APPENDIX D

VRTC REPORT

TESTS REGARDING ALLEGED INERTIAL UNLATCHING OF SAFETY BELT BUCKLES

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
ENGINEERING TEST FACILITY
EAST LIBERTY, OHIO 43319

NOVEMBER 1992
FINAL REPORT

PREPARED FOR:
NATIONAL HIGHWAY SAFETY ADMINISTRATION
OFFICE OF DEFECTS INVESTIGATION
WASHINGTON, D.C. 20590

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
		DP92-017

4. Title and Subtitle	5. Report Date
Tests Regarding Alleged Inertial Unlatching of Safety Belt Buckles	November 1992
	6. Performing Organization Code: NRD-23
7. Author(s): Gavin Howe, Russ Kirkbride, Aloka Prasad, Mike Monk	8. Performing Organization Report No.: VRTC-72-0280
9. Performing Organization Name and Address: National Highway Traffic Safety Administration, Vehicle Research and Test Center, P.O. Box 37, East Liberty, Ohio 43319	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address: National Highway Traffic Safety Administration, 400 Seventh Street, S.W., Washington, D.C. 20590	13. Type of Report and Period Covered: FINAL REPORT 09/92 - 11/92
	14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This test program was performed to measure the performance of safety belt buckles under various test conditions, including simulation of real-world events, to determine if there is a failure mode caused by impacting the backside of safety belt buckles during crashes or sudden stops. Data was obtained from a series of bench tests on a representative sample of side-release safety belts including "parlor tricks" (video cassette, karate chop, etc.), a series of tests conducted on a safety belt mounted in a vehicle, and six vehicle-crash tests conducted with safety belts mounted in the vehicles.

From the test results, the buckle acceleration levels required to cause the buckles to release is highly dependant on belt tension. The acceleration level increases with increasing belt tension. The many bench tests performed during this investigation indicate that sufficient velocity between the occupant and the belt must exist for an occupant to open a safety belt latch. For non-rigid impact surfaces with 0 to 5 lbf tension, this "opening velocity" is approximately 15 mph. For lower velocities it is unlikely that any part of the body would cause accelerations high enough to actuate the belt. Even in a relatively severe side impact crash, the relative velocity between the buckle and the human hip will be well below 15 mph. This study is illustrative of why safety belts can be opened by applied impacts to the back of the buckle, while real world accident situations do not result in opening. In the "parlor tricks", a person hits the back of the buckle with a seemingly low severity impact that causes the buckle to open. In fact, the velocity used in these seemingly low severity blows to the buckle (in the range of 15 mph) are not possible to achieve in real accidents because of the small distances that exist between occupants and properly worn safety belt buckles.

17. Key Words	18. Distribution Statement
Safety Belt Buckles Inertial Unlatching	Document is available to the public from the National Technical Information Service, Springfield, VA 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

This test program was performed at the Vehicle Research and Test Center (VRTC) in response to a request by the Office of Defects Investigation (ODI), National Highway Traffic Safety Administration (NHTSA). The ODI had received a petition from the Institute for Injury Reduction (IIR) alleging unintended unlatching of safety belt buckles in various vehicles equipped with safety belts with side-release mechanisms (as opposed to end-release mechanisms). The petition alleges that the inertial unlatching of safety belt buckles occurs as a result of a sharp impact to the backside of the buckle.

2.0 OBJECTIVE AND TEST PROCEDURES

The objective of the test program was to measure the performance of the subject buckles under various test conditions, including simulation of real-world events to determine if there is a failure mode caused by impacting the backside of the safety belt buckles during crashes or sudden stops.

Data was obtained from a series of bench tests on a representative sample of side-release safety belts, a series of tests conducted on a safety belt mounted in a vehicle, and six vehicle-impact tests including two lateral moving-barrier crash tests, a truck/car crash test, and three FMVSS No. 208 crash tests (30 mph, frontal, static barrier).

2.1 Test Equipment

In the bench tests, a drop tower was used to perform a series of dynamic tests (Figures 2.1 and 2.2). Endevco 7264 accelerometers were mounted on the safety belt buckle, and on the impacting object. An Interface load cell (2000 pound-force) was used to measure the pre-tension and the force generated in the safety belt webbing due to the impact. A program known as HIDAS (High-speed Data Acquisition System) was used with a personal computer to record and display the data. Video recordings were also used to document some of the tests and setups.

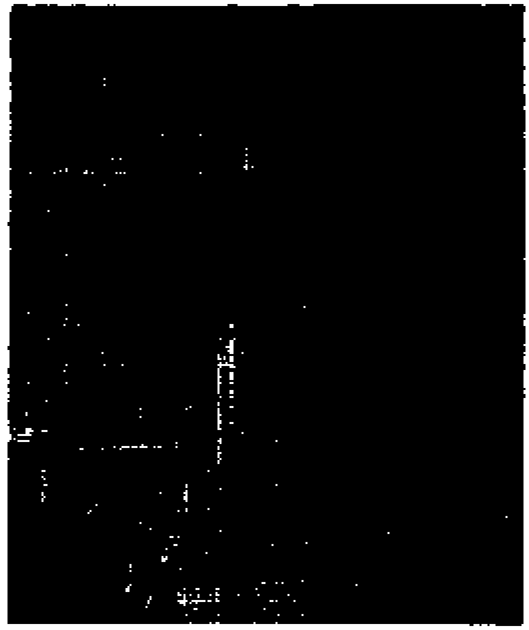


FIGURE 2.1: Drop Tower/Safety Belt Test Configuration

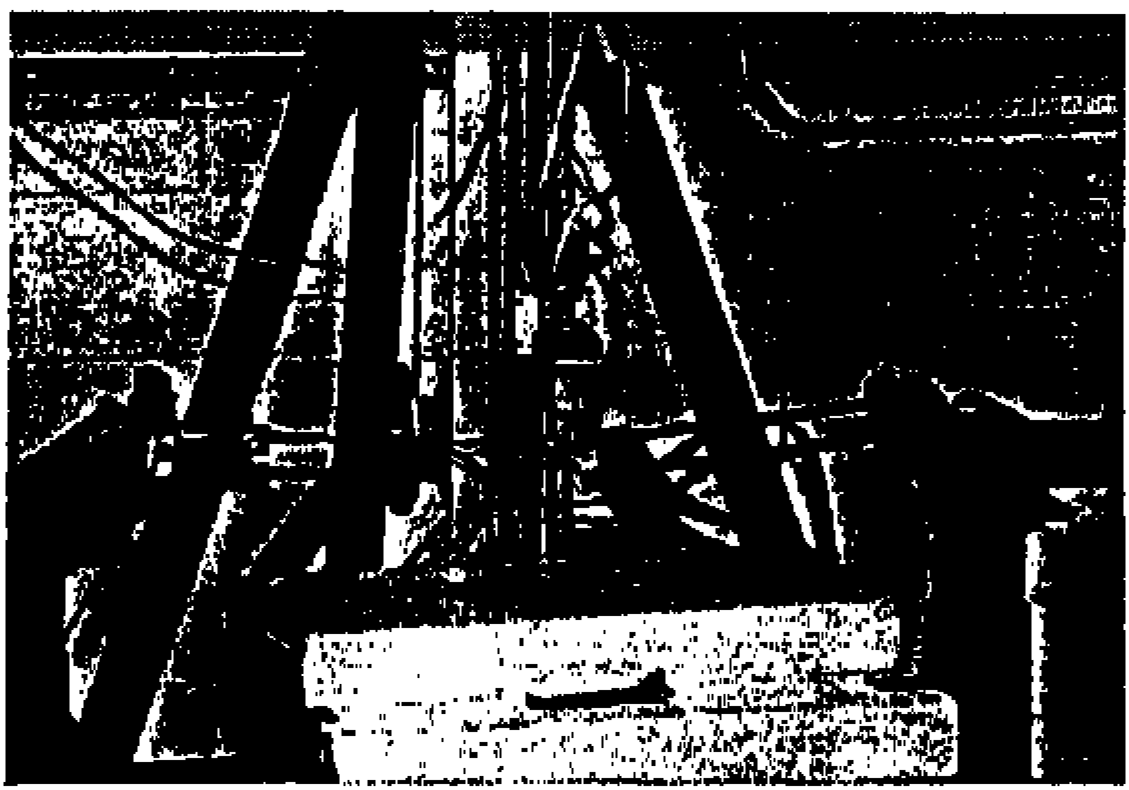


FIGURE 2.2: Safety Belt Test Fixture

Static tests were performed to determine force-deflection characteristics of the safety belt buckle side-release mechanism and of several padding materials used in the study. The basic test equipment for these tests included a tensile-test machine (Universal Testing Machine or UTM) and the instrumentation necessary to record the loading data for each sample tested.

Six crash tests were conducted on five vehicles. An accelerometer was mounted on the face (the push-button side of buckles with side-release mechanisms) of each safety belt buckle for all tests. This acceleration is nominally in a lateral or Y-direction relative to the vehicle. Although the buckles in three of the test vehicles had end-release mechanisms, lateral accelerations were still measured since the objective was to measure safety belt buckle lateral accelerations in a "crash" environment. In addition, data was also recorded for various vehicle accelerations. Entran Model EGA-125F-250DSC accelerometers were used to record the buckle and vehicle accelerations during the first two side-impact tests. Endevco Model 7264 accelerometers were used to record the buckle and vehicle accelerations during the subsequent tests. The shoulder and lap belt loads were measured using LeBow Model 3419 force transducers except for the three FMVSS No. 208 tests where no belt loads were measured. Several high-speed cameras and a 35mm camera were used for photographic documentation of these dynamic tests.

2.2 Test Procedures

2.2.1 Bench Test Procedures

A series of dynamic bench tests were conducted on Ford, GM, and Nissan safety belt buckles to collect data that demonstrated the dynamic conditions necessary to unlatch the buckle when it is impacted on its backside. This was accomplished by impacting the backside of the buckle with objects of varying degrees of hardness and weight and at various speeds. See Figure 2.2 for a description of the safety belt mounting hardware. A major portion of the tests were conducted by impacting the safety belt buckle with an 8 pound rigid steel block that was dropped on the back of the buckle from various heights. Three different materials were placed on the rigid mass to simulate different impacting conditions. Two of the materials were 1-inch-thick foams (Ethafoam and Ensolite) and the third material was a 1/8-inch-thick piece of dummy skin. The rigid mass and the three materials are shown in Figure 2.3. The measured force-deflection characteristics for the foams and for a Hybrid III dummy hip are given in Table 2.1. The force-deflection curves are in Appendix A. Tests were performed with 0, 5, 50, and 500 pounds-force (lbf) of pre-load on the belt to demonstrate a possible relationship between the buckle pre-load and the acceleration necessary to unlatch the buckle.

A series of "parlor tricks" were also performed to determine the acceleration levels for these seemingly low severity impacts. For these tests, the safety belt buckle was impacted with a videocassette, a "karate" chop, and a human hip.

