shock producing device can be used for evaluating package cushioning materials. Test cushions received a constant shock pulse at various levels of static loading and lateral restraint. Shocks transmitted through the cushions were measured by a crystal accelerometer mounted on an aluminum plate. The transmitted shocks were recorded as stored traces on a storage oscilloscope.

Results showed that varying amounts of lateral restraint and static loading affected the magnitude and duration of the transmitted shock pulses. Open structure cushioning materials, such as bonded animal hair, were affected more by lateral restraint than were closed structure materials, such as expanded bead polystyrene.

It was concluded that the effects of lateral restraint of a package cushion were greatest upon the movement of air in and around the material during dynamic loading. Lateral restraint has less effect upon material rigidity.

It was also concluded that a shock generating device can be used to study the properties of cushioning materials. It was not determined whether shock generating devices are more valid tests of cushion performance than present test methods.

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By

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INTRODUCTION

The generally accepted method of testing package cushioning materials is to drop a platen of known weight and cross section area on to the test cushion. The deceleration of the falling platen, as well as the deflection and recovery of the cushion, are used to predict cushion performance. In these tests, the cushion is not restrained laterally.

In actual use, the outer container absorbs part of the energy from a free fall and transmits a shock pulse to the cushion. The cushion absorbs some of this energy and transmits another shock to the product. It is felt that the shock pulse transmitted to the product by the cushion may be significantly different than the pulse obtained by dropping a given weight on to a stationary cushion.

During actual use the cushion is usually restrained laterally by the outer container. It has not been shown, however, how various amounts of lateral restraint affect cushion performance.

This study was concerned with the shock pulse transmitted from a cushion to its load when subjected to a shock input simillar to that transmitted from an A-flute corrugated box to its contents (333 G's deceleration and .4 milliseconds duration). This pulse was obtained by dropping an instrumented, corrugated box from 24 inches. Both static loading and lateral restraint of the cushions were varied.

BACKGROUND

Before World War II there was little interest in package cushion testing. During the war the Forest Products Laboratory in Madison, Wisconsin, began studies on package cushions for the evaluation of materials and prediction of performance. These early studies were based on static tests. Because static test results did not agree well with dynamic test results and dynamic testing more closely simulated the action on a cushion when the package is dropped, dynamic testing of cushions became the accepted method for evaluating cushion performance (1).

All dynamic tests of package cushioning operate on the same principle. A mass of known weight and cross section area is impacted on a cushion of known thickness and area. The deceleration of the falling body as well as deflection and recovery of the cushion can then be measured. Several methods were tried. The dynamic tester that became most common utilizes an instrumented variable weight platform that is dropped on to the sample cushion. It was found that impact velocity was easier to control with the free falling platform than with other dynamic testers(2).

Most dynamic testing of cushions has been performed without lateral restraint of the cushions. One study has shown that there is a significant increase in cushion stiffness when the cushion is restrained(3). However, it has not been determined how much different amounts of lateral restraint affect cushion performance.

As far as could be determined, no one has studied the shock pulse transmitted by a cushion at various levels of static loading and lateral restraint when subjected to a shock pulse of the type transmitted from a container to its contents.

Before the effect of shock transmissibility by a cushion could be examined it was necessary to determine the type of shock pulse transmitted from a particular container to its contents and find a method of duplicating this pulse.

It was decided to use the shock pulse transmitted by an A-flute RSC to a dummy load when dropped from 24 inches. Twenty-four inches was selected because it has been shown that the probability of a package drop exceeding 24 inches is 0.024(4). There is also a trend to reduce the drop height of present cushion testing methods from 30 to 24 inches. Appendix I shows the degradation of the shock pulse transmitted to the dummy load as the box is dropped 60 times.

The shock pulse of the 40th drop from 24 inches was selected as the level at which to study the effects of different static loadings and various amounts of lateral restraint on cushion efficiency. The 40th drop was selected because a package will receive 40 drops, or less, in over 97 percent of all trips. Drop heights greater than 24 inches and more than 40 drops occur in less than three percent of all shipments(5).

It was found that the pulse transmitted by an A-flute container to its contents could be approximated on the LAB drop shock tester. These pulses are shown in Appendix II.

TEST EQUIPMENT

This section covers all non-electrical equipment used. Included are the drop shock tester, rubber pads for the drop shock tester, aluminum platen and weights, the corrugated restraints, and the cushions themselves.

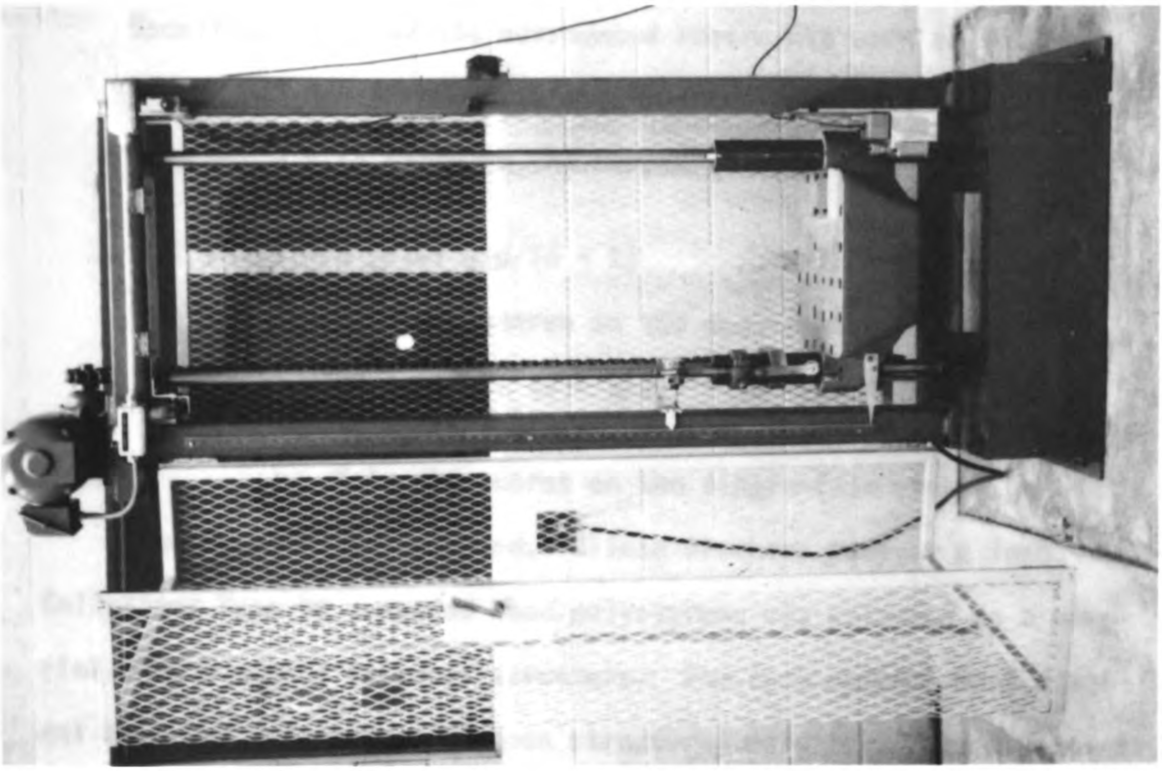
The drop shock tester was an LAB Corporation Type SD 16 42 100 Drop Shock Tester. The conical nose piece was removed. The drop shock tester drop head was dropped from a height of 5 3/4 inches on to 4 layers of 1/8 inch, 72 durometer natural rubber. The drop shock tester is shown in Figure 1.

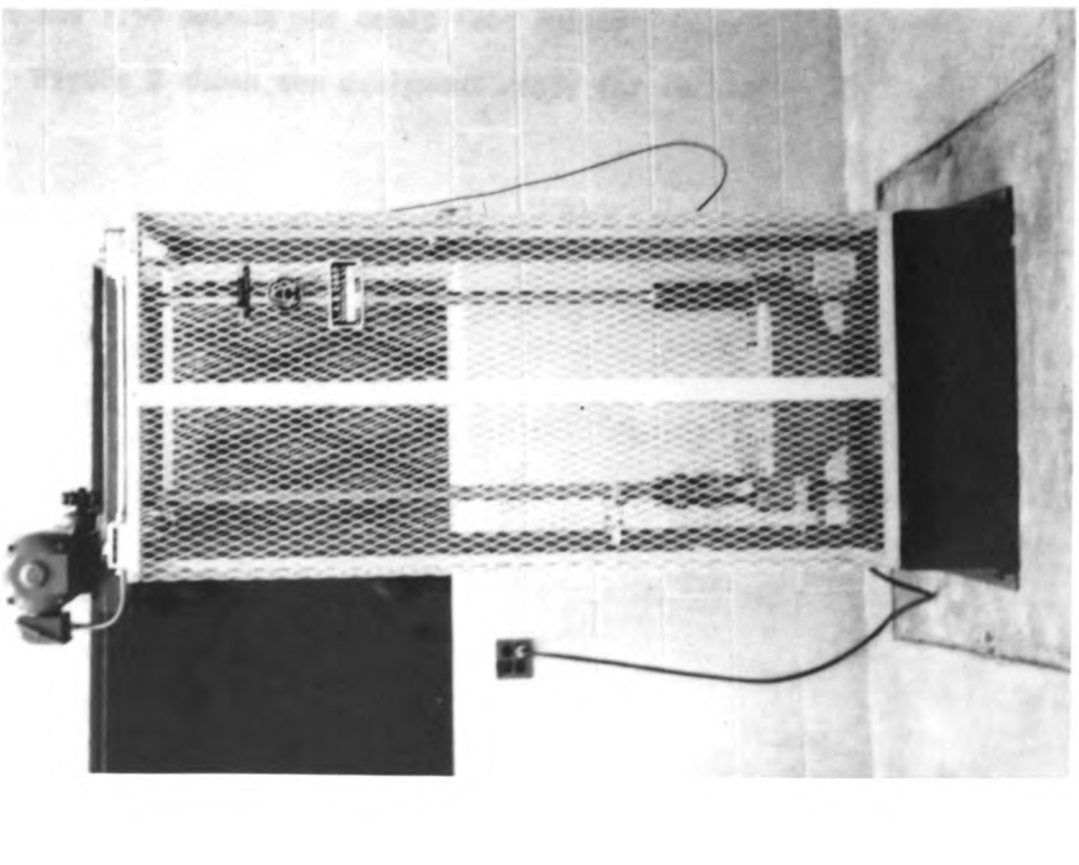
The aluminum platen was used to receive shock pulses transmitted by the cushions. This platen consisted of an 8 X 8 X ¼ inch aluminum plate tapped to receive additional weights and test instrumentation. The platen weighed 3.5 pounds with the test accelerometer and extra weight rods. Platen weight was increased by the addition of lead weights.

