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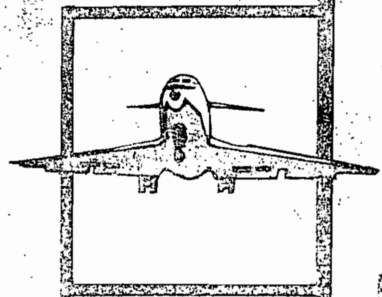
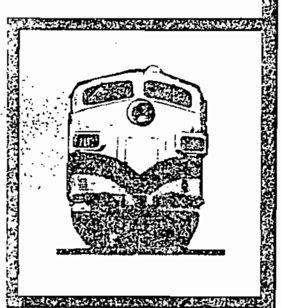
NATIONAL TRANSPORTATION SAFETY BOARD





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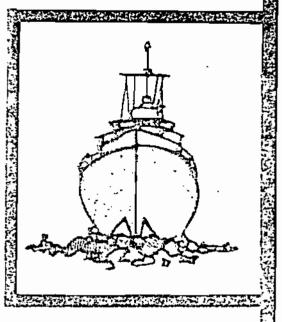
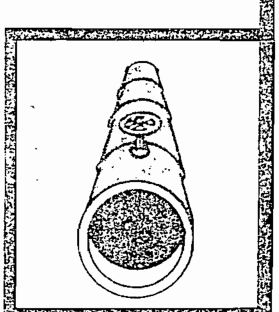


SAFETY STUDY

CRASHWORTHINESS OF LARGE POSTSTANDARD SCHOOLBUSES



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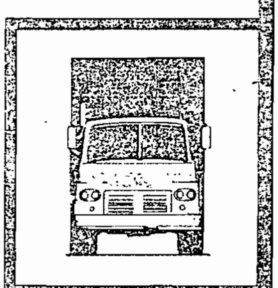

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16. Abstract

This study reports on the crash performance of large poststandard schoolbuses (schoolbus manufactured after April 1, 1977, and weighing more than 10,000 pounds unloaded) in 43 accidents investigated by the Safety Board. The report discusses the Safety Board's findings as to how well the standards are working to protect passengers from injury and whether changes in the standards are needed. The study focuses solely on events during the crash: how well did the bus perform; how did occupants sustain their injuries, if any; and how serious were the injuries. Each schoolbus passenger's experience in the crash also was analyzed to determine the difference, if any, lap belt use would have made. The report concludes with recommendations to the National Highway Traffic Safety Administration, schoolbus body manufacturers, and the State Directors of Pupil Transportation.

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NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C. 20594

SAFETY STUDY

Adopted: March 18, 1987

CRASHWORTHINESS OF LARGE POSTSTANDARD SCHOOLBUSES

INTRODUCTION

The schoolbus transporting children to school carries a family's and society's most precious possession. Although any fatality in a motor vehicle accident is tragic, the death of a child is particularly so. Moreover, injuries sustained in childhood are not only physically damaging, they can also result in lasting psychological damage. It is important, therefore, that crash protection be built into schoolbuses to the maximum practical extent.

In 1977, a series of special Federal motor vehicle safety standards went into effect, mandating a higher level of safety for schoolbuses compared to other buses. (See appendix R.) Before that date, schoolbuses were required only to meet the minimum standards required of all multipurpose passenger vehicles.

Data on the crash performance of schoolbuses built to Federal schoolbus standards have been lacking. For reasons to be pointed out later, available published data are insufficient to evaluate the performance of poststandard schoolbuses. Injury data, in particular, are inadequate.

Therefore, the Safety Board conducted a series of indepth accident investigations of the crash performance of schoolbuses built to Federal schoolbus standards to determine how well the standards are working to protect passengers from injury and whether changes in the standards are needed. Whether lap belts are needed for schoolbus passengers was also explored.

This report, addressing the crash performance of large poststandard schoolbuses (schoolbuses manufactured after April 1, 1977, and weighing more than 10,000 pounds unloaded), is the first of two reports based on accident investigations which will be issued by the Safety Board on the crashworthiness of poststandard school vehicles. The second report will focus on the crash performance of small poststandard schoolbuses (equal to or less than 10,000 pounds) and school vans built to Federal schoolbus standards. 1/ Safety Board investigators are continuing to conduct investigations of crashes involving small schoolbuses and school vans for the second report; investigations conducted for this report concluded March 1986.

1/ Small schoolbuses and school vans do not have to meet all the Federal standards that large schoolbuses must meet. Therefore, the Safety Board decided to study their performance separately. For example, small schoolbuses manufactured after April 1, 1977, are exempt from body joint strength requirements and are required to meet different fuel system integrity tests. They are, however, required to satisfy the seating standard in terms of some aspects of seat performance, seat height, with the added requirement that at least a lap belt be installed at every passenger seating position. Lap belts in small schoolbuses must meet all standards required of seat belts in multipurpose vehicles. Seats in small schoolbuses are required to withstand 5,000 pounds of crash force, similar to passenger cars; seats in large schoolbuses are required to withstand only 1,500 pounds of loading.

Published Schoolbus Accident Statistics

Schoolbuses have an excellent safety record. Each day, an estimated 350,000 schoolbuses travel more than 18 million miles, transporting 22 million students to and from public school. 2/ Although there are about 28,000 schoolbus accidents each year, schoolbus passenger fatalities are extremely rare. From 1980 to 1985, an average of 13 student passengers were killed per year. 3/ Two to three times as many children are killed each year while getting on and off the schoolbus than while riding the bus. Many are run over by their own bus. 4/

Injury-producing schoolbus accidents also are rare occurrences. According to National Safety Council (NSC) estimates, 8 out of 10 schoolbus accidents during the 1984-1985 school year resulted in property damage only. Of the 5,000 State-reported schoolbus accidents involving injury, the NSC estimates 6,700 pupils were injured. However, no breakdown by injury severity is available; NSC statistics do not distinguish between a bruise and an amputated leg. (NSC's injury statistics also do not distinguish between pupils injured while getting on and off the bus and those injured while riding the schoolbus nor do data distinguish between injuries sustained on prestandard versus poststandard schoolbuses.) Statistics developed in 1980, covering 16 years of NSC schoolbus data, estimated that 89 percent of all injuries in nonfatal accidents were minor and about 10 percent were moderate. 5/

It is important to emphasize that all schoolbus accident statistics are estimates and are not suitable for State-by-State comparisons or year-to-year analysis. 6/ Schoolbus accident statistics, particularly injury statistics, must be viewed with caution for the following reasons:

2/ National Safety Council, Accident Facts, 1986. The Safety Council uses State-reported schoolbus data and its own estimates to derive national schoolbus statistics. All types of vehicles—large schoolbuses (weighing more than 10,000 pounds), small schoolbuses (equal to or weighing less than 10,000 pounds), vans, station wagons, and other nonfamily owned motor vehicles used for school transportation—are included in the Safety Council's statistics.

3/ Based on the U.S. Department of Transportation (DOT) Fatal Accident Reporting System (FARS). FARS defines "schoolbus" solely on the basis of vehicle body type, regardless of its function (activity buses are included).

4/ The number of students killed while riding as schoolbus passengers or as pedestrians in the loading zone is as follows: 1980-1981 school year—15 passengers, 75 pedestrians; 1981-1982 school year—10 passengers, 50 pedestrians; 1982—1983 school year-10 passengers, 50 pedestrians; 1983-1984 school year—10 passengers, 35 pedestrians, and 1984—1985 school year (corrected figures)—15 passengers, 30 pedestrians.

5/ "Statistical Evaluation of the Effectiveness of Federal Motor Vehicle Standard 222: Schoolbus Seating and Crash Protection," Center for the Environment and Man, Inc., for the National Highway Traffic Safety Administration, U. S. Department of Transportation, Final Report, October 1980.

6/ NSC routinely warns in its Accident Facts booklet that national schoolbus accident statistics are not comparable year-to-year. Changes in schoolbus classifications and changes in methods by which the NSC adjusts State-reported data for inconsistencies and underreporting and inflates the total to compensate for nonreporting States account for the lack of comparability.

- the definition of "schoolbus" differs from State-to-State; 7/
- schoolbus accident reporting requirements vary State-to-State;
- the type of data requested on the accident form vary State-to-State;
- injury severity is rarely indicated; 8/ and
- national statistics derived by NSC consist of State-reported data supplemented by its own estimates when States fail to report.

A solution to some of the problems does exist. The 1985 National Conference on School Transportation, a conference of State Departments of Education, local school district personnel, contract operators, and advisors from the schoolbus industry, have proposed a uniform schoolbus accident report form which would provide standardized schoolbus accident data reporting throughout the schoolbus transportation industry. The Conference has adopted this form, but it is too soon to determine if school districts will use the standard form and generate the type of data useful to determine what types of accidents, nationwide, produce serious schoolbus passenger injuries. (It will be vital that trained personnel complete the accident forms so as to generate accurate data.) Yet, even with these data shortcomings, it is clear that schoolbuses are a very safe form of transportation. (See figure 1.)

Prestandard versus Poststandard Schoolbuses

Although schoolbuses as a whole have an excellent safety record, some schoolbuses provide a higher level of occupant protection than others. The safety inadequacies of schoolbuses manufactured before the Federal schoolbus safety standards (FMVSS) went into effect ("prestandard" buses) have been documented in Safety Board accident investigation reports. In the 1960's and early 1970's, the Safety Board investigated several catastrophic fatal schoolbus accidents involving massive disintegration of the schoolbus body as a result of widespread failures of the schoolbus body joints. (See figure 2.) The Safety Board issued a special study 9/ based on the findings of these accidents and recommended improved joint construction standards. Other safety inadequacies documented by the Safety Board investigations include the failure of the bus roof to

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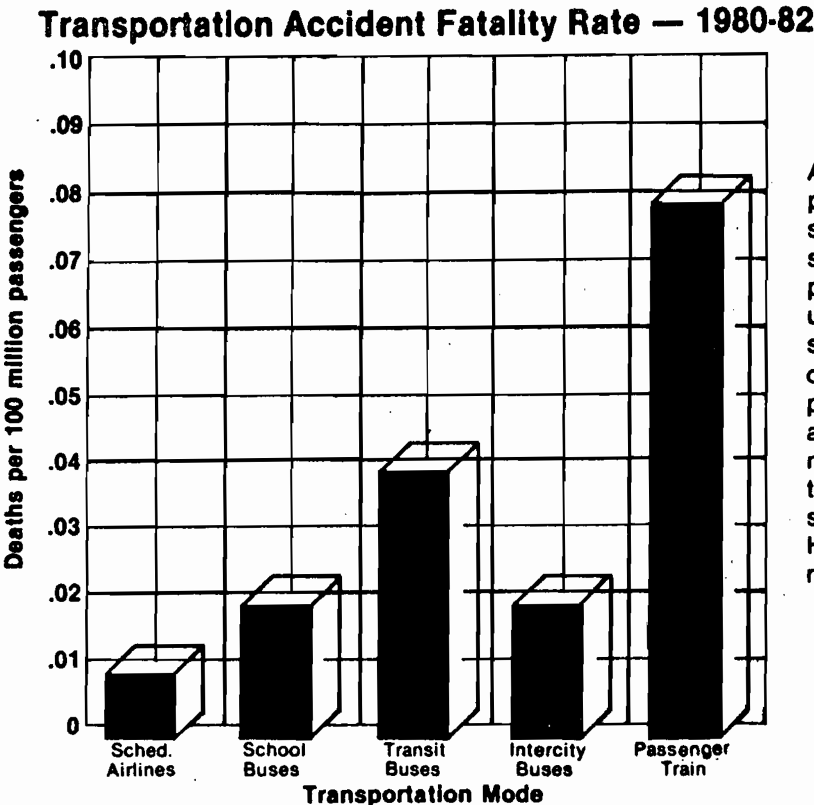
7/ Only some State schoolbus accident data include both private and public school accidents; accidents involving schoolbuses used as school activity buses also are reported by only some States. Furthermore, State schoolbus statistics may include vehicles other than schoolbuses, such as vans not built to schoolbus standards, if they are used for school transportation.

8/ The method by which schoolbus passenger injuries are reported and classified differs State-to-State. Police reports of individual schoolbus accidents also do not provide reliable, and comparable, measures of injury severity. Police highway accident reports filed at the State or local level use broad injury classifications such as the KABCO scheme that are of limited use to researchers. In KABCO, for example, a broken arm and a broken skull are both coded as "A" injuries, despite their vastly different threat to life. Internal injuries are not apt to be coded at all. Furthermore, each law enforcement officer may define "injuries" differently.

9/ Special Study--"Inadequate Structural Assembly of Schoolbus Bodies," July 29, 1970, (NTSB-HSS-70-2).



Although most pupil transportation officials consider school buses to provide the safest mode of mass transportation available, scheduled airlines still surpass school buses as the safest overall mode of mass transportation (as measured by accident fatality rates, or the number of passenger fatalities per 100 million passengers, shown in graph 1). However, as far as surface mass transportation is concerned, school buses are tied with intercity motorcoaches as the safest mode of surface mass transportation. And, considering the number of passengers carried each year by either scheduled airlines or intercity motorcoaches (see graph 2) — school buses may well be the safest mode of surface mass transportation in history.

Source: National Safety Council

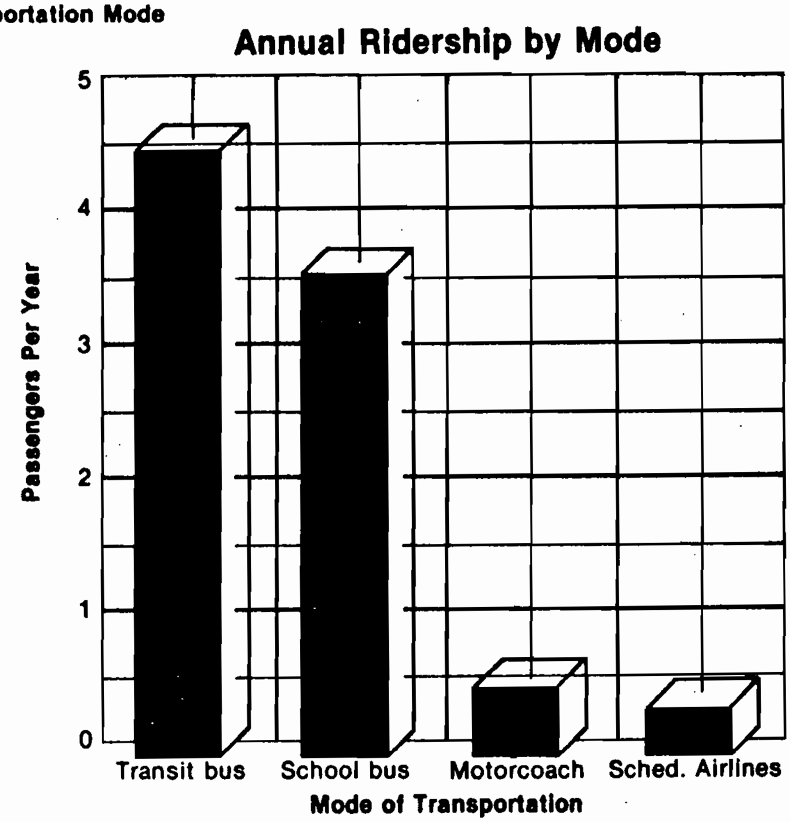


Figure 1.—Comparison of transportation modes.
(Reproduced with permission from Schoolbus Fleet Magazine, January 1986.)

Figure 2.—Schoolbuses built before 1977 provide inferior crash protection to occupants. This prestandard schoolbus underwent massive structural failure during a grade crossing accident in Congers, New York, on May 24, 1972. Arrows point to exposed metal edges which resulted from weak seam joints.

withstand rollover forces and seat backs with exposed metal frames which directly contributed to passenger head injuries. 10/

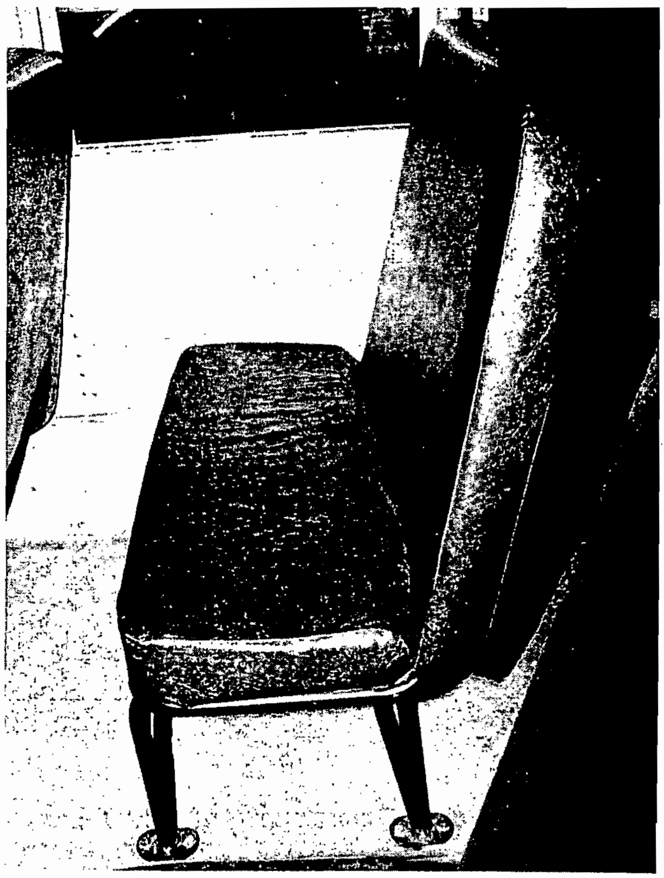
In 1977, in response to a Congressional mandate, a series of Federal Schoolbus Safety Standards went into effect. These standards required that all large schoolbuses manufactured on or after April 1, 1977, have increased roof strength, increased sheet metal panel seam strength, added protection for the gas tank, a minimum number of emergency exits, shatterproof glass, and extensive changes in seating design (higher backed, better padded seats, placed closer together.) (See figure 3 and appendix R.)

This was the first time the Federal government had instituted special safety standards for schoolbuses. 11/ Before that, the U.S. Department of Transportation (DOT) had required only that schoolbuses meet the same minimum standards required of all buses.

10/ Safety Board highway accident investigations involving prestandard schoolbuses include Wofford Heights, California; Decatur and Huntsville, Alabama; Devers, Texas; and Congers, New York. See appendix H for a complete list of Safety Board major schoolbus reports.

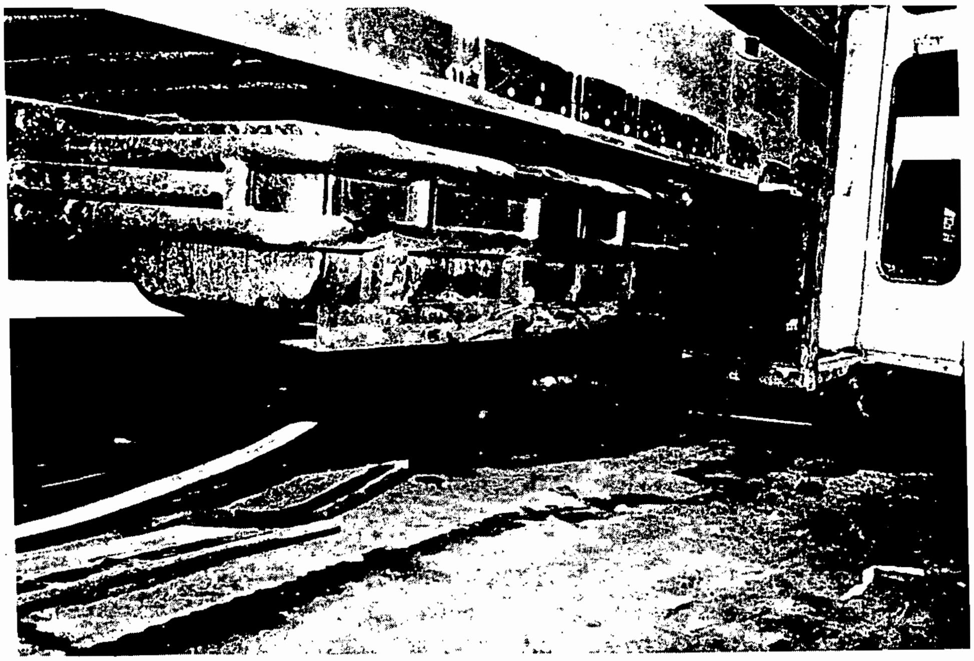
11/ FMVSS No. 220, 221, and 222 specify the minimum safety requirements for schoolbuses. Nothing prevents a State or local jurisdiction from purchasing schoolbuses with additional features such as armrests or lap belts for passengers as long as they are not inconsistent with existing Federal standards.

The seats in schoolbuses manufactured before April 1, 1977, typically were lower backed and padded for comfort, not crash protection, as evidenced by the exposed metal frames.

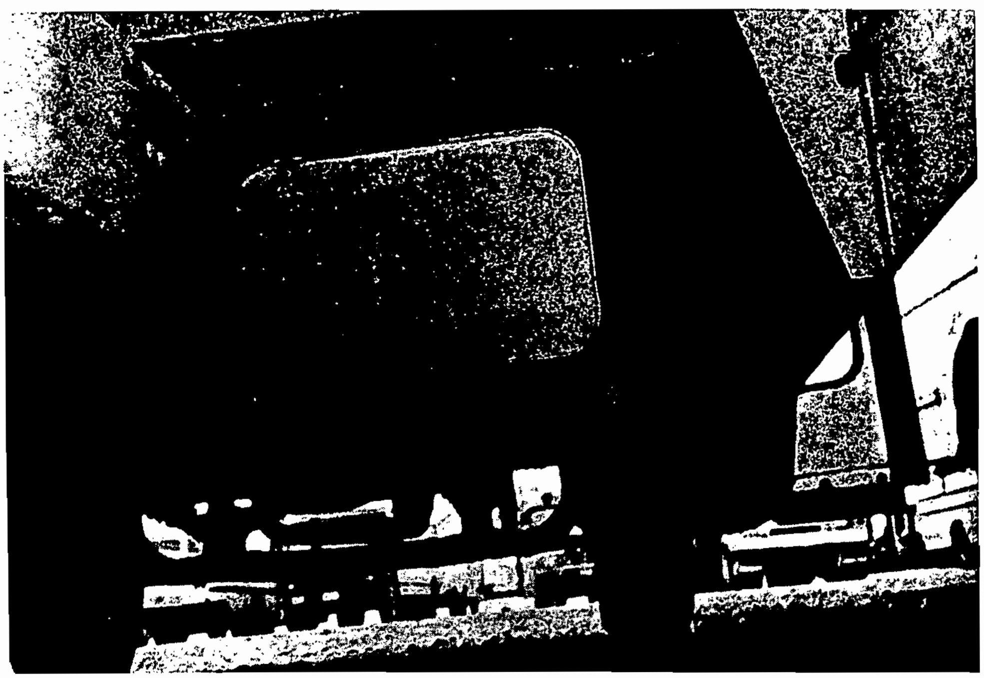


In poststandard schoolbuses, these problems were corrected. Seats have higher backs, increased padding for crash protection, and are placed closer together. Seat anchorage strength was increased significantly.

Figure 3.—Comparison of some of the aspects of prestandard versus poststandard schoolbuses.



Fuel tanks in poststandard schoolbuses are enclosed in a protective metal "cage" to minimize fuel leaks following a crash.



Fuel tanks in prestandard schoolbuses commonly are more exposed to impact damage and leak more frequently than those enclosed in protective cages.

Figure 3.—continued.

Evaluation of 1977 Federal Schoolbus Standards

Database Analyses.—In 1978 the Safety Board recommended that DOT's National Highway Traffic Safety Administration (NHTSA) review available accident statistics to determine the effectiveness of the schoolbus standards in reducing fatalities and injuries to schoolbus passengers.

In 1980, the NHTSA released the results of such an analysis. Because at that time only a small percentage of the nation's schoolbuses had been manufactured after 1977, and because fatal and injury-producing schoolbus accidents are so infrequent, the conclusions of the study had to be based on inferences drawn from analysis of accidents involving schoolbuses manufactured before 1977. The study concluded that the standards "are probably effective (about 60 percent injury reduction) in the vast majority of schoolbus accidents, which usually involve minor damage to the bus, with, at most, a few passengers injured at [minor to moderate injury] level. In the few violent schoolbus accidents that produce fatalities, [the standards have] lower effectiveness—about 29 percent injury reduction. The [standards have] only limited effectiveness in the extremely small subset of very violent accidents involving rollover, crashes with trains, etc." 12/

Real-world Accident Analyses.—In 1983 the Safety Board reviewed this analysis and concluded that the inferences drawn from it were sound. Nonetheless, the Safety Board wished to collect data on injuries to schoolbus passengers as a result of real-life accidents involving poststandard schoolbuses to evaluate the standard's effectiveness. The Safety Board's major schoolbus crash investigations would not provide sufficient data for such an analysis, since these investigations typically have been limited to those involving fatalities, the most atypical of all schoolbus accidents.

12/ "Statistical Evaluation of the Effectiveness of Federal Motor Vehicle Standard 222: Schoolbus Seating and Crash Protection," Op. cit.

ACCIDENT SELECTION CRITERIA

In the spring of 1984, the Safety Board launched a series of special investigations to evaluate the real-world performance of schoolbuses built to the 1977 Federal schoolbus standards. The crash investigation phase of this study, comprising 43 accidents, was conducted by headquarters staff and seven of the Safety Board's field offices, 13/ located around the country. Highway accident investigators asked State and local school transportation officials, law enforcement officers, hospitals, and safety advocates to notify them when schoolbus accidents meeting any of the following criteria occurred.

The large schoolbus (weighing more than 10,000 pounds) was manufactured after April 1, 1977, was occupied by school age children, and

- the schoolbus was involved in a moderate speed collision 14/ that disabled the bus (occupant injuries need not have resulted); or
- the schoolbus overturned; or
- one or more of the schoolbus occupants was seriously injured or killed in the accident (the accident could be any type).

Obviously, given the Safety Board's limited workforce, it could not investigate every schoolbus accident which met these criteria. In addition, notification was sometimes not received or received too late for follow-through on accidents potentially of interest. (It was necessary for the schoolbus to be available to the Safety Board investigator in its immediate postcrash state to document damage; many buses, however, were quickly repaired.) Priority was given to the investigation of schoolbus accidents involving rollover or side impact, since injury data are particularly lacking in these types of accidents, and these types of accidents have generated the most occupant protection discussion.

In each case, any damage to the exterior or interior of the schoolbus was carefully documented and medical information about each injured driver and passenger was obtained by interviewing the surviving occupants, parents, school officials, and medical personnel, and reviewing hospital records when available. The injury information was used to classify each injury according to the Abbreviated Injury Scale (AIS) (see appendix B), a well recognized system for classifying the severity of physical injuries.

13/ Investigations were conducted by Safety Board highway staff in Atlanta, Georgia; Chicago, Illinois; Denver, Colorado; Fort Worth, Texas; Kansas City, Missouri; New York, New York; and Seattle, Washington, Field Offices.
14/ The phrase "moderate speed" was included to preclude the Safety Board being notified of a minor accident occurring as the bus backed into an object or struck another vehicle as both vehicles were nearly at a standstill. This phase was necessary since the criteria specified "no injury need to have resulted."

The AIS codes used in this study are:

AIS	Severity code
1	Minor
2	Moderate
3	Serious
4	Severe
5	Critical
6	Maximum injury, virtually unsurvivable
7	Injured, unknown severity
9	Unknown if injured

Schoolbus occupant injuries are described throughout this report using the AIS coding system. Furthermore, each occupant is defined in terms of his or her maximum AIS level injury (MAIS). For example, if a schoolbus passenger sustained one serious injury, one moderate injury, and two minor injuries, the injured passenger is described in the text as sustaining a serious (MAIS 3) injury.

It is important to emphasize that the AIS code is only a measure of the severity of the injury being rated. It is not a measure of the likelihood of death or any other outcome. Five separate criteria (energy dissipation, threat to life, permanent impairment, treatment period, and incidence) were considered by the American Medical Association, the American Association for Automotive Medicine, and the Society of Automotive Engineers in developing the AIS system. A person can die from any AIS level injury, depending on the nature of injury, previous health, promptness and quality of medical treatment received, and other factors. The schoolbus driver in the Carrsville, Virginia, accident (case 42), for example, died from serious (MAIS 3) injuries 5 days after the accident after refusing blood transfusions or blood products for religious reasons. Death as an outcome is, of course, less likely at the lower levels and more likely at the higher AIS levels.

The Safety Board highway investigators also reconstructed the sequence of accident events for each schoolbus in the study and attempted to determine when in the accident sequence schoolbus occupants were injured and the probable contact point(s) that produced the injuries.

Because this study was undertaken solely to provide real-world data on how well modern schoolbuses protect occupants during a crash, it was not necessary to determine what caused the accident (the "probable cause"). Therefore, precrash factors (roadway condition, driver error or training and selection, discipline problems on the bus, improper passing by drivers of other vehicles, etc.) are not discussed in this report. Postcrash factors (evacuation and emergency medical care) also are not addressed in the study, except to distinguish between injuries sustained during the crash and those sustained during the evacuation. (Most injuries were sustained during the crash.) This study focuses solely on events during the crash: how well did the bus perform; how did occupants sustain their injuries, if any; and how serious were the injuries.

Since the Safety Board investigated 43 accidents involving poststandard schoolbuses 15/ and only those which met the study's selection criteria, 16/ data from these investigations are not representative of all schoolbus accidents, most of which are minor and involve no injury. Therefore, the results may not properly be extrapolated to all schoolbus accidents. For example, the set of cases in the study includes a much greater proportion of severe crashes and probably more rollover accidents than would be found in schoolbus accidents in the nation as a whole. This was the result of a deliberate choice; the Safety Board wished to examine the crash protection afforded by modern schoolbuses and, therefore, needed to look at the types of crashes in which schoolbus occupants would be at risk. The more typical schoolbus accident, which results in property damage only, would be of little use for this purpose.

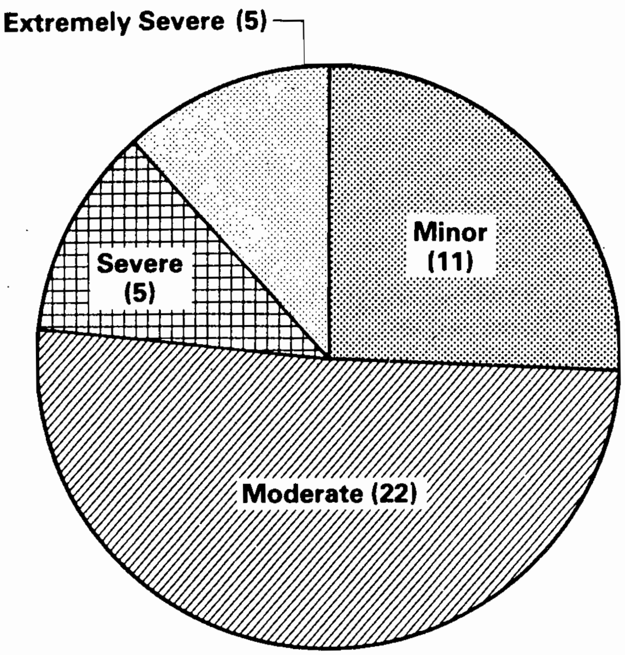
In this safety study, the Safety Board also considered the question of whether lap belts are needed for passengers of large poststandard schoolbuses. 17/ This question has been of mounting concern to parents, school boards, school transportation officials, researchers, and legislators. Thus, in this study each schoolbus passenger's experience in the crashes investigated was analyzed to determine the difference, if any, lap belt use would have made. The results of this analysis are presented in the chapter on "Lap Belt Discussion" and are based on the lap belt analysis which is part of every case summary in appendix A.

15/ How many crashes involving large poststandard schoolbuses occurred during the span of the Safety Board's study is unknown. Available accident statistics combine all sizes of school vehicles and prestandard and poststandard buses together. Nationwide, there were an estimated 5,000 "injury-producing" accidents involving school vehicles during the 1984-1985 school year. As noted earlier, most injuries were probably minor.

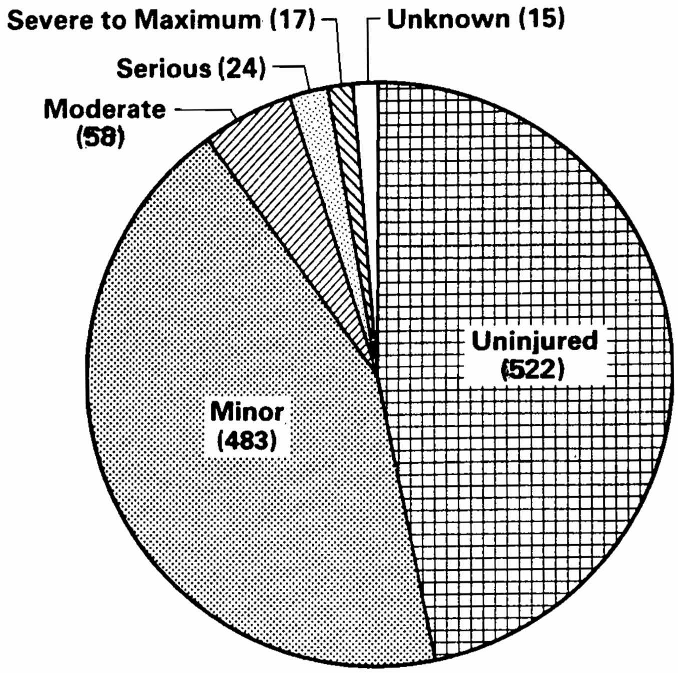
16/ The Greenburgh, New York, (case 16) accident involving a large poststandard schoolbus equipped with lap belts for all occupants was the only exception. This case did not meet the study's criteria (crash forces were virtually nonexistent), but was investigated because it involved a belted bus and had generated much publicity.

17/ Prestandard schoolbuses were not designed to accommodate the installation of lap belts. The Safety Board has pointed out, in recent accident reports involving prestandard large schoolbuses, that "the wooden floors and tubular steel seats within [the prestandard] schoolbuses were not designed to accommodate occupant restraints and would have had to have been substantially upgraded to do so." (For more detailed information, read Highway Accident Report— "Collision of Humbolt County Dump Truck and Klamath Trinity Unified District Schoolbus, State Route 96 near Willow Creek, California, February 24, 1983," (NTSB/HAR-83-9).) Such upgrading would have to include floor strengthening and replacement of all seats with exposed metal frames and inadequate padding.

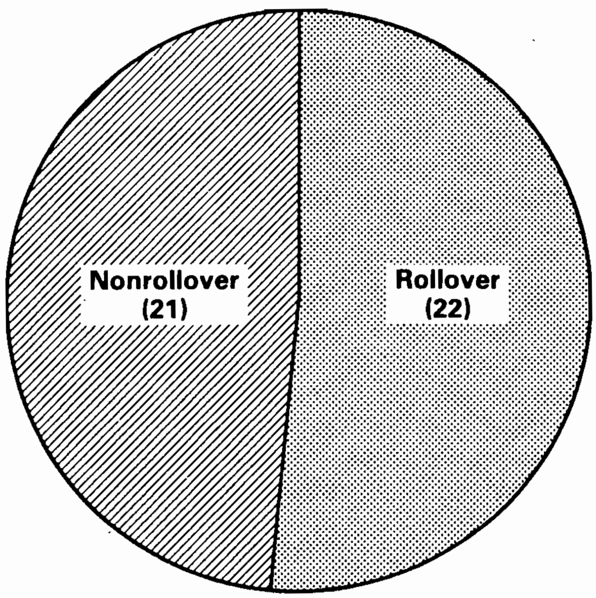
Chart 1.—Safety Board Large Poststandard Schoolbus Accident Investigations at a Glance
(43 accidents, 44 schoolbuses)



Accident Severity*
(by number of cases)



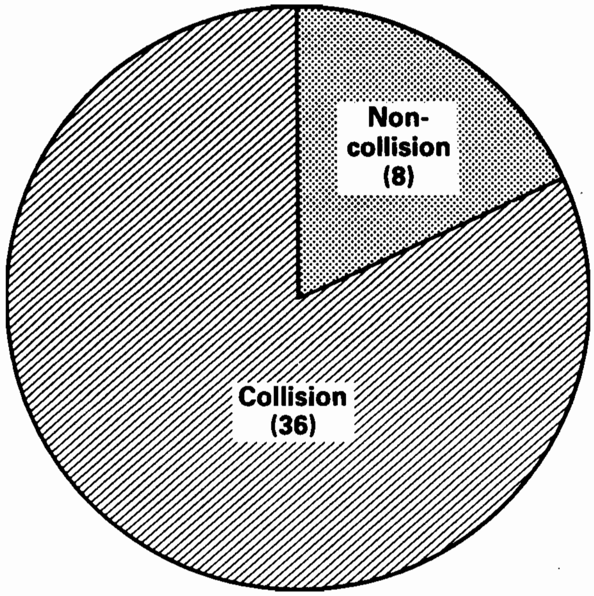
Unrestrained Schoolbus Passengers by Most Severe Injury Sustained
(a Total of 1,119 Passengers)
(by number of passengers)



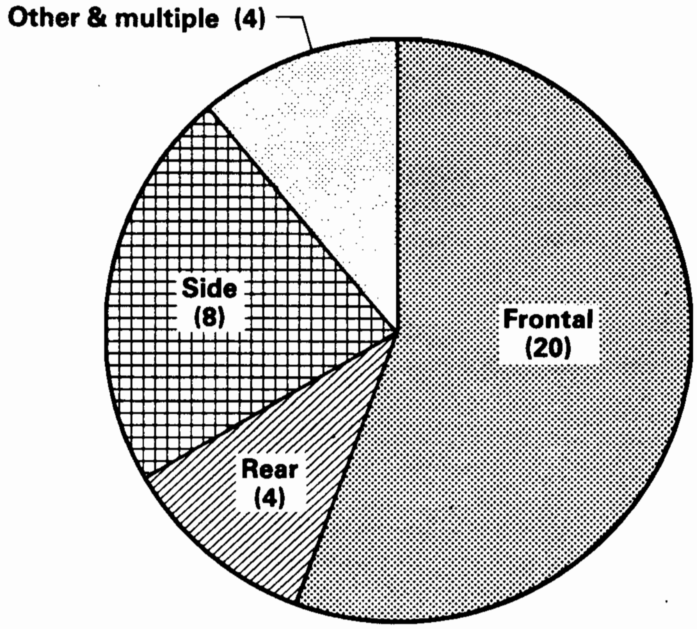
Rollover/Nonrollover*
(by number of cases)

*The Safety Board investigated only those schoolbus accidents which met specific selection criteria so the cases represented in the study undoubtedly contain a higher proportion of severe crashes and rollover accidents than would be found in U.S. schoolbus accidents as a whole.

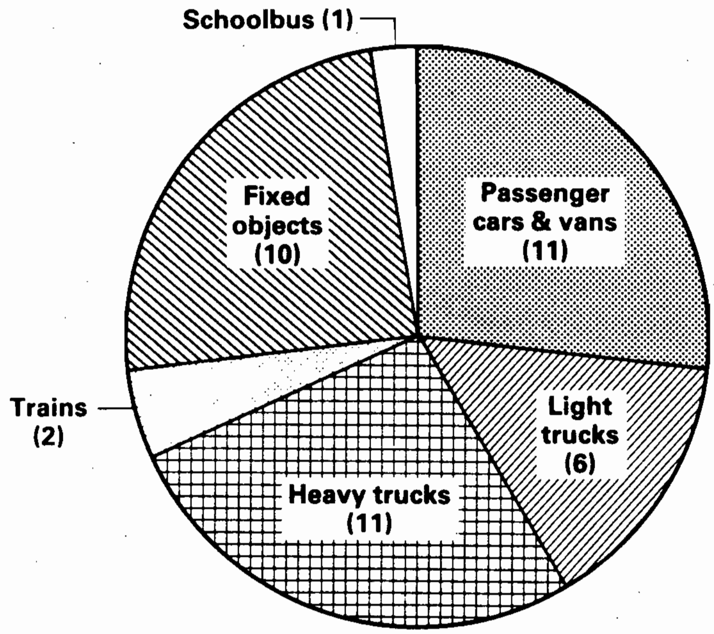
Chart 1.—continued



Collision/Noncollision
(by number of schoolbuses)



Principal Direction of Impact
in Collision Accidents
(by number of schoolbuses)



Other Vehicles(s) or Object(s)
Involved in Schoolbus Collision, If Any
(by number of vehicles or objects)

OVERVIEW OF SCHOOLBUS CRASHES INVESTIGATED

Any study's findings reflect the type of cases used as the basis for the analysis or investigation. This study is no exception. The accident selection criteria were intended to allow the Safety Board to investigate the crash performance and resulting passenger injuries in one particular kind of schoolbus—a large poststandard schoolbus. Furthermore, the crashes, to be instructive, had to be serious enough to provide an opportunity for the crash protection features of the bus to be evaluated. During the 29 months this study was conducted, the Safety Board probably investigated every accident involving a large poststandard schoolbus which resulted in a schoolbus passenger fatality, most, if not all, of the crashes which resulted in a serious or greater injury, and many of the crashes which produced moderate injuries. Some minor crashes also were investigated.

The Safety Board's study definitely is slanted towards the more serious rather than the minor schoolbus accidents, but this is precisely what the Safety Board intended. These are the crashes in which shortcomings in occupant protection will be more apt to be revealed. The Safety Board was not attempting to conduct a census of all schoolbus accidents in the United States, nor was it attempting to conduct a statistical sample of all injury-producing schoolbus accidents.

The Safety Board investigated 43 schoolbus accidents for this study. These investigations yielded data on the performance of 44 large poststandard schoolbuses (one accident involved two schoolbuses), and the injury outcome for 1,166 crash-involved schoolbus passengers and 44 schoolbus drivers. Passengers on four of the 44 schoolbuses involved in these crashes were using some form of occupant restraint; though small in an absolute sense, the number of large belted buses in the Safety Board's cases is disproportionately high, considering there are so few large buses equipped with restraints for passengers currently in the schoolbus fleet. (As of the 1986 school year, about 104 school districts had some large schoolbuses with lap belts for passengers.) Occupant restraints on these four buses included lap belts, "loop belts" (not considered a safety device), and secured wheelchairs. A total of 47 schoolbus passengers in the Safety Board investigated cases were restrained, 40 by lap belts only. See accidents in Greenburgh, New York (case 16), Des Peres, Missouri (case 22), Newark, New Jersey (case 33), and Wilmington, Ohio (case 36) for cases involving restrained schoolbus passengers. A fifth bus, St. Louis, Missouri, (case 13), was equipped with a passenger lap belt which was not in use.

Rollover/Nonrollover

Half of all the accidents investigated by the Safety Board for this study were rollover accidents. All degrees of rollover were represented, with rollover to one side (a 90° rollover) the most common (12 out of 22 cases). Eight cases involved rollovers of 270° or more (two were 450°). The percentage of rollover accidents in this study is probably much higher than would be found in schoolbus accidents as a whole. (The percentage of rollover accidents in the universe of schoolbus accidents is unknown.) It probably no way constitutes 50 percent of accidents as in this study. In 1986 in North Carolina, for example, there were 1,014 reportable schoolbus accidents on buses with occupants for which rollover/nonrollover and injury severity could be determined. Only 2 percent (19) of the 1,014 crashes were rollovers; 98 percent were nonrollovers. Rollover appears to be a common occurrence in fatal schoolbus accidents (half of all the fatally injured schoolbus occupants from 1981 to 1983 were in rollovers), but this does not mean that a rollover occurs in half of all the nonfatal accidents. Rollover seems correlated with more severe schoolbus accidents. This statement should not be construed to imply that the event of rollover caused the injuries, only that serious accidents often include rollover. For example, of the 82 serious injury-producing schoolbus accidents investigated by a multidisciplinary team in the late 1970's, 30 percent of the nonfatal crashes were rollovers as were 50 percent of the fatal crashes. Less severe schoolbus accidents appear less likely to involve rollover. For example, in the 1,014 North Carolina schoolbus accidents referred to earlier, rollovers represented only 2 percent of the crashes, but accounted for 26 percent of all serious "A" injury-producing accidents. Nonrollover accidents which represented 98 percent of all crashes accounted for 74 percent of all "A" serious injury crashes.

Collision/Noncollision

Thirty-five of the cases in the study involved collision. Eight were noncollision accidents -- and these were all noncollision rollovers. Frontal collision was most common direction of impact in the Safety Board's study, even when subsequent rollover was involved and the collision most often involved another vehicle, not a fixed object. Heavy trucks and passenger cars were the two types of vehicles most frequently involved in multivehicle accidents in the study, followed by light trucks, then trains. Heavy trucks were the vehicles most often involved in the more serious injury-producing, multivehicle accidents investigated. Collision with passenger cars generally produced little damage to the schoolbus. (See figure 4.)

Accident Severity

Accident severity in this study is defined solely in terms of the schoolbus, not the other vehicle(s), if any, involved in the accident. This is an important distinction since a minor accident for a schoolbus can be a severe accident for the passenger car involved. (See appendix C for an explanation of the accident severity scale used in this study.)

A wide range of accident severities is represented in this study, but three-fourths of the cases are in the minor or moderate category. In this study, with one exception, severe or extremely severe crash forces were required to produce schoolbus passenger fatalities. A total of 13 schoolbus passengers and 3 schoolbus drivers died in the 8 fatal schoolbus crashes investigated by the Safety Board.

Age of Student Passengers

Injury data collected by the Safety Board in its accident investigations reflect the wide range of ages and sizes among children transported by schoolbuses. Students from elementary school through high school were represented. The most common bus load in the study was a mix of school children — high school, junior high, and elementary — followed in frequency by bus loads of elementary students or high school students only.

Schoolbuses by Grade Level of Passengers

Grade Level	Number of Buses
Preschool	1
Preschool/Elementary	3
Elementary	12
Junior High/High School	2
High School	11
Mixed	15
Total	44

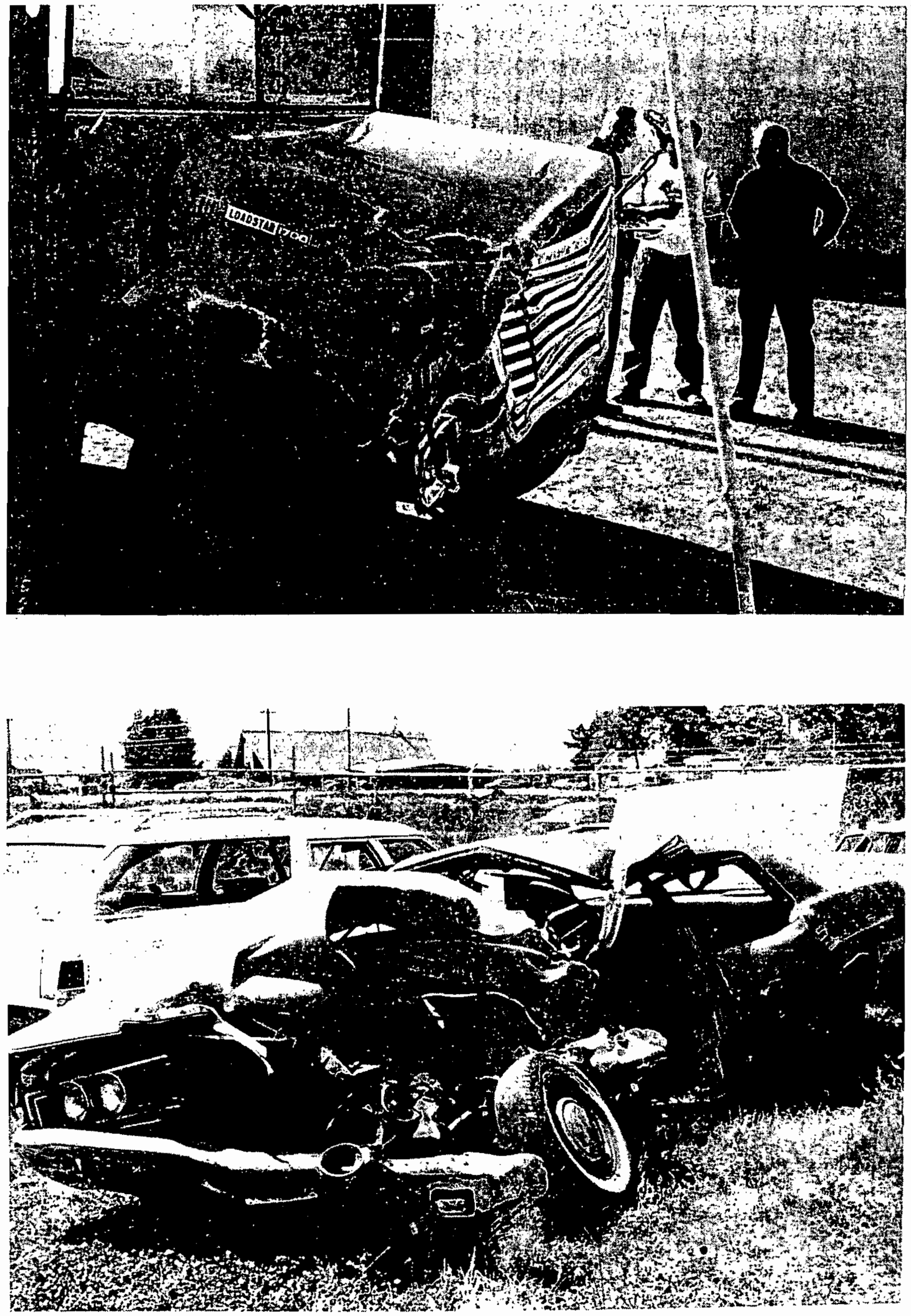


Figure 4.—The schoolbus generally sustained little damage in a schoolbus/passenger car collision, but damage was extensive to the car involved. As a result, car passengers were more likely to be injured than schoolbus passengers. The vehicles shown here were involved in a frontal crash outside Cornelius, Oregon. (See case 3.)

