Defect and Rulemaking Petition Findings

- o A comprehensive agency review of over 2,300 crash tests involving approximately 4,000 dummies, including frontal, oblique, rear, rollover, and side crashes did not provide one instance of inertial unlatching. In ten of these tests, belts did come unlatched due to other reasons, e.g., external contact with the release button, manufacturing defect in the buckle. It was also found that seven of the ten buckle unlatchings involved end release buckles.

- o Laboratory testing performed in response to this petition defined the engineering characteristic which can cause inertial unlatching. Most important, this testing demonstrated that these characteristics are not present in real-world crashes.

- o Manufacturer data did not demonstrate that inertial unlatching is a safety problem. In the tens of thousands of crash tests conducted by motor vehicle and belt manufacturers, only General Motors Corporation (GM) reported what it believes may be two possible, but unverifiable cases of inertial unlatching. Of the 30,000 tests GM has performed, it identified only these two such possible instances. No other reports were provided by either vehicle or belt manufacturers. Responses from safety belt buckle patent holders indicated that patents were sought to improve the general performance and ease of operation of buckles--not because of a safety problem associated with inertial unlatching.

- o Analysis of real-world crash data demonstrated that "there is no pattern of evidence in the crash data to support the allegation related to inadvertent unlatching for side-release systems." Thus, analysis of real-world data did not indicate the presence of a safety problem associated with inertial unlatching in side release buckles.

- o Review of consumer calls to the agency's Auto Safety Hotline did not suggest the presence of a safety problem. The complaint rate (the number of reports divided by the number of vehicles on the road) is essentially the same for vehicles with both side and end release buckles. Further, the complaint rate is extremely low compared to other safety problems reported to the agency. Additionally, the number of consumer calls to the Auto Safety Hotline subsequent to the "Street Stories" and CBS Evening News programs, the latter of which broadcast the toll-free Auto Safety Hotline telephone number, were no higher than the number of calls normally received. Generally, national TV publicity of a safety issue, in which the Auto Safety Hotline telephone number is presented, results in large increases in Auto Safety Hotline calls. The fact that such an increase did not occur in this instance suggests that the public does not consider this do be a safety concern.

PETITION DP92-017
INADVERTENT RELEASE OF SAFETY BELT BUCKLES

Office of Defects Investigation
The National Highway Traffic Safety Administration

November 18, 1992

PETITION DP92-017
INADVERTENT RELEASE OF SAFETY BELT BUCKLES
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BASIS:

Mr. Benjamin Kelley, President of the Institute for Injury Reduction (IIR), petitioned the National Highway Traffic Safety Administration (NHTSA) by letter dated September 11, 1992, requesting that the agency initiate a defect investigation leading to a recall and a rulemaking proceeding to preclude from sale in the future certain designs of safety belt buckles. The petition alleges that certain designs of buckles are susceptible to "inertial actuation" that causes them to open during a motor vehicle accident. The petition states, "The defect appears to involve seat buckle designs with release buttons on the front face of the buckle ('front release'). It has been found in seat belt configurations spanning about three decades, including new car designs."

The petition specifically requests the agency to "take the following actions concerning the 'inertial actuation' design of some seatbelt buckle-latch connections. . .

1. Initiation of a defect investigation of the design, leading to appropriate recall and corrective action by manufacturers whose belt systems have utilized it;

2. Initiation of a rulemaking leading to amendment of Federal Motor Vehicle Safety Standard 209 to preclude such designs in the future;

3. Issuance of warning and other information necessary to alert the public to the existence, nature and magnitude of such designs, and the hazards they represent [; and]

4. Issuance of guidelines to safety researchers, police investigators and others reporting crash-related and crash injury-related information that the presence of an unlatched belt following a car crash does not mean per se that the belt was not being worn prior to the crash."

BACKGROUND:

Coincident with the filing of this petition, on September 10, 1992, CBS aired a program on "Street Stories" concerning alleged unlatching of safety belt buckles. The content of the show was essentially based on the alleged defect of inertial unlatching as presented in the petition.

There are many different designs of safety belt buckles in motor vehicles. All have a release button that must be manually depressed for release. The petitioner states that the alleged defect appears to involve buckle designs with release buttons on the "front face" of the buckle. In the particular style that is the subject of this petition, the buckle is generally a rectangularly shaped assembly, about 1-3/4" by 2-1/2" in size and 3/4" thick. A latchplate, attached to the belt material, is inserted into the buckle. The release button is on the 1-3/4" by 2-1/2" side of the buckle and will be referred to hereafter as a side release buckle. The petitioner refers to this type as a "front release" button.

The other principal style of buckle uses a different location for the release button. The buckle is also rectangular in shape, however, it may be slightly thicker, about 1-1/4 inches. The release button is on the top end of the buckle, and next to the slot for inserting the latchplate. This type is hereafter referred to as an end release buckle. Both buckle styles are widely used by the automotive industry.

The internal designs of these two styles of latches are different by necessity. The direction for pressing the release button of the side release buckle is perpendicular to the direction for insertion of the latchplate. In contrast, the direction for depressing the button on an end release buckle is in the same direction as the insertion of the latchplate.

All new motor vehicles sold in the United States must comply with Federal Motor Vehicle Safety Standards (FMVSS). In particular, safety belts and buckles must meet the requirements specified in FMVSS No. 209, "Seat Belt Assemblies." Under this standard, the "[B]uckle release mechanism shall be designed to minimized the possibility of accidental release."

APPROACH:

To evaluate this petition, the agency conducted an extensive review of crash test data, analyzed real-world accident data, performed full-scale crash and other testing of buckles, requested information from motor vehicle manufacturers, manufacturers of safety belt buckles, and safety belt buckle patent holders, and reviewed complaints filed with the Auto Safety Hotline. The following specific actions have been taken during this evaluation:

- Wrote letters to eight motor vehicle manufacturers.
- Wrote letters to five safety belt manufacturers.
- Wrote letters to seven safety belt buckle patent holders.
- Analyzed real-world accident data.
- Reviewed agency laboratory crash data.
- Evaluated and interviewed ODI accident complaints alleging buckle release.
- Conducted vehicle and laboratory testing at the Vehicle Research and Test Center (VRTC). Reviewed previous VRTC testing on safety belt buckles.
- Conducted telephone interviews with callers to Hotline.

The findings from this evaluation is provided in the following sections.

VEHICLE MANUFACTURERS' RESPONSES:

The agency formally requested information from certain vehicle manufacturers regarding the alleged defect of inertial unlatching of safety buckles. Information requests were sent to General Motors (GM), Ford, Chrysler, Toyota, Honda, Nissan, Volkswagen (VW), and Volvo. Each manufacturer was asked to provide complaints, accidents reports, and lawsuits pertaining to the alleged defect. They were asked to describe all tests, studies, and surveys pertaining to the alleged defect and describe any design modifications pertaining to the alleged defect.

These responses are summarized below:

GM: GM's response stated, "GM has had very few reports alleging inertial unlatching of seat belt buckles. In most cases where the occupant reports that the seat belt buckle unlatched in an accident, it is not clear from the allegation whether the belt may have been released from 'inadvertent contact with the release button by external objects', whether it is alleged that the buckle release was caused by inertial forces, or whether some other condition is being alleged." GM has made no design changes in response to the alleged defect.

In response to the question of testing done with respect to the alleged defect, GM reports that it is aware of only two reports of buckle unlatching during its vehicle crash and sled testing that may relate to the alleged defect. Both incidents occurred in tests conducted during 1991. It reports that it conducted more than 749 crash and sled tests with belted occupants in 1991. Since 1970, GM has performed about 30,000 crash and sled tests, most with belted test dummies. Thus, GM data indicate that the alleged defect could be present in, at most, less that 0.007 percent (2/30,000) of its crash testing.

Ford: Ford reports that it has ". . . located a number of allegations that a seat belt had inadvertently opened or released during an accident. While some of those files contain occasional references to 'inertial unlatching,' few, if any, contain sufficient details to determine with certainty that they allege '. . . inadvertent release or opening of a safety belt latch due to inertial loading of the release button or latching mechanism caused by external forces acting on the back side of the latch housing.'" Ford did not report any safety belt buckle unlatching incidents associated with inertial forces during its crash and sled test programs. Ford has made no significant design changes related to the alleged defect.

Chrysler: Chrysler reports that it has only one complaint report that may relate to the alleged defect condition of inertial unlatching. In this case, Chrysler found the "seat belt was intact and functional--nothing to indicate that seat belt was in use at the time of the accident." Furthermore, the case went to trial and the jury found that the complainant was not wearing the seat belt at the time of the accident. Chrysler provided several other complaints alleging buckle unlatching, but finds no evidence that the seat belt was in use or evidence of a defect in the buckle. Chrysler did not report any safety belt buckle unlatching incidents associated with inertial forces during its crash and sled test programs. Chrysler has made no design changes related to the alleged defect.

Toyota: Toyota reports that it has received "only 7 lawsuits that pertain to the alleged defect, and no other owner complaints, field reports, etc." Toyota also reports it has made no modifications that could relate to the alleged defect and has issued no service or technical bulletins or other communications pertaining to the alleged defect. Toyota did not report any safety belt buckle unlatching incidents associated with inertial forces during its crash and sled test programs.

Honda: Honda reports no complaints or field reports, and only two lawsuits alleging that a seat belt buckle unlatched. Honda is aware of no investigations or surveys on this subject.

In response to the question concerning design changes, Honda's letter states that there has been one modification that "could be related to the alleged defect." Honda provided further clarification of its response by saying that its design change was not in response to allegations of inertial unlatching, but rather to reduce the latch spring force making the buckle easier to release while the belt is under tension. This was done to increase its margin of compliance with the buckle release force requirements in FMVSS No. 209, "Seat Belt Assemblies." Honda had taken a broad interpretation of the question to include any changes to components that are significant to the performance of a buckle when subjected to inertial forces.

Finally, with regard to the safety performance of end release buckles compared to side release buckles Honda reports, "We do not recognize any difference in safety between the end release type and the side release type." Honda did not report any safety belt unlatching incidents associated with inertial forces during its crash and sled test programs.

Nissan: Nissan reports it "is unaware of any accidents, subrogation claims, or lawsuits which specifically pertain to the alleged defect in the subject vehicles." However, they submitted four complaints alleging unlatching of a buckle. One complaint alleged unlatching of an empty child seat but it indicates that the claimant "admitted that she was not positive that the seat belt was hooked properly to secure the infant seat." Nissan reports that the alleged defect has not occurred in any of the variety of tests conducted to assure compliance with FMVSS's and other standards in other countries. Nissan has made no design changes related to the alleged defect.

Volvo: Volvo reports, "Volvo has never seen the alleged defect occur in its many years of conducting laboratory crash testing. Volvo is aware of no real-world accidents, allegations, or lawsuits pertaining to the alleged defect." Volvo did not report any safety belt buckle unlatching incidents associated with inertial forces during its crash and sled test programs. Volvo has made no design changes related to the alleged defect.

VW: Volkswagen has found no complaints, field reports, studies, surveys, investigations, or technical bulletins that relate to the alleged defect. It also reports, in all of its testing for compliance with United States standards, European Certification, and its own test requirements, that "there has not been one incident related to the alleged defect." VW has not made any design changes related to the design defect.

Table 1 shows a summary of complaints provided to NHTSA in the manufacturer responses. The reported vehicle population is given for vehicles from 1970 to the present. The computed rate of complaints per 100,000 vehicles with side release buckles is shown for each manufacturer.

Table 1
Summary of Complaints of
Inadvertent Release Received from Manufacturers
1970 to Present

MFR	SIDE RELEASE BUCKLE		
	REPORTS	VEHICLE POPULATION (MILLION)	RATE PER 100K
GM	63	119	0.05
FORD	48	67	0.07
CHRYSLER	13	38	0.03
TOYOTA	7	15	0.05
HONDA	2	8	0.03
NISSAN	2	12	0.02
VOLVO	0	1 (1977-92 data)	0
VW	0	3	0
TOTAL	135	263	0.05

The analysis of manufacturer complaints and lawsuits alleging unwanted buckle unlatching shows no evidence to demonstrate that inertial unlatching is a safety concern in crash tests or real world accidents. Contributing factors unrelated to inertial loading may be responsible for an unlatching complaint. The crash and forensic analysis of vehicles, buckles, and injuries show that, in many cases, the buckle was in good condition with no identifiable defects and that there is no evidence to indicate that the occupant used the safety belt.

Chrysler provided an analysis of inertial loads on safety belts and compared the results to what occurs in a crash test. It demonstrates that the impact required to unlatch a buckle greatly exceeds the acceleration loading on a buckle during a crash test. In the crash testing, the buckle acceleration peaked at 100 g at 1500 lbs of belt tension at the retractor. In Chrysler testing, the buckle system required 145 g to release with no belt tension. Chrysler's testing demonstrated, however, that increasing belt tension greatly increases the engagement force of the latch and greatly increases resistance to inertial movement of the release button, hence the acceleration necessary to unlatch the buckle. Its analysis shows more than a 600 percent increase in the acceleration required to release the buckle associated with an increase of belt tension from zero to 25 pounds. Its data shows, with the belt under tension such as occurs during a vehicle crash, that crash forces do not generate the necessary impact acceleration loading on the buckle to overcome the engagement forces resulting from the belt tension. This finding is consistent with the results of the agency testing discussed later in this report.

The automotive manufacturers uniformly report that their test programs conducted as part of research, development, and certification of vehicles has not shown any problem associated with inertial releasing of buckles in the vehicle crash environment that would indicate a safety risk in the real world.

In summary, the information received from the motor vehicle manufacturers on the performance of safety belt buckles does not indicate that a safety problem with unlatching of safety belt buckles during crashes, due to inertial actuation, exists. The scope represented by these responses includes millions of vehicles over many years of vehicle usage and thousands of crash tests.

<u>SAFETY BELT BUCKLE MANUFACTURERS' RESPONSES</u>:

The agency sent letters to the five principal manufacturers of safety belt buckles (latch assemblies) for vehicles produced for sale in the United States. Each manufacturer was asked to describe its latches and provide drawings, provide reports of complaints and lawsuits, provide all tests and studies with respect to the alleged inertial unlatching, and describe all modifications made in response to the alleged inertial unlatching problem.

These responses are summarized below:

<u>Takata Inc.</u>: Takata responded with only one reported lawsuit involving a 1983 GM vehicle. The vehicle was involved in a frontal collision. Takata reports, "Examination of the belt and vehicle found no defects." It reports that this type of buckle was supplied to GM for vehicles from 1977 through the present for application in several vehicle

platforms (A, F, G, H, J, L, N, W and X-body). Takata has not made any design modifications to this latch that relate to the subject condition of inertial unlatching.

General Safety Corporation: General Safety has manufactured one type of latch assembly, the GM Type 1, from 1970 to the present. This buckle has been used for Cadillac, Buick, Pontiac, Oldsmobile, and Chevrolet vehicles during that period of time. It is unaware of any complaints, field reports, accidents, lawsuits, studies or surveys that relate to the alleged defect of inertial unlatching. No modifications have been made to the design of the buckle during this period of time.

Indiana Mills and Manufacturing, Inc. (IMMI): IMMI reports receiving no complaints, field reports, lawsuits, studies, or surveys that pertain to the alleged defect of inertial unlatching. No changes have been made to its products that relate to the alleged defect, and it is not aware of any instances where latches on belts manufactured by that company opened because of inertial actuation.

TRW: TRW reports no complaints, field reports and two lawsuits. Both lawsuits alleged a possible inertial actuation of the latch during an accident. In one, the court found "no credible evidence of a design defect." The second incident, which occurred in October 1990, is still in litigation. TRW has not identified any test information that relates to the alleged defect of inertial unlatching. No changes or modifications have been made to buckles in response to the alleged defect.

Allied Signal/Bendix: Allied reports receiving no complaints or field reports, but indicated four lawsuits claiming alleged inertial release with side release type buckles. It states that in three of the four lawsuits, inspection of the vehicle and buckle revealed that the injured individuals were not wearing the safety belt. The fourth lawsuit concerns a suspected aftermarket installation of a safety belt manufactured by Irvin Industries (now Takata) allegedly using an Allied design. Allied has not yet inspected this vehicle or buckle.

As part of the design and development of its buckles, Allied conducts sled testing. It has "no evidence that such buckles have released inertially during such testing." Its buckles are also tested by independent laboratories, Hunt Laboratories and United States Testing, and they have never informed Allied that a buckle released inertially. Allied has made no design changes related to the alleged defect.

In summary, the buckle manufacturers report no complaints and several lawsuits relating to the alleged defect. These manufacturers have made no design changes relating to the alleged defect. Testing of the buckles, performed by the buckle manufacturers, or that which the buckle manufacturers are otherwise aware of, has not provided any indication of a unlatching problem that could be associated with the alleged defect. The information does not support the allegation of a real-world problem with unlatching of safety belt buckles during crashes.

<u>END RELEASE BUCKLE PATENT HOLDER RESPONSES</u>:

Mr. Ralph Hoar, of Ralph Hoar & Associates, sent the agency two letters in support of the IIR petition. His letters allege that the industry is aware of inertial unlatching and is active in providing design solutions to the problem as indicated by several patents. He provided copies of eight United States patents that briefly discuss inertial unlatching in some context, but not necessarily in reference to crash forces. Every patent provided by Mr. Hoar described a type of end release buckle.

The agency sent letters to the holders of seven of the eight patents for end release buckles provided by Mr. Hoar. One patent holder is a foreign firm and not readily accessible to provide a timely response for this analysis. The following patent holders have been asked to respond to the concern of inertial unlatching as it relates those specific patents that mention inertial forces. The patent holders were asked to describe inertial actuation as it relates to the patent, respond to allegations that the patent provides evidence of a problem with side release buckles, and provide any technical reports and studies discussing inertial unlatching.

<u>Allied Signal/Bendix</u>: Allied reports having no knowledge of inertial release of side release buckles in accident conditions. Allied reports that these patents were developed "in response to customer's specification to design an end-release buckle. In the late 1970's and early 1980's the 'parlor trick' of causing a 'side release' buckle to open by slapping it on a table was widely demonstrated in Europe and was being used by European competitors as a way to induce customers to purchase competitive buckles which were more resistant to that particular 'parlor trick.'" With respect to side release buckles, Allied explains that "web tension acts a restraining force and significantly influences the amount of button force required to cause latch movement. Latch movement can also be induced by acceleration forces if the resultant inertia force on the buckle is in the proper direction and also is capable of overcoming internal (pre-load, spring rate, frictional and damping forces) and external (web tension) restraining forces acting on the latch." Allied in not aware of any type of accident that could generate the necessary forces to cause inertial release. The end release patents were not developed because of any known deficiency causing them to be susceptible to inertial unlatching.

<u>GM</u>: GM responded by reporting, "although all buckles can theoretically become disengaged by inertial forces at some levels of acceleration and direction relative to the buckle, General Motors does not believe that buckles are susceptible to inertial release under normal conditions of usage, including under accident conditions." In response to the question of whether GM developed the patent to present a solution to the alleged defect of inertial unlatching, GM reports that all of its buckles, both side release and end release types, have been designed to "overcome inertial forces in real world use situations, and to avoid unwanted buckle disengagement." GM did not indicate that the incorporation of inertial considerations in the patent was indicative of a real-world problem of inertial unlatching in side release buckles.

Takata, Inc.: This manufacturer has not provided a response to the questions in the agency's information request pertaining to two Takata patents.

TRW: The TRW patent contains a statement describing possible unlatching of an end release type buckle when used in conjunction with a pyrotechnic pre-tensioning device. This is attributed to the movement and sudden stopping of the buckle during the automatic pre-tensioning phase, in which inertial forces can unlatch the buckle in this particular design application. The TRW patented features are new and not yet on vehicles sold in the United States. The TRW patent seeks to correct the conditions resulting from the pyrotechnic device and not from accident conditions. It states, "There is no evidence that real world accidents, in and of themselves, will result in buckle accelerations or occupant to buckle impacts sufficient to inertial release a buckle using a conventional side release button configuration."

IMMI: IMMI reports, "There were no theoretical, actual or alleged instances of inadvertent buckle release due to inertial actuation forces that led IMMI to develop the buckle covered by the patent." IMMI explains that it has developed the subject features in the patent to minimize the "theoretical risk of release due to inertial forces. This would also make the buckle usable with pre-tensioners, which may eventually come in our application."

The patent holders report no knowledge of real-world inertial unlatching of buckles. Certain patents show buckle designs that can be used with pyrotechnic belt pre-tensioners and those designs must anticipate the inertial forces due to the pre-tensioning device. Finally, these patent holders do not indicate that development of the end release buckle patents was in response to performance deficiencies in side release buckles.

REAL-WORLD CRASH DATA ANALYSIS:

Numerous research studies dating from 1984 to 1992 uniformly show a substantial reduction in the risk of injury to occupants in a motor vehicle accident when safety belts are used. These studies include those by the major industrialized countries of Europe, Canada, Australia, and in the United States. The results clearly indicate that, when used, lap and shoulder safety belts reduce the risk of fatal and serious injury to front seat occupants by 40 to 50 percent.

As part of the analysis related to this petition, crash files maintained by the NHTSA's National Center for Statistical Analysis (NCSA) were reviewed for reports of possible inertial unlatching of buckles. Searches were made of the computerized National Accident Sampling System (NASS)[1] database from 1988 through 1991 to identify specific crash investigations

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[1] NASS is a sample of nationwide crashes investigated by NHTSA contractors. The investigation consists of vehicle inspection, crash scene analysis and occupant interviews. These

which suggest that the safety belt buckle released and for which "hard copy" files were available. This search identified 19,444 belted front seat occupants. Of these, cases were selected that indicated that a manual belt buckle opened, that the manual or automatic buckle failed, or that the occupant was restrained by a manual safety belt, but was ejected. These searches identified a total of 34 cases for review of the "hard copy" investigation file. These 34 represent 0.17 percent of the belted occupants.

The 34 reports provided no evidence of inertial buckle unlatching. The reports indicated examples of extreme vehicle damage that resulted in tearing away of the doors, the B-pillars, the belt anchorages at the floor, cutting of the webbing, shattering of the buckle housing, and structural failure of the retractor mechanism.

The agency also has conducted statistical analyses of its accident data files to determine whether the data contains any evidence of a difference in occupant crash protection between vehicles equipped with end release buckles compared with vehicles equipped with side release buckles. The analyses utilized the Fatal Accident Reporting System (FARS) files for 1985 through 1991 and selected state accident data from the CARDfile[2] for 1988 through 1990 (the three most recently available years). The data were analyzed to assess ejection, fatality and incapacitating injury rates for vehicles equipped with side release and end release buckles. Descriptions and summaries of the analyses conducted by NCSA are included in Appendix A.

The FARS analysis compared specific vehicles from model years 1985 and later that were equipped with either side release or end release buckles, but did not include vehicles with passive belts or air bags. Vehicles from model years 1985 and later were selected because the agency had data available to indicate whether those vehicles were equipped with end or side release buckles. A list of those "specified vehicles" studied in this analysis is given in Appendix B. Since the analysis included several categories of vehicles, differences in driver and vehicle characteristics were accounted for in the analysis. Further analysis was conducted of accident data for specific vehicles that had a production change from side release buckles to end release buckles, but with no other vehicle changes that could impact the effectiveness in the belt system. These vehicles (referred to as cross-over vehicles) changed from a side release buckle to an end release buckle. Three sets of cross-over vehicles were analyzed--Ford Taurus/Mercury Sable, Lincoln Continental, and Plymouth Voyager/Dodge Caravan. These vehicles were subjected to an additional analysis to determine whether the data suggested any discernable difference in crash protection provided by end versus side release buckles in essentially identical vehicles.

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cases provide a detailed description of the crash severity and occupant injury consequences.

[2] CARDFile - Crash Avoidance Research Data file. CARDFile is a file incorporating six states' police-reported accident files in a standard format.

The NCSA report concludes that "there is no pattern of evidence in the crash data to support the allegation related to inadvertent unlatching for side-release systems." This analysis, based on fatal and less serious crash data, did not indicate a safety performance problem with side release buckles.

CRASH TEST DATA:

The agency has accumulated a large body of crash test data involving safety belts to restrain test dummies in both vehicle and sled tests. This includes testing of child safety seats as well. The testing has been conducted in three programs areas; the Office of Vehicle Safety Compliance, Research and Development, and New Car Assessment Program (NCAP). In order to identify and understand any occurrences of the alleged problem of buckles unlatching, the agency conducted a comprehensive review of all its testing to locate specific reports of buckles unlatching during these tests.

Crash testing with belted test dummies includes front, rear, side and vehicle rollover impacts. In the frontal and side impact category, tests were conducted at both 90 degree and oblique impact angles. Table 2 shows a summary of agency crash ant sled test data involving full sized belted dummies.

Table 2
Agency Crash and Sled Tests
with Belted Test Dummies

Type of Test	No. of Tests	No. of test Dummies	Latch Openings
Frontal 90 degree	1,353	2,491	8
Front Oblique	53	104	0
Rear	409	811	1
Roll Over	17	17	0
Side	235	307	0
Total	2,067	3,730	9

A total of nine buckles have opened during testing with belted test dummies. Three openings were associated with defective latches. These buckles were <u>end release</u> type buckles and the vehicles using these defective belt buckles with end release buttons were recalled after an investigation conducted by the agency's Office of Defects Investigation (ODI). Four buckles opened during the rebound movement of the dummy when a portion of the dummy body contacted the release button on the buckle. These four buckles were also end release buckles. Each of these events occurred during frontal testing under the NCAP program and the impact speeds were 35 mph. The dummies were restrained during the initial impact and the recorded injury level of the dummy at the seating position of the released buckle was not significantly different from the injury level of a restrained dummy at the other seating position in which the belt remains latched. This leads to the conclusion that any belt release was after the crash event was over.

The remaining two of the nine buckles that opened were side release designs. One occurred during a frontal 30 mph barrier crash test of a 1979 International Scout II. The vehicle was equipped with a lap belt only and the buckle was found to be in an open condition during the post crash inspection. The crash test film shows the buckle not out of position but resting in the lap of the dummy. If the buckle had released during the initial impact or during any other phase of high deceleration, the belt and buckle most likely would have been forced out of position, rather than resting in a normal position on the dummy's lap. It appears that the safety belt restrained the dummy during the initial impact, but released upon rebound. The other side release buckle opened during a 35-mph rear impact test of a 1980 Honda Prelude. The dummy moved rearward upon the initial vehicle impact by a moving barrier. It does not appear from the kinematics of the vehicle during the rear impact and the reactive motion of the dummy that the backside of the buckle was impacted during the initial period of this test when the apparent buckle unlatching occurred. However the precise reason for the buckle opening cannot be determined.

A comprehensive review of all of dynamic sled testing of child safety seat tests was also conducted. A total of 239 tests were performed. Only two motor vehicle buckles opened during testing of child safety seats. Both buckles were the side release type. One buckle failed when it broke into two pieces due to a bending load applied to the buckle. During the test, the buckle was pulled across the metal bar of the child safety seat while its two ends were subjected to a tensile load in opposite directions, approximately 90 degrees apart with respect to each other. The resulting bending moment on the buckle fractured the latchplate at the webbing attachment point. The other buckle release occurred in a test of the interaction with a passenger-side air bag. The rear-facing child safety seat was intentionally positioned close to the air bag housing to test the dynamic interaction between the air bag and the child safety seat--this is contrary to all manufacturers' warnings and instructions for positioning a child safety seat in a vehicle with a passenger-side air bag. As the air bag deployed, the air bag impacted the back of the child safety seat, forcing the safety seat downward. This motion forced the vehicle's safety belt buckle under the edge of the child safety seat and into the bottom seat cushion, at which point the buckle released. Based on the direction of the application of the initial and reactive forces, there is no indication of an impact with the backside of the buckle that would be indicative of an alleged inertial unlatching.

A summary of the above reported latch openings during agency testing is in Appendix C.

In summary, the agency has reviewed all available data of testing of restrained occupants in search for evidence of alleged inertial unlatching of buckles. This review encompassed testing of a total of 3,730 belted test dummies and 239 child dummies in child safety seats. No evidence of buckle release due to alleged inertial unlatching was found.

TESTING IN SUPPORT OF PREVIOUS INVESTIGATION EA77-040

In June 1977, an Engineering Analysis (EA77-040) was opened to investigate a single complaint alleging that the seat belt buckle in a 1975 Chevrolet Monza would open if a sharp impact was applied to the back of the buckle. In support of the investigation, a test program was initiated on sample buckles from a Monza and other vehicles. The purpose of the testing was to duplicate and observe the unlatching when the buckle was impacted by a rubber mallet on the front and rear surfaces of the buckles. An impact device was constructed to provide a repeatable impact force. Testing was expanded to include other vehicles from model years 1971 through 1978. This testing included the passenger seat buckles in a total of 225 vehicles.

The testing demonstrated that buckles, including the Chevrolet Monza, would unlatch if impacted with a sharp blow to either the rear or the front face of the buckle. The expanded testing of other model years also showed that many buckles would open when hit on the rear surface with a sharp impact. It was noted that 50 of 225 buckles opened during these tests.

The test device did not simulate the portion of the human body that is in contact with the back of the buckle when the buckle is worn. Also, the impact was not selected based on a correlation of the force that might be applied by the body to the back of the buckle during a vehicle accident. The primary intent of the test device was to allow for the gathering of empirical and repeatable data that would demonstrate, in a laboratory setting, the phenomena of buckle unlatching due to a non-accident-related impact force.

While the testing demonstrated that certain impacts on the buckle not representative of real-world crashes could open a buckle, there was no correlation made to the dynamic forces that are present in real-world crashes. Thus, this testing did not establish a risk of buckles opening in real-world crashes. The Engineering Analysis in EA77-040 report indicates that there were no additional complaints in the ODI consumer complaint file of the alleged problem of buckle unlatching. Based on the lack of evidence that the alleged problem was present in the real world, EA77-040 was closed.

The report of testing done under investigation EA77-040 recommended additional work using a more realistic impact force. The recommendation specifically identified the need for data concerning rollover and corner impacts to the vehicle. The agency has done this. NHTSA has conducted a comprehensive vehicle testing program involving belted occupants in compliance, NCAP and research and development testing. As described in a prior section of this report, the agency tested 307 full sized belted dummies in side impacts, 104 in front oblique impacts, 2,491 in frontal impacts, 811 in rear impacts, and 17 in vehicle rollovers. No evidence of inertial unlatching was reported in those tests. These tests, which represent real-world crashes, represent a thorough and comprehensive assessment of safety belt performance.