The corrugated restraints were designed to laterally restrain the cushions. A-flute corrugated board was used for their construction. The dimensions of these restraints were 2 1/8 inches deep by 8 X 8, 8¼ X 8¼, 8½ X 8½ or 8 3/4 X 8 3/4 inches nominally. Length and width were 1/8 inch less than the nominal dimensions. The restraints were reinforced and taped to the drop head with fiberglass reinforced, pressure sensitive tape.

FIGURE 1

LAB CORPORATION TYPE SD 16-42-100 DROP SHOCK TESTER





Specifications for the corrugated restraints were as follows:

1 S X S X 2 1/8 A-flute corrugated restraint

Where S is equal to the nominal length and width of the restraint.

Small - 5 9/16: 2 5/16 + 2¼

Male die scores on the double-back side.

Large - 4S + 14/15: (S + 3/16) + (S + ¼) + (S + ¼) + (S + 3/16)

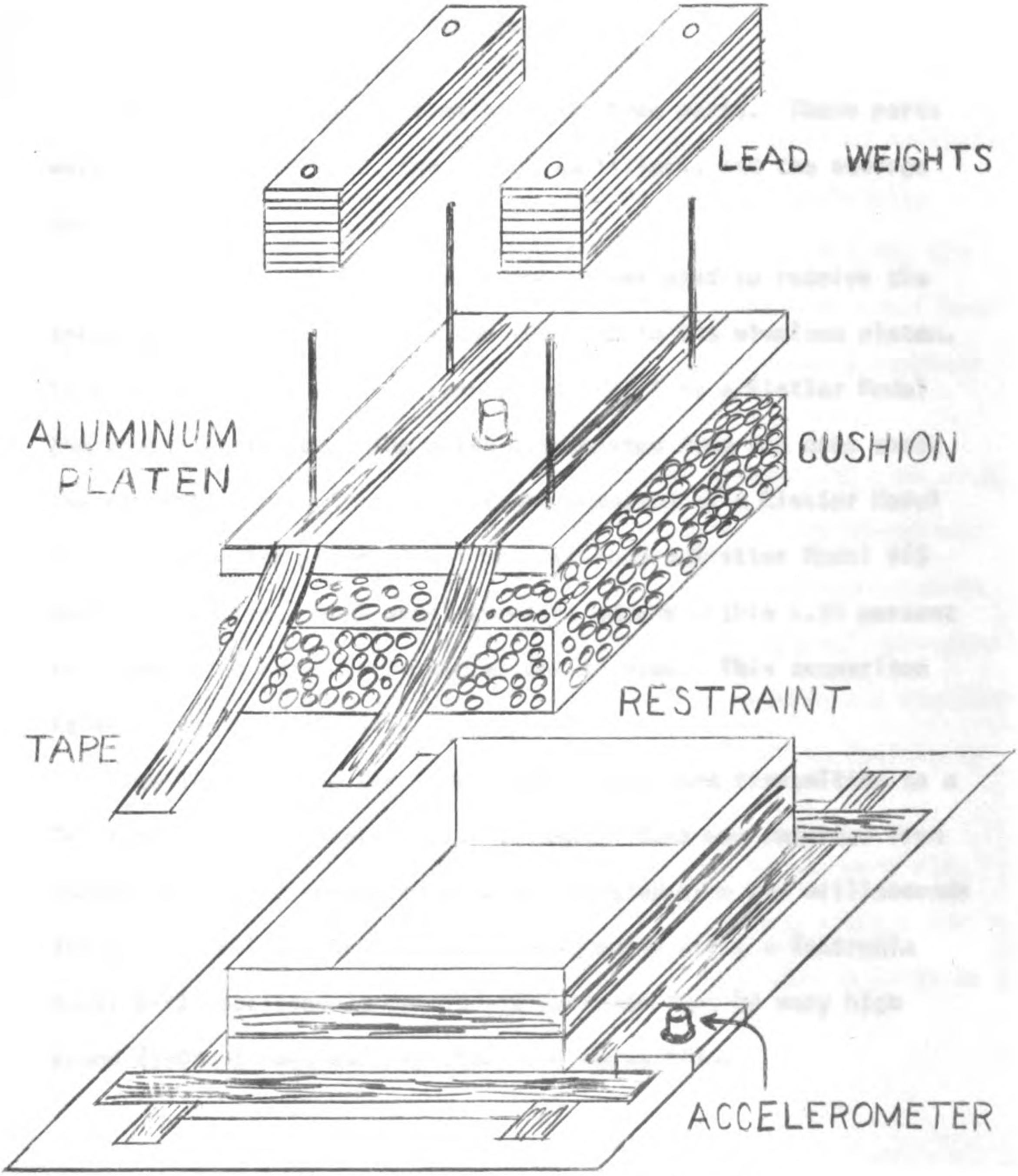
Male die scores on the single-face side.

Two cushions were studied. Gilman Brothers Company 2 inch, Celluliner Type 40 expanded bead polystyrene was selected as a material with a closed cellular structure. Two inch nominal bonded animal hair was selected as an open structured material. The dimensions of all cushions were 8 X 8 X 2 inches. Densities of the expanded bead polystyrene and bonded animal hair were 1.48 pounds per cubic foot and 1.50 pounds per cubic foot respectively.

Figure 2 shows the equipment ready for testing.

FIGURE 2

EXPLODED VIEW OF TEST EQUIPMENT



SHOCK DROP TESTER DROP HEAD

TEST INSTRUMENTATION

Test instrumentation consisted of three parts. These parts were the accelerometers, the charge amplifiers, and the storage oscilloscope.

A Kistler Model 808A accelerometer was used to receive the shock pulse transmitted from the cushions to the aluminum platen. This signal from the accelerometer was fed into a Kistler Model 566 charge amplifier. The pulse transmitted from the drop shock tester drop head to the cushions was measured by a Kistler Model 808 accelerometer whose signal was fed into a Kistler Model 565 charge amplifier. Both accelerometers agreed within 5.34 percent throughout the range of decelerations studied. This comparison is shown in Appendix III.

The signals from the charge amplifiers were transmitted to a Tektronix Type 564 storage oscilloscope. Data was recorded from stored traces and converted into G's deceleration and milliseconds duration. Selected traces were photographed using a Tektronix Model C-12 oscilloscope camera and Polaroid Type 47 very high speed (3000 ASA equivalent) black and white film.

EXPERIMENTAL PROCEDURE

Three cushions of each type were used at each level of restraint. The expanded bead polystyrene cushions were tested individually throughout the loading range because of difficulty in handling the aluminum platen when heavily weighted. The three bonded animal hair cushions in each series were tested at each loading before increasing the platen weight.

Each cushion was placed on the drop shock tester drop head with or without lateral restraint. The instrumented aluminum platen was then placed on the cushion. The cushion and platen were secured to the drop shock tester drop head with fiberglass reinforced, pressure sensitive tape in order to reduce rebound of the cushion and aluminum platen. In-put shocks were generated at intervals of approximately one minute.

The shock pulses transmitted to the aluminum platen were read off the storage oscilloscope and the disturbing pulses checked for consistancy. Both charge amplifiers were grounded between drops to eliminate residual electrical charges.

TABLE I

2 INCH EXPANDED BEAD POLYSTYRENE, UNRESTRAINED

Platen Weight

	3.5 lbs Primary	3.5 lbs Secondary	5.5 lbs Primary	5.5 lbs Secondary	7.5 lbs Primary	7.5 lbs Secondary	10.0 lbs Primary	10.0 lbs Secondary
G's	122	71.1	86.4	61.0	71.1	45.7	61.0	40.6
msec	5.0	7.0	6.5	9.5	7.5	11.5	--	--
	117	61.0	86.4	55.9	71.1	45.7	61.0	40.6
	5.0	8.0	6.0	10.0	8.0	12.0	8.5	12.5
	117	66.0	86.4	50.8	71.1	40.6	61.0	40.6
	1.0	8.0	6.5	9.5	7.0	12.5	8.5	12.0
	102	55.9	86.4	50.8	66.0	50.8	61.0	45.7
	5.0	8.5	7.0	9.0	6.5	12.0	9.5	12.5
	102	55.9	81.3	50.8	66.0	50.8	55.9	45.7
	5.0	8.5	6.5	10.0	6.5	11.5	9.0	13.0
	102	55.9	81.3	50.8	66.0	50.8	55.9	45.7
	5.0	8.5	7.0	9.5	6.5	12.0	9.5	12.5
	107	61.0	91.4	50.8	71.1	45.7	61.0	40.6
	5.0	8.5	7.0	10.0	8.0	11.0	9.0	13.0
	107	61.0	86.4	50.8	71.1	50.8	61.0	45.7
	5.0	8.5	7.0	10.0	8.0	12.0	9.0	13.0
	107	55.9	86.4	50.8	71.1	50.8	61.0	40.6
	5.0	8.5	7.0	10.0	8.0	12.0	9.5	12.5
Av. G's	109	60.4	85.8	52.5	69.4	48.0	59.9	42.9
Av. msec	5.0	8.2	6.7	9.7	7.3	11.8	9.1	12.6

TABLE I CONTINUED

2 INCH EXPANDED BEAD POLYSTYRENE, UNRESTRAINED

Platen Weight

	16.0 lbs		23.5 lbs		29.5 lbs		35.5 lbs	
	Primary	Secondary	Primary	Secondary	Primary	Secondary	Primary	Secondary
G's	45.7	40.6	40.6	30.5	30.5	25.4	30.5	20.3
msec	7.0	18.0	15.0	20.0	15.0	23.0	17.0	30.0
	45.7	40.6	40.6	30.5	35.6	25.4	30.5	25.4
	7.0	18.0	15.0	20.0	16.0	23.0	17.0	--
	45.7	45.7	40.6	30.5	35.6	25.4	35.6	--
	7.0	18.0	15.0	20.0	15.5	23.5	18.0	--
	45.7	40.6	35.6	35.6	30.5	25.4	30.5	--
	11.0	17.5	14.0	22.0	16.0	25.0	17.5	--
	45.7	40.6	35.6	35.6	30.5	25.4	30.5	20.3
	12.0	18.0	14.0	21.0	16.0	25.2	17.5	25.0
	40.6	40.6	35.6	30.5	30.5	30.5	30.5	20.3
	12.0	17.5	14.0	21.0	16.0	25.1	13.5	25.0
	45.7	35.6	35.6	30.5	35.6	25.4	35.6	20.3
	12.0	15.0	14.0	20.0	15.0	22.5	18.0	25.0
	45.7	40.6	40.6	30.5	35.6	30.5	35.6	20.3
	14.0	15.2	14.0	20.0	16.0	23.0	15.0	26.0
	45.7	35.6	35.6	30.5	35.6	30.5	35.6	15.2
	11.0	15.1	14.0	21.0	16.0	23.0	16.0	30.0
Av. G's	45.1	40.1	37.8	31.6	31.6	27.1	32.8	20.3
Av. msec	10.3	16.9	14.3	20.6	15.7	23.7	17.3	27.0