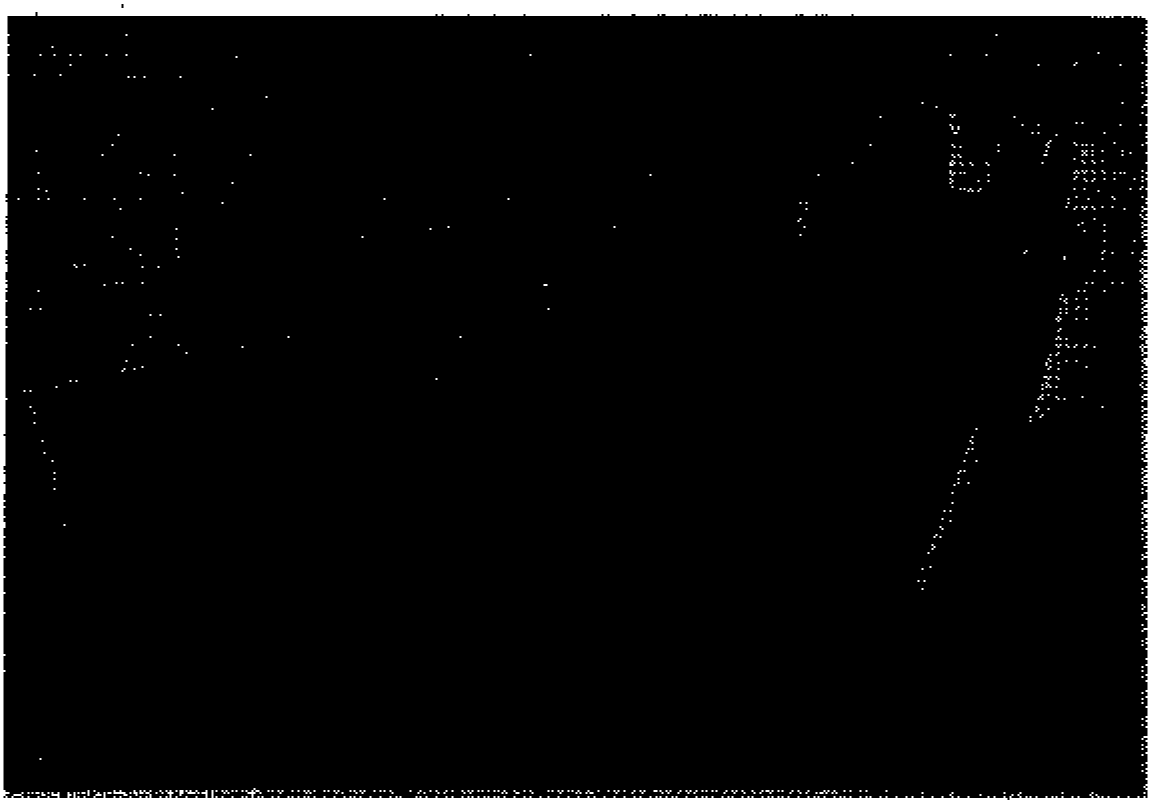


FIGURE 2.3: Rigid Mass and Padding Materials

TABLE 2.1: Linear Regression Equations for Padding Force-Deflection Curves (F=Force in lbf, D=Displacement in inches)

Material	Linear Regression Equation
Ethafoam	F = 117.4 x D - 5.0
Ensolite	F = 18.3 x D + 2.1
Hybrid III Hip	F = 304.9 x D - 72.5

2.2.2 In-Vehicle Test Procedures

A series of tests were performed on a GM belt mounted in a Chevy Impala. These tests included hitting the back of the safety belt buckle with a videocassette, a Fisher Price child seat, and a human volunteer's hip. The videocassette tests were performed to show that the accelerations required to open the safety belt buckle in the Chevy Impala were similar to those required to open the GM belt in the bench tests. The Fisher Price child seat tests were performed by mounting the child seat in the vehicle and properly orienting the safety belt through the child seat. The child seat was then slammed into the safety belt buckle by a human volunteer. The Fisher Price child seat was selected because it has a metal frame that can contact the safety belt buckle. The human volunteer tests were conducted by a single volunteer. The volunteer sat in the vehicle and was wearing the safety belt. The volunteer attempted to open the buckle by throwing his hip against the backside of the buckle.

2.2.3 Vehicle Impact Test Procedures

Two side-impact tests (920928-1 & -2) were conducted on the left (driver) side of the first vehicle, a 1985 Chevrolet C10 Scottsdale pickup truck. This truck had a Vehicle Identification Number (VIN) of 2GCDC14H3F1105869 (built 7/84), an odometer reading of 120,532 miles, and was equipped with an active 3-point belt restraint system (side-release mechanism). A moving barrier, used for FMVSS No. 301 testing, was used as the side-impact device. The vehicle accelerometer was mounted on the exterior of the passenger side "C" pillar area to measure lateral accelerations. An electrical "trip" wire was also used to record any buckle/tongue disconnection on an "event" channel for each buckle.

The first test had a 20 mph impact speed. Two 50th-percentile adult male test dummies were used in the driver and passenger seating positions. The second test had a 30 mph impact speed. A 50th-percentile adult male test dummy was used in the driver seating position and a 3-year-old child test dummy was used in a Fisher Price Model 9100 child restraint system (CRS) mounted on the passenger seat. The passenger belt retractor pendulum was locked after obtaining a belt pre-tension of 12 to 15 lbf with the CRS installed.

The third test, a 30 mph frontal-impact test (921006), was conducted on a new 1993 Dodge Dakota pickup truck equipped with an active 3-point belt restraint system (end-release mechanism). This test was conducted in accordance with FMVSS No. 208 into a fixed collision barrier. Two vehicle accelerometers were mounted on the floor behind the outboard rails of the front seats to measure longitudinal accelerations (X-direction relative to the vehicle). Two 50th-percentile adult male test dummies were used in the driver and passenger seating positions.

The fourth test, a 50 mph angled-impact test (921012), was conducted on a 1989 Ford Taurus equipped with an active 3-point belt restraint system (end-release mechanism). A moving test buck, made to simulate a medium-duty truck weighing approximately 20,000 lb, was used as the impact device. This test buck impacted the stationary Taurus at approximately 20° from the vehicle front and toward the driver side. Two vehicle accelerometers were mounted on the floor behind the outboard rails of the front seats to measure longitudinal accelerations (X-direction relative to the vehicle) and a tri-axial array of accelerometers was mounted on the floor near the center-of-gravity (CG) of the vehicle to measure longitudinal, lateral, and vertical accelerations (X, Y, and Z-directions relative to the vehicle). A 50th-percentile adult male test dummy was used in the driver seating position. The passenger seat was removed to allow camera coverage.

The fifth test, a 30 mph frontal-impact test (921013), was conducted on a new 1993 Nissan Sentra equipped with a passive 3-point belt restraint system (end-release mechanism). This test was conducted in accordance with FMVSS No. 208 into a fixed collision barrier. Two vehicle accelerometers were mounted on the floor behind the outboard rails of the front seats to measure X-accelerations and a tri-axial array of accelerometers was mounted on the floor near the center-of-gravity (CG) of the vehicle to measure X, Y, and Z-accelerations. Two 50th-percentile adult male test dummies were used in the driver and passenger seating positions.

The sixth test, a 30 mph frontal-impact test (921020), was conducted on a new 1993 Buick Century equipped with a passive 3-point belt restraint system (side-release mechanism). This test was conducted in accordance with FMVSS No. 208 into a fixed collision barrier. Two vehicle accelerometers were mounted on the floor behind the outboard rails of the front seats to measure X-accelerations and one accelerometer was mounted on the floor near the center-of-gravity (CG) of the vehicle to measure Y-accelerations. Two 50th-percentile adult male test dummies were used in the driver and passenger seating positions.

3.0 TEST RESULTS

3.1 Safety Belt Buckle Release Mechanism Static Force/Deflection Characteristics

The force on the release button required to open the buckles for the three belt tension conditions are listed in Table 3.1. For all three belts, the force required to open the buckle increased with increasing belt tension. Even with 300 lbf applied to the release mechanism, the GM buckle would not open with 500 lbf belt tension.

The linear regression equations for the force-deflection curves for the release mechanisms are listed in Table 3.2. The force-deflection curves are located in Appendix A.

TABLE 3.1: Safety Belt Buckle Release Force Values

Safety belt Manufacturer	Safety Belt Buckle Button Release Force (lbf)		
	0 lbf tension	50 lbf tension	500 lbf tension
Ford	6.0	13.2	89.4
GM	6.5	13.7	did not release
Nissan	4.8	11.7	59.5

TABLE 3.2: Linear Regression Equations for Button Force-Deflection Curves (F=Force in lbf, D=Displacement in inches)

Belt Type	Linear Regression Equation		
	0 lbf tension	50 lbf tension	500 lbf tension
Ford	F=58.7xD+1.72	F=176.6xD+3.1	F=609.8xD+6.71
GM	F=58.6xD+1.22	F=99.5xD+2.98	n.a.
Nissan	F=14.7xD+1.32	F=58.3xD-.38	F=263.8xD-10.3

3.2 Bench Test Results

The drop tower tests conducted for this analysis are listed in Table 3.3. The corresponding test numbers are listed in the appropriate table cell. If the table cell is blank, that particular test condition was not performed. In general, the drop height was started low and was continuously raised until the buckle released, or the acceleration levels exceeded the instrumentation ratings.

Buckle openings are listed in Table 3.4. If the table cell has a "yes", the buckle opened; if it has a "no", the buckle did not open. In general, the higher the belt tension the harder the belt was to open. There was one exception to this rule. The GM/Ensolite/50-lbf-belt-tension condition opened at a lower

TABLE 3.3: Drop Tower Test Conditions and Test Numbers

Padding	Drop Height (ft)	GM @ Pre-Load (lbf)			Nissan @ Pre-Load (lbf)		
		5	50	500	5	50	500
Ethafoam	2	9001					
	3	9002					
	4	9000&3	9006				
	5	9004&5	9007				
	6		9008		9029	9033	
	7		9009		9030	9034	
	8		9010		9031	9035	
	9				9032	9036	
	10.5		9011			9037	
Ensolite	3	9012					
	4	9013					
	5	9014					
	6	9015	9023&24		9038		
	7	9016	9022&25	9026	9039		
	8	9017	9021	9027		9042	
	9	9018&19	9020	9028	9040		
	10.5				9041	9043	
Dummy Skin	.5	9096					
	1	9097	9100		9065		
	2	9098	9101	9103	9067&69		
	3	9099	9102	9104	9068		
	4			9105	9070		
	5			9106	9071		
	6				9072		
Rigid	.5	9108&9					
	1	9107&10	9112				
	2	9111	9113	9114			
	3			9115			
	4			9116			
	5			9117			
	6			9118			
	7			9119			
	10.5			9120			

TABLE 3.4: Drop Tower Test Buckle Openings

Padding	Drop Height (ft)	GM @ Pre-Load (lbf)			Nissan @ Pre-Load (lbf)		
		5	50	500	5	50	500
Ethafoam	2	no					
	3	no					
	4	y/n	no				
	5	yes	no				
	6		no		no	no	
	7		no		no	no	
	8		no		no	no	
	9				no	no	
	10.5		no			no	
Ensolite	3	no					
	4	no					
	5	no					
	6	no	no		no		
	7	no	y/n	no	no		
	8	no	yes	no		no	
	9	yes	yes	yes	no		
	10.5				no	no	
Dummy Skin	.5	no					
	1	no	no		no		
	2	yes	no	no	no		
	3	yes	yes	no	no		
	4			no	no		
	5			no	yes		
	6				yes		
Rigid	.5	no					
	1	yes	no				
	2	yes	yes	no			
	3			no			
	4			no			
	5			no			
	6			no			
	7			no			
	10.5			yes			

drop height than the corresponding 5-lbf-belt-tension condition. There are two possible explanations. The accelerometer mount broke off the GM buckle at the end of the 5-lbf-belt-tension tests. A different buckle was used for the 50-lbf-belt-tension tests. This buckle may have been slightly easier to open than the first buckle. A more likely explanation is the degradation of the Ensolite. The Ensolite may have lost its resiliency due to multiple tests or due to the short time duration between tests. Identical tests were conducted with a used and a new piece of Ensolite. The peak acceleration of the buckle was approximately 200 g's higher for the old versus the new (using unfiltered data). This suggests a degradation of the Ensolite, but more tests would need to be conducted to confirm this hypothesis.