ODI COMPLAINTS:

Before Petition:

A search of the ODI database identified 1,886 records of consumer complaints regarding belt failures in accidents as of September 9, 1992, one day before the showing of the CBS "Street Stories" program. The computer print-out of these records was reviewed for allegations of seat belt buckle failures. Key words such as: buckle, buckle unlatched, unfastened, disengaged, and opened, were targeted for further review. Complaints of seat belts breaking, problems fastening, belt spooled out/pulled out, belt did not lock up, belt released (retractor), false latching, or no latching were not followed up because they are not related to the alleged defect. Out of the 1,886 records, 85 were identified as possibly relating to buckle disengagement. Full copies of these reports were retrieved and reviewed for pertinency, which included telephone calls to consumers for clarification where appropriate. The agency attempted to reach 63 complainants by telephone and successfully made contact with 40. After this process, 35 reports were identified in which it was alleged that a seat belt buckle inadvertently disengaged during an accident.

The 35 complaint reports were analyzed by type of buckle, type of accident, severity of accident, and severity of injury. The type of buckle reported is either a side release or an end release buckle. The underlying presumption for the inertial unlatching in a side release buckle to occur is that the impact necessary to release the buckle must be applied to the inside (the side next to the occupant) of the buckle. Accordingly, the reports were reviewed to determine the type of accident by principal location of impact. The location of the vehicle impact determines the initial direction of forces applied to the vehicle, occupant and the buckle.

Table 3 shows a listing of 35 complaints by model and model year. The complaints are widely distributed among many makes and models, and over many model years. Of the 35 reports, 24 were for vehicles equipped with side release buckles, and 11 were for vehicles with end release buckles. A rate comparison was made of the number of complaints for both buckle types by dividing the number of complaints by the vehicle population for each particular vehicle. The rate for side release buckles is 0.7 per 100,000 vehicles and the rate for end release buckles is 0.9 per 100,000 vehicles.

Table 3
List of Complaint Vehicles

MODEL YEAR	MANUFACTURER	MODEL	SIDE RELEASE	END RELEASE
1980	FORD	CAPRI	1	
1981	GM	CHEVETTE	2	
1984	FORD	BRONCO	1	
1984	GM	CELEBRITY	1	
1984	GM	CUTLASS	1	
1984	FORD	ESCORT	1	
1984	GM	REGAL	1	
1985	GM	ASTRO VAN	1	
1985	GM	BLAZER	1	
1985	GM	ELECTRA	1	
1985	FORD	ESCORT	2	
1985	MAZDA	GLC		1
1985	CHRYSLER	NEW YORKER	1	
1985	GM	SPRINT	1	
1985	GM	SUBURBAN	1	
1986	GM	CAMARO		1
1986	GM	LESABRE	1	
1986	MITSUBISHI	MIRAGE		1
1986	GM	NOVA	1	
1986	GM	FIREBIRD		1
1986	MAZDA	323		1
1987	GM	SAFARI VAN	1	
1988	GM	CORSICA	1	
1988	GM	CUTLASS	1	
1988	GM	CELEBRITY	1	
1988	GM	REGAL	1	
1988	CHRYSLER	SHADOW		1
1989	FORD	PROBE		1
1990	GM	CORSICA	1	
1990	CHRYSLER	DYNASTY		1
1991	FORD	EXPLORER		2
1992	GM	METRO		1
		TOTAL	24	11

Two critical conclusions are evident from these data. First, even if all of the complaints did in fact reflect instances in which the buckles actually released as a result of an accident, the complaint rate is extremely low--far below the levels indicative of a potential problem that would warrant a determination of a safety-related defect. Second, no significant difference was noted between the complaint rates for side release buckles compared to end release buckles. This is consistent with the real-world accident data analysis which demonstrated no difference in the occupant protection of side versus end release buckles.

The vehicle age at the time of the complaint was analyzed in response to the possibility that over time, buckles may be more vulnerable to inertial unlatching because of weakening of the buckle release spring. Table 4 shows the relationship of complaints to vehicle age. No trend was noted to indicate that buckle aging contributes to an increase in alleged opening of safety belt buckles in motor vehicle accidents.

Table 4
Complaints by Vehicle Age
At the Time of Alleged Failure

VEHICLE AGE (YEARS)	REPORTS	
	SIDE RELEASE	END RELEASE
9	1	0
8	0	0
7	0	0
6	2	0
5	6	0
4	1	0
3	1	2
2	5	3
1	4	2
0	4	4
TOTAL	24	11

The impact location to the vehicle was also considered. Because the buckle position is at the side of the occupant, an impact to the side of the vehicle would likely transmit the most direct impact from the occupant to the buckle. Table 5 shows a comparison of impact location on the accident vehicle by the type of buckle. For both the end and side release buckles, most of the reported impacts were to the front and rear and not the side of the vehicle.

Table 5
Vehicle Impact Location by Buckle Type

IMPACT LOCATION	RELEASE BUTTON LOCATION	
	SIDE	END
FRONT	8	6
REAR	4	2
SIDE	8	2
ROLL	4	1
TOTAL	24	11

The reported vehicle damage or accident severity ranged from moderate to severe. Injuries were reported in 33 of the 35 accident reports. The type of injury varied and is shown in Table 6. The seriousness of the injury as measured by the type of treatment (where reported in the complaint or determined by follow-up telephone calls) is shown in Table 7.

Table 6
Type of Injury

INJURY TYPE	SIDE RELEASE	END RELEASE
NONE	1	1
ABRASION	6	1
LACERATION	2	0
BROKEN BONE	6	1
TRAUMA	3	4
CONCUSSION	1	1
NOT REPORTED	5	3
TOTAL	24	11

Table 7
Type of Treatment

TREATMENT	SIDE RELEASE	END RELEASE
NONE	4	2
EMERGENCY ROOM	3	2
HOSPITALIZED	7	1
FATAL	0	0
NOT REPORTED	9	5
TOTAL	23	10

Of the 35 complaint reports, eight alleged that a child seat was released by the opening of the vehicle's seat belt buckle. Of the eight, five were side release buckles and three were end release buckles. The complaint rate associated with the alleged release of child seats for the side release buckles is 0.5 per 100,000 vehicles sold compared to 0.8 per 100,000 vehicles sold for the end release buckles. Again, no significant trend is noted to indicate an inertial unlatching phenomenon of the side release buckles.

After Petition:

In the 4 days immediately following the "Street Stories" program, which was broadcast on nationwide television, the agency received approximately 4,800 calls to the agency's toll-free Auto Safety Hotline. These calls represent inquiries to the Hotline requesting consumer information on a variety of subjects, including child safety seats, New Car Assessment Program crash test results, Uniform Tire Quality Grading System, drunk driving literature, etc. Additionally, these calls include callers who either want to discuss a safety issue with a Hotline contact representative or file a consumer complaint about a safety problem they have experienced with a motor vehicle or item of motor vehicle equipment. These include Hotline calls in response to the "Street Stories" and "CBS Evening News" presentations. When compared with the total phone calls received by the Hotline over the same Friday through Monday time period for the preceding 6 weeks, the 4,800 calls are very close to the average 4,400 calls over that 6-week period.

As another comparison of the public's response to the claims of safety belt buckle unlatching based on presentation in the media, the agency reviewed the number of consumer calls to the Auto Safety Hotline in two other instances where the Hotline telephone number was illustrated on national television. After a February 1990 child safety seat segment on "Good Morning America," the agency received over 8,000 calls during the next 5 days. After a February 1992 ABC broadcast concerning child safety seats, nearly 10,000 calls were received by the Hotline within 5 days. Additionally, after agency press releases announcing the availability of consumer information on such subjects as the Uniform Tire Quality Grading System, the New Car Assessment Program, and child safety seats, the agency received between 9,000 and 25,000 requests for the information within 4 days, depending on the subject.

The relatively few number of calls to the Hotline concerning safety belt buckles as a result of broad national publicity can be taken as a strong indication that the alleged defect is not a real-world problem.

Aside from the total number of consumer calls to the Hotline, calls actually reporting a safety belt problem were analyzed. Of the calls that were in response to the "Street Stories" and "CBS Evening News" presentations, the vast majority were from those consumers who either expressed concern over what they had seen on television, including a number of persons stating "I could make my safety belt do what the show indicated," or requested information from the agency on safety belts. From the date the CBS program was shown on September 10, 1992 to September 28, 1992, only 47 callers actually reported complaints related to safety belt performance. Of the 47 complaints, 30 involved accident situations, and only 18 of these specifically alleged that the safety belt became unlatched for some reason. None of these complainants indicated or suggested that the reason for the unlatching was an impact to the backside of the buckle. Like the complaints received before the "Street Stories" program, these complaints include vehicles equipped with end release as well as side release buckles. Four of the 18 complaints were on vehicles with an end release buckle. Two reports indicated that a vehicle buckle failed to hold a child safety seat--one report each for side and end release buckles. Serious injuries were reported for both the side and end release buckles. Four reported injuries required hospitalization, three were in vehicles with side release buckles and one was in a vehicle with end release buckles.

One fatality was reported and was investigated by an independent experienced accident investigator. The investigation included examination of the crash scene, the vehicle, the belt and buckle, the autopsy report, and interviews with the police officer, the victim's relatives, and the medical examiner. The police accident report indicates that the victim was not wearing the safety belt. The investigator found no evidence to indicate that this finding was incorrect.

It is apparent that calls to the Hotline were not significantly affected by the publicity associated with the "Street Stories" and "CBS Evening News" broadcasts alleging safety belt unlatching due to inertial loading. Further, consumer complaints concerning belt unlatching in crashes have been extremely low in number. The fact that the low volume of calls to the agency's Auto Safety Hotline, and more specifically, the small number of consumer complaints specifically addressing unlatching of safety belts in crashes, suggests that the public does not consider this to be a safety concern. It also suggests that the public understands the benefits of safety belts and the protection they provide to vehicle occupants in real-world crashes. Additionally, the complaints of buckle release that were received fail to show any evidence to support an inertial release phenomena. Complaints have been reported on both the side and end release buckle designs, but no significant difference was noted in the complaint rate between side and end release buckles for alleged unlatching incidents. Interestingly, most complainants report the unlatching occurred during a front or rear impact, which would not appear to be the direction providing the greatest susceptibility to alleged inertial unlatching of side release buckles.

RECENT TESTING:

Following the receipt of the petition, ODI initiated a test program to assess the performance of side release buckles under various conditions. The purpose of the testing was to: (1) determine the dynamic physical conditions necessary to cause side release buckles to release under inertial loading from a sharp impact to the back side of the buckle; (2) measure buckle response in crash conditions and compare these to measured and predicted conditions that would cause a buckle to unlatch due to inertial forces; and (3) measure in-vehicle conditions using a human volunteer and metal frame child seat. The full report of testing is attached as Appendix D.

Testing included full scale vehicle crash tests; bench testing of buckles involving striking the back of sample buckles with a human hand or hip, and a video cassette; and in-vehicle testing of buckles using a metal frame child seat and a human volunteer's hip. A computer model was developed to predict the required impulse, acceleration, and pulse width to the buckle that would cause a buckle to unlatch under inertial forces.

The bench testing consisted of dropping an 8 lb weight from selected heights onto the back side of a side release buckle. The buckles were equipped with accelerometers to measure the acceleration-time history of the impacts. The buckle was stretched horizontally between two posts and placed under tension. The belt/buckle tension was held at 5, 50, and 500 lbs. The back of the buckle was impacted with and without padding. Three types of padding were used, two types of foam and 1/8th inch thick dummy skin.

In addition to bench testing, accelerometers were placed on the safety belt buckles in several full scale crash tests incorporating test dummies restrained by safety belts to gather laboratory crash data for comparison with the modeling and the bench testing data. The full scale vehicle tests included the following:

- o 20 mph side impact, 1985 GM pickup truck, 2 - 50 percentile test dummies
- o 30 mph side impact, 1985 GM pickup truck, 1 - 50 percentile test dummy and 1 child seat with a 3-year old test dummy
- o 30 mph front impact, 1993 Chrysler pickup, 2 - 50 percentile test dummies
- o 50 mph oblique front impact, 1989 Taurus impacted with a 20,000 moving test buck, 1 - 50 percentile test dummy
- o 30 mph front impact, 1993 Sentra, 2 - 50 percentile test dummies
- o 30 mph front impact, 1993 Century, 2 - 50 percentile test dummies

The results of the test program shows that the phenomenon of inertial unlatching can be described in terms of the physical parameters of acceleration amplitude, duration of the acceleration pulse, and belt tension. As belt tension increases, the acceleration required to open a buckle also increases. As the pulse width decreases, the acceleration required to inertially open the buckle increases. Most importantly, the testing demonstrates that acceleration pulses needed to unlatch a safety belt are not representative of conditions experienced in real-world crashes.

These parameters are shown graphically in Figure 1. This figure shows the predicted line for inertially opening the buckle with a belt tension of 50 lb. The area above the line indicates the conditions under which it is theoretically possible to open the buckle release by inertial acceleration. Conditions below the line would not cause the buckle to release. Data points taken from the bench testing, using drop weight, video cassette, and human hip impacts are plotted to show their relation to the predicted threshold for opening. Laboratory crash data points are also shown.

No buckle releases were observed during the crash testing. The laboratory test results indicate that, while it is possible to create inertial acceleration that could cause a safety belt buckle to release, such conditions are extremely unlikely to exist in real-world crash conditions.

RECALLS:

The agency has an aggressive program to investigate alleged safety defects in motor vehicles. The agency Hotline receives complaints and these are codified and entered into a computerized database. Each and every safety defect complaint is reviewed by professional staff to look for possible defect trends. When evidence indicates a possible safety defect trend, the agency will open an investigation to analyze the basis of the complaints and identify any safety defects. Many of these investigations result in safety defect recalls. Manufacturers may also initiate safety defect recalls without direct influence by NHTSA investigations. During the past 4 years, motor vehicle manufacturers have issued ten safety recalls to correct defects in safety belt buckles and recall a total of 2,722,850 vehicles. Of these, NHTSA investigations influenced the recall of 2,371,000 vehicles in three investigations that resulted in safety recalls. Appendix E shows a listing of all safety belt buckle recalls received by the agency during the past 4 years.

A review was made of all motor vehicle safety recalls, from 1968 to the present, that reported a defect in safety belt buckles. The recalls were reviewed to determine if there was any relationship between the reported defect in the recall and the alleged defect of inertial unlatching. The defects in these recalls included a broad range of reported problems, such as improper latching, false latching, failure to unlatch, failure to remain fastened under high tensile loads, and mechanical failure (cracking and disintegration) of certain parts as a result of aging. There have been no recalls that relate to the alleged problem of inertial release of a buckle due to impact to the back of the buckle housing.

FOREIGN STANDARDS--CANADA

The agency asked representatives of the Canadian government for any information it may have of investigations and reports of inertial unlatching of safety belt buckles. An official of Transport Canada responded as follows, "First of all, I would like to say how disappointed I was with the 'Street Stories' newscast on this matter. Scare stories of this nature can undo many years of work in building public confidence in occupant restraint systems." Canada conducted many investigations into alleged release of buckles but "in NO case was it concluded that the buckle released due to inertial forces." Transport Canada tested several hundred vehicles and have "NO documented cases of inadvertent actuation of the buckle system." It reports three cases in which a buckle was found to be unlatched at the end of the test. It concludes that, in two cases the buckles were either not fastened or improperly fastened, and in the third case, it believes the dummy's hand struck the buckle release.

FOREIGN STANDARDS--UNITED KINGDOM

The Department of Transport of the United Kingdom was contacted for information related to unwanted buckle release in seat belt assemblies. The response from the United Kingdom stated that its in-depth accident investigations have shown no instances of inertial release of safety belt buckles and, that its counterpart to our defect investigations and compliance testing efforts have found no defects of this nature in its testing and investigations.

FOREIGN STANDARDS--AUSTRALIA

The Australian Federal Office of Road Safety (AFORS) was contacted for information related to unwanted buckle release in seat belt assemblies. Of particular interest were any regulations which may, either by intent or effect, discourage use of the side release buckles in Australia. AFORS commented that no such regulations existed. The agency requested any information from Australia's investigative files related to the subject buckle types. AFORS noted that review of the safety defect investigations found "no record of any alleged problems with this type of buckle in Australia."

While not containing any provisions specifically related to side release buckles, current Australian Design Rules (ADR) and Australian Standards (AS) for seat belt assemblies include several requirements intended to limit the possibility of unwanted buckle release in general. These requirements involve tests for partial engagement, inadvertent release, dynamic performance, and buckle-spring fatigue resistance. A brief discussion of each follows.

Partial engagement Clause 9a of AS 2596-1983, "Seat Belt Assemblies for Motor Vehicles," states that "the buckle shall be of a quick-release type and shall not be capable of partial engagement." Partial engagement is defined as "any stable condition, other than complete engagement, in which the buckle components will withstand a separating force of not less than 1 N applied by tensile forces in the strap components, without disengaging. The tensile forces may be readily applied by holding one part of the buckle so that the other part tends to fall out vertically under its own weight."

__Inadvertent release__ Clause 9b of AS 2596-1983 states that "the buckle shall not have a potential for inadvertent release by the vehicle occupants." A buckle assembly is considered free of such potential if, when tested in accordance with AS 2597.4, release is not caused. This test involves application of a flat planar surface against a latched buckle assembly such that the surface is normal to the line of action of the actuator.

__Dynamic performance__ The seat belt assembly is subjected to dynamic forces designed to cause a nominated deceleration of a dummy of specified characteristic. A dummy with mass of 72 $\pm$ 2 kg (163 $\pm$ 5 lbs) is mounted on a test sled and restrained by the seat belt assembly to be tested. The seat belt assembly is configured in a manner consistent with its intended usage. From a nominal initial velocity of 13.6 m/s (29.0 mph) the apparatus achieves a deceleration of between 235 m/s^2 (771 ft/s^2) and 335 m/s^2 (1010 ft/s^2) within 30 ms. The deceleration must be substantially within the specified range for at least 20 ms, disregarding values outside the range that occur for periods of less than 1 ms. Upon completion of the test, the seat belt assembly is checked for separation of any components within themselves or from the anchorages and for proper release operation of the buckle.

__Buckle-spring fatigue resistance__ Clause 4.5.3 of ADR 4/01, "Seat Belts," states that "in the case where a spring is incorporated in the unlatching mechanism of a buckle, the load required to operate the spring shall not be reduced by more than 20% after the spring has been subjected to 50,000 operations each involving a movement not less than 95% of the design movement for buckle unlatching."

__CONSUMER REACTION__:

As discussed earlier, the agency received a number of phone calls to the Auto Safety Hotline after the news media (September 10, 1992, "Street Stories") allegation of a buckle unlatching phenomena due to inertial loading. The Street Stories show was based on the alleged defect as discussed in this petition. Most of the calls were from consumers who were genuinely concerned about what they had seen or heard about the alleged design defect in safety belt buckles that utilize a side release buckle. Many of the callers stated that they were able to replicate the buckle unlatching by striking the backside of the buckles in their own vehicles with objects ranging from screw driver handles to books.

After listening to the concerns voiced by the callers to the Hotline, it was important to learn if the allegations made on television and in the print media about safety belts unlatching in crashes had any effect on consumers' attitudes and perceptions about the benefits of using their safety belts. In an attempt to identify and understand any consumer impacts that may have resulted from the allegation of buckle release, a number of call backs to consumers who had originally called the agency after having seen or heard about the "Street Stories" program were conducted. The objective of these phone calls was to determine if the show had any effect on a person's decision to use safety belts when riding in a motor vehicle. The results of these telephone calls are not statistically based, but rather are indicative of consumers' reactions to the media claims of safety belt buckle unlatching.

A total of 128 persons were called, and all indicated that they use their safety belts all or most of the time. This is exactly the type of person one would expect to have called the Hotline on an issue concerning safety belts. Calls from non-belt users would not be expected, since the allegation that safety belts can become unlatched in a crash may be supportive of the reasons cited for not wearing safety belts.

Of the 128 consumers, 124 people (97%) stated that they continue to wear their safety belts. Of those 124 people, 22 also stated that because of the program, they were being more careful in ensuring that their safety belts were securely fastened. Several other consumers stated that they took extra precautions to ensure that the safety belt buckle did not come in direct contact with any hard spots on child safety seats. In most instances, the safety belt buckle does not contact rigid components of the child safety seat; however, in instances where contact does occur, consumers stated that they placed padding under the buckle. Obviously consumer actions to ensure that safety belts are securely fastened and worn correctly are beneficial to highway safety.

The remaining four consumers (3%) stated that they stopped wearing their belts altogether or use them less often. These comments are of great concern. NHTSA, in cooperation with the entire safety community, has spent many years and millions of dollars on initiatives to encourage safety belt use. Given the thousands of lives that have been saved, and the reduction in injury levels to millions of other motor vehicle occupants because of safety belts, there is no doubt that safety belts are a highly effective means of providing crash protection to occupants of motor vehicles. It is disheartening that someone may be seriously injured or killed in a motor vehicle crash simply because they no longer wear their safety belts after the media claims of safety belt buckle unlatching--especially when scientific studies, real-world crash data, and consumer reports all demonstrate that such media claims are unfounded.

SUMMARY:

The petitioner alleges that certain designs of safety belt buckles are vulnerable to unlatching caused by inertial forces that may be applied to the buckle in a crash. To support this contention, the petitioner demonstrated the unlatching of side release buckles by hitting sample buckles on the backside with a sharp impact, typically with a video cassette box, or human hip. Also, the petitioner provided consumer complaints alleging the unlatching of buckles in motor vehicle accidents.

The agency conducted an extensive review of all available information to assess the real-world risk of inadvertent unlatching of buckles. It sent information request letters to eight vehicle manufacturers, five safety belt manufacturers, and holders of seven patents of end release buckles. The agency reviewed its accident data, consumer complaint file, and crash test data to assess this alleged problem. Further, full scale vehicle crash tests and other laboratory tests were conducted in the course of this evaluation to determine the possible real-world risk associated with the alleged inertial unlatching.

The vehicle manufacturers' information demonstrates a very low rate of complaints of alleged releasing of buckles in motor vehicle accidents. Side release buckles have been used in vehicles from all of the major manufacturers for many years. Since 1970, about 263 million vehicles have been equipped with side release buckles. The manufacturers report either no or very few complaints of alleged unlatching in that period of time. No manufacturer developed test programs to address the alleged defect because real-world data suggested there was no need. Several manufacturers point out that the level of acceleration or impact on a buckle during a motor vehicle crash is far below the level needed to release a buckle. The buckle manufacturers report no complaints and only seven lawsuits pertaining to buckle unlatching. These manufacturers have made no design changes due to the alleged defect.

Several patents for end release buckles reference the need for a design to consider the inertial effects on the performance of a buckle. The patent holders provided two reasons for this. First, some designs are intended to be used with pyrotechnic belt pre-tensioning devices. These devices can impart impact loads to the buckle and these must be anticipated in the design to prevent inadvertent unlatching. Second, all designs of buckles, both end release and side release, must operate safely without inadvertent release in real-world use.

The agency analyzed its accident data for evidence of the alleged defect. The analyses compared injury and fatality levels between vehicles using side release buckles and vehicles using end release buckles. The analyses showed no pattern of evidence to support an allegation of inadvertent unlatching of side release buckles. Specific accident files show no evidence to indicate inertial unlatching of buckles.

The agency reviewed all of its records of vehicle crash and sled test data for evidence of inertial unlatching. The agency has records on 2,067 tests involving 3,730 belted full-size test dummies and 239 tests of child dummies in child safety seats. Nine buckles unlatched in vehicle tests and one broke and one unlatched in child seat sled tests. Of the unlatched buckles, three were side release and seven were end release buckles. The agency has reviewed the written reports and films of these incidents and concluded that the test data provides no evidence of the alleged inertial unlatching phenomena.

The ODI consumer complaint database contains some complaints of alleged unlatching. However, the level of complaints is very low in comparison to the population of vehicles and is not concentrated in vehicles with side release buckles. The complaints of alleged unlatching include end release type buckles. The complaint rate for end release buckles compared to side release buckles is about the same (0.9 for end release compared to 0.7 for side release complaints per 100,000 vehicles).

A test program was conducted, including tests of belt buckles and vehicle crash tests. The laboratory data shows that, as belt tension increases, the level of acceleration required to unlatch a buckle increases. Further, the data demonstrates that accelerations necessary to inertially unlatch a belt buckle do not occur in actual vehicle crash conditions. Crash tests of vehicles shows that during the crash, the highest acceleration on the buckle occurs with significant loading of the belt. None of the buckles opened during crash tests, and the measured level of acceleration on the buckles was well below the level to cause a buckle to unlatch.

FINDINGS:

- o A comprehensive agency review of over 2,300 crash tests involving approximately 4,000 belted dummies, including frontal, oblique, rear, rollover, and side crashes, did not provide one instance of inertial unlatching. In ten of these tests, belts did come unlatched due to other reasons, e.g., external contact with the release button, manufacturing defect in the buckle. It was also found that seven of the ten buckle unlatchings involved end release buckles.

- o Laboratory testing performed in response to this petition defined the engineering characteristic which can cause inertial unlatching. Most important, this testing demonstrated that these characteristics are not present in real-world crashes.

- o Manufacturer data did not demonstrate that inertial unlatching is a safety problem. In the tens of thousands of crash tests conducted by motor vehicle and belt manufacturers, only General Motors Corporation (GM) reported what it believes may be two possible, but unverifiable, cases of inertial unlatching. Of the 30,000 tests GM has performed, it identified only these two such possible instances. No other reports were provided by either vehicle or belt manufacturers. Responses from safety belt buckle patent holders indicated that patents were sought to improve the general performance and ease of operation of buckles--not because of a safety problem associated with inertial unlatching.

- o Analysis of real-world crash data demonstrated that "there is no pattern of evidence in the crash data to support the allegation related to inadvertent unlatching for side-release systems." Thus, analysis of real-world data did not indicate the presence of a safety problem associated with inertial unlatching in side release buckles.

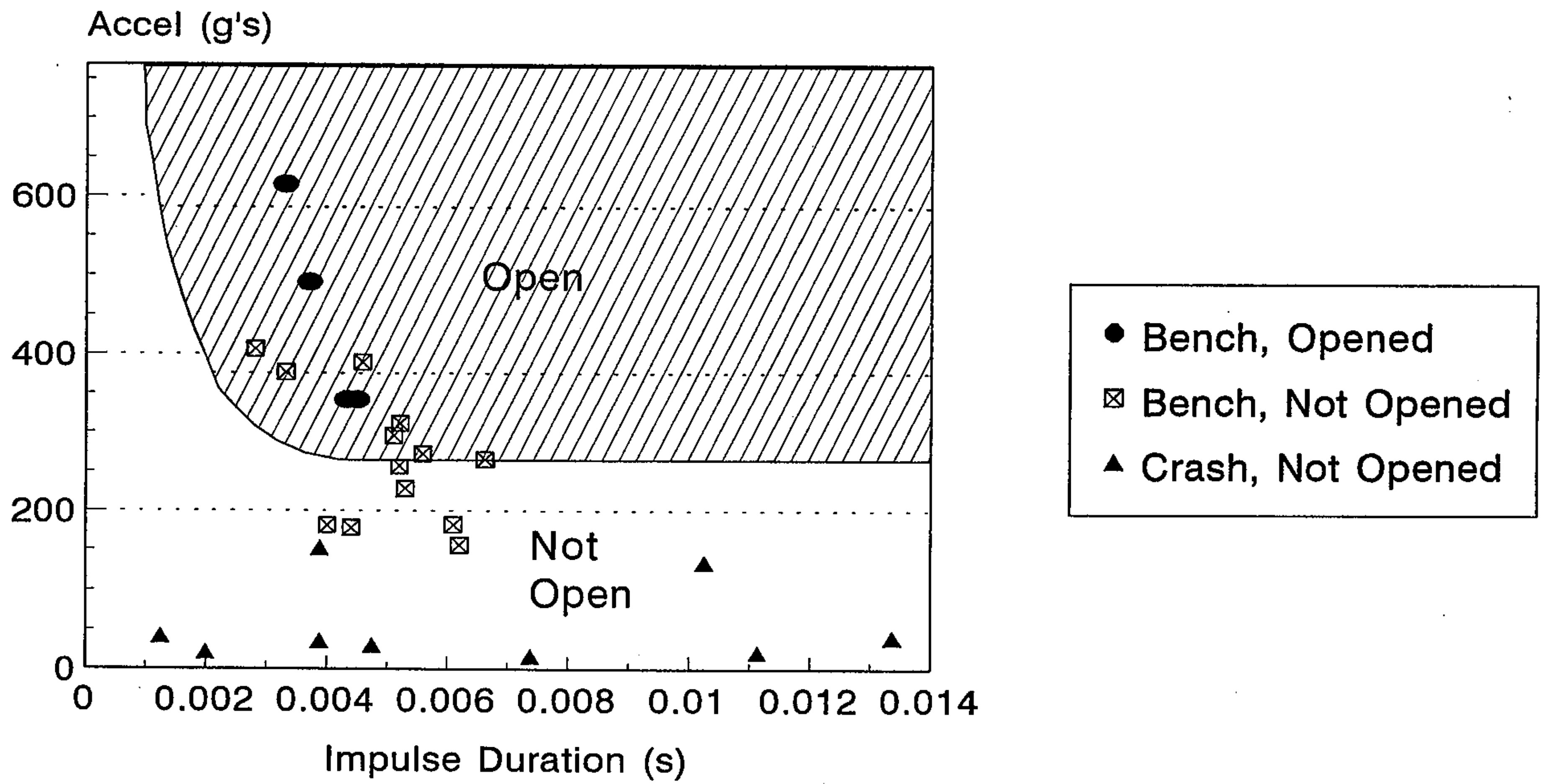
- o Review of consumer calls to the agency's Auto Safety Hotline did not suggest the presence of a safety problem. The complaint rate (the number of reports divided by the number of vehicles on the road) is essentially the same for vehicles with both side and end release buckles. Further, the complaint rate is extremely low compared to other safety problems reported to the agency. Additionally, the number of consumer calls to the Auto Safety Hotline subsequent to the "Street Stories" and CBS Evening News programs, the latter of which broadcast the toll-free Auto Safety

Hotline telephone number, were no higher than the number of calls normally received. Generally, national TV publicity of a safety issue, in which the Auto Safety Hotline telephone number is presented, results in large increases in Auto Safety Hotline calls. The fact that such an increase did not occur in this instance suggests that the public does not consider this do be a safety concern.

RECOMMENDATION:

This petition should be denied.

Buckle Impulse Opening Characteristics



All bench tests used 50 lb. preload and GM buckles.
Crash tests were performed full scale.

Figure 1

APPENDIX A

NCSA ANALYSIS

Inadvertent Safety Belt Unlatching

November 17, 1992

Summary of Findings

This analysis, conducted by staff of the National Center for Statistics and Analysis, focused on specific make, model and model year vehicles equipped with either side-release or end-release manual lap-and-shoulder belts, as specified by the staff of the Office of Defect Investigation. Data from the Fatal Accident Reporting System (FARS) for 1985-1991 and selected state files from CARDfile for 1988-1990 (the three most recently available years) were used.