TABLE I CONTINUED

2 INCH EXPANDED BEAD POLYSTYRENE, UNRESTRAINED

Platen Weight

	41.5 lbs		48.875 lbs		53.875 lbs	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
G's	30.5	25.4	30.5	20.3	30.5	20.3
msec	20.0	27.0	21.0	32.0	20.0	55.0
	25.4	25.4	30.5	30.5	30.5	10.2
	18.5	27.5	22.0	34.0	23.0	--
	30.5	25.4	30.5	25.4	30.5	10.2
	21.0	29.0	21.5	31.0	22.0	--
	35.6	25.4	25.4	20.3	30.5	20.3
	21.0	27.0	22.0	34.0	21.0	41.0
	30.5	20.3	25.4	20.3	30.5	25.4
	20.0	--	20.0	40.0	24.0	31.0
	30.5	30.5	30.5	25.4	30.5	25.4
	20.5	32.0	20.0	35.0	22.0	32.0
	30.5	20.3	30.5	25.4	35.6	20.3
	18.0	32.0	21.0	21.0	22.0	30.0
	30.5	25.4	30.5	25.4	30.5	20.3
	19.0	32.0	20.0	20.0	23.0	34.0
	30.5	25.4	30.5	25.4	35.6	20.3
	18.0	30.0	22.0	22.0	22.0	35.0
Av. G's	30.0	24.8	29.4	24.3	31.6	19.2
Av. msec	19.6	29.6	21.1	30.0	22.1	37.0

TABLE II

2 INCH EXPANDED BEAD POLYSTYRENE, 8 X 8 INCH RESTRAINT

Platen Weight

	3.5 lbs Primary - Secondary	5.5 lbs Primary - Secondary	7.5 lbs Primary - Secondary	10.0 lbs Primary - Secondary
G's	112 - 81.3	81.3 - 55.9	66.0 - 45.7	55.9 - 35.6
msec	5.0 - 6.0	7.0 - 8.0	8.0 - 10.0	9.5 - 11.0
	112 - 76.2	81.3 - 61.0	66.0 - 35.6	55.9 - 40.6
	5.0 - 6.0	7.0 - 8.0	8.0 - 10.5	9.5 - 12.0
	112 - 76.2	81.3 - 61.0	66.0 - 50.8	55.9 - 40.6
	5.0 - 6.0	7.0 - 8.0	8.5 - 10.0	9.5 - 12.0
	117 - 81.3	86.4 - 66.0	66.0 - 55.9	55.9 - 50.8
	-- - --	6.5 - 7.5	7.5 - 9.5	8.5 - 11.0
	117 - 81.3	86.4 - 61.0	66.0 - 61.0	55.9 - 50.8
	5.0 - 5.0	7.0 - 7.0	7.5 - 9.5	8.5 - 11.5
	112 - 86.4	86.4 - 61.0	66.0 - 61.0	61.0 - 50.8
	5.0 - 5.0	7.0 - 7.0	7.5 - 9.5	8.0 - 10.0
	117 - 86.4	81.3 - 61.0	66.0 - 61.0	61.0 - 50.8
	5.0 - 5.0	6.0 - 8.0	8.0 - 9.5	9.0 - 10.5
	117 - 86.4	86.4 - 61.0	66.0 - 55.9	55.9 - 50.8
	5.0 - 5.0	7.5 - 7.5	8.0 - 9.0	9.0 - 11.5
	112 - 91.4	86.4 - 66.0	66.0 - 61.0	55.9 - 50.8
	5.0 - 5.0	6.5 - 8.0	8.0 - 9.0	7.0 - 12.0
Av. G's	114 - 81.9	84.1 - 61.5	66.0 - 54.2	56.2 - 46.8
Av. msec	5.0 - 5.4	6.8 - 7.7	8.0 - 9.6	8.7 - 11.3

TABLE II CONTINUED

2 INCH EXPANDED BEAD POLYSTYRENE, 8 X 8 INCH RESTRAINT

Platen Weight

	16.0 lbs	29.5 lbs	41.5 lbs	53.875 lbs
	Primary - Secondary	Primary - Secondary	Primary - Secondary	Primary - Secondary
G's	40.6 - 30.5	25.4 - 20.3	25.4 - 20.3	25.4 - 25.4
msec	12.0 - 16.0	16.0 - 23.0	13.0 - 28.0	20.0 - 40.0
	40.6 - 30.5	25.4 - 20.3	25.4 - 20.3	25.4 - 20.3
	13.0 - 16.0	16.0 - 28.0	15.0 - 26.0	24.0 - 38.0
	40.6 - 35.6	30.5 - 25.4	25.4 - 15.2	25.4 - 20.3
	12.0 - 17.0	15.0 - 24.0	19.0 - 27.0	22.0 - 36.0
	40.6 - 40.6	35.6 - 20.3	30.5 - 20.3	25.4 - 20.3
	11.0 - 17.0	19.0 - 20.0	23.0 - 25.0	23.0 - 30.0
	40.6 - 35.6	35.6 - 15.2	30.5 - 20.3	30.5 - 15.2
	12.0 - 14.0	17.0 - 20.0	22.0 - 25.0	24.0 - 34.0
	40.6 - 40.6	35.6 - 15.2	30.5 - 20.3	25.4 - 15.2
	12.0 - 13.0	17.0 - 20.0	23.0 - 25.0	24.0 - 32.0
	40.6 - 35.6	30.5 - 20.3	25.4 - 20.3	30.5 - 15.2
	12.0 - 13.5	15.0 - 24.0	21.0 - 28.0	23.0 - 20.0
	40.6 - 35.6	30.5 - 20.3	25.4 - 20.3	30.5 - 15.2
	12.5 - 17.0	15.0 - 25.0	21.0 - 28.0	23.0 - 22.0
	40.6 - 35.6	30.5 - 20.3	30.5 - 20.3	25.4 - 15.2
	12.0 - 16.5	15.0 - 25.0	23.0 - 26.0	27.0 - 24.0
Av. G's	40.6 - 35.6	31.1 - 19.7	27.7 - 19.7	27.1 - 18.0
Av. msec	12.0 - 15.6	16.1 - 23.2	20.7 - 26.4	24.4 - 30.7

TABLE III

2 INCH EXPANDED BEAD POLYSTYRENE, 8¼ X 8¼ INCH RESTRAINT

Platen Weight

	3.5 lbs	5.5 lbs	7.5 lbs	10.0 lbs
	Primary - Secondary	Primary - Secondary	Primary - Secondary	Primary - Secondary
G's	112 - 66.0	86.4 - 50.8	76.2 - 50.8	61.0 - 50.8
msec	5.0 - 8.0	6.0 - 8.5	8.0 - 9.5	9.0 - 11.0
	112 - 61.0	86.4 - 50.8	76.2 - 50.8	61.0 - 45.7
	5.0 - 7.5	6.5 - 9.0	8.0 - 10.5	9.0 - 11.5
	112 - 61.0	86.4 - 50.8	71.1 - 50.8	61.0 - 50.8
	5.0 - 7.5	6.5 - 9.5	8.0 - 11.5	9.0 - 11.0
	112 - 61.0	81.3 - 55.9	76.2 - 50.8	66.0 - 40.6
	5.0 - 6.5	6.0 - 9.0	7.5 - 10.0	9.0 - 11.0
	112 - 66.0	86.4 - 50.8	76.2 - 50.8	66.0 - 40.6
	5.0 - 5.5	6.5 - 8.5	7.5 - 10.0	9.0 - 12.0
	112 - 61.0	86.4 - 50.8	71.1 - 50.8	66.0 - 45.7
	5.0 - 7.0	6.5 - 8.5	8.0 - 9.5	9.0 - 11.5
	112 - 66.0	81.3 - 50.8	66.0 - 50.8	55.9 - 40.6
	5.0 - 6.5	6.5 - 8.5	8.0 - 10.0	9.0 - 12.0
	107 - 66.0	81.3 - 50.8	66.0 - 50.8	55.9 - 45.7
	5.0 - 7.0	7.0 - 8.5	8.0 - 9.5	9.0 - 11.5
	107 - 66.0	81.3 - 55.9	66.0 - 50.8	55.9 - 45.7
	5.0 - 7.5	7.0 - 8.5	8.0 - 10.5	9.0 - 12.0
Av. G's	111 - 63.8	84.1 - 48.3	71.7 - 50.8	61.0 - 45.1
Av. msec	5.0 - 7.1	6.5 - 8.7	7.9 - 10.1	9.0 - 11.5

TABLE III CONTINUED

2 INCH EXPANDED BEAD POLYSTYRENE, 8¼ X 8¼ INCH RESTRAINT

Platen Weight

	16.0 lbs Primary	16.0 lbs Secondary	29.5 lbs Primary	29.5 lbs Secondary	41.5 lbs Primary	41.5 lbs Secondary	53.875 lbs Primary	53.875 lbs Secondary
G's	45.7	40.6	40.6	20.3	30.5	25.4	30.5	25.4
msec	11.5	15.0	17.0	20.0	19.0	31.0	21.0	38.0
	45.7	40.6	35.6	25.4	30.5	25.4	30.5	25.4
	11.5	15.5	16.0	24.0	19.0	28.0	21.0	37.0
	45.7	40.6	35.6	25.4	30.5	25.4	30.5	25.4
	11.5	15.0	15.0	24.0	19.0	28.0	20.5	32.0
	50.8	30.5	30.5	25.4	30.5	20.3	30.5	20.3
	12.0	14.0	14.0	26.0	18.0	32.0	21.0	34.0
	45.7	35.6	30.5	25.4	30.5	20.3	30.5	20.3
	12.0	15.5	14.0	26.0	19.0	31.0	21.0	31.0
	45.7	35.6	35.6	25.4	30.5	20.3	30.5	20.3
	12.0	15.5	16.0	24.0	19.0	31.0	21.0	32.0
	40.6	35.6	30.5	25.4	30.5	20.3	25.4	25.4
	12.0	16.0	15.0	26.0	22.0	26.0	21.0	42.0
	45.7	35.6	30.5	25.4	30.5	20.3	30.5	20.3
	12.0	16.0	17.0	24.0	21.0	28.0	22.0	36.0
	45.7	35.6	30.5	25.4	30.5	20.3	30.5	25.4
	12.0	16.0	16.0	25.0	21.0	28.0	21.0	40.0
Av. G's	45.7	36.7	35.5	24.8	30.5	22.0	29.9	23.1
Av. msec	11.8	15.4	15.7	24.3	19.6	28.8	21.1	35.8