The peak buckle accelerations are listed in Table 3.5. All of the acceleration traces were filtered with a BLPP 500 Hz 10-pole filter. The peak buckle accelerations listed in this table are for the initial impact of the rigid mass. Sometimes there were secondary peaks that were of greater magnitude than the initial peak. These secondary peaks were ignored because they did not cause the buckle to release. If a table cell is filled with an "n.a." the accelerometer mount separated from the buckle during testing or data was not taken because of instrumentation limits. Figure 3.1 shows a series of acceleration data for three tests. In the first test, the secondary peak is larger than the first. For the second test, the drop height was increased and the initial peak is greater than the secondary peak. In the third test the drop height is sufficient enough to open the buckle and there is no secondary peak.

The videocassette, karate chop, and hip-impact test results are summarized respectively in Tables 3.6, 3.7, and 3.8. For the videocassette and karate chop tests, the pre-load on the belt was 5 lbf. For the hip-impact tests there was judged to be no tension on the belt.

TABLE 3.5: Peak Accelerations (g's) for the Drop Tower Tests

Padding	Drop Height (ft)	GM @ Pre-Load (lbf)			Nissan @ Pre-Load (lbf)		
		5	50	500	5	50	500
Ethafoam	2	122.8					
	3	125.1					
	4	170 & 146	156.5				
	5	234 & 208	182.2				
	6		228.6		271.6	259	
	7		300.8		339.0	295.4	
	8		322.3		378.2	325.7	
	9				401.9	377.4	
	10.5		413.7			435.4	
Ensolite	3	74.6					
	4	140.8					
	5	196.1					
	6	317.2	338 & 257		174.0		
	7	493.6	370 & 428	397.7	305.5		
	8	466.9	512.4	466.7		470.1	
	9	684 & 387	629.9	n.a.	502.0		
	10.5				550.9	637.3	
Dummy Skin	.5	136.6					
	1	370.4	178.7		299.4		
	2	320.2	400.2	587.3	3046315		
	3	450.1	369.3	500.5	449.5		
	4			608.8	401.8		
	5			638.1	514.6		
	6				482.0		
Rigid	.5	333 & 232					
	1	270 & 301	181.8				
	2	456.6	n.a.	n.a.			
	3			n.a.			
	4			n.a.			
	5			n.a.			
	6			n.a.			
	7			n.a.			
	10.5			n.a.			

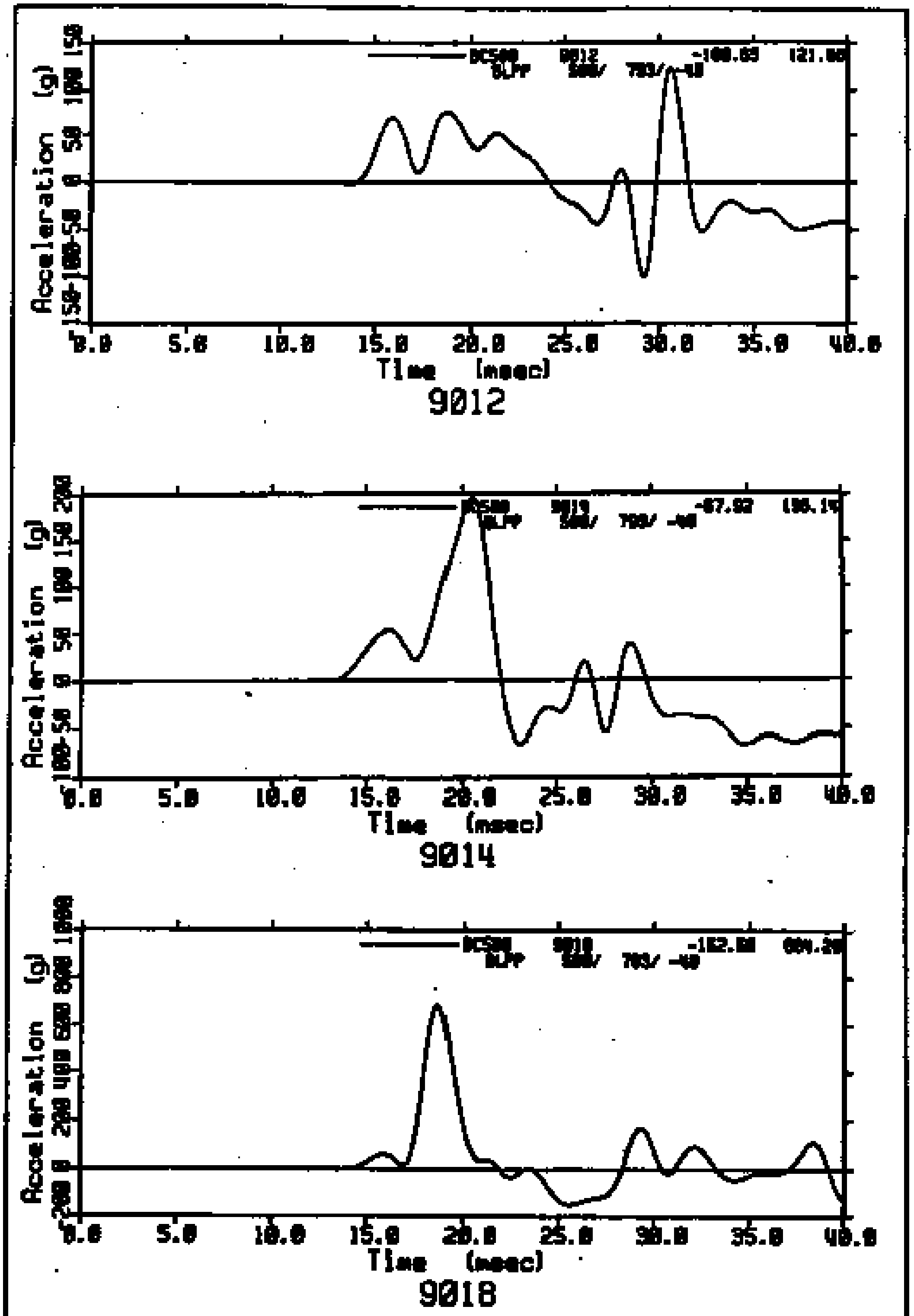


FIGURE 3.1: Series of Acceleration Traces for GM/5-lbf-Belt-Tension/Ensolite Tests

TABLE 3.6: Summary of Videocassette Impact Tests

Buckle Manufacturer	Test Number	Open?	Peak Acceleration
GM	8006	Yes	256.8
GM	8007	Yes	176.2
GM	8008	No	77
GM	8009	No	162.4
GM	8010	Yes	191.7
GM	8011	Yes	397.9
GM	8012	Yes	709.2
Nissan	9044	No	255.5
Nissan	9045	No	339.4
Nissan	9046	No	450.2
Nissan	9047	No	495.9
Nissan	9048	No	445.6
Nissan	9049	No	433.3
Nissan	9050	No	416.4
Nissan	9051	No	393
Ford	9082	Yes	261.2
Ford	9083	No	184.3
Ford	9084	Yes	215.2

TABLE 3.7: Summary of Karate Chop Impact Tests

Buckle Manufacturer	Test Number	Open?	Peak Acceleration
GM	8001	Yes	224.3
GM	8002	No	108.2
GM	8003	No	157.2
GM	8004	No	133.3
GM	8005	Yes	188.7
Ford	9085	No	67.7
Ford	9086	No	101.1
Ford	9087	No	120.2
Ford	9088	No	176.7
Ford	9089	No	186
Ford	9090	No	207.5
Ford	9091	No	172.2
Ford	9092	No	242.1
Ford	9093	No	264.1

TABLE 3.8: Summary of Human Hip Impact Tests

Buckle Manufacturer	Test Number	Open?	Peak Acceleration
GM	8013	Yes	95.2
GM	8014	No	54.8
GM	8015	No	56.5
GM	8016	Yes	263.6
GM	8017	Yes	202.8
GM	8018	Yes	152.7
GM	8019	Yes	116.9
GM	8020	No	74.3
GM	8021	No	119
GM	8022	Yes	220
Nissan	9060	No	234.3
Nissan	9061	No	403
Nissan	9062	No	299.4
Nissan	9063	No	386.5
Ford	9076	Yes	252.6
Ford	9077	No	109.7
Ford	9078	No	272.2
Ford	9079	Yes	166.5
Ford	9080	Yes	161.3
Ford	9081	No	117.8

The range of accelerations for both opening and non-opening test conditions are summarized in Table 3.9. Acceleration ranges for each combination of impacting object, belt pre-load, and belt manufacturer are tabulated. Overall acceleration ranges for each combination of belt pre-load and belt manufacturer are also tabulated (overall meaning all types of impacting objects).

The data summarized in Table 3.9 shows that there is a great deal of overlap in the peak acceleration levels that would and would not open the safety belt buckle. It was judged that both the peak acceleration and the pulse duration were important in determining whether the latch would actuate. It was thought that if both peak acceleration and pulse duration were taken into account, that the degree of overlap in the data may be reduced. The Head Injury Criteria (HIC) is a calculation that considers both peak acceleration and pulse duration. Even though the buckle accelerations are not head impacts, HIC calculations were made on these acceleration pulses in an attempt to reduce the degree of overlap. Cumulative distributions of the acceleration traces were also calculated to try and reduce the overlap in the data. Neither the HIC calculations or the cumulative distributions significantly reduced the degree of overlap. The results of these calculations are in Appendix B.

Comparing the minimum accelerations required to open the belts for different levels of belt pre-tension shows that the minimum acceleration level to open the buckle increases with belt tension. This is not surprising since the force required to open the buckle increases with increasing belt tension.

The safety belt buckle acceleration and belt tension data are given in Appendix C.

3.3 In-Vehicle Test Results

The results of the videocassette tests are listed in Table 3.10. These tests were primarily performed to show that the acceleration levels required to open this belt were similar to those in the bench tests. Comparing the results in Table 3.10 to the videocassette-GM buckle results listed in Table 3.9 shows that the belt opening acceleration levels required for opening are similar.