Types of Schoolbus

Schoolbuses involved in regularly scheduled public school transportation are represented in the study, as well as schoolbuses used for activity buses, for transportation to summer programs, or for other special uses. For the purposes of this study, the Safety Board defined "schoolbus" by vehicle configuration and not by function. Thus, any large bus built to Federal schoolbus safety standards which was involved in an accident and met the selection criteria was considered for inclusion in the study.

This study reflects a cross section of schoolbus sizes and bus body/chassis manufacturers in the U.S. fleet of large schoolbuses, such that the findings of the study do not reflect the crashworthiness of only one particular type of large poststandard schoolbus. (See tables 1, 2, and 3.)

Table 1.—Passenger capacity and body manufacturer of schoolbuses

Passenger Capacity	Manufacturer						
	Blue Bird	Wayne	Thomas Built	AMTRAN/ Ward	Carpenter	Superior	Total Number of School Buses
30-35	1	1		1		1	4
47-50	2		3		3	1	9
53-54	1	1	2	1	1	0	6
59		2				1	3
64-66	6	1	4	3		1	15
71-72		1		2	1		4
77		1					1
84-85	2						2
Total	12	7	9	7	5	4	44

Table 2.—Number of schoolbuses by year of bus body manufacture

Year	Number of Buses
1977 (after April)	3
1978	2
1979	9
1980	7
1981	2
1982	4
1983	8
1984	6
1985	3
1986	0

Table 3.—Number of schoolbuses by chassis manufacturer

Manufacturer	Number of Buses
International Harvester	21
Ford	12
All-American	1
Chevrolet	7
GMC	2
Bluebird	1

SCHOOLBUS PASSENGER INJURY OUTCOME

Overview

Passenger Injury Levels

Schoolbus passengers fared very well in the crashes investigated for the study, despite the fact that the accidents selected for investigation were slanted toward more serious schoolbus accidents. Ninety percent of the 1,119 unrestrained, schoolbus passengers in the study sustained no injuries or only minor (MAIS 1) injuries as their most severe injury; 5 percent received moderate (MAIS 2) injuries as their most severe; and only 4 percent sustained more than moderate injuries (MAIS 3-6). Outcome for 1 percent was unknown. (See chart 2 for a more detailed distribution of schoolbus passenger injuries by MAIS level.)

Rollover/Nonrollover Comparisons

As a subset of the entire accident sample, those accidents involving a rollover had relatively similar passenger injury outcomes. (See chart 3.) However, passengers in the rollover accidents were significantly 18/ more often injured than those in the nonrollover accidents: 20 percent of the unrestrained passengers in rollover accidents received no injury, compared to 63 percent in the nonrollover accidents. Instead of being uninjured, passengers in rollover accidents studied by the Safety Board more often sustained minor injuries.

Compared to the passengers in nonrollover accidents, a larger percentage of passengers in the rollover accidents sustained injuries of moderate to maximum severity (MAIS 2-6): 14 percent compared to 6 percent in nonrollover accidents. 19/ This difference, however, was mainly attributable to the more severe injuries sustained by passengers in one type of rollover: rollover preceded by collision. 20/ Even in these rollovers, the overwhelming majority of passengers received minor injuries at worst. In all types of rollover accidents in the study, 86 percent of the unrestrained passengers still sustained only minor or no injuries.

Few schoolbus passengers sustained injuries above the moderate (MAIS 2) level, even in severe rollovers. An accident in Brunswick, Georgia, (case 40) is an example. The stopped schoolbus was rear-ended by a tractor-semitrailer travelling 50 to 55 mph, which crushed the back of the bus and pushed the bus forward about 100 feet. The schoolbus then went into a ditch, rolled 100° onto its left side, and then pitched forward, flipping

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NOTE: The small number of lap-belted passengers (40 out of 1,166 crash-involved schoolbus passengers) in the study did not provide data for meaningful comparisons between injuries sustained by restrained versus unrestrained passengers. Compounding the problem, 23 of the 40 lap-belted passengers were in an accident in which restraint use made no difference (Greenburgh, New York, case 16).

18/ P is less than 0.01—probability is less than 1 in 100 that the differences observed could have been obtained by chance alone. This comparison is based on the difference of proportions test.

19/ P is less than 0.01—probability is less than 1 in 100 that the differences observed could have been by chance alone.

20/ Rollovers and the importance of impact as the most harmful event in collision rollovers, are discussed in the chapter entitled "Discussion by Type of Accident."

Chart 2.—Unrestrained Schoolbus Passengers
in the Safety Board's Study by Most Severe Injury (MAIS).

(A total of 1,119 unrestrained passengers)

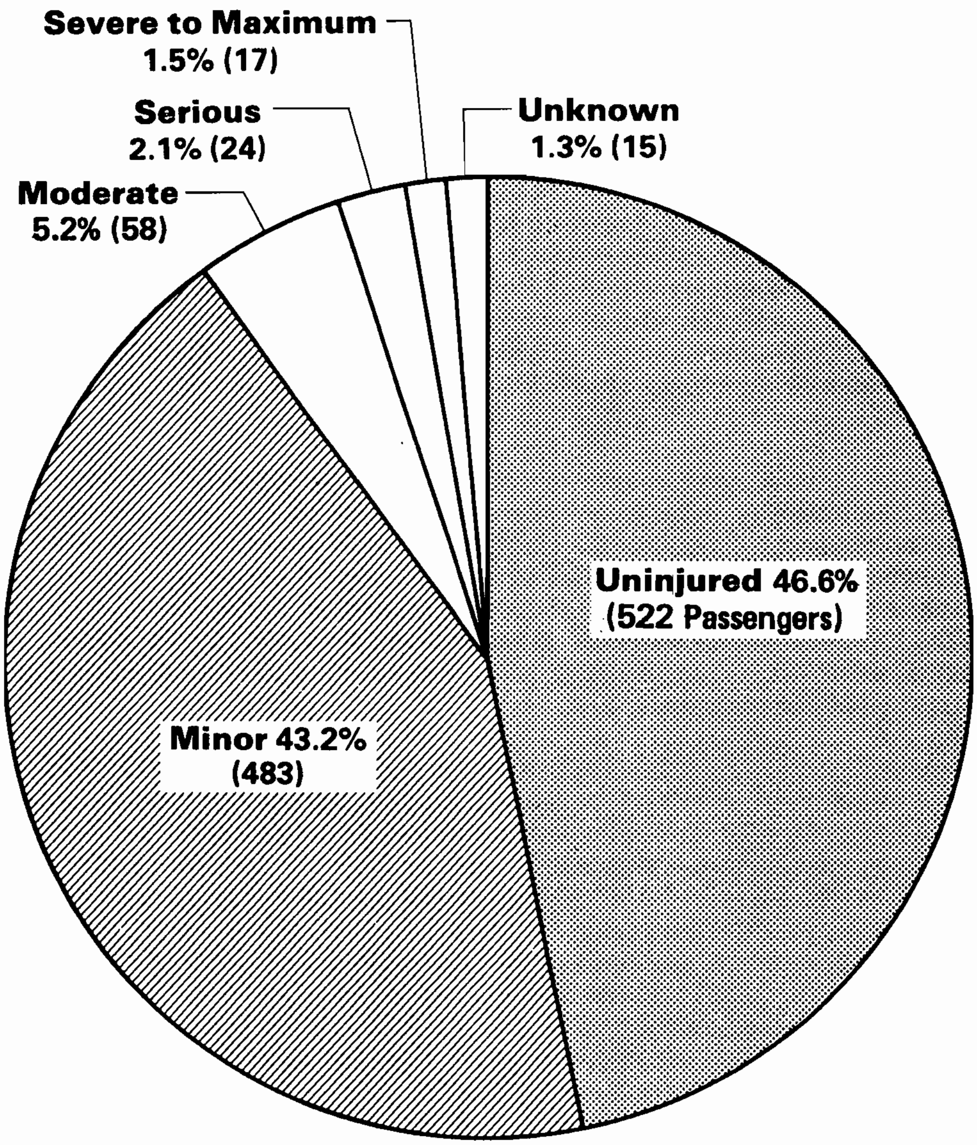
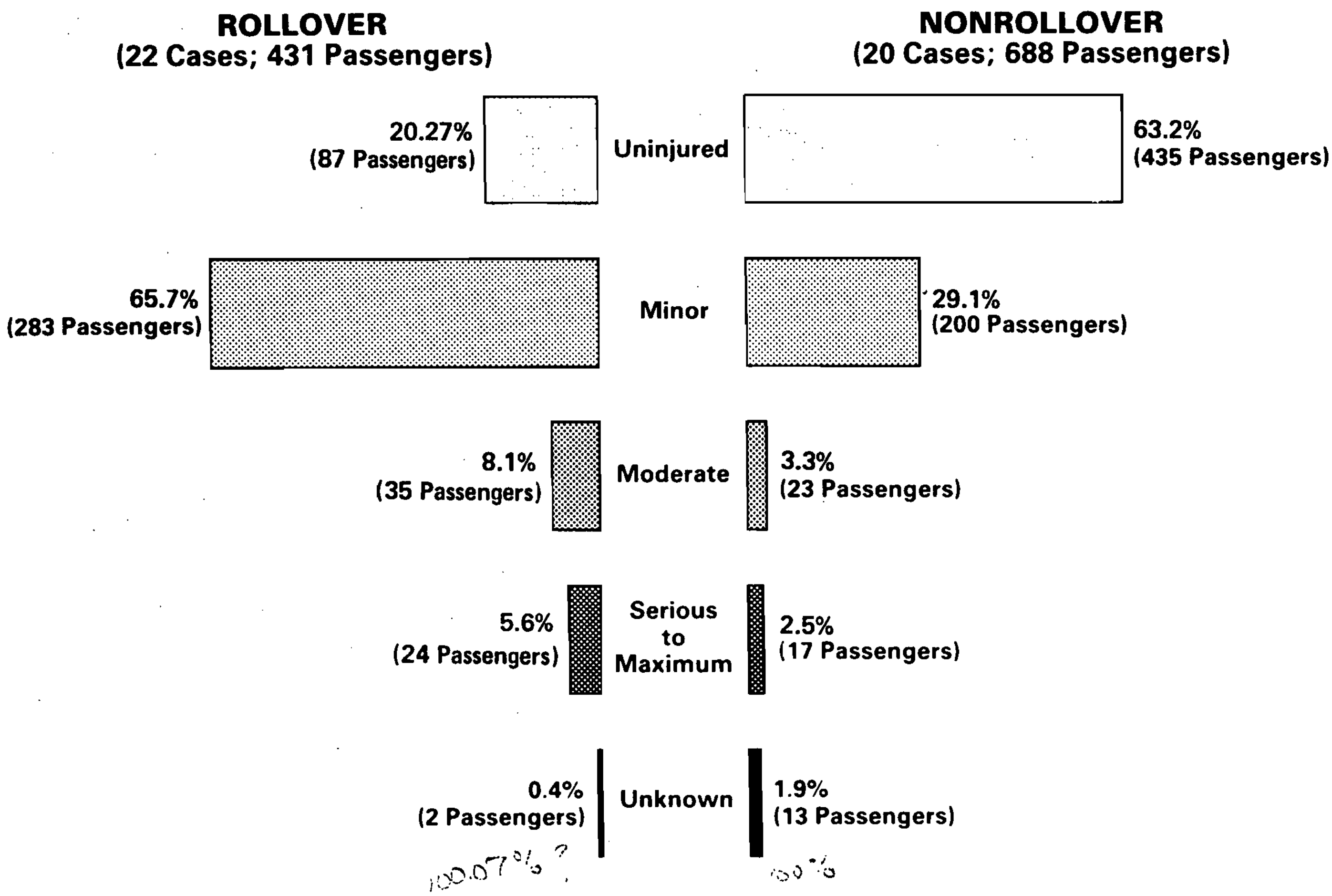


Chart 3.—Comparison of Unrestrained Schoolbus Passenger Injuries in Rollover versus Nonrollover Schoolbus Accidents in the Study.



end-over-end, finally coming to rest on its right side. (See figure 5.) Of the 10 passengers, aged 13 to 18 years, 6 sustained minor (MAIS 1) injuries, 1 sustained moderate (MAIS 2) injuries, and 3 sustained serious (MAIS 3) injuries. No one was killed or ejected, and all of the serious injuries were sustained by passengers in the rear who were in the area crushed by the initial impact.

Ejection

Very few schoolbus passengers were ejected in the cases investigated for this study. Of the 1,119 unrestrained schoolbus passengers, only approximately 15 were either partially or totally ejected. 21/ Students were ejected in both rollover and nonrollover accidents. Injury outcome varied widely, from minor to critical injuries.

21/ The exact number of passengers ejected in the Safety Board's schoolbus crash investigations is not known. In the Snow Hill, North Carolina, crash (case 14), investigators could not determine how many passengers were ejected and how many left the bus under their own power. Eight definitely were ejected in the Snow Hill crash. See cases 14, 29, 31, and 32 for accidents involving schoolbus passenger ejection. Case 20 involves a schoolbus driver ejection.

Figure 5.—Views of the Brunswick, Georgia, schoolbus (case 40) following the crash. This schoolbus underwent one of the most complex and violent crashes in the study. Considering the accident dynamics, the schoolbus body performed quite well. All of the moderate and serious injuries were attributed to the rear-end impact and subsequent crushing in that area.

Of the 15 schoolbus passengers known to be totally or partially ejected, 4 sustained minor injuries, 2 moderate injuries, 2 serious injuries, 5 severe injuries, and 2 critical injuries. Six of the ejected passengers died. The Safety Board does not know if they died as a result of injuries sustained outside the bus, during ejection, or as a result of injuries sustained within the bus before ejection. It is not correct to assume automatically that all injuries sustained by ejected passengers occurred as a result of ejection and thus, had they been restrained, injury outcome would have improved. 22/ For example, in one accident in the study, the schoolbus was penetrated at the seating positions of the ejected passengers, and bench seats were ripped from the floor and ejected, taking the occupants with them. This was the accident in Snow Hill, North Carolina (case 14).

All of the six ejected passengers who died in the Safety Board's study were in this accident (a nonrollover) which accounted for more than half of all the ejections in the study. This case involved an extremely severe head-on collision with a tractor-semitrailer, followed by sideswipe penetration of the schoolbus body and failure of floor panels which created a huge gap in the schoolbus body. (See figure 6.)

Figure 6.—When the tractor-trailer sideswiped the side of this bus in Snow Hill, North Carolina, it tore open the bus and ejected several seats, along with their occupants (case 14). (Photo courtesy of the Goldsboro News Argus.)

22/ Contrary to common belief, ejected occupants more often receive their injuries in the vehicle before being ejected. Analysis of passenger car crash data in the National Crash Severity Study (NCSS) and Washtenaw County, Michigan, crashes indicates that more than half of the serious injuries occurred in the car before the ejection. Donald Huelke, Charles Compton, and Richard Studer, "Ejection, and Occupant Contacts, in Passenger Car Rollover Crashes," (SAE 850336) Proceedings, Society of Automotive Engineers Conference, 1985.

Fatal Crashes

The Safety Board investigated eight fatal schoolbus accidents (two involving bus driver fatalities only) as part of this study. (See table 4.) The majority of the fatalities occurred in accidents which did not involve rollover. Nine of the 13 schoolbus passenger fatalities were in nonrollover accidents involving frontal collision. A total of four passenger fatalities resulted from three rollover accidents but in each case, it was the impact which preceded the rollover, not the rollover itself, which was most harmful.

Table 4.—Schoolbus occupant fatalities in large poststandard schoolbuses in the study

Location	Type of Accident (for schoolbus)	Accident Severity (for schoolbus)	Fatally Injured Schoolbus Occupant		Comments
			Driver	Passenger	
Carmel (Mahopac), NY Case 1	Run-off-the-road, followed by head-on collision with tree	Minor	-	1	Passenger unrestrained, out of position; abnormal physique.
Palmyra, NE Case 11	Left front angle collision with tractor-semitrailer	Moderate	1	-	Intrusion, driver restrained.
St. Louis, MO Case 13	Frontal collision with concrete sign support pedestal; bus body separated, and rear rotated upward and forward around sign post	Extremely Severe	-	2	Roof collapse and intrusion, both passengers unrestrained.
Snow Hill, NC Case 14	Head-on collision and sideswipe by tractor-semitrailer	Extremely Severe	-	6	Intrusion; ejection of seats. Four of six fatalities seated on bench seats torn out of bus by truck penetration; all six ejected, passengers unrestrained.
McGrath, MN Case 39	Right side impact with tractor-trailer, followed by rotation, then rollover (90°)	Severe	-	1	Force of impact and rotation; passenger unrestrained.
Rehoboth, MA Case 41	Left front impact with tractor-semi-trailer, followed by rollover (180°)	Extremely Severe	1	1	Intrusion, driver restrained; passenger unrestrained.
Carrsville, VA Case 42	Right side impact by freight train, followed by rollover (270°)	Extremely Severe	1	-	Restrained driver seated at major impact area; refused blood transfusion.
Tuba City, AZ Case 43	Rear-end collision by tractor-semitrailer, followed by rollover (90°)	Extremely Severe	-	2	Intrusion -- no survivable space; standing in rear of stopped bus. Both passengers unrestrained.
TOTAL SCHOOL BUS OCCUPANT DEATHS: 16			3	13	

With the possible exception of three students (cases 1, 13, and 39), the 13 students who were killed were in accidents that, given their seating positions and the crash sequence, were unsurvivable for them. A short description follows each of the six accidents in which schoolbus passengers died. (For a complete discussion, see the case summaries in appendix A.)

Carmel, New York (case 1): A schoolbus went out of control, ran off the road to the left, then veered back onto the road and off to the right. As it ran off to the right, it bounced over a dirt embankment, struck a small tree, and came to rest. One passenger, in the right rear of the bus, initially had not been seated and was leaning over the seat back in front of him when the accident occurred. When the rear wheels of the schoolbus bounced over the embankment, the seat back was pushed up into his torso, injuring his abnormal liver. He died shortly thereafter.

St. Louis, Missouri (case 13): A schoolbus travelling between 59 and 67 mph left the roadway and struck a concrete sign support pedestal and sign pillar at a front angle. The severe impact separated the bus body from its chassis and crushed the front roof back and down into the passenger compartment. The roof was collapsed down to within 24 inches above the floor in some places. Two passengers were killed. One, before the crash, had been seated directly beneath the area of maximum roof collapse; the other was flung forward and killed when her head struck the crushed-in roof.

Snow Hill, North Carolina (case 14): A schoolbus was struck head-on, then sideswiped by a loaded tractor-semitrailer. As the truck struck the left side of the bus, it penetrated and peeled back the side wall, ripping out the first three rows of seats on the left and almost ejecting the fourth row. When the truck reached the schoolbus' rear axle, penetration stopped and the truck rotated, tearing the bus floor open and creating a large gap. Six passengers were killed. All had been seated in the area next to the sidewall ripped off by the truck. Four were on seats torn out of the bus by the same penetration. Two others were also ejected.

McGrath, Minnesota (case 39): A schoolbus was struck in the right side, just rear of center, by an oncoming tractor-trailer. The schoolbus rotated clockwise as it rode up over the front of the truck and was carried for several feet before it rotated off the truck's front and overturned onto its left side in a ditch. One passenger was killed. She was seated in the rear of the bus on the right and was flung to the right into the sidewall during impact and rotation.

Rehoboth, Massachusetts (case 41): A tractor-semitrailer struck the left front of the schoolbus, crushing in the front of the bus. The impact partially separated the bus body from its frame and pushed the schoolbus off the road. The schoolbus then rolled over and came to rest on its roof. One passenger (and the schoolbus driver) died. The fatally injured passenger was seated in the front of the bus near the area of maximum intrusion.

Tuba City, Arizona (case 43): A schoolbus stopped to discharge passengers and was rear-ended by a tractor-semitrailer travelling about 54 mph. The rear of the bus was lifted up at impact and crushed in 9 feet at the left rear. The bus was then pushed forward, rotating as it went off the road. It overturned onto its left side and slid before coming to rest. Two passengers standing in the back row were killed.

Three schoolbus drivers were killed in three cases investigated by the Safety Board, and their deaths all involved intrusion. (See cases 11, 41, and 43.)

Passenger Injuries by Probable Contact Point and Affected Body Region

"A major deficit in the current literature on bus collisions is the virtual absence of data on the cause, nature, and severity of injuries sustained by bus occupants during collision. Almost all data collection agencies are concerned primarily with fatalities, not injuries . . . ." 23/

This was a conclusion reached by University of California, Los Angeles (UCLA) trauma researchers in 1971 when they attempted to determine what kinds of injuries passengers were sustaining in prestandard schoolbus and other bus crashes. The situation is virtually unchanged today. With the exception of this Safety Board study, detailed data on schoolbus passenger injuries in poststandard schoolbuses are hard to find.

Knowledge of the interaction of crash configuration and level and frequency of passenger injuries along with probable contact points, is essential if effective injury-reducing countermeasures are to be proposed or, for that matter, to know if they are needed. If, for example, many students are sustaining serious lower leg injuries from contact with seat legs, certain changes in schoolbus seat design are needed. If lower leg injuries are not a problem, such changes are probably unnecessary.

Existing schoolbus accident databases cannot answer these questions. Few injury data are routinely collected by State or local agencies. When collected, data do not provide injury location or severity, nor does it distinguish between injuries sustained by

23/ Siegel, A. W., Nahum, A. M., and Runge,D. E. , "Bus Collision Causation and Injury Patterns" (SAE 710860), Proceedings, Society of Automotive Engineers Conference, 1971.

passengers on prestandard schoolbuses versus those on poststandard schoolbuses. 24/ For that matter, data also do not distinguish between large and small schoolbuses and school vans with lap belts for passengers. Given the inadequacies of existing databases, the Safety Board collected as much injury information as possible on each passenger involved in the large poststandard schoolbus accidents investigated for the study.

The following analysis is by individual injuries, not by passengers. An example may help explain why the Safety Board chose this approach.

> On January 14, 1986, a tractor-semitrailer struck the rear end of a schoolbus which had stopped to pick up children near Brunswick, Georgia (case 40). A 15-year-old boy seated in the rear of the bus was one of the seriously injured passengers. He sustained three injuries, all of different severity levels and from different sources. His most serious injury was an AIS 3 contusion of the kidneys, probably caused by contact with a seat back. He also received an AIS 2 laceration on the forehead above his right eye from flying shards of window glass. The boy's third injury was an AIS 1 spinal strain (wedging of the T2, 3, and 4 vertebrae) probably caused by contact with crushed-in bus roof.

As this example shows, a single passenger can receive a variety of injuries from a variety of sources. For this reason, the injury analysis to follow is by individual injuries classified by the AIS classification system as moderate or greater (MAIS 2 and above) and not by individual passengers. Analysis by passenger would obscure useful data. Minor (MAIS 1) injuries (abrasions, minor lacerations, contusions, etc.) are excluded from this analysis because they are the most likely to lack medical documentation and to lack a known contact point. Minor injuries also are the least likely to be lessened by the addition of lap belts. (Seat belts in passenger cars, for example, are estimated to be only 10 percent effective against minor injuries. 25/)

Summary of Findings

Based on the 189 injuries MAIS 2 and above sustained by unrestrained schoolbus passengers in the study, the Safety Board found that:

- intrusion played a major part in injury causation—from 45 to 66 percent of injuries AIS 2 and above;

- the head, skull, or face was the body region most frequently injured, and the frequency increased with injury severity. Forty-three percent of AIS 3 and above injuries were to this region of the body;

24/ Poststandard schoolbuses are estimated to comprise about 60 percent of all public schoolbuses nationwide. (The percentage varies according to the State and wealth of the school district.) This does not automatically mean that 60 percent of all passengers reported as being injured in schoolbus accidents were on large poststandard buses. It may be that prestandard schoolbuses or small schoolbuses with lap belts are involved in a disproportionately large share of injury-producing schoolbus crashes. Data are not available to answer this question.

25/ U.S. Department of Transportation, "Final Regulatory Impact Analysis of the Amendment to FMVSS 208: Passenger Car Front Seat Occupant Protection."

- the upper leg was the next most common region of the body to be injured; nearly one-third of all AIS 3 injuries were fractured femurs;
- chest, abdomen, back, and lower leg injuries were extremely rare;
- contact points were unknown for many injuries;
- of the interior objects determined by the investigator as probable contact points, the sidewall of the bus was most often specified;
- contact with the seat back was identified as causing very few moderate and above injuries; and
- contact with other schoolbus passengers (i.e., being thrown on top during rollover) was identified as causing only minor injuries (with one exception at the moderate level).

Probable Contact Points

Investigators gathered information as to the probable contact points (see table 5) within the bus by examining physical evidence (i.e., presence of blood, human tissue, hair), by interviewing passengers, and by reconstructing, as well they could, occupants' probable movements during the crash in light of the crash dynamics. The source of more than half the injuries was unknown. This is probably the result, in part, of the complex vehicle dynamics involved in many accidents. Consider, for example, case 38, an accident outside Cherokee, Iowa, involving a schoolbus collision with a passenger car. This accident involved a head-on collision, a 135° clockwise rotation, and a 450° rollover.

Investigators were more successful in reconstructing what passengers struck to cause injuries of MAIS 3 and greater severity: for more than 60 percent of these injuries the probable contact point was determined.

In both injury categories, sidewalls, followed by windows and window frames, were the most frequently named contact points, when a part of the bus was specified, as inflicting injury. (See table 5.) (Figures 7 and 8 illustrate less frequent sources of injury.)

The Safety Board also investigated three cases in which the schoolbuses had unsecured luggage or band instruments, either stored in the back of the bus or on the seats with the students. Fortunately, in the study's cases, the accidents were such that schoolbus passengers received only minor injuries from these unsecured items. In other accidents, passengers may not be so fortunate. The Safety Board believes that school districts should be aware of the injury potential of unsecured objects which can become flying missiles in some accidents. Steps should be taken to secure all loose items, by cargo nets or other means, before putting the bus in motion. Activity trips, since they often involve passenger luggage, deserve special emphasis.

Intrusion played a large role in causing the more serious injuries included in this study. The proportion of intrusion-involved injuries was 45 percent for the moderate and above injuries (AIS 2 and above), and 66 percent for serious and above injuries (AIS 3 and above).

Table 5.—Probable contact point for schoolbus passenger injuries in study

	Moderate and above injuries (AIS 2-6)		Serious and above injuries (AIS 3-6, excludes moderate injuries)		
Probable Contact	No. of Injuries	Percent	Probable Contact	No. of Injuries	Percent
Sidewall (includes intrusion)	14	7	Sidewall (includes intrusion)	9	21
Side window or window frame	13	7	Side window or window frame	5	12
Roof (crush only)	8	4	Roof (crush only)	6	14
Stanchion or modesty panel	6	3	Stanchion or modesty panel	3	7
Overhead luggage racks	6	3	Overhead luggage racks	0	0
Seat legs	6	3	Seat legs	1	2
Seat backs	2	1	Seat backs	1	2
Other*	16	9	Other**	1	2
Unknown	118	62	Unknown	16	38
Total	189		Total	42	

NOTE: No injury serious and above was known to be caused by contact with the bus floor. Only one moderate injury was known to be caused by contact with another bus occupant.

* The "other" categories in AIS 2-6 includes diverse items such as windshield -3 injuries (2 percent); bus floor - 3 injuries (2 percent), heater under the seat -2 injuries (1 percent); and emergency door - 2 injuries (1 percent).

** The "other" category in AIS 3-6 consists of emergency door only - 1 injury (2 percent).

"Intrusion" here includes both injuries resulting from contact with side walls, roofs, etc., damaged by intrusion and injuries resulting from transmission of forces released during the intrusion event. All of the moderate and above injuries traceable to roof contact, for example, were injuries caused by contact with a crushed roof. When unrestrained passengers were known to have contacted an intact roof (during rollover) only minor injuries were caused. Some of the injuries caused by contacting the sidewall involved contact with a crushed sidewall. (See figure 9.) The addition of padding on the sidewall could conceivably reduce the number of injuries caused by contact with the sidewall, but the Safety Board is not aware of any ongoing or past research in that area.

Passengers who sustained AIS 2 and above injuries from a known contact with an intruded sidewall were seated in the immediate area. They were not thrown into the area of intrusion from another part of the bus.

Figure 7.—Contact with metal luggage racks caused moderate injuries to five students in the Hobbs, New Mexico, noncollision rollover (case 26). The racks also caused minor injuries including deep line-type bruises on two students' backs, mirroring the rack rails.

Figure 8.—Unsecured tire chains pose a hazard to schoolbus passengers during a crash. Loose chains may have pinned a passenger's leg under the seat frame and contributed to his serious injury, multiple leg fractures, in the Durango, Colorado, accident (case 35).

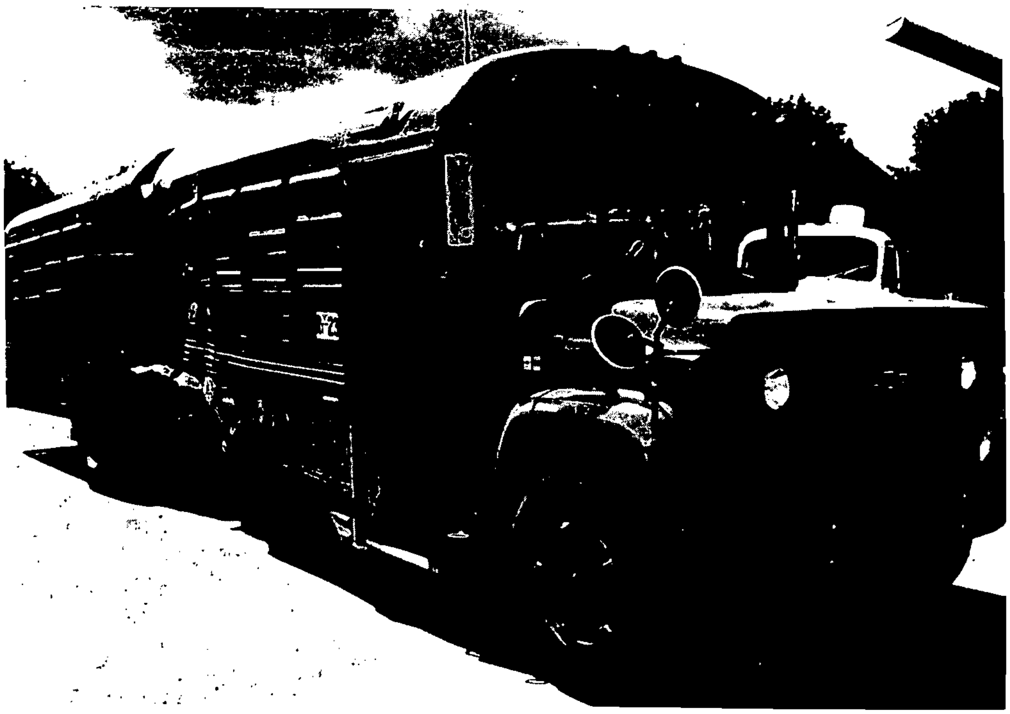


Figure 9.—The damage was caused by intrusion. As the schoolbus in the Woodside, Delaware, accident (case 21) attempted to make a left turn, it was struck by an oncoming tractor-trailer.

The Safety Board also summarized what part of the passenger's body was injured; once again, a different profile emerged when AIS 3 and above injuries were examined. Head injuries, for example, were 30 percent of the AIS 2 and above injuries, but were 43 percent of the AIS 3 and above injuries. Upper leg injuries were only 11 percent of the AIS 2 and above, but 31 percent of the AIS 3 and above injuries. Chest injuries, the third most frequent injury, were only 5 percent of the AIS 2 and above injuries, and 10 percent of the AIS 3 and above injuries. (See charts 4 and 5.)

Whether passengers on prestandard schoolbuses involved in similar accidents would show the same injury distribution is unknown. The Safety Board was unable to compare its injury findings in the poststandard schoolbus cases with injury patterns in prestandard schoolbuses. 26/ Little is known about the severity and cause of injuries on prestandard buses, and the studies which do exist are not comparable to the Safety Board's study.

26/ Prestandard schoolbuses are estimated in 1986 to constitute 30 to 40 percent of the nation's public schoolbus fleet.

Chart 4.—Schoolbus Passenger Moderate and Above Injuries by Percentage to Body Part
(frequency is in parenthesis)
The total MAIS 2 and above injuries in the Safety Board's study was 189.

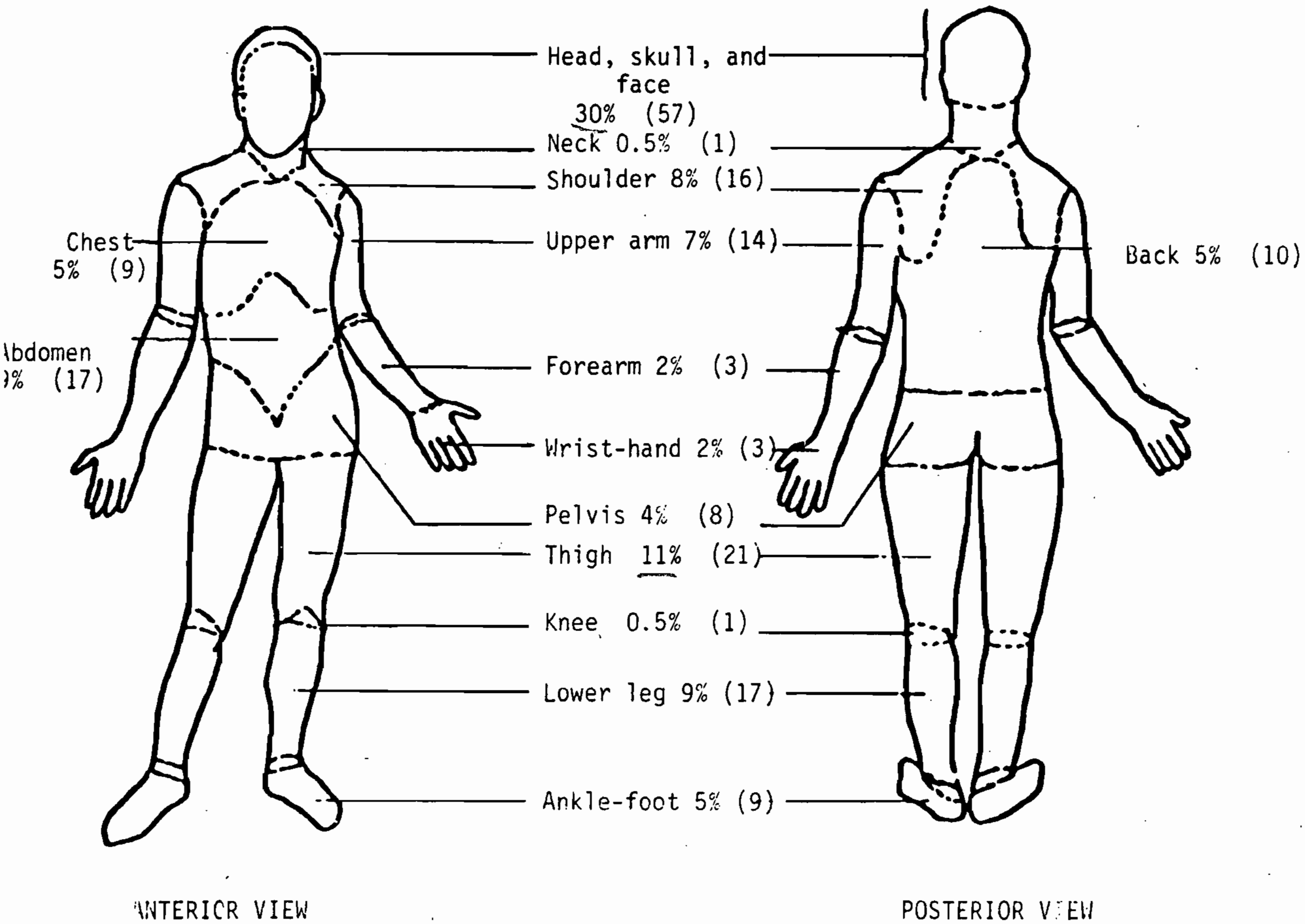
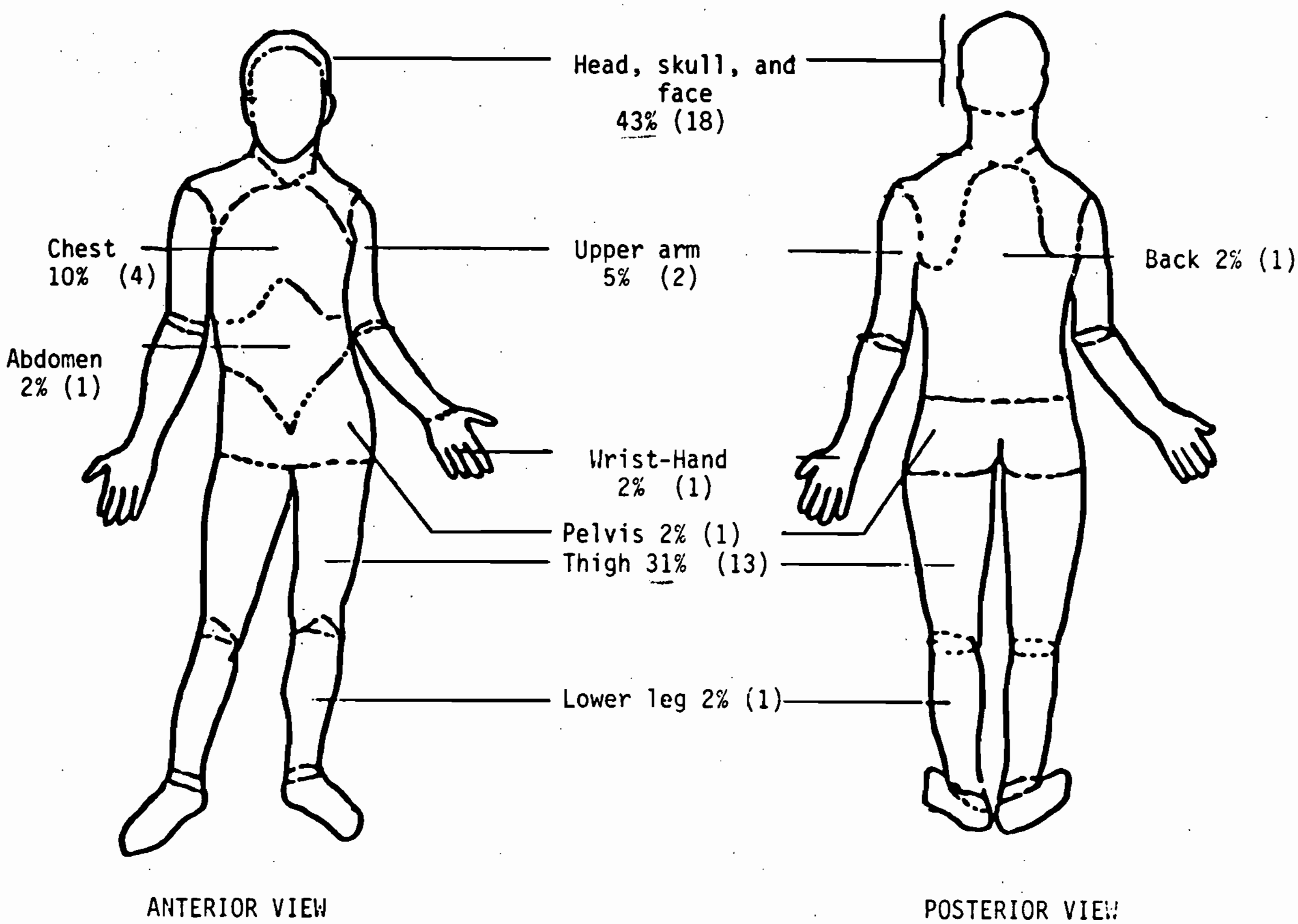


Chart 5.—Schoolbus Passenger Serious and Above Injuries by Percentage to Body Part; Excludes Moderate Injuries (frequency is in parenthesis)

The total MAIS 3 and above injuries in Safety Board's study was 42.



The Safety Board is aware of only three studies which attempted to document the source and type of injuries sustained by passengers in real-life crashes involving prestandard schoolbuses, and even these studies cannot be compared to one another.

1. A study conducted by the State of Maryland in 1969 which retroactively analyzed police records of 228 schoolbus collisions in 16 States. 27/ The study concluded that police reports did not contain sufficient data to reveal causes of injury. Injury data for less than half of the crash-involved schoolbus occupants were available, and injury severity and source could not be determined even for the known injuries.

2. A 1971 study conducted by a UCLA Trauma Research Group which immediately investigated and then analyzed the injury outcome in 12 bus collisions, using a multidisciplinary team of engineers and medical personnel. 28/ The buses included prestandard schoolbuses, charter buses, and cross country buses--i.e., vehicles with quite dissimilar designs. Injuries were coded using the AIS system, but injury data for all three types of buses were combined. Specific injuries for each passenger were not included in the cross summaries.

3. A 1980 study conducted by a clinical analysis team of medical and engineering personnel, hired by a NHTSA contractor, analyzed accident records and made judgments about the difference the new seating standards would have made on the level of passenger injuries seen in prestandard schoolbuses. 29/ Eighty-two accidents nationwide that had been investigated in depth since 1969 were analyzed, along with some data on fatal schoolbus accidents and some State of Connecticut schoolbus data.

All of these studies did find that head injuries (primarily facial injuries) predominated to varying degrees, and the exposed metal frame of the prestandard schoolbus seat was the overwhelming cause for many of these injuries.

Injury Level and Seating Position

Schoolbuses in the Safety Board's study were rarely filled to capacity. Overall, the average occupancy was 44 percent; in the 16 buses in which a fatality or serious or above injury occurred, the average occupancy was 31 percent. Empty seats were scattered throughout the buses.

In the Tuba City, Arizona, fatal accident (case 43), for example, the 84-passenger bus was carrying only 32 passengers. Almost two-thirds of the seats were vacant. When the bus was rear-ended by the tractor-semitrailer, the left rear was crushed in nearly 10 feet.

27/ Baltimore, Maryland State Department of Education, "A Study of the Availability and Nature of Information on Schoolbus Accidents Recorded at the Local Level," May 1969.

28/ Siegel, A.W., Nahum, A.M., Trauma Research Group, University of California, San Diego, and Runge, D.E., Automobile Club of Southern California, "Bus Collision Causation and Injury Patterns," Proceedings of 15th Stapp Car Crash Conference, Society of Automotive Engineers, Inc., pp. 301-385, 1972.

29/ "Statistical Evaluation of the Effectiveness of Federal Motor Vehicle Standard 222: Schoolbus Seating and Crash Protection," Op. cit.

The students who were killed were in the last row of seats; no survivable space existed at their positions. Three of the four schoolbus passengers who sustained serious injuries in this accident also were occupying the rear of the bus. The rear clearly was the most dangerous place to be sitting in this particular accident. (See figure 10.)

The front of the bus also has been hypothesized as being a more dangerous seating position, but the Safety Board did investigate one accident in which being seated in front was favorable. This was the grade crossing accident in Stephenson, West Virginia (case 18). In this crash, the train tore a gaping hole in the side of the bus at rows 12 and 13. No passenger was injured by the intrusion because the driver had insisted that all sit in the front of the bus--no students were seated in the area penetrated by the train.

Figure 10.—Two students died in this rear-end crash which was followed by a rollover outside Tuba City, Arizona (case 43). The schoolbus was stopped to unload passengers when a tractor-semitrailer travelling about 59 mph crashed into its rear. The fatally injured students reportedly had been standing in the rear of bus in the crushed area.

Researchers have long been interested in the relationship between seating position and injury level. Some have suggested that it might be safer overall for schoolbus passengers to be seated in the middle of the bus rather than either the front or rear, basing this thesis on the premise that frontal or rear impacts are the most common types of schoolbus accidents.

The Safety Board examined the data from the accidents in this study to see if they shed light on this question. The Safety Board's data are consistent with the hypothesis — 79 percent of the 42 schoolbus passengers who were either killed or who survived with serious or worse injuries (MAIS 3 and above) were seated in either the first three or last three rows of the bus. However, there are two problems with this finding. First, 4 of the 44 buses in the study had only six rows of seats (i.e., all seats were either in the first three or last three rows). Nine additional buses had only one or two "middle" rows. These 13 buses produced 8 of the total 13 schoolbus passenger fatalities and 10 of the total 29 passenger injuries of MAIS 3 or worse severity.

These, of course, must be omitted from the analysis, since on these buses there effectively were only "front" and "rear" seating available, ensuring that any injuries that occurred would occur in the "front" or the "rear" of the bus. When these data were eliminated, the Safety Board found that all of the 5 remaining passenger fatalities occurred in the last three rows of seats and 14 of the remaining 29 passengers who survived with MAIS 3 and above injuries were seated in the three front or three rear rows (5 front, 9 rear).

However, a second weakness in the Safety Board's data affects the possible significance of these correlations between injury and seating location. Although the seating location by row was known for every passenger killed or surviving an MAIS 3 and above injury, this was not the case for many of the uninjured passengers. Therefore, it may be that some of the uninjured passengers were also seated in the first three or last rows. Thus, while 56 percent of the seriously injured or killed passengers were in either the first three or last three rows, it may also be true that the same proportion of the uninjured passengers were also seated in these hypothetically less safe rows.

Finally, the high proportion of more seriously injured students seated in the front and rear of the bus in the Safety Board's study is no doubt influenced by the fact that frontal or rear collision was the most common direction of impact in the study. However, no national data are available to determine whether this is also true of the national population of schoolbus accidents.

There are some indications from other studies, however, that front or rear impacts are quite common. In 1967, UCLA researchers stated that "owing to the many stops made each day by schoolbuses, the rear-end collision is the most frequently occurring type of schoolbus accident." 30/ The Safety Board does not know on what data this statement was based.

If newspaper accounts of schoolbus accidents are to be believed, frontal or rear impact appears to be a common type of schoolbus collision. A 5-year summary of schoolbus collision data compiled by the NHTSA from newspaper reports of schoolbus accidents during July 1968 through June 1973 found that front or rear impact was mentioned in 34.2 percent of the reports, side impact in 14.2 percent, and rollover (with

30/ Severy, Derwyn M.; Brink, Harrison M.; and Baird, Jack, "School Bus Passenger Protection," Institute of Transportation and Traffic Engineering, University of California, Los Angeles, 1968.

and without impact) in 8.4 percent. (For 41.3 percent, the type of accident was not specified or involved a pedestrian or noncollision). The large number of unspecified types of accidents flaws this analysis. In addition, newspaper accounts are not the most accurate source of accident data, and they include only the accidents serious enough to receive media attention.