TABLE IV

2 INCH BONDED ANIMAL HAIR, NO RESTRAINT

Platen Weight

	3.5 lbs	6.5 lbs	9.5 lbs
	Primary - Secondary	Primary - Secondary	Primary - Secondary
G's	14.2 - 59.0	10.2 - 28.5	12.2 - 20.3
msec	38.0 - 8.0	54.0 - 17.0	74.0 - 18.0
	14.2 - 63.0	12.2 - 24.4	12.2 - 20.3
	38.0 - 9.0	52.0 - 17.0	74.0 - 16.0
	14.2 - 63.0	10.2 - 26.4	12.2 - 18.3
	38.0 - 8.0	52.0 - 16.0	72.0 - 16.0
	16.3 - 34.6	14.2 - 24.4	16.3 - 8.12
	36.0 - 8.0	41.0 - 12.0	46.0 - 6.0
	16.3 - 24.4	14.2 - 26.4	16.3 - 8.12
	32.0 - 5.0	36.0 - 13.0	46.0 - 3.0
	14.2 - 36.6	14.2 - 28.5	16.3 - 6.10
	32.0 - 8.0	36.0 - 14.0	48.0 - 3.0
	14.2 - 48.8	8.12 - 12.2	10.2 - 16.3
	38.0 - 16.0	52.0 - 6.0	48.0 - 18.0
	16.3 - 40.6	10.2 - 28.5	10.2 - 18.3
	36.0 - 12.0	56.0 - 14.0	72.0 - 18.0
	5.08 - 40.6	10.2 - 20.3	12.2 - 16.3
	36.0 - 14.0	56.0 - 10.0	68.0 - 22.0
Av. G's	19.0 - 45.6	11.5 - 24.4	13.1 - 14.7
Av. msec	36.0 - 9.8	48.3 - 13.2	60.9 - 13.3

TABLE V

2 INCH BONDED ANIMAL HAIR, 8 X 8 INCH RESTRAINT

Platen Weight

	3.5 lbs		6.5 lbs		9.5 lbs	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
G's	34.6	12.2	28.5	NR	28.5	NR
msec	17.0	6.0	27.0	NR	30.0	NR
	48.8	12.2	28.5	NR	30.5	NR
	17.5	6.0	27.0	NR	31.0	NR
	50.8	10.2	30.5	NR	30.5	NR
	19.0	5.0	27.0	NR	32.0	NR
	57.0	16.3	32.5	8.12	24.4	NR
	20.0	15.0	25.0	16.0	30.0	NR
	61.0	18.3	30.5	8.12	24.4	NR
	19.0	9.0	27.0	20.0	29.0	NR
	61.0	16.3	30.5	8.12	26.4	NR
	17.0	8.0	27.0	24.0	3.0	NR
	48.8	10.2	30.5	6.10	24.4	NR
	18.0	14.0	17.0	25.0	32.0	NR
	57.0	14.2	30.5	4.06	26.4	NR
	18.0	14.0	17.0	25.0	29.0	NR
	57.0	12.2	28.5	6.10	28.5	NR
	18.0	14.0	17.0	25.0	29.0	NR
Av. G's	52.9	13.6	30.1	7.67	27.1	--
Av. msec	18.2	10.1	23.4	22.5	30.2	--

TABLE VI

2 INCH BONDED ANIMAL HAIR, $8\frac{1}{4}$ X $8\frac{1}{4}$ INCH RESTRAINT

Platen Weight

	3.5 lbs		6.5 lbs		9.5 lbs	
	Primary	Secondary	Primary	Secondary	Primary	Secondary
G's	12.2	61.0	10.2	17.3	10.2	11.2
msec	35.0	6.0	35.0	11.0	46.0	14.0
	16.3	20.3	6.10	26.4	9.14	12.2
	34.0	10.0	35.0	13.0	40.0	14.0
	16.3	20.3	14.2	18.3	9.14	14.2
	35.0	10.0	35.0	13.0	33.0	14.0
	14.2	16.3	10.2	18.3	7.11	16.3
	30.0	10.0	30.0	8.0	40.0	14.6
	14.2	14.2	10.2	12.2	8.12	16.3
	30.0	10.0	30.0	8.0	40.0	15.0
	14.2	14.2	10.2	10.2	8.12	16.3
	30.0	10.0	30.0	NR	40.0	15.0
	20.3	8.12	10.2	6.10	8.12	10.2
	28.0	8.0	34.0	NR	46.0	8.0
	12.2	10.2	10.2	8.12	8.12	11.2
	25.0	12.0	34.0	9.0	43.0	8.0
	28.5	6.10	12.2	10.2	8.12	11.2
	28.0	14.0	40.0	6.0	43.0	8.0
Av. G's	16.5	19.0	10.4	14.1	8.47	13.2
Av. msec	30.6	10.0	33.9	9.7	37.4	12.2

TABLE VII

2 INCH BONDED ANIMAL HAIR, 8½ X 8½ INCH RESTRAINT

Platen Weight

	3.5 lbs Primary	3.5 lbs Secondary	6.5 lbs Primary	6.5 lbs Secondary	9.5 lbs Primary	9.5 lbs Secondary
G's	18.3	34.6	11.2	16.3	10.2	8.12
msec	34.0	12.0	46.0	20.0	60.0	20.0
	12.2	30.5	11.2	NR	10.2	10.2
	35.0	12.0	47.0	NR	60.0	12.0
	12.2	34.6	10.2	NR	10.2	11.2
	36.0	10.0	46.0	NR	60.0	18.0
	16.3	34.6	11.2	14.2	9.14	11.2
	32.0	12.0	40.0	14.0	64.0	20.0
	14.2	28.5	11.2	18.3	9.14	9.14
	34.0	12.0	38.0	8.0	64.0	20.0
	14.2	30.5	12.2	18.3	11.2	8.12
	34.0	33.0	38.0	8.0	68.0	18.0
	14.2	24.4	10.2	16.3	10.2	10.2
	38.0	10.0	60.0	17.0	64.0	26.0
	12.2	24.4	10.2	14.2	11.2	10.2
	38.0	12.0	60.0	13.0	66.0	25.0
	12.2	28.5	10.2	12.2	10.2	8.12
	39.0	10.0	60.0	16.0	66.0	26.0
Av. G's	14.0	30.1	10.9	15.7	10.2	9.6
Av. msec	35.6	13.7	48.3	10.7	63.6	20.6

TABLE VIII

2 INCH BONDED ANIMAL HAIR, 8 3/4 X 8 3/4 INCH RESTRAINT

Platen Weight

	3.5 lbs Primary - Secondary	6.5 lbs Primary - Secondary	9.5 lbs Primary - Secondary
G's	20.3 - 50.8	11.2 - 26.4	12.2 - 15.2
msec	30.0 - 10.0	33.0 - 12.0	53.0 - 14.0
	20.3 - 61.0	13.2 - 28.5	11.2 - 15.2
	30.0 - 10.0	38.0 - 14.0	58.0 - 14.0
	20.3 - 54.8	14.2 - 28.5	10.2 - 14.2
	30.0 - 10.0	40.0 - 14.0	57.0 - 14.0
	20.3 - 40.6	12.2 - 28.5	12.2 - 17.3
	32.0 - 8.0	48.0 - NR	NR - NR
	16.3 - 34.6	10.2 - 26.4	13.2 - 15.2
	32.0 - 10.0	45.0 - 14.0	60.0 - 14.0
	20.3 - 44.8	11.2 - 31.5	12.2 - 14.2
	32.0 - 9.0	46.0 - 16.0	60.0 - 16.0
	16.3 - 50.8	14.2 - 28.5	11.2 - 11.2
	30.0 - 10.0	44.0 - 13.0	52.0 - 13.0
	16.3 - 54.8	14.2 - 30.5	9.14 - 18.3
	30.0 - 10.0	42.0 - 13.0	50.0 - 13.0
	18.3 - 57.0	13.2 - 30.5	11.2 - 17.3
	30.0 - 10.0	48.0 - 16.0	58.0 - 16.0
Av. G's	18.7 - 49.9	12.6 - 28.8	11.4 - 15.3
Av. msec	30.7 - 9.7	43.4 - 14.0	50.9 - 14.3

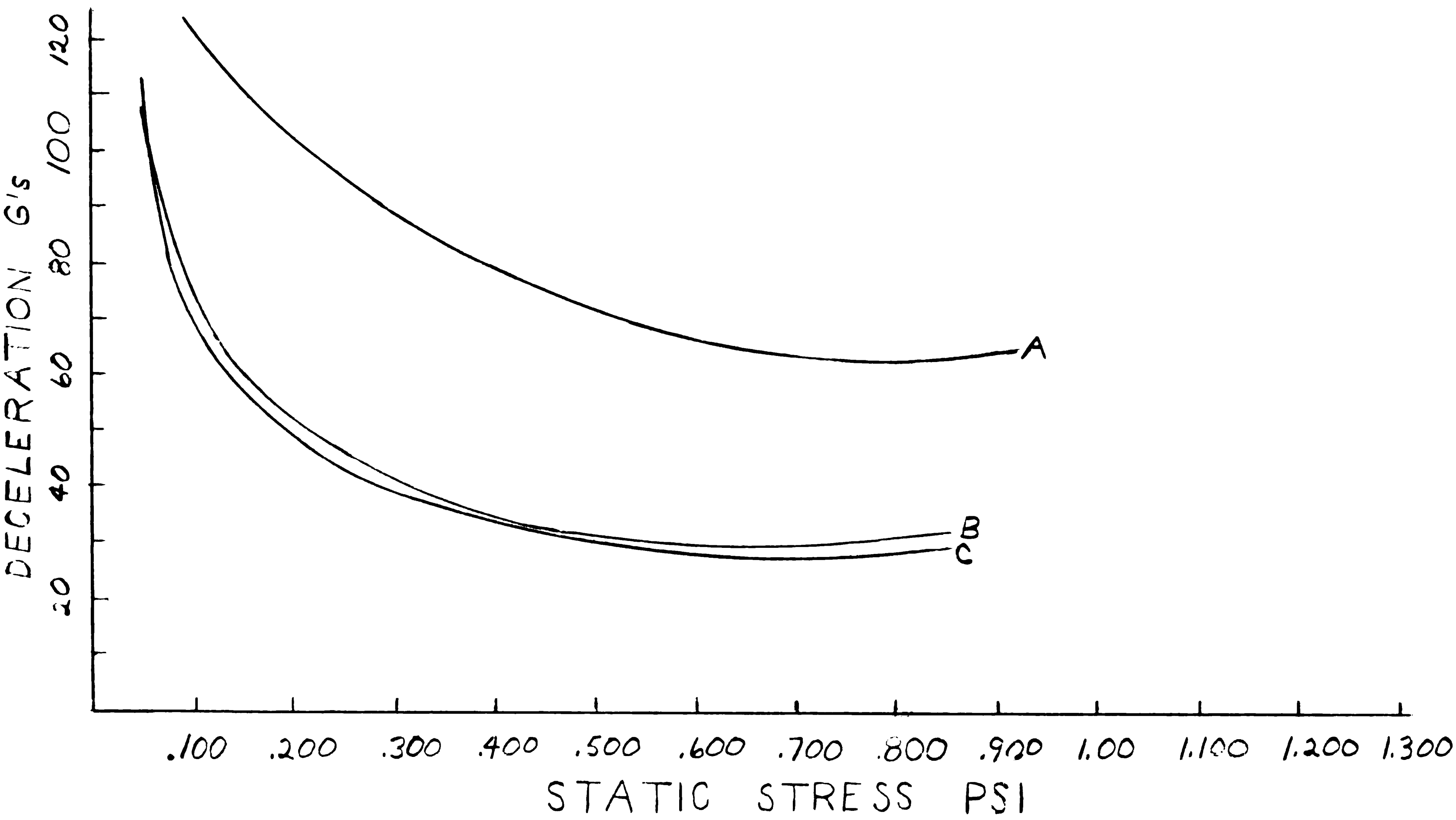
FIGURE 3

PULSE MAGNITUDE vs STATIC STRESS, 2 INCH
EXPANDED BEAD POLYSTYRENE

A. 24 Inch Equivalent Free Fall(5)

B. Drop Shock Tester, No Restraint

C. Drop Shock Tester, 8 X 8 Inch Restraint



DECELERATION G's
120
100
80
60
40
20
A
B
C
.100 .200 .300 .400 .500 .600 .700 .800 .900 1.00 1.100 1.200 1.300
STATIC STRESS PSI