TABLE 3.9: Safety Belt Buckle Opening and Non-Opening Peak Acceleration Ranges

Impacting Object	Buckle Manufacturer	Belt Pre-Load (lbf)	Opening Range (g's)	Non-Opening Range (g's)	Percent Overlap
Human Hip	GM	0	95-264	55-119	11.5
Videocass.	GM	5	176-709	77-162	0
Karate Chop	GM	5	189-224	108-157	0
Ethafoam	GM	5	170-234	123-146	0
Ensolite	GM	5	387-684	75-494	17.6
Dummy Skin	GM	5	320-450	137-370	16.0
Rigid	GM	5	270-456	232-333	28.1
Ethafoam	GM	50	-	156-414	0
Ensolite	GM	50	370-630	257-428	15.5
Dummy Skin	GM	50	369	179-400	14.0
Rigid	GM	50	-	182	0
Ensolite	GM	500	506	398-467	0
Dummy Skin	GM	500	-	500-638	0
Rigid	GM	500	no data	no data	n.a.
Human Hip	Nissan	0	-	234-403	0
Videocass.	Nissan	5	-	255-496	0
Ethafoam	Nissan	5	-	272-402	0
Ensolite	Nissan	5	-	174-551	0
Dummy Skin	Nissan	5	482-515	299-450	0
Ethafoam	Nissan	50	-	259-435	0
Ensolite	Nissan	50	-	470-637	0
Human Hip	Ford	0	110-272	161-253	88.3
Videocass.	Ford	5	215-261	184	0
Karate Chop	Ford	5	-	68-264	0
Overall	GM	0	95-264	55-119	11.5
Overall	GM	5	170-709	75-494	51.1
Overall	GM	50	369-630	157-428	32.3
Overall	GM	500	506	398-638	55.0
Overall	Nissan	0	-	234-403	0
Overall	Nissan	5	482-515	174-551	18.3
Overall	Nissan	50	-	259-637	0
Overall	Ford	0	110-272	161-253	0
Overall	Ford	5	215-261	68-264	25.0

TABLE 3.10: Summary of In-Vehicle Videocassette Tests

Impacting Object	Buckle Manufacturer	Opening Range	Non-Opening Range
Videocassette	GM	260-282	131-181

The results of the Fisher Price child seat tests are listed in Table 3.11. None of these tests caused the safety belt buckle to open. The maximum acceleration levels produced fall in the range of values required to open the buckle when there is no tension on the belt (Table 3.9), but are below the required accelerations for even 5 lbf tension in the belt. Even though belt force was not measured in these tests, it is very likely that belt tension was produced when the child seat was slammed into the back of the buckle.

TABLE 3.11: Summary of In-Vehicle Fisher-Price Child Seat Tests

Impacting Object	Buckle Manufacturer	Opening Range	Non-Opening Range
F-P Child seat	GM	-	57-125

The human volunteer hip tests were done primarily to show the difficulty in opening the safety belt buckle with the part of the anatomy that impacts a safety belt buckle in an actual crash environment compared to the relative ease of opening the safety belt buckle with hard surfaced objects like a videocassette cartridge. The results of the human volunteer hip tests are listed in Table 3.12. None of these tests caused the safety belt buckle to open. The acceleration levels were well below those required to open the buckle, even with zero tension in the belt. Although belt tension was not measured in these tests, the volunteer noted that a significant belt tension was produced.

TABLE 3.12: Summary of In-Vehicle Human Hip Tests

Impacting Object	Buckle Manufacturer	Opening Range	Non-Opening Range
Human Hip	GM	-	14-20

The safety belt buckle acceleration data for the in-vehicle tests are given in Appendix D.

3.4 Vehicle Impact Test Results

The peak buckle acceleration and the shoulder belt force at the peak acceleration for each crash test are listed in Table 3.13. Most of the acceleration levels are well below those required to open the safety belt buckle, even with zero tension. The driver safety belt buckle accelerations for the '85 Chevy 30 mph side impact and the '89 Taurus/truck 20° frontal impact have peaks that are within the range of opening the buckle with zero tension in the belt and slightly below those required to open the buckle with 5 lbf belt tension. The driver side buckle acceleration and shoulder belt force for the '85 Chevy (30 mph) and the Taurus/truck tests are plotted respectively in Figures 3.2 and 3.3. For the '85 Chevy test, the shoulder belt had 40 lbf tension at the beginning of the largest acceleration pulse and 140 lbf tension at peak acceleration. For the Taurus/truck test, the shoulder belt had over 600 lbf tension at the beginning of the pulse and over 800 lbf tension at the peak acceleration. The peak accelerations required to open the safety belt buckles with 50 lbf of pre-load are well above those seen for these crash tests (at least 270 g's required).

Table 3.13: Summary of Peak Buckle Acceleration and Corresponding Belt Tension for the Vehicle Impact Tests

Test Vehicle	Type of Vehicle Impact	Impact Velocity (mph)	Driver		Passenger	
			Buckle Accel (g's)	Belt Force (lbf)	Buckle Accel (g's)	Belt Force (lbf)
'85 Chevy P/U	Side	19.5	43.6	44	n.a.	n.a.
'85 Chevy P/U	Side	30.1	134.7	142	40.7	46
'93 Dakota P/U	Frontal	29.3	58.0	n.a.	35.9	n.a.
'89Taurus/Truck	20° Frontal	51.5	152.5	823	n.a.	n.a.
'93 Sentra	Frontal	29.3	21.2	n.a.	41.6	n.a.
'93 Century	Frontal	29.3	16.4	n.a.	21.0	n.a.

The safety belt buckle acceleration and belt tension data for the vehicle impact tests are given in Appendix E.

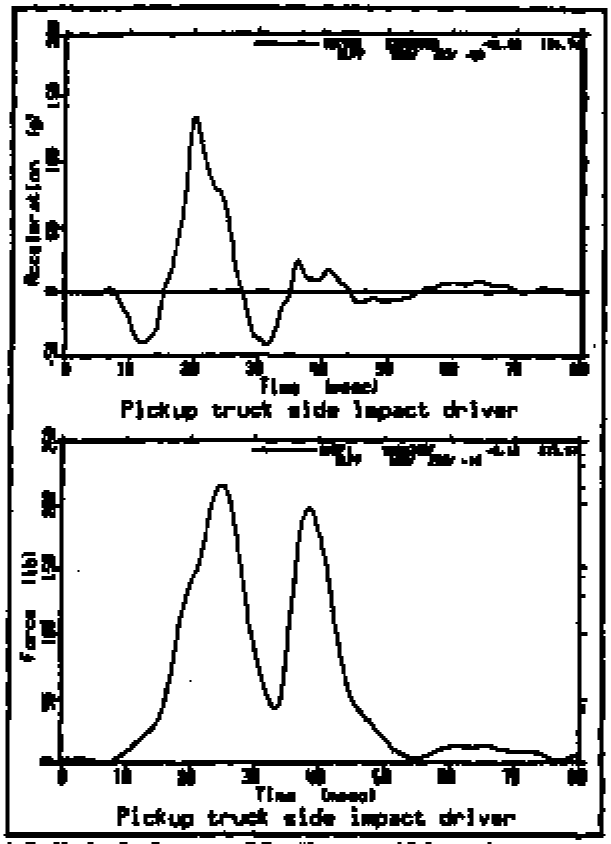


FIGURE 3.2: 85 Chevy (30mph) Driver Buckle Acceleration and Shoulder Belt Force

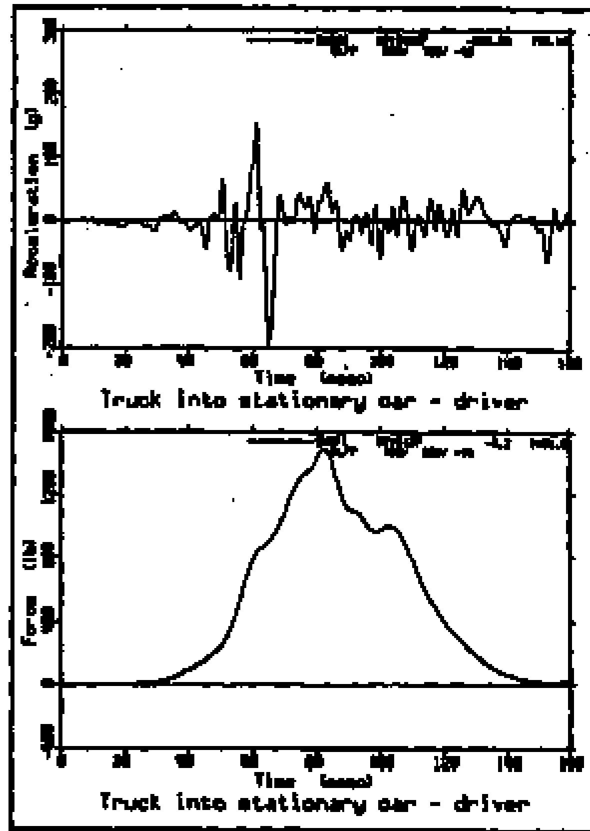


FIGURE 3.3: Taurus/Truck Driver Buckle Acceleration and Shoulder Belt Force

4.0 DISCUSSION

4.1 Peak Acceleration and Pulse Width Required for Buckle Opening

It was judged that both peak acceleration and time duration were important in determining whether or not the latch would actuate. This is because the safety belt actuation button must displace the required distance before opening occurs, and therefore shorter duration pulses would be expected to require higher accelerations and vice versa.

The peak safety belt buckle accelerations for the GM 5 lbf tension tests are plotted as a function of pulse width in Figure 4.1. The GM data was used because more tests were performed with the GM buckle. The GM 50 lbf tension test results are plotted in Figure 4.2. The pulse widths were measured from when the acceleration pulse first reaches 10% of the peak to when it comes back down to 10% of the peak. It is noted that the pulse durations vary between 2 and 10 milliseconds, which is not a very large spread. This is because of practical limitations of the drop tower fixture for testing the belts. Softer paddings, of reasonable thickness, would not result in buckle opening from the highest drop height (10.5 feet). If the thickness was reduced, the soft padding bottomed out, resulting in stiff contact.

A mathematical model was derived to examine the effect of pulse amplitude and duration. The model consisted simply of two masses representing the buckle and button, and a linear spring connecting the masses. The mass values were derived by disassembling and weighing the components of a buckle, and the spring constant was derived from the data measured in the UTM, at various levels of belt tension. The resulting differential equation of motion was solved using a PC-based software system called Mathematica. Appendix F contains a description of the model, the derived parameters, and the analysis of output values. Figure 4.3 contains the theoretical relationships between the amplitude and pulse duration required for belt opening. It is noted that the values are highly dependant upon belt tension. At low belt tensions, peak amplitudes of 200 g's are sufficient to open the belt, while at 200 lbf of belt tension, peak accelerations of approximately 1000 g's are required.