More recently, the North Carolina study referred to earlier found that the accident buses had "often" been struck in the rear at passenger stops by other vehicles. 31/ The crashes in the 2-year study ranged from minor to relatively severe accidents; they included nearly three-quarters of all the bus accidents in the three-county area during the period. Nonetheless, the authors cautioned against extending their findings to the State as a whole. Caution obviously also should be exercised in extending these findings to the nation as a whole.

Data from a much larger base — police reports of Canadian schoolbus accidents in 1981--suggest that "approximately 55 percent of accidents involving schoolbuses are head-on type collisions." 32/

If analysis is restricted to fatal schoolbus accidents, frontal or rear impacts appear to be common. A 1980 NHTSA study found that 22 of the 45 schoolbus occupants (passengers and drivers) who died in accidents that occurred between 1975 and 1978 were in front- or rear-end crashes. A more recent NHTSA study looked at fatal schoolbus accident data from 1981-1983, restricting the analysis to large schoolbuses (both pre- and poststandard), and found that 34 schoolbus occupants (drivers and passengers) had been killed during that period. When these occupant fatalities were analyzed by principal direction of impact and rollover, the NHTSA found that frontal impact was involved in 56 percent of the fatal crashes, including rollover and nonrollover. Fatal accidents, however, are the rarest and least typical of all injury-producing accidents.

Analysis of nonfatal accidents is often complicated by the fact that if the schoolbus crash involved an impact followed by rollover, the accident is commonly categorized simply as a "rollover," losing information as to the direction of the initial impact.

More information on the principal direction of impact will be available if States adopt the revised report form developed by the 1985 National Conference on School Transportation described in the introduction to this study. Today, it simply is unknown what percentage of all schoolbus accidents (or even what percentage of all injury-producing schoolbus accidents) involve frontal or rear collision.

In 1978, the Safety Board issued a safety recommendation that schoolbuses be loaded from the middle seats out. Based on the deaths and injuries of a tractor-semitrailer/schoolbus collision and overturn outside Rustburg, Virginia, on March 8, 1977, 33/ the Safety Board asked the NHTSA to expand Highway Safety Program Standard No. 17, "Pupil Transportation Safety," to "provide that no passengers occupy seats in either the foremost or rearmost rows of passengers seats until all other seats

31/ Lacey, John H.; Daniel, Robert B.; Orr, Beverly T., "Investigations of 61 School Bus Crashes in Three North Carolina Counties," University of North Carolina, Highway Safety Research Center, Chapel Hill, North Carolina, January 1980.
32/ School Bus Collision Tests, TP622E, Transport Canada, February 1985.
33/ For more detailed information, read Highway Accident Report—"Tractor-Semitrailer/Schoolbus Collision and Overturn, Rustburg, Virginia, March 8, 1977," (NTSB/HAR-78-01).

have been occupied." Safety Recommendation H-78-9 was "Closed—Acceptable Alternate Action" when the NHTSA sent a letter on December 30, 1980, to all State Directors of Pupil Transportation, urging them to incorporate the Safety Board recommendation as part of the bus driver instructional program and manual. The NHTSA stated in the letter that it supported the concept of limiting bus occupant exposure to rear- and front-end impacts by adopting a seating policy to fill rearmost and foremost seats last and empty them first. In its letter, the NHTSA noted that one State "has determined that front- and rear-end crashes total 65 percent of all crashes involving schoolbuses."

The Safety Board did not find any evidence, in the cases investigated for this study, that a policy of loading from the middle out or of first emptying the foremost and rearmost seats was in effect. Therefore, considering that the majority of the student passengers killed or sustaining at least MAIS 3 injuries were occupying the first three or last three rows, and that in almost all cases, their injuries would not have occurred had they been seated elsewhere, the Safety Board believes further consideration should be given to the concept of using the middle row seats in preference to foremost and rearmost seating rows to the extent possible.

DISCUSSION BY TYPE OF ACCIDENT: ROLLOVER/NONROLLOVER AND PRINCIPAL DIRECTION OF IMPACT

In the Safety Board's study, schoolbus passenger injury levels were greater in the rollovers than in the nonrollover accidents. This finding, however, had less to do with the occurrence of the rollover itself, than it did with the seriousness of the collision which preceded many rollovers. In other words, impact, not rollover, was the most harmful event. Analysis which simply lumps schoolbus accidents into one of two categories, rollover or nonrollover, obscures this finding and may lead to suggestions for occupant protection based on the need to protect passengers during overturn.

The section to follow presents schoolbus passenger injury data from the study's cases organized by type of accident. Nonrollover accidents are discussed in terms of principal direction of impact: frontal or rear impact, side impact, and multiple collision. Rollover accidents are discussed in terms of rollovers precipitated by collision and those without prior collison. Data summarizing the injury outcome in each type of accident are presented along with the Safety Board's interpretation of these data. (See table 6.)

The Safety Board investigated 43 crashes involving 44 schoolbuses and 1,166 schoolbus passengers for this study. When these data were broken down by accident type, they sometimes provided an insufficient basis for conclusions as was the case in nonrollover crashes involving side or rear impact. Study data were too limited, both in terms of numbers of accidents and numbers of schoolbus passengers involved, to be used as the basis for any conclusions about the level of occupant protection provided in side or rear impact accidents. On the other hand, the Safety Board certainly did not find evidence in the limited number of cases it investigated that schoolbus passengers involved in side impact accidents fared much worse than passengers in frontal collisions.

Nonrollover Accidents

Frontal or Rear Collision

		By MAIS							
No. of Schoolbuses in Safety Board Study	Schoolbus Passengers	Uninjured	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	MAIS 6	Unknown
16	Unrestrained: 515	333 (64.7%)	142 (27.6%)	11 (2.1%)	4 (0.8%)	8 (1.6%)	4 (0.8%)	0	13 (2.5%)
	Restrained: 0								

Nine schoolbus passengers died from injuries sustained in this type of accident.

Overall, schoolbus passengers fared very well in the frontal nonrollover collisions investigated for this study, despite the fact that this group contained some of the most violent crashes, crashes which compromised the passenger compartment. More than half (65 percent) of all the passengers involved in the frontal collisions were uninjured; more than 92 percent received no injuries or sustained only minor injuries.

The Safety Board was notified of only one nonrollover accident involving rear-end collision which met the selection criteria. Based on the limited data from this one investigation, no assessment can be made of the adequacy of occupant protection in rear impact. 34/

34/ Other cases involving rear impact also involved rollover (cases 31, 37, 40, and 43) and/or additional impacts (cases 19 and 20) which complicated analyses.

Table 6.—Summary of unrestrained schoolbus passenger injuries and fatalities by type of accident (rollover/nonrollover and principal direction of impact)

(1,119 unrestrained passengers of 43 large poststandard schoolbuses)

	Number of School-buses w/o all Passengers Restrained	Total No. of Unre-strained Schoolbus Passengers	Uninjured	Minor AIS 1	Moderate AIS 2	Serious AIS 3	Severe AIS 4	Critical AIS 5	Max. AIS 6	Unknown	No. of Accidents Involving Schoolbus Passenger Fatality	No. of Fatally Injured Schoolbus Passengers
NONROLLOVER CASES												
By principal direction of impact:												
Head-on or front-angle	15	453	293	120	11	4	8	4	--	13	3	9
Rear	1	62	40	22	--	--	--	--	--	--	--	--
Side or sideswipe	2	109	96	12	1	--	--	--	--	--	--	--
Multi-collision	3	64	6	46	11	1	--	--	--	--	--	--
Total for nonrollover (All are collision accidents)	21	688	435	200	23	5	8	4	--	13	3	9
ROLLOVER CASES												
By collision/ noncollision:												
Preceded by collision	14	235	42	150	19	17	2	1	2	2	3	4
Breakdown by principal direction of impact												
Head-on or front angle: 5												
Rear: 3												
Side: 5												
Mult.: 1												
Noncollision	8	196	45	133	16	2	--	--	--	--	--	--
Total for rollover	22	431	87	283	35	19	2	1	2	2	3	4
TOTAL FOR ALL CASES	43	1,119	522	483	58	24	10	5	2	15	6	13

Note: All passengers in one bus in the study (case 16) were restrained. This bus is not included in the table above, hence the number of buses totals 43, not 44. This table shows the injury outcome for unrestrained passengers only. In three other buses, only some of the passengers were restrained (cases 22, 33, and 36); in these cases injury data for the unrestrained passengers only are shown in the table.

Nonrollover accidents involving frontal collision (head-on and front angle) comprise the largest subgroup in the study, both in terms of numbers of buses and numbers of passengers. Notification of frontal crashes was so common that the Safety Board suspended investigation of accidents of this type after December 1985. (From January through March 1986, only rollover accidents or accidents involving small school vehicles were investigated.)

A wide range of accident severity is represented in the crashes in the frontal impact category: six minor, seven moderate, and two extremely severe. The two extremely severe frontal crashes in Snow Hill, North Carolina, and St. Louis, Missouri, (cases 13 and 14) produced the largest number of serious to maximum passenger injuries (MAIS 3-6) of the accidents in the study. In the Safety Board's study 9 of 13 students died in nonrollover accidents involving frontal collision. (See cases 1, 13, and 14.)

One passenger, however, died in a very minor frontal crash, a run-off-the-road accident in Carmel, New York (case 1). This case deserves special scrutiny since it was a very unusual fatal accident. Crash forces were extremely low and, except for the fatally injured student, the unrestrained passengers were either uninjured or received minor injuries only; the fatally injured passenger was leaning over the seat back in front of him and this contributed to his death. Perhaps most importantly, the student who died was at special risk because of a pre-existing medical condition. The injury which proved fatal, a blow to his diseased liver, probably was not sustained during the head-on crash into a small tree but rather when the schoolbus went over a dirt embankment.

One of the three schoolbus driver deaths in this study also occurred in a frontal nonrollover crash in Palmyra, Nebraska (case 11).

As stated before, the Safety Board investigated only one nonrollover case involving a rear impact which was an accident involving two schoolbuses in Key Largo, Florida (case 15). This accident is interesting since it illustrates the variety of minor injuries sustained by schoolbus passengers and the probable contact points of these injuries. This accident, because it involved two schoolbuses colliding with one another, also allows comparison of injuries sustained in a minor crash with rear end impact versus those sustained in a minor frontal collision. No differences emerged, other than the fact that more passengers on the lead bus, which was struck in the rear, were uninjured compared to passengers on the second bus which sustained a frontal impact.

Side Impact

		By MAIS							
No. of Schoolbuses in Safety Board Study	Schoolbus Passengers	Uninjured	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	MAIS 6	Unknown
3	Unrestrained: 109	96 (88.1%)	12 (11.0%)	1 (0.9%)	-- --	-- --	-- --	-- --	-- --
	Restrained: 29	29							

No passengers died from their injuries.

The Safety Board investigated only three nonrollover accidents involving side impact 35/; one of the three cases involved a large schoolbus equipped with lap belts for all passengers. Unfortunately, due to the nature of these accidents and the limited

35/ Five rollover accidents also involved side impact. See cases 33, 34, 35, 39, and 42. These cases cannot be compared to nonrollover side impacts, since crash dynamics are so dissimilar.

data they provided, no judgments as to the level of occupant protection provided to unrestrained schoolbus passengers in side impacts could be made, nor could any judgments as to the value of lap belts in side impact be made.

The belt-equipped bus (case 16) was involved in a minor sideswipe accident with a passenger car in Greenburgh, New York. All schoolbus passengers were wearing the available lap belts at the time of the accident, but little can be learned of the value of passenger restraints. Crash forces were so slight that the students' books and papers placed on the seats did not even slide to the floor at impact; damage to the bus was barely discernible. All of the passengers were uninjured, but they probably would have been uninjured even if they had been unrestrained. (See figure 11.) The Greenburgh case is included in this study because it is often cited by the media and advocates of seat belts on schoolbuses as an example of the lifesaving value of lap belts.

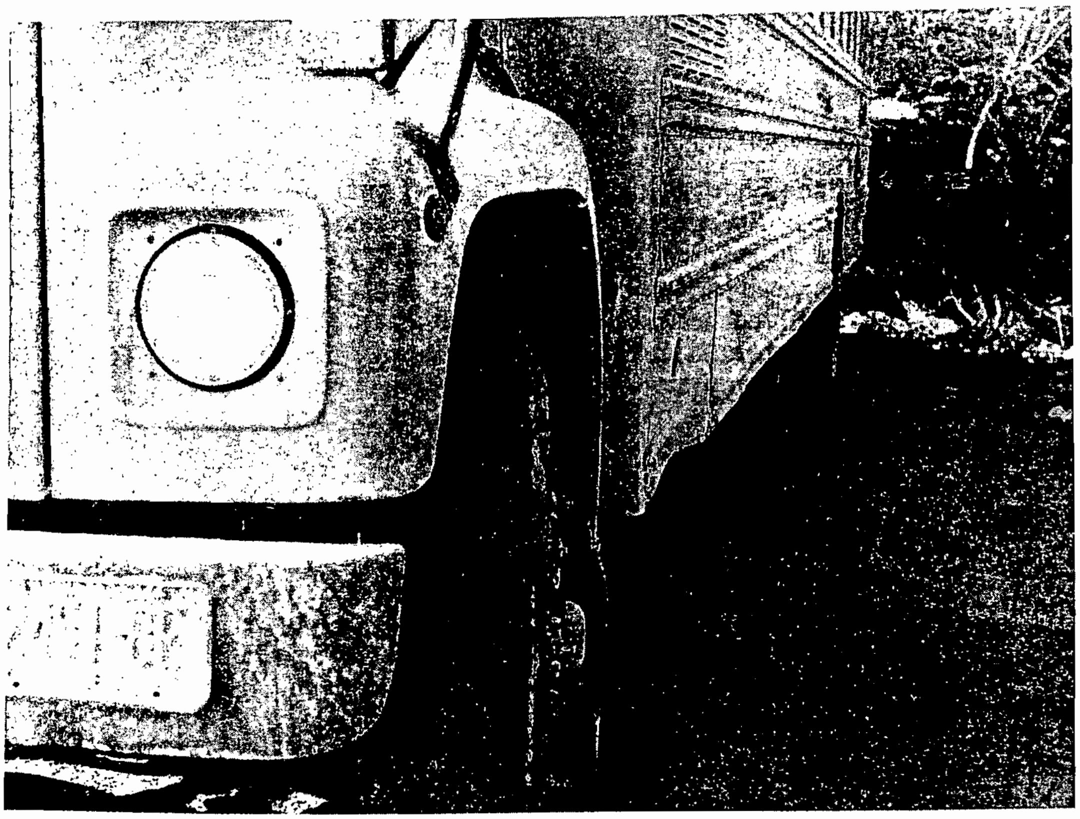


Figure 11.—The only damage to the schoolbus in the Greenburgh, New York accident (case 16) was minor damage to the front left side panels.

The other two cases were a minor sideswipe accident in Snyder, Oklahoma (case 17), and a moderate grade crossing accident in Stephenson, West Virginia (case 18). Both have unique features which make any generalizations about side impact difficult. The first involved a minor collision between a schoolbus transporting kindergarten and first grade students and a fertilizer spreader. The spreader sideswiped the left side of the bus at the level of the passenger windows, breaking several windows. Five children seated near the impact area received multiple minor lacerations (MAIS 1) from flying glass; one of the five also received a concussion (MAIS 2). The short stature of the passengers probably saved many of them from severe cuts from the glass.

The second case was a railroad-highway grade crossing accident of moderate severity. The schoolbus was clearing the tracks when it was struck on the right side just behind the rear wheel by an oncoming train. The train tore a gaping hole in the side of the bus at rows 12 and 13, but no passengers were seated in the area since the schoolbus driver had insisted students sit in the front of the bus. Most passengers were uninjured; others sustained only minor (MAIS 1) injuries. If passengers had been seated in the direct impact area, the injury levels would have been much higher.

In these two nonrollover side impact crashes involving unrestrained passengers, 96 of the 109 unrestrained passengers were uninjured. If minor injuries are included, all but one were either uninjured or received only minor injuries. However, these two cases do not present sufficient data to make any judgments about the level of occupant protection provided to unrestrained passengers in side impacts.

Multiple Collision

No. of Schoolbuses in Safety Board Study	Schoolbus Passengers		By MAIS							
			Uninjured	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	MAIS 6	Unknown
3	Unrestrained:	64	6 (9.4%)	46 (71.9%)	11 (17.2%)	1 (1.6%)	-- --	-- --	-- --	-- --
	Restrained:	0								

No passengers died from their injuries.

Only three crashes investigated by the Safety Board were multiple collision nonrollovers: Kerrick, Texas (case 19); Hecla, South Dakota (case 20); and Woodside, Delaware (case 21) (see cases 35, 37, and 40 for rollover accidents involving multiple collision). Again, the small number of accidents makes generalizations about schoolbus performance in multiple collisions difficult, but the data do indicate, as might be expected, that unrestrained passengers involved in nonrollover accidents involving multiple collisions are more apt to be injured than those in other nonrollovers.

In fact, multiple collision accidents were the worst (in terms of injury) schoolbus accidents in the entire study. About 90 percent of the schoolbus passengers involved in multiple collision nonrollover accidents were injured, compared to 35 percent of all nonrollovers cases. Minor injuries, however, remained the most common type of injury (nearly 72 percent of all injuries) as in all schoolbus accidents in this study.

The three accidents in this category were classified as moderate or above. Two involved side collisions; one of these two involved two side impacts (case 21). Thus, schoolbus passengers were repeatedly exposed to risk of injury.

Rollover Accidents

For the purpose of discussion, rollover crashes in this general category are separated into two groups: rollover accidents which occurred without a prior collision and rollover accidents precipitated by collision with a fixed object or other vehicle. Both groups, noncollision rollover and collision rollover accidents, involve impact--the schoolbus impacts the ground as it rolls over and strikes the side upon which it comes to rest. Therefore, strictly speaking, all rollover accidents involve some degree of collision. The speed of overturn, degree of rollover, and nature of the terrain will all influence the severity of these impacts. Nevertheless, it is important to distinguish between rollover accidents precipitated by collision and those which are not, since some passengers may sustain their injuries during the initial impact or penetration of the striking vehicle and not during the rollover or overturn which followed. Experience gained in conducting this special study convinced the Safety Board that analyses which lump all rollover accidents under one heading are likely to obscure the real source of injuries.

When schoolbus crashes involving rollover were analyzed, it was clear that schoolbus passengers fared better in rollover accidents that did not have a prior collision compared to those that did. (See chart 6.)

In this study, rollover accidents precipitated by collisions involved a greater percentage of schoolbus passengers sustaining moderate or greater injuries than those involved in noncollision rollovers. The rollover part of the accidents apparently did not contribute substantially to this finding: collision rollover accidents actually had a lesser degree of overturn than rollovers without prior collision. Instead, it was the seriousness of the precipitating collision that was responsible for most, but not all, of the more serious injuries.

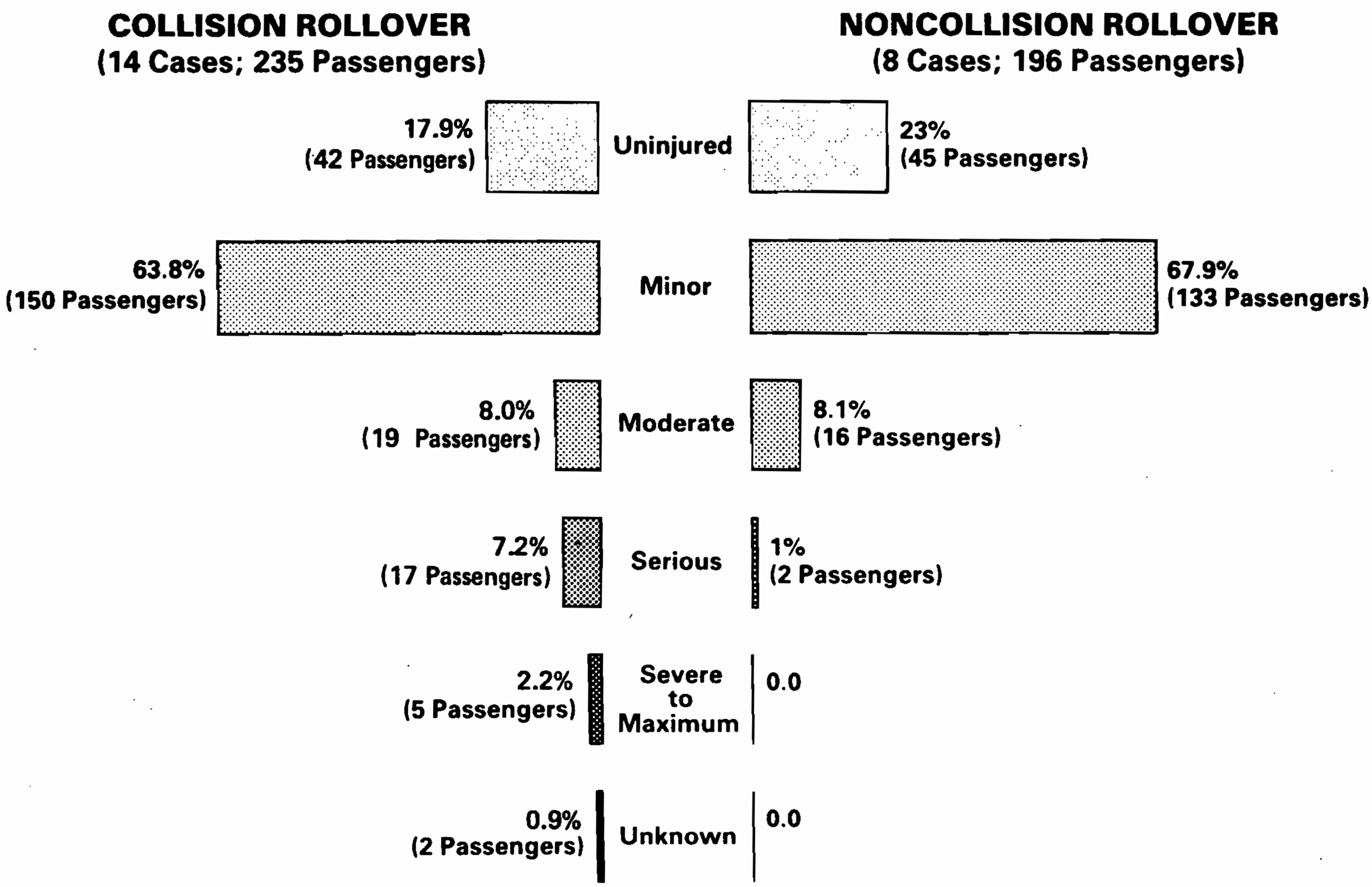
For example, in an accident which occurred in Carrsville, Virginia (case 42), the rollover itself contributed little to passenger injuries. A schoolbus transporting 26 students home from school was stopped at a railroad crossing when the bus was struck by a freight train travelling 49 mph. The train impacted the schoolbus in front of the right side door, tearing away the front of the schoolbus forward of the driver's seat. At the initial impact, the schoolbus body and steering axle separated from the chassis, and the bus body rotated 180° counterclockwise. As it rotated, the right rear of the schoolbus struck the side of the train, and the schoolbus rolled over to the right 270° and came to rest on its left side, approximately 80 feet from the crossing.

The two serious injuries and the majority of the 24 minor to moderate injuries sustained by passengers occurred either when the train initially struck the schoolbus or during the second collision between the right rear of the bus and the train.

The dynamics of the specific accident will determine how important the event of rollover is in terms of passenger injury causation. A comparison of two other rollover cases may help illustrate this point.

In the first example (case 38), the rollover was responsible for all of the moderate and serious injuries. A schoolbus transporting 13 members of a high school athletic team to a distant school was travelling on a rural 2-lane highway outside Cherokee, Iowa. As the schoolbus crossed an intersection, a car drove into its path. The bus collided front first into the right side of the car and, following the impact, both vehicles travelled in the same direction approximately 25 to 30° from the original travel direction of the schoolbus.

Chart 6.—Rollover accidents in the Safety Board study:
Comparison of most severe injury sustained by unrestrained passengers
(by percent at each injury level)



The schoolbus rotated approximately 135° clockwise and underwent a 450° rollover as it continued to travel more than 100 feet from the initial impact area. The schoolbus came to rest on its left side. In all, the bus rolled over one and one-quarter times.

The four moderate and serious injuries, all head injuries, occurred at the beginning of the rollover as the left side of the bus struck the ground with a force great enough to deform the upper left side substantially.

In the second example (case 31), both the initial collision and the subsequent rollover were responsible for the students' injuries. A schoolbus transporting 32 students to school in Greenfield, Illinois, was travelling 10 to 15 mph, getting ready to make a left turn. As the bus turned, it was struck in the rear by a tractor-trailer. The truck jackknifed, and the right rear corner of the bus was struck by the left front of the tractor as well as by the left front of the trailer. The rear of the bus was pushed counterclockwise, and the bus went off the road, struck a ditch, and turned over onto its right side. One passenger was totally ejected and another was partially ejected.

Of the 32 passengers, 19 sustained minor injuries, 3 sustained moderate injuries, and 1 sustained serious injuries; 9 passengers were uninjured. The minor injuries were probably sustained during both the impact and rollover. Two of the three moderate injuries occurred at initial impact. The most serious injury (MAIS 3), occurred during rollover; this was the passenger who was partially ejected. (The totally ejected student received minor injuries only.)

Rollover clearly is the major injury-causing event in noncollision rollover accidents such as case 25, an accident precipitated by driver loss of control, followed by run-off-the-road and a rollover down an embankment. However, even in noncollision rollover accidents, sudden braking, skidding, or rotation can contribute to passenger injuries. Hence, it is important to look at the crash dynamics of each accident in order to determine when in the accident sequence passengers may have sustained their injuries. If the data for all schoolbus accidents involving rollover appear under a single heading, "Rollovers," many readers will assume rollover to be the most important event.

A more detailed discussion of noncollision and collision rollover cases in Safety Board's study follows.

Noncollision Rollover

		By MAIS							
No. of Schoolbuses in Safety Board Study	Schoolbus Passengers	Uninjured	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	MAIS 6	Unkno
8	Unrestrained: 196	45 (23.0%)	133 (67.9%)	16 (8.1%)	2 (1.0%)	-- --	-- --	-- --	-- --
	Restrained: 1*								

No passenger died from their injuries.
*See case 22; one schoolbus passenger was restrained by a diagonal "loop belt," not a seat belt, which provided upper torso restraint. The loop belt was an after-market restraint reportedly consisting of a belt looped around the seatback cushion and passed between the junction of the lower and upper cushion, forming a diagonal loop.

The schoolbus passengers in the eight noncollision rollovers investigated for this study fared quite well. Many of the rollovers were low speed, and this undoubtedly affected injury outcome; the passengers merely slid from one surface to another.

In case 25, a 270°-rollover outside Point Pleasant, West Virginia, 17 of the 53 passengers were uninjured following the three-quarter-revolution down an embankment; 32 received minor injuries and only 4 sustained moderate injuries. (See figure 12.) Case 27, a 270°-rollover on the Baltimore-Washington Parkway outside Bladensburg, Maryland, was another slow rollover: of the 51 passengers, 4 were uninjured and 47 sustained minor injuries only. Case 29, a 360°-rollover outside Jefferson, North Carolina, is another example of low injury levels.

In noncollision rollover accidents in this study, the schoolbus driver typically lost control on a wet surface, 36/, the bus ran off the road, and overturned; the rollover usually was more than 90°. Five of the eight noncollision rollovers investigated by the Safety Board involved a 270° or greater overturn: three were 90°-rollovers, two were 270°, two 360°, and one was 450°. 37/

In contrast, the majority of the collision rollovers (9 of 14) were only 90°. Nonetheless, passenger injury outcome was better in the noncollision rollovers even with their greater amount of overturn, than in those preceded by collision.

Figure 12.—The schoolbuses involved in noncollision rollovers in the study generally sustained little damage. The bus shown here (case 25) underwent a 270°-rollover down an embankment, in Point Pleasant, West Virginia, but maintained its structural integrity. Damage was minor and confined to the exterior, primarily the right front fender.

The difference is not apparent at the lower injury levels, where most of the injuries are grouped: 91 percent of all schoolbus passengers involved in noncollision rollovers either were uninjured or received only minor injuries, compared to 82 percent of those in

36/ Five of the eight cases occurred on wet roadways. See cases 22, 23, 24, 25, and 26.
37/ See case 26. The most extreme rollover investigated by the Safety Board was 450°; only two cases involved 450°-rollovers: Hobbs, New Mexico, and Cherokee, Iowa (cases 26 and 38).

collision rollovers. There were differences at the middle and high end of the injury scale: 9 percent of those in noncollision rollovers received moderate or serious injuries, (only two passengers sustained an MAIS 3), compared to 17 percent in the collision rollovers. No passenger in a noncollision rollover sustained an injury greater than serious (MAIS 3); 2 percent of those in collision rollovers sustained injuries worse than serious. No passenger died in the noncollision rollover cases in the study; four died in collision rollovers. Whether similar differences exist between the overall populations of collision and noncollision rollovers is not known.

Collision Rollover

No. of Schoolbuses in Safety Board Study	Schoolbus Passengers		By MAIS: Uninjured	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	MAIS 6	Unknown
14	Unrestrained:	235	42 (17.9%)	150 (63.8%)	19 (8.1%)	17 (7.2%)	2 (0.9%)	1 (0.4%)	2 (0.9%)	-2 (0.9)%
	Restrained:	17*	11	6						

Four passengers died from their injuries in this type of accident.
*See cases 33 and 36: restraints included lap belts, "loop belts," and wheelchairs.

Of the 14 collision rollovers in this study, 5 were preceded by frontal impact, 5 by side impact, 3 by rear impact, and 1 involved multiple impact. Rollovers preceded by collision resulted in a greater proportion of schoolbus passengers sustaining moderate or greater injuries, compared to rollovers which had no prior collision.

The collision rollover accidents in this study, were generally more severe than the noncollision rollovers, even though they more often involved a 90°-overturn. Six of the 14 collision rollovers were classified as severe or extremely severe accidents, while only 1 of the 8 noncollision rollovers fit those categories.

All four fatal rollover accidents investigated by the Safety Board were collision rollovers. Four of the 13 fatally injured schoolbus passengers and 2 of the 3 fatally injured schoolbus drivers received their fatal injuries in collision rollovers. (See cases 39, 41, 42, and 43 for fatal rollover crashes.)

All four of the passengers who were killed in rollover crashes were killed by the forces at impact, not during the rollover. The importance of the initial impact as the main harmful event in collision rollover cases is also supported by analysis of the surviving passengers in this study who sustained serious or greater injuries. In the 10 collision rollovers in which passengers received more than moderate injuries, 19 surviving passengers sustained serious, severe, or critical injuries (MAIS 3-5); 14 of the 19 received their injuries at impact. (See cases 37, 39, 40, 41, 42, and 43.) Only five surviving passengers who sustained MAIS 3 or greater injuries level sustained their injuries during the rollover. (See cases 31, 35, 37, and 38.)

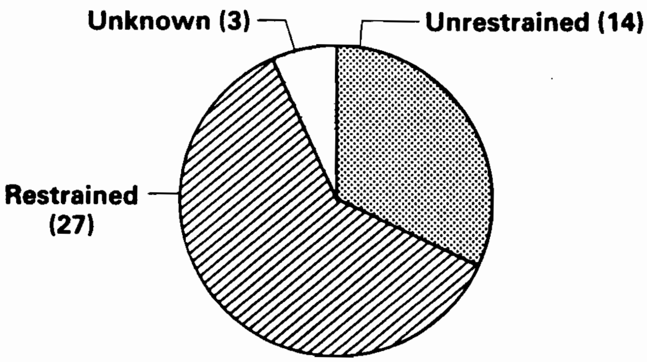
In summary, all of the passenger fatalities and slightly more than two-thirds of the serious or greater injuries in collision rollovers in this study were due to the force of the collision, not to the dynamics of the rollover. Initial impact, not rollover, appears to be the most harmful event in these cases.

SCHOOLBUS DRIVER RESTRAINT USE AND INJURY PATTERNS

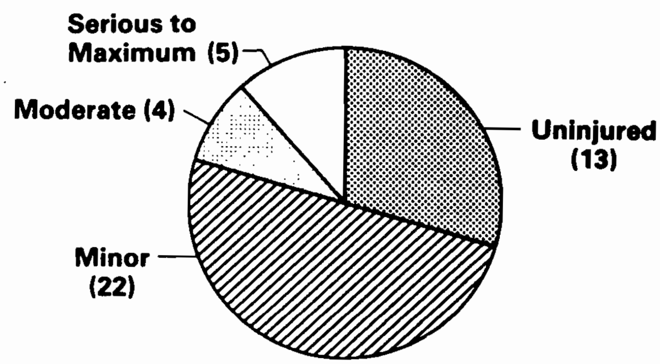
Lap belts are now routinely available for drivers of large schoolbuses, and Federal safety standards recommend that all schoolbus drivers be required to wear their seat belts whenever the bus is in motion. 38/ This recommendation is based on more than the need to provide some form of occupant protection for the driver (who is faced by a considerably more hostile vehicle environment than passengers); proper lap belt use by the driver helps protect the schoolbus passengers as well. Drivers must remain in their seats at all times and in control of the vehicle, in order to take evasive maneuvers if needed and to minimize the consequences of the crash for all schoolbus occupants. Drivers who have fallen from their seats due to a sudden swerve, impact, or rollover, have relinquished control of the vehicle and are unable to influence the outcome of subsequent crash events.

Nevertheless, only slightly more than half of the schoolbus drivers in this study were wearing their available lap belts at the moment of the crash. (See chart 7.) Drivers were even unrestrained in buses which had restrained passengers. (See cases 33 and 36.)

Chart 7.—Schoolbus driver injury and restraint use.



Schoolbus Driver Restraint Use (by number of drivers)



Schoolbus Drivers (Restrained and Unrestrained) By Most Severe Injury) (by number of drivers)

Even more disturbing, many drivers who reported they were restrained probably were not wearing their lap belts properly, and thus were not afforded the full benefits of the restraint. In some cases in this study it is apparent that, although the schoolbus drivers were wearing their lap belts, the belts were improperly worn and thus allowed the drivers to slip off their seats, resulting in the loss of control of the bus.

38/ Federal Highway Safety Program Standard (HSPS) 17 — -Pupil Transportation Safety.

Poor Design of Driver Lap Belt

The type of driver lap belt currently installed in most schoolbuses may favor such improper use. Most lap belts installed for schoolbus drivers are equipped with nonlocking retractors on each side of the belt to store belt webbing when the lap belt is not in use. When the belt is fastened around the driver, these storage retractors (see figure 13) provide some tension or feeling of tightness to the belt. Unfortunately, drivers may assume these storage retractors are automatic or emergency locking retractors, i.e., that the retractors will stay locked in a crash so no additional belt can be played out. This is not the case; drivers must manually pull all the webbing out of both of the retractors and tighten both sides of the lap belt around them before the belt is properly "snugged up." If this is not done, all of the belt may play out in a crash, leaving the driver with a lap belt far too loose to provide proper restraint.

Indeed, as shown in figure 14, an unadjusted belt can allow drivers to fall completely off their seats, still wearing the belt. Clearly, a belt worn so loosely will not provide any degree of restraint. Unfortunately, many drivers and school district personnel appear unaware of the hazards of wearing an unadjusted belt.

Improper lap belt wearing was involved in the Swink, Oklahoma, accident (case 29). The driver lost control of her bus, the bus left the roadway, and it rolled over; 27 passengers and the driver were injured. The schoolbus driver stated that she was wearing her lap belt, but that it did not restrain her. Investigators found the lap belt was fully extended. It had played out completely during the crash because both sides had not been manually "snugged up," as this type of belt requires.

In a few cases, the lack of restraint for the driver clearly led to passenger injuries. For example, in the fatal schoolbus accident in Carmel, (Mahopac) New York (case 1), the driver slipped from her seat when the bus went out of control and left the road. The bus eventually veered back onto the road and went off the other side of the road. Events which occurred in the second runoff subsequently resulted in the death of one of her passengers. The driver in this case may have had her belt partially on at the onset of the accident or she may have been not wearing the belt at all, but it was clear she had fallen from her seat before the second runoff and thus could not control the bus. If the driver had remained in her seat, she might have regained control of the bus in time to prevent the second runoff and thus would have prevented the passenger's death and the other passengers' injuries (all injuries occurred during the second runoff).

Of course, lap belt use is recommended for schoolbus drivers for more than increased control of the vehicle. Restraint use hopefully increases the chances the driver will be conscious following the crash and be able to direct evacuation efforts, thus sparing passengers from postcrash injuries. The most dramatic example is case 32, a schoolbus overturn near Caldwell, Texas. Students were standing in the aisle of the schoolbus retrieving displaced papers. When the schoolbus struck a dirt embankment and overturned, a student who had been standing had her leg trapped between the bus and ground. A fire broke out shortly following the crash. The schoolbus driver had been restrained during the rollover and was uninjured, so she was able to direct rescue efforts. All passengers were safely evacuated from the bus; the trapped student was freed minutes before the fire reached her seat.

In the Durango, Colorado, accident (case 35), the bus had rolled down a mountain embankment and had come to rest in an icy river. Passengers easily could have panicked. Although the restrained driver sustained two broken ribs and multiple contusions during the rollover, he was conscious and able to direct evacuation efforts.

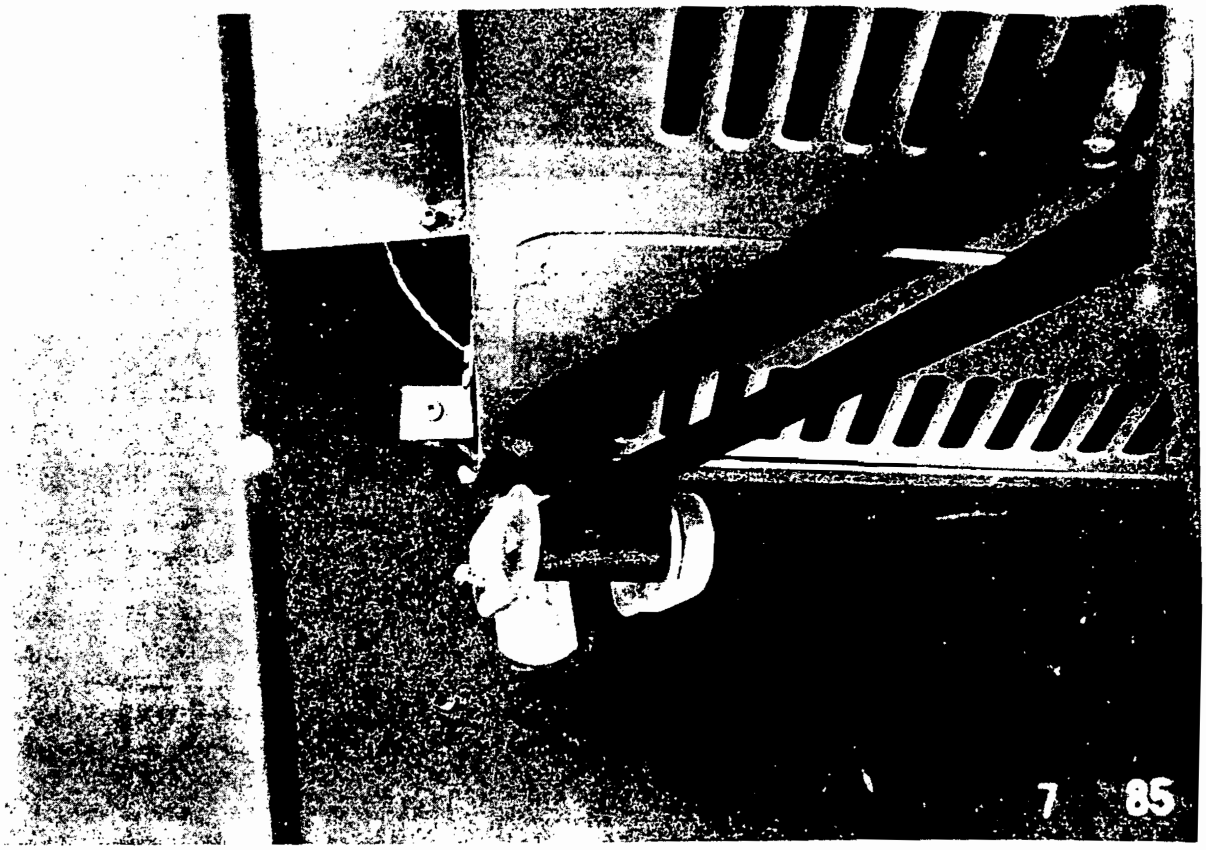


Figure 13.—The spring-loaded retractor on this schoolbus driver lap belt provides a feeling of snugness when the lap belt is worn. The retractor, however, does not lock the belt, and so additional webbing can be played out in a crash. The retractor's sole function is to store belt webbing when the belt is not in use, and keep the belt off the floor. Schoolbus drivers must manually adjust the belt before it provides proper restraint.

In only one case in this study did a seat belt clearly fail. The driver in the Fort Myers, Florida, accident (case 34) was released by her lap belt upon impact. This lap belt was removed by Safety Board investigators and tested in a laboratory, revealing that the buckle latch was faulty because a component was bent from its proper position. The Safety Board has since investigated a case in Lincolnton, North Carolina, involving a similar failure by this make of belt, a Beam 300. The Beam 300 lap belt has a metal flap type latch plate similar to those found in airplanes.

There is some suggestion that these two accidents involving lap belt buckle failure are not isolated occurrences. The Safety Board has learned that in 1979 Canada recalled 710 Thomas Built buses manufactured from July 1, 1978, to June 11, 1979, because "the driver's seat belt buckle (Beam double adjust model) may only partially engage and may not adequately restrain the wearer in a vehicle crash" (Transport Canada recall #79205, issued December 4, 1979). Canadian files also contain a formal complaint filed in 1982 by a school board in Windsor, Nova Scotia, alleging that the Beam 300 buckle comes unfastened when the driver "moves his position on seat." The school board noted that the same Beam 300 seat belts were on all the 1976-1978 General Motors schoolbuses in their fleet.

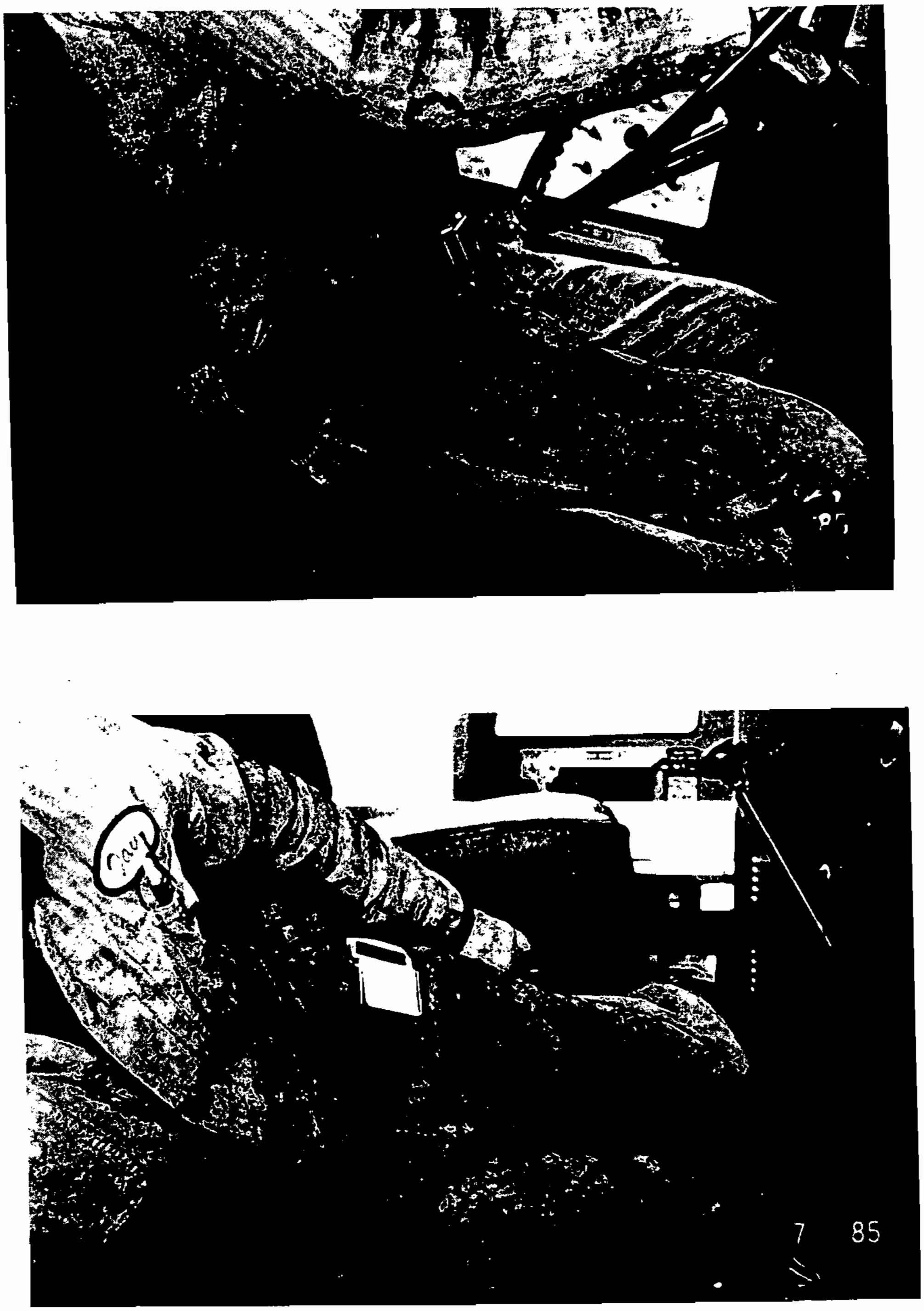


Figure 14.—These photographs illustrate how a schoolbus driver, who has failed to manually adjust his belt, can fall completely off the seat with the lap belt still around him.

Prompted in part by the Safety Board's two cases of buckle failure, the NHTSA's Office of Defects Investigations has undertaken a preliminary evaluation of Beam 300 seat belts manufactured from 1978 through 1979. Latch disengagement was cited as the reason for the defects investigation.

The NHTSA has rulemaking underway to eliminate these flap type release latch plates now allowed in buses weighing over 10,000 pounds and to require push button release buckles similar to those required in passenger cars. This rule, if enacted, would eliminate the type of Beam 300 latch plate found in the Florida and the North Carolina accidents.

The same rulemaking also contains a proposal that all lap belts for drivers of vehicles weighing over 10,000 pounds Gross Vehicle Weight Rating (GVWR) (this would include large schoolbuses) must be equipped with emergency locking retractors. The Safety Board understands that the NHTSA is now considering amending the proposal to also allow automatic locking retractors in driver lap belts. Such automatic locking retractors would have to be especially designed not to "rachet-up" because of vehicle motion. Otherwise, they could become quite uncomfortable for the driver.

Regardless of what type of locking retractors are required, the NHTSA proposal would go a long way toward eliminating the problem of unadjusted lap belts found in the Safety Board's study. Rulemaking is in its final stages and a new rule is expected to be issued soon. Only new large schoolbuses, however, would be affected by the rule. The problems of poorly designed driver lap belts and improper belt use would remain on the older buses. Therefore, the Safety Board is issuing a recommendation that all large schoolbuses be retrofitted with the new belts. This would ensure that drivers of old and new schoolbuses are afforded adequate restraints. The Safety Board is also issuing a recommendation that school districts instruct drivers on how to adjust properly the lap belts currently in the schoolbuses, because it may take time before all schoolbuses have improved lap belts for drivers. Schoolbuses are retired, on the average, after 10 to 12 years of service from the public school fleet.

