This is to certify that the

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MEASURING THE SHOCK RESPONSE IN PALLET BOXES
ON HORIZONTAL AND INCLINE IMPACT TESTERS
USED TO SIMULATE RAILCAR COUPLING AND PALLET MARSHALLING

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MEASURING THE SHOCK RESPONSE IN PALLET BOXES ON HORIZONTAL AND INCLINE IMPACT TESTERS USED TO SIMULATE RAILCAR COUPLING AND PALLET MARSHALLING

By

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ABSTRACT

MEASURING THE SHOCK RESPONSE IN PALLET BOXES ON HORIZONTAL AND INCLINE IMPACT TESTERS USED TO SIMULATE RAILCAR COUPLING AND PALLET MARSHALLING

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This study measured the shock response inside a pallet box using the horizontal and inclined impact testers. These testers are used to simulate impacts that occur during railcar coupling and pallet marshalling. Using a round 'robin test' procedure, the impacts were performed in several different labs using programmable horizontal, programmable incline, and incline impact testers.

The results show that for 4 mph impacts, the minimum and maximum levels of velocity change measured in the pallet box along the direction of impact were 87.4 in/sec and 184.5 in/sec. Data collected also shows that for 5 mph impacts, the minimum and maximum levels of velocity change measured in the pallet box along the direction of impact were 113.7 in/sec and 232.3 in/sec. In both cases of the railcar coupling simulation tests, the minimum levels were measured on an incline tester and the maximum levels were measured on the horizontal tester.

For the pallet marshalling tests, the minimum and maximum levels of velocity change measured in the pallet box for 10 g, 50 ms pallet marshalling tests were 72.2 in/sec and 181.4 in/sec. Similarly the minimum and maximum levels of velocity change measured in the pallet box for 40 g, 10 ms pallet marshalling tests were 10.9 in/sec and 181.4 in/sec.

I would like to thank my wife Nancy and my parents for the love and support they have given me.

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1.0 INTRODUCTION

Since the development of the first railcar there have been many advances in rail transportation. Inventions such as welded tracks, draft gears, and cushioned undercarriages have reduced the severity of this transportation mode. However, to adequately protect the product from the various dynamic inputs occurring during rail transportation, it is important to characterize and correctly simulate these forces in a lab environment. It has been estimated that annual damage resulting from excessive railcar coupling or inadequate packaging is well over a 100 million dollars (Baillie, 1959).

The longitudinal shock occurs when freight cars are coupled to build up a train (Baillie, 1959). This is a common practice that occurs frequently at various rail shipping yards as trains are separated and combined to be re-routed to appropriate destinations. The characteristics of this type of longitudinal shock is dependent on a variety of factors including impact speed, draft gear, undercarriage, number of stationary freight cars and track conditions. Several studies have been done to evaluate the various factors and their effect on railcar coupling. This thesis reviews the data collected in earlier studies measuring these various levels and then evaluates the test methods developed to simulate these conditions for package testing.

The magnitude of the shock loading is influenced by such factors as: (1) impact speed, (2) weight of cars, (3) coupler design, (4) load configuration (integral and ridged, non-integral such as cartons, compartmentalized, slack, etc.), (5) number of cars active in impact, (6) location of test car, (7) track orientation, (8) car center of gravity location, and (9) length of car (Wallace, 1959).

Several studies have investigated the dynamics involved during railcar humping. Simmons et-al (1964) studied the acceleration levels produced during horizontal rail coupling as a function of impact velocity and type of draft gear used. The research showed that impact velocities higher than 8 mph and acceleration levels above 7 g's are a result of severe rough handling (Figure 1). Normal impacts usually have impact velocities less than 6 mph and acceleration levels below 3 g's (Simmons 1964). The study compared various draft gear types like conventional, hydraulic, long travel high capacity, and sliding sill. The sliding sill type of draft gear generates the lowest accelerations (resulting in minimum damage) even at very high impact velocities (up to 10 mph) as compared to the other draft gears. The information presented in this figure can be used to determine expected damage levels based on type of draft gear used and product horizontal shock fragility data.

Conventional draft gears are generally short travel cushioning systems. The construction varies depending on the

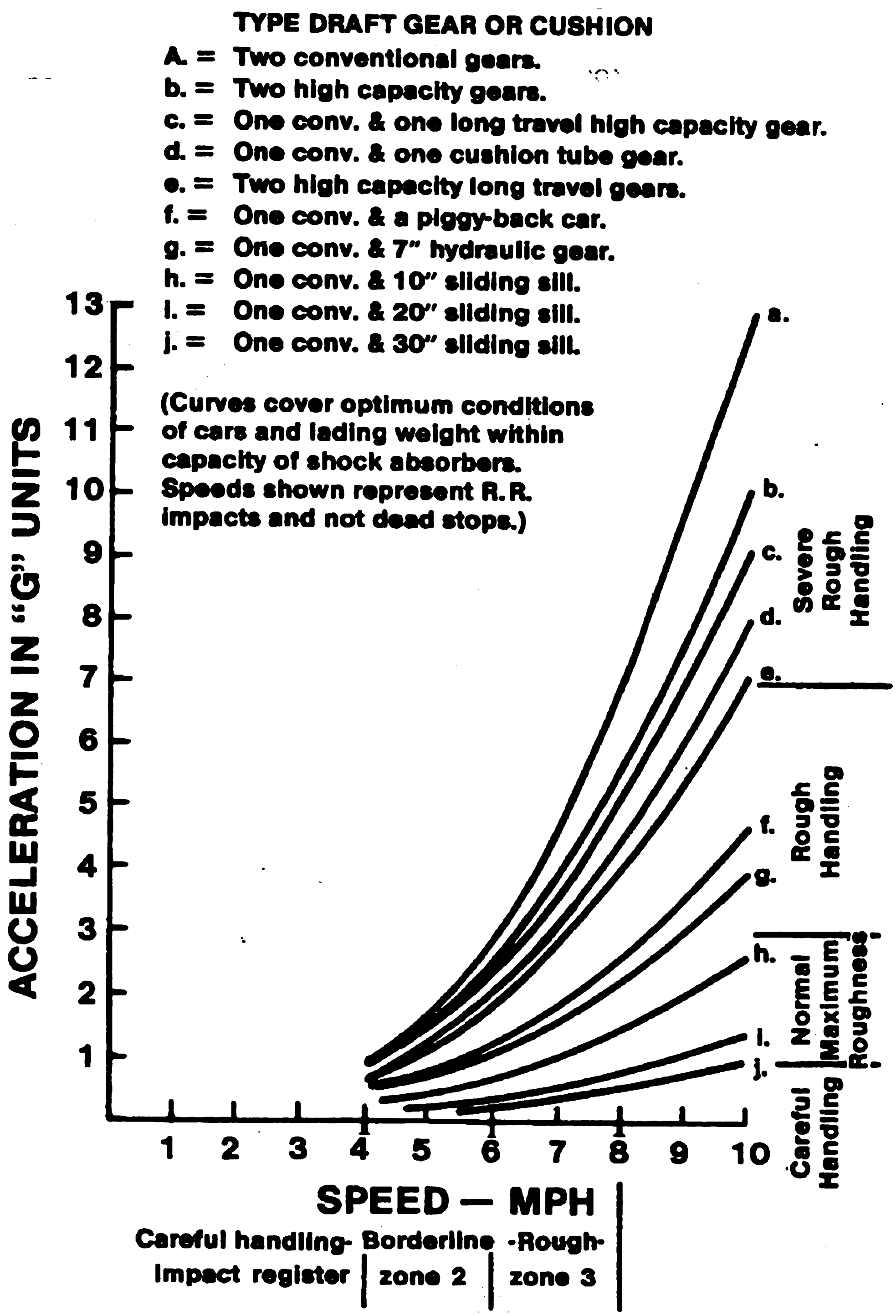

TYPE DRAFT GEAR OR CUSHION
A. = Two conventional gears.
b. = Two high capacity gears.
c. = One conv. & one long travel high capacity gear.
d. = One conv. & one cushion tube gear.
e. = Two high capacity long travel gears.
f. = One conv. & a piggy-back car.
g. = One conv. & 7" hydraulic gear.
h. = One conv. & 10" sliding sill.
i. = One conv. & 20" sliding sill.
j. = One conv. & 30" sliding sill.
(Curves cover optimum conditions of cars and lading weight within capacity of shock absorbers. Speeds shown represent R.R. impacts and not dead stops.)
ACCELERATION IN "G" UNITS
1 2 3 4 5 6 7 8 9 10 11 12 13
a. b. c. d. e. f. g. h. i. j.
Severe Rough Handling
Rough Handling
Normal
Maximum Roughness
Careful Handling
SPEED — MPH
1 2 3 4 5 6 7 8 9 10
Careful handling- Impact register
Borderline zone 2
-Rough- zone 3