The relationships obtained from the modeling were overlaid with the experimental results for the GM belt at tensions of 5 and 50 lbf. The results are shown in Figures 4.4 and 4.5. It is noted from the 5 lbf results, that the theoretical line agrees quite well with the experimental data. That is, all belt openings occurred at levels above the line, several being very close to the line. It is also noted on the 5 lbf response plot that there are several test responses above the line which did not open. This may indicate a deficiency in the assigned pulse durations, or that more factors are involved in producing opening

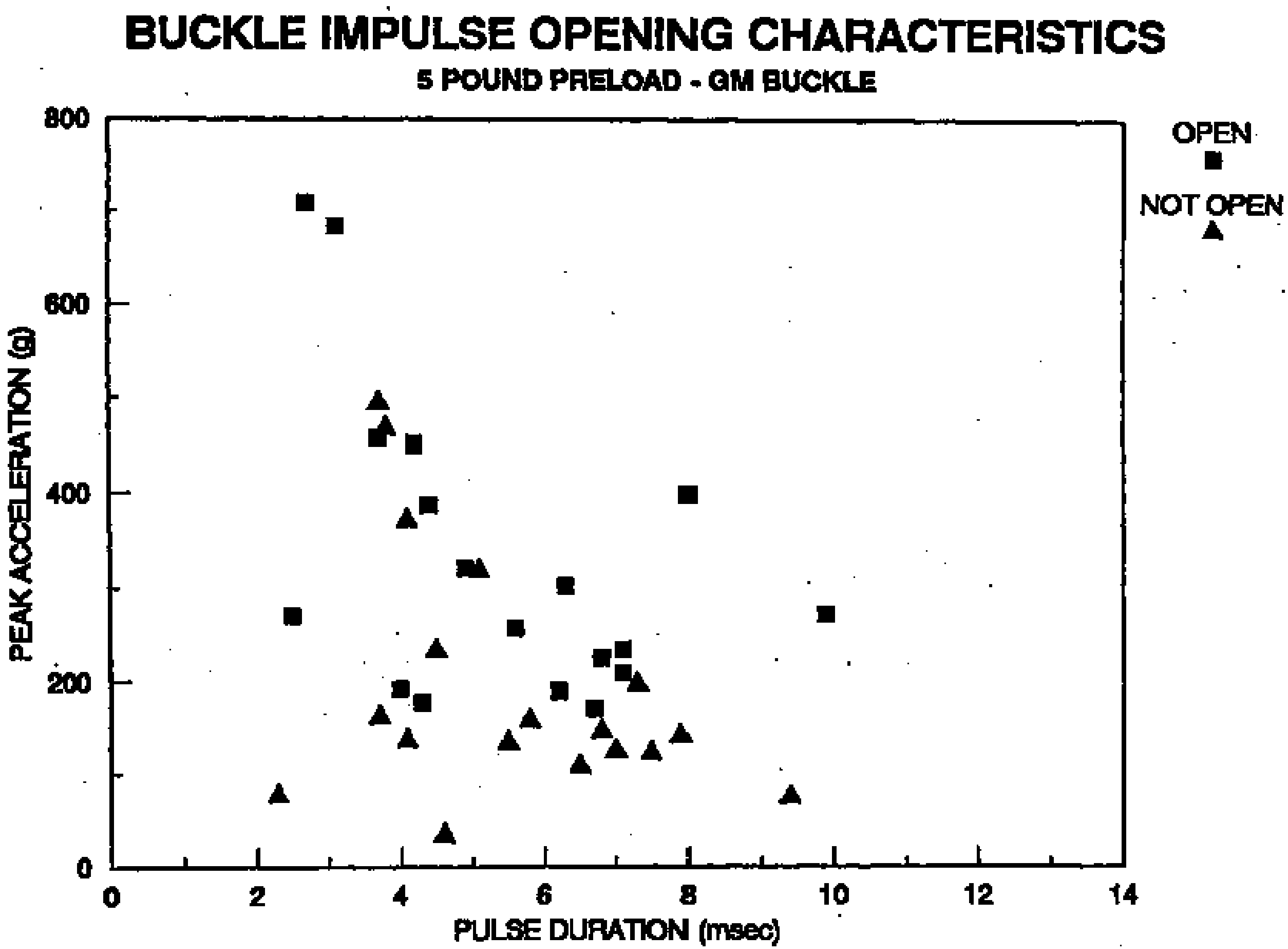

BUCKLE IMPULSE OPENING CHARACTERISTICS
5 POUND PRELOAD - GM BUCKLE
OPEN
NOT OPEN
PEAK ACCELERATION (g)
0
200
400
600
800
PULSE DURATION (msec)
0
2
4
6
8
10
12
14

FIGURE 4.1

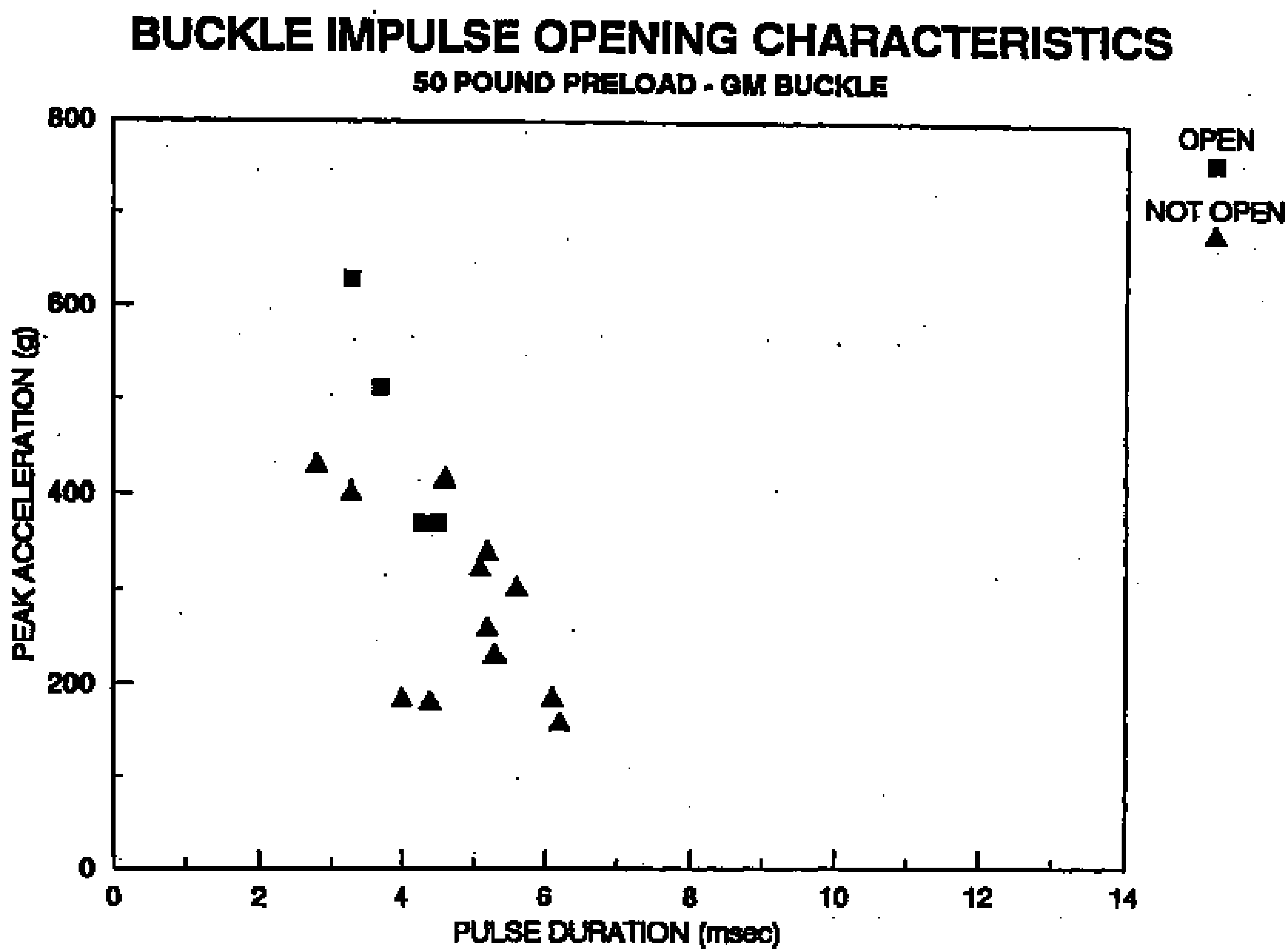

BUCKLE IMPULSE OPENING CHARACTERISTICS
50 POUND PRELOAD - GM BUCKLE
800
600
400
200
0
PEAK ACCELERATION (g)
0
2
4
6
8
10
12
14
PULSE DURATION (msec)
OPEN
NOT OPEN