FIGURE 4

PULSE DURATION vs STATIC STRESS, 2 INCH
EXPANDED BEAD POLYSTRENE

A. 24 Inch Equivalent Free Fall(7)

B. Drop Shock Tester, No Restraint

C. Drop Shock Tester, 8 X 8 Inch Restraint

D. Drop Shock Tester $8\frac{1}{4}$ X $8\frac{1}{4}$ Inch Restraint

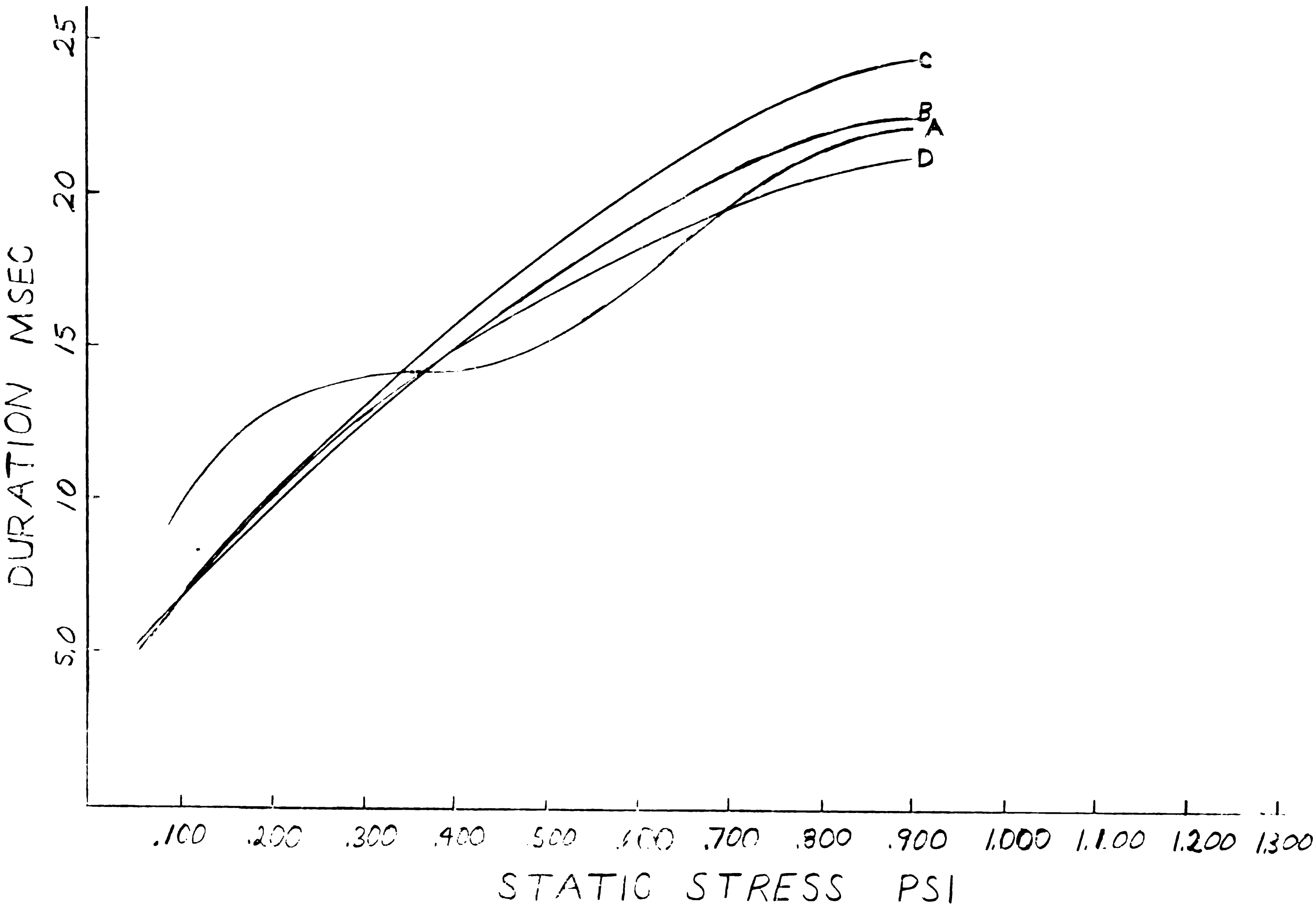

DURATION MSEC
25
20
15
10
5.0
C
B
A
D
.100
.200
.300
.400
.500
.600
.700
.800
.900
1.000
1.100
1.200
1.300
STATIC STRESS PSI