Figure 1

manufacturer. Some of the different types and cushioning capacities of these gears are presented in this section. The Peerless type T-1 frictional draft gear approved in April, 1957 by the Association of American Railroads uses two sets of coil springs and friction shoes, which slide forward and backward in the housing to provide cushioning during impact. The unit is about 22 inches long, 12 inches wide, about 9 inches deep, and has a travel of about 2.5 inches. The unit is officially rated for 26,400 ft-lbs energy absorption. A second type of conventional draft gear (Miner Class A-22-XL) is a friction draft gear which has friction shoes and a single inner and outer spring all contained in the unit. They function by sliding back and forth to provide necessary cushioning. The Miner A-22-Xl was approved in June, 1947, by the Association of American Railroads and has a total capacity of 22,500 ft-lbs. In the same classification of conventional draft gears is the Miner class FR-19 certified by the Association of American Railroads. This unit is 24.5 inches long, 12.5 inches wide, and 9 inches deep and has a travel of 2.75 inches and a rated capacity of 45,135 ft-lbs. The unit uses a rubber cushion which compresses to absorb 16,250 ft-lbs. at its maximum rating. The Miner RF-333 draft gear uses both rubber and friction cushioning to absorb the impact. It has a travel of 2.5 inches and a total capacity of 40,000 ft-lbs. This unit is relatively smaller with a length of 22.75 inches, a width of 12.5 inches, and a depth of 9 inches.

Another type of system is the hydraulic draft gear developed by Freightmaster. This gear is a 10 inch long hydraulic cushioning device that is effective in reducing the impact during coupling. This unit uses a sealed hydraulic fluid system to reduce the shock at impact. This unit has a 9 inch travel. The hydraulic system is completely filled and is divided into two separate chambers connected by valves and ports. One hydraulic chamber includes the high pressure inner-cylinder, and the other consists of the low pressure outer-housing. The high pressures created upon impact are confined to the internal cylinder and these pressures are substantially dissipated into the outer-housing. Impact energy is transmitted from the coupling through the outer-housing and hydraulic cylinder system to the center sill of the rail car. As the cylinder closes on the piston through impact, oil is forced from the cylinder into the outer-housing through metering ports appropriately sized and spaced. The oil is instantly returned behind the piston so that hydraulic cushioning will immediately be provided within the cylinder if movement of the unit is reversed. A unique compensator is used to keep the hydraulic cylinder and outer-housing completely full of oil. When external forces are removed from the unit, repositioning springs are provided to return the unit to its normal position (Freightmaster, 1963).

Long travel high capacity draft gears are similar to the conventional draft gear except that they use much longer travel than the conventional draft gear. The conventional draft gear requires a 24.5 inches pocket and provides approximately 2.5 inch of travel whereas the long travel high capacity requires a pocket in the range of 36 inches and provides a travel of 4.5 inches. The cushion tube, which utilizes both gears during impact, more than doubles the gear capacity by increasing the closure distance, and also splits the reaction between both ends of the car (Simmons et-al, 1964).

The Association of American Railroads requires that the draft gear should have a minimum cushion capacity of 18000 ft-lbs., and a minimum travel of 2.5 inches (Wallace, 1957).

There are several types of sliding sill units, that are built in many different ways. One such type uses draft gears at each end, a combination of springs, and allows the sills to float within the body bolsters (Sillcox, 1941). Another sliding sill utilizes a floating center sill with approximately 20 inches of travel, a draft gear like friction or hydraulic to reduce impact energy, and a set of return springs (Association of American Railroads, 1963).

Peterson (1959) determined the lading force produced during rail humping as a function of impact velocity and draft gear (cushion) travel (Figure 2). The study also showed that lading force in excess of 1000 pounds per square foot resulted in damage to glass bottles. Studies done to determine impact speeds in marshalling yards, where impacts occur as trains are combined and separated, reveal a wide distribution of impact speeds. The standard operation of coupling cars in the yard is to roll the cars down the track to impact the stationary line of cars. This was typically done based on driver judgment. Usually a 2 mph impact speed was desired. In modern yards, computers and breaking devices control the impact speed resulting in less variation and manage to maintain a 4 mph impact. However, variations result due to wheel surface and weather conditions. Figure 3 shows the distribution of impact speed measured in modern yards (Van Der Sluys et-al, 1966). The study measured the impact speeds based on 4647 actual observations conducted in various rail couplings in modern yards. Figure 3 describes the results of this study in terms of cumulative percent of occurrence as a function of impact speeds. The data evaluated showed that about 8% of the impacts still occur in the 9-11 mph range. Seventy eight percent of all the impacts were between 4-7 mph range.

The impact duration also plays a significant role in damage produced by the conventional railcar. The duration for conventional draft gears is shorter as than the sliding sill railcar. The sliding sill result in higher shock magnification and yield more damage. Pierce (1970) instrumented railcars to obtain impact data resulting from rail coupling. They used this information to perform package tests using the Conbur incline tester. Some of the problems with the Conbur is that it provides a shorter impact duration (approximately 4 ms) and the g levels experienced in the railcar are much higher than produced by the Conbur tester.

The impact duration during coupling is a function of the

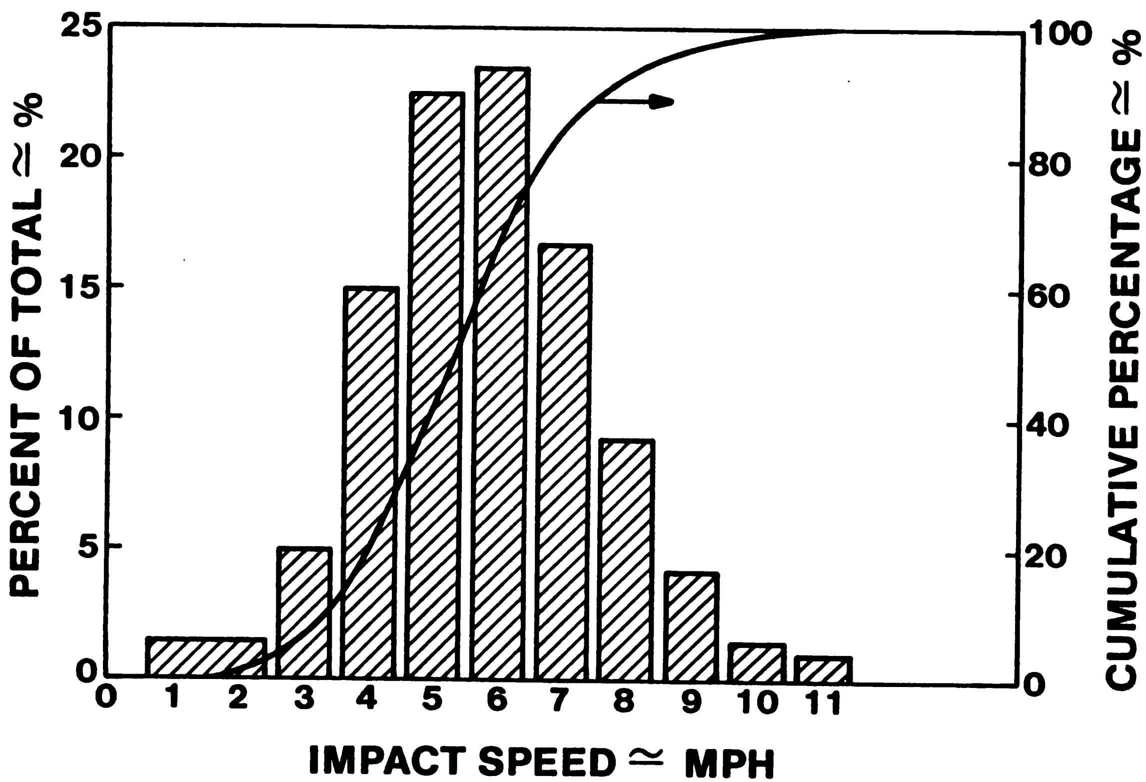

25
20
15
10
5
0
PERCENT OF TOTAL ≃ %
100
80
60
40
20
0
CUMULATIVE PERCENTAGE ≃ %
0 1 2 3 4 5 6 7 8 9 10 11
IMPACT SPEED ≃ MPH

Figure 3

type of draft gear used. Some of the first cars equipped with draft gears used coil spring that are inefficient friction type draft gears to provided shock protection. These types of draft gears provided protection up to about 2 mph impact velocities. Wallace (1957) stated that nearly all of the devices employing just plate or coil springs have been eliminated in the United States. Since then there have been new developments on the frictional gears that are used on 75 percent of the 2 million cars in use.