Need for Drivers to be Restrained

The Safety Board previously has made recommendations relating to seat belt availability and use by schoolbus drivers. (See appendix F.) Early recommendations called for seat belts to be installed for schoolbus drivers (at one time they were not standard equipment) and urged that schoolbus drivers use the available restraints. The most recent recommendation, H-83-41, was issued in 1983 to all Governors:

> Review State laws and regulations, and take any necessary legislative action, to ensure that drivers of schoolbuses are required to wear their seatbelts whenever the vehicle is in motion, that all schoolbus drivers are made aware of this requirement, and that periodic monitoring of schoolbus driver seatbelt use is conducted.

This recommendation has been closed for 18 States but is open for the remainder of the States. A 1984 survey conducted by the National School Transportation Association found that 42 States had requirements that schoolbus drivers wear their belts. The Safety Board believes that although most States now have such requirements. However, judging by the low restraint rates seen in the study, enforcement appears deficient. Hence, as a result of this study, the Safety Board is issuing a new recommendation, superseding H-83-41 and reiterating the concept that schoolbus drivers need to be restrained and emphasizing enforcement. The new recommendation will be sent to the State Directors of Pupil Transportation.

Regardless of restraint status, the driver of a schoolbus is seated in a considerably more vulnerable position than a schoolbus passenger. The driver is surrounded by large, potentially dangerous areas of metal and glass, with the steering wheel and gearshift in the immediate vicinity, while a passenger is in a more protected environment, with padded seats in front and behind. In a frontal collision, the most common direction of force in the study, the driver is in the main impact area; the steering column and wheel also can be displaced and pushed back into the driver's body. In a side impact, driver, even when lap belted, can contact the side wall, the side window, and the gear shift; if unrestrained, they can fall into the stairwell.

Schoolbus drivers, both restrained and unrestrained, fared much worse than their unrestrained passengers. Whether lap belted or unbelted, drivers were more frequently injured, and if injured, tended to be injured more severely. Nine of the 44 schoolbus drivers in the study (including both lap belted and unbelted) sustained moderate or greater injuries (MAIS 2-6). (See chart 7.)

There is some question whether lap/shoulder belts should be considered for schoolbus drivers. Such belts clearly offer superior protection over lap belts for occupants of passenger cars; perhaps schoolbus drivers also would benefit from the upper torso restraint provided by lap/shoulder belts. However, analysis of the serious and worse injuries sustained by schoolbus drivers in this study does not support the need for lap/shoulder belt installation for schoolbus drivers. Intrusion was responsible for all the serious and above injuries, and no belt system can prevent injuries caused by intrusion. It is possible lap/shoulder belts might have prevented or mitigated some of the moderate injuries sustained by the schoolbus drivers, but the number of schoolbus drivers who sustained such injuries in the study is too small to support any conclusions. More study needs to be done before the safety benefits of lap/shoulder belts for schoolbus drivers can be evaluated.

Installation of lap/shoulder belts for schoolbus drivers also poses problems. It is unclear where the upper anchor for the shoulder portion could be located. The seat would probably have to be redesigned to permit the anchor to be part of the frame. Furthermore, the driver is surrounded by windows, without the "B" pillar type structure available in passenger cars for shoulder anchorage.

The Safety Board understands Thomas Built Buses has developed a prototype lap/shoulder belt assembly for drivers and is investigating the feasibility of installation. However, they are not prepared to offer driver lap/shoulder belts on their large buses yet.

Seriously Injured Schoolbus Drivers

Five of the 44 schoolbus drivers in the study received more than moderate injuries (MAIS 3 and above) and 3 died as a result. Two of the fatally injured drivers were restrained. A short description of these five crashes follows.

A head-on crash in Cornelius, Oregon, occurred when the driver lost control of the bus. The bus crossed the center line and collided head-on with a car travelling in the opposite lane. It is unknown whether the schoolbus driver was restrained. She said she was wearing her lap belt before the accident, but the nature of her injuries was such that the Safety Board believes she was essentially unrestrained at the time of the accident, either through failure to wear or to adjust the belt. The driver contacted various portions of the bus interior including the stairwell, dislocating and fracturing her right shoulder, fracturing a rib, and sustaining multiple lacerations and contusions. (See case 3.)

The second case occurred in Palmyra, Nebraska, when a tractor-semitrailer crossed the center line and struck the left front fender of a schoolbus travelling in the opposite direction. (See figure 15.) The schoolbus driver was seated in the direct area of impact and died of critical injuries inflicted when the steering assembly was displaced back into his seating position. His injuries included multiple pericardium trauma, multiple rib fractures, and bilateral fractures of the sternum. He had been restrained by a lap belt, but the circumstances of the accident were such that lap belt use was immaterial. (See case 11.)

Figure 15.—A schoolbus driver was killed in the Palmyra, Nebraska, accident involving a collision with a truck (case 11), but students were largely uninjured. Of the 20 passengers, 11 were uninjured and 9 sustained minor injuries only. All passenger injuries were caused by flying glass. The arrow points to the truck door embedded in the bus.

The third accident, involving a seriously injured schoolbus driver, occurred in St. Louis, Missouri. A schoolbus driver, reportedly driving between 59 and 67 mph, lost control of the bus. The bus went off the road and struck a concrete sign support pedestal and metal sign post head-on. The force of the collision was so great that the post penetrated the front of the bus, and the bus swung up and around the post, crushing the roof down into the passenger seating area for more than 100 inches rearward of the firewall. The driver sustained a serious injury (cerebral concussion) in addition to a fractured ulna and lacerations to the forehead and right eye. The driver was wearing his lap belt. (See case 13.)

Figure 16.—Intrusion was responsible for most of the serious and worse injuries sustained by schoolbus drivers in the study. The schoolbus driver in this crash in Carrsville, Virginia (case 42) was in the main impact zone and sustained serious injuries, which included traumatic amputation of her lower left leg and right foot.

The fourth crash took place in Rehoboth, Massachusetts, when a tractor-semitrailer crossed the center line of a 2-lane highway and struck the left front corner of the schoolbus. The driver was seated in the major area of intrusion, and the intrusion resulted in critical injuries which proved fatal. The driver sustained a ruptured heart, compound fractures of the left leg and right wrist, and multiple lacerations and contusions. She was unrestrained; however, restraint use would not have prevented these injuries. (See case 41.)

The last schoolbus driver in the study to receive more than moderate injuries was injured during a grade crossing accident in Carrsville, Virginia (case 42). The train struck the bus on its right side, just in front of the door. It sheared off the whole engine compartment and windshield area, inflicting serious injuries on the driver. (See figure 16.) She suffered a traumatic amputation of the left leg below the knee, a fractured femur, a pelvic fracture, a traumatic amputation of the right foot, and a fractured forearm. The driver died of her injuries 5 days after the accident, after refusing blood transfusions for religious reasons (her injuries otherwise probably would have been survivable). She had been wearing her lap belt at the time of the accident, which no doubt prevented her ejection through the gaping hole in the front of the bus created by the train, but could not prevent her multiple serious injuries.

Limitations of Data

Compounding the difficulty of collecting schoolbus driver restraint data is the fact that 42 States require schoolbus drivers to be restrained when their vehicle is in motion. In the absence of a State regulation, many school districts also require the drivers to wear their belts. Many schoolbus drivers involved in a crash may be reluctant to admit that they were unrestrained, and therefore in violation of a State statute or school district rule. Hence, the actual level of restraint use among schoolbus drivers is not clear. 39/

Schoolbus driver injury data also probably are unreliable in this study and others. Following a schoolbus crash, the emphasis is, quite naturally, on the welfare of the child passengers. The bus drivers may tell police they are unharmed and to "tend to the students," rather than report their own injuries. In fact, under these conditions, a bus driver may not even be conscious of injuries. Injury levels (both in terms of frequency and injury severity), therefore, may be higher than reported. This probably impacts the number of minor and moderate injuries reported rather than the number of serious or severe injuries since the latter would be documented by hospital records. Nevertheless, the Safety Board did investigate one crash involving a small schoolbus where the driver reported only minor injuries yet was unable to work for an extended period of time (about 3 months). She probably had sustained more than moderate injuries.

39/ Restraint use among schoolbus drivers in this study also was higher than that found in the North Carolina study. In North Carolina, all schoolbus drivers are instructed and directed to wear their seat belts while driving the bus. Nonetheless, only 57 percent of the bus drivers in the HSRC study were wearing their lap belts.

OCCUPANT PROTECTION SHORTCOMINGS

Deficiencies in Joint Strength

The Federal standard, FMVSS 221, Schoolbus Body Joint Strength, requires that an inside or outside body panel of a schoolbus be fastened so that the body panel is capable of holding the body panel to the member to which it is joined when subjected to a force of 60 percent of the tensile strength of the weakest joined body panel. The purpose of this standard is to reduce the deaths and injuries resulting from the structural collapse of schoolbus bodies during crashes.

The rule defines the term "body panel" as a body component used on the exterior or interior surface to enclose the schoolbus occupant space, and defines "body panel joint" as the area of contact or close proximity between the edges of a body panel and another body component, excluding spaces designed for ventilation or other functional purpose, and excluding doors, windows, and maintenance access panels.

Overall, in the cases investigated for this study, the Safety Board found the joint standard working very well. Schoolbus bodies withstood crash forces very well, maintaining structural integrity even in severe crash forces. In the few cases where the body did fail, crash forces probably exceeded performance standards.

However, as a result of this study, the Safety Board believes two areas of the standard are deficient: maintenance access panels and floor panels.

Maintenance Access Panels

Maintenance access panels are panels, either on the exterior or interior of the bus, which allow access to mechanical functions (i.e. door opening) and electrical functions (wiring for lights, turn signals, stop arm, etc.) of the bus. The design and placement of maintenance access panels varies. For example, if maintenance access panels are located in the bus interior, they might be located above the windows, below the windows, or both above and below. Methods of enclosing the panel and its attachment to the bus body also differ.

Federal standards do not specify where access panels can be located. More importantly, maintenance access panels in large poststandard schoolbuses are not required to meet Federal schoolbus joint requirements. This omission has been and continues to be a source of concern.

On November 27, 1981, the NHTSA issued a notice of proposed rulemaking to amend FMVSS 221 to require that most maintenance access panels in large schoolbuses comply with the joint strength requirements of that standard. The notice stated that NHTSA had become concerned that schoolbus manufacturers were circumventing FMVSS 221 to a limited extent by the excessive use of maintenance access panels, and that most manufacturers had located these panels above the window area and extending the entire length of the schoolbus. The notice further stated that these panels usually were loosely attached and could not withstand much force before they would detach from the schoolbus body. The NHTSA tentatively had concluded that many of these panels were located in areas of the schoolbus likely to be struck by the heads of the passengers.

Comments on the proposed amendment were submitted by more than 200 individuals, organizations involved in the manufacture or sale of schoolbuses, school districts, schoolbus contractors, and private individuals. Most opposed the amendment, stating that documentation did not exist to attribute schoolbus occupant injuries to contact with separated maintenance access panels; that the cost was excessive for the possible benefits to be accrued; that the proposed rule did not provide enough time for retooling to meet the proposed standard; and that the matter needed further study. In July of 1984, the NHTSA terminated the rulemaking action, but urged the schoolbus manufacturing industry to minimize the number of maintenance access panels.

Maintenance access panels separated in 5 of the 44 schoolbuses in this study. (See cases 13, 21, 27, 35, and 43.) These separations definitely resulted in schoolbus passenger injuries in two accidents. Based on the investigations conducted during this study, the Safety Board believes that the separations of the maintenance access panels from the adjacent interior body panels continue to be a hazard to schoolbus passengers. When a maintenance panel separates, sharp edges are exposed not only in the access panel itself, but also in the body panels to which it had been joined. Passengers who contact exposed metal edges of the body or maintenance access panels during collisions and overturns can sustain disfiguring and sometimes life-threatening injuries.

The first accident in which separated access panels caused injury occurred when a tractor-trailer rear-ended a stopped schoolbus which then rolled over. The crash took place in Tuba City, Arizona, on April 29, 1985, and involved a 1979 Blue Bird schoolbus (case 43). This bus had interior maintenance access panels installed on both sides above the windows. Following the crash, joint separations were noted at the connections joining the left and right maintenance access panels to the interior body side walls at the rear. (See figure 17.) Above the 13th row of seats, where the separation of the maintenance access panel left the bottom edge of the body panel exposed, a quantity of blood, hair, and human tissue was present on the edges of the body panel. How many students were injured on this sharp metal edge is not known, but the occupant of seat 13A probably sustained his head laceration when he contacted this edge. Other passengers may have been injured as well.

Figure 17—A separated maintenance access panel in the Tuba City, Arizona, accident (case 43).

In the second case, the St. Louis, Missouri, accident (case 13), a 1979 Ward schoolbus travelling between 59 and 67 mph struck a sign post head-on. Major impact was to the right front of the bus which was torn open from the side wall to approximately the third window on the right. The front roof was also extensively damaged and collapsed almost down to the seat backs in the front of the bus. Investigators found a 6-foot 10-inch maintenance access panel, which before the crash had been installed at the right front of the bus under the side windows, lying across the seat backs on the left side of the bus. (It probably had been moved there by rescuers.) The joint which the access panel had covered previously was splattered with blood, hair, and tissue. This indicates that the sharp edges of the exposed joint caused a head injury to one of the schoolbus occupants. (See figures 18 and 19.)

Both of these accidents were extremely severe crashes. However, the body panels subject to FMVSS 221 in the direct impact area did not fail. Some of the maintenance access panel separations, however, were outside the area of direct crush. Even if the access panels in these two crashes had met Federal joint strength standards, they still might have separated since crash forces may have exceeded the standard.

In three other moderate crashes (case 21, Woodside, Delaware; case 27, Bladensburg, Maryland; and case 35, Durango, Colorado), maintenance access panels separated, but injuries were not attributed to this failure. If access panels had been required to meeet Federal joint strength standards, they probably would not have failed in these three cases.

The five cases in this study involving post-1977 schoolbuses with maintenance access panel separations suggest that FMVSS 221 should be revised to include maintenance access panels. If the panels are located within the interior of the schoolbus they should be subject to the same joint strength requirements as the other body panels.

The Safety Board has in the past issued Safety Recommendation H-86-51 to NHTSA requesting that the joints of the interior body maintenance access panels meet the standard's requirements. This was done in in connection with the Tuba City, Arizona, investigation (case 43). The NHTSA, however, declined to revise the standard, citing insufficient evidence of a problem. The Safety Board classified this recommendation as "Closed—Unacceptable Action" in 1985, but is issuing a new recommendation based on this study.

Schoolbus Floor Panel Joints

The Safety Board also found FMVSS 221 deficient in that it does not clearly address whether schoolbus floor joints are required to meet the standard's performance requirements. Confusion arises when floor joints are considered structural joints.

As noted earlier, the rule defines the term "body panel" as a body component used on the exterior or interior surface to enclose the schoolbus' occupant space, and defines "body panel joint" as the area of contact or close proximity between the edges of a body panel and another component.

The Safety Board issued Safety Recommendation H-86-55 to the NHTSA take action to "amend or clarify FMVSS 221 to include all body panel joints that enclose the occupant space," even if they are structural. All joints should meet minimum standards. Failure to do so can have tragic consequences as in the Snow Hill, Carolina (case 14) accident.

Figure 18.—Blood on fourth window and side wall in the St. Louis, Missouri, accident (case 13). The metal edge was exposed by access panel separation.

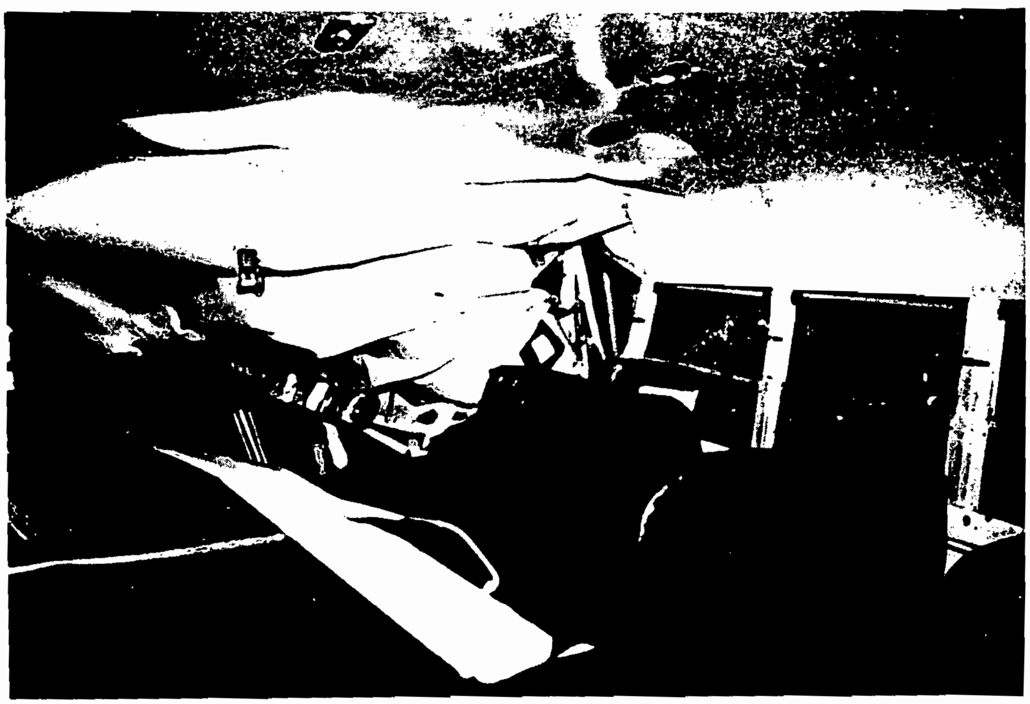


Figure 19.—A view of collapsed roof from inside the bus in the St. Louis, Missouri, accident (case 13). A maintenance access panel lies across seat at left. (It may have been moved to that position by rescuers.)

The floor of a Thomas bus failed in the Snow Hill, North Carolina, schoolbus crash (case 14) investigated by the Safety Board, and its failure probably contributed to the severity of the schoolbus passenger injuries.

The schoolbus floor consisted of 0.075-inch-thick steel bent into C-shaped channels. The channels were joined together by an exterior steel "cap" around the outside perimeter of the floor, by welds along the flanges at each end, by welds on the underside of the floor structure, and by spot welds near the center of the flanges on each channel. (See figure 20.) The collision separated two of these floor channel sections at the floor joint near the seat legs of the fourth row of bench seats in front of the schoolbus drive axle. The floor separation created a triangular opening across the schoolbus floor which measured about 45 inches wide at the left sidewall. (See figure 21.)

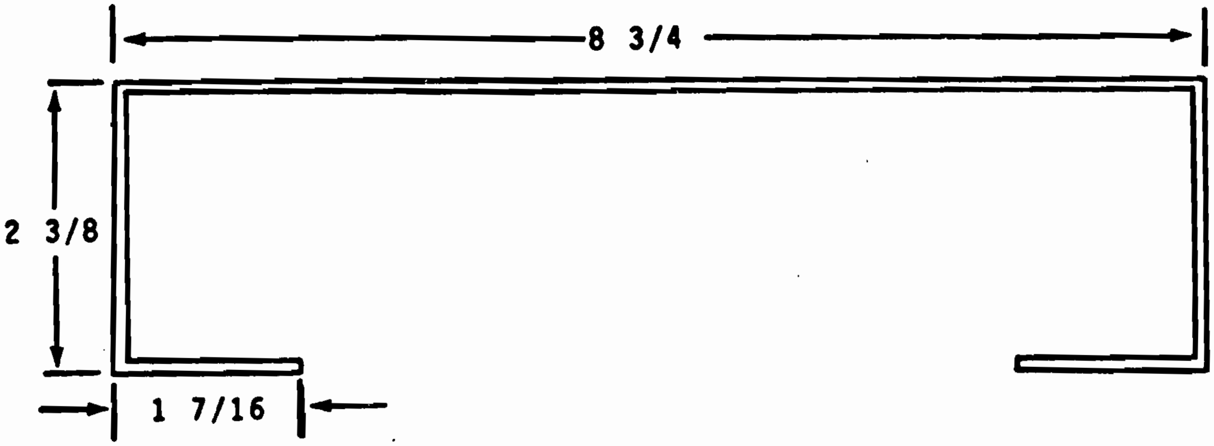
The Safety Board tested three floor joint specimens from the Snow Hill accident bus and determined that the strength of the strongest joint specimen was 7 percent of the strength required for the floor joint to meet the requirements of FMVSS 221.

The Safety Board has investigated one other accident (not in this study), a schoolbus/train collision near Greenville, North Carolina, May 21, 1986, and the NHTSA has data on another accident (a grade crossing accident near Two Harbors, Minnesota, on February 9, 1980) in which the floors of Thomas schoolbuses have separated. The Safety Board also has investigated several other accidents which involved schoolbuses not manufactured by Thomas, accidents similar in many respects to the three accidents involving Thomas buses. However, the floors of these schoolbuses did not separate. (See case 41, Rehoboth, Massachusetts, and case 42, Carrsville, Virginia.)

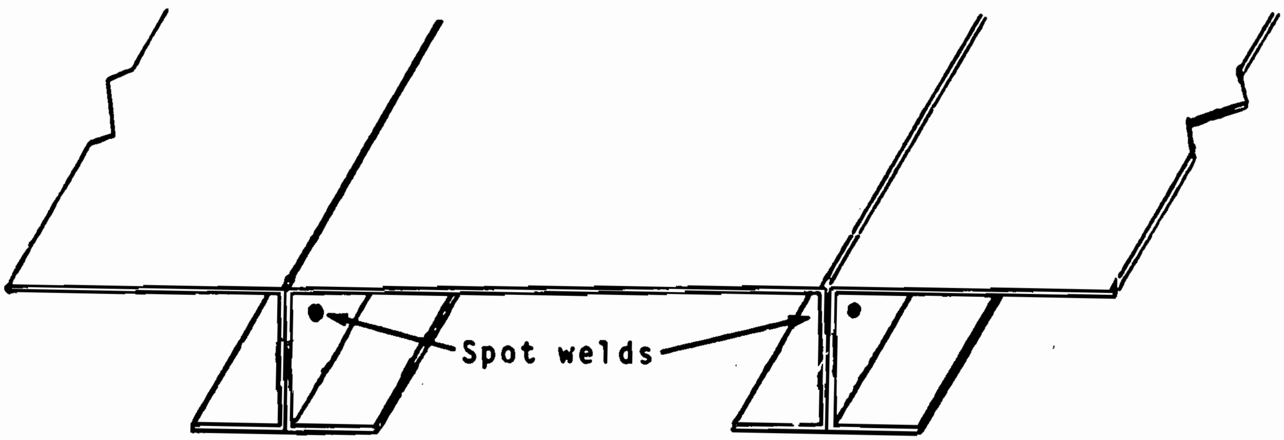
As a result of its investigation of the Snow Hill, accident, the Safety Board also issued Safety Recommendation H-86-57 to Thomas Built Buses:

> Strengthen the floor panel joints of all newly-manufactured schoolbuses to ensure that they comply with the requirements of Federal Motor Vehicle Safety Standard 221.

This recommendation is currently open and awaiting reply.



Side view of C-shaped channel section.
Dimensions are in inches.



Side view of three C-shaped channel sections welded together.

Figure 20.—Schoolbus floor construction in the Snow Hill, North Carolina, accident bus (case 14).

Figure 21.—Opening in schoolbus floor in the Snow Hill, North Carolina, accident (case 14).
(Photograph courtesy of the Goldsboro News Argus)

Deficiencies in Seat Cushion Attachment

Schoolbus seat design has improved with the enactment of Federal schoolbus safety standards. Seats on poststandard schoolbuses do not have the low seat backs with exposed metal frames and insufficient padding that were typical of buses built before 1977 and were responsible for many serious head injuries. Schoolbus seats now have increased padding, increased seat back height, and are placed closer together. Furthermore, the seat backs are designed to "give" in a controlled way when impacted by a person in the seat behind. (See appendix P for discussion of some of the seat design changes.) In this study, contact with the seat back was not a significant source of injury on poststandard schoolbuses. If injuries did result, they almost always were minor bruises or abrasions.

Nonetheless, the crashworthiness of schoolbus seats needs improvement. In 16 of the 44 accidents investigated for the study, seat cushions came loose during the crash. In four crashes, all of the passenger seat bottom cushions came loose (see cases 8, 11, 27, and 29); in the other 12 crashes, the number of bottom seat cushions unsecured following the accident varied between 2 and 15. (See appendix E for a complete listing of cases involving loose cushions.) In 3 of the 16 cases, passengers received minor injuries from contact with the loose cushions. (See case 27, Bladensburg, Maryland; case 29, Swink, Oklahoma; and case 31, Greenfield, Illinois.)

Cushions came loose in all types of schoolbuses in the study and in all types of accidents. Rollovers were particularly apt to result in unsecured cushions.

The problem of unsecured seat cushions is confined to the bottom cushion. The top cushions are permanently secured to the seat frame, whereas most of the bottom cushions can be flipped up or removed to facilitate bus cleaning and other types of maintenance. (See figure 22.)

The lack of a fail safe method of fastening bottom seat cushions is potentially dangerous for a variety of reasons. During an accident, particularly during a rollover, loose cushions can become missiles, tumbling about the bus and striking passengers. In addition, students can injure their backs and other parts of their bodies if they fall through the open seat frames or contact the exposed frame. (See figure 23.)

Loose seat cushions pose yet another potential danger when they fall into the aisle and hamper or block passenger escape routes or emergency exits. This occurred in two cases in this study (case 27, Bladensburg, Maryland; case 32, Caldwell, Texas.) A blocked exit could spell disaster in a fire or in any other type of accident where passengers evacuate the bus quickly. (See figure 24.)

Finally, loose cushions pose a threat to preschool or elementary school passengers. If seat cushions come loose in a bus, it is conceivable that loose cushions could hide an unconscious small child from view and thus prevent emergency rescue personnel from locating and rescuing a small child quickly.

FMVSS 222 requires that ". . . the seat cushion shall not separate from the seat at any attachment point when subjected to an upward force of five times the seat cushion weight. . . ."

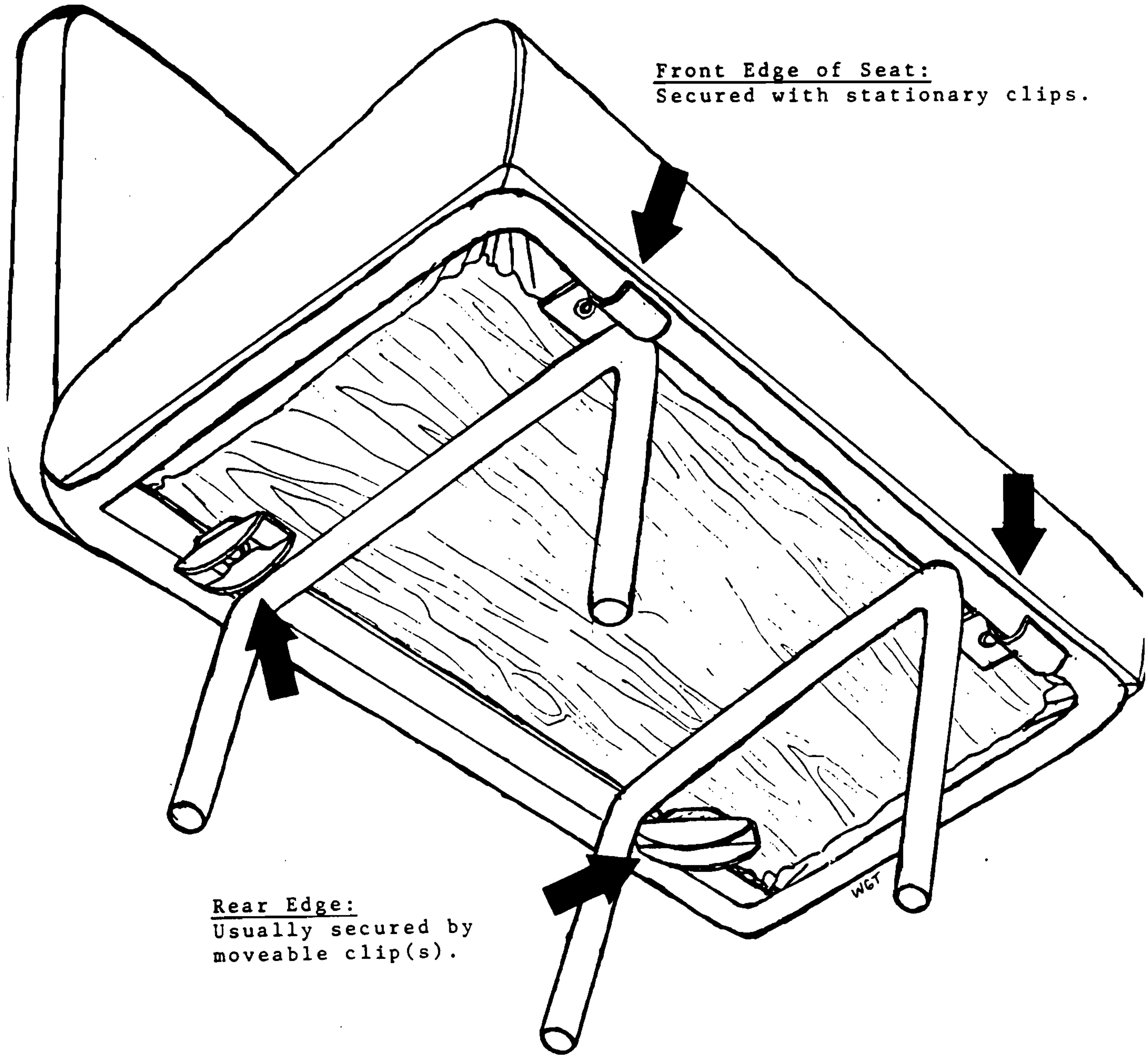


Figure 22.—Bottom cushion as viewed from the floor.

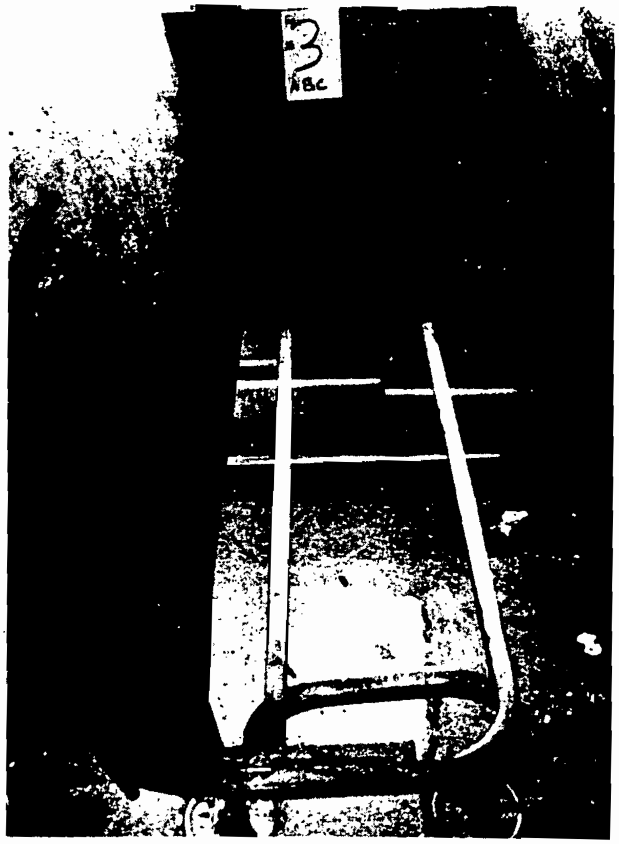


Figure 23.—If bottom seat cushions come loose, restrained and unrestrained passengers can come in contact with the exposed metal frame and sustain injuries. Passengers can also fall through the frame.

Figure 24.—Loose seat cushions can block aisles and hinder evacuation.

Schoolbus bottom seat cushions are attached to the seat frame by retaining clips on the front and rear of each cushion. The front clips are stationary; the rear clips usually are not. (See figure 22.) To install a seat cushion, the cushion is dropped perpendicular into the frame to engage the fixed front clip, then rotated toward the seat back, and the rear clip is put into place. Safety Board investigators found that attachment problems focused on the rear clips.

Three types of hardware used to secure the rear of the seat cushion to the seat frame were seen in the cases investigated by the Safety Board. (See figure 25.) The first two used rotating clips which could be turned to fasten or unfasten the cushion. The clips differed in design: one used a single, two-pronged piece of thin metal which clipped over the tubular seat frame; the other used a pair of swivel type clips of a more rigid design to attach the bottom cushion to the seat. In some instances, the latter type may have failed to secure the seat cushion because the clips were not secured tightly and they swivelled to the open position. The third type of hardware was a nonswivelling clip bolted to the seat frame.

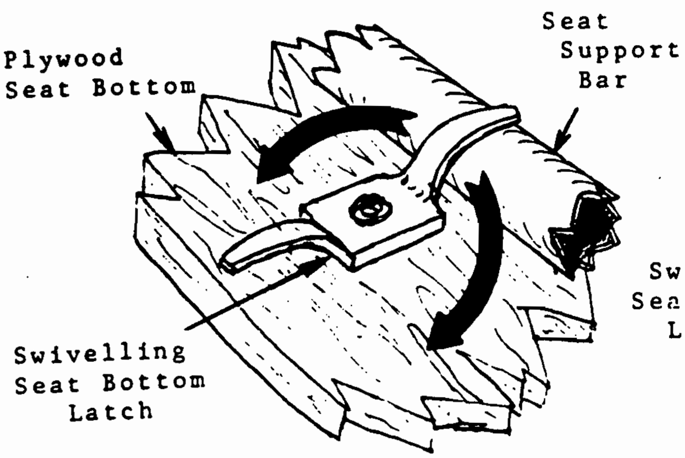
In some accidents, the seat cushions came free because the seat cushion clips had not been secured to the seat frames before the accident. In other cases, the bottom seat cushions came free probably because the clips at the rear of the cushion were loose and free to rotate and, therefore, did not secure the cushion to the rear of the seat frame. In still other cases, the clips may have been properly secured to the seat before the accident but rotated to the unsecured position during the impact or rollover. In the Bladensburg, Maryland, schoolbus accident, a nonswivelling clip "failed" because the bus seats had been reupholstered covering some of the clips in the process, and the clips were not properly resecured (case 27). Passengers were injured in this accident by contact with loose seat cushions and exposed seat support rails.

Even when not secured to the seat frame, seat cushions did not necessarily come loose and tumble around the passenger compartment. The type of accident determined whether they came free. For example, in an activity bus accident investigated by the Safety Board in Bloomfield Township, Ohio (case 8), a 1984 Carpenter schoolbus crashed head-on into the side of a passenger car which had gone out of control. After the collision, the bus ran off the road into a 5-foot drainage ditch and came to rest on its right side at a 45° angle.

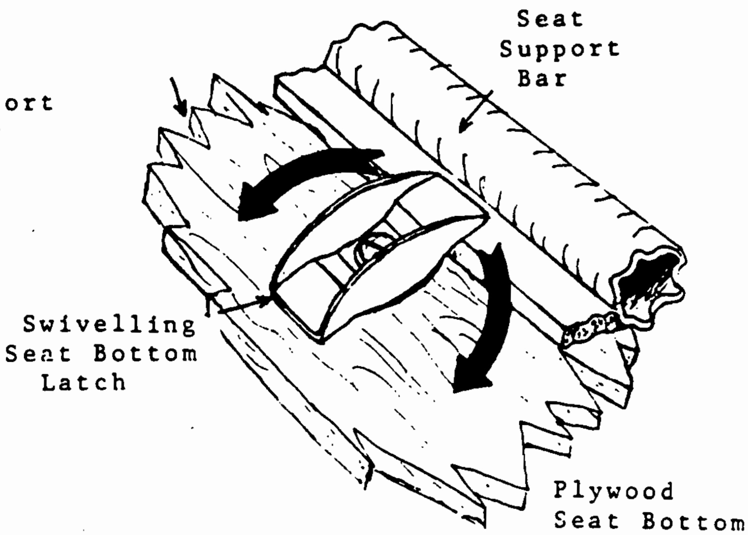
Following the accident, the Safety Board found that the bottom seat cushions of all passenger seats on the bus were unsecured but still resting on the seat frame. The system of attaching the seat bottoms on this bus consisted of three metal clips bolted to the plywood bottom of the cushion which were then fastened to the rails of the supporting seat frame. Two clips engaged the front rail, and the third clip rotated to lock the seat bottom in the frame. (See figure 25.) The Safety Board investigator found that all rear clips on the seats had rotated approximately 90° from the locked position. This allows the seat cushion to flip up and possibly become unhinged from the seat. In this crash, the accident dynamics were such that no seat cushion came loose. If the rollover had been more extreme, they could have come free.

Consequences of failure to secure the seat cushions in a more extreme rollover accident is illustrated by an accident in Swink, Oklahoma (case 29). This accident involved a 1982 Wayne bus in which all of the seat cushion clips had been left unsecured in order to facilitate sweeping the bus floor. Seven of the seat bottom frame clips could never have been fastened because the stationary front clips had been bent backward.

Moveable Prong Clip:
A single clip secures the rear of the cushion.



Formed Metal Swivelling Clip:
Two clips secure the rear of the seat cushion.



Stationary Clip:
Two clips secure the seat cushion.

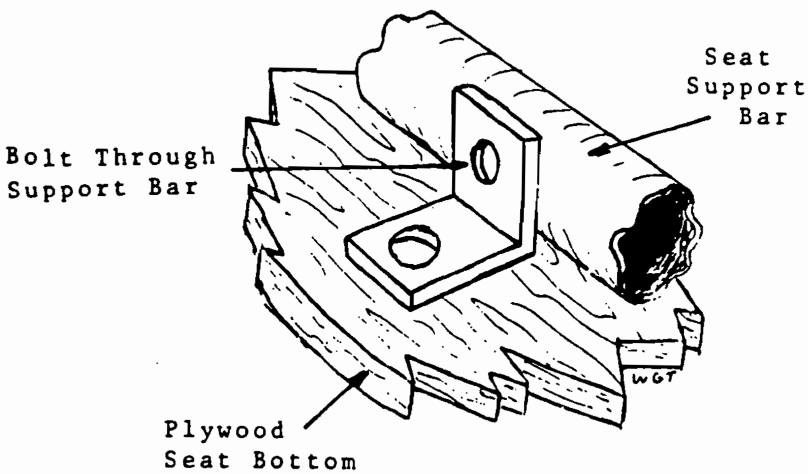


Figure 25.—Types of clips used to secure rear of seat cushion to frame.

When this bus made a 360°-revolution, every bottom seat cushion came loose and tumbled around the passenger compartment. Cushions struck three students and inflicted abrasions and lacerations. When the bus came to rest upright, the cushions littered the aisle and obstructed evacuation. Fortunately, no fire followed the crash and all students had time to climb over and around the seat cushions and evacuate the bus.

Since that accident, Wayne Schoolbus Company has implemented a more secure method of seat cushion attachment. Beginning with schoolbus bodies manufactured on or after July 11, 1985, all cushions are now permanently fastened to the front of the seat frame. This new attachment method should hold the cushion to the seat frame even if the rear clips are unsecured.

Even before this study, the Safety Board had been concerned about industry methods of seat cushion attachment. For instance, the Safety Board conducted a major investigation of an extremely severe schoolbus crash in 1984 in Rehoboth, Massachusetts (see case 41), in which a number of the 13-pound seat cushions came loose during the rollover. It is possible some of the movable seat cushion clips were not secured to the seat frames before the accident or that the clips rotated to the unsecured position during the rollover. At least seven seat cushions came loose and were lying on the inside panels of the bus after it came to rest on its roof. Although no injury could be traced to contact with the loose cushions, the potential danger prompted the Safety Board to issue Safety Recommendation H-84-75 to the NHTSA:

> For newly manufactured vehicles, revise Federal Motor Vehicle Safety Standard No. 222 to include a requirement that school bus seat cushions be installed with fail-safe latching devices which ensure they remain in their latched positions during impacts and rollovers.

The NHTSA replied on December 23, 1985:

> We share the Board's concern about improperly secured seat cushions that may become disengaged during an accident and become a potential hazard to passengers . . . . Nevertheless, it is our judgment that the seat cushion retaining clips would not likely have rotated to the unlatched position as a result of crash forces. We have no evidence that the seat cushion securement did not meet the requirements of FMVSS No. 222. In fact, a 1979 Wayne schoolbus was included in our compliance test program, and it passed the FMVSS No. 222 requirements. Also, we have measured the unlatching forces for seat cushion retaining clips on a small sample of schoolbuses, including two Waynes, used in our compliance test program and found the forces to be sufficiently high relative to retaining clip weights to likely keep retaining clips latched, even in a severe crash. As noted in the report, the retaining clips holding the cushions in place may not have been resecured by maintenance personnel. Properly secured, these clips hold the seat cushions in place, and no problems have ever been noted; therefore, we do not believe that a revision or amendment to the standard can be justified at this time. Certainly, retainers which rotate or loosen in use and/or failure to resecure the seat cushion retainers not only compromise FMVSS No. 222, but expose the manufacturers and operators to liability actions if such negligence should result in personal injury. We plan to contact schoolbus manufacturers and schoolbus operators, through their associations, and alert them to this potential problem.

The Safety Board responded, acknowledging that in the Rehoboth schoolbus crash it could not determine if the seat cushions came loose due to accident impact or because the clips were not secured properly. Nonetheless, the cushions had come loose and had posed a threat to the passengers. The Safety Board stated in its March 1985 response:

> It is our conviction that since there is a way to mount the cushions in a secure fashion, it should be used throughout the industry. There is a definite cause for concern when an anchoring device can lead to a safety hazard if it is not properly secured.

The NHTSA's reply on July 28, 1986, reiterated its position that insufficient data were available on which to base an amendment to FMVSS 222 at this time:

> No data indicate that seat cushions secured in compliance with FMVSS No. 222 are inadequate or that complying seat cushions have caused injury. Moreover, we believe that your concerns can be adequately addressed through means other than rulemaking action, such as through voluntary measures taken by manufacturers.

In September 1986, the NHSTA sent a letter to schoolbus manufacturers and schoolbus operators alerting them to the "potential problem" of loose seat cushions. During October, representatives of the schoolbus industry also attended a technical briefing on the Safety Board's schoolbus study and were presented with data on the pervasive nature of the problem of unsecured seat cushions (16 out of 44 schoolbuses in the study had all or some cushions unsecured) and the real life hazards posed by these loose cushions both during and following the crash.

In January 1987, the NHTSA the told the Safety Board that three schoolbus manufacturers had responded to the NHTSA's letter of information, saying that their new buses will have permanently attached seat cushions. In the same letter, the NHTSA reported the results of an informal poll they had conducted of manufacturers who had not responded:

> The six largest schoolbus manufacturers, representing approximately 80 percent of the new schoolbus production, have indicated that their seat cushions will be permanently affixed in future production. The remaining manufacturers could not give a definite answer, but indicated that a positive response, in line with the other manufacturers, was most probable.

The Safety Board is pleased with industry's prompt and positive response. Schoolbus seat cushions should be securely attached and remain attached to their seat frames even during a crash. In addition to improving crashworthiness, permanent attachment should help circumvent poor maintenance practices which otherwise could negate a well-designed attachment system.

The Safety Board is concerned, however, about the 20 percent of new schoolbuses which apparently will not have seat cushions permanently attached. The Safety Board urges those schoolbus manufacturers who, at present, do not have firm plans to implement permanent attachment to formulate such plans as rapidly as possible. In the meantime, the Safety Board believes that if a company plans to manufacture new buses without permanent seat attachment, the company must ensure that the method of attachment used provides a means for the schoolbus drivers, in their pretrip inspection, to ascertain visually from a standing position that the seat cushions are indeed securely fastened.

Permanent attachment is proposed, however, for new schoolbuses only. The problem of ensuring that seat cushions remain attached during a crash will persist in schoolbuses, both large and small 40/ currently in use. For this reason, based on the findings of this study, the Safety Board is issuing new recommendations designed to address the problem of loose seat cushions in existing schoolbuses.

The Safety Board also reiterates Safety Recommendation H-84-75 which urges the NHTSA to amend FMVSS 222 to require a more fail-proof method of seat cushion attachement. Whether the loose cushions came about as a result of improper maintenance practices by school personnel or as a result of the seat clip's failure to withstand crash forces is still not known in many of the cases in this study; 41/ therefore, the new recommendations are designed to address all the possible causes of cushion disengagement.

40/ Loose seat cushions are not confined to large schoolbuses. The Safety Board has investigated crashes involving small schoolbuses and school vans with loose seat cushions. (Little Rock, AR, FTW-83-F-H001; San Antonio, TX, FTW-H-OR20; Washington, D.C., no case number.)

41/ In a few cases, it clearly was a maintenance problem, as in the Lanconia, New Hampshire, accident (case 9) when some seats were totally without rear clips.

LAP BELT DISCUSSION

Whether larger poststandard schoolbuses should have lap belts for passengers has been debated since the beginning of Federal rulemaking on schoolbus occupant protection. 42/ (See appendix P for a discussion of seat belt-related rulemaking and seat design requirements.)

The Safety Board recently has issued a safety study on the performance of lap belts in passenger cars and vans in frontal collisions. 43/ However, the study did not include schoolbuses. Since schoolbuses are dissimilar in size, configuration, and possibly in the distribution of crash forces and the types of accidents in which they are involved, the question of lap belt performance in schoolbuses would necessarily require a separate study. Hence, the applicability of the Safety Board's lap belt study findings to poststandard schoolbuses is simply unknown. For the same reason, no other lap belt effectiveness estimates derived from analysis of nonschoolbus vehicles are necessarily valid for schoolbuses.

At this time, there are insufficient laboratory-generated data (basically crash tests) and real-life accident data on the effects of lap belt use on schoolbus passengers.

Schoolbus Crash Tests

Only three sets of crash tests provide current data on the performance of lap belts in poststandard schoolbuses: frontal crash tests conducted by Transport Canada (the Canadian counterpart of DOT) and side impact and frontal crash tests by Thomas Built Buses, L.P., a schoolbus manufacturer.

In the 1984 Transport Canada tests, 44/ researchers crashed three sizes of poststandard schoolbuses (66-passenger bus, a 22-passenger bus, and a 20-passenger van conversion) head-on into a fixed barrier at 30 mph. Lap belted and unbelted dummies equipped with instruments to record crash forces were used to estimate injury. 45/ Seat spacing on the buses varied between 21 to 27 1/8 inches, 46/ since Canadian researchers were concerned that closely spaced seats, an essential element of compartmentalization, might be incompatible with lap belt use. Regardless of seat spacing tested, Transport Canada concluded that "the use of lap seat belts in any of the three sizes of recent model

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42/ The Safety Board and other groups involved in schoolbus safety do not recommend that prestandard schoolbuses (buses built before April 1, 1977) be retrofitted with lap belts. Prestandard schoolbuses were not designed for use with lap belts and would require extensive modifications, i.e., replacement of seats and floor strengthening.

43/ For more detailed information read, Safety Study—"Performance of Lap Belts in 26 Frontal Crashes," July 28, 1986 (NTSB/SS-86/03).

44/ School Bus Collision Tests, TP6223E, Transport Canada, February 1985.

45/ Each bus contained six fifth percentile adult female instrumented test dummies complying with the U.S. anthropomorphic testing requirements then in force. The dummies, according to the Transport Canada, were to approximate "large elementary students." DOT presently does not have an approved child dummy other than a 6-month or 3-year-old child dummy. Hence, testing is done with scaled-down adult dummies to approximate children.

46/ FMVSS 222, the U.S. standard for schoolbus passenger seating, currently specifies that schoolbus seats may be no further than 24 inches apart as measured from a seating reference point (SRP). (See appendix O for discussion of SRP.) FMVSS 222 has, at other times, required seats to be no further than 20 inches apart. (See appendix P for details on spacing changes.)

school bus which were tested may result in more severe head and neck injuries for a belted occupant than an unbelted one in a severe frontal collision." (The results of the Canadian tests appear in appendix I.) Lap belted dummies on all three school vehicles received higher head injury scores than the unbelted dummies. On the large schoolbus, however, the lap belted dummies' head injury levels were below the life-threatening level; the levels were life-threatening in the smaller school vehicles. (Note: only one dummy on the large schoolbus sustained a life-threatening injury: the unrestrained dummy seated in the front row who struck the restraining barrier. This dummy sustained a chest force of 0.4 over the allowable limit.)