The analysis of state data focused on the fatal and incapacitating injury rate (K+A) per driver involved in these vehicles as a function of relevant crash, vehicle and driver characteristics. Only towed vehicles were included in the analysis. Files used for this analysis included Indiana, Maryland, Michigan and Pennsylvania (Washington and Texas do not include a towaway indicator on the file; Indiana's vehicle make/model codes did not permit identification of Caravan/Voyager). Since not all states identify the presence of right-front passengers unless they are injured, the analysis of state data used only drivers for consistency between states and with previous state data applications. Occupant ejection in the state files was sufficiently rare to prohibit any analysis from being conducted.

The analysis of FARS data focused on the rate of fatal injury per involved front outboard occupant, as well as the ejection rate per involved front outboard occupant (ejection is much more common in fatal crashes and therefore, could be analyzed).

The major portion of the analysis employed logistic regression models, using both FARS and state data, to estimate the effect of side- vs. end-release buckles, accounting for differences in the relevant crash, vehicle and driver attributes associated with occupant injury and ejection, as available and appropriate.

In addition to the effort to develop explanatory statistical models, several vehicles under study, (Ford Taurus/Mercury Sable, Lincoln Continental, and Dodge Caravan/Plymouth Voyager) changed from side-release to end-release buckles during the study period. These "crossover vehicles" were subjected to additional, separate study, comparing the before-and-after injury and ejection experience of vehicle occupants.

The findings are as follows.

Analysis of Crossover Vehicles

The first analysis uses the raw crash data to investigate vehicles that switched from the side- to end-release system. Using these vehicles in a before vs. after comparison forms a "natural peer group", such that the crash and driver characteristics should be quite similar. The asterisk in the column labeled "Stat Sign" indicates the difference between side- and end-release was statistically significant at the alpha=0.05 level, two-tailed test.

1. Analysis of Fatal Crashes

	Side Release		End Release		
Ejection	N	% Eject	N	% Eject	Stat Sign
Caravan/Voyager	592	8.3%	298	7.0%	
Continental	97	8.2%	14	7.1%	
Taurus/Sable	1090	6.0%	297	4.7%	

	Side Release		End Release		
Fatal Injury	N	% Fatal	N	% Fatal	Stat Sign
Caravan/Voyager	592	31.4%	300	21.3%	*
Continental	98	45.9%	14	50.0%	
Taurus/Sable	1089	43.0%	297	45.5%	

Of the six comparisons, only the difference for Caravan/Voyager fatal injury per involved occupant was statistically significant, with a higher rate for side-release buckles. It may be worthwhile to investigate this result further.

2. Analysis of State Data

Indiana	Side Release		End Release		
K+A Injury	N	% Inj	N	% Inj	Stat Sign
Taurus/Sable	455	1.0%	122	1.6%	

Maryland	Side Release		End Release		
K+A Injury	N	% Inj	N	% Inj	Stat Sign
Caravan/Voyager	418	15.3%	168	16.1%	
Taurus/Sable	1061	9.9%	273	11.7%	

Michigan	Side Release		End Release		
K+A Injury	N	% Inj	N	% Inj	Stat Sign
Caravan/Voyager	1931	6.5%	535	4.7%	
Taurus/Sable	3511	5.8%	791	5.6%	

Pennsylvania	Side Release		End Release		
K+A Injury	N	% Inj	N	% Inj	Stat Sign
Caravan/Voyager	1606	2.0%	511	2.2%	
Taurus/Sable	2227	2.1%	509	2.8%	

None of the comparisons of K+A injury rates were statistically significant within each state. A second-stage analysis was conducted, combining the resulting statistics for Caravan/Voyager across states (MD, MI, PA) and Taurus/Sable across states (IN, MD, MI, PA). Neither of the two test statistics yielded a significant difference in the K+A injury rate for side- vs. end-release.

In summary, only one statistically significant difference was found in all of the analyses of crossover vehicles.

Analysis of All Specified Vehicles

The vehicles specified by ODI staff were used in investigating the effect of side- vs. end-release systems on the likelihood of K+A injury using the state data files, the likelihood of occupant ejection in fatal crashes, and the fatal injury rate per occupant involved in a fatal crash. Logistic regression models were employed, using relevant variables for the crash, vehicle and occupant characteristics.

In preliminary analyses it was noted that the vehicles equipped with side-release systems tended to weigh more than those equipped with end-release systems. In addition, vehicle weight has been shown to be a significant factor in the likelihood of occupant injury. Therefore, it was important to incorporate vehicle weight into these analyses.

Due to the bias in reported safety belt use and the relationship of reported use to the event of interest, belt use was not employed in these models.

In general, the following explanatory variables were used in the modeling process (subject to availability on the state files):

- o Posted speed limit,
- o Vehicle weight (or ratio of weights for two-vehicle crashes),
- o Impact location (farside/nearside/other),
- o Rollover,
- o Occupant (driver for state files) age,
- o Occupant (driver for state files) sex,
- o Seating position (for FARS data), and
- o Side- vs. end-release system as equipped in vehicle.

3. Analysis of Fatal Crashes

The analysis of fatal crashes (both fatal injury and complete ejection) was conducted two ways - using two-vehicle crashes and all crashes, resulting in four separate analyses. The results of these analyses were consistent: in each analysis, the side-release system was associated with significantly lower ejection rates and rates of fatal injury per involved occupant compared with the end-release system. However, while the release type was statistically significant, it was generally marginally so compared with the remaining variables and in light of the large sample sizes (ranging from 8,000 for two-vehicle crashes to 24,000 for all crashes). Its importance was relatively small compared to the other variables included in the models.

4. Analysis of State Data

The analysis of state data investigated the likelihood of K+A injury; there were enough cases to analyze ejection risk. In these analyses the release type was never statistically significant, in spite of the fact that several states provided over 30,000 cases for analysis. In addition, the state data models did not provide as good a statistical fit to the data compared with the models estimated for fatal crashes.

Summary

Having reviewed all of these analytical results, there is no pattern of evidence to suggest that side-release systems are less safe than end-release systems. On the contrary, the FARS analysis would suggest that end-release systems may be less safe. However, it must be remembered that the analysis employs surrogate measures (injury and ejection) representing the outcome of the event of interest (inadvertent unlatching), a phenomenon which cannot be measured directly in the crash data. In addition, due to the bias in reported safety belt use and the relationship of reported use to the event of interest, belt use was not employed in these models. Differential use rates between side- and end-release systems, due to factors other than the system itself (e.g., equipped vehicle, driver demographics, etc.) could easily confound the interpretation of this result.

It is likely that the most serious consequences of the occurrence of the alleged event would be represented in more serious crashes; for example, ejection is much more common in fatal crashes than in less serious crashes (ejection is a serious outcome in and of itself). Therefore, it is not surprising for the state data to show no difference.

In closing, there is no pattern of evidence in the crash data to support the allegation related to inadvertent unlatching for side-release systems.

APPENDIX B

Side Release Button	
Model Year	Model
1985-1987	Tempo
1985-1988	T-bird
1985-1989	Crown Victoria/Grand Marquis
1986-1988	Taurus/Sable
1985-1989	Mustang
1985-1988	Continental
1985-1989	Celebrity
1985-1988	Park Avenue, Old 98
1985-1989	Caprice
1985-1988	Monte Carlo
1985-1986	Bonneville, Olds 88, Buick LeSabre
1985-1989	Cadillac Seville
1985-1986	Pontiac Grand Am, Buick Skylark or Somerset, Olds Calais
1985-1987	Chrysler Lebaron (4dr & 2dr)
1987	Sundance and Shadow
1985-1987	Daytona
1985-1989	Aries, Reliant
1985-1988	Dodge 600, Plymouth Caravelle, Chrysler New Yorker
1985-1987	Dodge Diplomat, Plymouth Grand Fury, Chrysler Fifth Avenue
1985-1988	Caravan, Voyager

End Release	
Model Year	Model
1989	Taurus
1988-1990	Tracer
1989	Continental
1985-1989	Camaro, Firebird
1985-1989	Fiero
1989	Spirit, Acclaim
1989-1991	Caravan, Voyager (Front only in 1989 and 1990)
1985-1989	BMW 3 Series
1985-1986	Accord, Civic 2dr
1985-1989	Accord, Civic 4dr
1985-1986	Maxima
1985-1988	Sentra
1985-1989	Stanza
1985-1986	Volvo 7 Series
1985-1988	Volvo 2 Series
1985-1986	VW Golf, Jetta
1985-1986	Mercedes Benz

APPENDIX C

Safety Belt Buckle Test Openings Based on 2306 Tests and 3969 Dummies

Test Type	Vehicle/Restraint Make	Comments	Restraint Type	Restrained Device	HIC Driver Pass		Buckle Type	Report #
30 mph frontal, NEF-FMVSS 301	1979 IH Scout II	"Possible acceleration affecting buckle spring tension"	3-Pt man	50th male	-	-	side	HS-6-01478
35 mph rear, NCAP-NEF-FMVSS 301	1980 Honda Prelude	"Seat belt buckle failed early in the event, permitting dummy to move rearward freely."	3-pt man.	50th male	n/a	n/a	side	HS-9-02274
35 mph frontal, NCAP-NEF	1980 Datsun 310 GX	RECALLED, Internal mechanical failure, passenger buckle failed at 44 msec.	3-pt. man.	50th male	1059	**2019**	end	HS-9-02274
35 mph frontal, NCAP-NEF	1980 Subaru	RECALLED, Internal Mechanical Failure, Driver buckle (see next entry)	3-pt. man.	50th male	**1086**	2836	end	DOT 0133
35 mph frontal, NCAP-NEF	" (same car as above)	RECALLED, internal mechanical failure, passenger buckle	"	"	1086	**2836**	end	"
35 mph frontal, NCAP-NEF	1984 Isuzu Impulse	"On rebound the driver . . . arm struck the buckle release button. . . "	3-pt man.	50th male	**1769**	2454	end	212-CAL-84-025
35 mph frontal, NCAP-NEF	1984 Plymouth Conquest	Post-impact, passenger belt released, drivers right elbow struck button	3-pt man.	50th male	1118	**1035**	end	212-CAL-84-080
34 mph 2 cars frontal, 90% overlap	two 1989 Hyundai's	Head hit the automatic belt release on rebound (in vehicle 2)	2-pt auto, man lap	50th male	1058	**682**	end	DOT #1373
Sled - CRABI 30 mph	Lincoln Belts	Test 16, Airbag pushed child seat and buckle into seat cushion	Child seat, Rear Face, A/Bag 3-pt	p 3/4 (9 Month)	n/a	**486**	side	CR/AB - 16
Sled - Child Seats	GM belt	Test 33, buckle used to restrain the child seat broke at the webbing connection. Belt load 853 lbs.	child seat, forward	3-year old	n/a	n/a	side	DOTHS 807466 Test 33
35 mph frontal, NCAP	1992 Dodge Dakota Pickup	Driver safety belt unlatched on rebound during impact. Film analysis show apparent elbow impact into end-release button.	3-pt man.	50th male	**1005**	**987**	end	NCAP No. MN0302

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

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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.

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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.

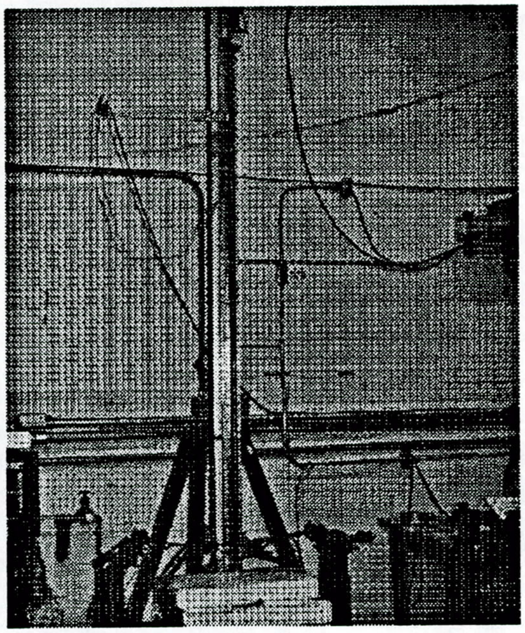


FIGURE 2.1: Drop Tower/Safety Belt Test Configuration

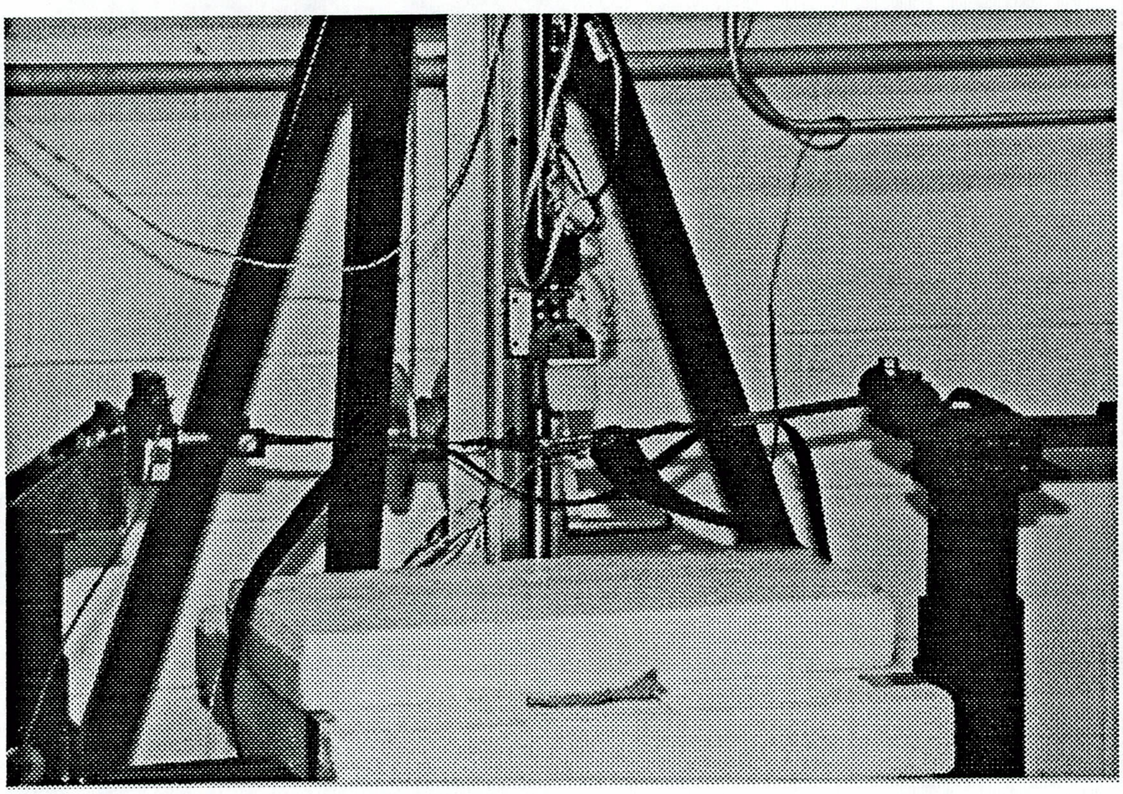


FIGURE 2.2: Safety Belt Test Fixture

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.

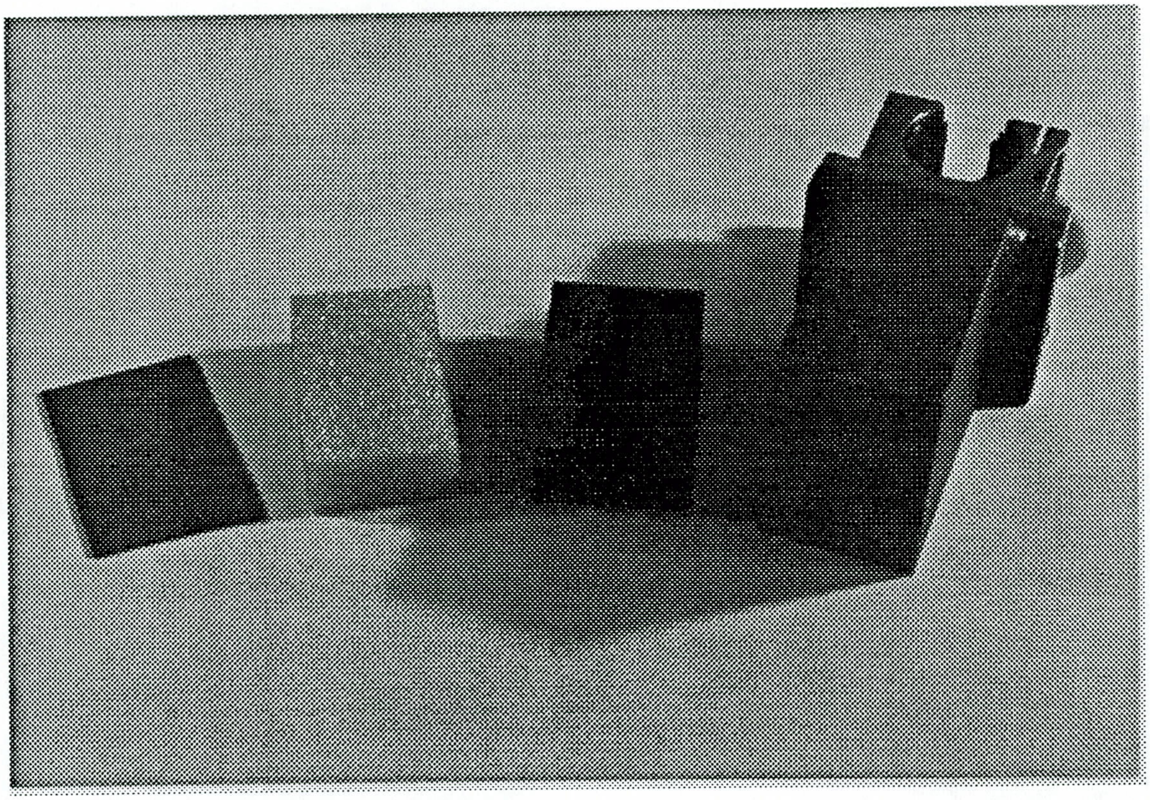


FIGURE 2.3: Rigid Mass and Padding Materials

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 2GCDC14H5F1105869 (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-10.5

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	304&315		
	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.			

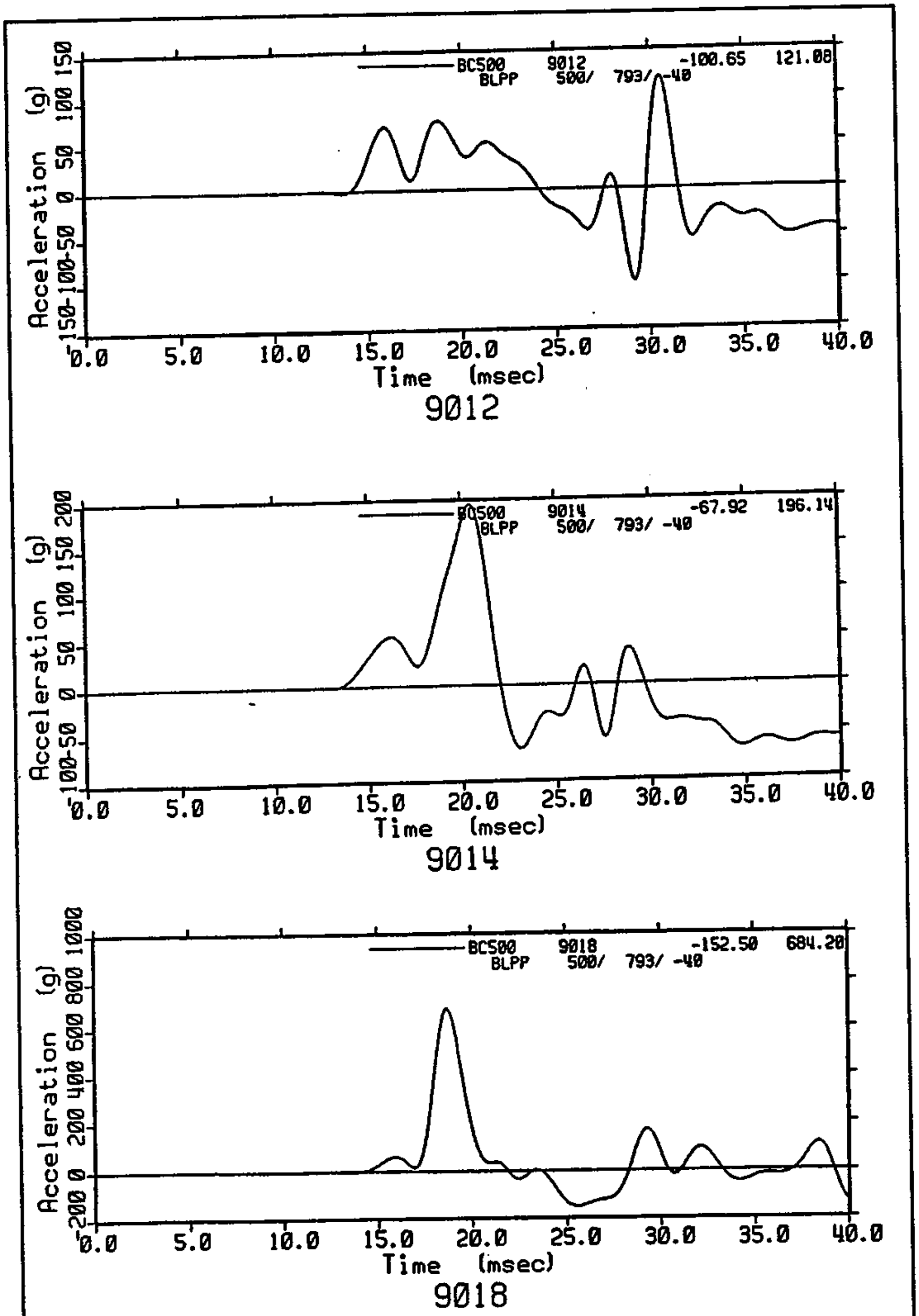


FIGURE 3.1: Series of Acceleration Traces for GM/5-lbf-Belt-Tension/Ensolite Tests

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.

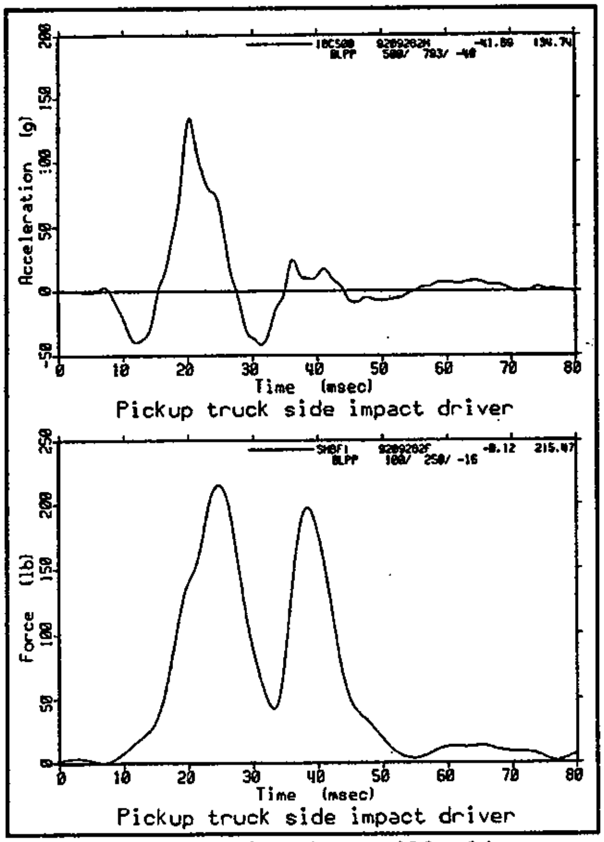


FIGURE 3.2: 85 Chevy (30mph) Driver Buckle Acceleration and Shoulder Belt Force

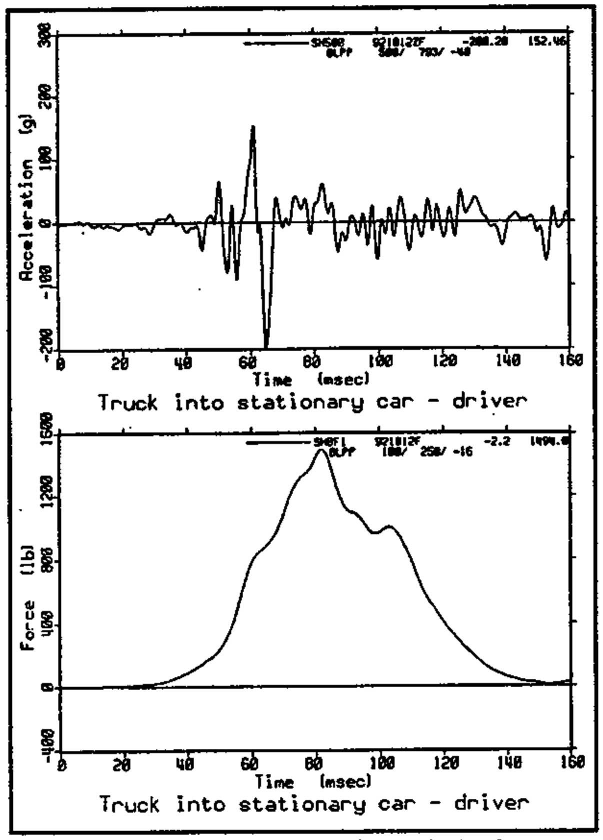


FIGURE 3.3: Taurus/Truck Driver Buckle Acceleration and Shoulder Belt Force

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

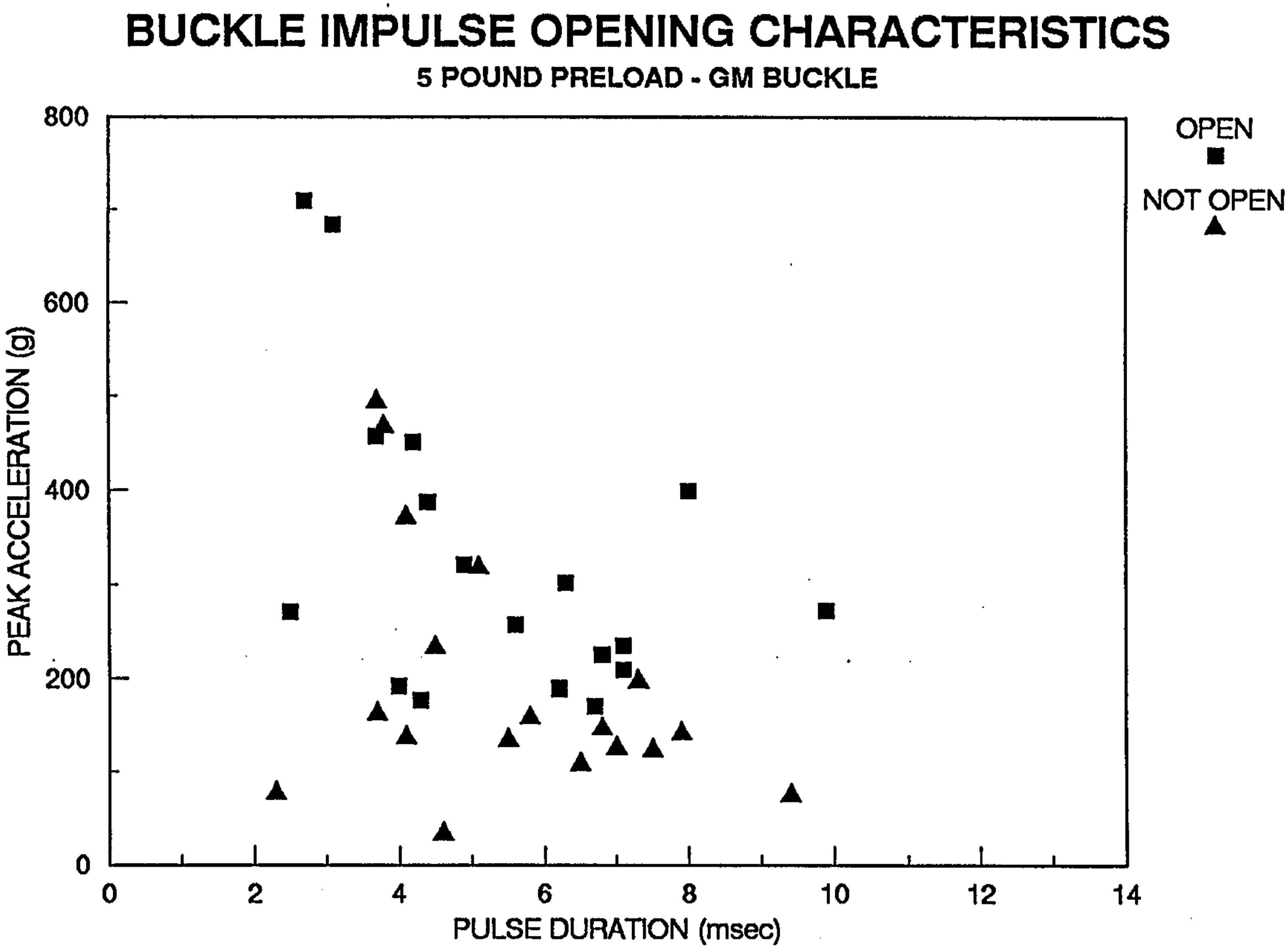

BUCKLE IMPULSE OPENING CHARACTERISTICS
5 POUND PRELOAD - GM BUCKLE
PEAK ACCELERATION (g)
800
600
400
200
0
PULSE DURATION (msec)
0
2
4
6
8
10
12
14
OPEN
NOT OPEN