Various studies have been done to evaluate damage in terms of length of travel and type of draft gear used. Peterson (1959) studied the cushioning requirements needed for adequate lading protection. He compared coupling conditions for a eight inch travel cushioned under-frame car to a friction type draft gear car. In this test the cars were loaded with ceramic tiles. It was determined that there was a substantial reduction in acceleration levels, coupler force, and damage in the cushioned car as compared to the friction type car. This test was then repeated using gallon glass bottles, and even though acceleration levels and coupler forces were reduced in the cushioned car, the damage levels in both cars were almost the same. The study used packaged bottles and tins and determined damage levels for various impact conditions. The study showed that higher impact speeds resulted in more damage and that this could be reduced by using a longer cushion travel.

There are various tests that are used by packaging engineers to simulate the impact levels caused during railcar coupling. ASTM (1990) recommends tests like D4003 for simulating horizontal impacts during coupling. The standard details simulating the rail switching impact test and provides information to be used by the user in order to select test levels. It states that;

> "the number of impacts to which a product will be subjected in transit may range from 2 to 15. The velocity changes range between 1 and 10 mph with an average velocity of approximately 5 mph. The duration of the impact shocks is dependent on the draft gear of the rail cars used to transport the products. The duration normally ranges from 30 ms for standard draft gears to in excess of 300 ms for long travel gear and floating sill cushioning devices. The acceleration levels observed are normally a function of the velocity change and pulse duration rather than a controlling input parameter. The accelerations corresponding to the above durations are about 15 G and less than 1 G, respectively. It must be realized that the rail car switching impacts normally occur many times during shipment. It is recommended that a test consists of a number of lower level impacts or an incremental series of increasing impact magnitude rather than a single large magnitude impact."

2.0 EXPERIMENTAL DESIGN

The purpose of this experiment was to measure the impact levels produced by different types of test equipment that is used to simulate railcar coupling and pallet marshalling for palletized loads in accordance with ASTM standards. This chapter describes the different types of test equipment that was used to perform the impacts. In addition, the specifications of the instrumented pallet box are described.

2.1 Test Equipment and Instrumented Container:

The two general types of equipment compared are the inclined impact tester and the horizontal impact tester made by different manufacturers. A range of impact velocities were evaluated using a instrumented pallet box. A series of five replicates were performed for each set impact velocities on each piece of equipment compared.

A pallet box measuring 48 inches long, 45 inches wide, and 34 inches high made from high density polyethylene structural foam was used. This is a standard returnable container used by General Motors to ship automobile parts from suppliers to assembly plants. Two accelerometers were used to measure the acceleration levels at impact inside this container. These were mounted in a rigid plywood box that was then placed in the container. Accelerometer #1 was mounted on the side wall of the plywood box, and positioned 18 inches from the bottom of the pallet box and centered on the side face. This face was used to impact on the bulkhead of the impact tester. Accelerometer #2 was mounted at the bottom of the plywood container and positioned 9 inches from the impacting face. The plywood box was encapsulated using expanded polystyrene. The impacting face of the instrumented plywood box was cushioned using 2 inches of polyethylene cushion (Ethafoam 220, Dow Chemical Company).

Accelerometer #1 monitored the sidewall and the impacting face and was used to measure the impact in the direction of travel. Accelerometer #2 monitored the bottom of the container and was used to record rotations at impact and track vibrations. A third accelerometer was used to measure the shock on the test carriage itself in case of the horizontal impact machines. The details of all the accelerometers are listed below;

Accelerometer #1- PCB Piezotronics, Inc., Serial # 17801 Model #302A02, Sensitivity 10.00 mV/g

Accelerometer #2- PCB Piezotronics, Inc., Serial #17809 Model #302A02, Sensitivity 9.80 mV/g

Accelerometer #3 - Used available instrumentation at test sites.

In addition, a piezoelectric coupler were used with the accelerometers (Kistler 5004 Dual Mode Amplifier). The recorded data was acquired, saved and processed using 'Test Partner' data acquisition software made by Lansmont Corporation, Monterey, CA.

The initial part of each test consisted of recording the acceleration levels for velocity changes of 6 mph and 8 mph on each type of impact tester. These levels are recommended test levels for railcar coupling.

The second part of the test setup were tests used for pallet marshalling. These are impacts that occur during handling of palletized containers using fork trucks. During various fork truck handlings, two types of impacts are simulated. These are 10 G, 50 ms, and 40 G, 10 ms. shock pulses.

At the start of each test sequence, the pallet container was placed on the sled or test carriage of the impact tester. The tests were performed in accordance with ASTM D4003. The purpose of this standard is to determine the performance of a package and its contents during expected impacts during rail shipment and fork truck handling.

Two main types of equipment were compared in this study. The first type uses a track with a 10^0 incline to obtain the desired impact velocity, and is also referred to as a incline impact tester. The second type uses a horizontal track and uses a pneumatically activated carriage to arrive at the desired impact velocities. The impact velocity can be controlled by adjusting the gas pressure in the cylinder that is used to drive the carriage. This type of test machine is also called a horizontal impact tester. Both machines require a back stop which must have sufficient rigidity to limit displacement during impact. The equipment can also be equipped with a sail which is also called a bulkhead as shown in Figure 4. The sail impacts the back stop. In order to control the shock pulse duration and shape, a medium between the sail and the back stop is provided that is called a programmer. The programmer may be made up of plastic, rubber, coil springs, or hydraulic cushioning devices that control the shock duration and pulse shape. Generally the horizontal impact testers are equipped with various types of programmers that can produce both sinusoidal and trapezoidal shock pulses. The incline impact testers usually do not have a sail and are limited to the choice of programmers. Figures 4 and 5 show the details of the equipment used.

All these performance testers have to be equipped with a device that stops the table after first impact to prevent multiple impacts in order to comply with ASTM standards. All of these testers need some type of instrumentation device to determine the velocity change at impact.

2.2 Test Setup:

The test container was placed on the test carriage and strapped to the sail. No backload was used. A backload is specified load that is placed behind the test specimen of the same size and weight. This is used to simulate the lading that is present in a loaded vehicle. The carriage was then calibrated to the test levels described above. A series of five impacts were recorded for each test condition. The shock data was recorded and analyzed to determine peak acceleration, shock duration, and velocity change for each impact and orientation.