A significant contribution of the Canadian tests was the documentation of the difference in body movements between lap belted and unrestrained passengers in a frontal crash. (See figure 26.) Films showed that, for the unrestrained dummies, the crash forces tended to be spread out over a large area of their bodies, whereas crash forces for lap belted passengers were concentrated on their heads. During a frontal crash, unrestrained passengers moved forward and contacted the seat in front of them, first with their knees, then chest, and finally chest and face. Crash forces were thus spread out over time and a large area of the body. In contrast, in a frontal crash, the lap belted dummy pivoted around the lap belt, jackknifing forward, and striking the seat back with the head.

In 1986, Transport Canada conducted a second series of poststandard schoolbus crash tests using belted dummies. The tests used a variety of restraint options: lap belted dummies seated in modified schoolbus seats; dummies restrained by lap shoulder belts; dummies restrained by five-point harnesses; and dummies seated in rear-facing schoolbus seats. As of this date, test results have not been released.

The only other current crash test data on lap belts in poststandard schoolbuses come from side impact crash tests conducted by Thomas Built Buses in the spring of 1985 and a frontal crash test in the summer of 1986.

The first set of tests are described in detail in appendix J. A small schoolbus, a 16-passenger Thomas Minotour, was used, and both lap-belted and unrestrained 50th percentile dummies were used. The small bus was impacted on its left and right sides by a moving barrier at about 30 mph. Both restrained and unrestrained dummies were recorded as sustaining nonlife threatening head injuries during the side impact. Thomas Built Buses concluded, "Compartmentalization works as it was designed to work in frontal or side impact. These tests also indicate that in the case of the side impact, there seems to be very little significant difference between the belted and unbelted dummies in these test conditions relating to head and chest injuries."

In these crash tests, lap belted and unrestrained dummies were seated side by side, so the test results probably reveal more about the crash experience of a bus with both belted and unbelted passengers, than what is to be expected of a small schoolbus loaded with all unrestrained passengers or all lap-belted passengers. For example, if a lap-belted dummy is seated on the aisle, the dummy will help keep the unrestrained dummy seated next to him on the seat.

The second series of crash tests conducted by Calspan for Thomas Built Buses also involved a Minotour bus, a small schoolbus. In May 1986, Calspan crashed a 1986 Minotour bus into a frontal barrier at about 30 mph. In this test, two 6-year-old dummies and one fifth percentile adult dummy were used. One of the 6-year-old dummies was secured only by a lap belt; the other 6-year-old dummy and the adult dummy were secured by lap/shoulder belts. Load cells were placed on the belts to record the forces exerted on the abdomen and pelvis.

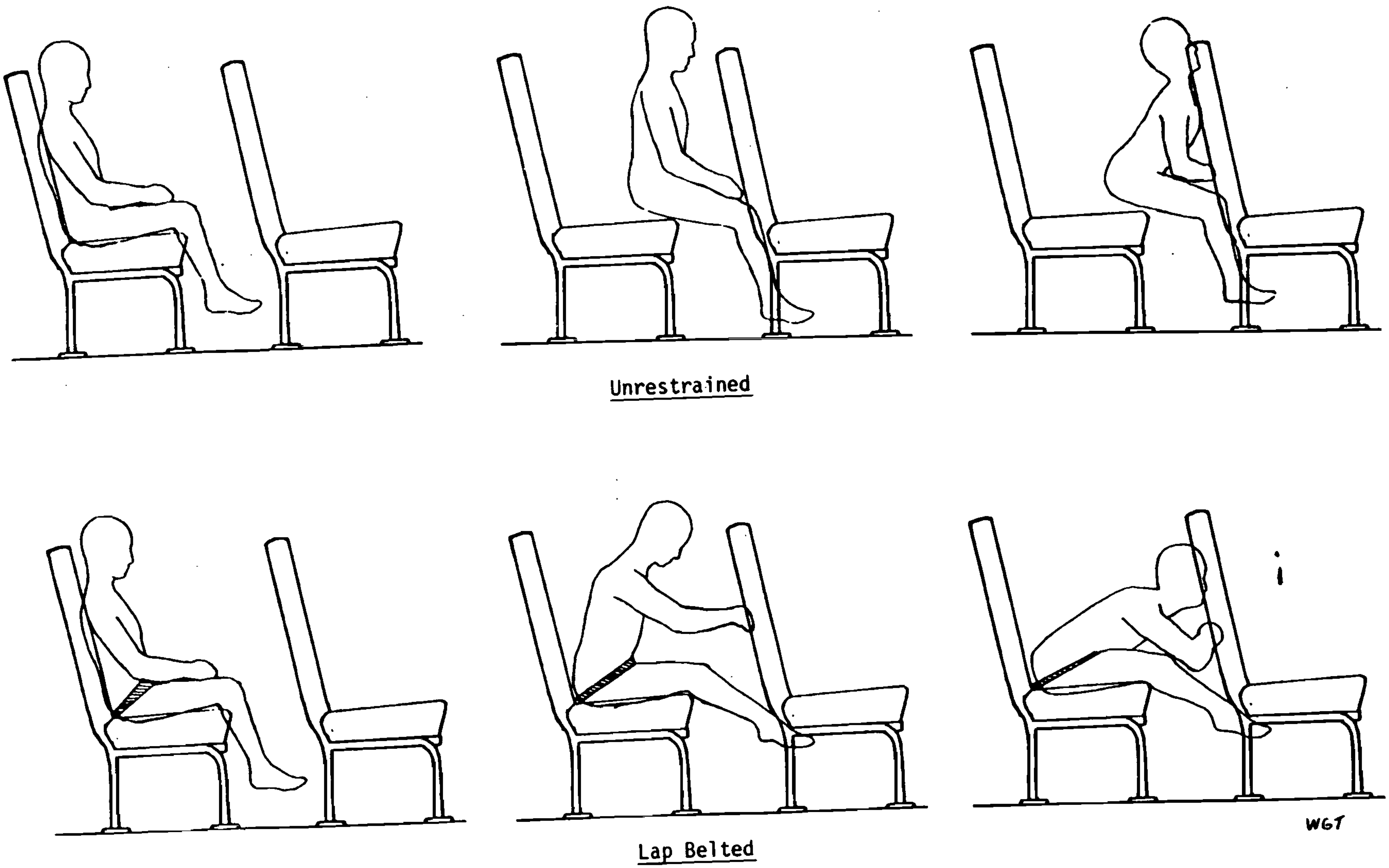


Figure 26.—Transport Canada crash tests:
Comparison of lap belted versus unrestrained dummy body movements in frontal crash.

On the 6-year-old dummy wearing the lap belt only, tension forces in the lap belt during the crash translated into "direct lap abdominal total pressures of 1,768 pounds at peak and in excess of 1,200 pounds on the lap or abdomen for a significant time period" according to Calspan. For comparison, the director of engineering for Thomas Built Buses offered an auto investigation involving a 128-pound adult female in which 1,573 pounds of abdominal pressure resulted in injuries which included tearing of the liver and lacerations of the colon. (The case is described in SAE Paper No. 791032, "Evaluation of Human Tolerance in Frontal Impacts" by D. Cesari and M. Ramet, published in the 23rd. Stapp Car Crash Conference Proceedings, 1979.)

The dummy wearing the lap/shoulder belt, registered much lower belt forces. The belt forces translated into "lap abdominal pressure of 440 at peak and above 300 pounds for a significant period of time."

In the November 12, 1986, issue of the "School Transportation Director" newsletter, Thomas Built Buses concluded that the abdominal pressure observed in the lap-belted dummy in its frontal crash test is "sufficient to indicate that serious consideration must be given before we install lap belts in schoolbuses." The Safety Board notes that the crash test involved a small schoolbus, not a large schoolbus, the type of vehicle under discussion.

The University of California in Los Angeles (UCLA) conducted crash tests in 1967; tests that also are frequently cited during discussion of whether lap belts are necessary on large schoolbuses. 47/ UCLA researchers used a variety of dummy types and sizes, restraint options (lap/shoulder belt, lap belt, air bag, etc.) and conducted three tests: a head-on collision between two schoolbuses, each travelling 30 mph; a stationary bus rear-ended by a passenger car travelling 60 mph; and a stationary bus impacted on its right side by a passenger car travelling 60 mph. These crash tests, however, used two prestandard large schoolbuses: a 1944 Mack-Superior Coach and a 1965 GMC-Superior Coach. The crash performance and interior design of a prestandard bus are not comparable to that of a poststandard bus, the vehicle under discussion. Furthermore, each of the prestandard buses crash tested by UCLA was outfitted with a variety of seat types. Ten different seat types, including a conventional seat found in a 1965 Superior bus, a fiberglass molded seat, an automotive-type "bucket" seat with headrest, and an airline seat were tested. None of these seats correspond to the type of schoolbus seat now mandated by Federal schoolbus standards. The results of the UCLA crash tests were influential in helping formulate Federal schoolbus standards; the crash tests, however, do not answer what the effects of lap belt use on today's schoolbuses would be. 48/ (See appendix L for the seating unit recommendations of the UCLA tests.)

The California Highway Patrol (CHP) has been asked by the California legislature to contract a statistical research and literature to review the issue of seatbelts on schoolbuses. 49/ A contractor has yet to be chosen for the $200,000 study on the effectiveness and advisability of seat belts in schoolbuses, originally scheduled for completion on March 1, 1987. The winter of 1987 is now the target date for completion.

47/ Severy, Derwyn M., Brink, Harrison M., and Baird, Jack D. "School Bus Passenger Protection," Institute of Transportation and Traffic Engineering, University of California, Los Angeles. Originally published in Society of Automotive Engineers (SAE) Transactions, Vol. 76 (1968), paper 670040.

48/ The film "Broken Bus," often shown by advocates of seatbelts on schoolbuses, shows films of the UCLA crash tests of prestandard schoolbuses.

49/ The CHP study is part of California law AB1974 signed by Governor George Deukmejian July 1986. Originally the bill required that seat belts be installed in new schoolbuses, but the State Senate removed the provision and limited the measure to the study.

As of 1987, about 140 school districts are reported to have some large poststandard schoolbuses equipped with lap belts for all passengers. So far as the Safety Board knows, none of these large belted buses have yet been involved in accidents of sufficient severity to test the effects of lap belts. The four cases involving restrained schoolbus passengers in the study did not yield data sufficient for comparison. In short, the Safety Board lacks real-life data on the effects of lap belts on injury outcome in crashes of large schoolbuses. This is not surprising, since schoolbus accidents of sufficient magnitude to produce passenger injuries are, in any case, extremely rare.

How the Lap Belt Analysis Was Conducted

In this study, the Safety Board has analyzed the injuries to unrestrained passengers of large poststandard schoolbuses, in order to estimate what difference lap belt use might have made. Injury outcome and contact points for 1,119 passengers were considered.

In performing the analysis, the Safety tried to answer the following questions for each passenger:

- What injuries sustained by the unrestrained passengers would have been eliminated if they had been lap belted?
- What injuries would have been sustained if the passengers had been lap belted and held in place?

To answer these questions, the Safety Board considered the body movements a lap-belted passenger could make in the particular accident and the passenger's relationship to crush and compartment deformation.

It is important to ask both questions. A lap belted passenger may sustain different injuries than an unrestrained passenger, but if the injuries are identical in injury severity, no injury reduction would result from belt use. (See figure 27.) The Safety Board's analysis reflects the informed, best judgment of safety professionals, based on knowledge of the body movements to be expected of a lap-belted passenger. Lap belt analysis is part of each case summary in appendix A. The possibility that lap belts would increase the risk of head injury (as suggested by the Transport Canada crash tests) or would introduce other belt-induced injuries (intra-abdominal, spinal), was not factored in the overall analysis although mentioned in relevant case summaries.

Table 7 provides a summary of the potential impact on schoolbus fatalities and surviving passengers had they been wearing lap belts. The Safety Board found, on the basis of its investigations, that passengers riding on large poststandard schoolbuses would, overall, receive no safety benefit from lap belt installation and use. (Indeed, the number of schoolbus passengers killed could have increased by one.) If lap belt-induced injuries, especially the chance of increased head injuries, were to be factored in, the net result of lap belt use in the Safety Board's cases would have been negative.

As a result of this study, the Safety Board reaffirms its 1983 position, as expressed in a letter to the Governors, that from a safety viewpoint, there is not "sufficient justification at this time to recommend extending the mandatory passenger restraint system requirements to large schoolbuses." Furthermore, the Safety Board no longer "would support decisions by parents and State and local school authorities to install occupant restraint systems in their large buses on an after-market basis." Further discussion of the Safety Board's decision regarding lap belts for schoolbus passengers appears in the Lap Belt Summary chapter.

Table 7—Lap belt analysis

Potential Impact on Schoolbus Passenger Fatalities

Out of a total of 13 schoolbus passenger fatalities, lap belt use probably:

Could have prevented	:	2 deaths
Would have made no change	:	10 deaths
Effect cannot be determined	:	1 death

In addition, lap belt use possibly would have caused 3 surviving passengers to die. See accident in Snow Hill, North Carolina (case 14) and St. Louis, Missouri (case 13). (Probable net effect: none; possibly one additional passenger would have been killed.)

Potential Impact on Surviving Schoolbus Passengers

Severe to maximum injuries (MAIS 4 or above)

Out of a total of 4 surviving passengers with injuries MAIS 4 or above, lap belt use probably would have:

Reduced injuries to MAIS 3 and below	:	1 passenger
Made no change	:	2 passengers
Worsened outcome	:	1 passenger

(Probable net effect: none.)

Serious injuries (MAIS 3)

Out of a total of 24 surviving passengers with injuries MAIS 3, lap belt use probably would have:

Reduced injuries to MAIS 2 or below	:	8 passengers
Made no change	:	12 passengers
Worsened outcome to MAIS 4 or above	:	1 passenger
Effect cannot be determined	:	3 passengers

Note: One passenger in the "reduced" category had a seat belt available but did not use it. Five passengers in the "no change" category might be equally well placed in the "worsened" category. See accident in Cherokee, Iowa, (case 38) and Brunswick, Georgia (case 40).

Moderate injuries (MAIS 2)

Of the total of 58 surviving passengers with injuries MAIS 2, lap belt use probably would have:

Worsened outcome to MAIS 3 or above (primarily passengers in extremely severe crashes)	:	12 passengers
Effect cannot be determined	:	46 passengers

For about 9 of the passengers with moderate injuries, lap belt use might have lessened injury severity, but the injury outcome is unknown (i.e., whether passengers would have received minor or no injuries.) For the remainder of the unrestrained schoolbus passengers (those with no injuries, or minor injuries), while the Safety Board did estimate in some individual cases the effect lap belt use could have made, overall, it is not prepared to make the same injury outcome determinations as done for the higher level injuries. It is unlikely lap belt use would have reduced the minor injuries.

Figure 27.—The number of students who sustained minor injuries in the Fort Myers, Florida collision rollover (case 34) would not have been altered by lap belt use. The accident had at least three injury-causing events: side impact, a 90° counterclockwise lateral rotation, and a 90° overturn. Lap-belted passengers would have had ample opportunity to contact one another, the sidewalls, and the seat backs in front of them to sustain at least minor injuries.

The Safety Board first conducted a fatal/nonfatal analysis to determine whether passenger lives would have been saved had they been wearing lap belts. It also considered cases involving unrestrained passengers who survived the accident, but who might have been killed if they had been lap belted and, therefore, had remained in their precrash seating position.

The Safety Board then analyzed the injuries sustained by surviving schoolbus passengers. Injuries were grouped into three categories: uninjured to moderate injuries (MAIS 0-2); serious injury (MAIS 3); and severe to maximum injuries (MAIS 4-6). The Safety Board then looked at each unrestrained schoolbus passenger in the study, in terms of injury level, probable contact points for these injuries if known, accident dynamics, precrash seating position in relation to bus damage, and crash forces. Based on these factors, the Safety Board estimated the probable change in injury outcome if the passenger had been lap belted.

Analysis of possible change in injury outcome for the uninjured to moderate injury (MAIS 0-2) group proved difficult. Little is known about the effect of restraint use on minor and moderate injuries; seat belts of all types are thought to be only about 10 percent effective in passenger car front seats against minor (MAIS 1) injuries. 50/

Finally, the effect of lap belt use on passengers who were unrestrained and uninjured also is unclear. As noted earlier, some crash tests suggest that lap belted passengers on poststandard schoolbuses run the risk of increased head injury. The Canadian frontal crash test discussed earlier in the chapter found this to be true. Since a lap belt holds a passenger's pelvis on the seat, it increases the fulcrum-like effect. This means lap -belted passengers may experience increased opportunity for injury in frontal, rear, and side impacts as well as during rotation as the passengers pivot about the belt, striking the interior and other passengers with increased force.

Thus, it is possible that passengers who were unrestrained and uninjured, if lap belted in the same crash, would have sustained injuries. Data just are not sufficient at this time on which to base judgements as to the outcome or the severity of injuries to be expected. Therefore, the Safety Board did not reach conclusions in its summary table as to the change in outcome for unrestrained uninjured passengers and those with minor injuries. The individual accident summaries do mention instances in which the accident sequence indicates an unrestrained passenger with no injuries or minor to moderate injuries might have been better or worse off if lap belted. In some cases it was clear that the unrestrained passengers had left their seating position before intrusion at that seating position.

Early Rulemaking Proposals and Lap Belts

The use of lap belts in schoolbuses has been the subject of much debate since the earliest days of Federal proposals to set schoolbus standards. The debate has centered on FMVSS 222, Schoolbus Passenger Seating and Crash Protection. When the standard was first proposed in 1973, it included a lap belt option 51/ along with specific seat design requirements: seats were to be placed no more than 40 inches apart as measured from a seating reference point (SRP) 52/ and were to be at least 28 inches high as measured from

50/ U.S. Department of Transportation, Final Regulatory Impact Analysis of the Amendment to FMVSS 208: Passenger Car Front Seat Occupant Protection, July 11, 1984. Assuming 100 percent use rates (all car occupants use lap belt all the time) the NHTSA estimates lap belt use for front seat occupants of passenger cars to be 30 to 40 percent effective against fatality, 25 to 35 percent effective for MAIS 2 to 5, and 10 percent effective for MAIS 1. These estimates, however, are for front seat car occupants only. For rear seat occupants in frontal crashes the NHTSA found lap-belted and unrestrained passengers had about the same fatality risk and also that the unrestrained back seat passengers had the same fatality risk in frontal crashes as a lap/shoulder belted driver. (Kahane, Charles J., "Fatality and Injury Reducing Effectiveness of Lap Belts For Back Seat Occupants," SAE Paper No. 870 486.)

51/ The lap belt option included an alarm system which would signal both the schoolbus driver and passenger if the passenger was not belted when the vehicle was in motion.

52/ The SRP is essentially the manufacturer's design reference point which simulates the pivot center of the human torso and thigh.

the SRP. 53/ (See figure 28.) The standard also included substantial padding requirements. (Appendix P presents details of this and other seat belt-related schoolbus proposals).

The 1973 proposal envisioned seats that would be radically different from the seats in schoolbuses manufactured in the 1960's and, for that matter, different from those in schoolbuses today.

The 1973 proposal, however, was not adopted. Instead, a new proposal was issued, considerably different from the first. The lap belt option had been eliminated and schoolbus manufacturers were to be required to provide only seat anchorages for lap belts. Seats were to be placed very close together, no more than 23 inches apart (as measured from the SRP), and the seat back height requirement was reduced to 24 inches (as measured from the SRP). Thus, the concept of passive protection for schoolbus passengers through "compartmentalization" was adopted over that of active protection through the installation (and necessary use) of lap belts. This is the concept in use today.

"Compartmentalization" is considered passive protection because no action (such as buckling a lap belt) is needed by a schoolbus passenger to obtain protection. Protection is automatically provided by the high backed, padded seats placed close together. (See figure 29.) Compartmentalization essentially is the concept of a "friendly interior," a form of passive protection which U.S. car manufacturers have begun to introduce in a few models.

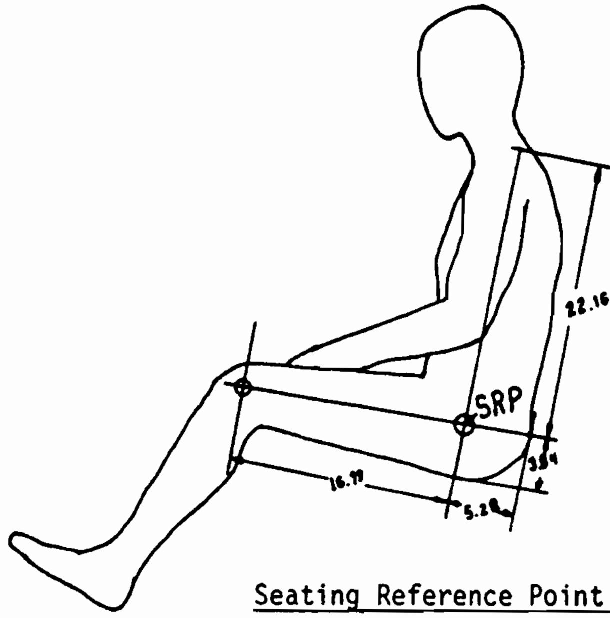
The proposals for FMVSS 222 underwent several more modifications before being finally enacted in 1976. Today, there is no requirement for seat belt anchorages; the seat back height requirement has been reduced to 20 inches; and the maximum allowable seat spacing has increased to 24 inches; it was only 20 inches when the rule was first enacted. Thus, seats in today's buses are considerably different from the seats proposed for use with the lap belt option in 1973. Petitions by seat belt advocates to require lap belts or at least require belt anchorages and to increase the seat back height to the original 28 inches have been consistently denied by the NHTSA.

The NHTSA has also not ruled on a proposal that, if States or school districts voluntarily install seat belts for passengers of large poststandard schoolbuses, these belts be required to meet the same Federal safety standards required of restraint systems in passenger cars, namely FMVSS 208, 209, and 210.

53/ In the introduction to the proposed rule, the NHTSA made clear that the seat back height requirement (of at least 28 inches) reflected the results of schoolbus crash tests conducted for the agency at UCLA in 1967. The UCLA study was quite explicit that seat belts should not be installed on seats with seat backs less than 28 inches high, stating:

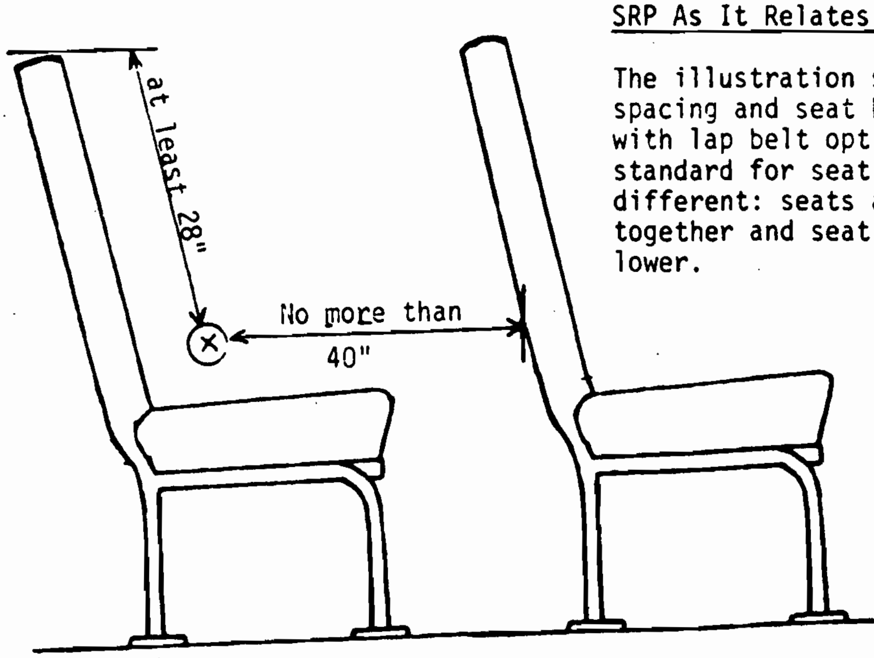
> During front-end impacts and following rebound from their seat backs for rear-end collisions, the lap-belted passenger pivots about his belt and slams his head, face, and if tall enough, his chest into the seat back ahead. The low back seat presents dangerous surfaces to the belted or unbelted passenger hurled forward against it during the collision. In addition, exposure to serious back and neck injuries results when passengers in low back seats experience a rear-end collision.

(The complete text of the UCLA study's occupant protection findings appears in appendix L.)



Seating Reference Point (SRP)

SAE Standard Two-Dimensional Manikin



SRP As It Relates to Seat Design

The illustration shows original seat spacing and seat back height proposed with lap belt option. The current standard for seat design is quite different: seats are placed closer together and seat backs are considerably lower.

Figure 28.—Illustration of seating reference point (SRP).

Figure 29.—High backed, well padded seats placed close together and securely fastened to the floor form the basis of the passive protection concept of compartmentalization mandated by FMVSS 222. Not all poststandard seats are the same; the minimum height and spacing requirements of the standard have varied over the years.

Arguments for Lap Belt Installation

One argument advanced by proponents of lap belt installation in schoolbuses is that children should be provided "protection similar to that available in the rear seats of automobiles." 54/ Many belt proponents believe that schoolbus "compartmentalization" offers protection only in frontal or rear crashes. They also argue that discipline on buses might improve if children were belted. Furthermore, proponents feel children need to "form the buckle-up habit" in schoolbuses in the hopes that the habit will carry over into the family passenger car, the vehicle where the overwhelming majority of child occupant deaths and injuries occur. Belt proponents feel that children receive an inconsistent message about restraint use when seat belts are not available in large schoolbuses.

Popular misconceptions about the protection offered by seat belts have complicated the debate over whether poststandard large schoolbuses should have lap belts for passengers. It is crucial to understand that no belt system can prevent all injuries or

54/ January 23, 1986, letter from child passenger safety researchers at the University of Michigan to colleagues concerned about child passenger safety.

deaths. Belt systems are effective against total ejection and, to a lesser extent, against partial ejection, i.e., lap-belted passengers seated next to a window could still get their arms out the window. 55/ Some researchers have suggested that the main benefit of lap belt use is to prevent ejection and the potential serious injuries associated with that event. If this is the case, the experience of schoolbus passengers in the Safety Board's study does not suggest a strong benefit from installing lapbelts in schoolbuses; ejection was rare and lap belts would have prevented only some of the ejections and would not have reduced injury severity even for some of these ejected passengers. 56/

A look at how a lap belt would restrain a schoolbus passenger in various types of crashes might be helpful in understanding the advantages and disadvantages of this form of seat belt, for it is precisely lap-only belts which are under discussion for poststandard large schoolbuses. (Lap belts can be installed on existing schoolbus seats; lap/shoulder belts, if possible at all, would require substantial seat redesign.) Lap belts, unlike lap/shoulder belts, do not provide upper torso restraint. This means the head and chest are free to react to crash forces. The upper and lower extremities — the arms and legs — also are free to move (as they would be in any belt restraint).

Lap-Belted Schoolbus Passengers in Frontal Impact

A properly worn lap belt will keep passengers' pelvis firmly on the seat, and they will not slide off the seat, be propelled over the seat at the initial impact, or fall into the aisle at rebound. Contact with areas of the bus damaged by crush or penetration will be limited to those in the immediate seating area. The passenger will not be ejected unless the bus bench seat is torn out or the belt is torn or damaged (or worn too loosely).

At impact, a body restrained by a lap belt will "jackknife" — the head and chest will pivot forward from the hips and the arms and legs will flail forward and then rebound back. (See figure 30.)

If lap-belted passengers are tall enough (if the upper torso is long enough), their heads or necks will strike the seat back in front, the lower legs will come up underneath the seat in front, possibly striking the seat legs or the bottom of the seat in front, and the arms will strike the seat back or the passenger in the adjoining seat. At rebound, the passenger's body will move back into the seat.

Small children wearing a lap belt would be less likely to contact the seat back or seat frame with any part of their anatomy. (See figure 31.) Their heads could go between the legs and hit the seat if crash forces are severe enough.

A rear-end accident would be similar to a frontal accident for lap belted passengers of all ages, except that the passengers would first accelerate backward into the seat, bending their heads and necks, if it extended above the seat back, over the seat, with arms and legs flailing up. On rebound (generally a weaker force), the passengers may jackknife forward.

55/ Other Federal safety standards also relate to ejection prevention: for passenger cars, those governing door locks and window glazing help reduce ejection; for schoolbuses, those governing body joint strength and window retention are related to ejection.

56/ In the Safety Board's schoolbus study, only 15 of the 1,119 unrestrained schoolbus passengers were known to be fully or partially ejected. Lap belt use probably could have prevented only nine of these ejections (see case 14, Snow Hill, North Carolina). Injury severity for six of the nine ejectees probably would not have been reduced if these six had been protected from ejection by a lap belt.

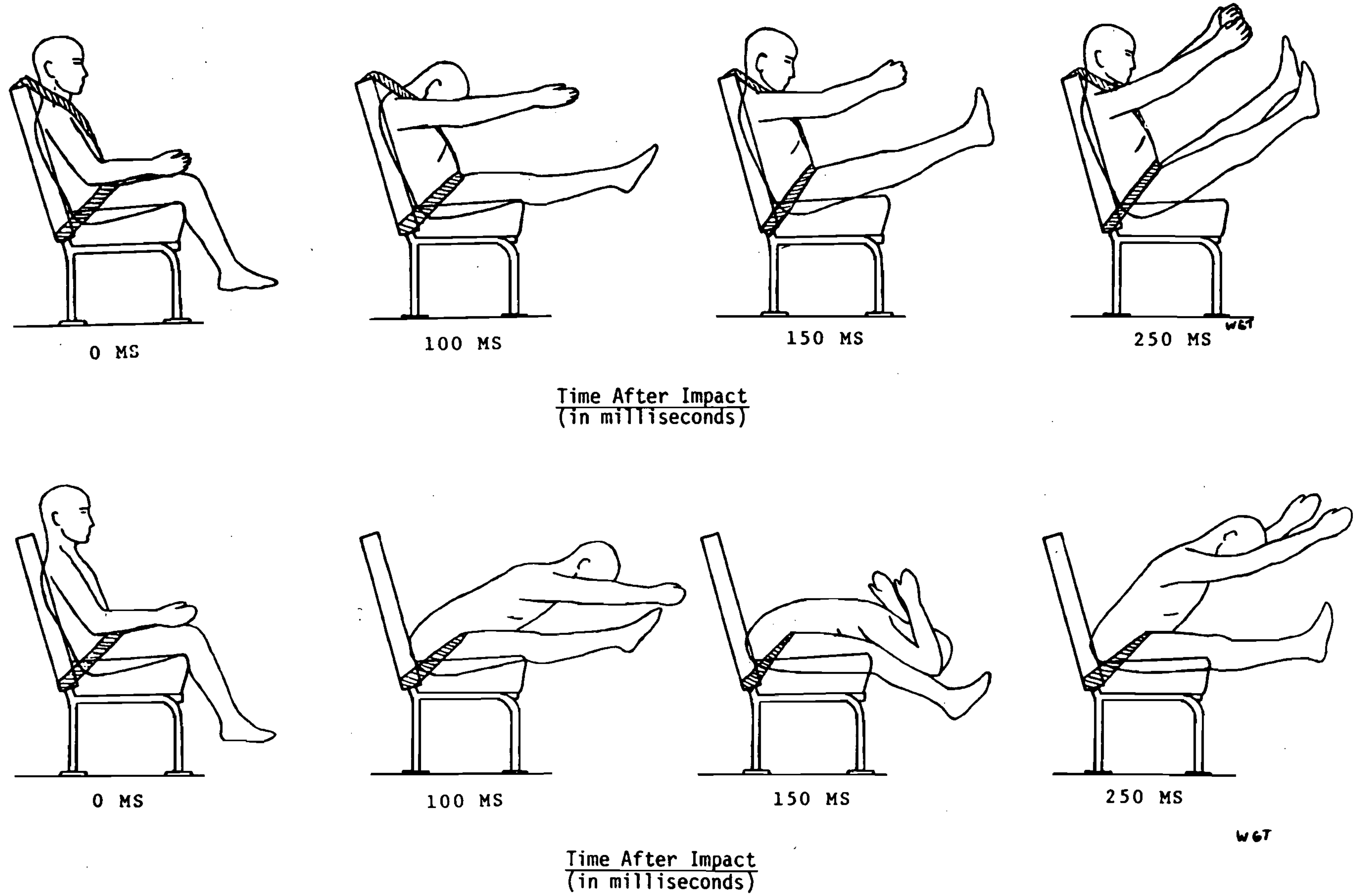


Figure 30.—Body movements during frontal impact: comparisons of lap-belt restrained occupant versus lap/shoulder belt restrained occupant. (Source: Child Restraint Systems, Frontal Impact Performance by Thomas Turbell, Stockholm 1974 Report No. 36A.)

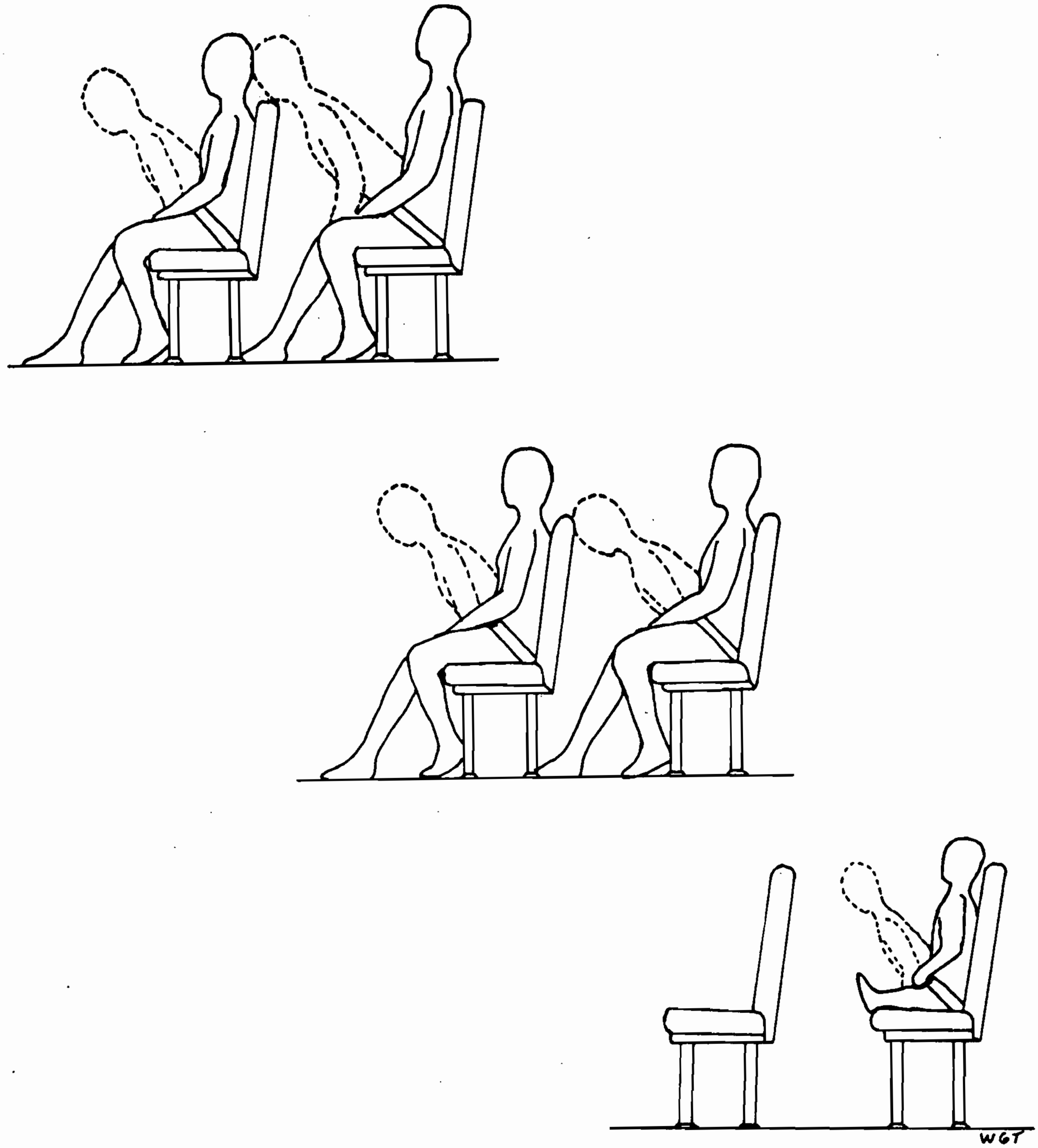


Figure 31.—Passenger size will determine if and how lap-belted passenger will strike seat back in frontal collision.

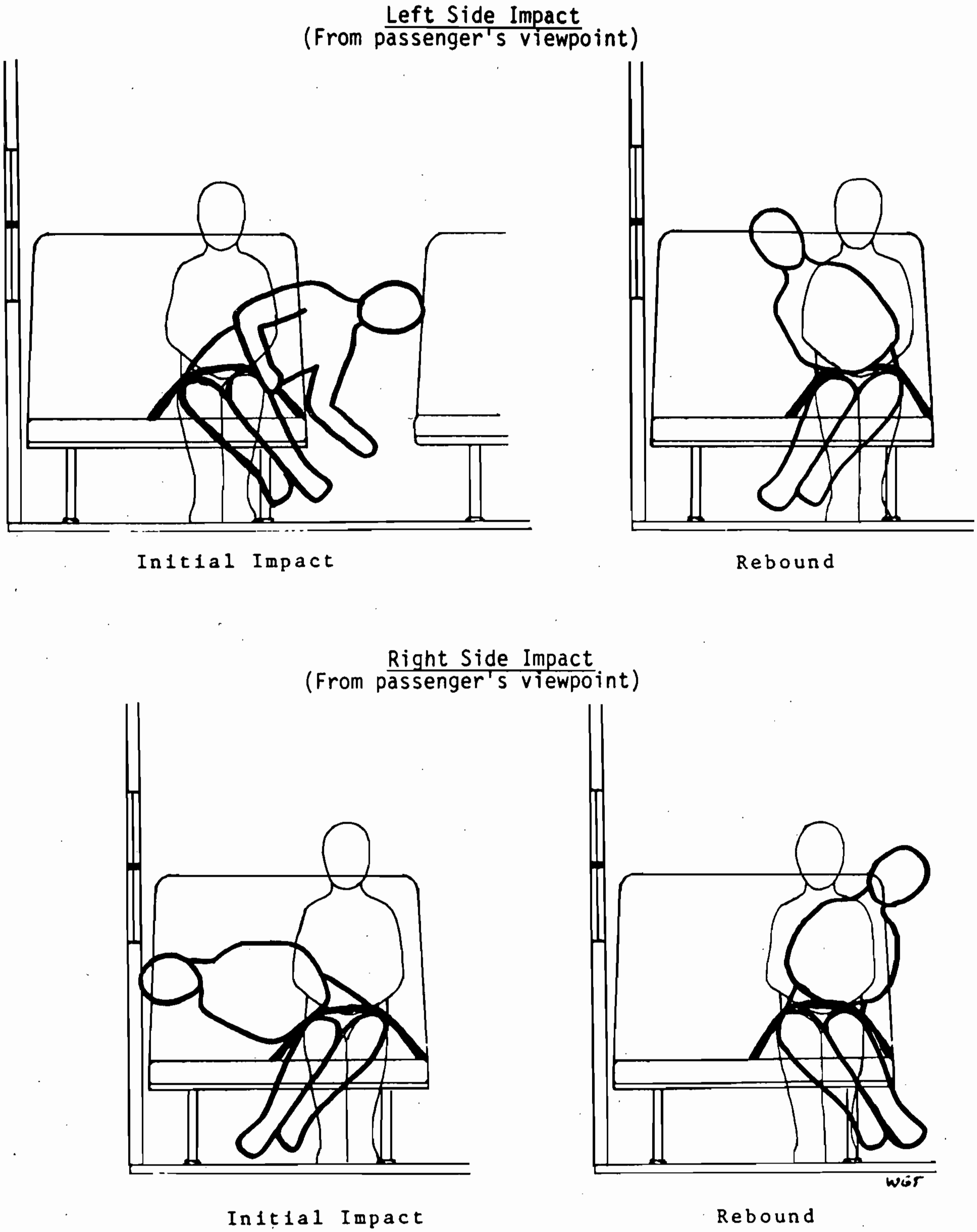


Figure 32.—Movement of lap-belted passenger seated alone on seat in a side impact accident.

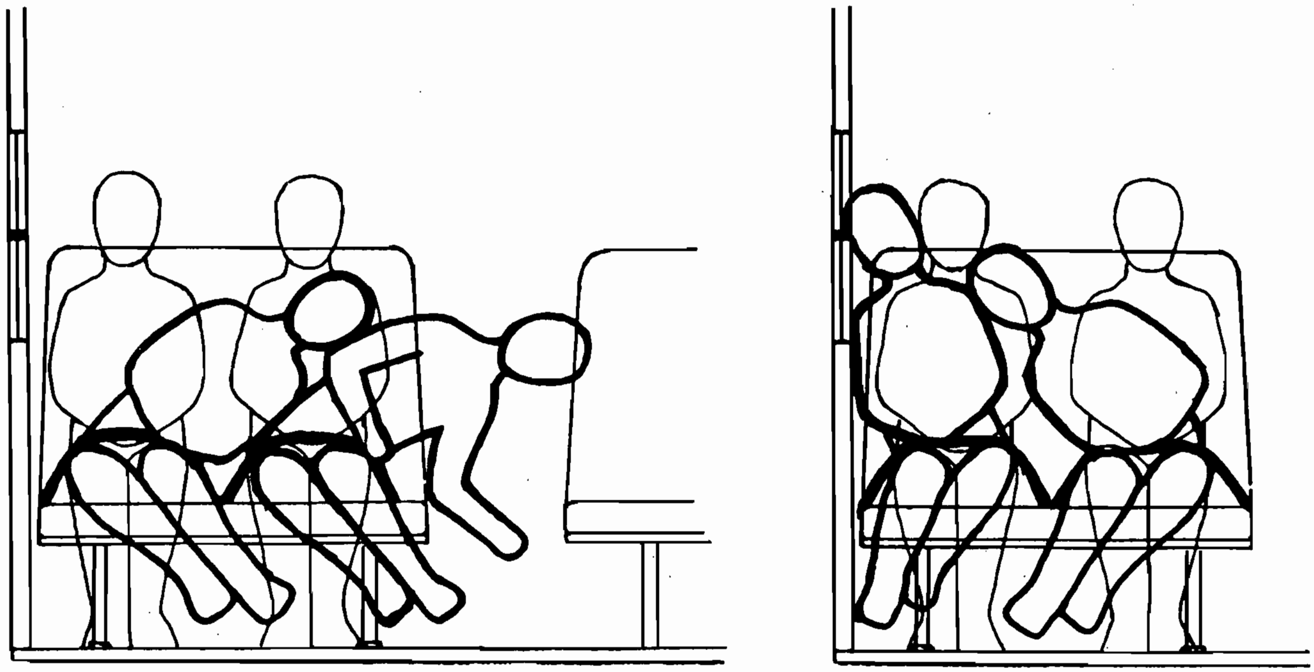
<u>**Lap-Belted Schoolbus Passengers in Side Impact**</u>

In a side impact accident, a lap-belted passenger's upper torso, arms, and legs will go in the direction of the impact (i.e., the torso moves toward the right in a right side impact). If seated by the window, the passenger will hit the window, window frame, and/or side wall either at initial impact or at rebound. A lap-belted passenger seated on the aisle, if tall enough, can contact the next seat across the aisle if impact comes from that side. If impact comes from the other side, the passenger in the aisle can strike the neighboring passenger or even the side wall or window. (See figures 32 and 33.)

Since a lap belt does not provide upper torso restraint, it will not be able to keep the passenger upright. Hence, lap-belted passengers seated next to each other on the bench seat will be free to strike one another in a side impact, hitting heads and flailing arms or legs. If passengers are seated alone on the bench seat, they can pivot and fall sideways on the seat, although their pelvis' are still held by the belt.

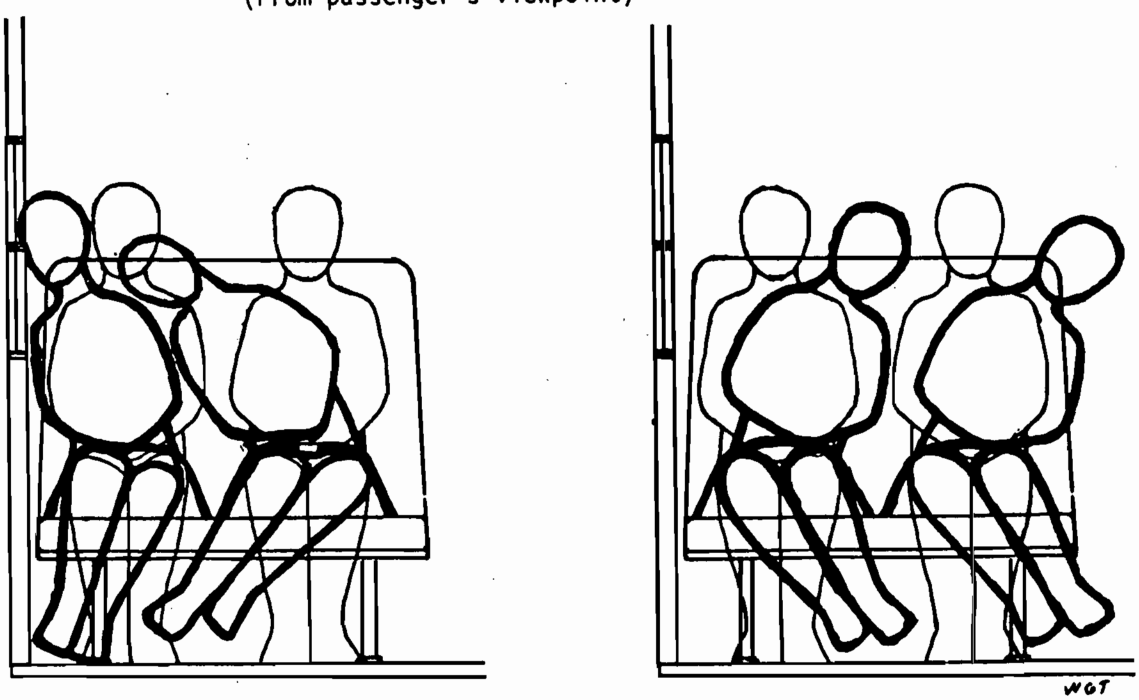
Lap belt use will ensure that the passenger remains in the same seat. The passengers will receive no protection if they are in the direct impact zone, but may gain some protection if seated outside the major impact area. The passenger then will not be thrown across the bus into the next row of seats or into the aisle. Contact with areas of the bus damaged by penetration or crush will be limited to those passengers in seating positions immediately adjacent to the damaged area. Again, ejection would be impossible unless the bench seat itself is ejected or the belt is compromised (or worn too loosely).

Left Side Impact
(From passenger's viewpoint)



Initial Impact Rebound

Right Side Impact
(From passenger's viewpoint)



Initial Impact Rebound

Figure 33.—Lap-belted passengers' movement in a side impact accident.

Lap-Belted Passengers in Rollover

Rollover is a considerably more complex situation. The lap-belted passengers seated away from the side on which the bus comes to rest gains some measure of protection, since they will not be flung to that side and sustain the ground impact; lap belt use will not protect passengers seated on the near side, however. The dimensions of the bench seats are such that all passengers, even preschoolers, seated on the impact side will be able to contact the windows and side walls. (See figure 34.)

Total ejection is unlikely unless the seat itself is ejected or the lap belt is compromised or worn too loosely. Partial ejection is still possible.