FIGURE 4.2

PEAK BUCKLE ACCELERATION AS A FUNCTION OF PULSE DURATION - MATH MODEL RESULTS

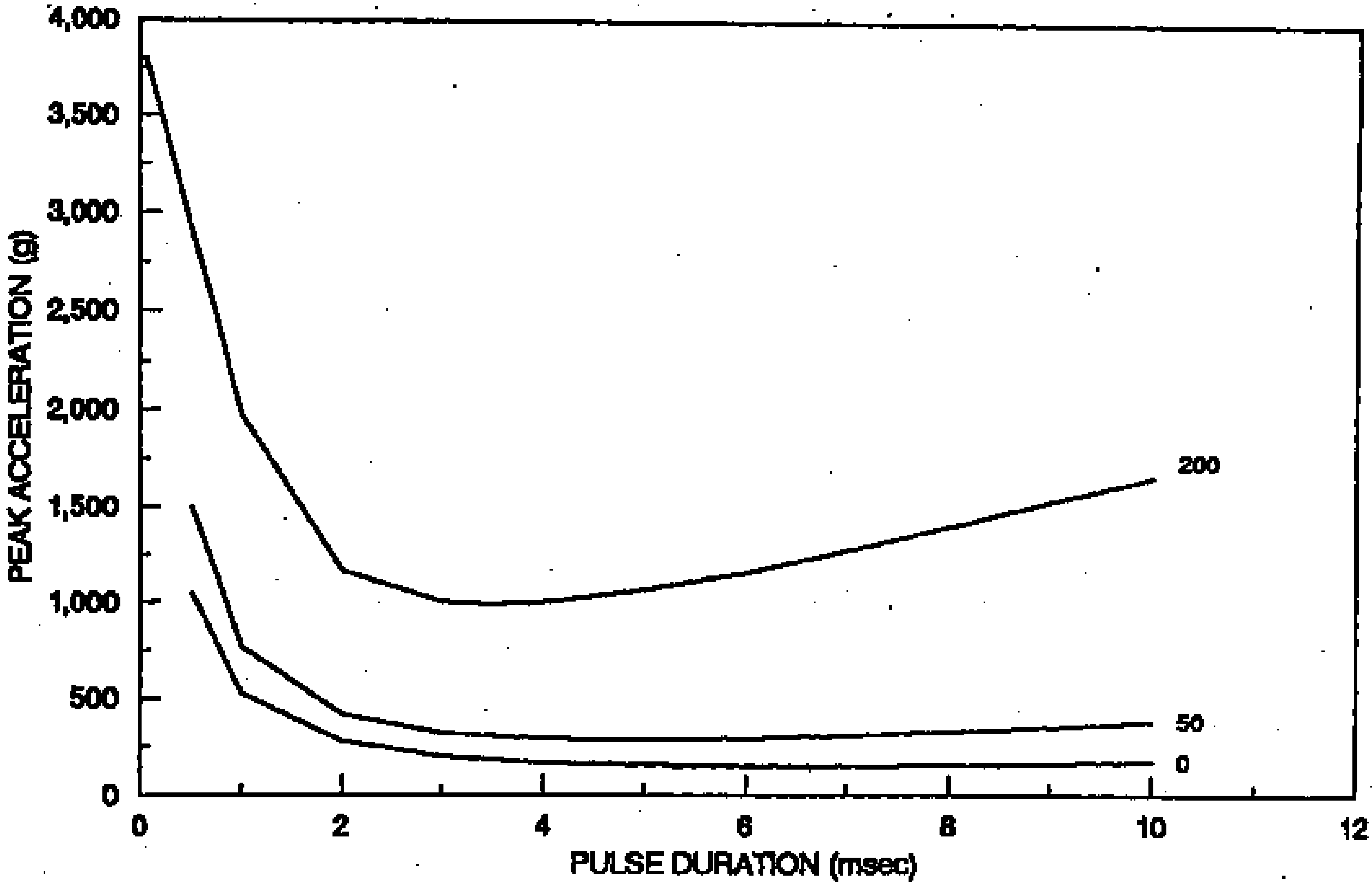


FIGURE 4.3

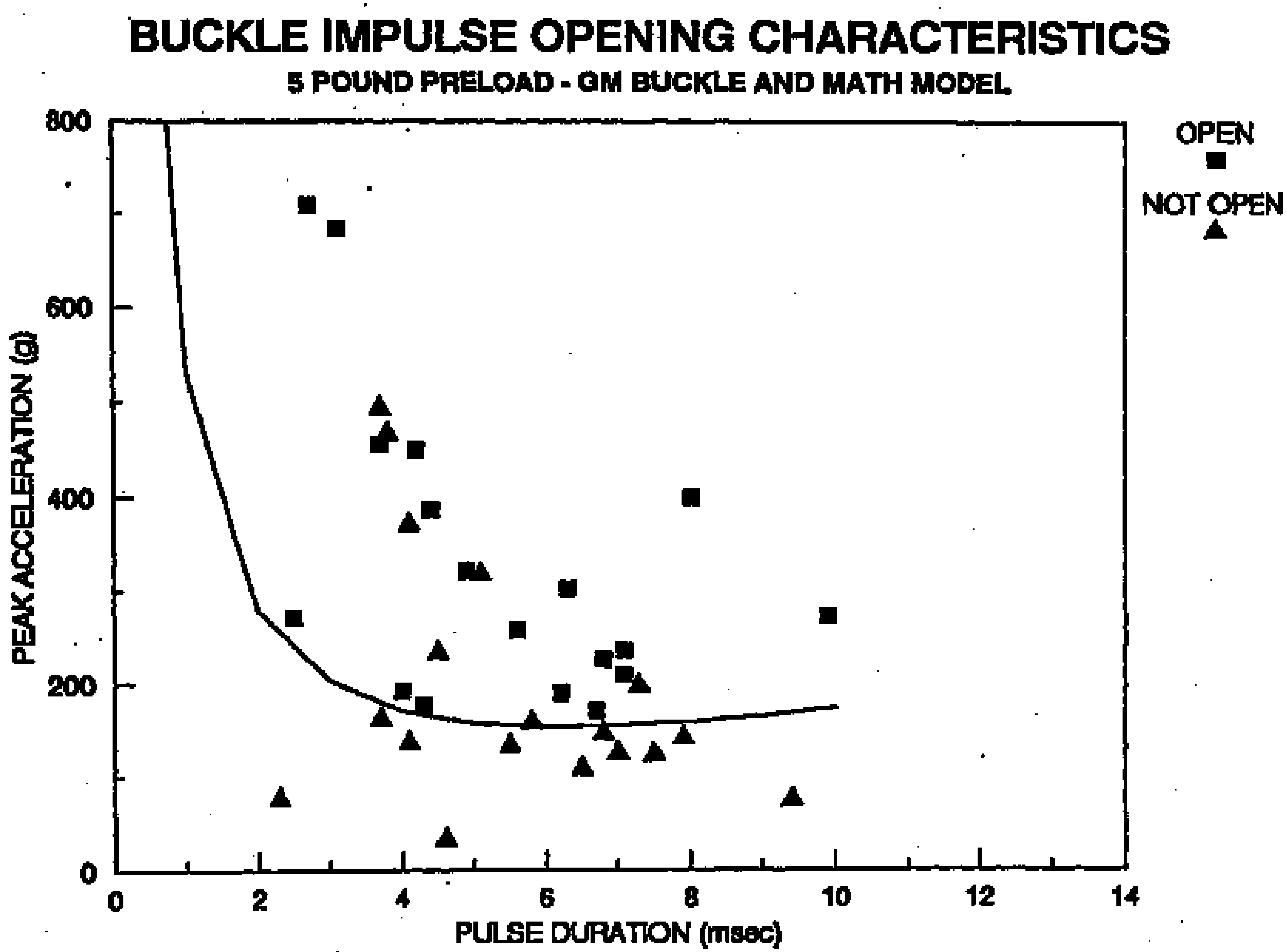
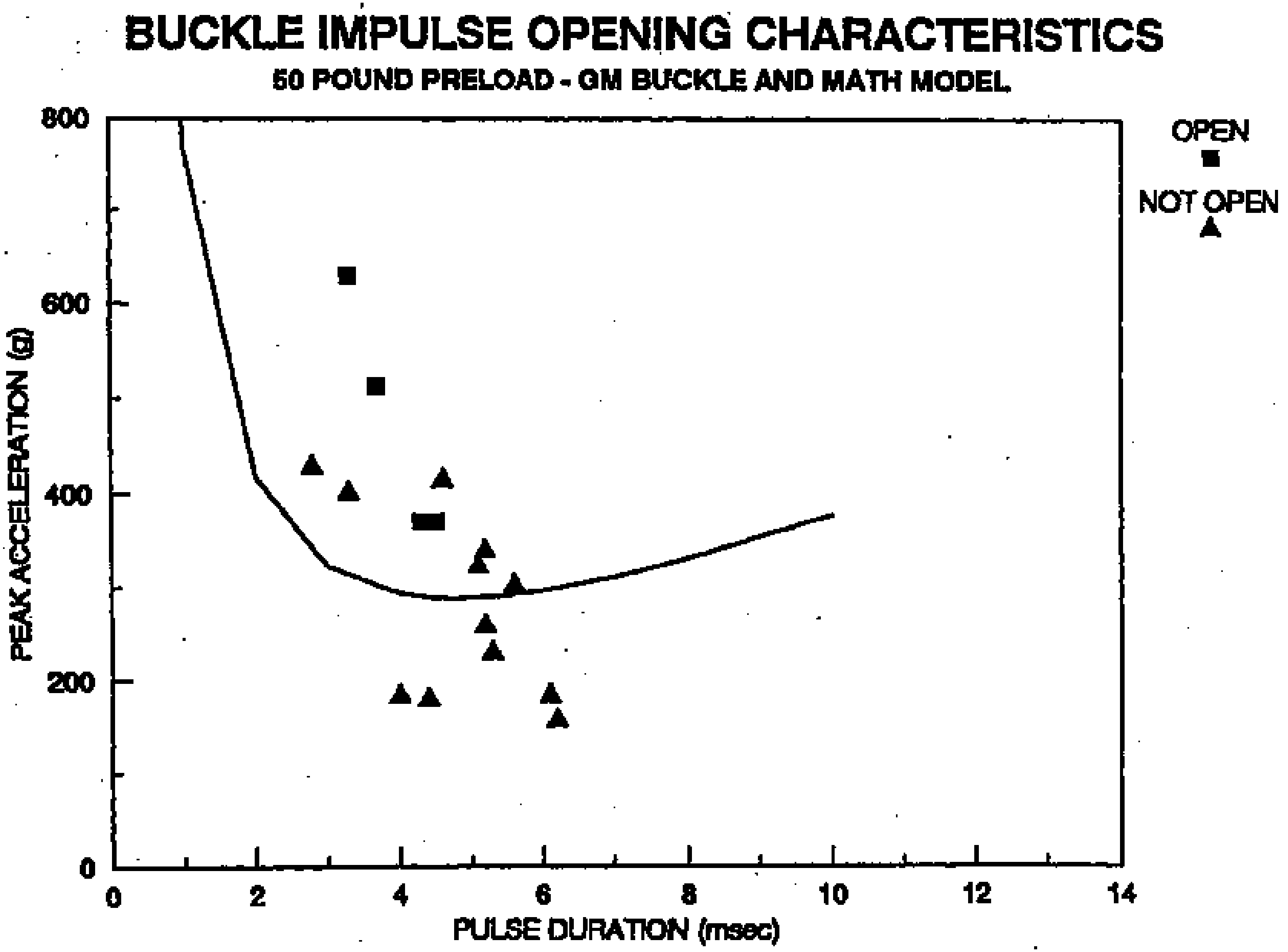

BUCKLE IMPULSE OPENING CHARACTERISTICS
5 POUND PRELOAD - GM BUCKLE AND MATH MODEL
PEAK ACCELERATION (g)
800
600
400
200
0
0
2
4
6
8
10
12
14
PULSE DURATION (msec)
OPEN
NOT OPEN

FIGURE 4.4



BUCKLE IMPULSE OPENING CHARACTERISTICS
50 POUND PRELOAD - GM BUCKLE AND MATH MODEL
800
600
400
200
0
PEAK ACCELERATION (g)
0
2
4
6
8
10
12
14
PULSE DURATION (msec)
OPEN
NOT OPEN

FIGURE 4.5

than just the pulse. Perhaps friction, random vibrations of the casing, or other parameters also affect the opening levels of the system.

The responses shown on the 50 lbf pre-load are similar, but the data are fewer and more narrow in pulse durations. Again, several did not open at responses above the line. Overall, it is judged that the theoretical relationships are indicative of the experimental responses.

Based upon the mathematical model and test data, it is apparent that safety belt systems in real vehicle crash environments must be analyzed on the basis of buckle acceleration amplitude and duration, as well as the tension on the belt at the time of peak buckle acceleration. The crash test responses of belt buckles are added to the 50 lbf belt tension data and math model in Figure 4.6. The 200-lbf belt tension math model results and the crash test responses are plotted in Figure 4.7. All of the crash test accelerations are well below the accelerations required to open the buckle with either 50 or 200 lbf belt tension.

4.2 Analysis of Velocity of Occupant/Belt Interaction in Side Collisions

The many bench tests performed during this investigation indicate that sufficient velocity between the occupant and the belt must exist for an occupant to open a safety belt latch. It has been demonstrated that the buckle can be actuated by impacting it from the back with various objects such as a videocassette or the edge of a hand. In all cases, the velocity of the impact to the belt must be sufficient to generate the high accelerations required for opening. For non-rigid impact surfaces, this "opening" velocity would be approximately 15 mph (corresponding to drop height greater than 7 feet). For lower velocities, it is unlikely that any part of the body would cause accelerations high enough to actuate the belt.