FIGURE 4.1

BUCKLE IMPULSE OPENING CHARACTERISTICS

50 POUND PRELOAD - GM BUCKLE

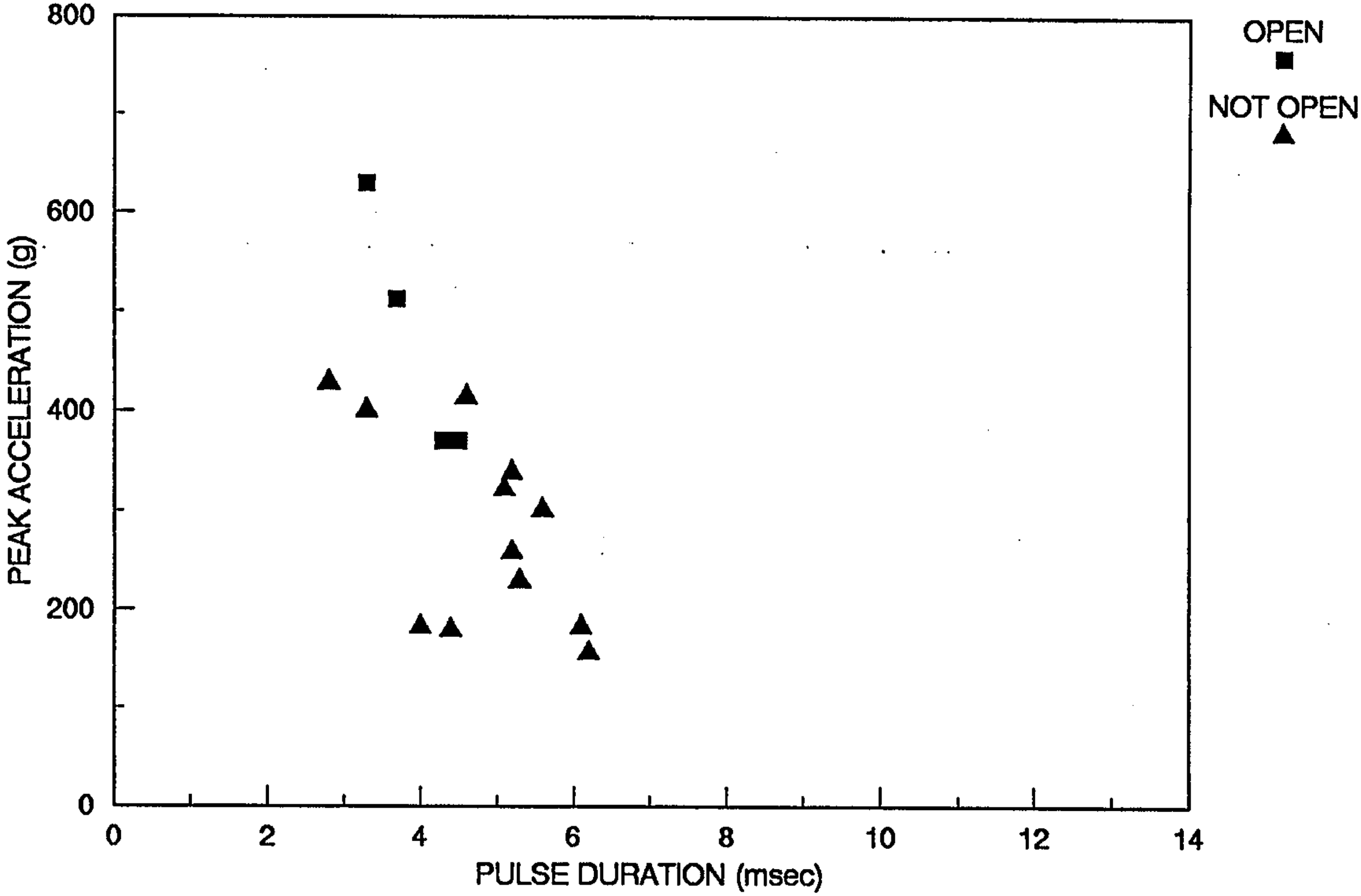


FIGURE 4.2

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

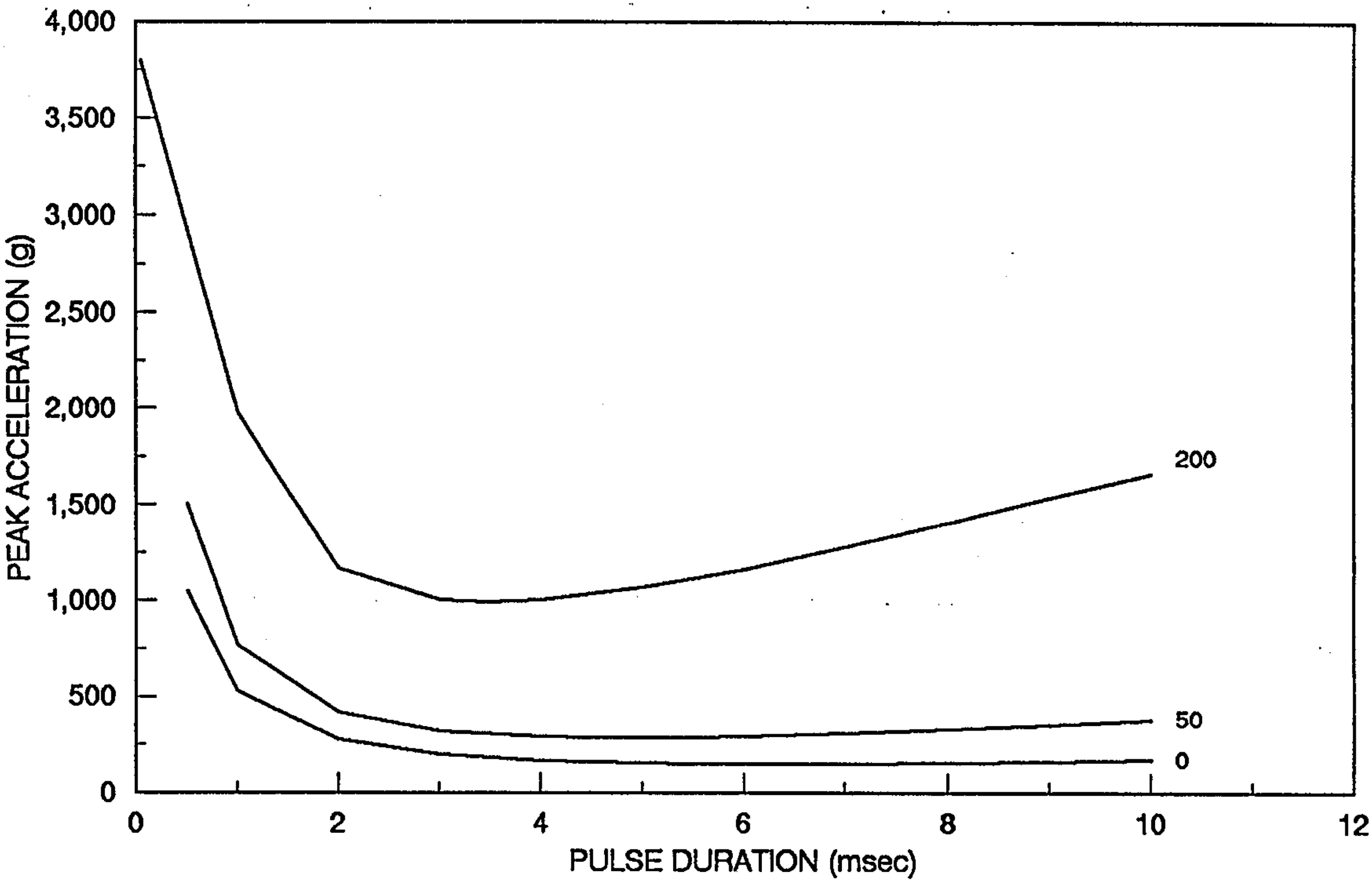


FIGURE 4.3

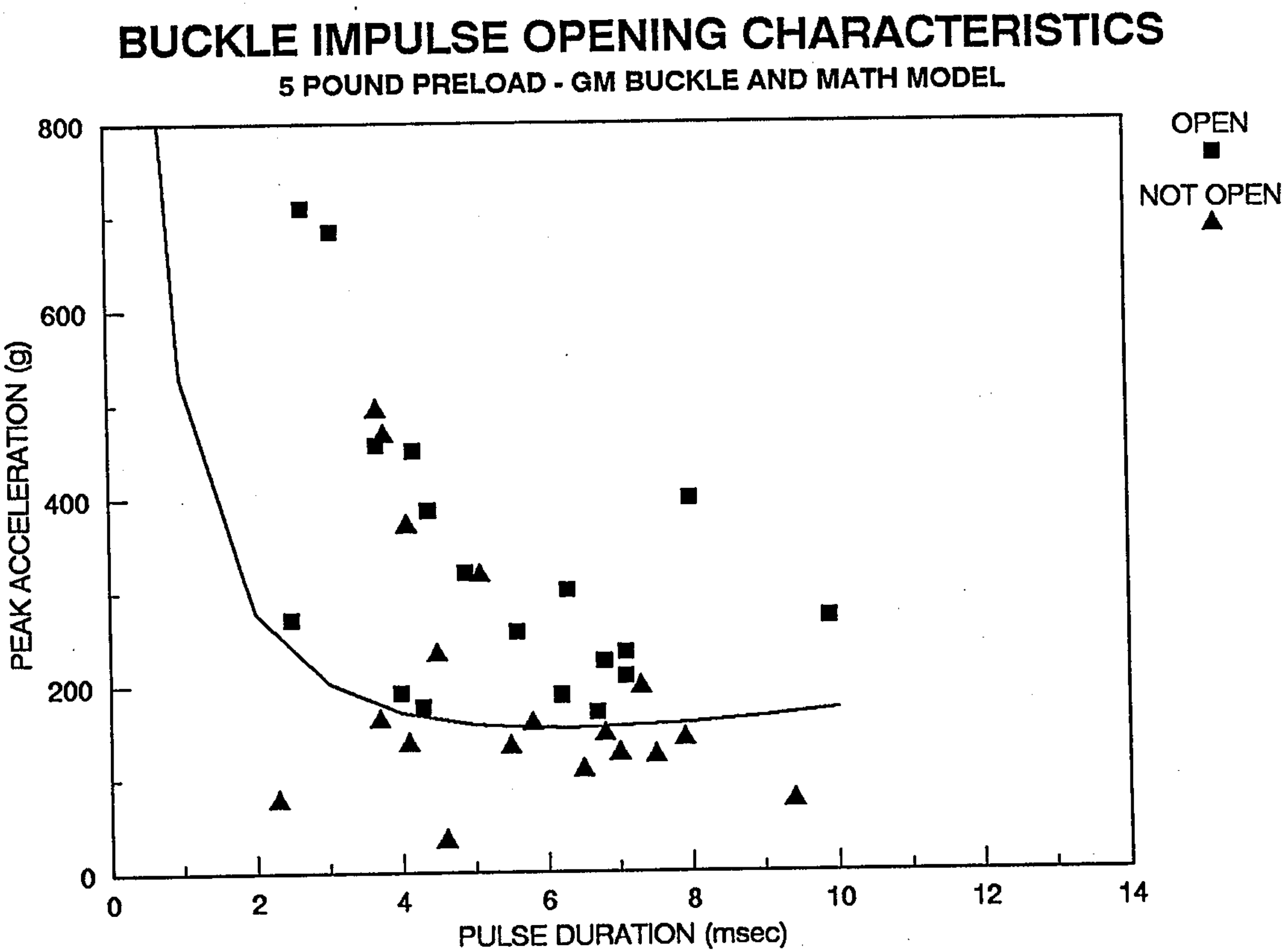
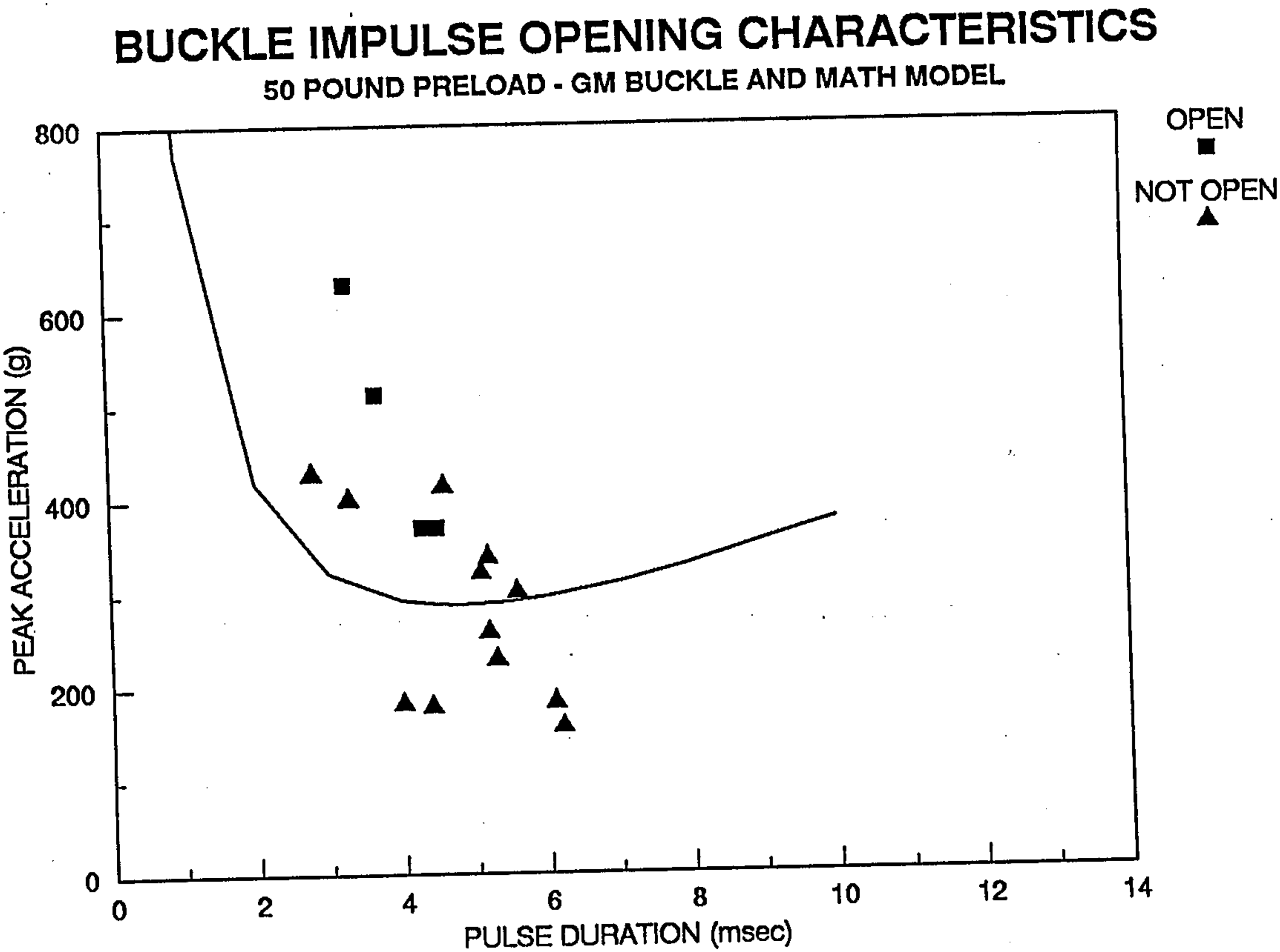

BUCKLE IMPULSE OPENING CHARACTERISTICS
5 POUND PRELOAD - GM BUCKLE AND MATH MODEL
OPEN
NOT OPEN
PEAK ACCELERATION (g)
800
600
400
200
0
0
2
4
6
8
10
12
14
PULSE DURATION (msec)

FIGURE 4.4



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

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

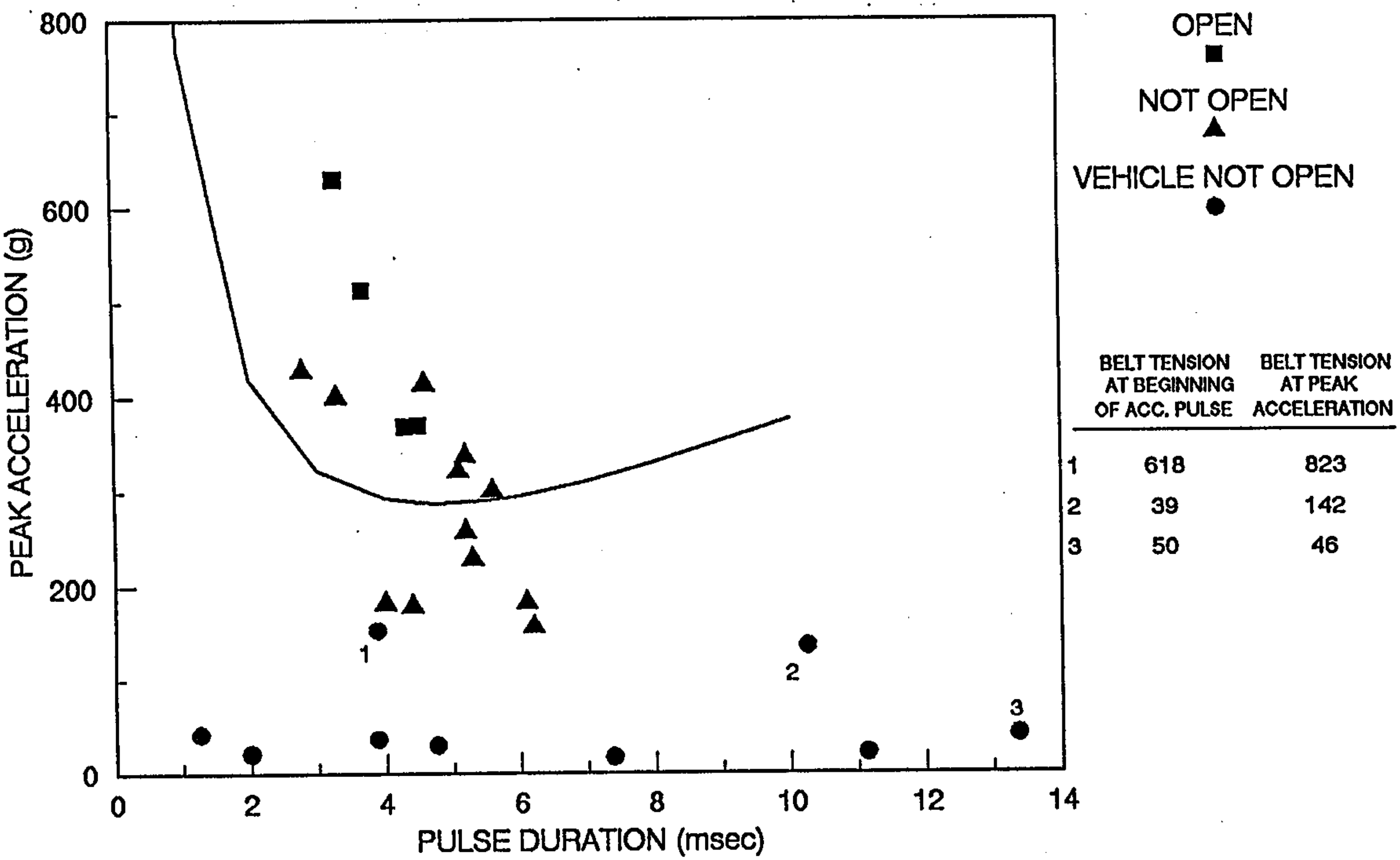


FIGURE 4.6

BUCKLE IMPULSE OPENING CHARACTERISTICS

200 POUND BELT TENSION - GM BUCKLE MATH MODEL AND CRASH DATA

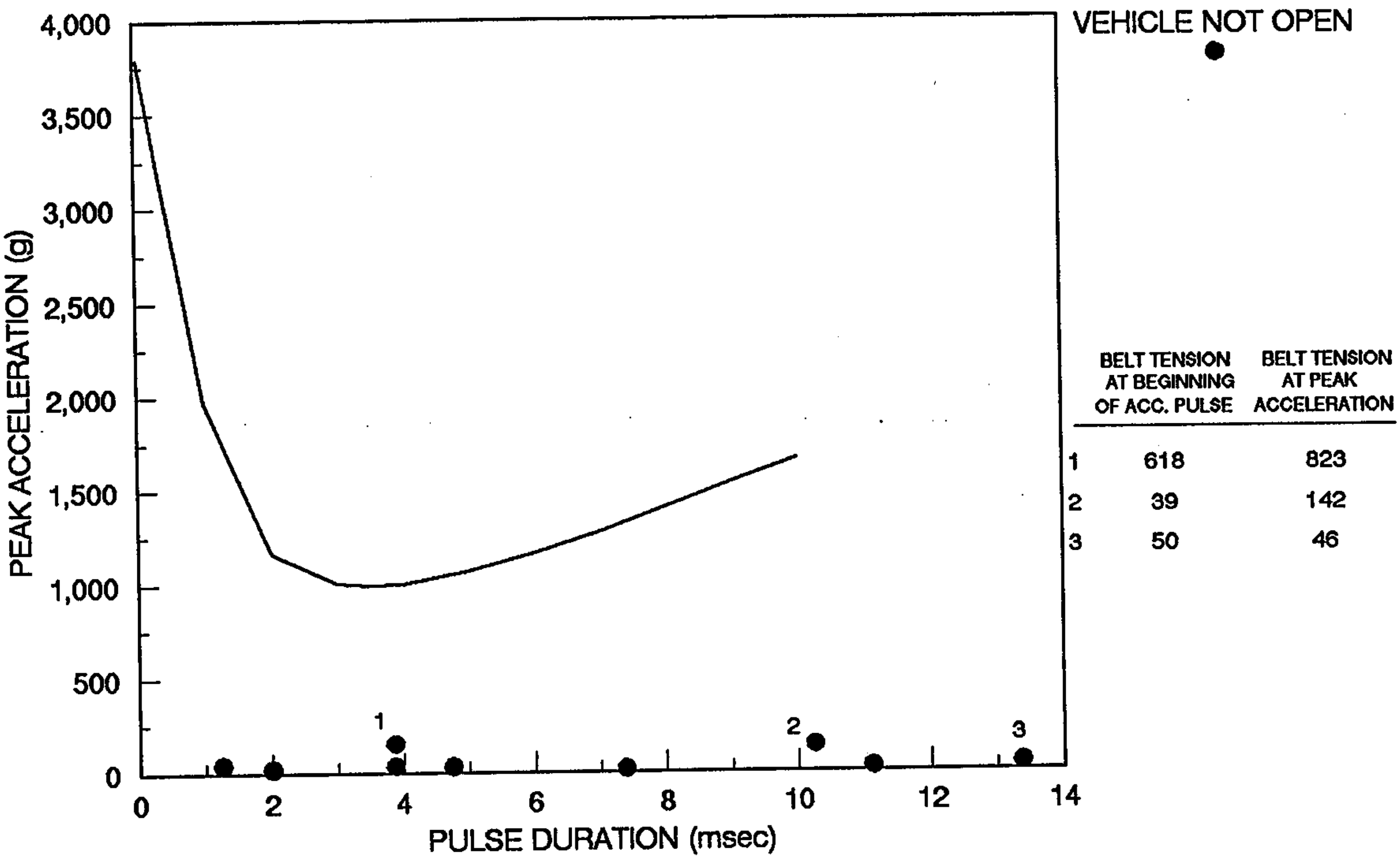


FIGURE 4.7

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

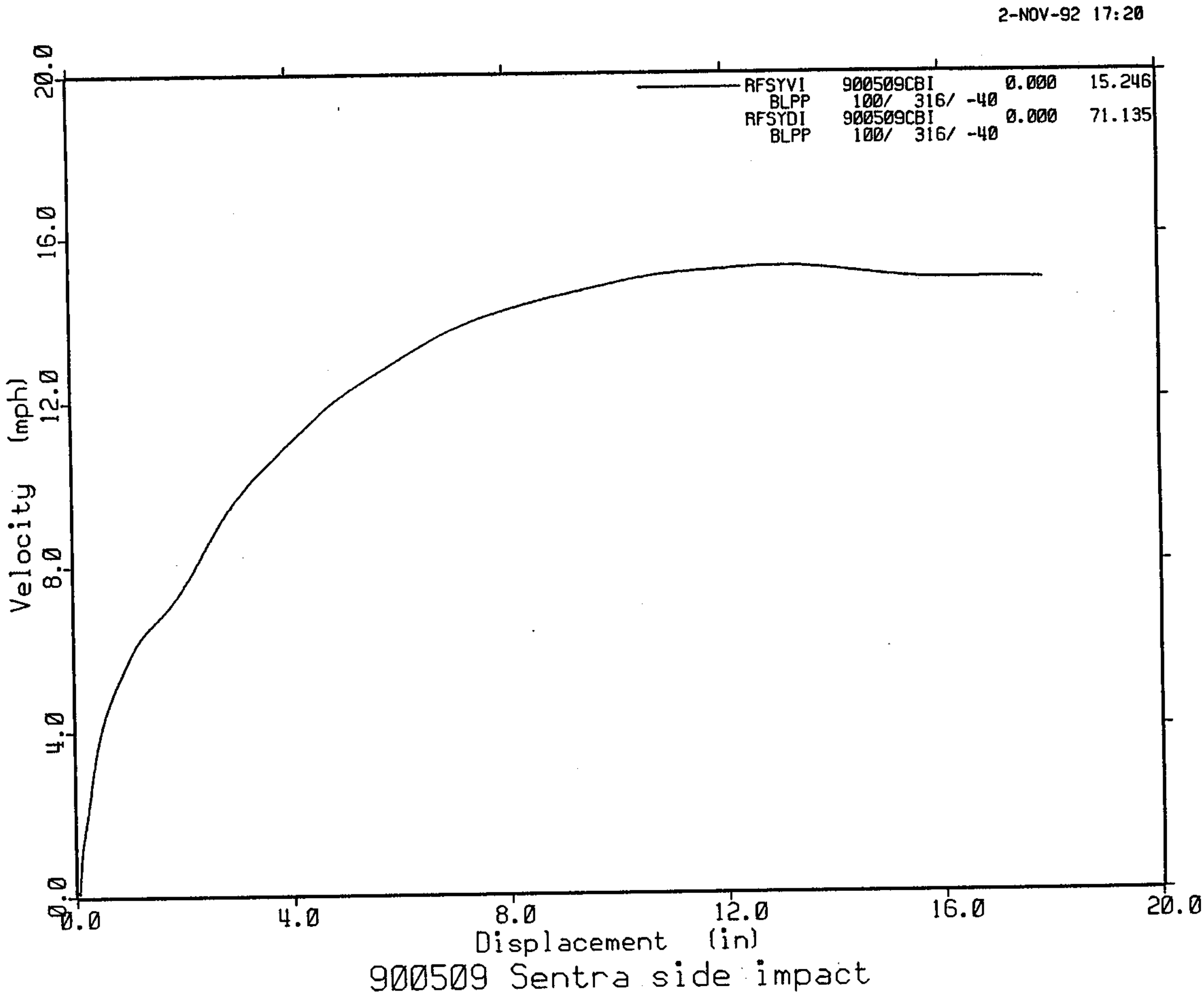

2-NOV-92 17:20
RFSYVI 900509CBI 0.000 15.246
BLPP 100/ 316/ -40
RFSYDI 900509CBI 0.000 71.135
BLPP 100/ 316/ -40
Velocity (mph)
0.0
4.0
8.0
12.0
16.0
20.0
Displacement (in)
900509 Sentra side impact

FIGURE 4.8

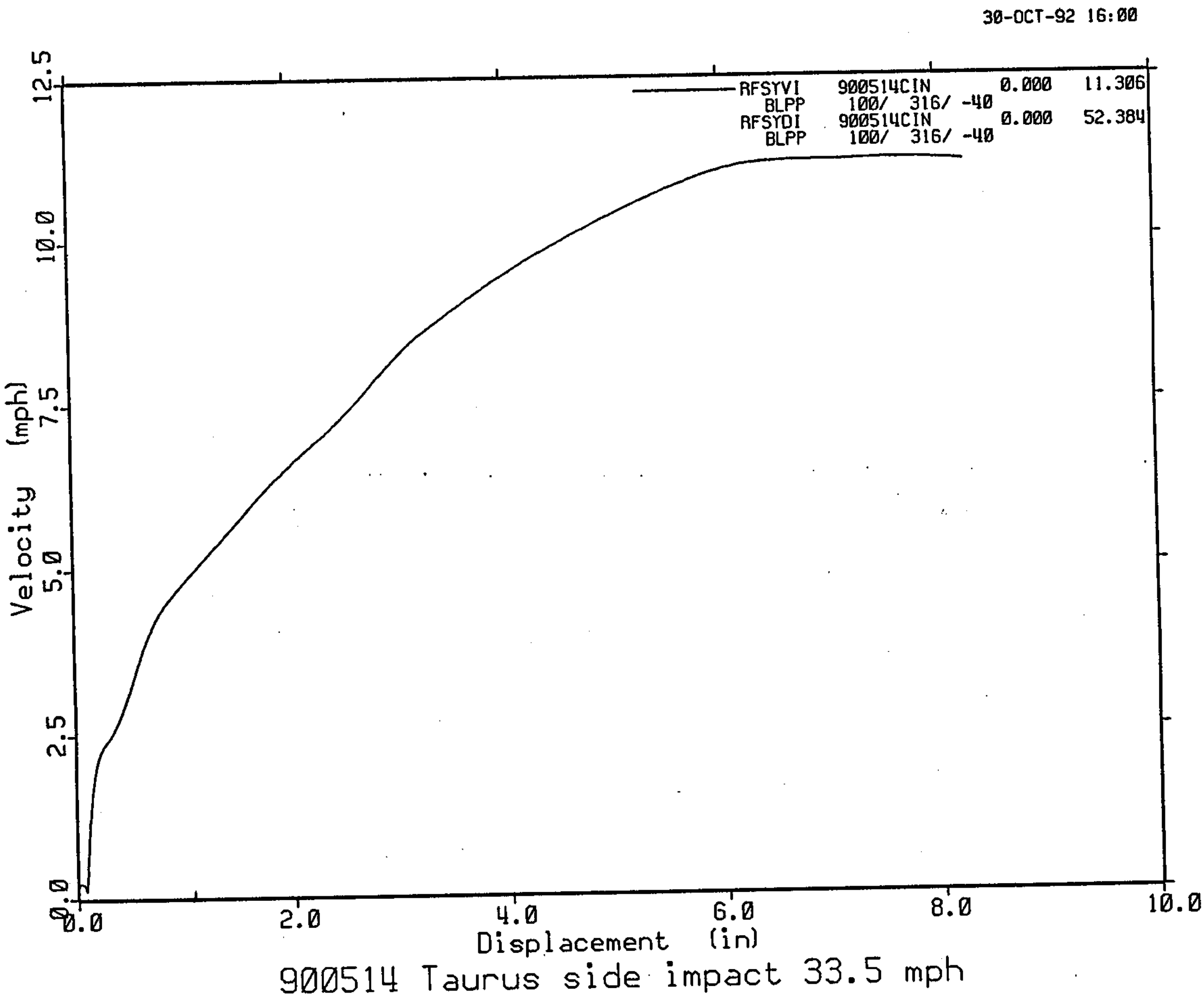

30-OCT-92 16:00
RFSYVI 900514CIN 0.000 11.306
BLPP 100/ 316/ -40
RFSYDI 900514CIN 0.000 52.384
BLPP 100/ 316/ -40
Velocity (mph)
0.0
2.5
5.0
7.5
10.0
12.5
0.0
2.0
4.0
6.0
8.0
10.0
Displacement (in)
900514 Taurus side impact 33.5 mph

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

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	565,000

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.

MAR 1 1994

DP92-017: Inadvertent Release of Safety Belt Buckles

Original signed by
William G. Boehly

Charles L. Gauthier, Director
Office of Defects Investigation

Public File, Petition DP92-017

Please include the attached addendum to the public file for petition DP92-017. This is an addendum to the Final Report - VRTC-72-0280, "Tests Regarding Alleged Inertial Unlatching of Safety Belt Buckles."