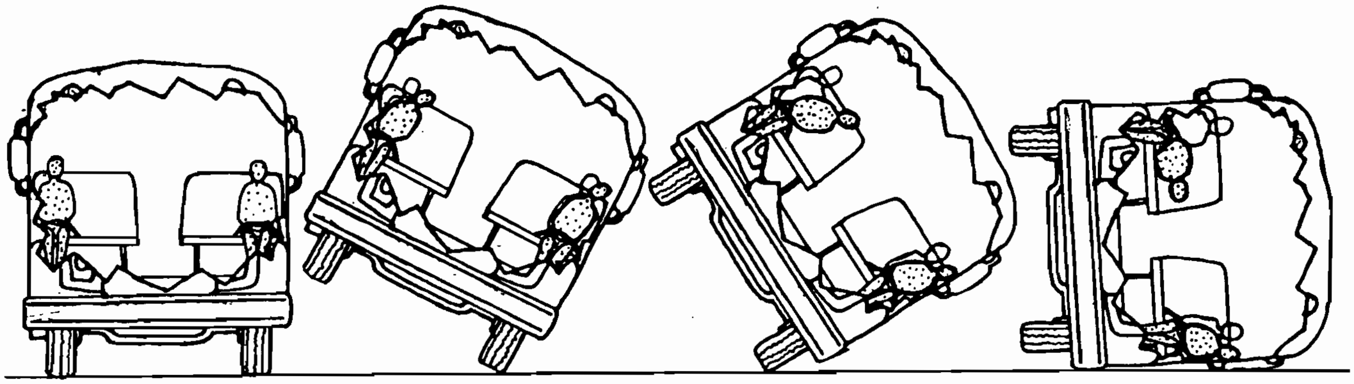
Regardless of where they are seated, lap-belted passengers will still be free to strike one another during the rollover and to hit the windows, side walls, and seat backs during the rollover. Contacts with flying objects, such as broken glass, books, and lunch pails, also will not be prevented by lap belt use. If the roof crushes in at their seating position, lap belt use will be of little benefit, and may, in fact, increase chance of injury (since otherwise they might be moved from that position before the roof crush).

In passenger cars, lap/shoulder belts clearly provide superior occupant protection to lap-only belts, particularly in frontal collisions; they may perform only slightly better in side collisions, since the lap/shoulder-belted passenger can still slide out from the shoulder harness if the impact comes from the side of the shoulder anchor point. (Seat belts, of all kinds, are expected to provide protection primarily in front impacts and rollovers and only limited protection in side impacts. Some researchers have suggested their main function in a side impact is to reduce the chance of ejection.)

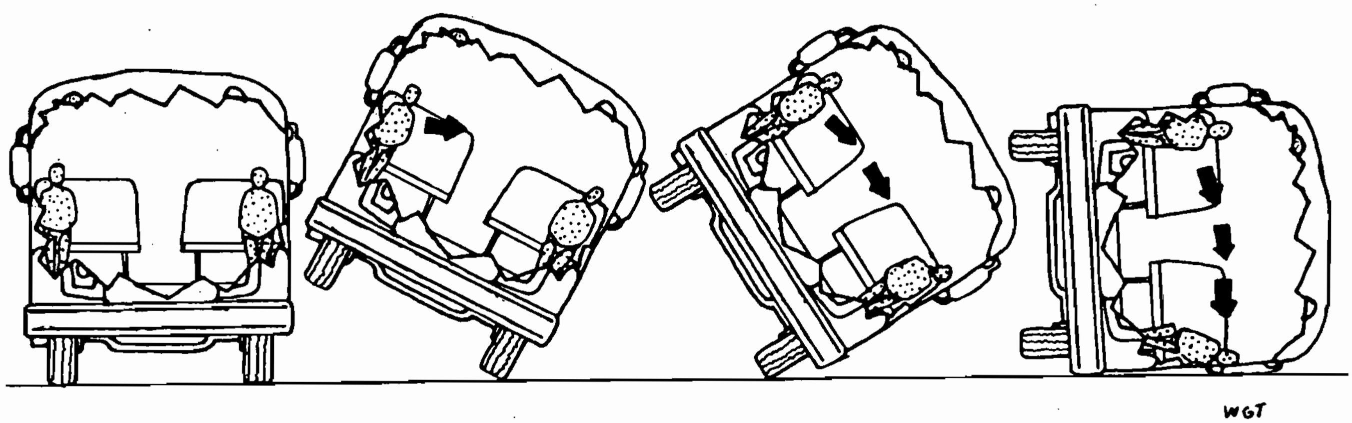
Unfortunately, the feasibility of lap/shoulder belt installation in poststandard schoolbuses is unclear, as are the safety benefits to be expected in terms of injury reduction. (Thomas Built Buses has conducted some crash tests with lap/shoulder belted dummies in a prototype small schoolbus, and Transport Canada is conducting tests using a large schoolbus.) Little is known about the changes in seat design which would have to be made before lap/shoulder belts could be installed on large poststandard schoolbuses.

One problem is that the Federal requirements for lap/shoulder belt anchorage may conflict with the Federal requirements for schoolbus seat back strength (one of the key components of compartmentalization). It may be that the energy absorbing schoolbus seats now required would be incompatible with lap/shoulder belt installation, since the anchorage requirements for such belts may require a "stiffer" seat.

One manufacturer has suggested that FMVSS 222, the Federal standard which sets schoolbus seat performance requirements (the basis of compartmentalization), may be in conflict with FMVSS 210, the Federal standard which specifies anchorage requirements for a lap/shoulder belt. Specifically, seats in a poststandard schoolbus are designed to yield and absorb crash forces; anchorage requirements for lap/shoulder belt might require that the seat back be stiff. (FMVSS 222 specifies that seat backs must yield when 2,400 pounds of pressure is reached, while FMVSS 210 requires a shoulder belt anchorage to resist a minimum of 3,000 pounds applied to the pelvic and upper torso blocks simultaneously without yielding.)



Restrained Passengers



Unrestrained Passengers

Figure 34.—Comparison of movements of lap-belted schoolbus passengers versus unrestrained schoolbus passengers (90°-rollover).

This means one or more of the following changes may be necessary before lap/shoulder belts can be installed:

1. The Federal standard setting performance requirements for schoolbus seats may have to be amended to allow stiffer seats, thus reducing the benefits of compartmentalization.

2. The shoulder portion of a lap/shoulder belt must be attached to a point other than the frame of the schoolbus seat so excessive loading would not occur (but no other location seems obvious).

3. A Federal standard for lap/shoulder belt anchorages applying only to schoolbuses would have to developed.

Habit Formation

It has been suggested that the largest safety benefit of lap belt use in schoolbuses would be that this use might have a "carryover effect" of increasing students' use of seat belts in passenger cars. Passenger car crashes remain the leading cause of death for children under 14 years of age, and increased restraint use could reduce the number of these child passenger casualties.

In February 1986, the NHTSA released a report 57/ on this theoretical "carryover effect," based on a study of nine school districts that had initiated their own bus belt programs. Study sites accounted for 85 percent of 143 lap belt-equipped large schoolbuses operating in April 1985. No surveys were conducted; the data were the result of self-reported use and informal discussions with a nonstatistically sampled group of students, parents, schoolbus drivers, and school officials.

Reported belt use by grade school students aboard the lap-belted buses appeared to be about 80 to 100 percent; reported high school usage was 50 percent or less.

The NHTSA found no conclusive evidence of a "carryover" effect between the schoolbus and family car. The report concluded:

> Parent car rules and attitudes, mandatory State car belt use laws, and classroom education programs appeared to play more dominant roles in students' car belt use than bus-belt carryover effects. . . . As more States enact mandatory car belt use laws, more students will already use car belts, and hence, fewer will remain to be affected by any possible carryover effects.

Furthermore, the NHTSA noted that because only a fraction of the school districts in the United States have the demographic, academic, and other characteristics of the study sites, schoolbus belt use rates in other districts may not be as high and the likelihood of "carryover" effect may be even more diminished.

Some evidence of "carryover" was claimed in a 1984 self-reported survey of elementary students in Glenoe, Illinois. All kindergarten, first, second, and third grade students were asked in May 1984 (before they rode in lap belt-equipped buses) whether

57/ School Bus Safety Belts: Their Use, Carryover Effects and Administrative Issues, DOT HS 806965, Final Report, February 1986.

they never, sometimes, or always wore their seatbelts in the family car or in a friend's car. They also were asked whether their parents never, sometimes, or always wore their seat belts. In late fall, the young children were again surveyed regarding their seat belt habits. Since the beginning of the school year, the elementary students had been riding in belted buses and now had viewed films on the need for seat belt use. Of the 704 students responding, 23.6 percent reported they had increased their own seat belt use in passenger cars and 4.6 percent had decreased. The grade school students also suggested that parents had increased use by 20 percent.

Of course, all surveys of self-reported use are to be viewed with caution -- over-reporting is common. The NHTSA found that the use rates cited were those of students who said they used lap belts at least some of the time or who were observed by drivers to be buckled up at a particular time while on the bus. Full-time belt use is implied by belt use rates; this might not be true. Observers also noted that some students in the NHTSA study who wore their belts failed to tighten them and wear them properly. (At least one district has ordered retractable safety belts to solve this problem.)

Based on the evidence available thus far, a strong case cannot be made that lap belt availability on poststandard large schoolbuses will result in safety benefits to student passengers because of the increased seat belt use it will engender in passenger cars.

LAP BELT SUMMARY

Based on the findings of this study, the Safety Board does not recommend that States or school districts allocate funds to retrofit or order large poststandard schoolbuses with lap belts for passengers. The Safety Board also does not recommend that Federal schoolbus safety standards be amended to require that all new large schoolbuses be equipped with lap belts for passengers. The safety benefits of such actions, both in terms of reduced injuries for schoolbus passengers and in seat belt use habit formation, have not been proven.

For reasons outlined in the introduction to this chapter, arguments for and against lap belts on schoolbuses cannot rely on passenger car data for an answer. For this reason, the Safety Board analyzed the types of injuries sustained by unrestrained schoolbus passengers and tried to determine the difference lap belt use would have made on passenger injuries. The Safety Board concluded that, overall, the passengers in these cases would have received no net benefit from lap belt use. This finding of no overall benefit does not include the possibility of lap belt-induced injuries; if this possibility is counted, the introduction of lap belts would have had a negative effect on these passengers' safety. Without lap belt use, 90 percent of the unrestrained passengers in the study's cases (which were slanted toward the more serious accidents in an effort to uncover shortcomings in occupant protection) received minor or no injuries. What effect lap belt use would have had on these passengers is unknown, but it is unlikely lap belts would have reduced the minor injuries any further.

The possible safety benefits and the installation feasibility of lap/shoulder belts for passengers on large poststandard schoolbuses are an even more unknown factor.

If money is to be spent to increase the safety of schoolbus passengers, there are more effective ways of allocating funds to increase the chance of a greater safety payoff than introduction of restraint systems for passengers. Some of these ways are discussed later in this summary. Clearly, however, rapid retirement of any prestandard schoolbuses in the fleet and their replacement by poststandard buses should be a top priority.

The Safety Board found that, overall, large poststandard schoolbuses perform very well, in a wide range of accidents in protecting schoolbus passengers from injury. This finding held true even when the rollover accidents investigated for this study were looked at separately. Eighty-six percent of the unrestrained schoolbus passengers involved in rollover accidents in this study received no injuries or only minor injuries (typically abrasions and contusions). Furthermore, of the small number of passengers who did sustain serious or greater injuries in the study's rollover cases, all of the passengers who died and slightly more than two-thirds of the passengers who survived with serious or greater injuries were injured during the impact which occurred before the rollover. These passengers usually had been seated in the direct impact zone, and it is unlikely that any restraint system would have made a difference.

The Safety Board's cases also do not support an argument for the need for passenger lap belts to prevent ejection and to minimize the injuries associated with ejection. Very few schoolbus passengers were ejected in cases in the study (about 15 of the 1,119 unrestrained passengers were known to be fully or partially ejected). Unlike cars, schoolbus seats are not near a door which can open and allow the passengers to be ejected upon impact. Windows are partitioned, also making ejection more difficult.

Lap belt use would not have necessarily reduced the level of injuries sustained by all of the schoolbus passengers who were ejected. Four passengers who were ejected received only minor injuries; if they had remained in their seats, they still could have received minor injuries. (In one case an ejected passenger who received only minor injuries could have been hurt more severely had he remained in his seat; his seat was pushed to within a few inches of the seat back in front of him.) Two ejected passengers received moderate injuries and nine received serious to critical injuries. Before the crash many of these ejected passengers were seated at positions which were penetrated by a striking vehicle. In fact, in some instances, lap belts probably would not have prevented ejection since the passengers' seats were ejected.

Structural failure is sometimes involved in passenger ejections, but overall, the bodies of poststandard schoolbuses maintained their integrity very well during quite severe crashes; this was not the case in many prestandard schoolbus crashes investigated by the Safety Board.

After retirement of prestandard buses, the real safety payoff for schoolbus occupants no doubt lies in accident prevention--better training for drivers, improved maintenance, improved equipment (such as better mirrors to overcome blind spots), and other preventive measures.

Additional or improved equipment is one form of accident prevention. Replacement of the poorly designed driver lap belts now present in most schoolbuses is an obvious step in this direction since it would help ensure that drivers stay behind the wheel when involved in an accident. Investment in equipment to improve the safety of children in the schoolbus loading and unloading zone, where the majority of schoolbus-related pupil deaths occur each year, is another priority.

Advocates of seatbelts on schoolbuses have proposed that installation of lap belts for passengers may help prevent accidents from occurring. They argue that lap belt use increases orderly behavior on the bus, thus decreasing distractions to the driver created by unruly passengers. Opponents, on the other hand, argue that a driver can be distracted trying to ensure that all passengers are belted.

The NHTSA study on the possible carryover effects of belt use on schoolbuses cited earlier in this study found no evidence of carryover but did find that both students and schoolbus drivers reported that discipline had improved on the buses with lap belts. This study, however, was conducted in school districts which had voluntarily installed lap belts on their schoolbuses, and thus were highly motivated populations. Whether the same use rates and increase in discipline would be evident in other school districts if they installed passenger lap belts on buses is not known. Even if it could be proved that discipline improved automatically on buses with lap belts, the effect this would have had on accident rates is unclear. Driver distraction due to discipline problems does not appear to be a common cause of schoolbus accidents.

North Carolina is one State that has traditionally allowed high school students to serve as schoolbus drivers. It would not be unwarranted to expect that North Carolina might have a larger than usual number of accidents caused by driver distraction from failure to maintain discipline on the bus. After all, 16-year-old drivers might find it especially difficult to enforce order among their peers. Yet, when researchers at the University of North Carolina studied schoolbus accidents in a three-county area in the State to determine the cause of accidents, only 5 percent (3 out of 61 accidents) in a 2-year period were determined to have passenger distractions as a causal factor. The same researchers also analyzed statewide data to see to what extent driver distraction was listed as a problem. Since driver distraction was not listed as a separate item in the police report, it was necessary to examine the police officer's narrative description of each crash. In 1.5 percent (24 of 1,563) of the narratives, there was some indication that the schoolbus drivers had been distracted by their passengers. North Carolina researchers concluded that the true proportion of schoolbus crashes caused by schoolbus driver distraction in their State probably is between 1.5 percent and 5 percent.

The North Carolina study did find that schoolbus driver error was responsible for 70 percent of the investigated crashes and that the most frequent bus driver errors involved turning too widely or sharply, driving left of center, improper backing, and failure to yield. Other studies of schoolbus accident causation also have found driver error to be the leading precipitating factor, with failure to yield right of way and excessive speed the most common error. Clearly, driver training is one area with potential for safety payoff.

CONCLUSIONS

1. Poststandard large schoolbuses are an extremely safe form of transportation compared to other modes of transportation.

2. The Federal schoolbus safety standards, providing for "compartmentalization," worked well in the Safety Board-investigated crashes to protect schoolbus passengers from injury in all types of accidents. Ninety percent of the unrestrained passengers in the accidents in the Safety Board's schoolbus study received only minor or no injuries.

3. If schoolbus passengers were injured, they were most likely to receive minor injuries. Moderate injuries were rare, and serious to critical injuries extremely rare. Intrusion was responsible for the most of the moderate or greater injuries.

4. Intrusion was responsible for all but 2 of the 13 schoolbus passenger fatalities in this study and for all of the schoolbus driver fatalities.

5. Schoolbus occupant deaths and the serious or worse injuries sustained by survivors in the study were, for the most part, attributable to the occupants' seating position being in direct line with the crash forces. It is unlikely that the availability of any type of restraint would have improved their injury outcome.

6. Schoolbus accidents involving collisions with a heavy truck were the most serious injury-producing crashes in the study in terms of schoolbus passenger outcome. Accidents involving passenger cars were the least harmful to schoolbus passengers.

7. Ejection was extremely rare among the unrestrained schoolbus passengers in the study. Approximately 15 of the 1,119 unrestrained passengers were either partially or totally ejected. Since the accidents in the study represent the more severe end of the schoolbus accident scale, and include a disproportionate number of rollovers, it is reasonable to believe that ejection is extremely rare in the overall population of all schoolbus crashes.

8. The post-1977 Federal schoolbus standards requiring increased side panel and roof strength appear to have been successful in eliminating the structural failures responsible for many of the ejections which occurred in prestandard schoolbuses.

9. Schoolbus maintenance access panels failed to withstand crash forces in five cases, which included moderate as well as severe accidents, and came free, becoming a source of injury for passengers.

10. Schoolbus seat cushions were unsecured following 16 crashes; in some cases, schoolbus passengers were injured by contact with the loose cushions or the exposed seat frame.

11. Rollover accidents in the Safety Board's study were associated with higher levels of schoolbus passenger injuries than nonrollovers but to a much smaller degree than anticipated: nearly 86 percent of all the schoolbus passengers involved in rollover crashes were either uninjured or received only minor injuries.

12. The slight increase in the schoolbus passenger injury severity associated with rollover accidents in the study was due primarily to one type of rollover accident: rollover preceded by collision. The initial impact, not the rollover, was responsible for the higher injury levels.

13. Analysis which aggregates rollover accidents, regardless of severity or prior collision, may inflate the importance of the rollover itself as the injury-producing event and mask the importance of other events during the accident, i.e., crush from the initial impact, initial impact crash forces, and lateral rotation.

14. Lap belt use probably would have made no change in the total number of schoolbus passengers who died in the crashes investigated for this study (possibly one more death would have resulted).

15. Lap belt use probably would have made no change in the number of surviving schoolbus passengers with severe or worse injuries.

16. At best, lap belt use probably would have reduced somewhat the injuries of less than a third (8) of the 24 surviving schoolbus passengers with serious injuries in the study and made no change for the majority (12). At worst, it might have increased the injury to almost as many passengers with serious injuries as it improved.

17. Lap belt use probably would have worsened the outcome for one-fifth of the 58 schoolbus passengers with moderate injuries. The Safety Board cannot determine the effect belt use would have made on the remainder of the passengers with moderate injuries.

18. The Safety Board cannot estimate the probable net effect of lap belt use on the unrestrained schoolbus passengers in the study who were uninjured or received only minor injuries; it is unlikely that it would have reduced the minor injuries.

19. Almost half of the schoolbus drivers in the study, although required to be restrained when the bus is in motion, were not wearing their lap belts.

20. The lap belted schoolbus drivers did not fare better, overall, than the unrestrained drivers, an outcome probably attributable to the nature and severity of the crashes involving lap belted drivers.

RECOMMENDATIONS

As a result of its safety study of schoolbus crashworthiness the Safety Board made the following recommendations:

—to the National Highway Traffic Safety Administration:

> Amend FMVSS 221, Schoolbus Body Joint Strength, to include interior maintenance access panels in the standard's performance requirements. (Class II, Priority Action) (H-87-11)

—to schoolbus body manufacturers:

> Apply the performance requirements of FMVSS 221 to floor panels and interior maintenance access panels. (Class II, Priority Action) (H-87-12)

—to State Directors of Pupil Transportation:

> Enforce and publicize the existing regulation that schoolbus drivers must wear their seat belts whenever the school vehicle is in motion. (Class II, Priority Action) (H-87-13)
>
> Advise school districts under your jurisdiction to emphasize to maintenance personnel that seat cushions must be securely reattached after removal and to remind schoolbus drivers to include seat cushion attachment as part of the pretrip inspection. (Class II, Priority Action) (H-87-14)
>
> Require that all lap belts for drivers of large schoolbuses, regardless of the age of the bus, satisfy the requirements of the Federal rule affecting lap belts on vehicles weighing more than 10,000 pounds GVWR, when that rule is made final. Initiate retrofit programs as needed. (Class II, Priority Action) (H-87-15)
>
> Require that school districts incorporate, as a regular part of training for new schoolbus drivers and for inservice programs, explicit instructions on how to adjust the driver's lap belt properly. When applicable, emphasize that the belt must be manually adjusted on both sides. (Class II, Priority Action) (H-87-16)

The Safety Board, as a result of this study, also reiterates Safety Recommendation H-86-57, which was issued as part of the "Multiple Vehicle Collision and Fire, U.S. 13 near Snow Hill, North Carolina, May 31, 1985" Highway Accident Report issued August 15, 1986.

—to Thomas Built Buses, L.P.:

> Strengthen the floor panel joints of all newly-manufactured schoolbuses to ensure that they comply with the requirements of Federal Motor Vehicle Safety Standard 221. (Class II, Priority Action) (H-86-57)

Closed -- acceptable action 4/2/90

The Safety Board also reiterates Safety Recommendation H-84-75, which was issued as part of the "Collision of G & D Auto Sales, Inc., Tow Truck Towing Automobile, Branch Motor Express Company Tractor-Semitrailer Town of Rehoboth, Massachusetts, January 10, 1984" Highway Accident report issued September 5, 1984.

—to National Highway Traffic Safety Administration:

> For newly manufactured vehicles, revise Federal Motor Vehicle Safety Standard No. 222 to include a requirement that school bus seat cushions be installed with fail-safe latching devices which ensure they remain in their latched positions during impacts and rollovers.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT
Chairman

/s/ PATRICIA A. GOLDMAN
Vice Chairman

/s/ JOHN K. LAUBER
Member

/s/ JOSEPH T. NALL
Member

March 18, 1987

APPENDIXES

APPENDIX A

SUMMARIES OF SAFETY BOARD SCHOOLBUS ACCIDENT INVESTIGATIONS

The following summaries are organized by type of accident and then by accident severity. Cases are identified in this appendix by accident location and date.

Cases Involving Large Poststandard Schoolbuses
(schoolbuses manufactured after April 1, 1977
and weighing more than 10,000 pounds GVWR)

Nonrollover Accidents
(By principal direction of impact)

Frontal or Rear Collision

Case Number and Location		Date
1	Carmel, New York (Mahopac)	October 10, 1985
2	Chanute, Kansas	May 17, 1984
3	Cornelius, Oregon	June 28, 1985
4	Little Rock, Arkansas	April 16, 1984
5	Healdton, Oklahoma	May 22, 1984
6	Pasadena, Maryland	November 7, 1984
7	Tecumseh, Oklahoma	September 25, 1984
8	Bloomfield Township, Ohio	March 30, 1984
9	Lanconia, New Hampshire	March 19, 1984
10	Frankston, Texas	September 13, 1985
11	Palmyra, Nebraska	January 4, 1985
12	Sour Lake, Texas	March 19, 1984
13	St. Louis, Missouri	November 11, 1985
14	Snow Hill, North Carolina	May 31, 1985
15	Key Largo, Florida (rear impact)	September 12, 1985

Side Impact 1/

16	Greenburgh, New York	January 25, 1985
17	Snyder, Oklahoma	August 25, 1983
18	Stephenson, West Virginia	June 8, 1984

Multiple Impact

19	Kerrick, Texas	September 7, 1984
20	Hecla, South Dakota	May 24, 1985
21	Woodside, Delaware	September 11, 1985

1/ Also see the section on rollover accidents; five rollover accidents were preceded by side impact.

Rollover Accidents
(By collision/noncollision)

Noncollision Rollover

Case Number and Location		Date
22	Des Peres, Missouri	February 4, 1986
23	Rueter, Missouri	May 5, 1984
24	Leavenworth, Kansas	October 15, 1984
25	Point Pleasant, West Virginia	October 2, 1984
26	Hobbs, New Mexico	October 16, 1985
27	Bladensburg, Maryland	January 10, 1986
28	Jefferson, North Carolina	March 13, 1985
29	Swink, Oklahoma	March 6, 1986

Collision Followed by Rollover

30	Julian Boone, West Virginia	November 7, 1983
31	Greenfield, Illinois	September 25, 1985
32	Caldwell, Texas	April 23, 1985
33	Newark, New Jersey	March 18, 1985
34	Fort Myers, Florida	May 8, 1985
35	Durango, Colorado	December 11, 1984
36	Wilmington, Ohio	October 28, 1985
37	Georgetown, Texas	April 16, 1985
38	Cherokee, Iowa	November 10, 1984
39	McGrath, Minnesota	April 22, 1985
40	Brunswick, Georgia	January 14, 1986
41	Rehoboth, Massachusetts	January 10, 1984
42	Carrsville, Virginia	April 12, 1984
43	Tuba City, Arizona	April 29, 1985

Case No.: 1
NYC-86-HSB-02

Accident Location: Union Valley Road, Carmel, New York (Mahopac School District)

Date and Time: October 10, 1985, 8 a.m.

Description of Schoolbus: 66-passenger poststandard bus: 1978 International Harvester chassis with 1978 Thomas Built body

Type of Accident: Head-on collision (run-off-the-road)

Accident Severity: Minor

Summary of Events: A schoolbus transporting 15 elementary school students went out of control when the driver turned left onto a 2-way, 2-lane rural road. The bus, travelling an estimated 15 to 20 mph, ran off the left side of the road. The left side of the bus rode up the sloped embankment, and the left rear wheels bounced over a large boulder. The right wheels of the bus remained close to, or on, the road. The bus then veered back onto the road and travelled diagonally across the road and onto the right shoulder. The bus continued to the right, bouncing over a 2 1/2 foot high dirt embankment, where it struck and knocked down a small tree. The schoolbus came to rest, upright, in a wooded area adjacent to the road. Although the longitudinal Delta V was not calculated, it probably was less than 10 mph. The schoolbus occupants also experienced vertical acceleration when the bus went over an embankment.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 15 passengers, aged 4 to 12, 8 were uninjured, 4 sustained minor (AIS 1) injuries, 1 sustained critical (AIS 5) injuries which proved fatal, 1 sustained injuries of an unknown severity (AIS 7),*/ and for 1 passenger it was unknown if she was injured (AIS 9). **/ The 32-year-old driver, restraint use unknown, was uninjured.

The driver and all passengers evacuated the bus without incident and were taken to the hospital for examination. All were examined and released except for one 11-year-old boy who became unconscious en route to the hospital and was pronounced dead shortly after arrival.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: There was contact damage to the front, left side, and undercarriage of the bus. Damage to the front consisted of a 2 1/2-inch dent in the center of the front bumper in which tree bark was embedded. There were minor scrapes above and below the left side windows, and the exterior body panels on the bottom left side of the bus were scraped and deformed upward and inward. The right rear airbrake chamber came apart at the split lock ring. There was evidence of contact on the driveshaft, the differential, and the right rear airbrake chamber.

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*/ Insufficient medical information was available for this passenger on which to assign a specific injury severity code. His injuries appeared minor, though and were described in medical records as "minor trauma to left knee."

**/ This passenger was described as having a "red area over the eye." No further information was available.

In addition to the contact damage, the right front wheel suspension was damaged; the main leaf of the leaf spring and the lower mount of the shock absorber were fractured and separated.

Evaluation of Bus Performance: Bus performed well.

Injury Analysis

Passengers: Six of the 15 passengers were known to be injured in the accident; 1 was fatally injured, while the remaining injured students sustained minor injuries only.

It is believed that no injuries resulted from the initial run-off onto the left side of the road. Although the seven students seated on the left side were displaced to the right side when the bus rolled approximately 30° to the right, none were injured.

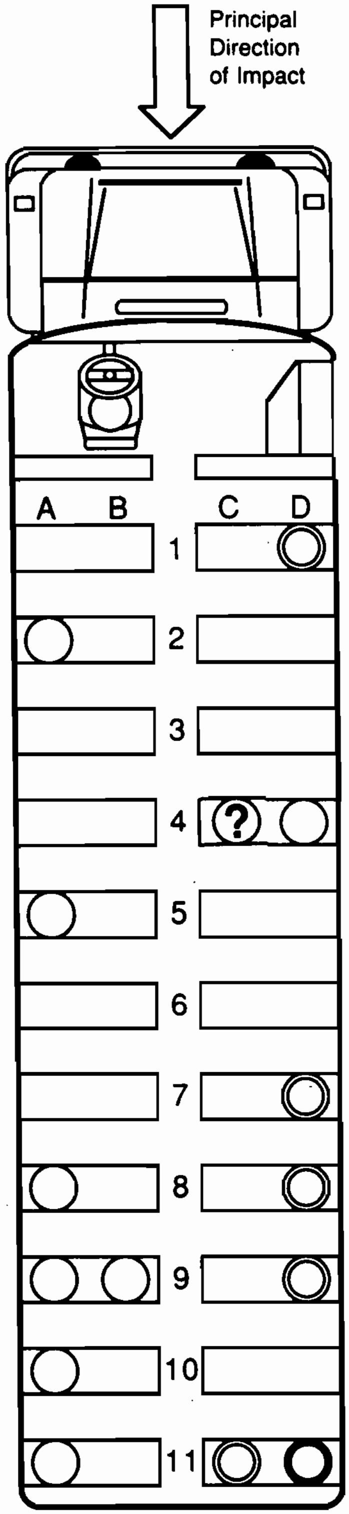
The minor injuries and the fatal injury apparently occurred during the second run-off, when the bus bounced over the dirt embankment and struck the tree. During this phase of the accident, the bus occupants probably experienced an approximate 5 to 10 mph longitudinal Delta V, while simultaneously experiencing a vertical acceleration.

The only injury pattern or noninjury pattern emerging from this accident was that the left side passengers and driver, although displaced from their seats, were uninjured. Of the eight children on the right side of the bus, one was uninjured, two received uncodable minor injuries, and four received very minor (AIS 1) injuries; in sharp contrast to the rest of the occupants, one boy received a fatal liver injury (severely lacerated liver). However, according to the pathologist, the boy was at higher risk to this type injury than other children because his liver was not a normal, healthy liver; the boy had an enlarged liver situated lower in the abdomen than normal. It is believed that during the accident sequence, this child, who initially was not seated, was leaning over the seat back in front of him, and when the rear wheels bounced over the embankment, the seat back was accelerated sharply into the child's torso and inflicted the fatal injury.

Lap belt use by all but the fatally injured student would have made little or no difference in the injury outcome. Had the fatally injured student been restrained by a lap belt, he probably would not have received the blow which lacerated his liver. Had he been properly seated and not restrained, he also would have avoided the injury. Lap belt-induced injury probably is not a concern despite his abnormal liver, since his movements during the crash would involve very little loading of the the seatbelt.

Schoolbus Driver: Restraint use unknown. The driver told the Safety Board investigator she had her lap belt "partially on" before the accident occurred. (Some students also state she was belted.) This could mean that she had her lap belt buckled but not adjusted. The lap belt at the driver's position in this bus must be manually adjusted before the belt is properly "snugged up." The retractors on the belt are used for storage of the belt webbing when the lap belt is not in use; they are not emergency locking retractors. Regardless of whether the driver was originally unbelted or not properly belted, she did not remain in her seat when the schoolbus went off the road to the left. Had she been restrained in her seat, she might have regained control of the bus after the initial run-off, thus preventing the second run-off which precipitated the injuries and fatality.

Carmel, New York
Case No. 1



Left Side of Bus

No Injuries

Right Side of Bus

Row 1D
M-5, MAIS 1

Row 4C
M-4, MAIS 9
"Red area under right eye"

Row 7D
F-9, MAIS 1

Row 8D
M-10, MAIS 7
"Minor trauma to left knee"

Row 9D
F-8, MAIS 1

Row 11C
M-12, MAIS 1

Row 11D
M-11, MAIS 5 (Fatal)
Lacerated liver

LEGEND

Uninjured
Injured
Fatally Injured
Unknown if Injured
Lap Belt Used

Example: M-17 (Male, Age 17)
MAIS-2 (Used for injured occupants only) Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Notes:
Fatally injured passenger was out of position, leaning over seatback, when his abnormal, diseased liver was injured.

School bus driver restraint use unknown.

The school bus shown is representational only.

Case No.: 2
MKC-84-H-SB26

Accident Location: County Road No. 7, outside Chanute, Kansas

Date and Time: May 17, 1984, 7:05 a.m.

Description of Schoolbus: 53-passenger poststandard bus:
1983 Ford chassis with a Blue Bird body

Type of Accident: Head-on collision (left front to left front)

Accident Severity: Minor

Summary of Events: A schoolbus transporting four students to school was travelling around a curve on an undivided, 2-way, narrow (15 1/2 feet wide) gravel road at an estimated speed of 19 mph. The bus driver noticed a pickup truck coming toward him, braked, and the bus skidded 30 feet toward the right shoulder. The schoolbus was stopped (or almost stopped) when the pickup, travelling about 28 mph, struck the left front of the bus.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the four passengers, aged 10 to 17, four were uninjured. The 39-year-old restrained driver was uninjured.

(No seating chart provided since no one was injured.)

Damage to Schoolbus: Very little damage. The front of the schoolbus, from the center to the left side, was damaged, including the bumper, grill, and fiberglass fender. No other exterior damage and no interior damage.

Evaluation of Bus Performance: The impact was very minor and only fiberglass components were substantially damaged.

Injury Analysis

Passengers: All passengers were seated on the right side of the bus, with one student each in row 1, 2, 7 and 8 (the first two and last two rows of this bus). Only one passenger remembers being thrown forward during the collision into the padded seat back, the other three passengers did not notice any forward force. This collision generated little crash force on the occupants and all were uninjured.

Restraint use could not have improved the outcome of no injuries.

Schoolbus Driver: Available lap belt used. Driver uninjured.

Outcome for Occupants of Other Vehicle

Vehicle Description: 1969 Ford F-100 pickup

Damage to Vehicle: Extensive damage. The left front of the pickup truck was smashed inward causing the hood to buckle upward. The bumper was pulled away from the truck, and the left front fender was completely crumpled.

Chanute, Kansas
Case No. 2

Occupant Restraint Use and Injury: Driver restrained; passenger unrestrained. The driver struck the steering wheel with such force that he bent the wheel. Neither the driver nor the passenger were reported to be injured.

Special Notes on the Accident

Several schoolbus seat bottom cushions were found to be only partially secured to the seat frame. Metal retainer clips were out of position.

<u>**Case No.: 3**</u>
SEA-85-H-SB-22

Accident Location: Golf Course Road, outside Cornelius, Oregon

Date and Time: June 28, 1985, 6:55 a.m.

Description of Schoolbus: 64-passenger poststandard bus:
1978 International Harvester chassis with
1979 Thomas Built body

Type of Accident: Right front angle collision (principal direction of impact at 1 o'clock)

Accident Severity: Minor; 6 mph Delta V for bus but 24.4 mph Delta V for car.

Summary of Events: A schoolbus transporting 46 children to a summer educational program was travelling approximately 25 mph on a level, 2-lane, undivided asphalt road. As the bus rounded a left curve, the driver lost control; the schoolbus crossed the centerline and struck an oncoming car travelling about 30 mph. The right front of the bus impacted the left front fender of the car and pushed the car approximately 15 feet off the road. The schoolbus came to rest upright diagonally across the road.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 46 passengers, aged 4 to 12, 40 were uninjured, and 6 sustained minor (AIS 1) injuries. The 42-year-old driver, restraint use unknown, received serious (AIS 3) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The front of the bus clearly absorbed the crash forces, resulting in no damage to the interior. The right front fiberglass fender was cracked and deformed rearward, and the bumper was bent on both ends. Damage to the front extended to grill and fiberglass hood. The undercarriage also was damaged. The frame was bent and the front axle had shifted on the springs.

Evaluation of Bus Performance: The bus performed well in the crash with all damage confined to the exterior.

Injury Analysis

<u>Passengers</u>: Passengers seated on the right side of the bus, in line with the direction of force in this crash, received most of the minor injuries. Contact with the seat backs in front of them was the source of these minor injuries which included bruises to heads, legs and one arm.

Lap belt use would not have reduced the injuries sustained in this accident.

<u>Schoolbus Driver</u>: Restraint use--lap belt use unknown. Driver sustained serious (AIS 3) injury: dislocated and fractured right shoulder, AIS 1 (minor): laceration on right forehead; fracture of the right seventh rib; and bruise on right lower leg.

Outcome for Occupants of Other Vehicle

Vehicle Description: 1972 Ford Custom 500 car

Damage to Vehicle: Entire left side of car from the rear axle forward was severely damaged, along with lesser damage to the left front of the vehicle.

Occupant Restraint Use and Injury: No restraints were used by the five occupants of the car. The driver, the right rear passenger, and another passenger received serious (AIS 3) injuries. The other two passengers received minor (AIS 1) injuries. Seating positions for three of the passengers in the car are unknown.

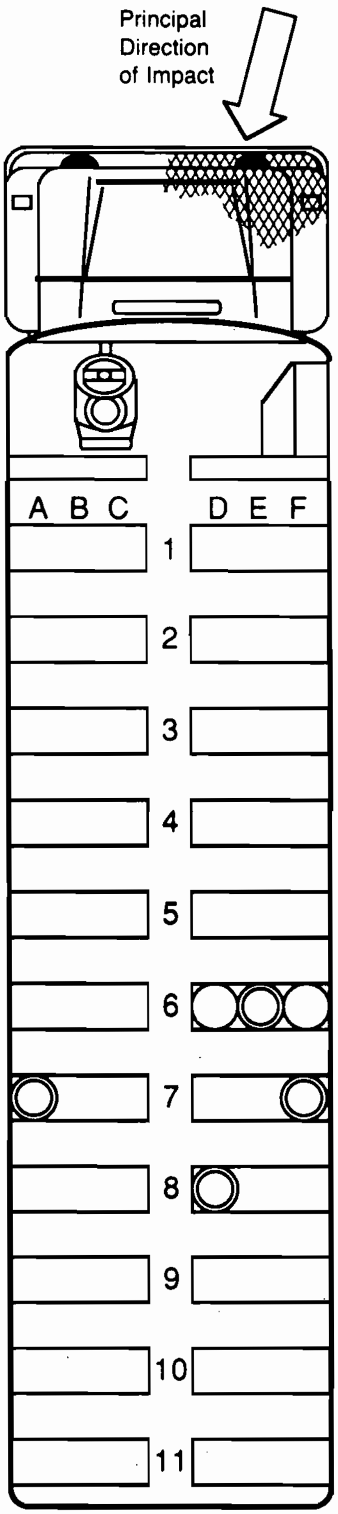
Special Notes on the Accident

The schoolbus driver stated she was restrained and in the driver's seat when the bus hit the car. She was not sure how her lap belt "came undone," or when in the accident sequence she was unseated. The last thing she recalled was "the wheel wrenching out of my hand and going flying." She ended up in the bus stairwell following the crash.

She told the Safety Board investigator she was "almost positive" she had been belted before the accident occurred. She previously had told police who interviewed her at the scene of the accident that she was unbelted. The schoolbus driver had no bruises or abrasions on her abdomen or hips consistent with belt use, and the lap belt buckle showed no signs of failure. This low speed collision normally most likely would not have caused normal seatbelt bruises, but had the driver been wearing her belt as she fell from the seat, bruises probably would have resulted.

The lap belt system in the accident bus is equipped with a nonlocking retractor on the latchplate side to store belt webbing when the lap belt is not in use. Because it is nonlocking the retractor is there for convenience, not safety, reasons. Unfortunately, drivers may assume the retractor is an automatic or emergency locking retractor, i.e., one which locks so no additional belt can be played out. With the type of retractor installed with this system, the user must pull all webbing out of the retractor and tighten the belt manually before the belt is properly "snugged up." If this is not done, the lap belt will be too loose to provide proper restraint during crash.

Cornelius, Oregon
Case No. 3



Left Side of Bus

Driver
F-42, MAIS 3
Dislocated and fractured right shoulder; AIS 1: fractured 7th rib on right side, laceration on right side of forehead, and a contusion on right lower leg.

Row 7A
M-10, MAIS 1

Right Side of Bus

Row 6E
F-9, MAIS 1

Row 7F
F-6, MAIS 1

Row 8D
F-9, MAIS 1

Special Notes:
46 passengers were on the bus. Seating position was unknown for two injured occupants: F-9, MAIS 1, M-12, MAIS 1.

Seating position was unknown for 38 uninjured occupants.

School bus driver restraint use unknown.

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 — Male, Age 17
MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

<u>Case No.: 4</u>
MKC 84-H-5B23

Accident Location: Tyler Street, Little Rock, Arkansas

Date and Time: April 16, 1984, 8:10 a.m.

Description of Schoolbus: 65-passenger poststandard bus:
July 1977 Ford chassis with Ward body

Type of Accident: Head-on collision

Accident Severity: Minor

Summary of Events: A schoolbus transporting 46 grade school students to school turned left onto a 2-lane, 1-way street from a city intersection. The schoolbus was travelling between 25 to 35 mph. The schoolbus struck the southwest curb with its right front tire, traveled southeasterly across the road, and struck the east curb. Bus speed at impact between 5 to 10 mph per Safety Board investigator estimate. The schoolbus then continued past the curb, skidded over the sidewalk, and struck a tree, 12 feet east of the curb, head-on.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 46 passengers, aged 6 to 10, 38 were uninjured, 7 sustained minor (AIS 1) injuries, and 1 sustained moderate (AIS 2) injuries. The 20-year-old unrestrained driver was uninjured.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Damage was confined to front exterior. Front bumper was bent in 5 1/2 inches at point of impact with tree, and right front fender and engine hoodsheet and support struts buckled and bent rearward. Radiator also displaced rearward.

Evaluation of Bus Performance: Performed well. No damage to passenger compartment.

Injury Analysis

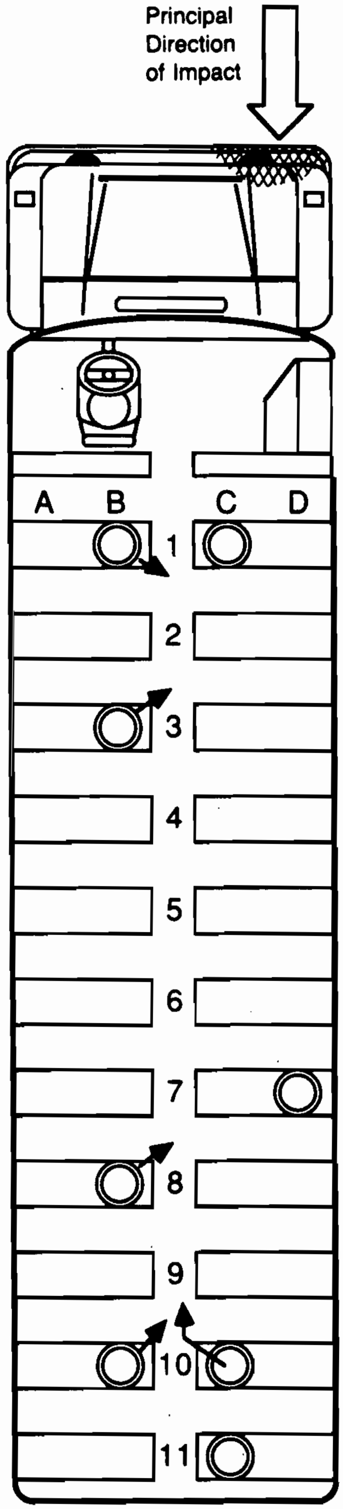
<u>Passengers</u>: All but one of the eight injured students were seated on the aisle; six probably were displaced from their seats prior to impact with tree. The most seriously injured student (AIS 2) was among those who fell into the aisle. She sustained her moderate injuries, a broken arm and period of unconsciousness, from contact with seat supports. The other six sustained minor injuries (AIS 1) consisting mainly of contusions, abrasions and lacerations to shoulders, head, and face.

Contact with the side wall caused the minor (AIS 1) injury sustained by the passenger in row 7; contact with the restraining barrier caused the minor (AIS 1) injury incurred by the passenger in row 1 on the right.

Lap belt use clearly would have prevented students from falling into the aisle, but lap belted passengers still could have sustained AIS 1 injuries (lacerations, abrasions, and contusions), or possibly even AIS 2 injuries, from contact with seat backs in front and passengers seated next to them. It is unlikely, though, that one of the specific AIS 1 injuries sustained — central incisors broken off (from contact with floor) -- would have occurred. It also is unlikely that the passenger in row 10 on the right, far from the impact zone, would have sustained her specific moderate (AIS 2) injury, a broken arm. This child fell into the aisle and struck seat legs.

Schoolbus Driver: Lap belt available but not used. Driver reportedly uninjured.

Little Rock, Arkansas
Case No. 4



Left Side of Bus

Row 1B
M-8, MAIS 1

Row 3B
F-6, MAIS 1

Row 8B
F-9, MAIS 1

Row 10B
M-10, MAIS 1

Right Side of Bus

Row 1C
M-6, MAIS 1

Row 7D
F-9, MAIS 1

Row 10C
F-9, MAIS 2
Fracture of right radius and unconscious for unspecified time period: fell into aisle floor, striking vertical seat supports of seat ahead of her.

Row 11C
F-9, MAIS 1

Special Notes:
Seating position unknown for 38 uninjured passengers.

5 students fell into aisle.

LEGEND

○ Uninjured
◎ Unknown if Injured
◎ Injured
⊖ Lap Belt Used
● Fatally Injured

Example: M-17 (Male, Age 17)
MAIS-2 (Used for injured occupants only)
Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

* American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

Case No.: 5
FTW-84-H-SB07

Accident Location: Carter County Road, Healdton, Oklahoma

Date and Time: May 22, 1984, 3:25 p.m.

Description of Schoolbus: 59-passenger post-standard bus:
1981 International Harvester chassis with Superior body

Type of Accident: Right front angle impact

Accident Severity: Very minor; Delta V of 5 mph for schoolbus.

Summary of Events: A schoolbus transporting approximately 15 to 20 students home from school was travelling about 30 mph on a 19-foot wide, straight and level gravel county road. As the bus approached an intersection with a second county road, a pickup pulled out in front of the bus. The schoolbus driver braked, and the bus skidded 34 feet before striking the right side of the truck with its right front. The schoolbus speed at impact was 11 mph; truck speed at impact was 8 mph. Following the impact, the schoolbus rotated 21° clockwise, pushing the truck sideways for 5 1/2 feet before coming to rest still upright.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 15 to 20 passengers, elementary to high school age, all but one were uninjured: that student sustained minor (AIS 1) injuries. The 50-year-old restrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Extensive damage to front exterior. Total structural collapse to the right front of the bus was 17 inches with the frame bowed and twisted approximately 10 inches over a length of 7 feet. The front end was damaged, including all the fiberglass (hood, fender, headlight housing), the grill was torn outward, the radiator was pushed rearward, the right front tire and wheel were displaced to the rear 10 inches, and the frame was bowed and twisted. The bus body shifted forward 1 inch on the right side of the frame. There was no interior damage. All seats and seat mountings were secure.

Evaluation of Bus Performance: The schoolbus performed well in this collision, maintaining its structural and interior integrity without serious deformation.

Injury Analysis

Passengers: The schoolbus driver stated that there were 15 to 20 passengers aboard the bus at the time of the accident, but she was unable to determine their seating positions or ages. Information, however, is available for the one passenger injured in this crash: a 9-year-old boy seated in row 2, seat F, a window seat on the right side of the schoolbus. This passenger received minor (AIS 1) injuries consisting of a small contusion to the right side of his face (he had been wearing glasses which broke) and a contusion to his right leg. Both injuries were sustained when he struck the right side wall during the collision.

Lap belt use would not have reduced this boy's injuries in this low-speed accident. Lap belt use affords no upper torso restraint so it cannot prevent a passenger seated by the window from contacting the side wall with his or her head (or prevent glasses from being broken), and no type of seat belt can prevent a passenger's leg from contacting the sidewall, especially if the passenger is seated by the window. Since the remaining passengers were uninjured, lap belt use could not reduce their injuries.