It was previously shown that the accelerations measured in severe crash tests were well below the thresholds required for belt actuation. Another way of looking at the same phenomena is to analyze the velocity profile of an occupant in a severe side impact collision. If the occupant/belt buckle impact

BUCKLE IMPULSE OPENING CHARACTERISTICS

50 POUND PRELOAD - GM BUCKLE, MATH MODEL, AND CRASH DATA

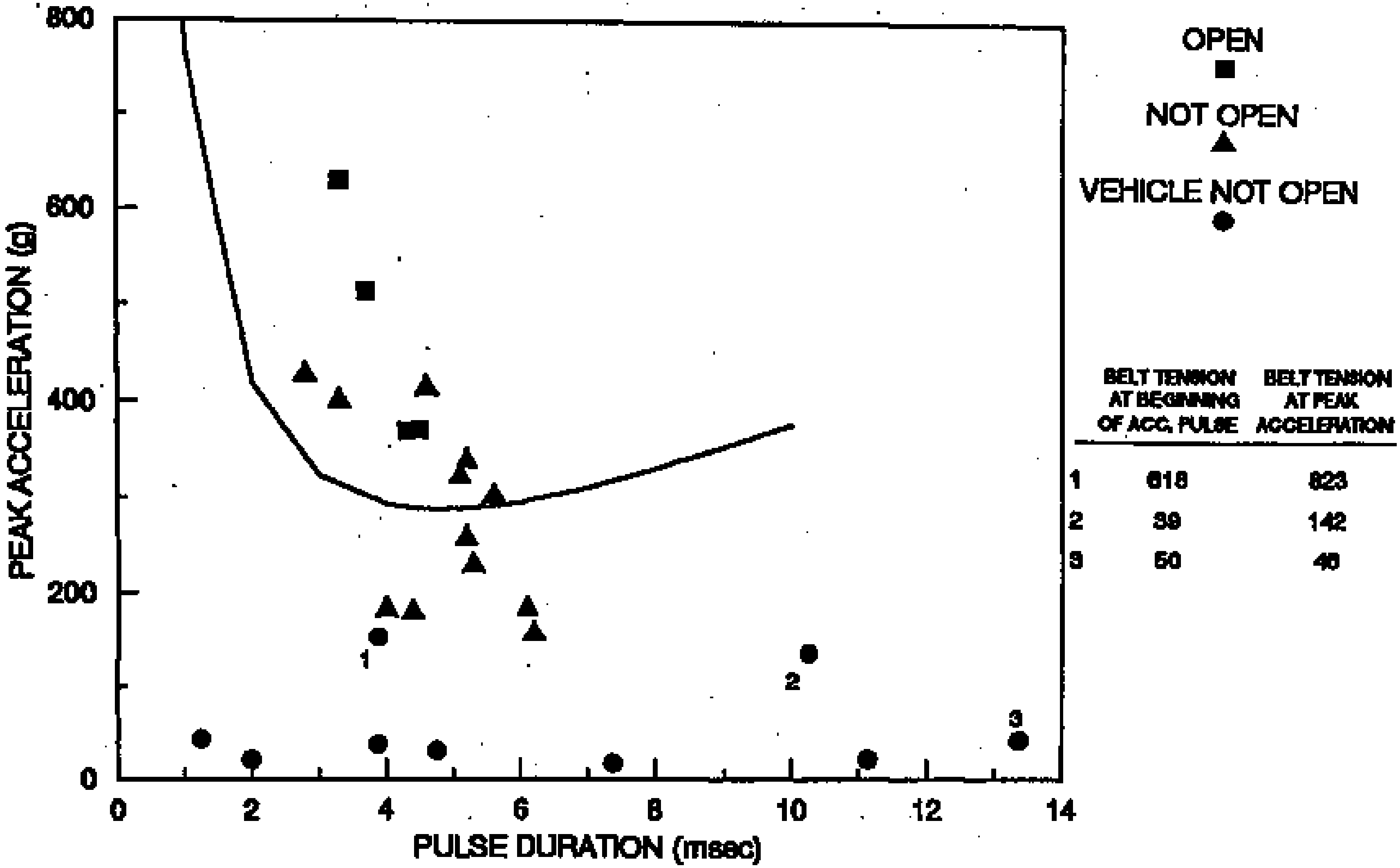
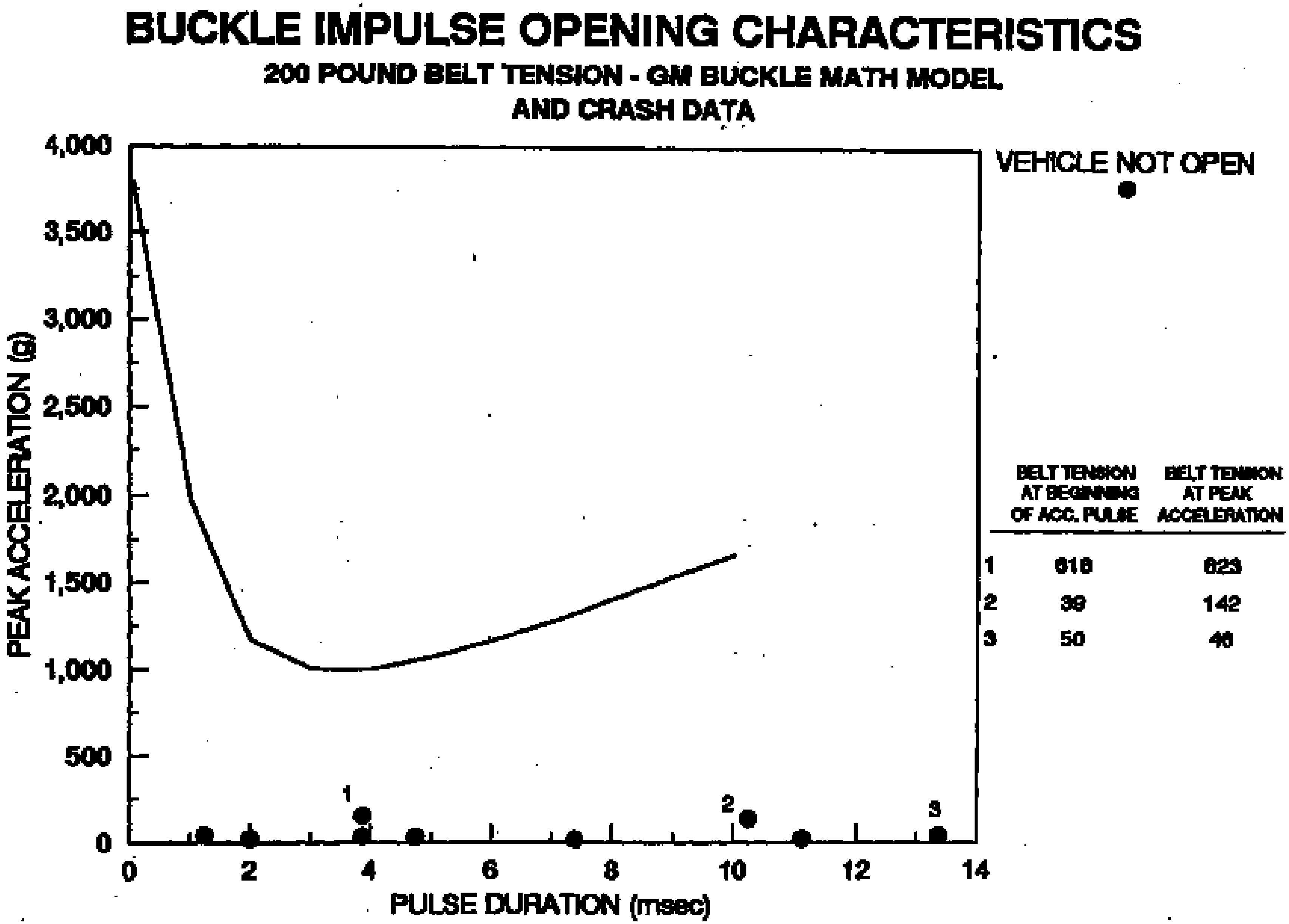


FIGURE 4.6



	BELT TENSION AT BEGINNING OF ACC. PULSE	BELT TENSION AT PEAK ACCELERATION
1	618	623
2	39	142
3	50	46

FIGURE 4.7

velocities generated are lower than those required, this will confirm the acceleration data measured in the crash tests.

Severe side impacts between the NHTSA side impact barrier and a small and a mid-size car were chosen for analysis. The impacted vehicles were a Nissan Sentra and a Ford Taurus. The impact conditions replicate those of an intersection collision where the small car is travelling 15 mph (such as starting out from a stop) and the barrier (representing a stiff impacting vehicle) impacts the car in the driver side at 30 mph. These conditions represent the threshold of serious-to-fatal injuries in highway accidents.

In the analysis of the collision, it is assumed that the occupant remains stationary in space, and that the vehicle accelerates out from under the occupant. As the vehicle is forced sideways in the collision, it gains velocity with respect to the occupant. This velocity increases as distance is covered during the collision. The relationship between the velocity gained and the distance covered is shown in Figures 4.8 and 4.9 (velocity and displacement were integrated from the right front sill acceleration). These figures can be used to determine the relative velocity between an occupant and the belt buckle by using the appropriate distance. A list of measured distances between a seated occupant and the belt buckle is given in Table 4.1 (the VW Jetta is n.a. because the buckle is below the seat). The occupant for these measurements was 5' 10" and weighed 150 lbf. Using the data given in Table 4.1, if a belt were worn properly, most of the time the distance between the hip and buckle would be less than 1 inch and always below 2 inches. Using Figures 4.9 and 4.10, it is noted that even in a severe side impact, the relative velocity would only be 5-6 mph when the occupant contacts the belt (distances < 1 inch). Even in extreme cases, the velocity is less than 7.5 mph (distances < 2 inches), still well below that required to actuate the belt.

This analysis is illustrative of why the belt can be opened by applied impacts to the back of the buckle, while real world accident situations do not result in opening. In the "parlor tricks" (videocassette, karate chop, etc.), a person hits the back of the buckle with a seemingly low severity impact that causes the buckle to open. In fact, the velocity used in these seemingly low

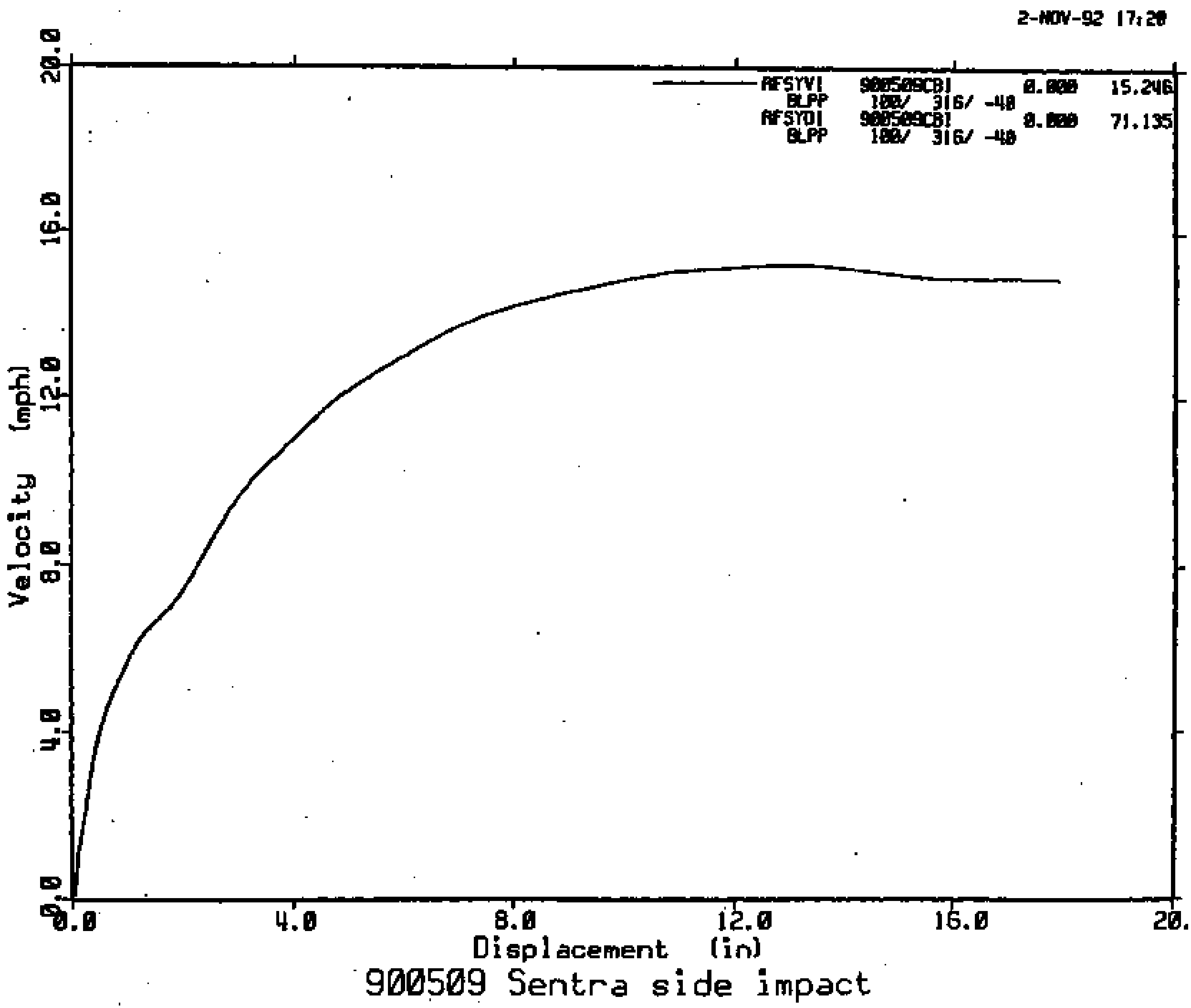

2-NOV-92 17:20
AFSYVI 900509CBI 0.000 15.246
BLPP 100/ 316/ -40
AFSYDI 900509CBI 0.000 71.135
BLPP 100/ 316/ -40
Velocity (mph)
0.0
4.0
8.0
12.0
16.0
20.0
Displacement (in)
900509 Sentra side impact