Attachment

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U.S. Department
of Transportation
National Highway
Traffic Safety
Administration

Memorandum

Vehicle Research and Test Center
P. O. Box 37
East Liberty, Ohio 43319
(513) 666-4511

Subject: Addendum to Final Report - VRTC-72-0280
Tests Regarding Alleged Inertial
Unlatching of Safety Belt Buckles

Date: FEB 25 1994

From: Michael W. Monk, Acting Director
Vehicle Research and Test Center

Reply to
Attn. of:

To: Charles L. Gauthier, Director
Office of Defects Investigation

This addendum to the subject final report is in response to a request by the Office of Defects Investigation (ODI), National Highway Traffic Safety Administration (NHTSA) for additional information. Specifically requested were the model numbers for the three safety belt buckles used in the "drop tower" tests referenced in Section 2.2.1 "Bench Test Procedure". Although the precise buckle model numbers are not known, the following identifying information was found to be stamped or marked on the subject buckles:

Ford: RCF-67, F284.

GM: 3CM405 28

NISSAN: TK810, TK820

The Nissan buckle (TK810; TK820) was from a 1989 Nissan Pickup.
It is not known from which specific vehicles the GM or Ford buckles were taken.

The original and three (3) copies of this memorandum report are enclosed. This completes the requirements for this program.

#

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FINAL

DP92-017: Inadvertent Release of Safety Belt Buckles

Charles L. Gauthier, Director, Office of Defects Investigation

Public File, Petition DP92-017

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Attachment

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Copy back to Charlie after Kim stamps it in FIRST THING!

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Addendum to Final Report - VRTC-72-0280
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Michael W. Monk, Acting Director
Vehicle Research and Test Center

Charles L. Gauthier, Director
Office of Defects Investigation

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NRD-23:RKirkbride:srs:513-666-4511:February 25, 1994
Copies to: NRD-23 Chron
Kirkbride
Proj. File

U.S. Department of Transportation
National Highway Traffic Safety Administration

Memorandum

Vehicle Research and Test Center P. O. Box 37
East Liberty, Ohio 43319
(513) 666-4511

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PETITION DP92-017
INADVERTENT RELEASE OF SAFETY BELT BUCKLES

Office of Defects Investigation
The National Highway Traffic Safety Administration

November 18, 1992

PETITION DP92-017
INADVERTENT RELEASE OF SAFETY BELT BUCKLES
November 18, 1992

BASIS:

Mr. Benjamin Kelley, President of the Institute for Injury Reduction (IIR), petitioned the National Highway Traffic Safety Administration (NHTSA) by letter dated September 11, 1992, requesting that the agency initiate a defect investigation leading to a recall and a rulemaking proceeding to preclude from sale in the future certain designs of safety belt buckles. The petition alleges that certain designs of buckles are susceptible to "inertial actuation" that causes them to open during a motor vehicle accident. The petition states, "The defect appears to involve seat buckle designs with release buttons on the front face of the buckle ('front release'). It has been found in seat belt configurations spanning about three decades, including new car designs."

The petition specifically requests the agency to "take the following actions concerning the 'inertial actuation' design of some seatbelt buckle-latch connections. . .

1. Initiation of a defect investigation of the design, leading to appropriate recall and corrective action by manufacturers whose belt systems have utilized it;

2. Initiation of a rulemaking leading to amendment of Federal Motor Vehicle Safety Standard 209 to preclude such designs in the future;

3. Issuance of warning and other information necessary to alert the public to the existence, nature and magnitude of such designs, and the hazards they represent [; and]

4. Issuance of guidelines to safety researchers, police investigators and others reporting crash-related and crash injury-related information that the presence of an unlatched belt following a car crash does not mean per se that the belt was not being worn prior to the crash."

BACKGROUND:

Coincident with the filing of this petition, on September 10, 1992, CBS aired a program on "Street Stories" concerning alleged unlatching of safety belt buckles. The content of the show was essentially based on the alleged defect of inertial unlatching as presented in the petition.

There are many different designs of safety belt buckles in motor vehicles. All have a release button that must be manually depressed for release. The petitioner states that the alleged defect appears to involve buckle designs with release buttons on the "front face" of the buckle. In the particular style that is the subject of this petition, the buckle is generally a rectangularly shaped assembly, about 1-3/4" by 2-1/2" in size and 3/4" thick. A latchplate, attached to the belt material, is inserted into the buckle. The release button is on the 1-3/4" by 2-1/2" side of the buckle and will be referred to hereafter as a side release buckle. The petitioner refers to this type as a "front release" button.

The other principal style of buckle uses a different location for the release button. The buckle is also rectangular in shape, however, it may be slightly thicker, about 1-1/4 inches. The release button is on the top end of the buckle, and next to the slot for inserting the latchplate. This type is hereafter referred to as an end release buckle. Both buckle styles are widely used by the automotive industry.

The internal designs of these two styles of latches are different by necessity. The direction for pressing the release button of the side release buckle is perpendicular to the direction for insertion of the latchplate. In contrast, the direction for depressing the button on an end release buckle is in the same direction as the insertion of the latchplate.

All new motor vehicles sold in the United States must comply with Federal Motor Vehicle Safety Standards (FMVSS). In particular, safety belts and buckles must meet the requirements specified in FMVSS No. 209, "Seat Belt Assemblies." Under this standard, the "[B]uckle release mechanism shall be designed to minimized the possibility of accidental release."

APPROACH:

To evaluate this petition, the agency conducted an extensive review of crash test data, analyzed real-world accident data, performed full-scale crash and other testing of buckles, requested information from motor vehicle manufacturers, manufacturers of safety belt buckles, and safety belt buckle patent holders, and reviewed complaints filed with the Auto Safety Hotline. The following specific actions have been taken during this evaluation:

- Wrote letters to eight motor vehicle manufacturers.
- Wrote letters to five safety belt manufacturers.
- Wrote letters to seven safety belt buckle patent holders.
- Analyzed real-world accident data.
- Reviewed agency laboratory crash data.
- Evaluated and interviewed ODI accident complaints alleging buckle release.
- Conducted vehicle and laboratory testing at the Vehicle Research and Test Center (VRTC). Reviewed previous VRTC testing on safety belt buckles.
- Conducted telephone interviews with callers to Hotline.

The findings from this evaluation is provided in the following sections.

VEHICLE MANUFACTURERS' RESPONSES:

The agency formally requested information from certain vehicle manufacturers regarding the alleged defect of inertial unlatching of safety buckles. Information requests were sent to General Motors (GM), Ford, Chrysler, Toyota, Honda, Nissan, Volkswagen (VW), and Volvo. Each manufacturer was asked to provide complaints, accidents reports, and lawsuits pertaining to the alleged defect. They were asked to describe all tests, studies, and surveys pertaining to the alleged defect and describe any design modifications pertaining to the alleged defect.

These responses are summarized below:

GM: GM's response stated, "GM has had very few reports alleging inertial unlatching of seat belt buckles. In most cases where the occupant reports that the seat belt buckle unlatched in an accident, it is not clear from the allegation whether the belt may have been released from 'inadvertent contact with the release button by external objects', whether it is alleged that the buckle release was caused by inertial forces, or whether some other condition is being alleged." GM has made no design changes in response to the alleged defect.

In response to the question of testing done with respect to the alleged defect, GM reports that it is aware of only two reports of buckle unlatching during its vehicle crash and sled testing that may relate to the alleged defect. Both incidents occurred in tests conducted during 1991. It reports that it conducted more than 749 crash and sled tests with belted occupants in 1991. Since 1970, GM has performed about 30,000 crash and sled tests, most with belted test dummies. Thus, GM data indicate that the alleged defect could be present in, at most, less that 0.007 percent (2/30,000) of its crash testing.

Ford: Ford reports that it has ". . . located a number of allegations that a seat belt had inadvertently opened or released during an accident. While some of those files contain occasional references to 'inertial unlatching,' few, if any, contain sufficient details to determine with certainty that they allege '. . . inadvertent release or opening of a safety belt latch due to inertial loading of the release button or latching mechanism caused by external forces acting on the back side of the latch housing.'" Ford did not report any safety belt buckle unlatching incidents associated with inertial forces during its crash and sled test programs. Ford has made no significant design changes related to the alleged defect.

Chrysler: Chrysler reports that it has only one complaint report that may relate to the alleged defect condition of inertial unlatching. In this case, Chrysler found the "seat belt was intact and functional--nothing to indicate that seat belt was in use at the time of the accident." Furthermore, the case went to trial and the jury found that the complainant was not wearing the seat belt at the time of the accident. Chrysler provided several other complaints alleging buckle unlatching, but finds no evidence that the seat belt was in use or evidence of a defect in the buckle. Chrysler did not report any safety belt buckle unlatching incidents associated with inertial forces during its crash and sled test programs. Chrysler has made no design changes related to the alleged defect.

Toyota: Toyota reports that it has received "only 7 lawsuits that pertain to the alleged defect, and no other owner complaints, field reports, etc." Toyota also reports it has made no modifications that could relate to the alleged defect and has issued no service or technical bulletins or other communications pertaining to the alleged defect. Toyota did not report any safety belt buckle unlatching incidents associated with inertial forces during its crash and sled test programs.

Honda: Honda reports no complaints or field reports, and only two lawsuits alleging that a seat belt buckle unlatched. Honda is aware of no investigations or surveys on this subject.

In response to the question concerning design changes, Honda's letter states that there has been one modification that "could be related to the alleged defect." Honda provided further clarification of its response by saying that its design change was not in response to allegations of inertial unlatching, but rather to reduce the latch spring force making the buckle easier to release while the belt is under tension. This was done to increase its margin of compliance with the buckle release force requirements in FMVSS No. 209, "Seat Belt Assemblies." Honda had taken a broad interpretation of the question to include any changes to components that are significant to the performance of a buckle when subjected to inertial forces.

Finally, with regard to the safety performance of end release buckles compared to side release buckles Honda reports, "We do not recognize any difference in safety between the end release type and the side release type." Honda did not report any safety belt unlatching incidents associated with inertial forces during its crash and sled test programs.

Nissan: Nissan reports it "is unaware of any accidents, subrogation claims, or lawsuits which specifically pertain to the alleged defect in the subject vehicles." However, they submitted four complaints alleging unlatching of a buckle. One complaint alleged unlatching of an empty child seat but it indicates that the claimant "admitted that she was not positive that the seat belt was hooked properly to secure the infant seat." Nissan reports that the alleged defect has not occurred in any of the variety of tests conducted to assure compliance with FMVSS's and other standards in other countries. Nissan has made no design changes related to the alleged defect.

Volvo: Volvo reports, "Volvo has never seen the alleged defect occur in its many years of conducting laboratory crash testing. Volvo is aware of no real-world accidents, allegations, or lawsuits pertaining to the alleged defect." Volvo did not report any safety belt buckle unlatching incidents associated with inertial forces during its crash and sled test programs. Volvo has made no design changes related to the alleged defect.

VW: Volkswagen has found no complaints, field reports, studies, surveys, investigations, or technical bulletins that relate to the alleged defect. It also reports, in all of its testing for compliance with United States standards, European Certification, and its own test requirements, that "there has not been one incident related to the alleged defect." VW has not made any design changes related to the design defect.

Table 1 shows a summary of complaints provided to NHTSA in the manufacturer responses. The reported vehicle population is given for vehicles from 1970 to the present. The computed rate of complaints per 100,000 vehicles with side release buckles is shown for each manufacturer.

Table 1
Summary of Complaints of
Inadvertent Release Received from Manufacturers
1970 to Present

MFR	SIDE RELEASE BUCKLE		
	REPORTS	VEHICLE POPULATION (MILLION)	RATE PER 100K
GM	63	119	0.05
FORD	48	67	0.07
CHRYSLER	13	38	0.03
TOYOTA	7	15	0.05
HONDA	2	8	0.03
NISSAN	2	12	0.02
VOLVO	0	1 (1977-92 data)	0
VW	0	3	0
TOTAL	135	263	0.05

The analysis of manufacturer complaints and lawsuits alleging unwanted buckle unlatching shows no evidence to demonstrate that inertial unlatching is a safety concern in crash tests or real world accidents. Contributing factors unrelated to inertial loading may be responsible for an unlatching complaint. The crash and forensic analysis of vehicles, buckles, and injuries show that, in many cases, the buckle was in good condition with no identifiable defects and that there is no evidence to indicate that the occupant used the safety belt.

Chrysler provided an analysis of inertial loads on safety belts and compared the results to what occurs in a crash test. It demonstrates that the impact required to unlatch a buckle greatly exceeds the acceleration loading on a buckle during a crash test. In the crash testing, the buckle acceleration peaked at 100 g at 1500 lbs of belt tension at the retractor. In Chrysler testing, the buckle system required 145 g to release with no belt tension. Chrysler's testing demonstrated, however, that increasing belt tension greatly increases the engagement force of the latch and greatly increases resistance to inertial movement of the release button, hence the acceleration necessary to unlatch the buckle. Its analysis shows more than a 600 percent increase in the acceleration required to release the buckle associated with an increase of belt tension from zero to 25 pounds. Its data shows, with the belt under tension such as occurs during a vehicle crash, that crash forces do not generate the necessary impact acceleration loading on the buckle to overcome the engagement forces resulting from the belt tension. This finding is consistent with the results of the agency testing discussed later in this report.

The automotive manufacturers uniformly report that their test programs conducted as part of research, development, and certification of vehicles has not shown any problem associated with inertial releasing of buckles in the vehicle crash environment that would indicate a safety risk in the real world.

In summary, the information received from the motor vehicle manufacturers on the performance of safety belt buckles does not indicate that a safety problem with unlatching of safety belt buckles during crashes, due to inertial actuation, exists. The scope represented by these responses includes millions of vehicles over many years of vehicle usage and thousands of crash tests.

SAFETY BELT BUCKLE MANUFACTURERS' RESPONSES:

The agency sent letters to the five principal manufacturers of safety belt buckles (latch assemblies) for vehicles produced for sale in the United States. Each manufacturer was asked to describe its latches and provide drawings, provide reports of complaints and lawsuits, provide all tests and studies with respect to the alleged inertial unlatching, and describe all modifications made in response to the alleged inertial unlatching problem.

These responses are summarized below:

Takata Inc.: Takata responded with only one reported lawsuit involving a 1983 GM vehicle. The vehicle was involved in a frontal collision. Takata reports, "Examination of the belt and vehicle found no defects." It reports that this type of buckle was supplied to GM for vehicles from 1977 through the present for application in several vehicle platforms (A, F, G, H, J, L, N, W and X-body). Takata has not made any design modifications to this latch that relate to the subject condition of inertial unlatching.

General Safety Corporation: General Safety has manufactured one type of latch assembly, the GM Type 1, from 1970 to the present. This buckle has been used for Cadillac, Buick, Pontiac, Oldsmobile, and Chevrolet vehicles during that period of time. It is unaware of any complaints, field reports, accidents, lawsuits, studies or surveys that relate to the alleged defect of inertial unlatching. No modifications have been made to the design of the buckle during this period of time.

Indiana Mills and Manufacturing, Inc. (IMMI): IMMI reports receiving no complaints, field reports, lawsuits, studies, or surveys that pertain to the alleged defect of inertial unlatching. No changes have been made to its products that relate to the alleged defect, and it is not aware of any instances where latches on belts manufactured by that company opened because of inertial actuation.

TRW: TRW reports no complaints, field reports and two lawsuits. Both lawsuits alleged a possible inertial actuation of the latch during an accident. In one, the court found "no credible evidence of a design defect." The second incident, which occurred in October 1990, is still in litigation. TRW has not identified any test information that relates to the alleged defect of inertial unlatching. No changes or modifications have been made to buckles in response to the alleged defect.

Allied Signal/Bendix: Allied reports receiving no complaints or field reports, but indicated four lawsuits claiming alleged inertial release with side release type buckles. It states that in three of the four lawsuits, inspection of the vehicle and buckle revealed that the injured individuals were not wearing the safety belt. The fourth lawsuit concerns a suspected aftermarket installation of a safety belt manufactured by Irvin Industries (now Takata) allegedly using an Allied design. Allied has not yet inspected this vehicle or buckle.

As part of the design and development of its buckles, Allied conducts sled testing. It has "no evidence that such buckles have released inertially during such testing." Its buckles are also tested by independent laboratories, Hunt Laboratories and United States Testing, and they have never informed Allied that a buckle released inertially. Allied has made no design changes related to the alleged defect.

In summary, the buckle manufacturers report no complaints and several lawsuits relating to the alleged defect. These manufacturers have made no design changes relating to the alleged defect. Testing of the buckles, performed by the buckle manufacturers, or that which the buckle manufacturers are otherwise aware of, has not provided any indication of a unlatching problem that could be associated with the alleged defect. The information does not support the allegation of a real-world problem with unlatching of safety belt buckles during crashes.

END RELEASE BUCKLE PATENT HOLDER RESPONSES:

Mr. Ralph Hoar, of Ralph Hoar & Associates, sent the agency two letters in support of the IIR petition. His letters allege that the industry is aware of inertial unlatching and is active in providing design solutions to the problem as indicated by several patents. He provided copies of eight United States patents that briefly discuss inertial unlatching in some context, but not necessarily in reference to crash forces. Every patent provided by Mr. Hoar described a type of end release buckle.

The agency sent letters to the holders of seven of the eight patents for end release buckles provided by Mr. Hoar. One patent holder is a foreign firm and not readily accessible to provide a timely response for this analysis. The following patent holders have been asked to respond to the concern of inertial unlatching as it relates those specific patents that mention inertial forces.. The patent holders were asked to describe inertial actuation as it relates to the patent, respond to allegations that the patent provides evidence of a problem with side release buckles, and provide any technical reports and studies discussing inertial unlatching.

Allied Signal/Bendix: Allied reports having no knowledge of inertial release of side release buckles in accident conditions. Allied reports that these patents were developed "in response to customer's specification to design an end-release buckle. In the late 1970's and early 1980's the 'parlor trick' of causing a 'side release' buckle to open by slapping it on a table was widely demonstrated in Europe and was being used by European competitors as a way to induce customers to purchase competitive buckles which were more resistant to that particular 'parlor trick.'" With respect to side release buckles, Allied explains that "web tension acts a restraining force and significantly influences the amount of button force required to cause latch movement. Latch movement can also be induced by acceleration forces if the resultant inertia force on the buckle is in the proper direction and also is capable of overcoming internal (pre-load, spring rate, frictional and damping forces) and external (web tension) restraining forces acting on the latch." Allied in not aware of any type of accident that could generate the necessary forces to cause inertial release. The end release patents were not developed because of any known deficiency causing them to be susceptible to inertial unlatching.

GM: GM responded by reporting, "although all buckles can theoretically become disengaged by inertial forces at some levels of acceleration and direction relative to the buckle, General Motors does not believe that buckles are susceptible to inertial release under normal conditions of usage, including under accident conditions." In response to the question of whether GM developed the patent to present a solution to the alleged defect of inertial unlatching, GM reports that all of its buckles, both side release and end release types, have been designed to "overcome inertial forces in real world use situations, and to avoid unwanted buckle disengagement." GM did not indicate that the incorporation of inertial considerations in the patent was indicative of a real-world problem of inertial unlatching in side release buckles.

Takata, Inc.: This manufacturer has not provided a response to the questions in the agency's information request pertaining to two Takata patents.

TRW: The TRW patent contains a statement describing possible unlatching of an end release type buckle when used in conjunction with a pyrotechnic pre-tensioning device. This is attributed to the movement and sudden stopping of the buckle during the automatic pre-tensioning phase, in which inertial forces can unlatch the buckle in this particular design application. The TRW patented features are new and not yet on vehicles sold in the United States. The TRW patent seeks to correct the conditions resulting from the pyrotechnic device and not from accident conditions. It states, "There is no evidence that real world accidents, in and of themselves, will result in buckle accelerations or occupant to buckle impacts sufficient to inertial release a buckle using a conventional side release button configuration."

IMMI: IMMI reports, "There were no theoretical, actual or alleged instances of inadvertent buckle release due to inertial actuation forces that led IMMI to develop the buckle covered by the patent." IMMI explains that it has developed the subject features in the patent to minimize the "theoretical risk of release due to inertial forces. This would also make the buckle usable with pre-tensioners, which may eventually come in our application."

The patent holders report no knowledge of real-world inertial unlatching of buckles. Certain patents show buckle designs that can be used with pyrotechnic belt pre-tensioners and those designs must anticipate the inertial forces due to the pre-tensioning device. Finally, these patent holders do not indicate that development of the end release buckle patents was in response to performance deficiencies in side release buckles.

REAL-WORLD CRASH DATA ANALYSIS:

Numerous research studies dating from 1984 to 1992 uniformly show a substantial reduction in the risk of injury to occupants in a motor vehicle accident when safety belts are used. These studies include those by the major industrialized countries of Europe, Canada, Australia, and in the United States. The results clearly indicate that, when used, lap and shoulder safety belts reduce the risk of fatal and serious injury to front seat occupants by 40 to 50 percent.

As part of the analysis related to this petition, crash files maintained by the NHTSA's National Center for Statistical Analysis (NCSA) were reviewed for reports of possible inertial unlatching of buckles. Searches were made of the computerized National Accident Sampling System (NASS)[1] database from 1988 through 1991 to identify specific crash investigations

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[1] NASS is a sample of nationwide crashes investigated by NHTSA contractors. The investigation consists of vehicle inspection, crash scene analysis and occupant interviews. These

which suggest that the safety belt buckle released and for which "hard copy" files were available. This search identified 19,444 belted front seat occupants. Of these, cases were selected that indicated that a manual belt buckle opened, that the manual or automatic buckle failed, or that the occupant was restrained by a manual safety belt, but was ejected. These searches identified a total of 34 cases for review of the "hard copy" investigation file. These 34 represent 0.17 percent of the belted occupants.

The 34 reports provided no evidence of inertial buckle unlatching. The reports indicated examples of extreme vehicle damage that resulted in tearing away of the doors, the B-pillars, the belt anchorages at the floor, cutting of the webbing, shattering of the buckle housing, and structural failure of the retractor mechanism.

The agency also has conducted statistical analyses of its accident data files to determine whether the data contains any evidence of a difference in occupant crash protection between vehicles equipped with end release buckles compared with vehicles equipped with side release buckles. The analyses utilized the Fatal Accident Reporting System (FARS) files for 1985 through 1991 and selected state accident data from the CARDfile[2] for 1988 through 1990 (the three most recently available years). The data were analyzed to assess ejection, fatality and incapacitating injury rates for vehicles equipped with side release and end release buckles. Descriptions and summaries of the analyses conducted by NCSA are included in Appendix A.

The FARS analysis compared specific vehicles from model years 1985 and later that were equipped with either side release or end release buckles, but did not include vehicles with passive belts or air bags. Vehicles from model years 1985 and later were selected because the agency had data available to indicate whether those vehicles were equipped with end or side release buckles. A list of those "specified vehicles" studied in this analysis is given in Appendix B. Since the analysis included several categories of vehicles, differences in driver and vehicle characteristics were accounted for in the analysis. Further analysis was conducted of accident data for specific vehicles that had a production change from side release buckles to end release buckles, but with no other vehicle changes that could impact the effectiveness in the belt system. These vehicles (referred to as cross-over vehicles) changed from a side release buckle to an end release buckle. Three sets of cross-over vehicles were analyzed--Ford Taurus/Mercury Sable, Lincoln Continental, and Plymouth Voyager/Dodge Caravan. These vehicles were subjected to an additional analysis to determine whether the data suggested any discernable difference in crash protection provided by end versus side release buckles in essentially identical vehicles.

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cases provide a detailed description of the crash severity and occupant injury consequences.

[2] CARDFile - Crash Avoidance Research Data file. CARDFile is a file incorporating six states' police-reported accident files in a standard format.

The NCSA report concludes that "there is no pattern of evidence in the crash data to support the allegation related to inadvertent unlatching for side-release systems." This analysis, based on fatal and less serious crash data, did not indicate a safety performance problem with side release buckles.

CRASH TEST DATA:

The agency has accumulated a large body of crash test data involving safety belts to restrain test dummies in both vehicle and sled tests. This includes testing of child safety seats as well. The testing has been conducted in three programs areas; the Office of Vehicle Safety Compliance, Research and Development, and New Car Assessment Program (NCAP). In order to identify and understand any occurrences of the alleged problem of buckles unlatching, the agency conducted a comprehensive review of all its testing to locate specific reports of buckles unlatching during these tests.

Crash testing with belted test dummies includes front, rear, side and vehicle rollover impacts. In the frontal and side impact category, tests were conducted at both 90 degree and oblique impact angles. Table 2 shows a summary of agency crash ant sled test data involving full sized belted dummies.

Table 2
Agency Crash and Sled Tests
with Belted Test Dummies

Type of Test	No. of Tests	No. of test Dummies	Latch Openings
Frontal 90 degree	1,353	2,491	8
Front Oblique	53	104	0
Rear	409	811	1
Roll Over	17	17	0
Side	235	307	0
Total	2,067	3,730	9

A total of nine buckles have opened during testing with belted test dummies. Three openings were associated with defective latches. These buckles were end release type buckles and the vehicles using these defective belt buckles with end release buttons were recalled after an investigation conducted by the agency's Office of Defects Investigation (ODI). Four buckles opened during the rebound movement of the dummy when a portion of the dummy body contacted the release button on the buckle. These four buckles were also end release buckles. Each of these events occurred during frontal testing under the NCAP program and the impact speeds were 35 mph. The dummies were restrained during the initial impact and the recorded injury level of the dummy at the seating position of the released buckle was not significantly different from the injury level of a restrained dummy at the other seating position in which the belt remains latched. This leads to the conclusion that any belt release was after the crash event was over.

The remaining two of the nine buckles that opened were side release designs. One occurred during a frontal 30 mph barrier crash test of a 1979 International Scout II. The vehicle was equipped with a lap belt only and the buckle was found to be in an open condition during the post crash inspection. The crash test film shows the buckle not out of position but resting in the lap of the dummy. If the buckle had released during the initial impact or during any other phase of high deceleration, the belt and buckle most likely would have been forced out of position, rather than resting in a normal position on the dummy's lap. It appears that the safety belt restrained the dummy during the initial impact, but released upon rebound. The other side release buckle opened during a 35-mph rear impact test of a 1980 Honda Prelude. The dummy moved rearward upon the initial vehicle impact by a moving barrier. It does not appear from the kinematics of the vehicle during the rear impact and the reactive motion of the dummy that the backside of the buckle was impacted during the initial period of this test when the apparent buckle unlatching occurred. However the precise reason for the buckle opening cannot be determined.

A comprehensive review of all of dynamic sled testing of child safety seat tests was also conducted. A total of 239 tests were performed. Only two motor vehicle buckles opened during testing of child safety seats. Both buckles were the side release type. One buckle failed when it broke into two pieces due to a bending load applied to the buckle. During the test, the buckle was pulled across the metal bar of the child safety seat while its two ends were subjected to a tensile load in opposite directions, approximately 90 degrees apart with respect to each other. The resulting bending moment on the buckle fractured the latchplate at the webbing attachment point. The other buckle release occurred in a test of the interaction with a passenger-side air bag. The rear-facing child safety seat was intentionally positioned close to the air bag housing to test the dynamic interaction between the air bag and the child safety seat--this is contrary to all manufacturers' warnings and instructions for positioning a child safety seat in a vehicle with a passenger-side air bag. As the air bag deployed, the air bag impacted the back of the child safety seat, forcing the safety seat downward. This motion forced the vehicle's safety belt buckle under the edge of the child safety seat and into the bottom seat cushion, at which point the buckle released. Based on the direction of the application of the initial and reactive forces, there is no indication of an impact with the backside of the buckle that would be indicative of an alleged inertial unlatching.

A summary of the above reported latch openings during agency testing is in Appendix C.

In summary, the agency has reviewed all available data of testing of restrained occupants in search for evidence of alleged inertial unlatching of buckles. This review encompassed testing of a total of 3,730 belted test dummies and 239 child dummies in child safety seats. No evidence of buckle release due to alleged inertial unlatching was found.

TESTING IN SUPPORT OF PREVIOUS INVESTIGATION EA77-040

In June 1977, an Engineering Analysis (EA77-040) was opened to investigate a single complaint alleging that the seat belt buckle in a 1975 Chevrolet Monza would open if a sharp impact was applied to the back of the buckle. In support of the investigation, a test program was initiated on sample buckles from a Monza and other vehicles. The purpose of the testing was to duplicate and observe the unlatching when the buckle was impacted by a rubber mallet on the front and rear surfaces of the buckles. An impact device was constructed to provide a repeatable impact force. Testing was expanded to include other vehicles from model years 1971 through 1978. This testing included the passenger seat buckles in a total of 225 vehicles.

The testing demonstrated that buckles, including the Chevrolet Monza, would unlatch if impacted with a sharp blow to either the rear or the front face of the buckle. The expanded testing of other model years also showed that many buckles would open when hit on the rear surface with a sharp impact. It was noted that 50 of 225 buckles opened during these tests.

The test device did not simulate the portion of the human body that is in contact with the back of the buckle when the buckle is worn. Also, the impact was not selected based on a correlation of the force that might be applied by the body to the back of the buckle during a vehicle accident. The primary intent of the test device was to allow for the gathering of empirical and repeatable data that would demonstrate, in a laboratory setting, the phenomena of buckle unlatching due to a non-accident-related impact force.

While the testing demonstrated that certain impacts on the buckle not representative of real-world crashes could open a buckle, there was no correlation made to the dynamic forces that are present in real-world crashes. Thus, this testing did not establish a risk of buckles opening in real-world crashes. The Engineering Analysis in EA77-040 report indicates that there were no additional complaints in the ODI consumer complaint file of the alleged problem of buckle unlatching. Based on the lack of evidence that the alleged problem was present in the real world, EA77-040 was closed.

The report of testing done under investigation EA77-040 recommended additional work using a more realistic impact force. The recommendation specifically identified the need for data concerning rollover and corner impacts to the vehicle. The agency has done this. NHTSA has conducted a comprehensive vehicle testing program involving belted occupants in compliance, NCAP and research and development testing. As described in a prior section of this report, the agency tested 307 full sized belted dummies in side impacts, 104 in front oblique impacts, 2,491 in frontal impacts, 811 in rear impacts, and 17 in vehicle rollovers. No evidence of inertial unlatching was reported in those tests. These tests, which represent real-world crashes, represent a thorough and comprehensive assessment of safety belt performance.

ODI COMPLAINTS:

Before Petition:

A search of the ODI database identified 1,886 records of consumer complaints regarding belt failures in accidents as of September 9, 1992, one day before the showing of the CBS "Street Stories" program. The computer print-out of these records was reviewed for allegations of seat belt buckle failures. Key words such as: buckle, buckle unlatched, unfastened, disengaged, and opened, were targeted for further review. Complaints of seat belts breaking, problems fastening, belt spooled out/pulled out, belt did not lock up, belt released (retractor), false latching, or no latching were not followed up because they are not related to the alleged defect. Out of the 1,886 records, 85 were identified as possibly relating to buckle disengagement. Full copies of these reports were retrieved and reviewed for pertinency, which included telephone calls to consumers for clarification where appropriate. The agency attempted to reach 63 complainants by telephone and successfully made contact with 40. After this process, 35 reports were identified in which it was alleged that a seat belt buckle inadvertently disengaged during an accident.