Schoolbus Driver: Available lap belt used. Driver sustained minor injuries (AIS 1): small laceration above chin (from contact with steering wheel) and contusions around hip area, (probably caused by the lap belt, an indication of the restraining forces provided by the belt).

Outcome for Occupants of Other Vehicle

Vehicle Description: 1977 Ford F-600 truck (blue)

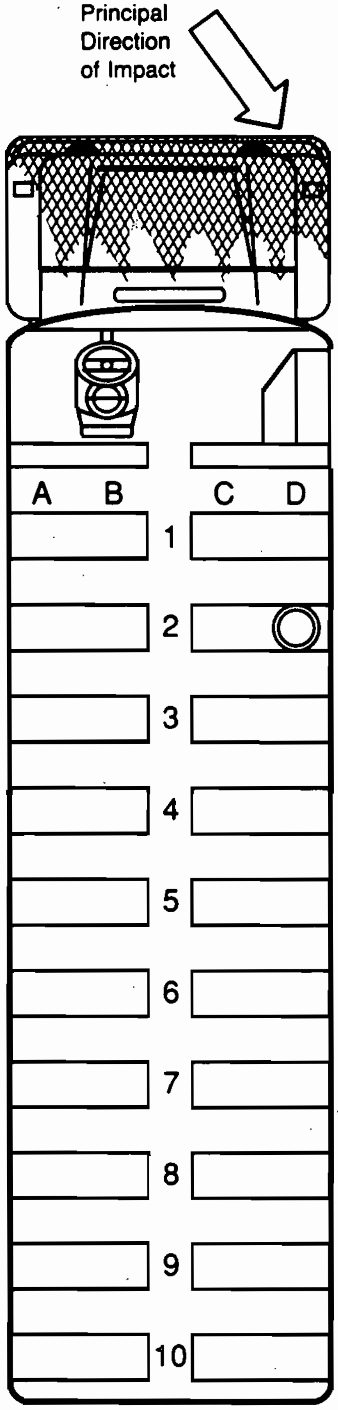
Damage to Vehicle: The right passenger door was smashed in and part of the right front fender was crinkled.

Occupant Restraint Use and Injury: No restraint used; the driver of the truck was not injured.

Healdton, Oklahoma
Case No. 5

Left Side of Bus

Driver
F-50, MAIS 1



Right Side of Bus

Row 2D
M-9, MAIS 1

Special Note:
The driver could not place the uninjured occupants. Only one passenger was injured though and he is shown on the seating chart.

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 (Male, Age 17) MAIS-2 (Used for injured occupants only) Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

* American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

Case No.: 6
NYC-85-HSB-02

Accident Location: Mountain Road outside Pasadena, Maryland

Date and Time: November 7, 1984, 4:24 p.m.

Description of Schoolbus: 54-passenger poststandard bus:
1980 International Harvester chassis with a 1980 Thomas Built body

Type of Accident: Head-on collision (left front)

Accident Severity: Moderate. 13 mph Delta V for the schoolbus.

Summary of Events: A schoolbus transporting 18 high school students home from school was travelling at about 33 mph on a 2-lane, 2-way, undivided asphalt road when it was struck head-on at its left front by an oncoming car travelling at 25 mph. The car's bumper struck the schoolbus' left front tire and knocked the front axle out from beneath the bus. The front of the bus dropped to the ground. As the schoolbus skidded toward the shoulder, the loose axle was caught and dragged by the bus until it lodged at the rear axle housing. The schoolbus came to rest upright on the shoulder.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 18 passengers, aged 14 to 17, 11 were uninjured, and 7 sustained minor (AIS 1) injuries. The 27-year-old restrained driver received minor (AIS 1) injuries, possibly postcrash.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The front of the schoolbus was damaged, especially on the left side. The front axle came loose and was lodged under the rear of the bus. This caused the bus to fall to the ground after the two vehicles separated, which caused major damage to the right front door and stairwell. The front door was inoperable because the bus slid into a large amount of dirt which blocked the doorway and prevented the door from opening. The body of the bus shifted on the chassis but then returned to its previous position. No damage to the interior.

Evaluation of Bus Performance: The bus performed well, considering the impact, a Delta V of 13 mph. Body/chassis separation sometimes allows force dissapation over greater distance, thereby lessening the crash impulse. Some of the crash energy also was dissipated when the U-bolt holding the front axle gave way and allowed the axle to slide to the rear of the bus. This was to the advantage of the passengers. A few passengers, however, probably were injured when the bus front dropped to the ground.

Other than the damage to the stairwell, there was no interior damage to the bus. Despite all the reports of students striking the seat backs in front of them, there was no noticeable contour damage to the seats. None of the seat leg attachments or other bolts separated from the floor or side walls.

Pasadena, Maryland
Case No. 6

Injury Analysis

Passengers: Injured passengers were seated throughout the bus: two were seated in the right front of the bus, four were on the left in the left side, and one was in the right rear seat. Passengers experienced two impacts in this accident: the first and major impact was the collision with the car; the second and minor impact occurred when the front of the bus dropped to the ground when the axle was displaced.

Injuries sustained were extremely minor: four bruised knees, one bruised elbow, and one bruised shoulder. Although there were many complaints of soreness, pulled muscles and ligaments, stiffness, etc., the only sprained back diagnosed was that of the passenger in the right front seat. Students complained that they went forward and struck their heads and then backwards and struck their heads against the seat they were sitting in.

Lap belt use would have prevented the specific minor injury sustained by the passenger who bounced up in his seat as front axle dropped off and struck his back as his body fell back. It also would have eliminated the specific minor injuries sustained by passengers who slid forward and off their seats. While lap belt use can prevent the body movements which caused these injuries, it cannot guarantee that these students would be uninjured in this crash. The kinematics of a lap-belted passenger in a head-on crash are such that other injuries could be substituted.

Schoolbus Driver: Available lap belt used.
Description of Injuries--Minor injuries (AIS 1): strained muscles in neck, right shoulder, right arm and hand. Collision forces and the strain of grasping the steering wheel tightly probably caused these injuries. The driver also caught students as they jumped out the rear door during evacuation.

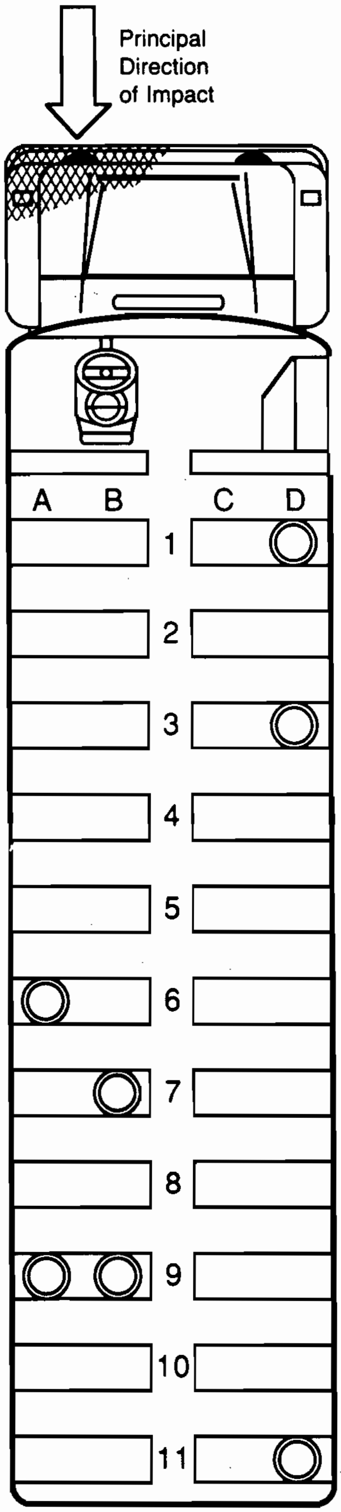
Outcome for Occupants of Other Vehicle

Vehicle Description: 1980 Chevrolet Chevette 2-door.

Damage to Vehicle: Extensive front end damage - vehicle destroyed.

Occupant Restraint Use and Injury: Driver was unrestrained and received injuries which proved fatal: extensive head injuries, including lacerated brain (AIS 6), and other injuries including lacerated liver, fractured left femur, etc. Passenger, also unrestrained, received moderate (AIS 2) head injuries, multiple soft tissue injuries, and blunt abdominal trauma.

Pasadena, Maryland
Case No. 6



Left Side of Bus

Driver
F-27, MAIS 1

Row 6A
F-15, MAIS 1

Row 7B
F-14, MAIS 1

Row 9A
F-16, MAIS 1

Row 9B
F-16, MAIS 1

Right Side of Bus

Row 1D
F-14, MAIS 1

Row 3D
F-17, MAIS 1

Row 11D
M-14, MAIS 1

LEGEND

Uninjured
Unknown if Injured
Injured
Lap Belt Used
Fatally Injured

Example: M-17 — Male, Age 17

MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Note:
The accident report did not include the seating positions of the uninjured occupants.

The school bus shown is representational only.

Case No.: 7
FTW-84-H-SB18

Accident Location: Gordon Cooper Drive, Tecumseh, Oklahoma

Date and Time: September 25, 1984, 8:25 a.m.

Description of Schoolbus: 65-passenger poststandard bus:
1981 Ford B-700 chassis with 1980 Superior body

Type of Accident: Head-on collision (left front to left front)

Accident Severity: Moderate; (police-estimated speed of pickup at 30 mph and schoolbus at 25 mph before collision; impact speed unknown).

Summary of Events: A schoolbus transporting 55 junior high school students home from school was travelling at a police-estimated speed of 25 mph on a wet, 2 lane, 2-way highway. A pickup, travelling the opposite direction at a police-estimated speed of 30 mph crossed the centerline and struck the left front of the schoolbus. Following impact, the schoolbus came to rest upright, in its lane with right tires on the shoulder and left tires on the road.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 55 passengers, aged 9 to 13, 36 were uninjured, and 19 sustained minor (AIS 1) injuries. The 32-year-old restrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Damage was moderate to the left front. No interior damage.

Evaluation of Bus Performance: The bus body performed well against the forces of the impact which should have been expected in this moderate speed collision.

Injury Analysis

Passengers: Only about 1/3 of the passengers (17 of 55) were injured in this accident, and the majority of the injured students complained of minor muscle strains and soft tissue injuries. Two students stated they were not seated when they sustained their injuries: one was standing in the aisle; the other was kneeling on his seat, leaning over the seat back in front of him in row 7. It is possible that the student seated in the extreme left rear seat also was out of position at the moment of impact, maybe facing the aisle. He contacted the forward seat back and then shifted to the right to contact the emergency door handle. Most of the injured students contacted the seat backs in front of their seating positions and/or windows.

The worst injury sustained by passengers in this accident was a minor (AIS 1) injury. Six head and face contusions were documented. Lap belt use would not eliminate these injuries.

Lap belts, if worn, would have prevented the three students from falling between the seats, and the student in the extreme left rear seat, if belted, could not have contacted the emergency door handle. If lap belt use was strictly enforced, the one student who was standing and the one kneeling on the seat would have been properly seated. Nonetheless, the overall outcome for lap-belted passengers in this accident, probably would not be any less harmful.

Schoolbus Driver: Available lap belt used. Driver sustained minor injuries (AIS 1): back strain and stomach muscle strain.

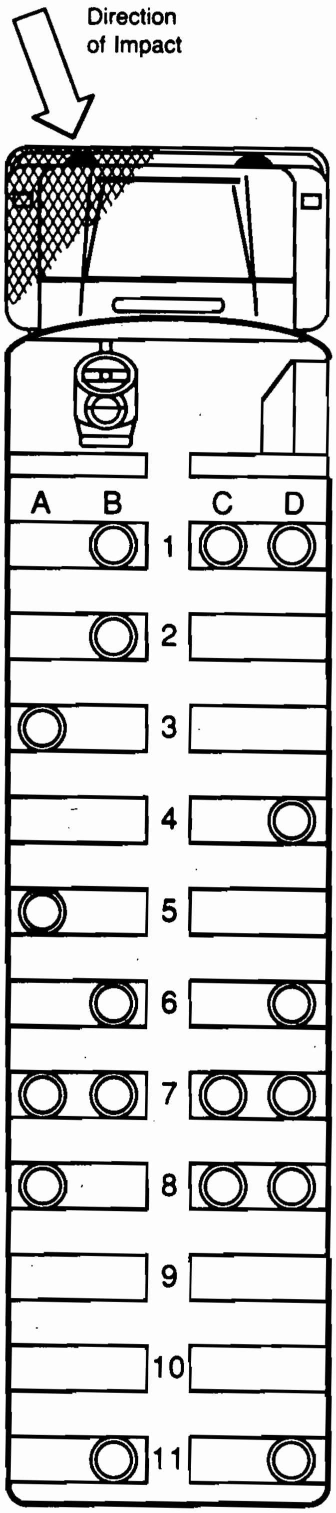
Outcome for Occupants of Other Vehicle

Vehicle Description: Ford half-ton pickup truck

Damage to Vehicle: Left front

Occupant Restraint Use and Injury : Occupants were unrestrained. Driver and passenger received minor injuries (AIS 1) to the head and upper torso.

Tecumseh, Oklahoma
Case No. 7



All Injuries MAIS 1

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 — Male, Age 17

MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

* American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Notes:

Seating position of uninjured passengers unknown.

2 passengers were out of position: Row 5A passenger standing; Row 8D passenger kneeling on seat, leaning over Row 7 seat back (Row 11B also possibly out of position).

Seating position of one injured passenger unknown.

The school bus shown is representational only.

Case No.: 8
CHI-84-H-SB15

Accident Location: State Route 45, Bloomfield Township, Ohio

Date and Time: March 30, 1984, 8:20 a.m.

Description of Schoolbus: 71-passenger poststandard bus:
1984 International Harvester chassis with a Carpenter body

Type of Accident: Head-on collision (with subsequent run-off-the-road into ditch)

Accident Severity: Moderate

Summary of Events: A pickup attempted to turn left onto a 2-lane, 2-way State road but struck the left side of a southbound passenger car. The driver of the car lost control, swerved into the opposing lane, and was struck broadside by a schoolbus transporting 53 high school students and a teacher on an activity trip. (The schoolbus had slowed down anticipating the collision.) After the collision, the schoolbus travelled off the road to the right and went into a 5-foot deep drainage ditch. The bus came to rest on its right side at about a 45° angle with the right wheels of the bus in the bottom of the ditch.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 54 passengers (53 students and 1 teacher), aged 14 to 19 (excluding the teacher), 48 were uninjured, and 6 sustained minor (AIS 1) injuries. The 45-year-old unrestrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Major damage to the bus was confined to the front. The bumper was pushed back into the tires, the front axle was shifted rearward, and the front body and part of the engine were damaged. Minor damage occurred on the right side of the bus from contact with the ditch. The schoolbus body shifted forward on the chassis about 3 1/2 inches. Interior was not damaged.

Evaluation of Bus Performance: The bus performed well in the crash, with all damage confined to exterior.

Injury Analysis

Passengers: Most of the injuries were sustained when the students struck their heads on the seat back in front of them or struck their legs and ankles on the seat legs. Some injuries occurred during evacuation, not during the impact or partial overturn. Students found it difficult to walk on the tilted bus floor.

Injured students were seated primarily in the left front of the bus, near the area of impact. Several students stated they were seated with their legs in the center aisle, not facing forward, at the time of the collision. Several students also reported they were thrown towards the right side of the bus as it came to rest in ditch.

Only one bus occupant was transported to emergency room of local hospital; she had fainted.

Most of the injuries sustained also would have been sustained if the students had been wearing lap belts. The injuries were very minor, and in some cases occurred, not during the accident sequence, but when students evacuated the bus.

Schoolbus Driver: Lap belt available but not used. Driver received minor injuries (AIS 1): bruised right elbow, stiff neck and shoulder. Driver reported that these injuries occurred when he fell as he left the bus.

Outcome for Occupants of Other Vehicle

No. 1 Vehicle Description: 1968 Pontiac 2-door Tempest

Damage to Vehicle: Severe right side damage, especially toward the rear. Sheet metal ripped apart and pushed inward, buckling the roof upward.

Occupant Restraint Use and Injury: According to the police report, the driver received minor injuries and the passenger received serious injuries. Neither the driver nor the passenger was restrained. No further injury information available.

No. 2 Vehicle Description: 1977 Chevrolet pickup truck

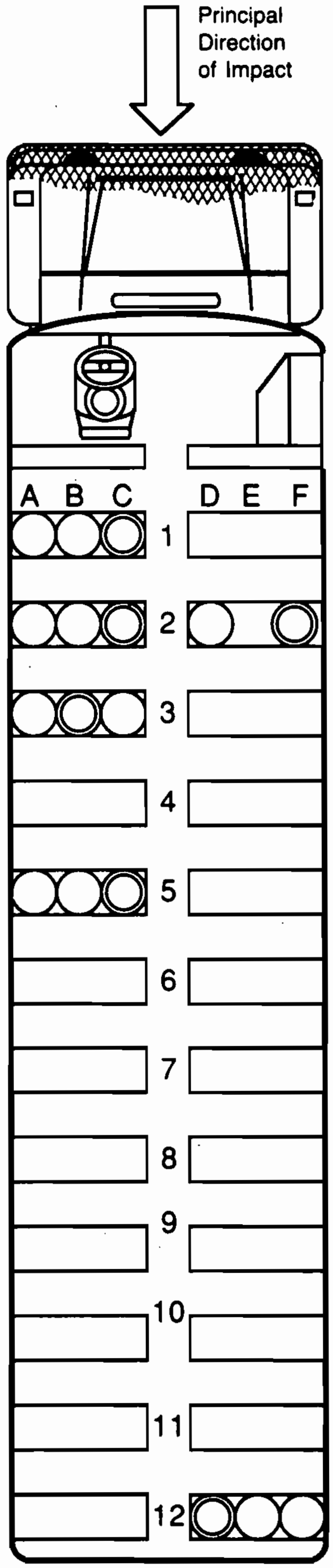
Damage to Vehicle: Minor damage to right front bumper and fender.

Occupant Restraint Use and Injury: The driver was restrained and was not injured.

Special Notes on the Accident

Following the accident, the Safety Board investigator found that the bottom seat cushions of all passenger seats on the accident bus were unsecured. The Carpenter system of attachment for seat bottoms consists of three sheet metal clips bolted to the plywood bottom of the cushion which are supposed to be fastened to the rails of the supporting seat frame. Two clips engage the front rail, and the third clip attaches the rear of the seat to the frame. This third clip rotates to lock the seat bottom in the frame. The Safety Board investigator found all the rear clips on the seats had rotated approximately 90° from locked position. This allows the seat cushion to flip up in the back and possibly become unhinged from the seat. In this crash, the accident dynamics were such that no seat cushion came lose.

Bloomfield Township, Ohio
Case No. 8



Left Side of Bus

Driver
F-49, MAIS 1

Row 1C
F-16, MAIS 1

Row 2C
F-15, MAIS 1

Row 3B
F-19, MAIS 1

Row 5C
F-18, MAIS 1

Right Side of Bus

Row 2F
F-15, MAIS 1

Row 12D
M-16, MAIS 1

LEGEND

Uninjured — Unknown if Injured

Injured — Lap Belt Used

Fatally Injured

Example: M-17 (Male, Age 17) MAIS-2 (Used for injured occupants only) Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

* American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Notes:
Seating position for 37 of 48 uninjured passengers is unknown.

Driver states his injury incurred while exiting bus. Some passengers also reported their injuries were sustained during evacuation.

Some students out of position with legs in center aisle.

The school bus shown is representational only.

Case No.: 9
NYC-84-H-SB03

Accident Location: Scenic Road, Laconia, New Hampshire

Date and Time: March 19, 1984, 7:50 a.m.

Description of Schoolbus: 47-passenger poststandard schoolbus: 1983 GMC chassis with Carpenter body

Type of Accident: Head-on collision (principal direction of impact approximately 1 o'clock)

Accident Severity: Moderate

Summary of Events: A schoolbus transporting 14 grade school children to school was travelling about 20 to 30 mph on a winding 2-lane roadway. The road was wet with about 1 1/2 inches of slush, salt, and sand. As the bus negotiated a lefthand curve, the right front wheel left the roadway. The bus travelled about 12 feet and plowed through 4-foot high by 6-foot wide snowbank on the right. The bus then continued 39 feet, struck head-on a brick sewage pump station house. The bus came to rest against the station house.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 14 passengers, aged 5 to 12, 3 were uninjured, 9 sustained minor (AIS 1) injuries, 1 sustained moderate (AIS 2) injuries, and 1 sustained injuries of unknown severity (AIS 7). The 30-year-old restrained driver was uninjured.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: No interior damage. Substantial exterior damage to the right front engine compartment, right front suspension, and right front frame rail. The passenger compartment slid forward on the frame about 1 inch.

Evaluation of Bus Performance: Bus performed well in the crash. Most damage confined to the exterior. No deformation of seat or seat anchorages.

Injury Analysis

Passengers: Students who sustained minor injuries (the most "serious" minor injury being a cut lip or sprained ankle) commonly attributed their injuries to contact with seat backs in front of them; two students received their minor injuries from contact with the padded modesty panel.

The most seriously injured person, a 10-year-old boy, sustained a moderate (AIS 2) injury to his knee. He was seated in the last row of the bus, next to the left window, and was bending down to tie his shoe at the moment of impact. He received his sprained knee and pulled collateral ligaments when he struck his knee on the heater under the seat in front of him.

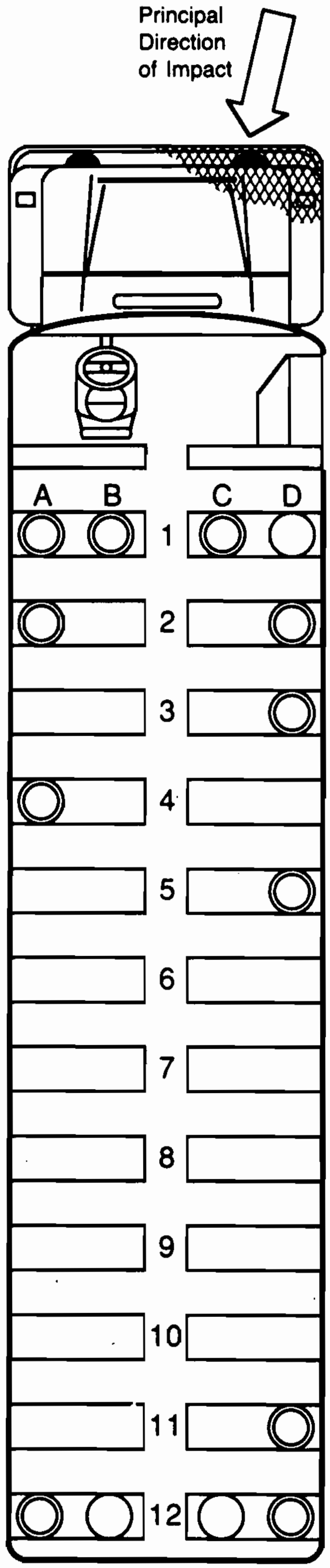
Lap belt use would not have reduced the number of students sustaining minor injuries, but lap belt use might have reduced the severity of the AIS 2 knee injury, provided, of course, that the student would not have unbuckled his lap belt in order to reach his shoe.

Schoolbus Driver: Available lap belt used. Driver uninjured.

Special Notes on the Accident

Twelve of the 24 seats in the accident bus had bottom seat cushions with the rear lock either open or missing; 9 were missing rear lock. The seat cushions on eight seats came loose during this accident. It should be noted, however, no passenger was injured by loose seat cushions in this frontal impact accident.

Laconia, New Hampshire
Case No. 9



Left Side of Bus

Row 1A
M-10, MAIS 1

Row 1B
M-12, MAIS 1

Row 2A
M-8, MAIS 1

Row 4A
F-11, MAIS 1

Row 12A
M-10, MAIS 2
Sprained knee and strained collateral ligaments.

Right Side of Bus

Row 1C
M-10, MAIS 1

Row 2D
M-7, MAIS 1

Row 3D
F-8, MAIS 1

Row 5D
F-8, MAIS 1

Row 11D
M-8, MAIS 1

Row 12D
M-8, MAIS 1

Special Note:
The injured passenger in Row 12A was kneeling to tie his shoe when the impact occurred. He struck his leg on the heater under the seat.

LEGEND

Uninjured — Unknown if Injured
Injured — Lap Belt Used
Fatally Injured

Example: M-17 (Male, Age 17) — MAIS-2 (Used for injured occupants only) Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

Case No.: 10
FTW-85-H-SB40

Accident Location: Unnamed county road outside Frankston, Texas

Date and Time: September 13, 1985, 3:48 p.m.

Description of Schoolbus: 65-passenger poststandard bus:
1979 International Harvester chassis with 1979 Ward body

Type of Accident: Head-on collision

Accident Severity: Moderate

Summary of Events: A schoolbus transporting 44 students home from school was travelling at about 20 mph down a 1-lane, 2-direction, asphalt road when the engine stalled. The schoolbus driver was unable to restart the engine, and the schoolbus picked up speed as the bus entered a winding 5 percent downgrade. When neither the foot brake nor the emergency brake would respond, the schoolbus driver deliberately steered the bus into a tree to avoid traveling onto a highway. The schoolbus was traveling approximately 20 mph when it struck the tree directly head-on.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 44 passengers, aged 5 to 17, in the schoolbus, 28 were uninjured, 6 received minor (AIS 1), injuries, and 10 received unspecified minor injuries (AIS 7). The 31-year-old restrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The center front of the schoolbus was crushed rearward 14 inches, while the bus body was displaced 2 inches forward of its original mounting on the chassis. Induced damage resulted in minor buckling of the passenger area floor of about the first seat row, partial obstruction of the passenger loading door, and cracks in both right and left side windshields. Several of the tubular posts which support passenger seats were found broken from their floor mounts; both screwed and welded attachment points failed at other locations.

Evaluation of Bus Performance: The schoolbus performed well in this moderate speed impact, with the collision forces being dissipated by both the body's displacement on the chassis and the occupant containment provided by the passenger seats. While failures of the occupant seat attachment points did occur, these failures did not contribute to injuries sustained by the student passengers. There were no major structural failures of the body structure or chassis.

Injury Analysis

Passengers: Most of the AIS 1 injuries were minor bruises and abrasions, primarily to the chest, shoulder, and lower extremities. These injuries may have been sustained when students struck the seat backs in front of them (photos show contact marks), each other, or the rigid lower framework of the bench seats. The minor injuries were scattered throughout the front, middle, and rear of the bus and were equally divided between the left and right side seats. No pattern of injury could be discerned; injured students were seated side-by-side with uninjured students. Four children also were sharing a seating position with another occupant, but they were not uniformly injured. The age, sex, and weight of the students did not correlate to postaccident injury status. It also does not appear that the presence of two rows (rows 9 and 10) of prestandard seats contributed significantly to passenger injury. These prestandard seats would have influenced the injuries of passengers seated in rows 10 and 11 or in row 9 only if the passengers' heads flexed back. Injury documentation of passengers in these rows shows no increase in number, type, or severity of sustained injuries, compared to those passengers who struck poststandard seat backs.

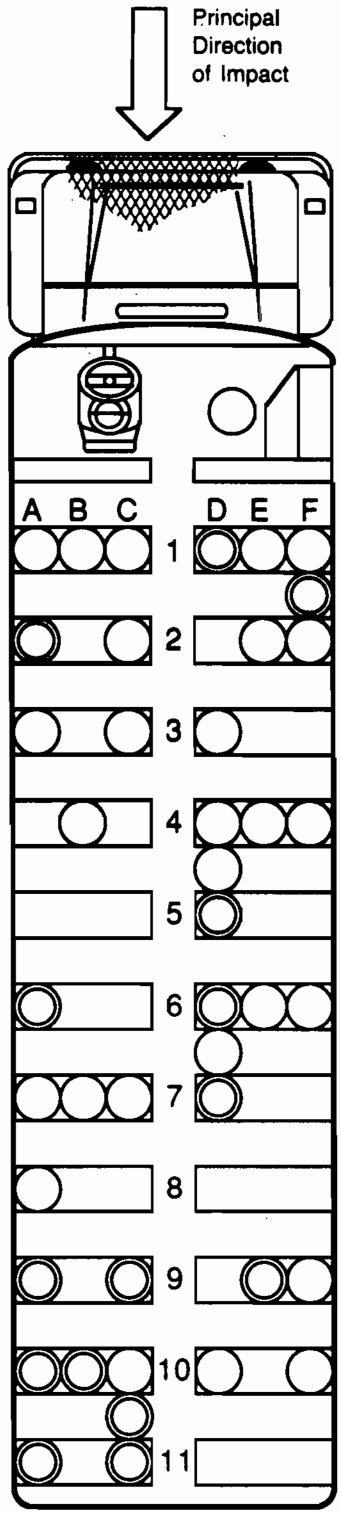
Lap belt use would not have reduced the number and type of minor injuries sustained in this collision. The bruises, abrasions, and strains still would have occurred as passengers struck seat backs, lower seat framework, and other occupants. Had lap belts been worn by the schoolbus passengers seated behind the prestandard seats installed at rows 9 and 10, serious head, neck, and facial trauma could have been sustained by contact with the prestandard seat's lightly padded seat back framework. These injuries would have occurred as an occupant's upper torso pivoted forward at the same time the lower body was held by the lap belt.

Schoolbus Driver: Available lap belt used. This driver sustained minor (AIS 1) injuries, including a lacerated right knee (from contacting the instrument panel-mounted gear selection lever) and bruised abdomen (due to the lap belt). An unrestrained schoolbus driver probably would have sustained more serious injuries from contact with the unforgiving frontal components of the driver's compartment.

Special Notes on the Accident

This schoolbus had been retrofitted with two rows (9 and 10) of prestandard passenger seats. Although the back cushion of the row 9 seat was deformed forward approximately 30° it does not appear that these prestandard seats contributed to the type or severity of occupant injury in this collision.

Frankston, Texas
Case No. 10



Left Side of Bus

Driver
F-31, MAIS 1

Row 2A
M-8, MAIS 7
Unspecified injury to lower left chest.

Row 6A
M-6, MAIS 1

Row 9A
F-13, MAIS 7
Unspecified injury to chest.

Row 9C
F-16, MAIS 1

Row 10A
F-12, MAIS 7
Unspecified injury to left shoulder and chest.

Row 10B
F-13, MAIS 7
Unspecified injury to neck.

Row 11A
F-11, MAIS 1
Unspecified injury to chest.

Row 11C
F-9, MAIS 1*
M-16, MAIS 7*
Unspecified injury to foot.

Special Note:
Unknown where seated:
M-10, MAIS 1.

* Indicates that passenger shared a seating position with another occupant.

The school bus shown is representational only.

Right Side of Bus

Row 1D
M-14, MAIS 1

Row 2F
F-7, MAIS 7*
Unspecified injury to flanks and hips.

Row 5D
F-12, MAIS 1*

Row 6D
F-16, MAIS 7
Unspecified injury to right side of chest and left foot.

Row 7D
F-17, MAIS 7*
Unspecified injury to abdomen wall.

Row 9E
F-10, MAIS 7
Unspecified injury to knee.

LEGEND

Uninjured
Unknown if Injured
Injured
Lap Belt Used
Fatally Injured

Example: M-17 — Male, Age 17
MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

* American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Case No.: 11
MKC-85-H-SB02

Accident Location: N.E. Route No. 2, outside Palmyra, Nebraska

Date and Time: January 4, 1985, 8:10 a.m.

Description of Schoolbus: 53-passenger poststandard bus:
1983 Ford chassis with 1983 Wayne body

Type of Accident: Left front angle collision (principal direction of impact at 11 o'clock)

Accident Severity: Moderate

Summary of Events: A schoolbus carrying 20 high school students to morning classes was travelling on a wet 2-lane, 2-way concrete roadway at a witness-estimated speed of 50 mph. An oncoming tractor-semitrailer crossed over the center line at a witness-estimated speed of 55 to 60 mph and collided with the bus. The bus was struck at its left front fender by the left front of the tractor. The deepest penetration of the bus was at the left front "A" pillar. After impact, the bus traveled 331 feet before coming to a stop, 114 feet north of the roadway.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 20 passengers, aged 12 to 17, 11 were uninjured and 9 sustained minor (AIS 1) injuries. The 65-year-old restrained driver was critically injured (AIS 5) and died of his injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Damage to the left front side from the bumper to the first passenger compartment on the left side. The maximum inward crush was 12 inches. The driver's side window was destroyed and displaced 40 inches rearward.

Evaluation of Bus Performance: All side seams and passenger window frames remained intact. All passenger seats remained in original position, seat anchorages secure. Glass was fractured or missing from the 10 double windows on the left side.

Injury Analysis

Passengers: The nine passengers who received minor (AIS 1) injuries complained of lacerations and contusions of the head and upper extremities as a result of flying fragments of window glass and contact with the interior sides of the schoolbus.

Most passengers were injured by flying glass or contact with interior side walls (6 of the 9 injured students were seated by windows). Lap belt use would not have prevented these injuries.

Schoolbus Driver: Available lap belt used. Driver received critical injuries (AIS 5) which proved fatal: multiple pericardium trauma, multiple rib fractures, and bilateral fractures of the sternum. The injuries likely resulted from a rearward displacement of the entire steering assembly, due to the impact at the left front of the bus.

Palmyra, Nebraska
Case No. 11

Outcome for Occupants of Other Vehicle

Vehicle Description: 1979 Kenworth tractor with Great Dane trailer.

Damage to Vehicle: Left side of cab completely destroyed.

Occupant Restraint Use and Injury: Lap belt not in use; open fracture of left leg (AIS 3).

Special Notes on the Accident

Broken glass caused AIS 1 injuries to four schoolbus passengers. Of the 10 double passenger windows on the left side, 5 were broken out, 4 had holes, and 3 were cracked.

All bottom cushions on passenger seats were unlatched. One seat could never be latched because the latch had not been installed properly.

The ceiling seam had an exposed sharp edge with potential for injury.

Palmyra, Nebraska
Case No. 11

Left Side of Bus

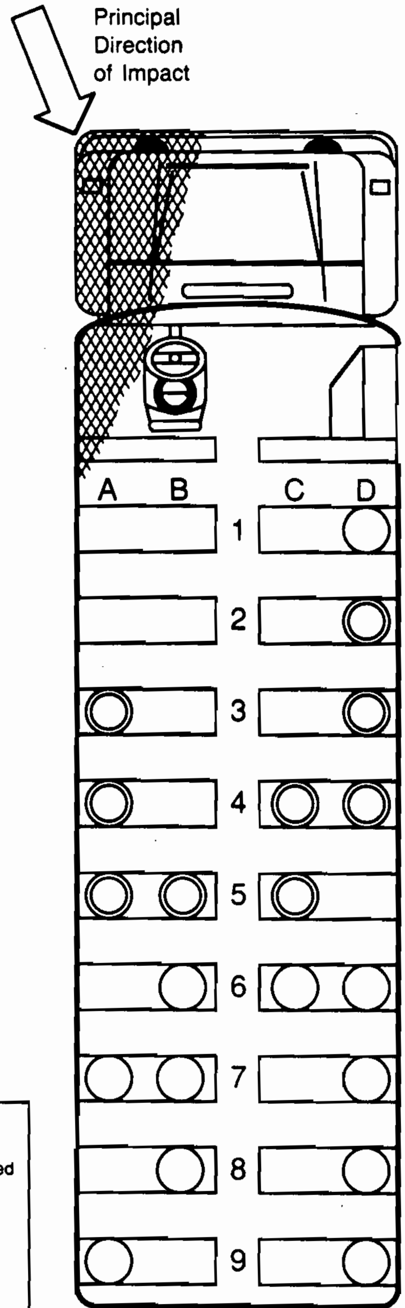
Driver
M-65, MAIS 5 (Fatal)
Chest and heart injuries

Row 3A
M-14, MAIS 1

Row 4A
F-16, MAIS 1

Row 5A
F-15, MAIS 1

Row 5B
F-14, MAIS 1



Right Side of Bus

Row 2D
F-17, MAIS 1

Row 3D
M-15, MAIS 1

Row 4C
F-16, MAIS 1

Row 4D
F-16, MAIS 1

Row 5C
M-14, MAIS 1

LEGEND

- Uninjured
- Unknown if Injured
- Injured
- Lap Belt Used
- Fatally Injured

Example: M-17 (Male, Age 17) MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

<u>**Case No.: 12**</u>
FTW-84-H-FRO5

Accident Location: Farm Road 326, outside Sour Lake, Texas

Date and Time: March 19, 1984, 8:10 a.m.

Description of Schoolbus: 71-passenger poststandard bus:
1984 International Harvester chassis
with 1983 Ward body

Type of Accident: Left front angle collision (principal direction of impact at approximately 11 o'clock)

Accident Severity: Moderate

Summary of Events: A schoolbus transporting approximately 30 high school students to school was travelling on a 2-lane, 2-way asphalt road at about 50 mph. As it approached a bridge, an oncoming tractor-semitrailer crossing the bridge dropped a spare tire assembly into the northbound lane. In an attempt to evade the bouncing tire, the schoolbus driver steered to the right and lost control of his vehicle when it entered the soft shoulder. The schoolbus travelled 328 feet on the shoulder before reentering the roadway 34 feet south of the bridge. It continued across both lanes, struck the southwest bridge abutment at an angle of 30°, and was redirected back onto the road. Speed of bus at impact was estimated at 27 to 30 mph. The bus then slid 46 feet on the wet bridge surface and came to rest still upright.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the approximately 30 student passengers, aged 14 to 18, in the schoolbus, 22 were uninjured and 8 received minor (AIS 1) injuries. The 49-year-old unrestrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Damage was confined to left front of schoolbus, the steering axle, and chassis frame. No interior damage was sustained.

Evaluation of Bus Performance: Bus performed well, with all damage confined to exterior. Schoolbus body remained firmly attached to chassis, with no forward displacement.

Injury Analysis

<u>Passengers:</u> Contact with seat back was the most common source of the minor injuries. No pattern as to body regions injured could be discerned.

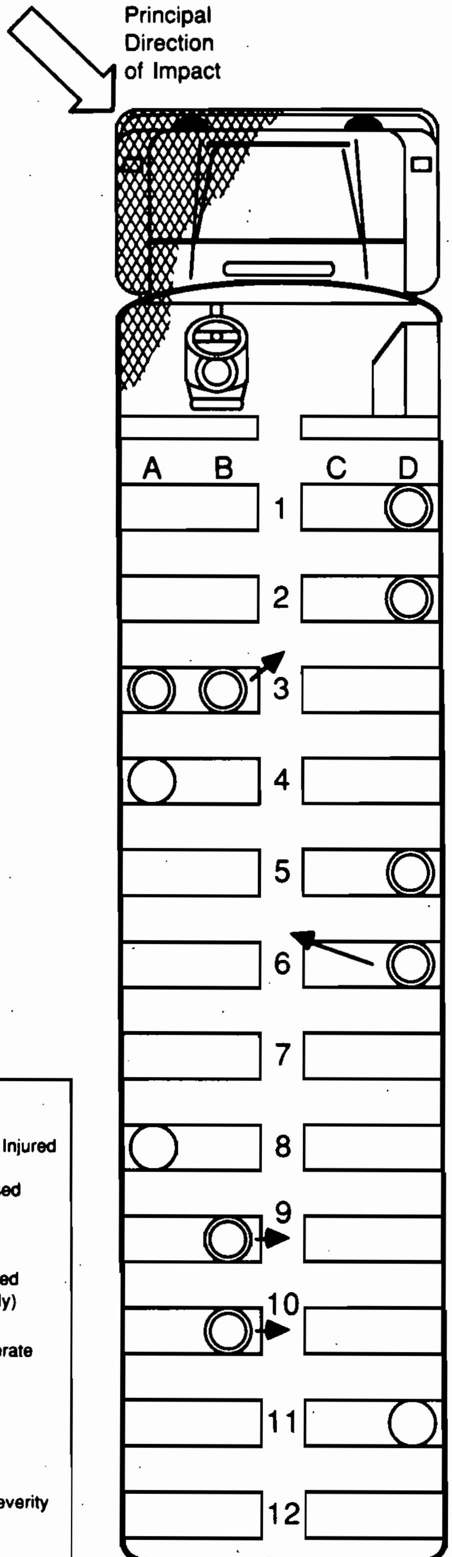
Four passengers (three of whom were seated on the aisle) were thrown into the center aisle following the impact. Only one, possibly two minor injuries could be attributed to the fall; the others probably occurred at the time of the initial collision.

Sour Lake, Texas
Case No. 12

While some of the specific AIS 1 level injuries might not have been incurred had passengers been wearing lap belts (i.e., contusion of left hip from falling into aisle), lap-belted passengers still might have incurred at least minor injuries at impact or as bus veered to the right and left.

Schoolbus Driver: Lap belt available but not used. Driver received minor (AIS 1) injury: Contusion to right hand (probably from contact with dashboard). Lap belt use would not have prevented this injury.

Sour Lake, Texas
Case No. 12



Left Side of Bus

Driver
M-49, MAIS 1

Row 3A
F-16, MAIS 1

Row 3B
F-17, MAIS 1

Row 9B
M-17, MAIS 1

Row 10B
M-15, MAIS 1

Right Side of Bus

Row 1D
F-18, MAIS 1

Row 2D
F-18, MAIS 1

Row 5D
F-16, MAIS 1

Row 6D
M-15, MAIS 1

LEGEND

Uninjured
Unknown if Injured
Injured
Lap Belt Used
Fatally Injured

Example: M-17 (Male, Age 17)
MAIS-2 (Used for injured occupants only): Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Notes:
Seating position unknown for 19 of 22 uninjured passengers.

Seating positions shown for all injured occupants.

The school bus shown is representational only.

Case No.: 13
DCA-86-MH-002

Accident Location: U.S. Route 70, outside St. Louis, Missouri

Date and Time: November 11, 1985, 2:43 p.m.

Description of Schoolbus: 35-passenger poststandard bus:
1979 International chassis with Ward body

Type of Accident: Front angle collision

Accident Severity: Extremely severe

Summary of Events: A schoolbus, transporting 13 high school students home from school, was travelling between 59 and 67 mph on a 6-lane divided highway when it left the roadway and struck a sign support pedestal and sign post. The impact separated the schoolbus body from its chassis. The rear of the passenger body rotated upward and forward, to approximately 54°, crushing the front and right forward top structure rearwards and down into the student seating area. As the sign pole reached its maximum penetration, a depth of 108 inches rearward of the firewall, the body swung clockwise for approximately 90° about the pole.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 13 passengers, aged 14 to 18, 8 sustained minor (AIS 1) injuries, 2 sustained moderate (AIS 2) injuries, 1 sustained serious (AIS 3) injuries, 1 sustained severe (AIS 4) */ injuries which proved fatal, and 1 sustained critical (AIS 5) injuries which proved fatal. The 26-year-old restrained driver received serious (AIS 3) injuries.

One passenger died in the crash while another passenger survived for 8 days before dying without regaining consciousness.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The schoolbus body was completely separated from its chassis. The major impact area was to the right front, which was torn open from the firewall to approximately the third window on the right side.

The left side restraining barrier was displaced forward for 23 inches and crushed downward by the driver's side window pillar. The right side restraining barrier was torn from the floor and entangled with the row 1 right side bench seat. There were four seat cushions found displaced following the crash.

The bus body roof was collapsed aft for a distance of 108 inches rearward of the firewall and collapsed downward to only 24 inches above the passenger floor at the forward right side of the bus. The inside roof had blood, hair, shoe prints, and clothing marks from the rear to the front of the bus.

Considering the speed at which the bus reportedly hit the sign support pedestal, the schoolbus body probably performed as well as could reasonably be expected.

*/ These injuries, if using the AIS 1985 coding manual, would be AIS 5, critical.

While the front and top right of the bus body were severely collapsed by the pole impact, there were no documented failures of the body panel joints nor of the bench seat structures that were not in the direct area of collapse. The separation of the bus body from its chassis probably benefited the passengers, since it allowed a dissipation of crash forces over a much greater distance than would have occurred had the body remained rigidly attached.

A maintenance access panel, which before the crash had been installed at the right front of the bus under the side windows, separated during the crash. The presence of blood, hair, and tissue on the body panel joint which was exposed when the panel separated indicates that one of the schoolbus occupants sustained a head injury due to contact with the exposed edges of this joint.

Injury Analysis

Passengers: Minor (AIS 1) injuries sustained by passengers consisted of contusions, abrasions, and both lumbar and cervical strains. One passenger's moderate (AIS 2) injuries were a cerebral concussion and a large laceration of the head; the remaining moderately injured student received a separation of the acromioclavicular (shoulder) joint. A fractured femur accounted for the serious (AIS 3) level injury sustained by the passenger seated at the extreme right rear position of the bus.

Both of the fatalities were the result of head injuries. One of the passengers who was killed was seated precrash in row 5 left side and the other passenger was seated in row 2 right side. The passenger reportedly seated precrash at the row 5 left side position was found lying in the front section of the damaged bus body, under the area of major structural collapse. It is believed that her fatal head injuries resulted from striking the damaged bus roof structure as she was vaulted from her precrash seating position by the crash forces. The passenger whose critical (AIS 5) head injuries also proved fatal was seated precrash at the row 2 right side position, directly beneath the area of maximum roof structure collapse. It is believed that this passenger's fatal injuries resulted from contact with the collapsed roof structure.

Had a lap belt been available and used by the fatally injured passenger in the row 5 left side seat, her forward travel would have been arrested by the belt. Thus, head injuries received due to striking the collapsed frontal interior of the bus passenger compartment would have been prevented. Use of a lap belt also would have prevented the occupant in the rear seat on the right side from sustaining the fractured femur. However, the severity of the injuries that would have been sustained by these two occupants if they had been lap belted cannot be determined.

Lap belt use by the remaining bus passengers would probably not have resulted in any reduction of injury severity. The fatally injured student seated at the row 2 right side position would almost assuredly have sustained the same type of injury due to the roof structure collapse. The collapse did not provide for survivable space.

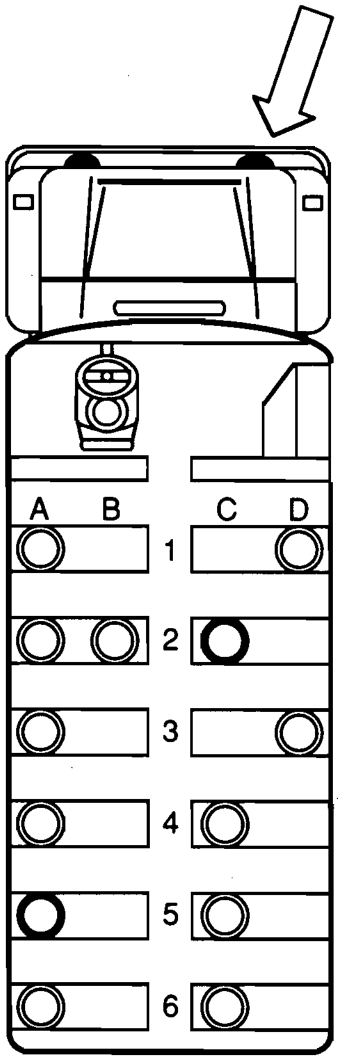
St. Louis, Missouri
Case No. 13

Postcrash examination of the lap belt installed in the first seat on the right side of the schoolbus disclosed that the lap belt was not in use at the time of the crash. The occupant of this seat was also in the major impact area, and initial collision forces probably propelled her forward against the padded restraining barrier resulting in her chest contusion (AIS 1), and out of the area, then crushed in by the subsequent collision with the sign pillar. This unrestrained passenger sustained minor injuries only, but probably would have sustained more severe or even fatal injuries if she had been restrained by a lap belt. The severity of the remaining passenger injuries, all minor (AIS 1) and moderate (AIS 2) injuries, might very likely have been increased by the use of a lap belt.

It should be noted that this crash involved extremely severe impact forces. No crash test data are available that would relate to survival expectations in a crash of this severity. The actual performance of lap belt restraints in a collision of this magnitude is unknown.

Schoolbus Driver: Available lap belt used.
Description of Injuries--Serious (AIS 3) injuries: cerebral concussion, fractured right ulna and laceration of the forehead and right eye. The driver was seated outside the area of direct crush. The bus body surrounding his seat was severely damaged but the seat itself was untouched.