DIAGRAM OF A HORIZONTAL IMPACT TESTER

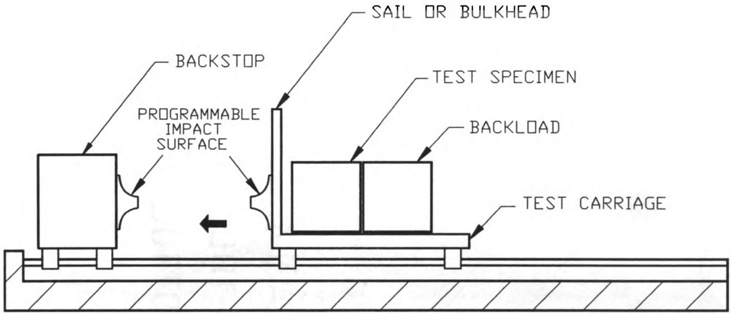


Figure 4

DIAGRAM OF AN INCLINED IMPACT TESTER

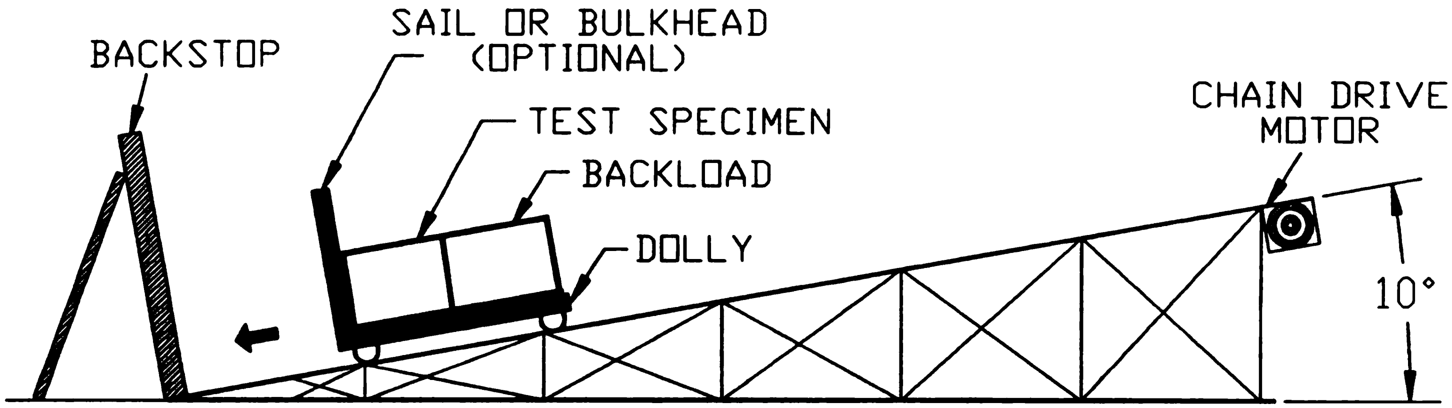


Figure 5

2.3 Test Equipment Used for Comparison:

A total of seven different impact testers were monitored in this study. These consist of three incline impact testers without a sail, one incline impact tester a sail and a coil spring programmer, and three horizontal impact testers with sails and programmers.

The first tester used (Tester 1) was a incline tester made by Gaynes (Model 600-c) and had a L.A.B. Velocity Monitor (Model 9000). This tester had a test carriage without a sail (bulkhead) and is located in the Package Testing Laboratory of Arvco Container Co., Kalamazoo, MI. The test carriage is raised up the incline track using a chain located between the two tracks. Upon reaching the desired height the sled is released and the carriage rolls down the steel track on steel rollers. The test specimen then impacts the backstop which was made of wood and reinforced with metal. Figure 6 shows this tester.

The second tester evaluated (Tester 2) was also an incline tester and used a velocity monitoring device made by GHI Systems Inc. This tester had a test carriage without a sail and is located in the Package Testing Laboratory of Menasha Co., Coloma, MI. This tester was slightly larger but the operating mechanism was similar to that for Tester 1. Figure 7 describes this impact tester.

The third tester (Tester 3) was also a incline impact tester located at Packaging Corporation of America, Skokie, IL. This tester was similar to Tester 1 and also had a

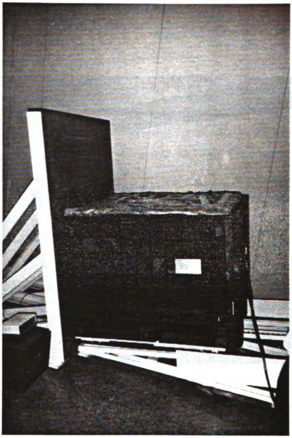


Figure 6

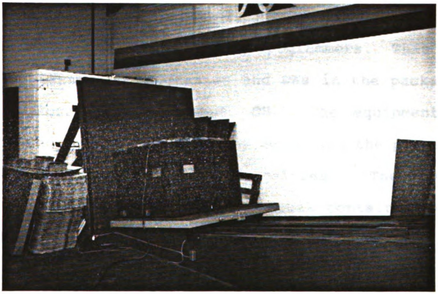


Figure 7

velocity sensor made by GHI Systems Inc. Figure 8 shows this test machine.

The fourth tester (Tester 4) used was also a incline tester but it also had a sail and programmers. Two types of programmers were available, one with steel coil springs and another with a hydraulic piston cylinder arrangement. A GHI velocity sensor was used to monitor the impact velocities. Figure 9 shows this test equipment.

The fifth tester (Tester 5) used was a horizontal impact tester which had both sail and programmers. This tester was made by Lansmont Corporation and was in the package testing lab at Ross Labs, Columbus, OH. The equipment is first calibrated for an empty sled by adjusting the pressure levels to attain required impact velocities. These values are further modified by using the actual container to reach at required levels.

The sixth tester (Tester 6) was also a horizontal impact type very similar to the one at Ross Labs and is also made by Lansmont Corporation. This equipment is placed in the testing laboratory of Georgia Pacific, Toledo, OH. This impact tester used a nitrogen charge to propel the sled forward. The sled was equipped with a sail and rode on ball bearings on a dovetail track. The backstop was equipped with different kinds of plastic programmers to produce all ASTM recommended horizontal impact test levels. Figure 10 shows a pictures of the test equipment and the programmer.

The seventh and last tester (Tester 7) evaluated was

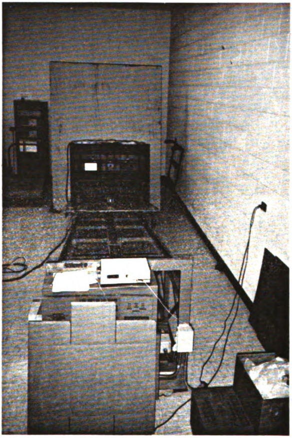


Figure 8

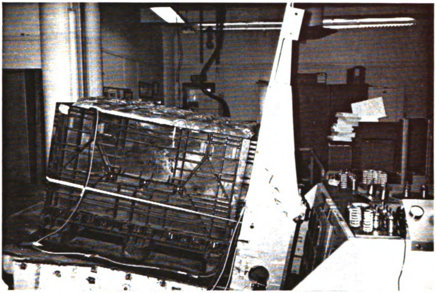


Figure 9

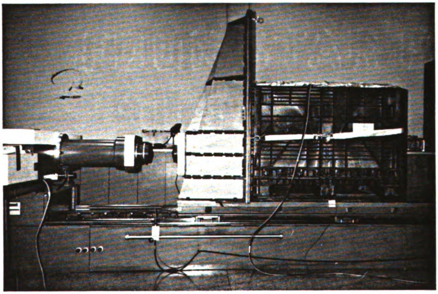


Figure 10

located at Admiral Labs, Peoria, IL. This is also a horizontal impact tester and was made by MTS Corporation. The tester was equipped with a sail and the test container was strapped to it. The test carriage was propelled down the track using a nitrogen charge. The tester also had plastic programmers that were used to control the shock pulse duration and shape. The test carriage moved along on steel bars with brass bushing to hold it to the track as in Figure 11.

In all of the programmable testers evaluated, the sail or the bulkhead was also monitored using an accelerometer located at roughly the center position.