The 35 complaint reports were analyzed by type of buckle, type of accident, severity of accident, and severity of injury. The type of buckle reported is either a side release or an end release buckle. The underlying presumption for the inertial unlatching in a side release buckle to occur is that the impact necessary to release the buckle must be applied to the inside (the side next to the occupant) of the buckle. Accordingly, the reports were reviewed to determine the type of accident by principal location of impact. The location of the vehicle impact determines the initial direction of forces applied to the vehicle, occupant and the buckle.

Table 3 shows a listing of 35 complaints by model and model year. The complaints are widely distributed among many makes and models, and over many model years. Of the 35 reports, 24 were for vehicles equipped with side release buckles, and 11 were for vehicles with end release buckles. A rate comparison was made of the number of complaints for both buckle types by dividing the number of complaints by the vehicle population for each particular vehicle. The rate for side release buckles is 0.7 per 100,000 vehicles and the rate for end release buckles is 0.9 per 100,000 vehicles.

Table 3
List of Complaint Vehicles

MODEL YEAR	MANUFACTURER	MODEL	SIDE RELEASE	END RELEASE
1980	FORD	CAPRI	1	
1981	GM	CHEVETTE	2	
1984	FORD	BRONCO	1	
1984	GM	CELEBRITY	1	
1984	GM	CUTLASS	1	
1984	FORD	ESCORT	1	
1984	GM	REGAL	1	
1985	GM	ASTRO VAN	1	
1985	GM	BLAZER	1	
1985	GM	ELECTRA	1	
1985	FORD	ESCORT	2	
1985	MAZDA	GLC		1
1985	CHRYSLER	NEW YORKER	1	
1985	GM	SPRINT	1	
1985	GM	SUBURBAN	1	
1986	GM	CAMARO		1
1986	GM	LESABRE	1	
1986	MITSUBISHI	MIRAGE		1
1986	GM	NOVA	1	
1986	GM	FIREBIRD		1
1986	MAZDA	323		1
1987	GM	SAFARI VAN	1	
1988	GM	CORSICA	1	
1988	GM	CUTLASS	1	
1988	GM	CELEBRITY	1	
1988	GM	REGAL	1	
1988	CHRYSLER	SHADOW		1
1989	FORD	PROBE		1
1990	GM	CORSICA	1	
1990	CHRYSLER	DYNASTY		1
1991	FORD	EXPLORER		2
1992	GM	METRO		1
		TOTAL	24	11

Two critical conclusions are evident from these data. First, even if all of the complaints did in fact reflect instances in which the buckles actually released as a result of an accident, the complaint rate is extremely low--far below the levels indicative of a potential problem that would warrant a determination of a safety-related defect. Second, no significant difference was noted between the complaint rates for side release buckles compared to end release buckles. This is consistent with the real-world accident data analysis which demonstrated no difference in the occupant protection of side versus end release buckles.

The vehicle age at the time of the complaint was analyzed in response to the possibility that over time, buckles may be more vulnerable to inertial unlatching because of weakening of the buckle release spring. Table 4 shows the relationship of complaints to vehicle age. No trend was noted to indicate that buckle aging contributes to an increase in alleged opening of safety belt buckles in motor vehicle accidents.

Table 4
Complaints by Vehicle Age
At the Time of Alleged Failure

VEHICLE AGE (YEARS)	REPORTS	
	SIDE RELEASE	END RELEASE
9	1	0
8	0	0
7	0	0
6	2	0
5	6	0
4	1	0
3	1	2
2	5	3
1	4	2
0	4	4
TOTAL	24	11

The impact location to the vehicle was also considered. Because the buckle position is at the side of the occupant, an impact to the side of the vehicle would likely transmit the most direct impact from the occupant to the buckle. Table 5 shows a comparison of impact location on the accident vehicle by the type of buckle. For both the end and side release buckles, most of the reported impacts were to the front and rear and not the side of the vehicle.

Table 5
Vehicle Impact Location by Buckle Type

IMPACT LOCATION	RELEASE BUTTON LOCATION	
	SIDE	END
FRONT	8	6
REAR	4	2
SIDE	8	2
ROLL	4	1
TOTAL	24	11

The reported vehicle damage or accident severity ranged from moderate to severe. Injuries were reported in 33 of the 35 accident reports. The type of injury varied and is shown in Table 6. The seriousness of the injury as measured by the type of treatment (where reported in the complaint or determined by follow-up telephone calls) is shown in Table 7.

Table 6
Type of Injury

INJURY TYPE	SIDE RELEASE	END RELEASE
NONE	1	1
ABRASION	6	1
LACERATION	2	0
BROKEN BONE	6	1
TRAUMA	3	4
CONCUSSION	1	1
NOT REPORTED	5	3
TOTAL	24	11

Table 7
Type of Treatment

TREATMENT	SIDE RELEASE	END RELEASE
NONE	4	2
EMERGENCY ROOM	3	2
HOSPITALIZED	7	1
FATAL	0	0
NOT REPORTED	9	5
TOTAL	23	10

Of the 35 complaint reports, eight alleged that a child seat was released by the opening of the vehicle's seat belt buckle. Of the eight, five were side release buckles and three were end release buckles. The complaint rate associated with the alleged release of child seats for the side release buckles is 0.5 per 100,000 vehicles sold compared to 0.8 per 100,000 vehicles sold for the end release buckles. Again, no significant trend is noted to indicate an inertial unlatching phenomenon of the side release buckles.

After Petition:

In the 4 days immediately following the "Street Stories" program, which was broadcast on nationwide television, the agency received approximately 4,800 calls to the agency's toll-free Auto Safety Hotline. These calls represent inquiries to the Hotline requesting consumer information on a variety of subjects, including child safety seats, New Car Assessment Program crash test results, Uniform Tire Quality Grading System, drunk driving literature, etc. Additionally, these calls include callers who either want to discuss a safety issue with a Hotline contact representative or file a consumer complaint about a safety problem they have experienced with a motor vehicle or item of motor vehicle equipment. These include Hotline calls in response to the "Street Stories" and "CBS Evening News" presentations. When compared with the total phone calls received by the Hotline over the same Friday through Monday time period for the preceding 6 weeks, the 4,800 calls are very close to the average 4,400 calls over that 6-week period.

As another comparison of the public's response to the claims of safety belt buckle unlatching based on presentation in the media, the agency reviewed the number of consumer calls to the Auto Safety Hotline in two other instances where the Hotline telephone number was illustrated on national television. After a February 1990 child safety seat segment on "Good Morning America," the agency received over 8,000 calls during the next 5 days. After a February 1992 ABC broadcast concerning child safety seats, nearly 10,000 calls were received by the Hotline within 5 days. Additionally, after agency press releases announcing the availability of consumer information on such subjects as the Uniform Tire Quality Grading System, the New Car Assessment Program, and child safety seats, the agency received between 9,000 and 25,000 requests for the information within 4 days, depending on the subject.

The relatively few number of calls to the Hotline concerning safety belt buckles as a result of broad national publicity can be taken as a strong indication that the alleged defect is not a real-world problem.

Aside from the total number of consumer calls to the Hotline, calls actually reporting a safety belt problem were analyzed. Of the calls that were in response to the "Street Stories" and "CBS Evening News" presentations, the vast majority were from those consumers who either expressed concern over what they had seen on television, including a number of persons stating "I could make my safety belt do what the show indicated," or requested information from the agency on safety belts. From the date the CBS program was shown on September 10, 1992 to September 28, 1992, only 47 callers actually reported complaints related to safety belt performance. Of the 47 complaints, 30 involved accident situations, and only 18 of these specifically alleged that the safety belt became unlatched for some reason. None of these complainants indicated or suggested that the reason for the unlatching was an impact to the backside of the buckle. Like the complaints received before the "Street Stories" program, these complaints include vehicles equipped with end release as well as side release buckles. Four of the 18 complaints were on vehicles with an end release buckle. Two reports indicated that a vehicle buckle failed to hold a child safety seat--one report each for side and end release buckles. Serious injuries were reported for both the side and end release buckles. Four reported injuries required hospitalization, three were in vehicles with side release buckles and one was in a vehicle with end release buckles.

One fatality was reported and was investigated by an independent experienced accident investigator. The investigation included examination of the crash scene, the vehicle, the belt and buckle, the autopsy report, and interviews with the police officer, the victim's relatives, and the medical examiner. The police accident report indicates that the victim was not wearing the safety belt. The investigator found no evidence to indicate that this finding was incorrect.

It is apparent that calls to the Hotline were not significantly affected by the publicity associated with the "Street Stories" and "CBS Evening News" broadcasts alleging safety belt unlatching due to inertial loading. Further, consumer complaints concerning belt unlatching in crashes have been extremely low in number. The fact that the low volume of calls to the agency's Auto Safety Hotline, and more specifically, the small number of consumer complaints specifically addressing unlatching of safety belts in crashes, suggests that the public does not consider this to be a safety concern. It also suggests that the public understands the benefits of safety belts and the protection they provide to vehicle occupants in real-world crashes. Additionally, the complaints of buckle release that were received fail to show any evidence to support an inertial release phenomena. Complaints have been reported on both the side and end release buckle designs, but no significant difference was noted in the complaint rate between side and end release buckles for alleged unlatching incidents. Interestingly, most complainants report the unlatching occurred during a front or rear impact, which would not appear to be the direction providing the greatest susceptibility to alleged inertial unlatching of side release buckles.

RECENT TESTING:

Following the receipt of the petition, ODI initiated a test program to assess the performance of side release buckles under various conditions. The purpose of the testing was to: (1) determine the dynamic physical conditions necessary to cause side release buckles to release under inertial loading from a sharp impact to the back side of the buckle; (2) measure buckle response in crash conditions and compare these to measured and predicted conditions that would cause a buckle to unlatch due to inertial forces; and (3) measure in-vehicle conditions using a human volunteer and metal frame child seat. The full report of testing is attached as Appendix D.

Testing included full scale vehicle crash tests; bench testing of buckles involving striking the back of sample buckles with a human hand or hip, and a video cassette; and in-vehicle testing of buckles using a metal frame child seat and a human volunteer's hip. A computer model was developed to predict the required impulse, acceleration, and pulse width to the buckle that would cause a buckle to unlatch under inertial forces.

The bench testing consisted of dropping an 8 lb weight from selected heights onto the back side of a side release buckle. The buckles were equipped with accelerometers to measure the acceleration-time history of the impacts. The buckle was stretched horizontally between two posts and placed under tension. The belt/buckle tension was held at 5, 50, and 500 lbs. The back of the buckle was impacted with and without padding. Three types of padding were used, two types of foam and 1/8th inch thick dummy skin.

In addition to bench testing, accelerometers were placed on the safety belt buckles in several full scale crash tests incorporating test dummies restrained by safety belts to gather laboratory crash data for comparison with the modeling and the bench testing data. The full scale vehicle tests included the following:

- o 20 mph side impact, 1985 GM pickup truck, 2 - 50 percentile test dummies
- o 30 mph side impact, 1985 GM pickup truck, 1 - 50 percentile test dummy and 1 child seat with a 3-year old test dummy
- o 30 mph front impact, 1993 Chrysler pickup, 2 - 50 percentile test dummies
- o 50 mph oblique front impact, 1989 Taurus impacted with a 20,000 moving test buck, 1 - 50 percentile test dummy
- o 30 mph front impact, 1993 Sentra, 2 - 50 percentile test dummies
- o 30 mph front impact, 1993 Century, 2 - 50 percentile test dummies

The results of the test program shows that the phenomenon of inertial unlatching can be described in terms of the physical parameters of acceleration amplitude, duration of the acceleration pulse, and belt tension. As belt tension increases, the acceleration required to open a buckle also increases. As the pulse width decreases, the acceleration required to inertially open the buckle increases. Most importantly, the testing demonstrates that acceleration pulses needed to unlatch a safety belt are not representative of conditions experienced in real-world crashes.

These parameters are shown graphically in Figure 1. This figure shows the predicted line for inertially opening the buckle with a belt tension of 50 lb. The area above the line indicates the conditions under which it is theoretically possible to open the buckle release by inertial acceleration. Conditions below the line would not cause the buckle to release. Data points taken from the bench testing, using drop weight, video cassette, and human hip impacts are plotted to show their relation to the predicted threshold for opening. Laboratory crash data points are also shown.

No buckle releases were observed during the crash testing. The laboratory test results indicate that, while it is possible to create inertial acceleration that could cause a safety belt buckle to release, such conditions are extremely unlikely to exist in real-world crash conditions.

RECALLS:

The agency has an aggressive program to investigate alleged safety defects in motor vehicles. The agency Hotline receives complaints and these are codified and entered into a computerized database. Each and every safety defect complaint is reviewed by professional staff to look for possible defect trends. When evidence indicates a possible safety defect trend, the agency will open an investigation to analyze the basis of the complaints and identify any safety defects. Many of these investigations result in safety defect recalls. Manufacturers may also initiate safety defect recalls without direct influence by NHTSA investigations. During the past 4 years, motor vehicle manufacturers have issued ten safety recalls to correct defects in safety belt buckles and recall a total of 2,722,850 vehicles. Of these, NHTSA investigations influenced the recall of 2,371,000 vehicles in three investigations that resulted in safety recalls. Appendix E shows a listing of all safety belt buckle recalls received by the agency during the past 4 years.

A review was made of all motor vehicle safety recalls, from 1968 to the present, that reported a defect in safety belt buckles. The recalls were reviewed to determine if there was any relationship between the reported defect in the recall and the alleged defect of inertial unlatching. The defects in these recalls included a broad range of reported problems, such as improper latching, false latching, failure to unlatch, failure to remain fastened under high tensile loads, and mechanical failure (cracking and disintegration) of certain parts as a result of aging. There have been no recalls that relate to the alleged problem of inertial release of a buckle due to impact to the back of the buckle housing.

FOREIGN STANDARDS--CANADA

The agency asked representatives of the Canadian government for any information it may have of investigations and reports of inertial unlatching of safety belt buckles. An official of Transport Canada responded as follows, "First of all, I would like to say how disappointed I was with the 'Street Stories' newscast on this matter. Scare stories of this nature can undo many years of work in building public confidence in occupant restraint systems." Canada conducted many investigations into alleged release of buckles but "in NO case was it concluded that the buckle released due to inertial forces." Transport Canada tested several hundred vehicles and have "NO documented cases of inadvertent actuation of the buckle system." It reports three cases in which a buckle was found to be unlatched at the end of the test. It concludes that, in two cases the buckles were either not fastened or improperly fastened, and in the third case, it believes the dummy's hand struck the buckle release.

FOREIGN STANDARDS--UNITED KINGDOM

The Department of Transport of the United Kingdom was contacted for information related to unwanted buckle release in seat belt assemblies. The response from the United Kingdom stated that its in-depth accident investigations have shown no instances of inertial release of safety belt buckles and, that its counterpart to our defect investigations and compliance testing efforts have found no defects of this nature in its testing and investigations.

FOREIGN STANDARDS--AUSTRALIA

The Australian Federal Office of Road Safety (AFORS) was contacted for information related to unwanted buckle release in seat belt assemblies. Of particular interest were any regulations which may, either by intent or effect, discourage use of the side release buckles in Australia. AFORS commented that no such regulations existed. The agency requested any information from Australia's investigative files related to the subject buckle types. AFORS noted that review of the safety defect investigations found "no record of any alleged problems with this type of buckle in Australia."

While not containing any provisions specifically related to side release buckles, current Australian Design Rules (ADR) and Australian Standards (AS) for seat belt assemblies include several requirements intended to limit the possibility of unwanted buckle release in general. These requirements involve tests for partial engagement, inadvertent release, dynamic performance, and buckle-spring fatigue resistance. A brief discussion of each follows.

Partial engagement Clause 9a of AS 2596-1983, "Seat Belt Assemblies for Motor Vehicles," states that "the buckle shall be of a quick-release type and shall not be capable of partial engagement." Partial engagement is defined as "any stable condition, other than complete engagement, in which the buckle components will withstand a separating force of not less than 1 N applied by tensile forces in the strap components, without disengaging. The tensile forces may be readily applied by holding one part of the buckle so that the other part tends to fall out vertically under its own weight."

Inadvertent release Clause 9b of AS 2596-1983 states that "the buckle shall not have a potential for inadvertent release by the vehicle occupants." A buckle assembly is considered free of such potential if, when tested in accordance with AS 2597.4, release is not caused. This test involves application of a flat planar surface against a latched buckle assembly such that the surface is normal to the line of action of the actuator.

Dynamic performance The seat belt assembly is subjected to dynamic forces designed to cause a nominated deceleration of a dummy of specified characteristic. A dummy with mass of 72 $\pm$ 2 kg (163 $\pm$ 5 lbs) is mounted on a test sled and restrained by the seat belt assembly to be tested. The seat belt assembly is configured in a manner consistent with its intended usage. From a nominal initial velocity of 13.6 m/s (29.0 mph) the apparatus achieves a deceleration of between 235 m/s^2 (771 ft/s^2) and 335 m/s^2 (1010 ft/s^2) within 30 ms. The deceleration must be substantially within the specified range for at least 20 ms, disregarding values outside the range that occur for periods of less than 1 ms. Upon completion of the test, the seat belt assembly is checked for separation of any components within themselves or from the anchorages and for proper release operation of the buckle.

Buckle-spring fatigue resistance Clause 4.5.3 of ADR 4/01, "Seat Belts," states that "in the case where a spring is incorporated in the unlatching mechanism of a buckle, the load required to operate the spring shall not be reduced by more than 20% after the spring has been subjected to 50,000 operations each involving a movement not less than 95% of the design movement for buckle unlatching."

CONSUMER REACTION:

As discussed earlier, the agency received a number of phone calls to the Auto Safety Hotline after the news media (September 10, 1992, "Street Stories") allegation of a buckle unlatching phenomena due to inertial loading. The Street Stories show was based on the alleged defect as discussed in this petition. Most of the calls were from consumers who were genuinely concerned about what they had seen or heard about the alleged design defect in safety belt buckles that utilize a side release buckle. Many of the callers stated that they were able to replicate the buckle unlatching by striking the backside of the buckles in their own vehicles with objects ranging from screw driver handles to books.

After listening to the concerns voiced by the callers to the Hotline, it was important to learn if the allegations made on television and in the print media about safety belts unlatching in crashes had any effect on consumers' attitudes and perceptions about the benefits of using their safety belts. In an attempt to identify and understand any consumer impacts that may have resulted from the allegation of buckle release, a number of call backs to consumers who had originally called the agency after having seen or heard about the "Street Stories" program were conducted. The objective of these phone calls was to determine if the show had any effect on a person's decision to use safety belts when riding in a motor vehicle. The results of these telephone calls are not statistically based, but rather are indicative of consumers' reactions to the media claims of safety belt buckle unlatching.

A total of 128 persons were called, and all indicated that they use their safety belts all or most of the time. This is exactly the type of person one would expect to have called the Hotline on an issue concerning safety belts. Calls from non-belt users would not be expected, since the allegation that safety belts can become unlatched in a crash may be supportive of the reasons cited for not wearing safety belts.

Of the 128 consumers, 124 people (97%) stated that they continue to wear their safety belts. Of those 124 people, 22 also stated that because of the program, they were being more careful in ensuring that their safety belts were securely fastened. Several other consumers stated that they took extra precautions to ensure that the safety belt buckle did not come in direct contact with any hard spots on child safety seats. In most instances, the safety belt buckle does not contact rigid components of the child safety seat; however, in instances where contact does occur, consumers stated that they placed padding under the buckle. Obviously consumer actions to ensure that safety belts are securely fastened and worn correctly are beneficial to highway safety.

The remaining four consumers (3%) stated that they stopped wearing their belts altogether or use them less often. These comments are of great concern. NHTSA, in cooperation with the entire safety community, has spent many years and millions of dollars on initiatives to encourage safety belt use. Given the thousands of lives that have been saved, and the reduction in injury levels to millions of other motor vehicle occupants because of safety belts, there is no doubt that safety belts are a highly effective means of providing crash protection to occupants of motor vehicles. It is disheartening that someone may be seriously injured or killed in a motor vehicle crash simply because they no longer wear their safety belts after the media claims of safety belt buckle unlatching--especially when scientific studies, real-world crash data, and consumer reports all demonstrate that such media claims are unfounded.

SUMMARY:

The petitioner alleges that certain designs of safety belt buckles are vulnerable to unlatching caused by inertial forces that may be applied to the buckle in a crash. To support this contention, the petitioner demonstrated the unlatching of side release buckles by hitting sample buckles on the backside with a sharp impact, typically with a video cassette box, or human hip. Also, the petitioner provided consumer complaints alleging the unlatching of buckles in motor vehicle accidents.

The agency conducted an extensive review of all available information to assess the real-world risk of inadvertent unlatching of buckles. It sent information request letters to eight vehicle manufacturers, five safety belt manufacturers, and holders of seven patents of end release buckles. The agency reviewed its accident data, consumer complaint file, and crash test data to assess this alleged problem. Further, full scale vehicle crash tests and other laboratory tests were conducted in the course of this evaluation to determine the possible real-world risk associated with the alleged inertial unlatching.

The vehicle manufacturers' information demonstrates a very low rate of complaints of alleged releasing of buckles in motor vehicle accidents. Side release buckles have been used in vehicles from all of the major manufacturers for many years. Since 1970, about 263 million vehicles have been equipped with side release buckles. The manufacturers report either no or very few complaints of alleged unlatching in that period of time. No manufacturer developed test programs to address the alleged defect because real-world data suggested there was no need. Several manufacturers point out that the level of acceleration or impact on a buckle during a motor vehicle crash is far below the level needed to release a buckle. The buckle manufacturers report no complaints and only seven lawsuits pertaining to buckle unlatching. These manufacturers have made no design changes due to the alleged defect.

Several patents for end release buckles reference the need for a design to consider the inertial effects on the performance of a buckle. The patent holders provided two reasons for this. First, some designs are intended to be used with pyrotechnic belt pre-tensioning devices. These devices can impart impact loads to the buckle and these must be anticipated in the design to prevent inadvertent unlatching. Second, all designs of buckles, both end release and side release, must operate safely without inadvertent release in real-world use.

The agency analyzed its accident data for evidence of the alleged defect. The analyses compared injury and fatality levels between vehicles using side release buckles and vehicles using end release buckles. The analyses showed no pattern of evidence to support an allegation of inadvertent unlatching of side release buckles. Specific accident files show no evidence to indicate inertial unlatching of buckles.

The agency reviewed all of its records of vehicle crash and sled test data for evidence of inertial unlatching. The agency has records on 2,067 tests involving 3,730 belted full-size test dummies and 239 tests of child dummies in child safety seats. Nine buckles unlatched in vehicle tests and one broke and one unlatched in child seat sled tests. Of the unlatched buckles, three were side release and seven were end release buckles. The agency has reviewed the written reports and films of these incidents and concluded that the test data provides no evidence of the alleged inertial unlatching phenomena.

The ODI consumer complaint database contains some complaints of alleged unlatching. However, the level of complaints is very low in comparison to the population of vehicles and is not concentrated in vehicles with side release buckles. The complaints of alleged unlatching include end release type buckles. The complaint rate for end release buckles compared to side release buckles is about the same (0.9 for end release compared to 0.7 for side release complaints per 100,000 vehicles).

A test program was conducted, including tests of belt buckles and vehicle crash tests. The laboratory data shows that, as belt tension increases, the level of acceleration required to unlatch a buckle increases. Further, the data demonstrates that accelerations necessary to inertially unlatch a belt buckle do not occur in actual vehicle crash conditions. Crash tests of vehicles shows that during the crash, the highest acceleration on the buckle occurs with significant loading of the belt. None of the buckles opened during crash tests, and the measured level of acceleration on the buckles was well below the level to cause a buckle to unlatch.

FINDINGS:

- o A comprehensive agency review of over 2,300 crash tests involving approximately 4,000 belted dummies, including frontal, oblique, rear, rollover, and side crashes, did not provide one instance of inertial unlatching. In ten of these tests, belts did come unlatched due to other reasons, e.g., external contact with the release button, manufacturing defect in the buckle. It was also found that seven of the ten buckle unlatchings involved end release buckles.

- o Laboratory testing performed in response to this petition defined the engineering characteristic which can cause inertial unlatching. Most important, this testing demonstrated that these characteristics are not present in real-world crashes.

- o Manufacturer data did not demonstrate that inertial unlatching is a safety problem. In the tens of thousands of crash tests conducted by motor vehicle and belt manufacturers, only General Motors Corporation (GM) reported what it believes may be two possible, but unverifiable, cases of inertial unlatching. Of the 30,000 tests GM has performed, it identified only these two such possible instances. No other reports were provided by either vehicle or belt manufacturers. Responses from safety belt buckle patent holders indicated that patents were sought to improve the general performance and ease of operation of buckles--not because of a safety problem associated with inertial unlatching.

- o Analysis of real-world crash data demonstrated that "there is no pattern of evidence in the crash data to support the allegation related to inadvertent unlatching for side-release systems." Thus, analysis of real-world data did not indicate the presence of a safety problem associated with inertial unlatching in side release buckles.

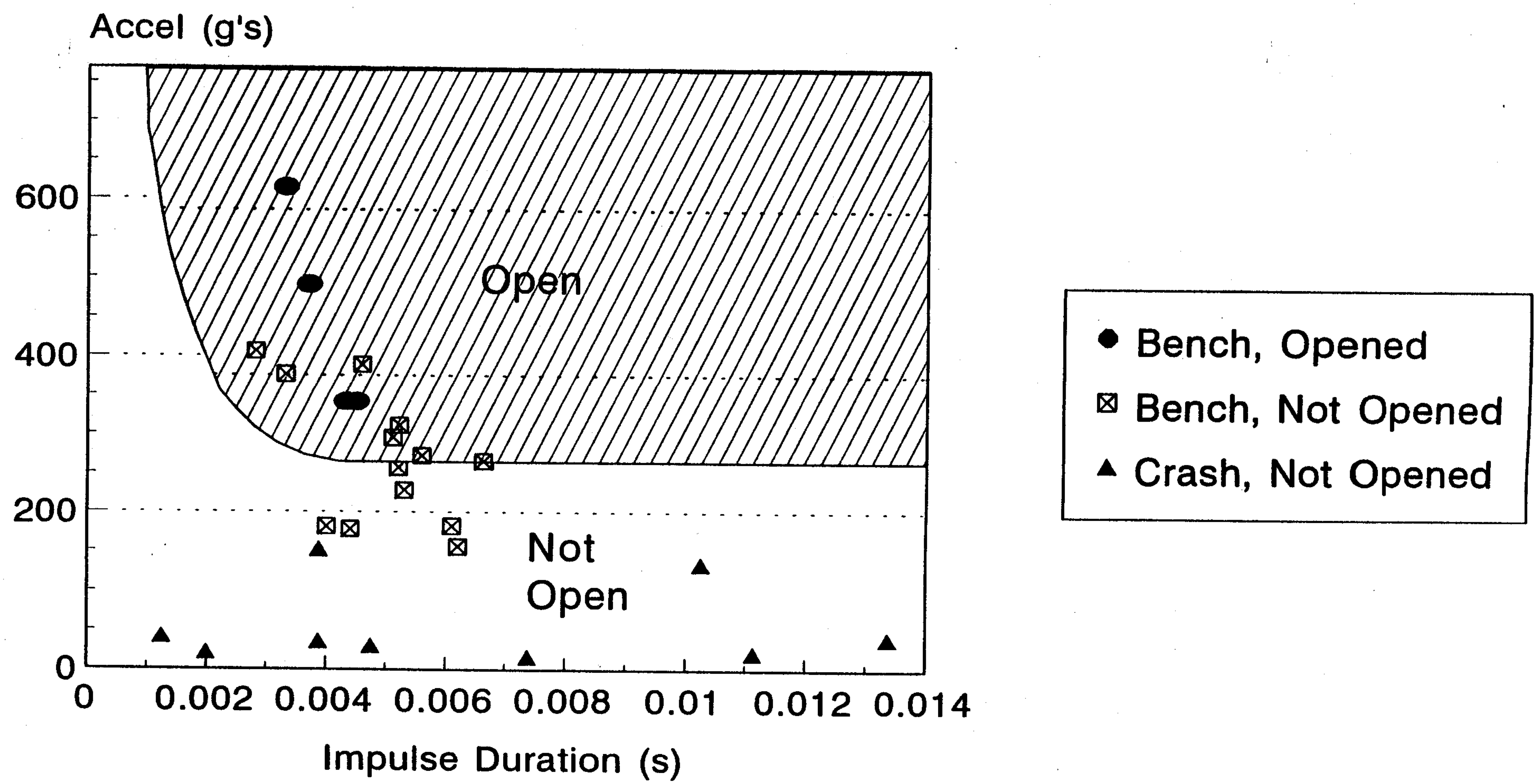
- o Review of consumer calls to the agency's Auto Safety Hotline did not suggest the presence of a safety problem. The complaint rate (the number of reports divided by the number of vehicles on the road) is essentially the same for vehicles with both side and end release buckles. Further, the complaint rate is extremely low compared to other safety problems reported to the agency. Additionally, the number of consumer calls to the Auto Safety Hotline subsequent to the "Street Stories" and CBS Evening News programs, the latter of which broadcast the toll-free Auto Safety

Hotline telephone number, were no higher than the number of calls normally received. Generally, national TV publicity of a safety issue, in which the Auto Safety Hotline telephone number is presented, results in large increases in Auto Safety Hotline calls. The fact that such an increase did not occur in this instance suggests that the public does not consider this do be a safety concern.

RECOMMENDATION:

This petition should be denied.

Buckle Impulse Opening Characteristics



All bench tests used 50 lb. preload and GM buckles.
Crash tests were performed full scale.

Figure 1

APPENDIX A

NCSA ANALYSIS

Inadvertent Safety Belt Unlatching

November 17, 1992

Summary of Findings

This analysis, conducted by staff of the National Center for Statistics and Analysis, focused on specific make, model and model year vehicles equipped with either side-release or end-release manual lap-and-shoulder belts, as specified by the staff of the Office of Defect Investigation. Data from the Fatal Accident Reporting System (FARS) for 1985-1991 and selected state files from CARDfile for 1988-1990 (the three most recently available years) were used.

The analysis of state data focused on the fatal and incapacitating injury rate (K+A) per driver involved in these vehicles as a function of relevant crash, vehicle and driver characteristics. Only towed vehicles were included in the analysis. Files used for this analysis included Indiana, Maryland, Michigan and Pennsylvania (Washington and Texas do not include a towaway indicator on the file; Indiana's vehicle make/model codes did not permit identification of Caravan/Voyager). Since not all states identify the presence of right-front passengers unless they are injured, the analysis of state data used only drivers for consistency between states and with previous state data applications. Occupant ejection in the state files was sufficiently rare to prohibit any analysis from being conducted.

The analysis of FARS data focused on the rate of fatal injury per involved front outboard occupant, as well as the ejection rate per involved front outboard occupant (ejection is much more common in fatal crashes and therefore, could be analyzed).