FIGURE 5

PULSE MAGNITUDE vs STATIC STRESS, 2 INCH BONDED ANIMAL HAIR

A. 24 Inch Equivalent Free Fall (8)

B. Drop Shock Tester, No Restraint

C. Drop Shock Tester, 8 X 8 Inch Restraint

D. Drop Shock Tester, 8¼ X 8¼ Inch Restraint

E. Drop Shock Tester, 8½ X 8½ Inch Restraint

F. Drop Shock Tester, 8 3/4 X 8 3/4 Inch Restraint

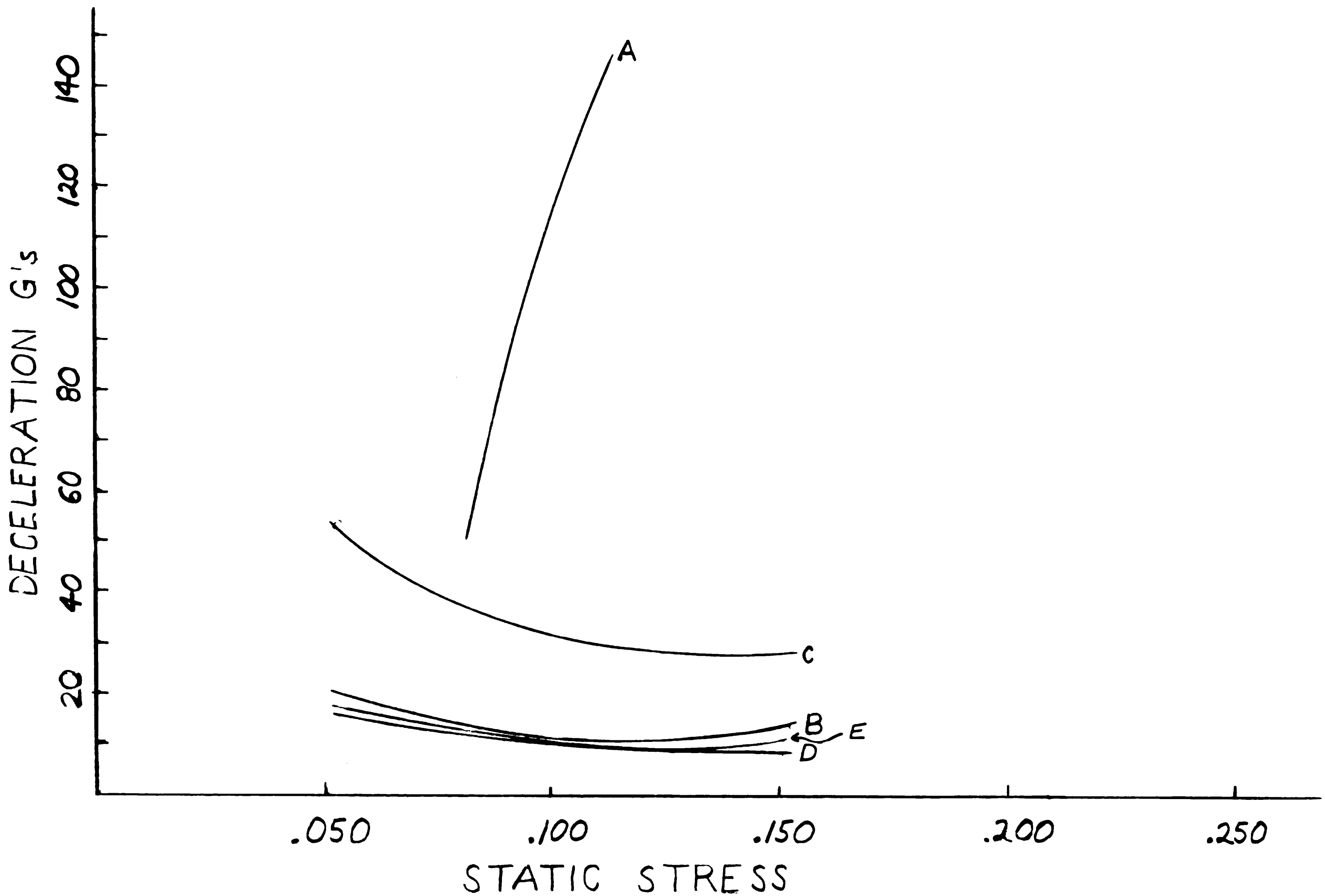

DECELERATION G's
140
120
100
80
60
40
20
A
C
B
E
D
.050
.100
.150
.200
.250
STATIC STRESS

FIGURE 6

PULSE DURATION vs STATIC STRESS, 2 INCH BONDED ANIMAL HAIR

A. 2¼ Inch Equivalent Free Fall(2)

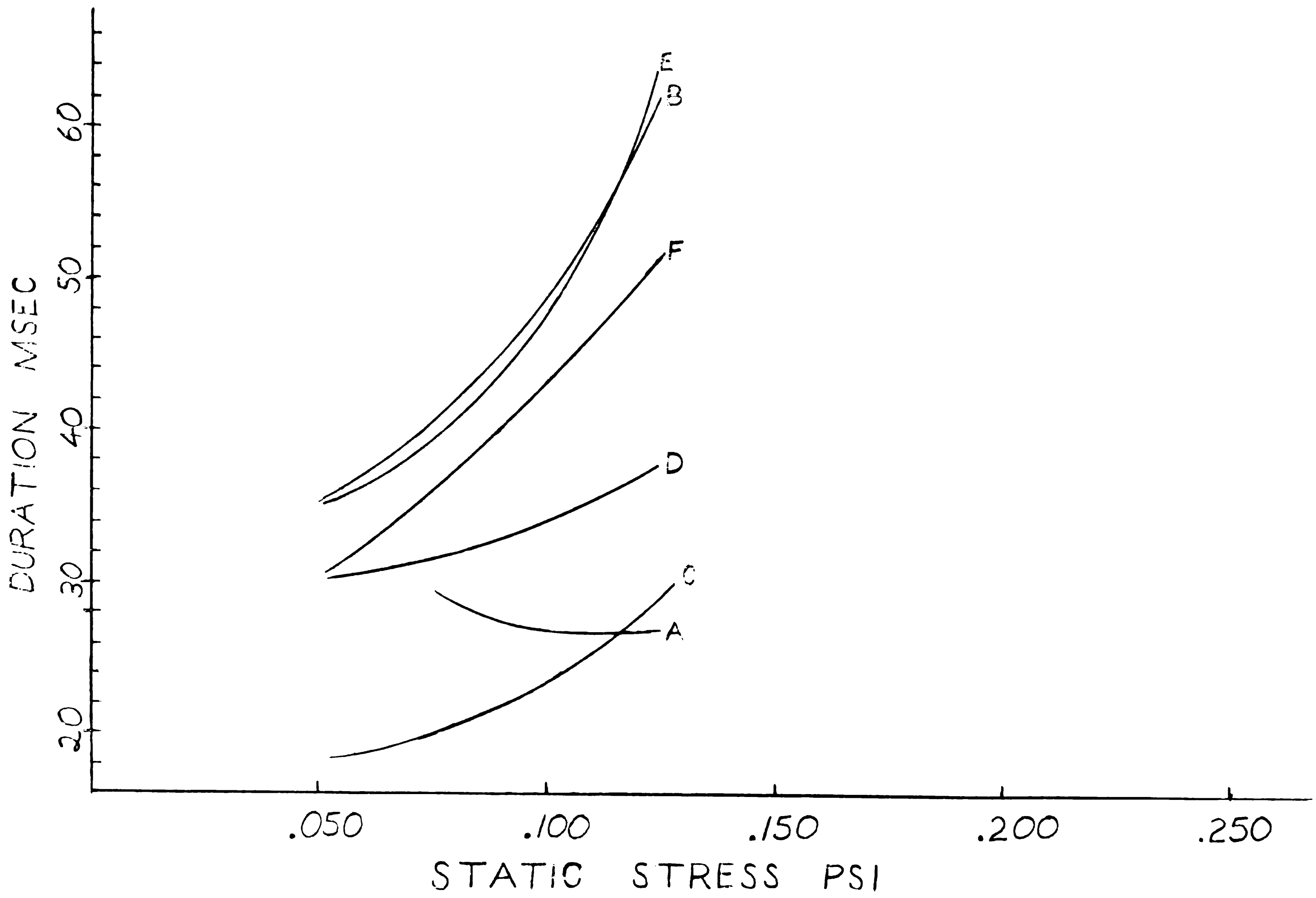
B. Drop Shock Tester, No Restraint

C. Drop Shock Tester, 8 X 8 Inch Restraint

D. Drop Shock Tester, 8¼ X 8¼ Inch Restraint

E. Drop Shock Tester, 8½ X 8½ Inch Restraint

F. Drop Shock Tester, 8 3/4 X 8 3/4 Inch Restraint


DURATION MSEC
20
30
40
50
60
E
B
F
D
C
A
.050
.100
.150
.200
.250
STATIC STRESS PSI

DISCUSSION OF TEST DATA

Only the primary shock pulses were used for the analysis of test data. The secondary pulse appeared to be cushion rebound which does not occur in actual package drops. Figure 9 (see Appendix IV) compares shock pulses obtained on the drop shock tester with those obtained from instrumented package drops.

Examination of the graphs of pulse magnitude (Figure 3) and pulse duration (Figure 4) for expanded bead polystyrene shows that the difference between shock pulses transmitted when restrained and unrestrained is small. Pulse magnitude of the restrained cushions was slightly less than the magnitude of the unrestrained cushions. Pulse duration of the restrained cushions was slightly longer than that of the unrestrained cushions. Pulse magnitude and duration transmitted by the restrained cushion varied from the unrestrained cushions by less than 10 percent.

Figures 5 and 6 show that tight restraint of the bonded animal hair had a large effect on the pulse transmitted. Reduced restraint had little effect on pulse magnitude and less effect on pulse duration. The tightly restrained cushion transmitted a pulse that was twice as large in magnitude and half the duration of the pulse transmitted by the unrestrained cushion. Pulse magnitude of less tightly restrained cushions remained virtually the same as the unrestrained cushions but pulse duration was less.

Varying static loading affected the shock pulses transmitted to the instrumented platen. The effect of increased static loading was somewhat greater on the bonded animal hair. in both cushions.

Drop shock tester results did not compare well with 24 inch equivalent free fall drop test results for either cushion.

Instrumented A-flute boxes containing cushions and instrumentation were dropped from 24 inches. Data for shock pulses transmitted from the cushions to the simulated product is given in Appendix IV.

Comparing instrumented package drop results with Figure 3--curve C, Figure 4--curve D, Figure 5--curve D, and Figure 6--curve D will show that instrumented package drop test results differed from values obtained by the drop shock tester. Observed G's for expanded bead polystyrene were 27 percent higher than those obtained by the drop shock tester. Pulse duration was 47 percent longer than that obtained by the drop shock tester. The error for bonded animal hair was less. Observed G's were 6 percent higher and pulse duration was 7.3 percent less than drop shock tester results.

Comparing instrumented package drop results with curve A of Figures 3, 4, 5 and 6 will show that instrumented package drop results differed from values obtained by the 24 inch equivalent free fall cushion test. Instrumented package drop G's for expanded bead polystyrene were 22 percent lower and pulse duration 13 percent longer than the results of the 24 inch equivalent free fall cushion test. While percent of error was not determined, it appears that the difference between 24 inch equivalent free fall data and instrumented package drop data is larger than the difference between drop shock tester data and instrumented package drop data.

CONCLUSIONS

It can be concluded that the shock pulse transmitted by expanded bead polystyrene was not greatly affected by lateral restraint. The pulse transmitted by bonded animal hair was greatly affected by close restraint and to a lesser amount by reduced restraint. This suggests 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.

The drop shock tester is useful for studying the properties of cushioning materials. While instrumented package drop results differed significantly from both drop shock tester and 24 inch equivalent free fall results, it cannot be concluded at the present time whether the drop shock test is a more valid test of package cushioning material properties than the 24 inch equivalent free fall cushion test.

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6. Blake, Howard C. III, "24 Inch Drop Height Peak Deceleration - Static Stress Curves for Selected Cushioning Materials." School of Packaging, Michigan State University, Technical Report No. 5, Project No. 1, November 1, 1964.

7. Blake, Howard C. III, Unpublished Data, School of Packaging Michigan State University, June 24, 1964.

8. Appendix IV, p. 40.

9. Appendix IV, p. 40.

10. Appendix I, p. 32 (Table IX)

11. McGinnis, Michael A., Unpublished Data, School of Packaging Michigan State University, June 19, 1965.

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2. Bull, Kenneth W. and Kossack, Carl F., "Measuring Field Handling and Transportation Conditions." Wright Air Development Division WADD Technical Report 60-4, February, 1960, p.20.

3. Klingenberg, A.D., "The Theory and Operation of a Dynamic Tester for Evaluating Package Cushioning Materials." Wright Air Development Center, WADC Technical Report 56-342, September, 1956, p. 6.

4. Stern, R.K., "The FPL Dynamic Compression Testing Equipment for Testing Package Cushioning Materials." Forest Products Laboratory Report No. 2120, August, 1958, p. 6.

Unpublished Material

1. Blake, Howard C. III, Unpublished Data. School of Packaging, Michigan State University, June 24, 1964.

APPENDIX I

THE DEGRADATION OF THE SHOCK PULSE TRANSMITTED TO THE CONTENTS OF AN A-FLUTE BOX

Equipment Used

1. 8 X 8 X 8½ inch A-flute boxes.

2. 8 X 8 X 8 inch wood block, constructed of laminated maple die board, one 3/8 inch bolt running top to bottom at each corner.

   Weight with accelerometer: 11 pounds, 10 ounces.

   Static loading: 0.181 pounds per square inch.

3. LAB Model SD-100 Drop Tester.

   Drop height: 24 inches.

Test Instrumentation

1. Kistler Model 808A Crystal Accelerometer.

2. Kistler Model 565 Charge Amplifier.

3. Tektronix Type 564 Storage Oscilloscope.

Procedure

Instrumented package was dropped from 24 inches. Pulses 1 through 10 and pulses 15 through 60 at 5 drop intervals were recorded. Selected pulses were photographed. The shape of the pulse remained basically the same after 10 drops. Figure 7 shows the degradation of the shock pulse during the first 10 drops. Data and average values are given in Table IX.

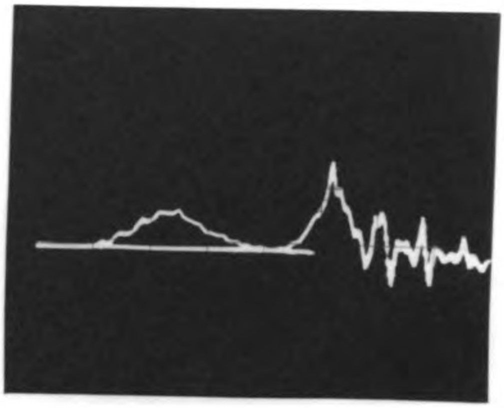
FIGURE 7

SHOCK PULSE TRANSMITTED TO THE CONTENTS OF
AN A-FLUTE BOX, 24 INCH DROP

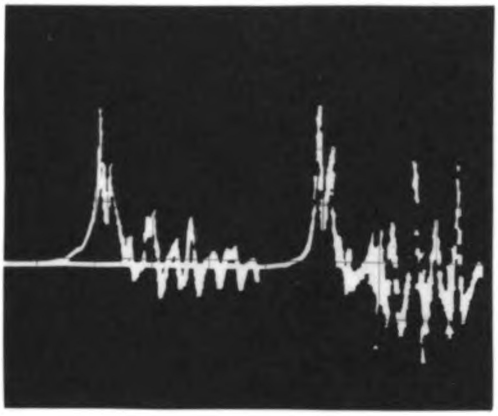
Calibration:

Vertical - 101.6 G's/division

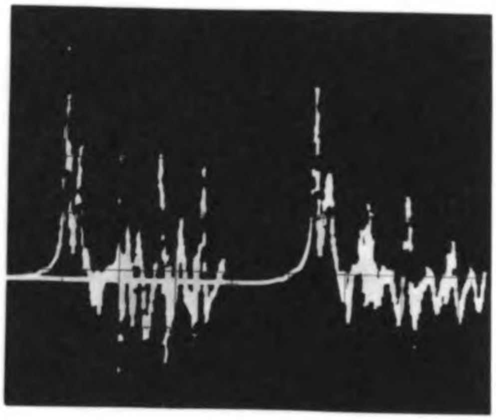
Horizontal - 2 msec/division



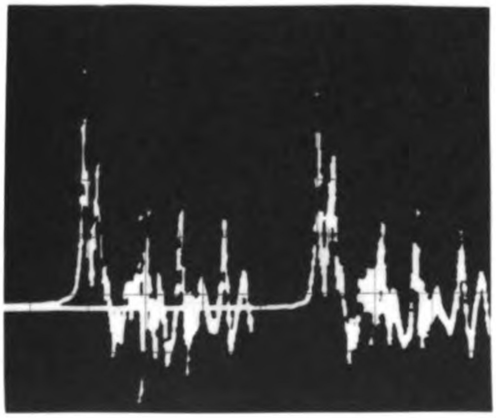
Drops 1 and 2



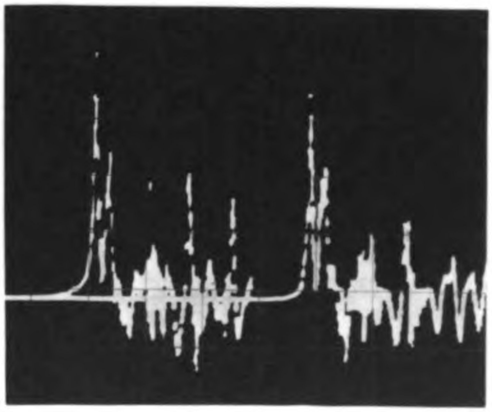
Drops 3 and 4



Drops 5 and 6



Drops 7 and 8



Drops 10 and 9

TABLE IX

SHOCK PULSE TRANSMITTED TO THE CONTENTS OF AN A-FLUTE BOX, 24 INCH DROP

Sum	19.0	16.2	13.6	11.8	8.8	9.4	10.0	9.0	7.8	9.2	9.8	9.6	8.6
Average	2.71	2.31	1.94	1.68	1.45	1.57	1.43	1.50	1.30	1.31	1.40	1.37	1.43

Maximum Deceleration G's

Drop Number		1	2	3	4	5	6	7	8	9	10	15	20	25
Box Number	1	71	112	142	213	172	234	193	-	234	203	254	203	-
	2	-	-	-	209	244	254	295	274	274	345	305	345	376
	3	102	132	152	224	213	234	244	284	-	254	203	213	224
	4	91	102	152	224	193	264	213	234	193	274	335	254	234
	5	112	102	163	103	-	-	234	284	224	305	325	274	345
	6	91	142	163	193	244	244	244	284	284	284	295	264	284
	7	102	112	152	224	224	264	234	213	264	305	264	335	305
Sum		569	702	924	1390	1291	1494	1657	1573	1473	1970	1981	1908	1768
Average		95	117	154	199	215	249	237	262	246	281	283	273	294

Pulse Rise Time Milliseconds

Drop Number		1	2	3	4	5	6	7	8	9	10	15	20	25
Box Number	1	3.6	2.0	1.4	1.2	1.4	1.6	1.0	-	0.8	1.0	1.4	0.6	-
	2	2.2	2.4	2.6	2.2	1.4	1.4	1.4	1.2	1.4	1.6	1.6	1.4	1.6
	3	3.0	2.8	1.6	1.6	1.4	1.4	1.4	2.0	-	1.2	0.4	1.4	1.2
	4	2.6	2.6	1.8	1.6	1.4	1.8	1.6	1.4	1.6	1.2	1.6	1.8	1.6
	5	2.2	2.0	1.8	1.8	-	-	1.4	1.4	1.2	1.4	1.6	1.6	1.6
	6	2.6	2.2	2.2	1.6	1.6	1.6	1.6	1.6	1.6	1.4	1.6	1.2	1.2
	7	2.8	2.2	2.2	1.8	1.6	1.6	1.6	1.4	1.2	1.4	1.6	1.6	1.4
Sum		19.0	16.2	13.6	11.8	8.8	9.4	10.0	9.0	7.8	9.2	9.8	9.6	8.6
Average		2.71	2.31	1.94	1.68	1.45	1.57	1.43	1.50	1.30	1.31	1.40	1.37	1.43

TABLE IX CONTINUED

SHOCK PULSE TRANSMITTED TO THE CONTENTS OF AN A-FLUTE BOX, 24 INCH DROP

Maximum Deceleration G's

Drop Number		30*	35	40	45	50	55	60
Box Number	1	896	814	814	977	713	-	-
	2	652	794	835	875	855	875	875
	3	896	652	794	835	875	-	977
	4	835	896	855	672	937	937	774
	5	590	713	835	814	957	957	855
	6	468	611	733	652	611	672	-
	7	-	-	-	-	-	-	-
Sum		4337	4480	4866	4825	4948	3441	3481
Average		722	747	811	804	824	860	870

Pulse Rise Time Milliseconds

Drop Number		30*	35	40	45	50	55	60
Box Number	1	1.6	1.6	1.6	1.4	-	-	-
	2	1.4	1.6	1.4	1.4	1.4	1.4	1.4
	3	1.8	1.6	1.6	1.6	1.6	-	1.4
	4	2.0	1.8	1.8	1.6	1.4	1.6	1.4
	5	1.6	1.4	1.4	1.6	1.6	1.4	1.6
	6	1.4	1.4	1.6	1.4	1.4	1.4	-
	7	-	-	-	-	-	-	-
Sum		9.8	9.4	9.4	9.0	7.4	5.8	5.8
Average		1.63	1.57	1.57	1.50	1.48	1.45	1.45

*Boxes used in drops 30 through 60 were not numbered the same as the boxes used in drops 1 through 25.

APPENDIX II

PULSES GENERATED BY LAB DROP SHOCK TESTER

The magnitude of the shock pulse was determined by dropping the drop head of the drop shock tester on to 4 layers of 1/3 inch, 72 durometer natural rubber. The drop height was 5 3/4 inches. Approximately 30 seconds elapsed between drops.

Instrumentation:	Kistler Model 808A Accelerometer
	Kistler Model 566 Charge Amplifier
	Tektronix Type 564 Storage Oscilloscope
Calibration:	508 G's/division
Pulse Duration:	4 milliseconds
Pulse Height:	1.8
	1.7
	1.6
	1.6
	1.7
	1.6
	1.55
	1.6
Average	1.64 divisions

G's=(1.64 divisions) (508 G's/division)

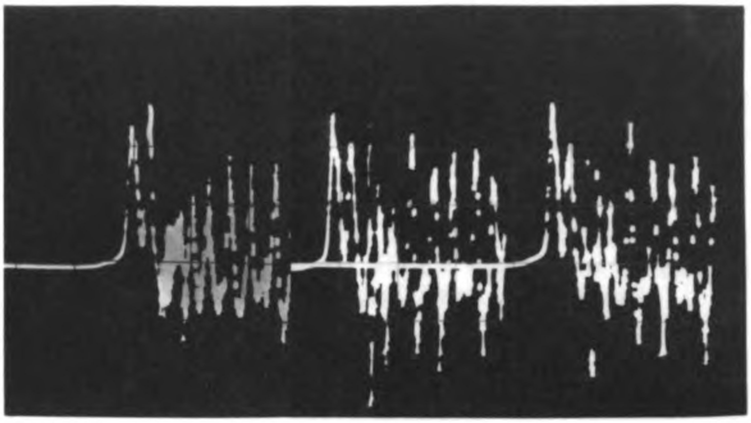
G's=833

Figure 8 shows some representative shock pulses from instrumented package drops and from the drop shock tester.

FIGURE 8

REPRESENTATIVE SHOCK PULSES FROM 24 INCH INSTRUMENTED

PACKAGE DROP AND DROP SHOCK TESTER



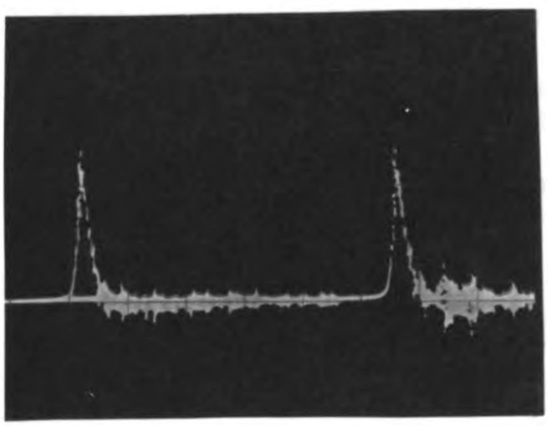
Left to Right:
Drops 21, 22, 23

24" Instrumented Package Drop. A-flute Box Instrumented Wood Block

Calibration:

Vertical - 101.6 G's/division

Horizontal - 2 msec/division



LAB Shock Drop Tester

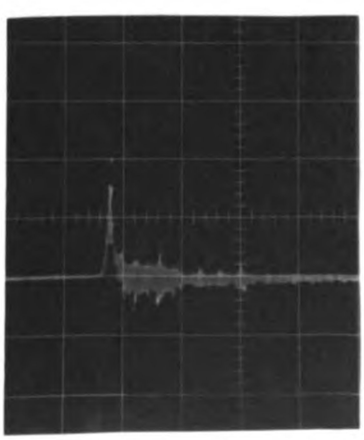
Drop Height: $1\frac{1}{4}$"

Cushion: 4 Layers 1/8" 72 Durometer Natural Rubber

Calibration:

Vertical - 101.6 G's/division

Horizontal - 2 msec/division



LAB Shock Drop Tester

Drop Height: 5 3/4"

Cushion: 4 Layers 1/8" 72 Durometer Natural Rubber

Calibration:

Vertical - 101.6 G's/division

Horizontal - 2 msec/division

APPENDIX III

COMPARISON OF KISTLER MODEL 808A S/N 1006 AND KISTLER 808 X/N 128 ACCELEROMETERS

Equipment: Shock pulse generator, LAB Type SD 16-42-100 Drop Shock Tester with the Concial nose piece removed from drop head.

Cushion Drop Head Dropped On: 3 layers of 1/8 inch, 72 durometer rubber under 1 layer of ¼ inch foamed polyurethane.

Oscilloscope: Tektronix Type 564 storage oscilloscope.

Accelerometers and Charge Amplifiers:

a. Kistler Model 808A accelerometer and a Kistler Model 566 charge amplifier. Output = 10.16 mv/g

b. Kistler Model 808 accelerometer and a Kistler Model 565 charge amplifier. Output = 10.0 mv/g

TABLE IX

COMPARISON OF KISTLER MODEL 808A S/N 1085 AND KISTLER MODEL 808 S/N 128 ACCELEROMETERS

	Average Output Millivolts*		Average Deceleration G's*		% Difference
Drop Height Inches	Kistler Model 808A	Kistler Model 808	Kistler Model 808A	Kistler Model 808	**
1	130	126.5	13.2	12.6	4.76
2	280	280	28.4	28.0	1.43
3	476	486	48.4	48.6	0.41
4	725	770	74.0	77.0	4.05
5	1075	1094	109	109	0.00
6	1470	1520	149	152	2.01
7	1730	1780	176	178	1.14
8	2280	2350	232	235	1.29
9	2920	3020	297	302	1.68
10	3300	3480	335	343	2.39
11	3780	3960	384	396	3.13
12	4700	4880	478	488	2.09
13	5550	5800	564	580	2.84
14	6450	6900	655	690	5.34
15	7050	7250	716	725	1.26
16	7800	8050	792	805	1.64
17	8350	8650	848	865	2.00

*Average of five observations at each drop height.