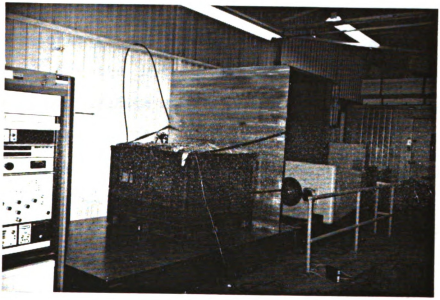


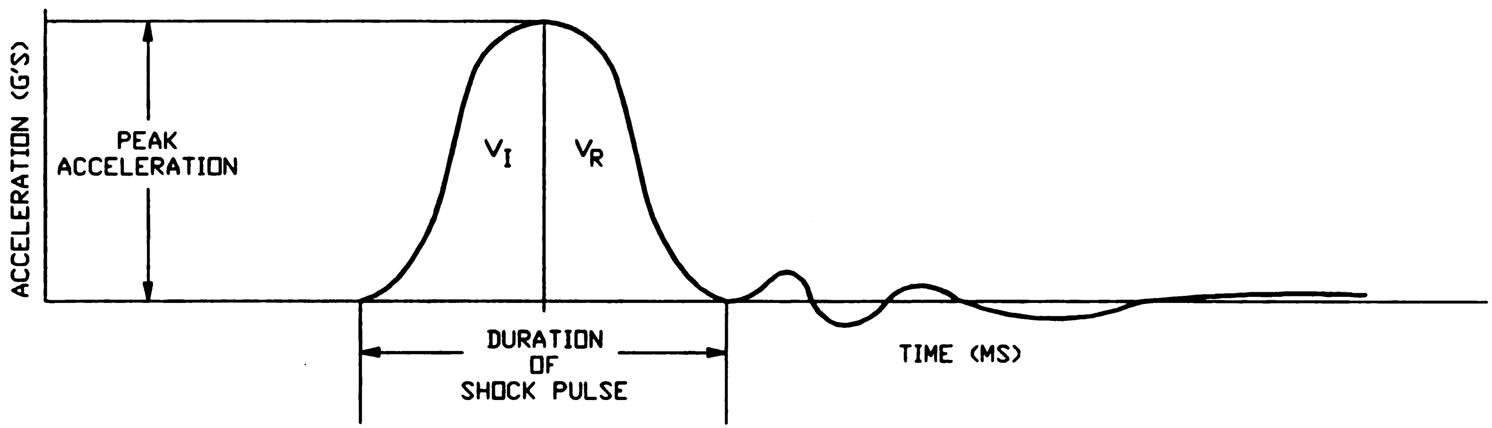
Figure 11

3.0 DATA AND RESULTS

The complete data recorded for each test condition and equipment type evaluated is listed in the Appendix (Tables A1 - A7). Figure 12 provides an explanation of the values recorded, peak acceleration, velocity change, and duration, in tables 1-5. Table 1 provides the average and standard deviation values for the peak acceleration (G), velocity change (in/sec), and shock duration (ms) for each channel monitored for the incline impact testers 1 - 4. Table 2 provides the average and standard deviation values for the peak acceleration (G), velocity change (in/sec), and shock duration (ms) for each channel monitored for the horizontal impact testers 5 - 7.

Table 3 lists the minimum and maximum levels of velocity change, peak acceleration, and shock duration for all the 4 and 5 mph railcar coupling simulation tests using all the different types of testers. Table 4 describes the minimum and maximum levels of velocity change, peak acceleration, and shock duration for all the 6 and 8 mph railcar coupling simulation tests using the horizontal impact testers.

Table 5 describes the minimum and maximum levels of velocity change, peak acceleration, and shock duration for all the pallet marshalling tests using the programmable impact testers. For Tester # 1, the minimum and maximum values measured in the instrumented pallet box for 4 mph impacts were



IMPACT VELOCITY (V_I) = AREA UNDER SHOCK PULSE FROM START TO PEAK ACCELERATION

REBOUND VELOCITY (V_R) = AREA UNDER SHOCK PULSE FROM PEAK ACCELERATION TO END OF SHOCK PULSE

CHANGE IN VELOCITY(ΔV) = $V_I + V_R$ OR TOTAL AREA UNDER SHOCK PULSE

Figure 12

velocity change 98.4 in/sec and 102.2 in/sec, acceleration 62.8 g's and 64.5 g's, and duration 6.3 ms and 6.8 ms. The minimum and maximum values measured for the 5 mph impacts were velocity change 125.9 in/sec and 132.7 in/sec, acceleration 81.1 g's and 92.0 g's, and duration 6.0 ms and 6.9 ms respectively. For Tester # 2, the minimum and maximum values measured in the instrumented pallet box for the 4 mph impacts were velocity change of 94.6 in/sec and 99.6 in/sec, acceleration 70.2 g's and 77.4 g's, and duration 4.1 ms and 6.8 ms. The minimum and maximum values measured for the 5 mph impacts were velocity

change 124.9 in/sec and 127.5 in/sec, acceleration 85.6 g's and 90.6 g's, and duration 6.4 ms and 7.2 ms respectively. For Tester # 3, the minimum and maximum values measured in the instrumented pallet box for the 4 mph impacts were velocity change 87.4 in/sec and 88.2 in/sec, acceleration 60.4 g's and 67.4 g's, and duration 7.0 ms and 7.4 ms. The minimum and maximum values measured for the 5 mph impacts were velocity change 113.7 in/sec and 115.6 in/sec, acceleration 80.0 g's and 91.3 g's, and duration 4.4 ms and 7.3 ms respectively. For Tester # 4, the minimum and maximum values measured in the instrumented pallet box for the 4 mph impacts were velocity change 104.0 in/sec and 148.2 in/sec, acceleration 19.7 g's and 22.5 g's, and duration 30.9 ms and 39.4 ms. The minimum and maximum values measured for the 5 mph impacts were velocity change 145.6 in/sec and 186.9 in/sec, acceleration 30.2 g's and 31.7 g's, and duration 29.1 ms and 34.1 ms respectively. For Tester # 5, the minimum and maximum values measured in the instrumented pallet box for the 4 mph impacts were velocity change 145.1 in/sec and 154.5 in/sec, acceleration 29.8 g's and 31.8 g's, and duration 27.4 ms and 29.0 ms. The minimum and maximum values measured for the 5 mph impacts were velocity change 194.9 in/sec and 207.1 in/sec, acceleration 33.8 g's and 43.2 g's, and duration 25.1 ms and 27.9 ms respectively. For Tester # 6, the minimum and maximum values measured in the instrumented pallet box for the 4 mph impacts were velocity change 175.0 in/sec and 184.5 in/sec, acceleration 39.1 g's and 41.2 g's, and duration 25.5 ms and 26.3 ms. The minimum and maximum values measured for the 5 mph impacts were velocity change 224.4 in/sec and 232.3 in/sec, acceleration 57.0 g's and 63.7 g's, and duration 23.6 ms and 24.5 ms respectively. For Tester # 7, the minimum and maximum values measured in the instrumented pallet box for the 4 mph impacts were velocity change 96.3 in/sec and 102.1 in/sec, acceleration 16.8 g's and 20.7 g's, and duration 6.3 ms and 30.6 ms. The measurements taken for the 5 mph impacts were in error due to pre-triggering of the data acquisition system.

The data collected shows that for the 4 mph impacts, the minimum and maximum levels of velocity change measured in the pallet box along the direction of impact were 87.4 in/sec and 184.5 in/sec. The minimum levels were measured on an incline tester and the maximum levels were measured on the horizontal tester.

The data collected shows that for the 5 mph impacts, the minimum and maximum levels of velocity change measured in the pallet box along the direction of impact were 113.7 in/sec and 232.3 in/sec. Again the minimum levels were measured on an incline tester and the maximum levels were measured on the horizontal tester.

The horizontal testers are also capable of producing horizontal impacts at higher impact velocities as compared to conventional incline testers. The velocity change levels for the 6 mph and 8 mph impacts were also measured for the horizontal testers and are provided in the appendix.

The pallet marshalling tests require a programmable shock input to the impacting table bulkhead. This test replicates impacts occurring to pallet loads being handled by fork trucks. The two impacts that are recommended in ASTM D4003 are a 10 g, 50 ms shock and a 40 g, 10 ms shock. The instrumented pallet box was subjected to the pallet marshalling on Testers 4, 5, and 6. Only these three testers were capable of performing these tests.

The minimum and maximum levels of velocity change measured in the pallet box for the 10 g, 50 ms pallet marshalling tests were 72.2 in/sec and 181.4 in/sec. Similarly the minimum and maximum levels of velocity change measured in the pallet box for the 50 g, 10 ms pallet marshalling tests were 10.9 in/sec and 181.4 in/sec.