The major portion of the analysis employed logistic regression models, using both FARS and state data, to estimate the effect of side- vs. end-release buckles, accounting for differences in the relevant crash, vehicle and driver attributes associated with occupant injury and ejection, as available and appropriate.

In addition to the effort to develop explanatory statistical models, several vehicles under study, (Ford Taurus/Mercury Sable, Lincoln Continental, and Dodge Caravan/Plymouth Voyager) changed from side-release to end-release buckles during the study period. These "crossover vehicles" were subjected to additional, separate study, comparing the before-and-after injury and ejection experience of vehicle occupants.

The findings are as follows.

Analysis of Crossover Vehicles

The first analysis uses the raw crash data to investigate vehicles that switched from the side- to end-release system. Using these vehicles in a before vs. after comparison forms a "natural peer group", such that the crash and driver characteristics should be quite similar. The asterisk in the column labeled "Stat Sign" indicates the difference between side- and end-release was statistically significant at the alpha=0.05 level, two-tailed test.

1. Analysis of Fatal Crashes

Ejection	Side Release N	Side Release % Eject	End Release N	End Release % Eject	Stat Sign
Caravan/Voyager	592	8.3%	298	7.0%	
Continental	97	8.2%	14	7.1%	
Taurus/Sable	1090	6.0%	297	4.7%	

Fatal Injury	Side Release N	Side Release % Fatal	End Release N	End Release % Fatal	Stat Sign
Caravan/Voyager	592	31.4%	300	21.3%	*
Continental	98	45.9%	14	50.0%	
Taurus/Sable	1089	43.0%	297	45.5%	

Of the six comparisons, only the difference for Caravan/Voyager fatal injury per involved occupant was statistically significant, with a higher rate for side-release buckles. It may be worthwhile to investigate this result further.

2. Analysis of State Data

Indiana

K+A Injury	Side Release N	Side Release % Inj	End Release N	End Release % Inj	Stat Sign
Taurus/Sable	455	1.0%	122	1.6%	

Maryland

K+A Injury	Side Release N	Side Release % Inj	End Release N	End Release % Inj	Stat Sign
Caravan/Voyager	418	15.3%	168	16.1%	
Taurus/Sable	1061	9.9%	273	11.7%	

Michigan

K+A Injury	Side Release N	Side Release % Inj	End Release N	End Release % Inj	Stat Sign
Caravan/Voyager	1931	6.5%	535	4.7%	
Taurus/Sable	3511	5.8%	791	5.6%	

Pennsylvania

K+A Injury	Side Release N	Side Release % Inj	End Release N	End Release % Inj	Stat Sign
Caravan/Voyager	1606	2.0%	511	2.2%	
Taurus/Sable	2227	2.1%	509	2.8%	

None of the comparisons of K+A injury rates were statistically significant within each state. A second-stage analysis was conducted, combining the resulting statistics for Caravan/Voyager across states (MD, MI, PA) and Taurus/Sable across states (IN, MD, MI, PA). Neither of the two test statistics yielded a significant difference in the K+A injury rate for side- vs. end-release.

In summary, only one statistically significant difference was found in all of the analyses of crossover vehicles.

Analysis of All Specified Vehicles

The vehicles specified by ODI staff were used in investigating the effect of side- vs. end-release systems on the likelihood of K+A injury using the state data files, the likelihood of occupant ejection in fatal crashes, and the fatal injury rate per occupant involved in a fatal crash. Logistic regression models were employed, using relevant variables for the crash, vehicle and occupant characteristics.

In preliminary analyses it was noted that the vehicles equipped with side-release systems tended to weigh more than those equipped with end-release systems. In addition, vehicle weight has been shown to be a significant factor in the likelihood of occupant injury. Therefore, it was important to incorporate vehicle weight into these analyses.

Due to the bias in reported safety belt use and the relationship of reported use to the event of interest, belt use was not employed in these models.

In general, the following explanatory variables were used in the modeling process (subject to availability on the state files):

- Posted speed limit,
- Vehicle weight (or ratio of weights for two-vehicle crashes),
- Impact location (farside/nearside/other),
- Rollover,
- Occupant (driver for state files) age,
- Occupant (driver for state files) sex,
- Seating position (for FARS data), and
- Side- vs. end-release system as equipped in vehicle.

3. Analysis of Fatal Crashes

The analysis of fatal crashes (both fatal injury and complete ejection) was conducted two ways - using two-vehicle crashes and all crashes, resulting in four separate analyses. The results of these analyses were consistent: in each analysis, the <u>side-release system</u> was associated with significantly <u>lower</u> ejection rates and rates of fatal injury per involved occupant compared with the end-release system. However, while the release type was statistically significant, it was generally marginally so compared with the remaining variables and in light of the large sample sizes (ranging from 8,000 for two-vehicle crashes to 24,000 for all crashes). Its importance was relatively small compared to the other variables included in the models.

4. Analysis of State Data

The analysis of state data investigated the likelihood of K+A injury; there were enough cases to analyze ejection risk. In these analyses the release type was never statistically significant, in spite of the fact that several states provided over 30,000 cases for analysis. In addition, the state data models did not provide as good a statistical fit to the data compared with the models estimated for fatal crashes.

Summary

Having reviewed all of these analytical results, there is no pattern of evidence to suggest that side-release systems are less safe than end-release systems. On the contrary, the FARS analysis would suggest that end-release systems may be less safe. However, it must be remembered that the analysis employs surrogate measures (injury and ejection) representing the outcome of the event of interest (inadvertent unlatching), a phenomenon which cannot be measured directly in the crash data. In addition, due to the bias in reported safety belt use and the relationship of reported use to the event of interest, belt use was not employed in these models. Differential use rates between side- and end-release systems, due to factors other than the system itself (e.g., equipped vehicle, driver demographics, etc.) could easily confound the interpretation of this result.

It is likely that the most serious consequences of the occurrence of the alleged event would be represented in more serious crashes; for example, ejection is much more common in fatal crashes than in less serious crashes (ejection is a serious outcome in and of itself). Therefore, it is not surprising for the state data to show no difference.

In closing, there is no pattern of evidence in the crash data to support the allegation related to inadvertent unlatching for side-release systems.

APPENDIX B

Side Release Button	
Model Year	Model
1985-1987	Tempo
1985-1988	T-bird
1985-1989	Crown Victoria/Grand Marquis
1986-1988	Taurus/Sable
1985-1989	Mustang
1985-1988	Continental
1985-1989	Celebrity
1985-1988	Park Avenue, Old 98
1985-1989	Caprice
1985-1988	Monte Carlo
1985-1986	Bonneville, Olds 88, Buick LeSabre
1985-1989	Cadillac Seville
1985-1986	Pontiac Grand Am, Buick Skylark or Somerset, Olds Calais
1985-1987	Chrysler Lebaron (4dr & 2dr)
1987	Sundance and Shadow
1985-1987	Daytona
1985-1989	Aries, Reliant
1985-1988	Dodge 600, Plymouth Caravelle, Chrysler New Yorker
1985-1987	Dodge Diplomat, Plymouth Grand Fury, Chrysler Fifth Avenue
1985-1988	Caravan, Voyager

End Release	
Model Year	Model
1989	Taurus
1988-1990	Tracer
1989	Continental
1985-1989	Camaro, Firebird
1985-1989	Fiero
1989	Spirit, Acclaim
1989-1991	Caravan, Voyager (Front only in 1989 and 1990)
1985-1989	BMW 3 Series
1985-1986	Accord, Civic 2dr
1985-1989	Accord, Civic 4dr
1985-1986	Maxima
1985-1988	Sentra
1985-1989	Stanza
1985-1986	Volvo 7 Series
1985-1988	Volvo 2 Series
1985-1986	VW Golf, Jetta
1985-1986	Mercedes Benz

APPENDIX C

Safety Belt Buckle Test Openings
Based on 2306 Tests and 3969 Dummies

Test Type	Vehicle/Restraint Make	Comments	Restraint Type	Restrained Device	HIC Driver	HIC Pass	Buckle Type	Report #
30 mph frontal, NEF-FMVSS 301	1979 IH Scout II	"Possible acceleration affecting buckle spring tension"	3-Pt man	50th male	-	-	side	HS-6-01478
35 mph rear, NCAP-NEF-FMVSS 301	1980 Honda Prelude	"Seat belt buckle failed early in the event, permitting dummy to move rearward freely."	3-pt man.	50th male	n/a	n/a	side	HS-9-02274
35 mph frontal, NCAP-NEF	1980 Datsun 310 GX	RECALLED, Internal mechanical failure, passenger buckle failed at 44 msec.	3-pt. man.	50th male	1059	**2019**	end	HS-9-02274
35 mph frontal, NCAP-NEF	1980 Subaru	RECALLED, Internal Mechanical Failure, Driver buckle (see next entry)	3-pt. man.	50th male	**1086**	2836	end	DOT 0133
35 mph frontal, NCAP-NEF	" (same car as above)	RECALLED, internal mechanical failure, passenger buckle	"	"	1086	**2836**	end	"
35 mph frontal, NCAP-NEF	1984 Isuzu Impulse	"On rebound the driver . . . arm struck the buckle release button. . . "	3-pt man.	50th male	**1769**	2454	end	212-CAL-84-025
35 mph frontal, NCAP-NEF	1984 Plymouth Conquest	Post-impact, passenger belt released, drivers right elbow struck button	3-pt man.	50th male	1118	**1035**	end	212-CAL-84-080
34 mph 2 cars frontal, 90% overlap	two 1989 Hyundai's	Head hit the automatic belt release on rebound (in vehicle 2)	2-pt auto, man lap	50th male	1058	**682**	end	DOT #1373
Sled - CRABI 30 mph	Lincoln Belts	Test 16, Airbag pushed child seat and buckle into seat cushion	Child seat, Rear Face, A/Bag 3-pt	p 3/4 (9 Month)	n/a	**486**	side	CR/AB - 16
Sled - Child Seats	GM belt	Test 33, buckle used to restrain the child seat broke at the webbing connection. Belt load 853 lbs.	child seat, forward	3-year old	n/a	n/a	side	DOTHS 807466 Test 33
35 mph frontal, NCAP	1992 Dodge Dakota Pickup	Driver safety belt unlatched on rebound during impact. Film analysis show apparent elbow impact into end-release button.	3-pt man.	50th male	**1005**	**987**	end	NCAP No. MN0302

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

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4. Title and Subtitle Tests Regarding Alleged Inertial Unlatching of Safety Belt Buckles		5. Report Date November 1992
		6. Performing Organization Code NRD-23
7. Author(s) Gavin Howe, Russ Kirkbride, Aloke 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 Safety Belt Buckles Inertial Unlatching		18. Distribution Statement 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

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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.

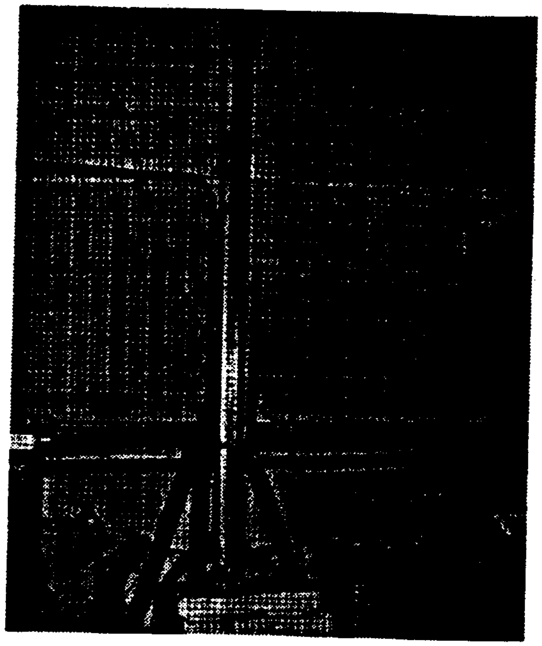


FIGURE 2.1: Drop Tower/Safety Belt Test Configuration

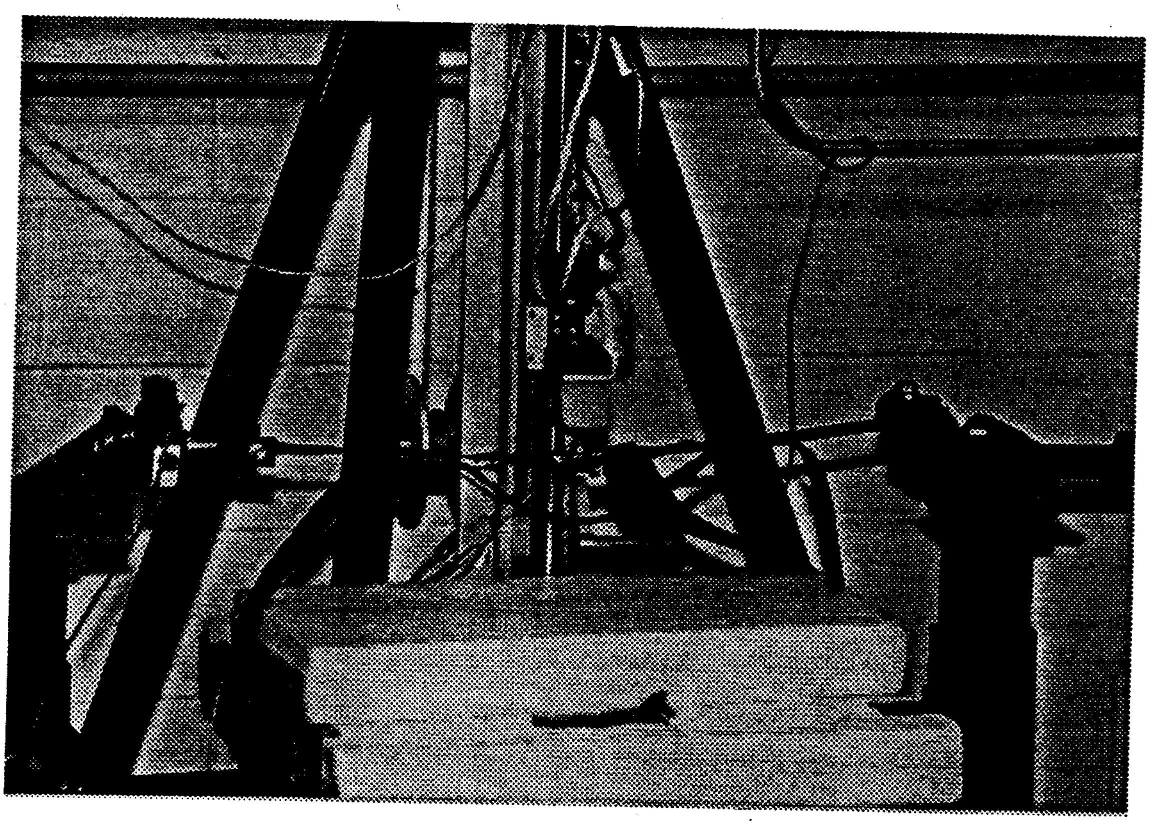


FIGURE 2.2: Safety Belt Test Fixture

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.

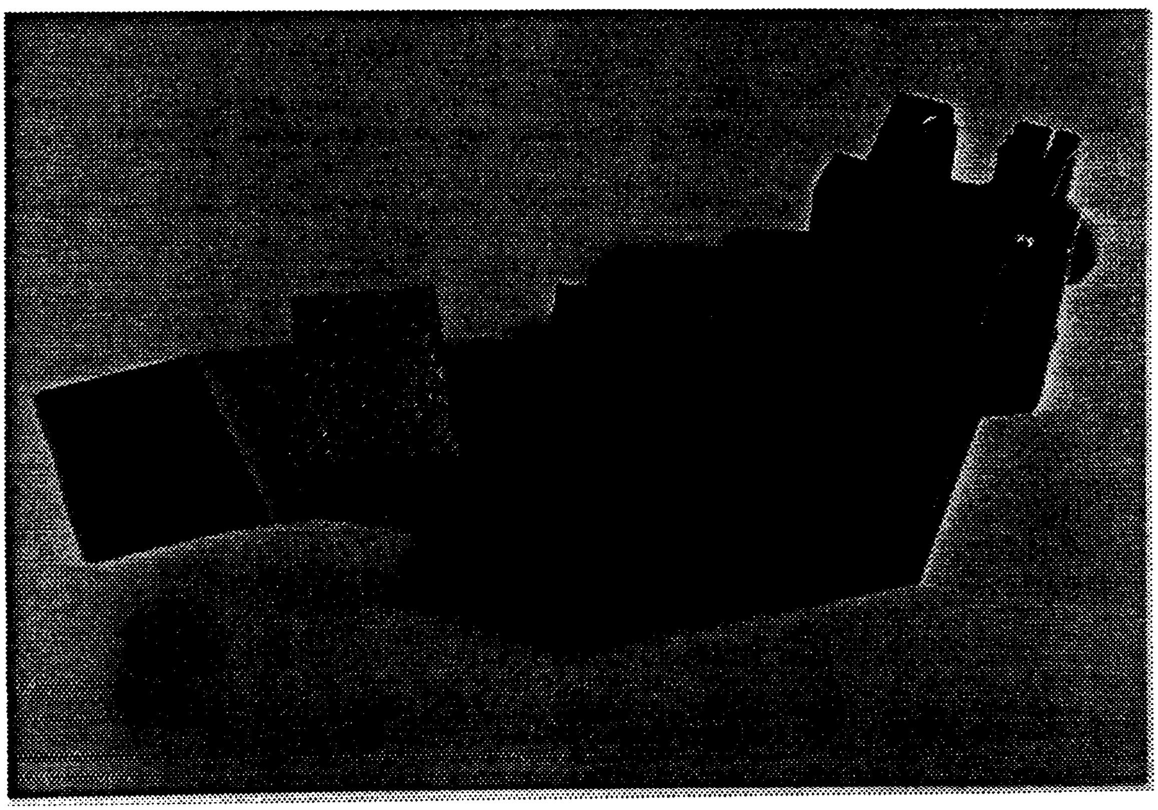


FIGURE 2.3: Rigid Mass and Padding Materials

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 2GCDC14H5F1105869 (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-10.5

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	304&315		
	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.			

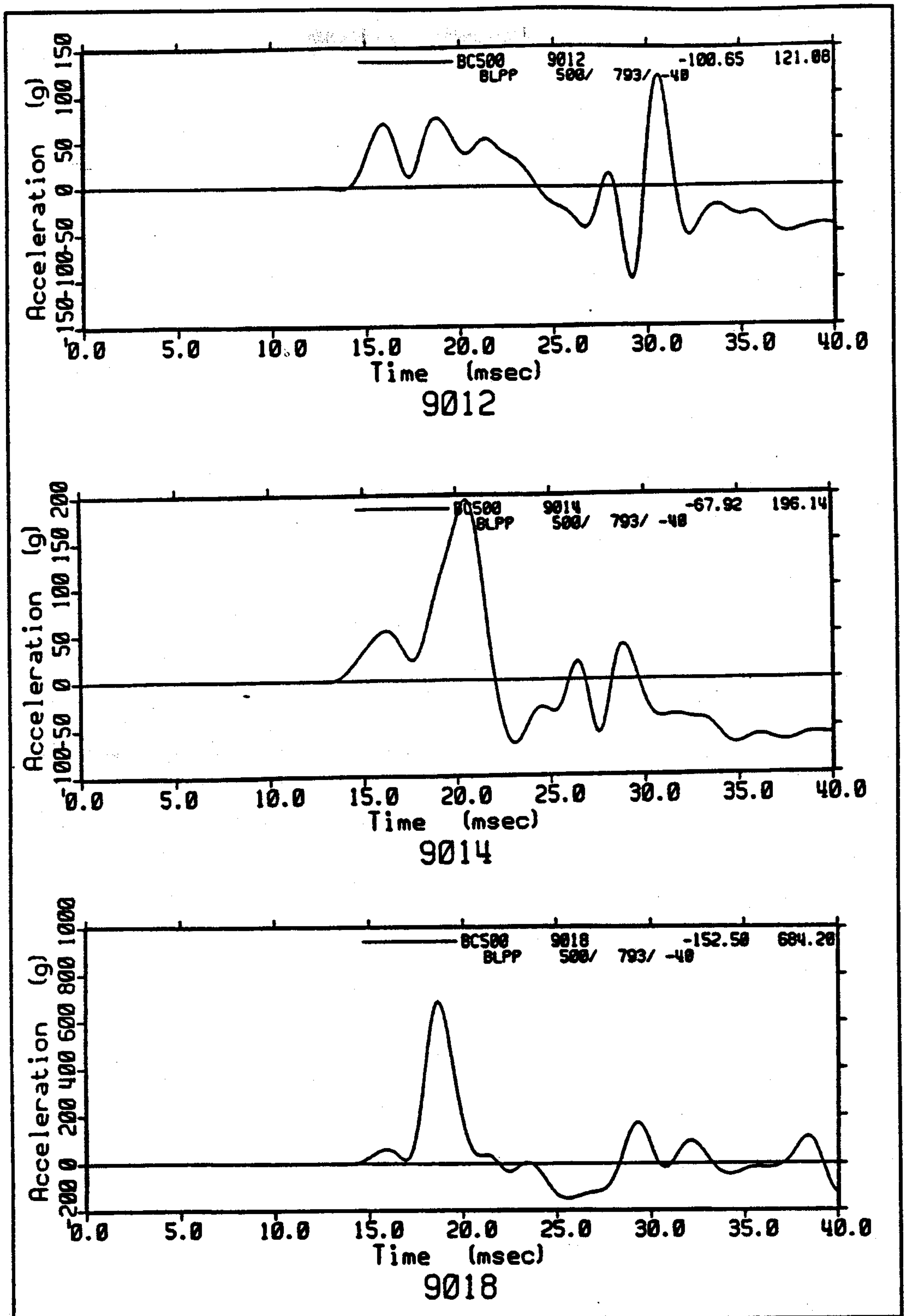


FIGURE 3.1: **Series of Acceleration Traces for GM/5-lbf-Belt-Tension/Ensolite Tests**

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.

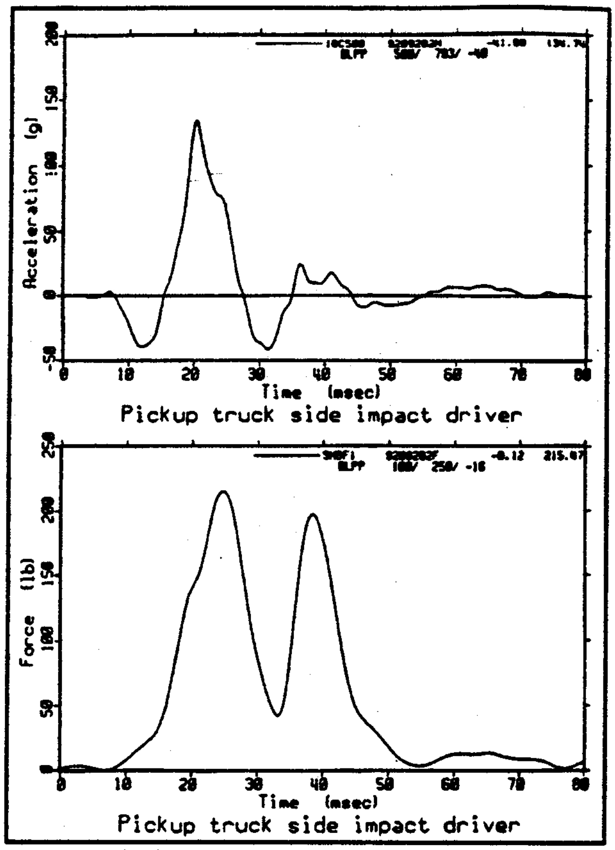


FIGURE 3.2: 85 Chevy (30mph) Driver Buckle Acceleration and Shoulder Belt Force

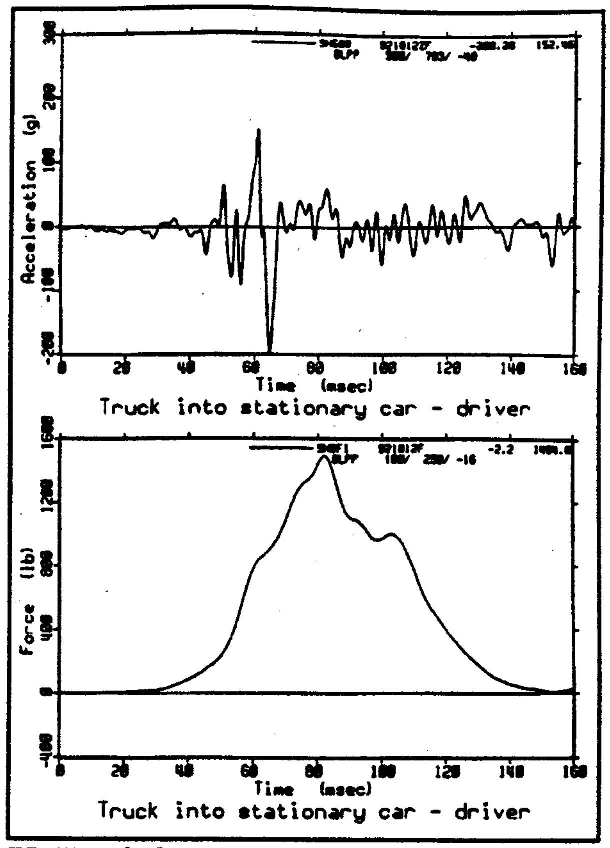


FIGURE 3.3: Taurus/Truck Driver Buckle Acceleration and Shoulder Belt Force

4.0 DISCUSSION

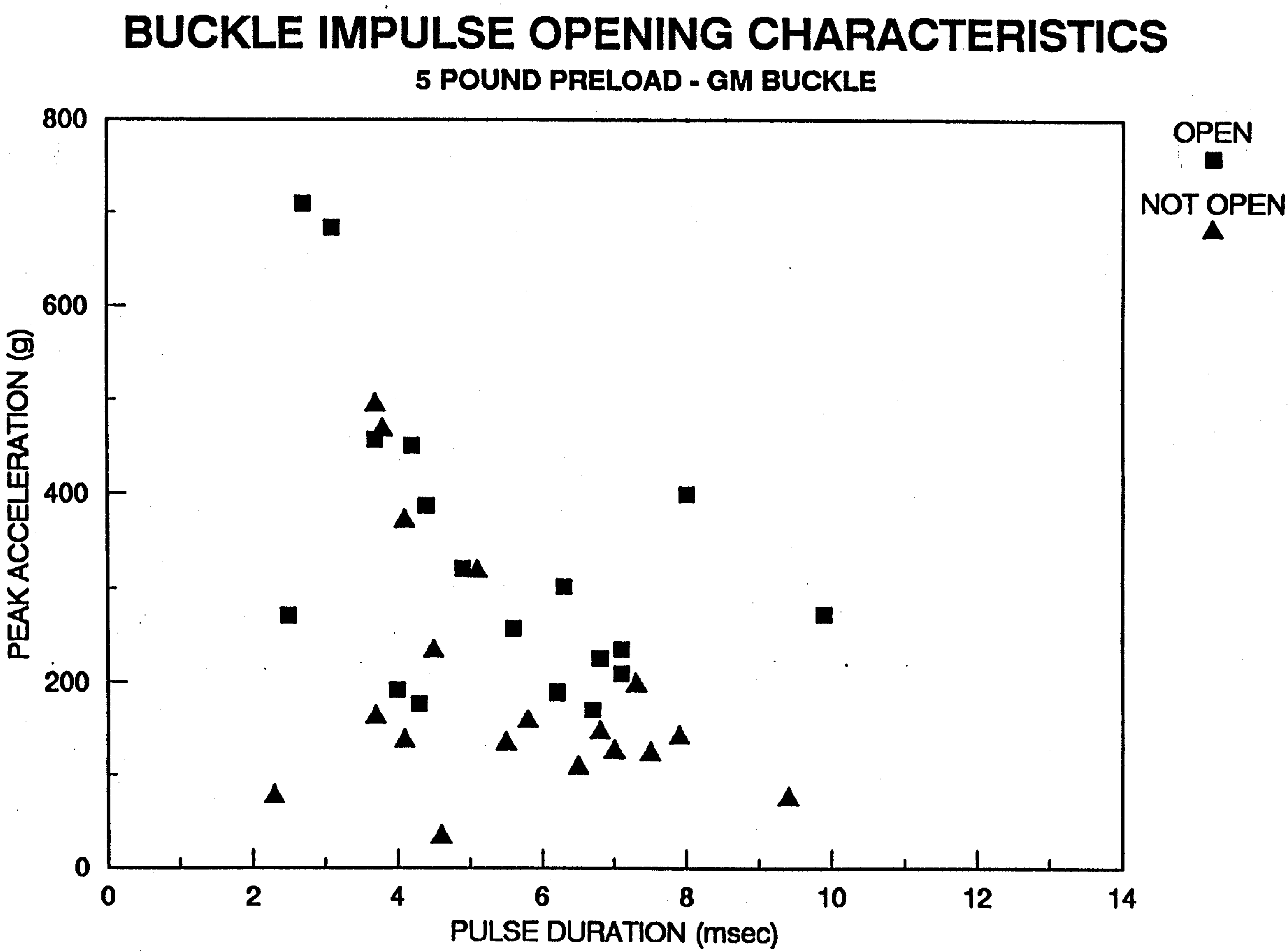
4.1 Peak Acceleration and Pulse Width Required for Buckle Opening

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
800
600
400
200
0
PEAK ACCELERATION (g)
0
2
4
6
8
10
12
14
PULSE DURATION (msec)
OPEN
NOT OPEN