FIGURE 4.8

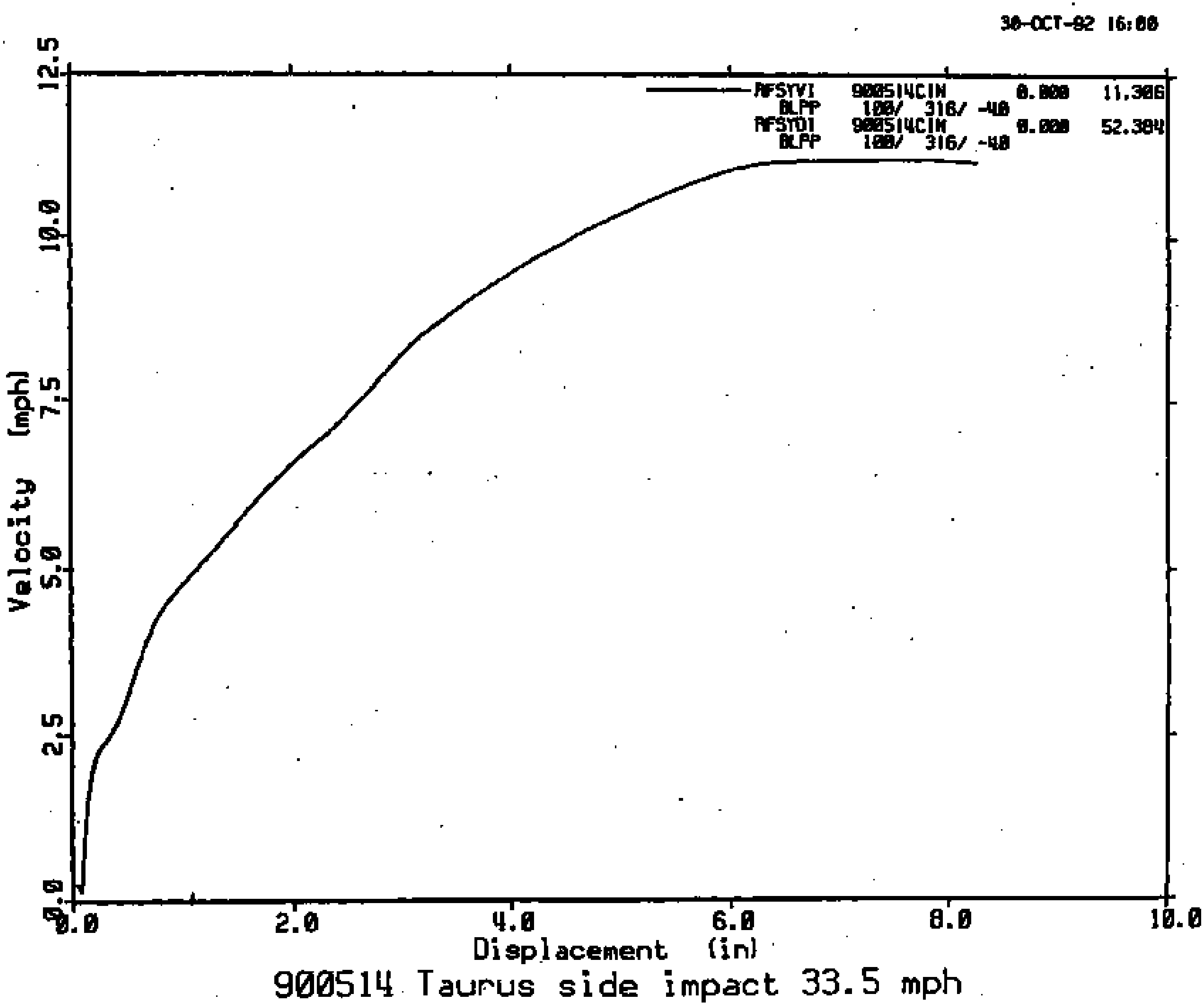

30-OCT-92 16:00
RFSYVI 900514CIN 0.000 11.306
BLPP 100/ 316/ -40
RFSYDI 900514CIN 0.000 52.304
BLPP 100/ 316/ -40
Velocity (mph)
0.0
2.5
5.0
7.5
10.0
12.5
0.0
2.0
4.0
6.0
8.0
10.0
Displacement (in)
900514 Taurus side impact 33.5 mph

FIGURE 4.9

TABLE 4.1: Distance Between Seated Occupant and Safety Belt Buckle

Vehicle Make and Year	Distance (Inches)
88 Ford Escort	0
88 Chevy Cavalier	1
86 VW Jetta	n.a.
87 Chevy S-10 Pick-Up	0
89 Hyundai Excel	.5
92 Saturn SC Coupe	1.375
86 Subaru GL	0
87 Toyota Camry	.875
87 Ford Taurus	0
87 Ford Thunderbird	.25
87 Honda Civic	0
91 Jeep Cherokee	.5

severity blows to the buckle (in the range of 15 mph) are not possible to achieve in real accidents because of the small distances that exist between occupants and properly worn safety belt buckles.

5.0 CONCLUSIONS

Based on the results of the safety belt buckle testing, the following conclusions are made:

1. The push button force required to release the safety belt buckle increases with increasing belt tension. In turn, the push button spring constant from the force-deflection curve also increases with increasing belt tension.

2. From the drop tower and "parlor trick" tests, the minimum acceleration required to open the safety belts increases with increasing belt tension.

3. From the in-vehicle test results, belt openings could not be produced by slamming a Fisher Price child seat into the back of the buckle or by a human volunteer throwing his hip into the back of the buckle. The acceleration levels for the Fisher Price child seat may have been high enough to open the buckle if there was no tension in the belt (not the case), but below those required to open the belt with just 5 lbs of tension. The belted occupant hip impact tests did not produce acceleration levels capable of opening the latch. Both of these test conditions produced significant belt tension that may have prevented the buckle from opening.

4. None of the seat belt buckles opened during the six crash tests. Only 2 out of 10 vehicle impact buckle accelerations were high enough to open the buckle when there is no tension in the belt and none of the acceleration levels were high enough to open the belt when there was just 5 lbs tension in the belt. None of the buckles opened because there was always significant tension in the belt whenever there was a relatively high acceleration level.

5. Based upon the test data and a mathematical model, it is apparent that safety belt systems in real vehicle crash environments must be analyzed on the basis of buckle acceleration amplitude and duration, as well as the tension on the belt at the time of peak buckle acceleration.

6. The many bench tests performed during this investigation indicate that sufficient velocity between the occupant and the belt must exist for an occupant to open a safety belt latch. For non-rigid impact surfaces, this "opening velocity" is approximately 15 mph. For lower velocities it is unlikely that any part of the body would cause accelerations high enough to actuate the belt. Even in a relatively severe side impact crash, the relative velocity between the buckle and the human hip will be well below 15 mph.

7. This study is illustrative of why safety belts can be opened by applied impacts to the back of the buckle, while real world accident situations

do not result in opening. In the "parlor tricks" (videocassette, karate chop, etc.), a person hits the back of the buckle with a seemingly low severity impact that causes the buckle to open. In fact, the velocity used in these seemingly low severity blows to the buckle (in the range of 15 mph) are not possible to achieve in real accidents because of the small distances that exist between occupants and properly worn safety belt buckles.

APPENDIX E

SAFETY BELT BUCKLE RECALLS SINCE 1988

1.	88V163000	1988	LeMans	85,063

Seat belt buckles may not properly latch allowing the latch plate to be removed from the buckle without pressing the release button. Seat belt could release during a sudden stop or collision. Seat belt buckles were replaced.

2.	89V034000	1989	Corsica, Beretta	29,951

Front seat belt latch plates may not engage the buckle assemblies. The occupant could incur a high risk to injury by being improperly belted. Improperly functioning buckle assemblies were replaced.

3.	90V016000	1989-1990	BMW 525	
		1989-90	535	62,000
		1988-1990	735,750	

Front seat center fold-down armrest may contact the safety belt buckle, causing damage to the release button, and preventing the belt tongue from latching when buckling. Shorter safety belt buckles were provided.

4.	90V105000	1984-1990	Camaro, Firebird	1,500,000

Breakage of plastic components within the buckle housing could prevent buckle from latching properly which would cause an occupant to be unprotected in a sudden stop or accident. Seat belt buckles were replaced or repaired.

5.	91V067000	1991	Camaro, Firebird	40,696

The metal latchplates may not engage the buckle causing a "no latch" condition. Movement of the seat occupant in this condition could cause latchplate and buckle release. The occupant would be at an increased injury risk in the event of an accident. Replacement safety belts were provided.

6.	91V075000	1985-1991	Volvo 740	
		1985-1990	760	485
		1991	740	

Instruction labels for belt routing are inadequate and can result in inadvertent release of the belt buckle. New instruction labels for proper safety belt routing and replacement buckles were provided.

7.	91V122000	1991	Imperial, Salan Fifth Avenue, LeBaron, Dynasty, Spirit, Acclaim	130,000

Front outboard safety belt may become difficult to latch due to webbing stiffener getting into the buckle housing and dislodging the buckle latch guide. The latch may open during an accident or sudden stop, increasing the occupants risk to injury. Buckle latches were replaced.

8.	92V063000	1984-1985	Mustang, Capri	306,000

The plastic sleeve which retains the the metal lock bar within the safety belt tongue assembly can deteriorate from prolonged exposure to sunlight, causing the tongue to detach from the safety belt webbing. If this were to occur, the webbing would detach from the tongue assembly increasing the risk of injury to the seat occupant. New plastic sleeves with a UV protector will be provided along with new tongue assembly.

9.	92V113000	1989-1990 1991	Taurus,Sable, Explorer	665,000

The safety belt tongue may be retained by the buckle, but it may not be latched sufficiently to provide occupant protection. An unsufficiently latched safety belt increases the risk of injury to the occupant in the event of a sudden stop or accident. Replacement buckles were provided.

10.	92V145000	1993	Toyota Truck	3,655

The wrong safety belt latch tongue plate was installed in some safety belt assemblies causing the safety belt to not latch correctly, exposing the occupant to increased risk in the event of a sudden stop or vehicle crash. Defective safety belt assemblies are being replaced.