Table 1: Shock Data for Instrumented Pallet Box Using Incline Impact Testers

Lab	VEL MPH	Channel 1			Channel 2			Channel 3		
		G's	Delta V	Time	G's	Delta V	Time	G's	Delta V	Time
1	4	67.24 (1.89)	100.3 (1.28)	6.56 (0.19)	19.44 (2.95)	9.4 (4.14)	1.46 (0.27)			
1	5	85.98 (4.06)	128.5 (2.28)	6.52 (0.31)	29.28 (5.65)	8.66 (3.67)	1.16 (0.31)			
2	4	73.96 (2.86)	97.18 (1.72)	6.16 (1.04)	26.32 (2.65)	3.44 (0.44)	0.68 (0.04)			
2	5	88.26 (1.89)	126.3 (0.97)	6.9 (0.33)	24.18 (1.59)	2.78 (0.55)	0.6 (0.13)			
3	4	64.14 (2.54)	87.78 (0.27)	7.18 (0.16)	14.94 (2.68)	1.02 (0.47)	0.4 (0.24)			
3	5	84.8 (3.89)	114.9 (0.67)	6.44 (1.04)	17.1 (1.43)	2.7 (1.36)	0.9 (0.46)			
4	4	20.94 (1.06)	122.40 (17.99)	34.88 (3.31)	7.74 (0.53)	11.66 (0.58)	5.36 (2.02)	71.58 (46.76)	4.50 (2.19)	0.48 (0.09)
4	5	30.92 (0.52)	163.14 (17.89)	30.96 (1.91)	8.02 (1.47)	1.30 (0.11)	0.96 (0.15)	29.26 (91.04)	13.86 (13.53)	0.52 (0.16)
4	6	16.86 (0.27)	97.78 (1.28)	35.00 (1.30)	6.20 (0.86)	1.90 (1.25)	1.44 (0.69)	89.54 (34.31)	10.30 (3.74)	0.7 (0.15)
4	7	18.90 (0.28)	122.92 (2.95)	35.64 (1.08)	4.98 (0.87)	5.64 (1.66)	5.20 (0.76)	110.20 (33.14)	3.36 (3.10)	0.52 (0.16)
4	10g 50ms	15.86 (0.52)	75.84 (2.11)	46.16 (0.60)	6.42 (1.10)	3.98 (1.40)	3.20 (1.00)	29.08 (4.00)	3.18 (0.99)	0.60 (0.18)
4	40g 10ms	24.08 (0.30)	17.46 (3.77)	3.8 (0.70)	11.94 (4.40)	17.82 (4.87)	5.72 (1.79)	430.30 (327.9)	48.12 (46.39)	0.72 (0.35)

Table 2: Shock Data for Instrumented Pallet Box Using Horizontal Impact Testers

Lab	VEL MPH	Channel 1			Channel 2			Channel 3		
		G's	Delta V	Time	G's	Delta V	Time	G's	Delta V	Time
5	4	30.82 (0.71)	149.06 (3.65)	28.14 (0.52)	5.56 (2.09)	2.42 (2.20)	1.56 (1.62)	14.34 (0.91)	135.3 (4.49)	41.52 (0.89)
5	5	38.16 (3.97)	200.24 (4.86)	26.78 (1.10)	5.68 (0.96)	1.10 (1.60)	1.04 (1.48)	23.78 (1.25)	184.22 (5.02)	36.52 (0.77)
5	6	18.26 (7.65)	107.70 (6.24)	35.32 (4.96)	3.36 (0.69)	0.96 (1.72)	1.42 (2.39)	9.42 (0.74)	104.68 (1.52)	47.36 (3.52)
5	8	38.414 (4.44)	154.50 (4.33)	26.74 (0.84)	7.06 (0.90)	1.80 (2.47)	1.30 (1.51)	16.50 (0.72)	145.54 (3.15)	39.86 (0.74)
5	10g 50ms	19.04 (3.35)	169.80 (7.95)	48.18 (4.90)	2.74 (0.55)	0.08 (0.12)	0.26 (0.08)	10.28 (0.49)	127.16 (3.85)	52.00 (0.69)
5	40g 10ms	37.62 (0.40)	75.86 (5.58)	5.40 (2.49)	30.32 (7.08)	19.44 (11.72)	2.48 (1.70)	39.52 (1.36)	86.34 (1.02)	10.52 (0.13)
6	4	40.18 (0.75)	179.18 (3.54)	25.82 (0.28)	8.44 (0.54)	16.88 (0.68)	10.30 (0.46)	27.24 (1.01)	153.62 (2.41)	27.94 (0.50)
6	5	59.54 (2.31)	227.26 (2.82)	24.00 (0.38)	17.94 (0.72)	31.70 (2.24)	7.72 (0.27)	36.60 (0.29)	188.70 (0.78)	24.88 (0.10)
6	6	40.06 (1.17)	110.50 (1.77)	27.04 (0.21)	2.78 (0.25)	6.94 (0.89)	11.58 (0.60)	13.78 (0.19)	106.48 (0.75)	35.42 (0.19)
6	8	38.06 (0.37)	157.94 (0.84)	26.12 (0.34)	6.96 (0.74)	12.96 (1.89)	10.52 (0.12)	22.96 (0.19)	112.34 (0.86)	29.96 (0.12)
6	10g 50ms	22.94 (0.25)	113.18 (0.93)	32.68 (1.94)	1.40 (0.21)	1.80 (0.24)	6.76 (0.31)	10.06 0.14)	113.48 (0.86)	49.28 (0.21)
6	40g 10ms	90.48 (1.85)	166.04 (0.69)	7.80 (0.23)	31.44 (1.69)	37.02 (1.47)	5.32 (1.24)	49.80 (0.00)	114.80 (0.38)	10.68 (0.07)
7	4	18.77 (1.34)	99.68 (2.11)	28.28 (2.62)	4.00 (0.47)	0.75 (0.88)	0.38 (0.19)	9.78 (0.32)	56.62 (28.48)	32.77 (0.26)
7	8	26.58 (6.68)	158.64 (5.65)	26.46 (1.36)	3.42 (1.46)	5.50 (4.91)	3.66 (3.82)	23.36 (5.13)	121.36 (6.25)	23.56 (11.30)

Table 3: Maximum and Minimum Shock Levels for 4 and 5 mph Railcar Coupling Tests

Lab	VEL MPH		Channel 1 G's	Channel 1 Delta V	Channel 1 Time	Channel 2 G's	Channel 2 Delta V	Channel 2 Time
1	4	Min.	64.5	98.4	6.3	16.9	9.0	1.1
		Max.	69.8	102.2	6.8	25.0	10.2	1.8
2	4	Min.	70.2	94.6	4.1	21.3	2.6	0.6
		Max.	77.4	99.6	6.8	29.0	3.8	0.7
3	4	Min.	60.4	87.4	7.0	11.4	0.6	0.2
		Max.	67.4	88.2	7.4	17.8	1.6	0.7
4	4	Min.	19.7	104.0	30.9	7.0	10.7	4.2
		Max.	22.5	148.2	39.4	8.5	12.2	9.4
5	4	Min.	29.8	145.1	27.4	4.2	0.1	0.2
		Max.	31.8	154.5	29.0	9.7	6.0	2.7
6	4	Min.	39.1	175.0	25.5	7.8	16.3	9.8
		Max.	41.2	184.5	26.3	9.4	17.7	10.9
7	4	Min.	16.8	24.0	6.3	3.3	0.0	0.2
		Max.	20.7	100.3	30.6	8.6	2.2	3.8
1	5	Min.	81.1	125.9	6.0	21.3	6.5	0.9
		Max.	92.0	132.7	6.9	33.4	15.3	1.7
2	5	Min.	85.6	124.9	6.4	22.6	2.0	0.5
		Max.	90.6	127.5	7.2	26.2	3.7	0.8
3	5	Min.	80.0	113.7	4.4	14.7	0.6	0.2
		Max.	91.3	115.6	7.3	18.8	4.1	1.3
4	5	Min.	30.2	145.6	29.1	5.6	1.1	0.8
		Max.	31.7	186.9	34.1	9.2	1.4	1.2
5	5	Min.	33.8	194.9	25.1	4.8	0.1	0.2
		Max.	43.2	207.1	27.9	7.5	4.3	4.0
6	5	Min.	57.0	224.4	23.6	17.1	28.0	7.2
		Max.	63.7	232.3	24.5	19.2	34.9	8.0
7	5	Min.	4.5	3.5	1.2	1.9	0.0	0.2
		Max.	14.3	66.4	22.6	10.0	8.1	9.5

measured in the pallet box for the 10 g, 50 ms pallet marshalling tests were 72.2 in/sec and 181.4 in/sec. Similarly the minimum and maximum levels of velocity change measured in the pallet box for the 40 g, 10 ms pallet marshalling tests were 10.9 in/sec and 181.4 in/sec. These results were all produced on the horizontal impact testers whereas the non-programmable incline impact testers were not capable of producing the desired shock pulses. This shows that pallet marshalling cannot be reproduced on a non-programmable impact tester and that the inclined and horizontal programmable impact testers are capable of producing larger array of shock pulses.