FIGURE 4.1

BUCKLE IMPULSE OPENING CHARACTERISTICS

50 POUND PRELOAD - GM BUCKLE

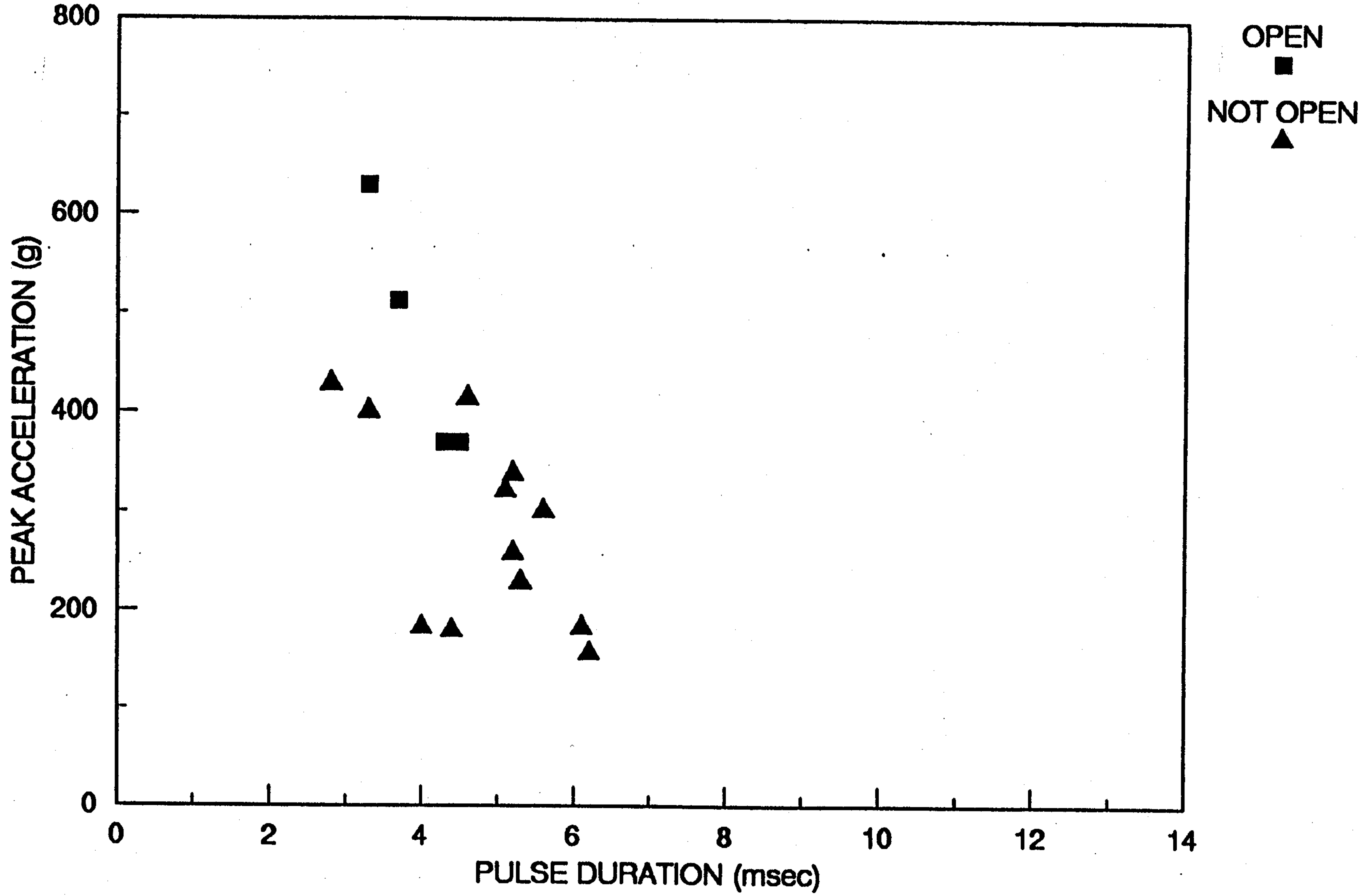


FIGURE 4.2

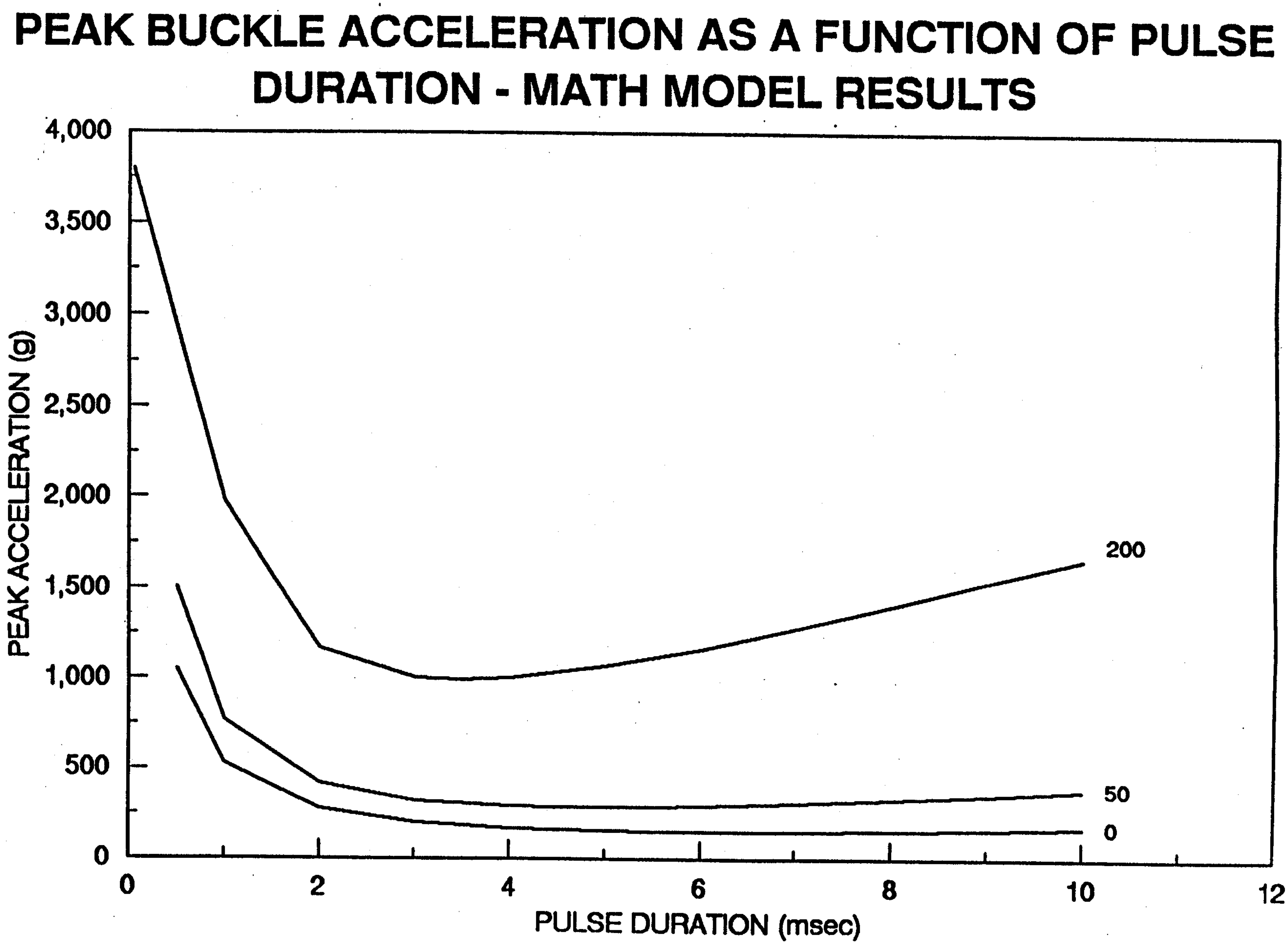

PEAK BUCKLE ACCELERATION AS A FUNCTION OF PULSE DURATION - MATH MODEL RESULTS
PEAK ACCELERATION (g)
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
2
4
6
8
10
12
PULSE DURATION (msec)
200
50
0

FIGURE 4.3

BUCKLE IMPULSE OPENING CHARACTERISTICS

5 POUND PRELOAD - GM BUCKLE AND MATH MODEL

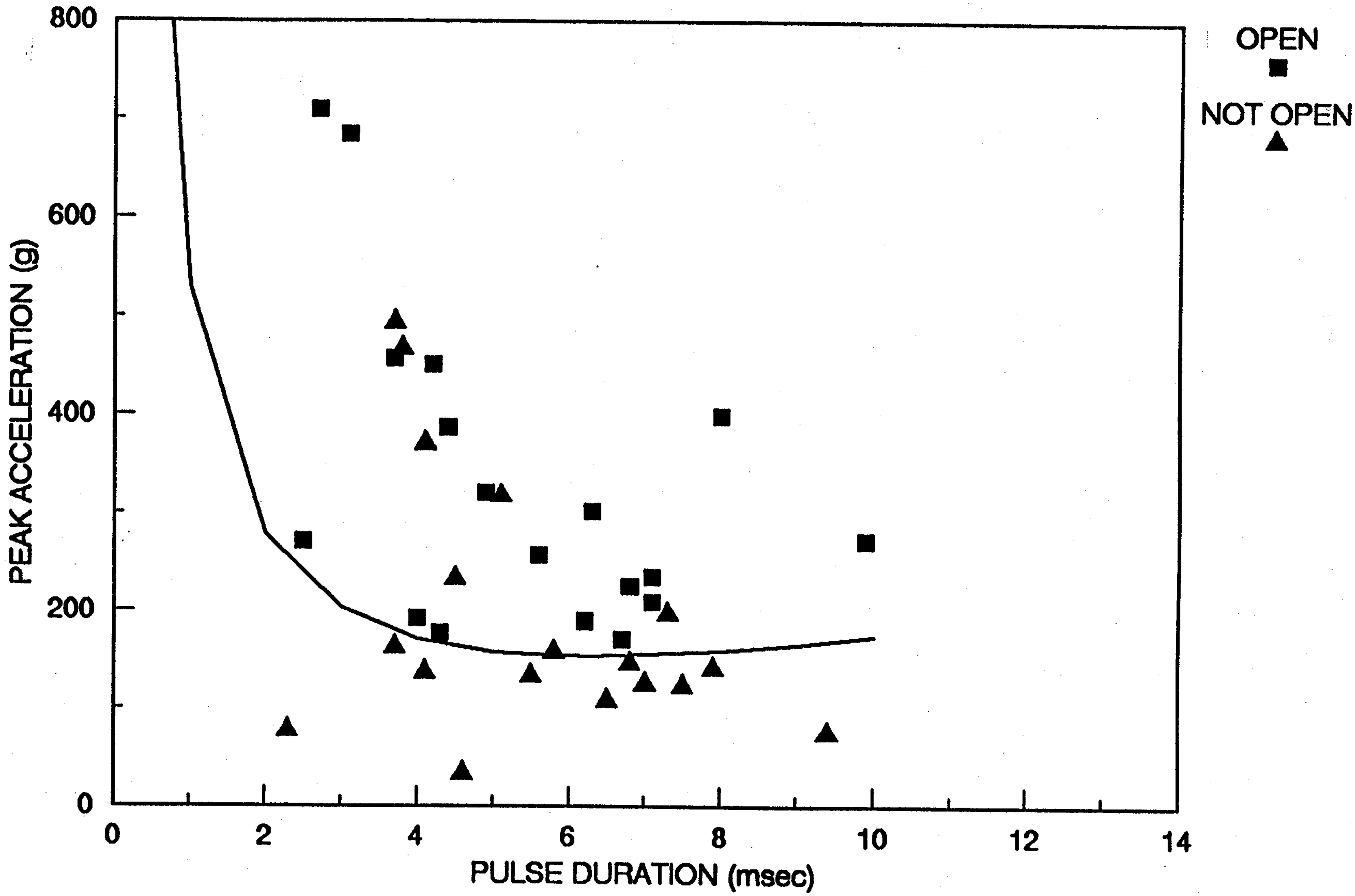


FIGURE 4.4

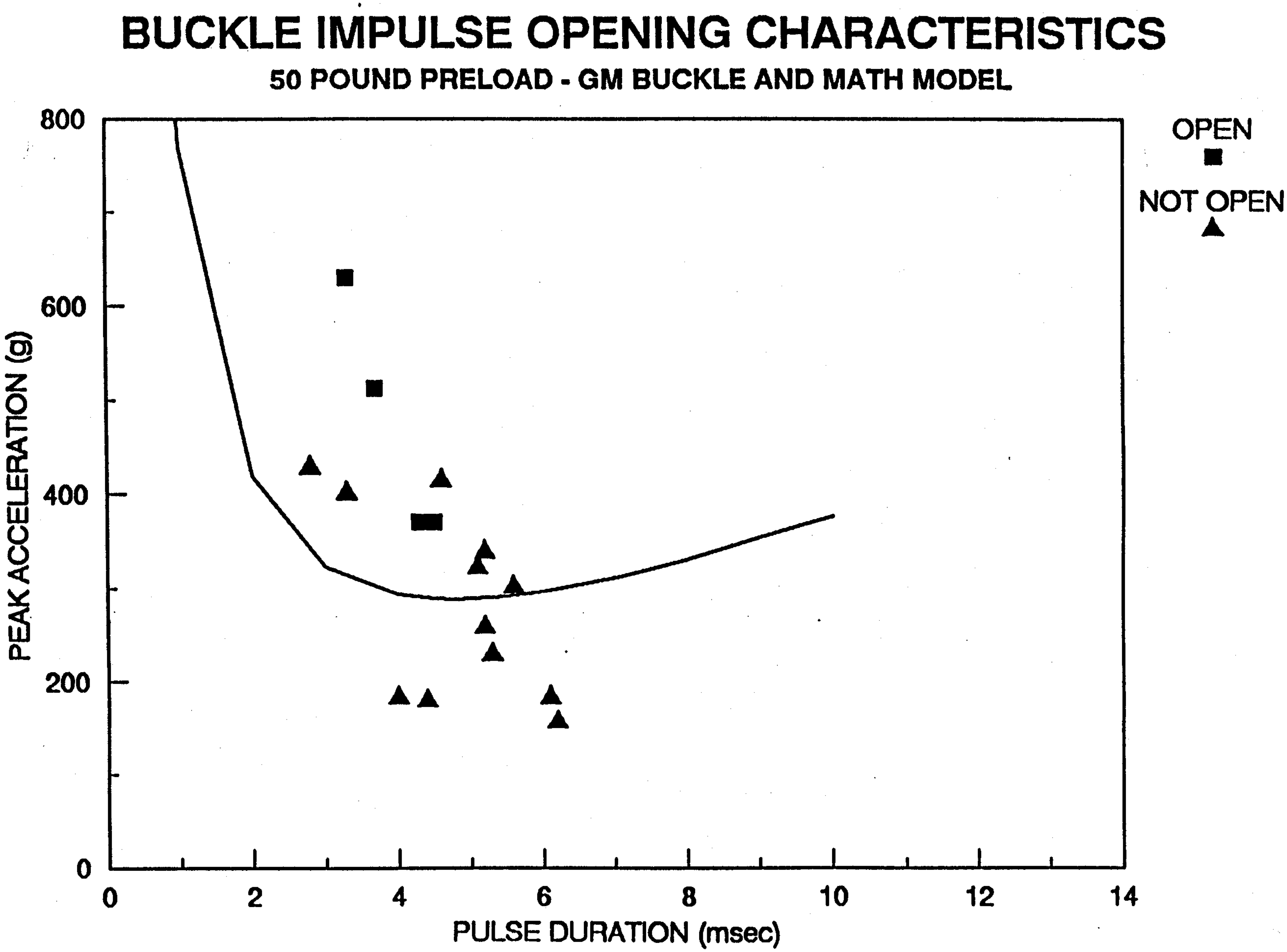

BUCKLE IMPULSE OPENING CHARACTERISTICS
50 POUND PRELOAD - GM BUCKLE AND MATH MODEL
PEAK ACCELERATION (g)
800
600
400
200
0
0
2
4
6
8
10
12
14
PULSE DURATION (msec)
OPEN
NOT OPEN

FIGURE 4.5

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

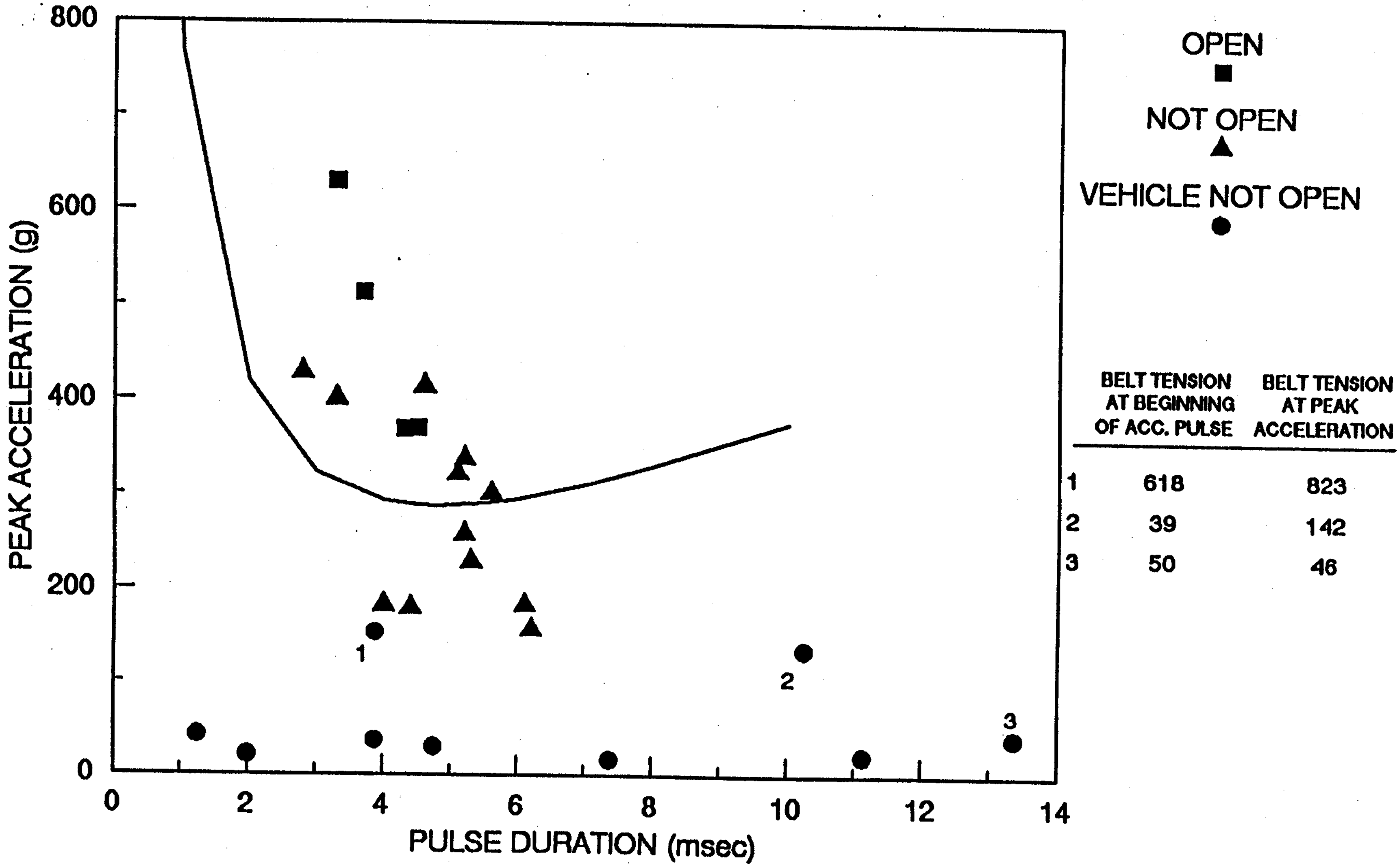
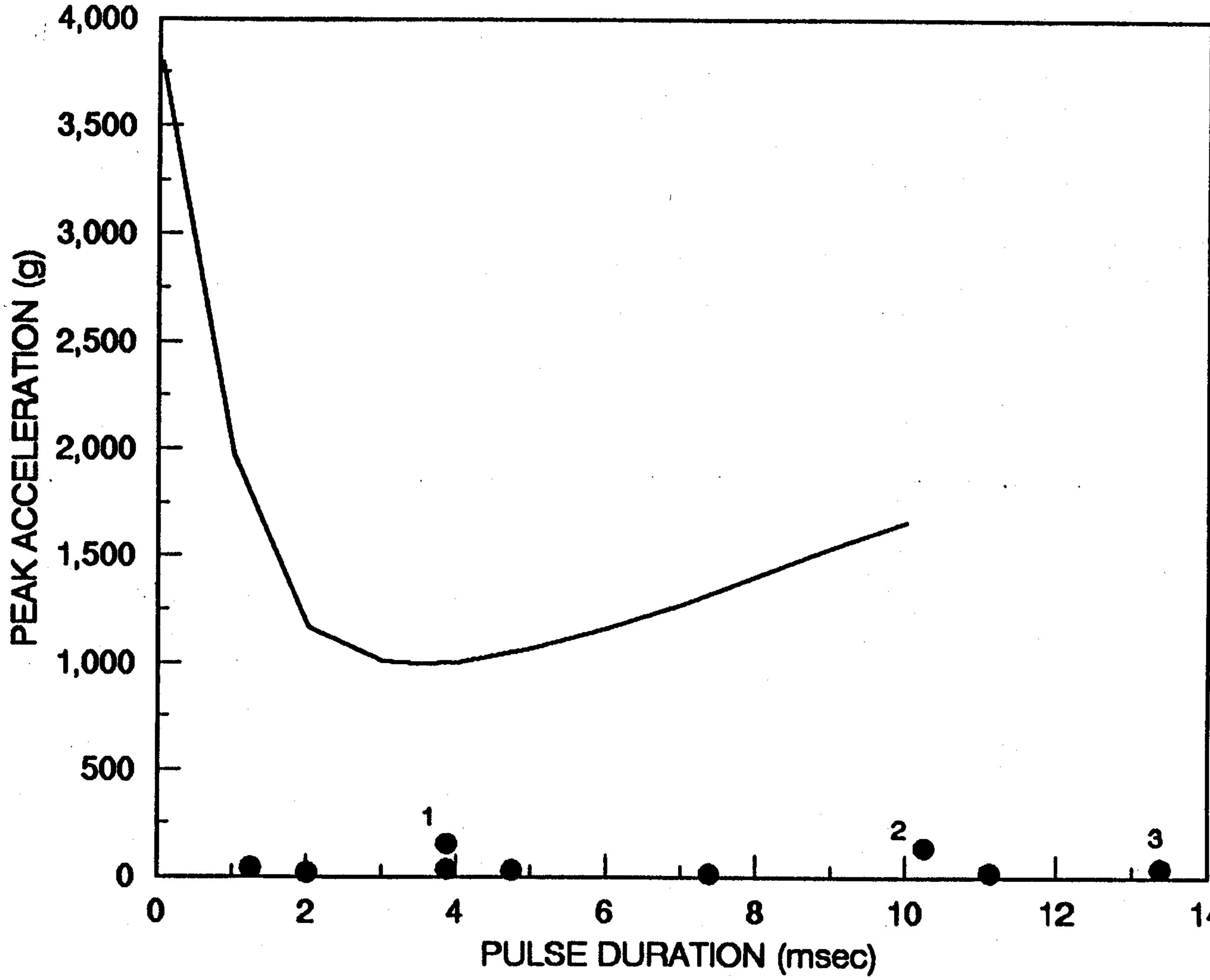


FIGURE 4.6

BUCKLE IMPULSE OPENING CHARACTERISTICS

200 POUND BELT TENSION - GM BUCKLE MATH MODEL AND CRASH DATA



VEHICLE NOT OPEN ●

	BELT TENSION AT BEGINNING OF ACC. PULSE	BELT TENSION AT PEAK ACCELERATION
1	618	823
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

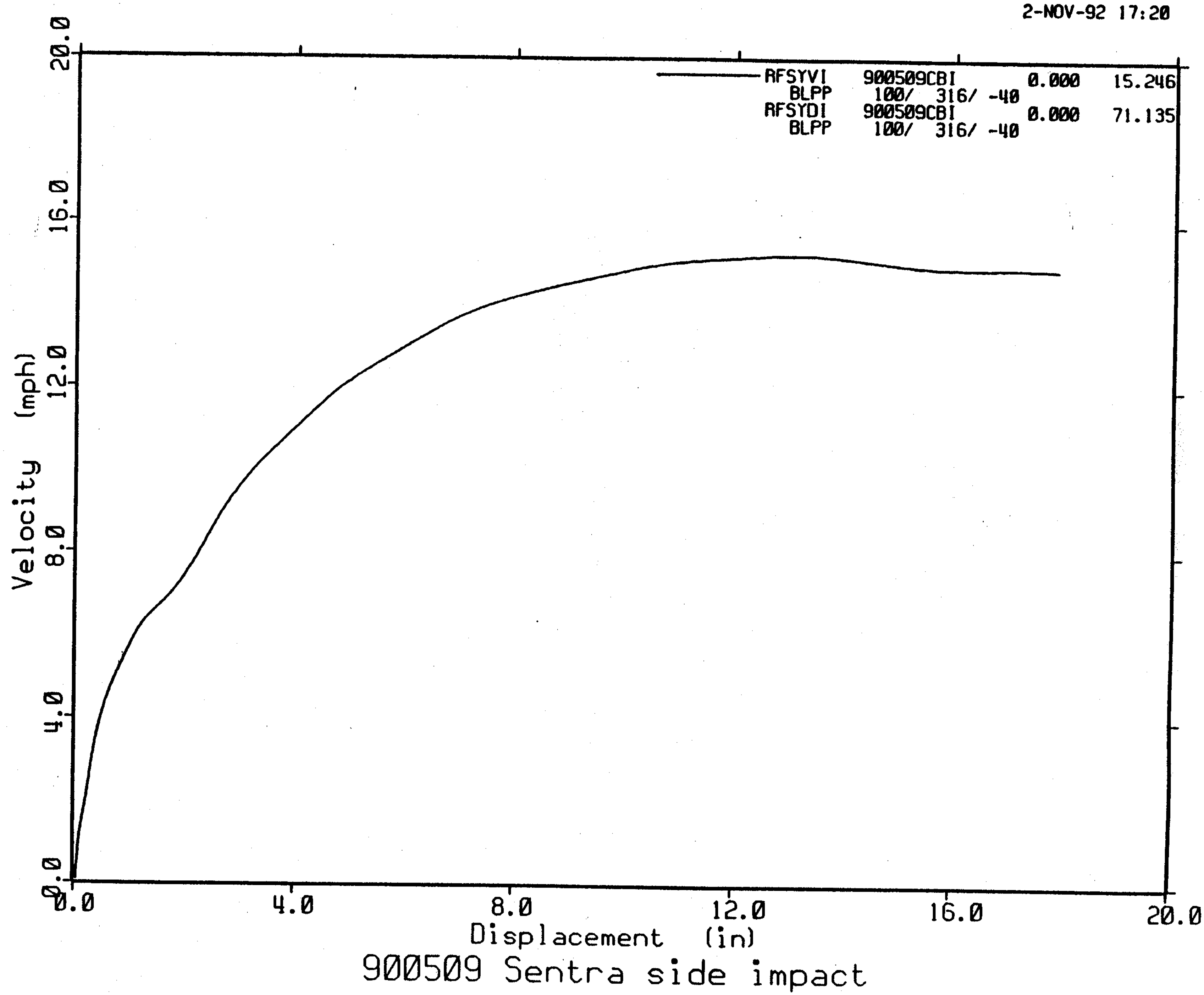

2-NOV-92 17:20
RFSYVI BLPP 900509CBI 100/ 316/ -40 0.000 15.246
RFSYDI BLPP 900509CBI 100/ 316/ -40 0.000 71.135
Velocity (mph)
0.0
4.0
8.0
12.0
16.0
20.0
Displacement (in)
900509 Sentra side impact

FIGURE 4.8

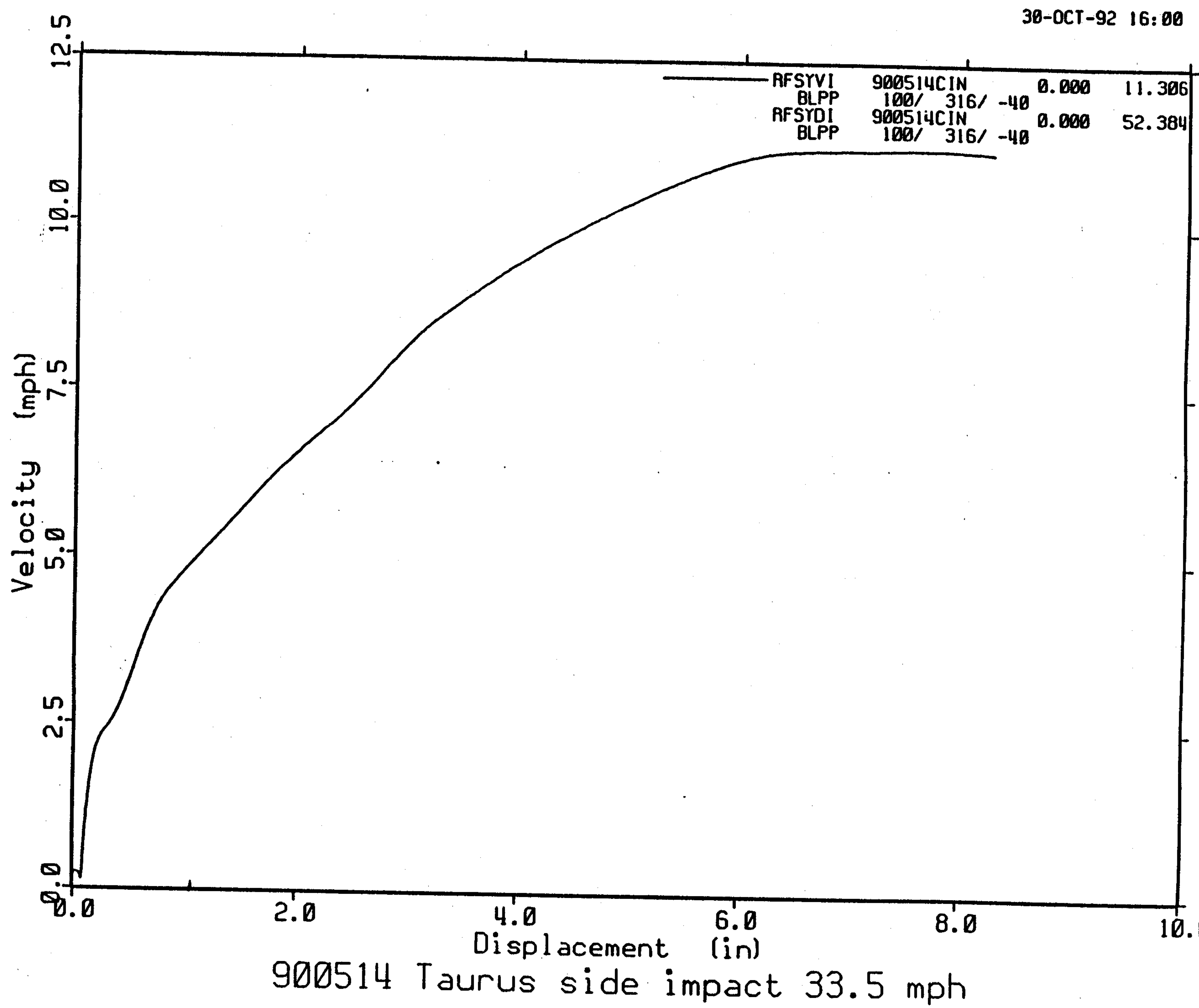

30-OCT-92 16:00
RFSYVI 900514CIN 0.000 11.306
BLPP 100/ 316/ -40
RFSYDI 900514CIN 0.000 52.384
BLPP 100/ 316/ -40
Velocity (mph)
0.0
2.5
5.0
7.5
10.0
12.5
0.0
2.0
4.0
6.0
8.0
10.0
Displacement (in)
900514 Taurus side impact 33.5 mph

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

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 1985-1990 1991	Volvo 740 760 740	485

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	565,000

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.