**

$$\text{Percent Difference} = \frac{\text{Difference between average G's of 808 and 808A}}{\text{Smaller of the two average G's}}$$

APPENDIX IV

COMPARISON OF 24 INCH INSTRUMENTED PACKAGE DROP DATA WITH RESULTS PREDICTED USING THE DROP SHOCK TESTER

Three cushions of each type studied were enclosed in 8¼ X 8¼ X 12 inch A-flute RSC's that had been degraded by 35 drops from 24 inches using an 11.5 pound instrumented 8 X 8 X 8 inch wood test block.

The polystyrene cushions were loaded with the wood test block and filler material. The combined loading on the polystyrene cushions was 11.63 pounds. Static stress was 0.181 pounds per square inch. The bonded animal hair cushions were loaded with the aluminum 8 X 8 X ¼ inch platen and filler material. The load on the bonded animal hair was 3.94 pounds. Static stress was 0.062 pounds per square inch.

All other equipment and test instrumentation was the same as used in Appendix I.

Each instrumented package was dropped ten times from 24 inches. The shock pulse magnitude and duration were recorded and representative photographs taken. Table X shows the results of this test.

The same cushions were then tested on the drop shock tester at a static loading close to that used in the instrumented package drop. An 8¼ X 8¼ inch corrugated restraint was used. Test equipment and

and instrumentation were the same as used in previous drop shock testing of cushions. Table XI shows the results of this test. Figure 9 shows comparative photographs of the pulses generated by the instrumented package drop and those generated on the drop shock tester.

TABLE X

24 INCH INSTRUMENTED PACKAGE DROP DATA

Gilman Brothers Celluliner
Type 40, 2 Inch
Expanded Bead polystyrene

Platen Weight 11.63 lbs

Drop	G's - msec	G's - msec	G's - msec
36	71.1 - 13.0	76.2 - 13.5	76.2 - 15.0
37	76.2 - 14.0	81.3 - 13.5	76.2 - 15.0
38	76.2 - 14.0	76.2 - 13.5	71.1 - 14.0
39	76.2 - 13.5	76.2 - 12.5	76.2 - 14.0
40	76.2 - 14.0	76.2 - 12.0	71.1 - 13.0
41	81.3 - 13.5	81.3 - 12.0	71.1 - 15.0
42	76.2 - 14.0	81.3 - 13.0	76.2 - 14.0
43	76.2 - 14.0	81.3 - 12.5	81.3 - 14.0
44	76.2 - 13.5	81.3 - 12.5	76.2 - 14.0
45	76.2 - 14.0	81.3 - 13.0	76.2 - 14.0
	76.2 - 13.75	79.26 - 13.0	75.18 - 14.2

Average G's 75.88

Average msec 13.65

Bonded Animal Hair
2 Inch Nominal

Platen Weight - 3.94 lbs

Drop	G's - msec	G's - msec	G's - msec
36	16.3 - 34.0	18.3 - 27.0	18.3 - 30.0
37	16.3 - 34.0	NR - NR	18.3 - 30.0
38	16.3 - 34.0	20.3 - 26.0	18.3 - 30.0
39	16.3 - 34.0	20.3 - 25.0	18.3 - 28.0
40	16.3 - 34.0	20.3 - 25.0	18.3 - 28.0
41	16.3 - 34.0	20.3 - 25.0	18.3 - 28.0
42	16.3 - 34.0	20.3 - 24.0	18.3 - 28.0
43	16.3 - 34.0	20.3 - 24.0	16.3 - 28.0
44	16.3 - 34.0	20.3 - 24.0	18.3 - 28.0
45	16.3 - 34.0	20.3 - 24.0	16.3 - 28.0
	16.3 - 34.0	20.1 - 25.0	17.9 - 28.6

Average G's 18.1

Average msec 29.2

TABLE XI

<u>SIMULATED</u> 24 INCH DROP TEST DATA USING

LAB DROP SHOCK TESTER

Gilman Brothers Celluliner

Type 40, 2 Inch
Expanded Bead Polystyrene

Platen Weight 11.5 lbs

	Primary - Secondary		Primary - Secondary		Primary - Secondary	
G's	50.8	45.7	55.9	40.6	50.8	40.6
msec	10.5	17.5	10.5	13.5	11.0	15.0
	50.8	45.7	55.9	40.6	55.9	40.6
	10.5	14.0	10.5	16.0	10.0	14.0
	50.8	40.6	50.8	35.6	55.9	40.6
	10.0	13.5	10.0	14.5	10.0	13.0
	50.8	40.6	55.9	35.6	55.9	40.6
	10.0	13.5	10.5	14.5	10.0	12.5
	50.8	40.6	55.9	35.6	50.8	45.7
	10.0	13.5	10.5	14.5	10.0	13.5
	50.8	42.64	54.83	37.6	53.86	41.62
	10.2	14.4	10.4	14.6	10.20	13.60

Average G's 53.18 - 40.62

Average msec 10.27 - 14.20

TABLE XI CONTINUED

SIMULATED 24 INCH DROP TEST DATA USING

LAB DROP SHOCK TESTER

Bonded Animal Hair

2 Inch Nominal

Platen Weight 4.0 lbs

	Primary - Secondary	Primary - Secondary	Primary - Secondary
G's	NR - NR	20.3 - 32.6	20.3 - NR
msec	NR - NR	38.0 - 8.0	44.0 - NR
	20.3 - 24.4	20.3 - 36.6	18.3 - NR
	38.0 - 12.0	37.0 - 9.0	4[illegible].0 - NR
	20.3 - 20.3	20.3 - 36.6	18.3 - NR
	40.0 - 12.0	38.0 - 9.0	47.0 - NR
	20.3 - 14.2	20.3 - 50.8	16.3 - NR
	41.0 - 12.0	38.0 - 9.0	46.0 - NR
	16.3 - NR	18.3 - 44.8	16.3 - NR
	39.0 - NR	37.0 - 11.0	45.0 - NR
	19.3 - 19.6	19.9 - 40.28	17.9 - --
	39.5 - 12.0	37.6 - 9.2	45.8 - --

Average G's 19.0 - 32.53

Average msec 41.07 - 10.25

FIGURE 9

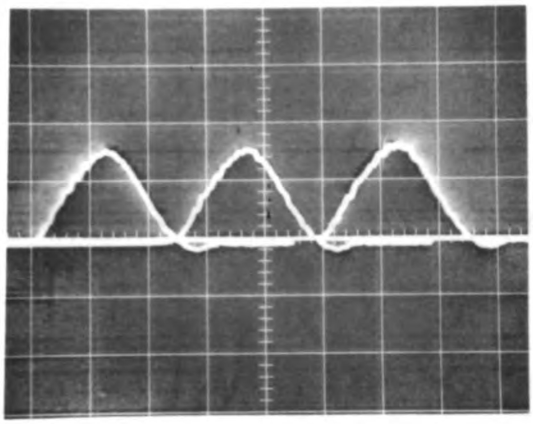
SHOCK PULSES TRANSMITTED BY CUSHIONS:

24 INCH INSTRUMENTED PACKAGE DROP

AND LAB DROP SHOCK TESTER

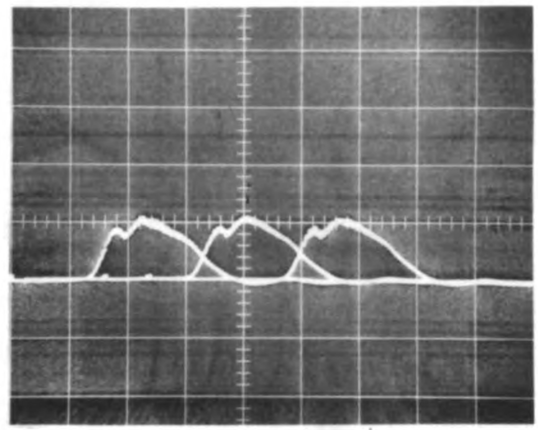
24 Inch Instrumented Package Drop

Expanded Bead Polystyrene



Vertical - 50.8 G's/division
Horizontal - 5 msec/division

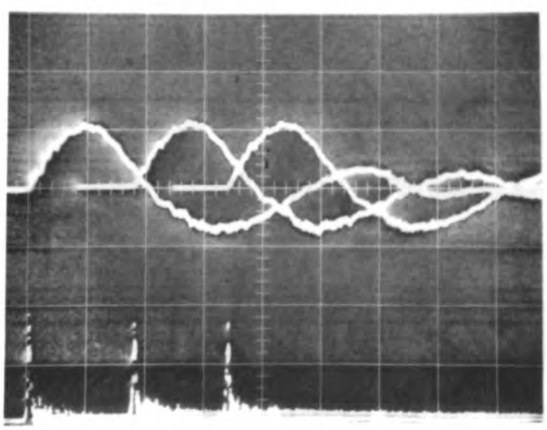
Bonded Animal Hair



Vertical - 20.32 G's/division
Horizontal - 10 msec/division

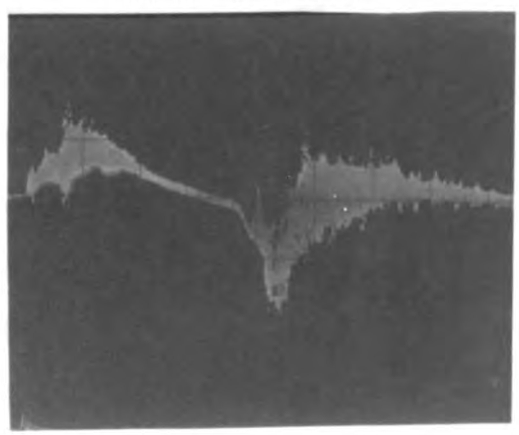
LAB Shock Drop Tester

Expanded Bead Polystyrene



Vertical - 50.8 G's/division
Horizontal - 5 msec/division

Bonded Animal Hair



Vertical - 20.32 G's/division
Horizontal - 10 msec/division

APPENDIX V

RESULTS OF 24 INCH EQUIVALENT FREE FALL CUSHION TEST

Gilman Brothers Company: Type 40 Celluliner, Expanded Bead Polystyrene. Thickness--2 Inches (7).

Static Loading PSI	Average G's	Average Pulse Duration msec
.078	122.9	9
.172	120.7	12
.266	84.9	14
.359	80.5	14
.453	82.7	14
.547	76.0	16
.641	67.1	18
.733	62.6	20
.828	62.6	22
.906	64.8	22

Bonded Animal Hair: Thickness--2 Inches (11)

0.077	56.0	29.7
0.010	102.8	26.8
0.123	142.2	26.6