4. The shock levels observed in the pallet box for similar impacting conditions generally show higher acceleration levels and shorter durations when using the incline impact testers with no programmers, whereas the programmable incline and horizontal impact testers show lower acceleration and longer duration levels. In terms of product damage, the result is that a product could survive on one particular piece of test equipment. For example the incline produces enough G's, but doesn't have enough velocity change therefore the product will not see any damage. In the horizontal impact testers a velocity change high enough to damage the product could be produced, but the G level may not exceed the product specifications to cause damage.

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APPENDIX

Table A-1 Shock Response Data Collected At Arvco Container.

VEL MPH	Test #	Channel 1				Channel 2			
		G's	Delta V	Time	F	G's	Delta V	Time	F
4	1	69.8	98.4	6.7	1493	17.0	10.2	1.8	5882
4	2	65.8	99.8	6.6	1515	16.9	9.0	1.2	9091
4	3	64.5	101.1	6.8	1471	25.0	9.2	1.1	9091
4	4	67.6	102.2	6.3	1587	19.3	9.3	1.6	6667
4	5	68.5	100.1	6.4	1538	19.0	9.3	1.6	6250
5	6	92.0	132.7	6.6	1515	33.4	15.3	1.7	6250
5	7	82.4	128.0	6.9	1449	23.6	8.1	1.0	10000
5	8	81.1	128.7	6.7	1493	21.3	6.7	1.3	7692
5	9	89.0	127.4	6.0	1515	33.2	6.7	0.9	10000
5	10	85.4	125.9	6.4	1562	34.9	6.5	0.9	0

Table A-3 Shock Response Data Collected at Packaging Corporation Of America

VEL MPH	Test #	Channel 1				Channel 2			
		G's	Delta V	Time	F	G's	Delta V	Time	F
4	1	62.4	87.8	7.3	1370	12.0	1.6	0.7	0
4	2	60.4	87.4	7.4	1351	11.4	1.6	0.7	0
4	3	64.2	87.9	7.2	1389	17.8	0.7	0.2	9091
4	4	67.4	87.6	7.0	1408	16.7	0.6	0.2	8333
4	5	66.3	88.2	7.0	1429	16.8	0.6	0.2	8333
5	6	91.3	113.7	4.4	2273	18.8	4.1	1.2	8333
5	7	80.0	115.4	6.8	1449	14.7	0.6	0.2	7692
5	8	82.6	115.1	6.9	1449	16.5	3.7	1.3	7692
5	9	86.7	115.6	6.8	1471	17.3	1.6	0.5	0
5	10	83.4	114.9	7.3	1351	18.2	3.5	1.3	9091

Table A-4 Shock Response Data Collected At Eastman Kodak

VEL MPH	Test #	Channel 1				Channel 2				Channel 3			
		G's	Delta V	Time	F	G's	Delta V	Time	F	G's	Delta V	Time	F
4	1	22.5	148.2	39.4	1042	7.3	11.9	4.4	2273	162.4	8.1	0.4	0
4	2	19.7	111.5	33.1	1042	8.5	12.2	4.4	2273	64.4	4.3	0.6	0
4	3	19.8	104.0	32.8	1136	7.9	12.2	4.2	2381	56.6	3.7	0.4	0
4	4	21.3	139.8	38.2	278	8.0	11.3	9.4	2500	42.4	4.2	0.6	0
4	5	21.4	108.5	30.9	1220	7.0	10.7	4.4	2273	32.1	1.8	0.4	0
5	6	31.3	182.2	32.2	1087	9.1	1.3	1.0	1463	330.0	40.8	0.8	0
5	7	30.7	145.7	29.1	1190	9.2	1.4	0.8	0	81.9	8.5	0.4	0
5	8	30.7	145.6	30.0	1190	9.2	1.4	0.8	0	81.9	8.5	0.4	0
5	9	31.7	155.3	29.4	1389	5.6	1.1	1.0	0	180.1	6.5	0.6	0
5	10	30.2	186.9	34.1	1087	7.0	1.3	1.2	0	151.5	5.0	0.4	0
6	11	16.7	95.7	32.8	1163	5.0	0.8	1.0	0	112.5	15.5	1.0	0
6	12	17.0	99.0	34.4	1064	7.6	1.8	1.2	0	141.9	12.5	0.8	0
6	13	16.4	89.5	35.6	1136	6.3	1.1	1.0	0	50.6	6.7	0.6	0
6	14	17.1	98.8	36.6	1163	5.7	4.3	2.8	3571	56.5	11.4	0.8	0
6	15	17.1	96.9	35.6	1064	6.4	1.5	1.2	0	86.2	5.4	0.6	0
8	16	18.6	119.9	34.1	1020	4.8	5.6	5.8	1724	154.6	0.9	0.6	0
8	17	18.7	119.2	34.7	1020	6.7	6.1	5.0	2778	97.5	1.8	0.4	0
8	18	18.8	123.4	36.6	1087	4.3	8.4	6.2	1613	59.0	4.1	0.4	0
8	19	19.4	126.7	35.9	833	4.6	4.7	5.0	2778	103.4	0.9	0.4	0
8	20	19.0	125.4	36.9	685	4.5	3.4	4.0	2381	136.5	9.1	0.8	0
10g 50ms	21	15.5	76.7	45.0	725	8.0	5.4	3.6	2632	26.9	4.7	0.8	0
10g 50ms	22	15.3	75.9	46.3	676	6.9	5.0	3.6	2632	36.9	2.2	0.6	0
10g 50ms	23	15.9	75.7	46.6	758	5.5	4.3	3.8	2632	26.2	2.1	0.4	0
10g 50ms	24	16.8	78.7	46.3	962	4.9	3.8	3.8	2632	28.7	3.0	0.4	0
10g 50ms	25	15.8	72.2	46.6	1064	6.8	1.4	1.2	0	26.7	3.9	0.8	0
40g 10ms	26	23.8	10.9	2.6	3846	9.2	12.3	5.6	1786	135.8	10.6	0.4	0
40g 10ms	27	24.1	17.8	3.8	3846	8.1	12.6	6.0	1667	995.7	109.0	0.6	0
40g 10ms	28	24.5	18.0	3.8	2632	11.8	18.4	4.4	2273	139.7	3.1	0.6	0
40g 10ms	29	23.7	17.9	4.0	4167	20.4	25.0	4.4	2273	593.2	100.1	1.4	0
40g 10ms	30	24.3	22.7	4.8	2083	10.2	20.8	8.2	1220	287.1	17.8	0.6	0

Table A-5 Shock Response Data Collected At Ross Labs

VEL MPH	Test #	Channel 1				Channel 2				Channel 3			
		G's	Delta V	Time	F	G's	Delta V	Time	F	G's	Delta V	Time	F
4	11	30.3	151.9	27.9	498	5.0	0.2	0.2	0	15.1	139.3	40.6	244
4	12	31.8	154.5	27.4	535	4.3	3.5	4.2	3571	15.7	141.7	40.3	246
4	13	30.9	145.1	28.3	370	4.6	0.1	0.2	0	13.5	130.1	42.1	239
4	14	31.3	145.5	28.1	496	9.7	6.0	0.5	0	14.0	134.0	42.1	238
4	15	29.8	148.3	29.0	357	4.2	2.3	2.7	3846	13.4	131.4	42.5	237
5	16	43.2	194.9	25.4	398	5.7	4.3	4.0	2500	23.1	180.1	36.7	272
5	17	42.7	207.1	25.1	654	7.5	0.3	0.2	0	26.0	193.4	35.1	283
5	18	35.9	205.0	27.4	394	5.0	0.4	0.4	0	24.3	185.8	36.4	275
5	19	33.8	197.5	27.9	380	5.4	0.1	0.3	0	22.7	181.0	37.2	267
5	20	35.2	196.7	27.7	556	4.8	0.4	0.3	0	22.7	180.8	37.2	270
6	1	11.4	100.4	41.4	342	3.1	0.1	0.3	0	8.9	105.5	49.8	219
6	2	10.8	105.3	41.1	296	4.1	0.1	0.2	0	8.9	106.2	49.8	220
6	3	20.5	104.1	31.7	341	2.2	0.1	0.2	0	8.8	105.5	50.9	221
6	4	16.8	118.5	32.9	498	4.0	0.1	0.2	0	10.7	104.3	42.1	234
6	5	31.8	110.2	29.5	1099	3.4	4.4	6.2	1613	9.8	101.9	44.2	224
8	6	43.2	152.0	27.5	1087	6.1	6.7	4.3	2326	16.5	143.5	39.0	254
8	7	43.1	159.5	25.3	1042	7.1	1.0	0.9	0	17.6	149.5	39.0	256
8	8	37.9	150.3	26.3	513	7.9	0.9	0.4	0	16.8	148.0	40.0	249
8	9	32.7	150.7	27.5	513	6.0	0.3	0.6	0	15.4	140.7	40.7	245
8	10	33.8	160.0	27.1	379	8.2	0.1	0.3	0	16.2	146.0	40.6	248
10g 50ms	21	19.8	174.5	45.9	251	3.2	0.1	0.3	0	10.5	128.3	51.9	192
10g 50ms	22	23.6	157.5	41.5	254	3.2	0	0.2	0	9.8	122.9	52.3	198
10g 50ms	23	19.8	167.8	46.7	262	2.9	0	0.2	0	9.8	123.4	52.4	190
10g 50ms	24	13.2	167.8	56.0	269	1.7	0	0.2	0	10.2	127.7	52.9	190
10g 50ms	25	18.8	181.4	50.8	254	2.7	0.3	0.4	0	11.1	133.5	51.3	195
40g 10ms	26	38.2	68.2	5.8	1724	23.4	30.4	4.8	2041	39.9	85.7	10.5	952
40g 10ms	27	37.2	79.9	7.2	1471	32.1	8.5	1.2	8333	39.8	86.6	10.5	962
40g 10ms	28	37.4	79.2	7.1	0	42.4	18.6	1.2	8333	41.5	87.8	10.3	962
40g 10ms	29	37.3	80.4	7.5	1333	30.7	34.8	4.3	2326	39.1	86.8	10.6	975
40g 10ms	30	38.0	71.6	5.9	1695	23.0	4.9	0.9	0	37.3	84.8	10.7	943

Table A-6 Shock Response Data Collected At Georgia Pacific

VEL MPH	Test #	Channel 1				Channel 2				Channel 3			
		G's	Delta V	Time	F	G's	Delta V	Time	F	G's	Delta V	Time	F
4	11	40.7	180.4	25.5	5000	9.4	17.7	9.8	1235	27.9	154.9	27.7	365
4	12	40.3	184.5	25.9	5000	8.4	16.0	10.0	1176	28.5	156.8	27.2	369
4	13	39.6	180.5	25.8	5000	8.5	17.6	10.8	0	27.7	154.8	27.8	364
4	14	39.1	175.0	26.3	5000	8.1	16.8	10.0	0	26.0	150.7	28.5	351
4	15	41.2	175.5	25.6	5000	7.8	16.3	10.9	1149	26.1	150.9	28.5	352
5	16	57.0	224.4	24.5	917	17.1	31.1	8.0	2128	36.1	188.0	24.8	407
5	17	58.4	225.6	24.4	909	18.0	28.0	7.8	1299	36.6	188.1	25.0	403
5	18	58.4	225.7	23.9	909	18.0	32.0	7.8	1299	36.6	188.1	25.0	403
5	19	60.2	228.3	23.6	952	17.4	32.5	7.2	1389	36.7	189.6	24.8	405
5	20	63.7	232.3	23.6	1010	19.2	34.9	7.8	1282	37.0	189.7	24.8	407
6	1	42.2	113.1	26.7	5000	3.2	5.9	12.3	0	14.0	107.2	35.3	285
6	2	40.3	109.4	27.2	5000	2.9	5.8	10.8	0	13.6	106.3	35.7	281
6	3	39.7	107.9	27.2	5000	2.6	7.6	10.9	0	13.5	105.1	35.6	282
6	4	39.2	111.4	26.9	5000	2.5	7.6	11.7	0	13.9	106.8	35.3	283
6	5	38.9	110.7	27.2	5000	2.7	7.8	12.2	0	13.9	107.0	35.2	285
8	6	38.6	157.2	25.8	5000	8.4	14.4	10.6	0	22.6	138.4	30.1	334
8	7	38.3	157.3	26.3	5000	6.7	12.4	10.6	0	23.1	140.8	29.8	338
8	8	38.0	157.6	25.9	5000	6.8	11.4	10.6	1075	23.0	140.4	29.9	334
8	9	37.9	158.1	26.7	5000	6.3	12.3	10.5	1075	23.0	1.1	30.1	333
8	10	37.5	159.5	25.9	5000	6.6	14.3	10.3	0	23.1	141.0	29.9	337
10g 50ms	21	23.2	112.4	29.1	5000	1.7	2.2	6.3	0	10.0	113.1	49.4	203
10g 50ms	22	23.2	114.2	32.2	5000	1.2	1.9	7.2	0	9.9	112.4	49.6	203
10g 50ms	23	23.0	114.0	33.8	5000	1.2	1.5	6.7	0	10.1	114.1	49.3	204
10g 50ms	24	22.7	111.8	33.8	5000	1.6	1.8	6.6	0	10.0	113.0	49.1	205
10g 50ms	25	22.6	113.5	34.5	5000	1.3	1.6	7.0	0	10.3	114.8	49.0	205
40g 10ms	26	89.0	166.7	7.4	1351	30.7	39.6	6.3	1587	49.8	115.4	10.6	935
40g 10ms	27	91.6	166.5	7.8	1282	32.1	37.5	6.3	1587	49.8	114.9	10.7	926
40g 10ms	28	91.9	165.2	7.9	1282	32.8	36.4	3.8	1961	49.8	114.2	10.8	935
40g 10ms	29	87.6	166.6	8.1	1235	28.5	36.3	6.4	1562	49.8	114.8	10.6	943
40g 10ms	30	92.3	165.2	7.8	1299	33.1	35.3	3.8	2632	49.8	114.7	10.7	935

A-7 Shock Response Data Collected At Admiral Corp.

VEL MPH	Test #	Channel 1				Channel 2				Channel 3			
		G's	Delta V	Time	F	G's	Delta V	Time	F	G's	Delta V	Time	F
4	1	16.8	24	6.3	1587	8.6	1.5	3.8	2632	8.6	0.5	0.3	0
4	2	19.3	96.3	24.0	417	4.2	0.1	0.2	0	9.3	7.3	33.2	352
4	3	20.7	100.3	28.3	422	4.6	0.7	0.7	0	9.8	73.2	32.7	352
4	4	17.9	102.1	30.2	347	3.9	0.0	0.3	0	10.2	73.5	32.5	344
4	5	17.2	100.0	30.6	351	3.3	2.2	0.3	0	9.8	72.5	32.7	352
8	16	13.3	161.3	24.9	400	2.6	2.7	3.2	3125	21.2	124.4	28.5	424
8	17	30.9	161.5	24.7	403	6.3	0.2	0.2	0	21.7	126.3	28.8	426
8	18	29.2	165.4	27.7	394	2.5	12.2	1.6	10000	21.1	126.1	29.0	426
8	19	30.6	155.9	27.5	364	3.1	1.8	2.0	0	33.5	109.6	1.0	0
8	20	28.9	149.1	27.5	362	2.6	10.6	11.0	909	19.3	120.4	30.5	328