St. Louis, Missouri
Case No. 13



Left Side of Bus

Driver
M-26, MAIS 3
Cerebral concussion, fractured right ulna, laceration of forehead and right eye.

Row 1A
F-17, MAIS 2
Separation of acromioclavicular joint.

Row 2A
F-14, MAIS 1

Row 2B
M-15, MAIS 1

Row 3A
F-15, MAIS 1

Row 4A
M-16, MAIS 1

Row 5A
F-18, MAIS 4 (Fatal)
Large laceration on right frontal area of head; basilar skull fractures w/CSF leak, cerebral edema.

Row 6A
M-16, MAIS 2
Cerebral concussion, laceration on head, contusion on right foot.

Right Side of Bus

Row 1D
F-14, MAIS 1
Chest contusion (lap belt available, but not used).

Row 2C
F-15, MAIS 5 (Fatal)
Cerebral edema, right subdural hematoma, unconscious and unresponsive to painful stimuli.

Row 3D
F-15, MAIS 1

Row 4C
M-16, MAIS 1

Row 5C
M-15, MAIS 1

Row 6C
M-16, MAIS 3
Distal fracture of right femur, 1.5 cm laceration above left eyebrow.

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 — Male, Age 17; MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Notes:
The bus body separated from its chassis upon impact with the pole.

The passenger in Row 1D was unrestrained although a lap belt was available at her seating position.

The school bus shown is representational only.

<u>**Case No.: 14**</u>
DCA-85-MH-008

Accident Location: U.S. Route 13, outside Snow Hill, North Carolina

Date and Time: May 31, 1985, 3:20 p.m.

Description of Schoolbus: 48-passenger poststandard bus:
1982 Ford chassis with Thomas Built body

Type of Accident: Head-on (principal direction of impact at 12 o'clock)

Accident Severity: Extremely severe

Summary of Events: A schoolbus transporting 27 students home from school on a 2-lane, 2-way road was initially struck head-on by a tractor-semitrailer (left front to left front). The tractor-semitrailer then sideswiped the left front of the bus, peeling back the left side wall and ejecting the three front seats on the left. The truck continued to penetrate the schoolbus until it reached the left rear tire drive axle, just before the fifth row of seats. The truck stopped then and rotated clockwise, tearing the schoolbus floor open and creating a large gap in the truck then disengaged. The schoolbus rotated about 120° counterclockwise and came to rest in a ditch on the right side of the roadway; the front of the bus faced the road and was almost perpendicular to the road. Several schoolbus passengers were ejected during the accident sequence.

After colliding with the schoolbus, the tractor-trailer struck another tractor-trailer that had been traveling behind the schoolbus. A car then struck the rear of the second tractor-semitrailer. The first tractor and the second tractor-semitrailer caught fire and burned.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 27 passengers, aged 5 to 13, 8 sustained minor (AIS 1) injuries, 7 sustained moderate (AIS 2) injuries, 3 sustained serious (AIS 3) injuries, 7 sustained severe (AIS 4) injuries, and 2 sustained critical (AIS 5) injuries. Injuries to 6 passengers proved fatal. The 18-year-old restrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The schoolbus was initially struck on the left 14 inches of the front bumper, bending the bumper rearward almost 90° and then was sideswiped by the truck along its left side, tearing the sheet metal 13 feet back and ejecting the first three rows of seats. A large, gaping hole was created in the bus. The anchorages on the left fourth seat were severed, but the seat remained inside the bus.

The left front corner of the roof crushed down and the front hood and engine were torn outward away from the bus. The entire bus was skewed right, and the right side seats were cocked in toward the aisle because the right sidewall had twisted. The flooring on the left side of the bus had torn apart just in front of the fifth row seat, leaving a gaping hole. From the first row to the fourth row on the left side a gaping hole existed along with crunched and buckled sheet metal siding. The driver's seat had bent backward during the collision, pinning the driver inside.

Evaluation of Bus Performance: Except for the floor separation, the schoolbus performed well in this severe crash. Seat cushions remained in place and the seatlegs remained secured to the floor except for the seats that were ejected and the seats in the immediate impact area. Sheet metal in the other areas of the bus remained intact.

Injury Analysis

Passengers: Six passengers died from their injuries in this crash. The fatally injured passengers were seated on the left side of the bus, behind the driver, in the first four rows: two in the first seat, two in the second, and one each in the outboard seats of the third and fourth rows next to the sidewall. This was the area of the bus penetrated by the tractor-trailer. The first three rows of the seats on the left were torn out of the bus by the tractor-trailer as it struck and penetrated the side, and the fourth row on the left almost was. This seat was found resting on the bus front wheel, almost totally torn from its anchorages.

Crash forces were concentrated on the front half of the bus, particularly on the left front. The distribution of passenger injuries reflect this. All fatalities were on the left front and five of the six surviving passengers who sustained serious and severe injuries were seated, precrash, in the front half. (The sixth passenger was in row 5.) The six surviving students who sustained AIS 3 and AIS 4 injuries were seated toward the front of the schoolbus. All were in the first five rows.

The AIS 1 injuries consisted of minor lacerations and contusions. The AIS 2 injuries included fractured pelvis, radius, humerous, ribs, skull, and scalp lacerations. The AIS 3 injuries included three fractured femurs. The AIS 4 injuries included ruptured spleens, lacerated liver, abraded spleen with hemmorhage, and closed head injuries. The AIS 5 injuries were a lacerated lung and a compound skull fracture with diffuse brain injury.

Installation and use of lap belts would not have prevented the six fatalities nor the serious and severe injuries sustained by the surviving two occupants of the first four rows of seats on the left side of the schoolbus. Any protection that lap belts may have afforded these occupants was negated by the penetration of the truck into these occupants' space. In addition, rows 1 to 3 on the left were torn loose from their anchorages and ejected out of the bus. Some seats were crushed between the schoolbus and truck. Any occupant restrained by a lap belt would have been ejected along with these seats. Injury outcome would have been the same or worse in some cases.

It is possible that the surviving occupant of the aisle seat in the third row, if restrained by a lap belt could have sustined more serious or even fatal injuries. This occupant then would have been held in his seat and crushed between the truck and the left side of the schoolbus when this seat was torn out of the schoolbus body during the collision sequence.

The surviving occupant of row 4 on the left, seated on the aisle, also might have fared worse if lap belted. As it was, this passenger while unrestrained sustained serious (AIS 3) injuries. He was ejected out of the bus as was the fatally injured passenger seated next to them. Investigators found this seatbench hanging in the bus, almost totally torn from its anchorage, resting on top of the wheel. If occupants of this seat had been lap belted, this seat, like the three rows before it, surely would have been totally ejected along with the children strapped to it, and possibly crushed between bus and truck. Lap belted occupants exert additional force on the seat anchorages.

Installation and use of lap belts probably would have mitigated two of the three serious and severe injuries sustained by surviving occupants seated on the aisle on the right side of the schoolbus. Crash forces would have propelled these occupants, out of their seats and toward the left front of the schoolbus.

The installation and use of lap belts by those who sustained minor and moderate injuries would not have prevented these occupants from striking the windows, the side walls, and/or the occupant seated next to them, and would have resulted in these occupants' upper torsos striking the seat back or barrier in front of them. These occupants would likely have sustained contusions, abrasions, and minor lacerations, and although the injuries may have been different, they probably would not have been any less severe.

Schoolbus Driver: Available lap belt used. Minor (AIS 1) injuries: lacerated scalp and left shoulder. Driver was pinned in her seat and had to be extricated. Truck struck just behind the driver's seat.

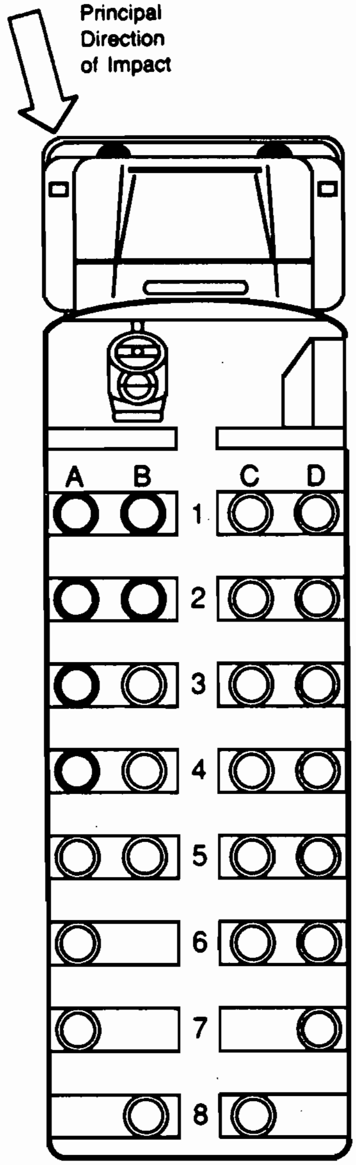
Outcome for Occupants of Other Vehicle

Vehicle No. 1 Description: Tractor trailer - 1984 International Harvester tractor with box;
Vehicle No. 2 Description: Tractor trailer - GMC tractor with box trailer.
Vehicle No. 3 Description: Car - 1981 Dodge Challenger

Damage to Vehicle: Two tractors destroyed; car - front end damage.

Occupant Restraint Use and Injury: Restraints were not used by drivers or occupants of any of the other vehicles involved. The driver of the first truck received multiple left posterior rib fractures, lacerated lung, lacerated aorta with hemothorax, contused left lung and heart, right posterior rib fractures, and extensive postmortem incineration (AIS 5). The driver of the second tractor-semitrailer sustained minor bruises and cuts (AIS 1); the driver of the car received facial scratches, chest bruised, wrist jammed (AIS 1). The passenger of the car had strained ligaments in the knee, a scratch on the forehead, and a bruised nose (AIS 1).

Snow Hill, North Carolina
Case No. 14



Left Side of Bus

Driver
F-18, MAIS 1

Row 1A
M-10, MAIS 5 (Fatal)
Multiple left rib fractures, lacerated lung, multiple internal injuries.

Row 1B
F-10, MAIS 4 (Fatal)
Basilar skull fracture, fractured left femur, comminuted fractured right tibia and fibula, partial amputation of right foot.

Row 2A
F-13, MAIS 5 (Fatal)
Compound skull fracture, diffused brain injury, multiple pelvic fractures.

Row 2B
M-13, MAIS 4 (Fatal)
Amputated left lower leg, comminuted fracture of right tibia and fibula, multiple fractures of right foot, deep groin laceration, deep laceration above right eye.

Row 3A
M-10, MAIS 4 (Fatal)
Partial amputation left lower leg, ruptured spleen, closed head injury, degloving of right lower leg, fractured right tibia and fibula.

Row 3B
M-11, MAIS 4
Lacerated liver, closed head injury, lacerated chin.

Row 4A
M-12, MAIS 4 (Fatal)
Partial amputation of left leg, comminuted compound fracture of left femur, lacerated left femoral artery, lacerated left foot.

Row 4B
F-12, MAIS 3
Fractured left femur, severe right facial laceration, leg laceration.

Row 5A
M-13, MAIS 2
Skull fracture.

Row 5B
M-11, MAIS 3
Fractured left femur, tibia and fibula, fractured right thumb, multiple severe lacerations.

Row 6A
M-11, MAIS 1

Row 7A
M-12, MAIS 1

Row 8B
F-13, MAIS 2
Concussion, lacerated scalp.

Right Side of Bus

Row 1C
M-9, MAIS 2
Deep laceration of right scalp, and left upper arm, multiple lacerations and contusions.

Row 1D
M-5, MAIS 4
Abraded spleen with hemorrhage, deep laceration over right eye, multiple contusions.

Row 2C
F-7, MAIS 3
Fractured left femur, facial lacerations, multiple contusions and abrasions.

Row 2D
F-6, MAIS 1

Row 3C
F-8, MAIS 1

Row 3D
F-6, MAIS 1

Row 4C
M-9, MAIS 4
Ruptured spleen, fractured left humerus, left rib fractures, superficial lacerations.

Row 4D
M-8, MAIS 1

Row 5C
F-6, MAIS 1

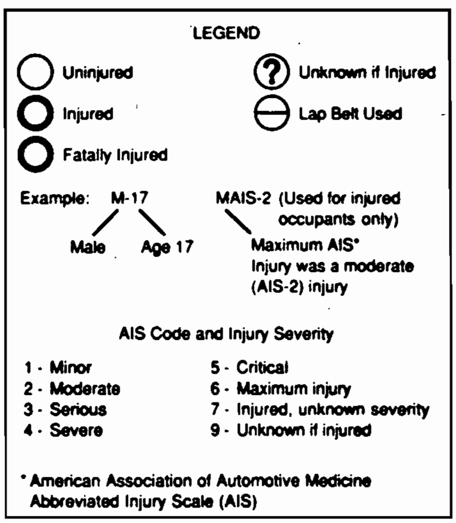
Row 5D
M-6, MAIS 2
Fractured right ribs and pelvis, multiple lacerations.

Row 6C
M-8, MAIS 2
Fractured right humerus, multiple contusions and abrasions.

Row 6D
M-9, MAIS 1

Row 7D
M-11, MAIS 2
Fractured right radius, sprained neck.

Row 8C
F-11, MAIS 2
Fractured left humerus, sprained right ankle (bending over at time of accident).



The school bus shown is representational only.

<u>Case No.: 15</u>
ATL-85-HSB-20

Accident Location: U.S. 1, Key Largo, Florida

Date and Time: September 12, 1985, 2:48 p.m.

Description of Schoolbus: Two 65-passenger poststandard buses were involved:
(1) 1984 International Harvester chassis with a Blue Bird body, and
(2) 1985 International Harvester chassis with a Blue Bird body

Type of Accident: Rear-end collision (and frontal collision for other bus)

Accident Severity: Minor; 9 mph Delta V for schoolbus.

Summary of Events: Two schoolbuses, transporting 62 and 47 elementary students, respectively, home from school were travelling approximately 30 to 35 mph on a straight and level dry road. The buses were following each other closely, separated by about 100 feet. When the lead bus stopped suddenly in response to a flagman's signal, the driver of the trailing bus failed to brake in time, skidded about 30 feet, and ran into the rear of the stopped bus. The impact propelled both buses forward about 6 feet. Both schoolbuses came to rest, upright, still engaged.

Outcome for Schoolbus Occupants by Most Severe Injury: First (lead) bus: Of the 62 passengers, aged 5 to 12, 40 were uninjured, and 22 sustained minor (AIS 1) injuries. The 31-year-old restrained driver received minor (AIS 1) injuries.

Second bus: Of the 47 passengers, aged 5 to 12, 25 were uninjured, and 22 sustained minor (AIS 1) injuries. The 49-year-old restrained driver received moderate (AIS 2) injuries.

(See schoolbus occupant seating position and injury charts.)

Damage to Schoolbus: First (lead) bus: Moderate damage to rear. The rear bumper and the sheet metal was damaged with most damage confined to the left side. Other than floorboard buckling, there was no interior damage. The rear emergency door, however, was jammed shut.

Second bus: Serious damage to front. The entire front of the schoolbus - the bumper, grill, fiberglass fenders and hood -- was damaged. The grill was pushed inward and the hood was pushed upward near the windshield. Windshield glass was cracked. The front floor of the bus was buckled slightly, but there was no other interior damage.

Evaluation of Bus Performance: Both buses performed well during this minor collision except for floor buckling. This buckling caused the emergency door to jam in the lead bus.

Injury Analysis

<u>Passengers:</u> The most severe injury sustained by any passenger was a minor (AIS 1) injury. The most severely injured occupant in this accident was the lap-belted driver of the second bus who sustained moderate (AIS 2) injuries.

Key Largo, Florida
Case No. 15

Forty-four students out of the 109 students involved received minor injuries. Minor injuries included 34 contusions to the head, 11 leg injuries, 3 back injuries, and 2 shoulder injuries. Students sustained a total of 63 individual minor injuries.

Twenty-nine passengers reported striking the seatback in front of them and/or their own seatback and receiving injuries from this contact. Two students reported striking the modesty panel and five reported striking the sidewalls. Three students received abdominal bruises from books and backpacks which they were holding in their laps, and in one case, a student received a bruised back from the backpack he was wearing at the time of the impact.

Blood stains were found on driver's seatback, on three passenger seatbacks, and at the right sidewall panelling below window. One passenger on the lead bus was standing in the rear aisle at moment of impact. He received only minor injuries. Overall, passengers on the lead bus, which was rear-ended, were less likely to be injured than those on the second bus.

Lap belt use would not have reduced the level of injuries sustained in this accident.

Schoolbus Driver: First (lead) bus: Available lap belt used. Driver sustained minor (AIS 1) injuries: contusion on left side of head (struck steering wheel and rim).

Second bus: Available lap belt used. Driver sustained moderate (AIS 2) injuries: open nose fracture (AIS 2) (struck steering wheel), and minor contusions (AIS 1) on both knees (knees struck lower dashboard).

Key Largo, Florida
Case No. 15
First Bus

Left Side of Bus

Driver
F-31, MAIS 1

Row 1C
M-6, MAIS 1

Row 2B
F-9, MAIS 1

Row 3A
M-7, MAIS 1

Row 4A
M-10, MAIS 1

Row 4B
M-11, MAIS 1

Row 5B
M-12, MAIS 1

Row 6A
M-9, MAIS 1

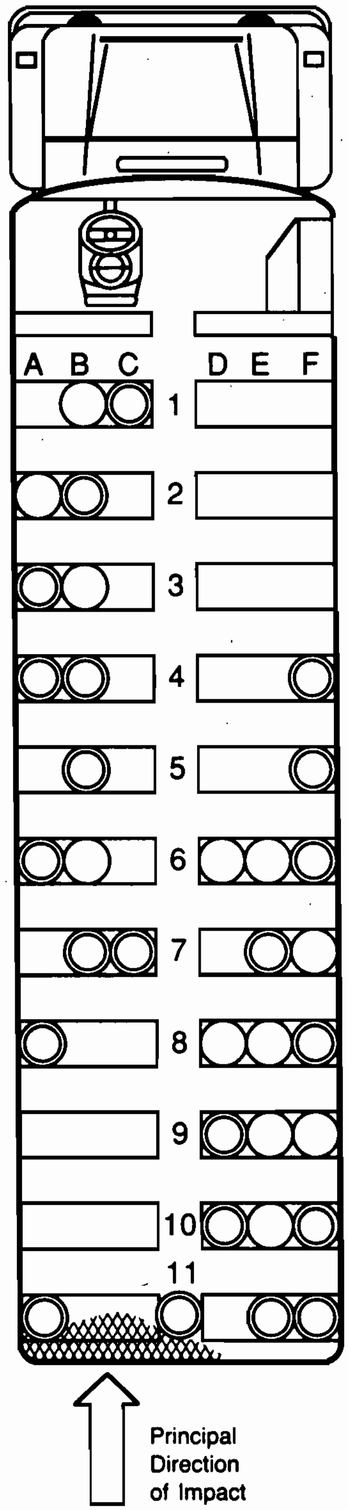
Row 7B
M-7, MAIS 1

Row 7C
M-7, MAIS 1

Row 8A
M-8, MAIS 1

Row 11A
M-9, MAIS 1

Row 11
(Standing in aisle)
M-9, MAIS-1



Right Side of Bus

Row 4F
M-5, MAIS 1

Row 5F
F-8, MAIS 1

Row 6F
F-7, MAIS 1

Row 7E
F-5, MAIS 1

Row 8F
F-6, MAIS 1

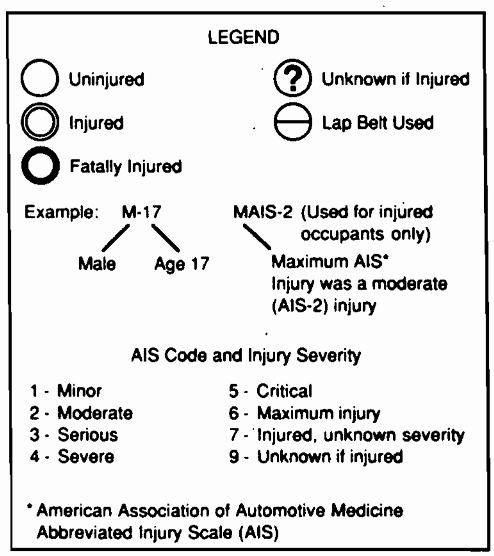
Row 9D
F-6, MAIS 1

Row 10D
M-7, MAIS 1

Row 10F
M-6, MAIS 1

Row 11E
F-6, MAIS 1

Row 11F
F-10, MAIS 1

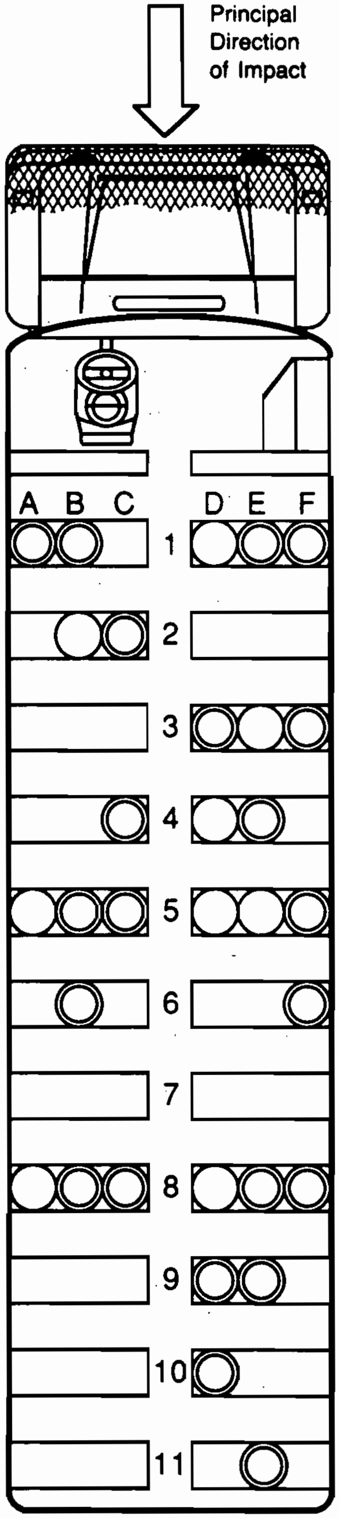


Special Notes:
Seating position unavailable for 28 of 40 uninjured passengers.

All of the injured passengers are shown.

The school bus shown is representational only.

Key Largo, Florida
Case No. 15
Second Bus



Left Side of Bus

Driver
F-49, MAIS 2
Open nose fracture and minor contusions on knees.

Row 1A
M-12, MAIS 1

Row 1B
F-10, MAIS 1

Row 2C
F-12, MAIS 1

Row 4C
M-9, MAIS 1

Row 5B
M-9, MAIS 1

Row 5C
M-10, MAIS 1

Row 6B
M-7, MAIS 1

Row 8B
M-5, MAIS 1

Row 8C
F-11, MAIS 1

Right Side of Bus

Row 1E
M-8, MAIS 1

Row 1F
M-10, MAIS 1

Row 3D
F-10, MAIS 1

Row 3F
F-6, MAIS 1

Row 4E
F-7, MAIS 1

Row 5F
F-10, MAIS 1

Row 6F
M-11, MAIS 1

Row 8E
F-10, MAIS 1

Row 8F
F-9, MAIS 1

Row 9D
F-12, MAIS 1

Row 9E
F-3, MAIS 1

Row 10D
M-11, MAIS 1

Row 11E
M-11, MAIS 1

LEGEND

Uninjured — Unknown if Injured
Injured — Lap Belt Used
Fatally Injured

Example: M-17 — Male, Age 17
MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Notes:
Seating position unavailable for 13 of 22 uninjured passengers.

All injured occupants are shown.

The school bus shown is representational only.

Case No.: 16
No case number was assigned, memo only. The Safety Board did not conduct an on-scene investigation of this accident. The Safety Board field staff did, however, interview the schoolbus driver, photograph the bus, and obtain the police report. This accident does not meet this study's accident selection criteria but is summarized for inclusion in the study because of its widespread publicity.

Accident Location: Sprain Road, Greenburgh, New York

Date and Time: January 25, 1985, 8:20 a.m.

Description of Schoolbus: 77-passenger poststandard bus:
1982 Wayne chassis with International Harvester body

Type of Accident: Sideswipe (left side)

Accident Severity: Extremely minor collision

Summary of Events: A schoolbus, equipped with lap belts for all occupants, was transporting 28 students and one adult passenger to school, travelling about 30 mph on a 2-lane, snow-covered, undivided, gently curving asphalt road. All occupants were restrained. An oncoming car travelling about 30 mph failed to negotiate a curve and crossed over into the schoolbus' lane. The schoolbus driver steered to the right shoulder to avoid collision, but the car sideswiped the left side of the bus, just past the schoolbus driver's seat. The impact was so slight, that according to the schoolbus driver, books and papers lying on the student's seats did not fall to the floor.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 29 restrained passengers, (28 students, aged 10 to 14, and an adult aid), 29 were uninjured. The 31-year-old restrained driver also was uninjured.

Damage to Schoolbus: The schoolbus received minor damage to one of the front left side panels. (See photograph in report.)

Evaluation of Bus Performance: This accident was so minor it would not be valid to address the performance or evaluate the crashworthiness of the schoolbus.

Injury Analysis

Passengers: All passengers were uninjured, and all were wearing the available lap belts. Unfortunately, nothing can be said about the value of lap belts in this accident. Passengers would not have sustained any injuries even if unbelted: the accident was so slight as to be a nonaccident. Impact forces on the passengers were negligible and damage to the bus was barely visible to the Safety Board investigator.

Schoolbus Driver: Available lap belt used. Driver was uninjured.

Outcome for Occupants of Other Vehicle

Vehicle Description: 1980 Buick 2-door car.

Damage to vehicle: Left front and left front fender were damaged along with the quarter panel.

Occupant Restraint Use and Injury: Lap/shoulder belt used. Driver sustained no injuries. No other car occupants.

Case No.: 17
MKC-83-H-SB04

Accident Location: Snyder, Oklahoma

Date and Time: August 25, 1983, 8:45 a.m.

Description of Schoolbus: 48-passenger poststandard bus:
1980 Chevrolet chassis and a Thomas Built body

Type of Accident: Sideswipe (left side)

Accident Severity: Minor, Delta V about 3 mph or less

Summary of Events: A schoolbus, transporting 48 kindergarten and first grade students to school, was travelling about 25 mph on a State highway. A pickup truck towing a fertilizer spreader not designed for use on highways, approached the bus from the opposite direction, travelling about 25 mph. As the pickup neared the schoolbus, the spreader came loose and travelled toward the centerline. The schoolbus driver saw the spreader, reduced his speed to 10 mph, and steered to the right shoulder to avoid collision. The fertilizer spreader sideswiped the left side of the bus, just forward of the bus's rear axle at the level of passenger windows in rows 8, 9, and 10.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 48 passengers, aged 5 to 6, 43 were uninjured, 4 sustained minor (AIS 1) injuries, and 1 sustained moderate (AIS 2) injuries. The 46-year-old restrained driver was uninjured.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The schoolbus superficially damaged along the left rear exterior sheet metal for about 101 inches. Three windows were damaged with five panes of glass broken. Dislodged window frame members intruded into the passenger seating area. One inch deformation. No seats damaged. Roof damage was limited to metal buckling.

Evaluation of Bus Performance: The schoolbus damage was confined to the area of impact with the fertilizer spreader. The bus performed well.

Injury Analysis

Passengers: The exact number of students injured in this accident is not known due to incomplete school records. Judging from the amount of broken glass inside the bus, probably more children received minor injuries from flying glass than reported. Shattered window glass sprayed the bus interior, fanning out within the passenger compartment. The lack of severe cuts due to flying glass perhaps can be attributed to low seating height of the young students. As is, all five students reported as injured received multiple lacerations from flying glass.

All injured passengers were seated on the left side of the bus in rows 10, 11, and 12, at or near the area of impact. The most seriously injured passenger, a 6-year-old boy, seated in row 11 on the left aisle seat, may have sustained his concussion when he struck the seatback in front of him or the sidewall as the driver braked before or after the impact, or when he fell into the bus aisle collision.

Snyder, Oklahoma
Case No. 17

Lap belt use might have reduced the severity of injuries sustained by the student with moderate injuries. If belted, he would have been prevented from falling to the floor. The passenger if restrained still would have sustained ninor injuries from flying glass as would the other injured students.

Schoolbus Driver: Available lap belt used. Driver was uninjured.

Special Notes on the Accident

Window glass and frame intrusion.

Snyder, Oklahoma
Case No. 17

Left Side of Bus

Row 10A
M-6, MAIS 1

Row 10B
M-6, MAIS 1

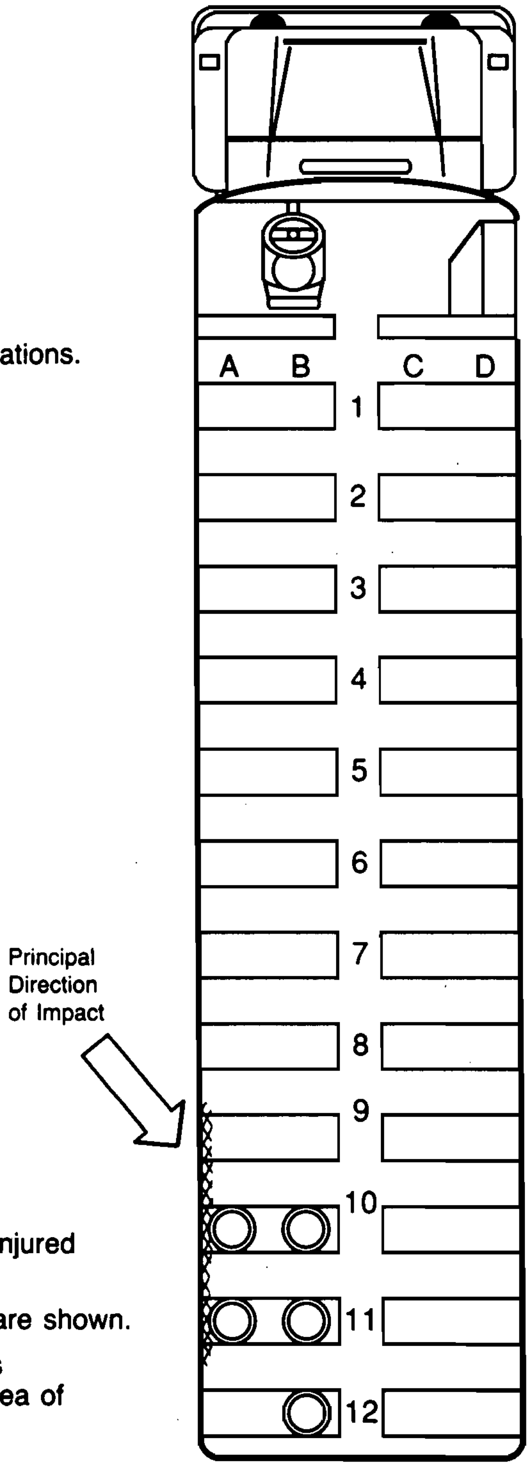
Row 11A
M-5, MAIS 1

Row 11B
M-6, MAIS 2
Concussion, multiple lacerations.

Row 12B
M-6, MAIS 1

Right Side of Bus

No injuries



Special Notes:
The seating positions are unavailable for the 43 uninjured passengers.

All 5 injured passengers are shown.

Broken window glass was distributed over a wide area of the interior.

The school bus shown is representational only.

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 — Male, Age 17; MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Case No.: 18
CHI-84-H-SB16

Accident Location: State Route 16/2, Stephenson, West Virginia

Date and Time: June 8, 1984, 2:50 p.m.

Description of Schoolbus: 89-passenger poststandard bus:
1982 All-American chassis with Blue Bird body

Type of Accident: Right side impact (principal direction of impact at about 1 o'clock)

Accident Severity: Moderate

Summary of Events: A schoolbus transporting 61 students home from school entered a grade crossing, slowed, and then accelerated to clear the railroad tracks. As the bus followed the road to the right, it was struck in the right side just behind the rear wheel by an oncoming train travelling approximately 11 mph. The schoolbus was pushed off the crossing by the train and came to rest, upright, approximately 60 feet from the crossing. The train remained on the track.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 61 passengers, aged 7 to 13, 53 were uninjured, and, 8 sustained minor (AIS 1) injuries. The 58-year-old unrestrained driver was uninjured.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Body and frame of the bus were bent to the left behind rear axle. The right side of the bus was torn open behind the right rear wheel. Integrity of bus body was compromised by a 10-foot wide opening on the right side. Floor of bus was split from right side behind 12th row of seats. The 13th and 14th seats on the right side were torn loose from anchors. Rows 13 through 15 were deformed by deformation and intrusion.

Evaluation of Bus Performance: Bus body was compromised, but crash forces probably exceeded Federal performance requirements. The body joint requirements of FMVSS 221 probably served to minimize the amount of joint separation which did occur in this accident.

Injury Analysis

Passengers: Only 8 out of 61 passengers were injured in this crash and these passengers incurred minor injuries (AIS 1). Seating positions for all the injured students could not be determined so analysis of injury by seating position was not possible.

The low level of passenger injuries in this accident is attributable to the busdriver's insistence that all students sit in the first 11 rows. The train struck the bus at a point between rows 12 and 13 and tore a gaping hole in the side of the bus. The severity of injuries was also lessened by the configuration of the vehicles involved which resulted in relatively low impact forces. The schoolbus was veering to the right when hit by the train. The impact caused the rear of the bus to be pushed off the tracks, dissipating some of the crash energy.

The eight students who received minor injuries sustained contusions to heads and legs, assorted muscle strains, and lacerated lips from contacting the sidewalls, windows and other passengers. Lap belt use since it provides no upper torso restraint (nor restraint for extremities), would not prevent these injuries from occurring.

Schoolbus Driver: Lap belt available but not used. No reported injuries.

Outcome for Occupants of Other Vehicle

Vehicle Description: Norfolk-Western train consisting of two locomotives and one caboose.

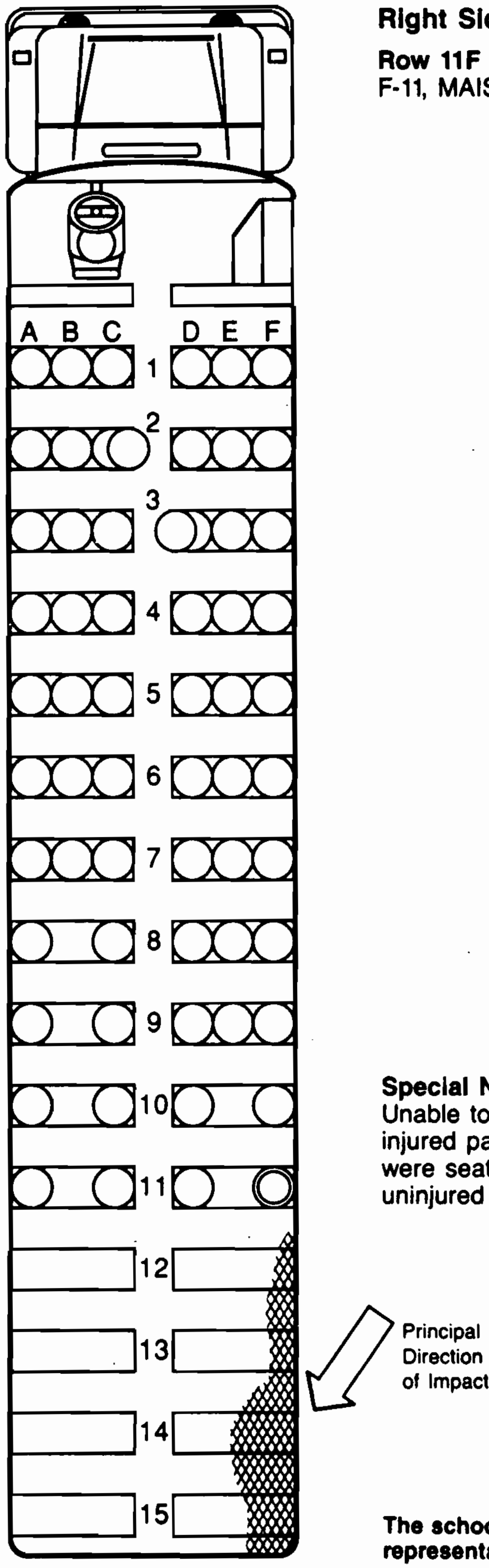
Damage to Vehicle: None

Stephenson, West Virginia
Case No. 16

Left Side of Bus

Unplaceable Injured

F-10, MAIS 1
F-8, MAIS 1
F-9, MAIS 1
M-6, MAIS 1
F-10, MAIS 1
F-12, MAIS 1
F-7, MAIS 1



Right Side of Bus

Row 11F
F-11, MAIS 1

LEGEND

Uninjured
Injured
Fatally Injured
Unknown if Injured
Lap Belt Used

Example: M-17 — Male, Age 17
MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Note:
Unable to place all but 1 of the 8 injured passengers. The other 7 were seated in spaces marked as uninjured on the chart.

The school bus shown is representational only.

<u>**Case No.: 19**</u>
FTW-84-H-SB15

Accident Location: Intersection of U.S. 257 and an unnamed gravel road outside Kerrick, Texas

Date and Time: September 7, 1984, 7:45 a.m.

Description of Schoolbus: 35-passenger poststandard bus:
1982 Chevrolet with a Blue Bird body

Type of Accident: Multiple collision: left front and left rear angle impact. (Direction of initial impact at about 10 o'clock.)

Accident Severity: Moderate

Summary of Events: A schoolbus transporting five students to school turned right into an intersection, directly into the path of an oncoming tractor-trailer travelling about 50 mph. The truckdriver steered to the left to avoid striking the schoolbus broadside, but still struck the left front of the schoolbus, just behind the bus's front axle. Following the initial collision, the truck's trailer swung around and sideswiped the left rear corner of the schoolbus.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the five passengers, aged 5 to 17, 1 was uninjured, and 4 sustained minor (AIS 1) injuries. The 60-year-old unrestrained driver received moderate (AIS 2) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Damage was to left front of bus in the area of left front wheel and the left rear corner. Left rear was displaced inward without ripping, tearing, or breaking of interior components.

Passenger seat row 5 was moved inboard three inches. Passenger seat row 6 was shifted inboard 9 inches with its left corner raised 5 inches. All seats and seat supports remained intact. No support rivets were broken or torn.

Injury Analysis

<u>Passengers:</u> Minor injuries sustained by passengers included abrasions, contusions, lacerations and one puncture wound. The student who received the puncture wound was standing in front of his seat in row 6 at the time of the initial impact, yelling to warn the driver about the oncoming truck. The student stated that at impact he was thrown against the rear emergency door handle, injuring his back. Contact points for other passengers included window frames, the modesty panel, and contact with a musical instrument wedged in seat corner.

A total of eight AIS 1 injuries were sustained by the four students injured. Of these, only three minor injuries probably would have been prevented by lap belt use: (1) abrasion probably from contact with floor; (2) a puncture wound from contact with emergency door handle; and (3) a contusion probably from contact with emergency door handle shield. Lap-belted passengers, however, could still sustain other minor or moderate injuries during the multiple collision. In some cases, the injuries might be more severe than sustained in this accident. If the passenger who received the puncture wound had been restrained, for example, he would have been kept in place on a seat which sustained most damage from the crash.

Kerrick, Texas
Case No. 19

Schoolbus Driver: Lap belt available but not used. Driver received cerebral concussion (AIS 2) (from contact with windshield, "A" pillar, and window) and contusions and muscle strain (AIS 1) (from contact with steering wheel and window). The driver was tall (6' 1") so a lap belt may not have prevented these injuries even if worn.

Outcome for Occupants of Other Vehicle

Vehicle Description: 1977 IHC tractor with 40-foot 1981 Dorsey trailer in tow.

Damage to Vehicle: Damage to right front of tractor and right middle of trailer.

Occupant Restraint Use and Injury: Unrestrained. Minor (AIS 1) injuries.

Kerrick, Texas
Case No. 19

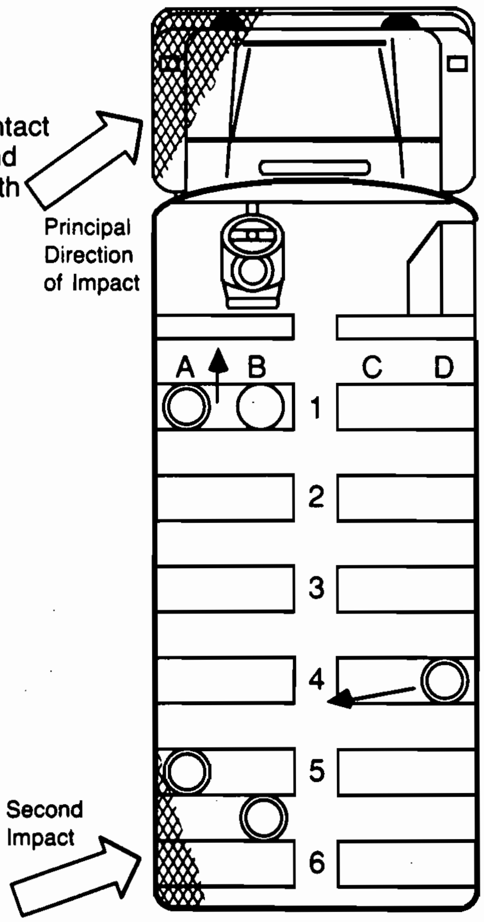
Left Side of Bus

Driver
M-60, MAIS 2
Cerebral concussion from contact with windshield. Contusion and muscle strain from contact with steering wheel.

Row 1A
F-7, MAIS 1

Row 5A
M-13, MAIS 1

Row 6B (Standing)
M-17, MAIS 1



Right Side of Bus

Row 4D
M-12, MAIS 1

LEGEND

- Uninjured
- Unknown if Injured
- Injured
- Lap Belt Used
- Fatally Injured

Example: M-17 (Male, Age 17) MAIS-2 (Used for injured occupants only)
Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Notes:
The passenger in Row 4D sustained abrasions and contusions from contact with a musical instrument sitting on the seat and from a fall to the floor.

The bus was first struck by the truck tractor and then by its jack-knifing trailer.

The school bus shown is representational only.

Case No.: 20
MKC-85-H-SB-20

Accident Location: Hecla, South Dakota
(intersection of Brown County Road 5 and State Highway 37)

Date and Time: May 24, 1985, 3:35 p.m.

Description of Schoolbus: 47-passenger poststandard bus:
1979 International Harvester chassis with Carpenter body

Type of Accident: Multiple collision with partial rollover: right side angle collision followed by secondary impact to right side, then impact to left front and right rear. (Direction of initial impact at 2 o'clock.)

Accident Severity: Moderate

Summary of Events: A schoolbus transporting 17 students home from school was making a left hand turn from a 2-lane State highway onto a county road when it was struck by an oncoming truck. Speed of schoolbus at impact estimated at 15 mph; speed of truck at impact estimated at 50 mph. The truck impacted the schoolbus at the passenger entrance door. The schoolbus was knocked away from the truck following the initial impact, but the vehicles collided once more as the right side of the bus and left side of the truck swung together. Both vehicles then left the roadway travelling closely together. The schoolbus slid into a 4-foot ditch, left front corner first, and as it went into the ditch, the back of the bus lifted up and came down heavily onto the side of the truck which had followed. At rest, the schoolbus lay at about a 45°-angle on its left side, with the right rear of the bus approximately 4 feet above ground. The schoolbus driver had been ejected and lay inside the bus' engine compartment; the hood had opened during the crash and the windshield had popped out.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 17 passengers, aged 7 to 16, 2 were uninjured, 9 sustained minor (AIS 1) injuries, 5 sustained moderate (AIS 2) injuries, and 1 received serious (AIS 3) injuries. The 29-year-old unrestrained driver received moderate (AIS 2) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Interior of schoolbus was penetrated 17 inches from passenger entrance door rearward by initial collision. Major penetration at row 1; seat displaced into aisle. Major damage to right front boarding door, and right side.

Fuel tank punctured by end of crash cage bent by initial collision. Little fuel, if any, spilled.

Engine compartment was offset 19 inches to the right and transmission housing was broken open from fall into ditch.

Evaluation of Bus Performance: Major damage was confined to exterior although there was some penetration of passenger compartment. Bus performed well during collision.

Injury Analysis

Passengers: Contact points were unknown for the majority of injuries (the exception being for a few AIS 1 injuries). Students also did not know at which point in the accident sequence they sustained their injuries. This is not surprising given the complexity of the crash: the passenger's bodies were subject to a variety of forces from four separate impacts all within a short time span. The investigator could not trace body movements but two students stated they went over their seats and another remembers being thrown from her seat.

The nine students who received only minor (AIS 1) injuries sustained abrasions, lacerations, and contusions to head, face, arms and legs. Seatbacks, windows,and sidewalls were identified as the contact points for some of these injuries; others were unknown.

Five students received moderate (AIS 2) injuries. Contact points could not be identified for these AIS 2 injuries which by affected body region consisted of three injuries to the head or skull, two to shoulder, one to wrist, and one to lower leg. A discussion of some of these AIS 2 injuries follows.

The student seated by the window in row 2 on the right fractured her left wrist. This student was seated just behind the area of greatest crush and near the point of initial impact.

Three students sustained concussions with retrograde amnesia; two were seated by windows with no one seated beside them (rows 3 and 4) and one was on the aisle with student next to him (row 8). The students who were seated next to windows may have contacted window frames, seatbacks in front of them or other interior features, injuring their heads. Students from across the aisle could have fallen against them but this is rather unlikely since the students seated across from them were uninjured or received only AIS 1 injuries. The student on the aisle seat (row 8) had a person seated next to him but it is unlikely they contacted one another since the passenger by window sustained AIS 1 injuries to right side of his head only. More likely the aisle passenger in row 8 was injured when the back of bus lifted up and then came down as the schoolbus went into the ditch. Investigators do not know if he fell into the aisle or contacted the seatback to cause his concussion.

The most seriously injured student was seated on the left, next to the window in row 1, almost directly behind the driver who was ejected. The contact point for her AIS 3 leg injury was the restraining barrier during initial collision. It can be said with some certainty that the restraining barrier helped contain her within the passenger compartment.

The two passengers on the right seated by the windows in row 1 and 2 who sustained AIS 1 and AIS 2 injuries were directly in the area of crush and would not have benefitted from lap belt use.

Lap belt use probably would have prevented or reduced the severity of AIS 3 injury, a fractured leg with displacement. Lap-belted passengers, however, still could sustain concussions and broken bones (AIS 2 injuries) and minor injuries during a crash of this type.

Hecla, South Dakota
Case No. 20

Schoolbus Driver: Lap belt available but not used. As a result, schoolbus driver was ejected through open windshield and came to rest inside engine compartment; the hood had opened during crash. He sustained moderate (AIS 2) injury: deep laceration of left thigh; also laceration of right knee and many abrasions and contusions (AIS 1).

Outcome for Occupants of Other Vehicle

Vehicle Description: 1977 Ford truck

Damage to Vehicle: Major damage to front bumper, grill, hood, engine and fenders.

Occupant Restraint Use and Injury: Restraint use unknown. Police report indicates "possible injury" to truckdriver, a 22-year-old male.

Special Notes on the Accident

Three schoolbus seats were missing screws in legs. One seat was not fastened to the wall and had been loose so long paint was rubbed off wall.

The aluminum cover for hot water hose had corner projecting out 2 inches and some ceiling light covers were broken: two potential causes of injury.

Two truckloads of sand used to cover spilled herbicide from truck obliterated physical evidence necessary to calculate Delta V.

Hecla, South Dakota
Case No. 20

Left Side of Bus

Driver
M-29, MAIS 2
Deep laceration of left thigh, laceration of right knee, abrasions and contusions.

Row 1A
F-8, MAIS 3
Fractured left tibia with displacement. Contusion over eye and hematoma on left leg.

Row 2A
F-10, MAIS 1

Row 3A
F-14, MAIS 1

Row 4A
F-10, MAIS 2
Displaced and fractured right clavicle and concussion with retrograde amnesia.

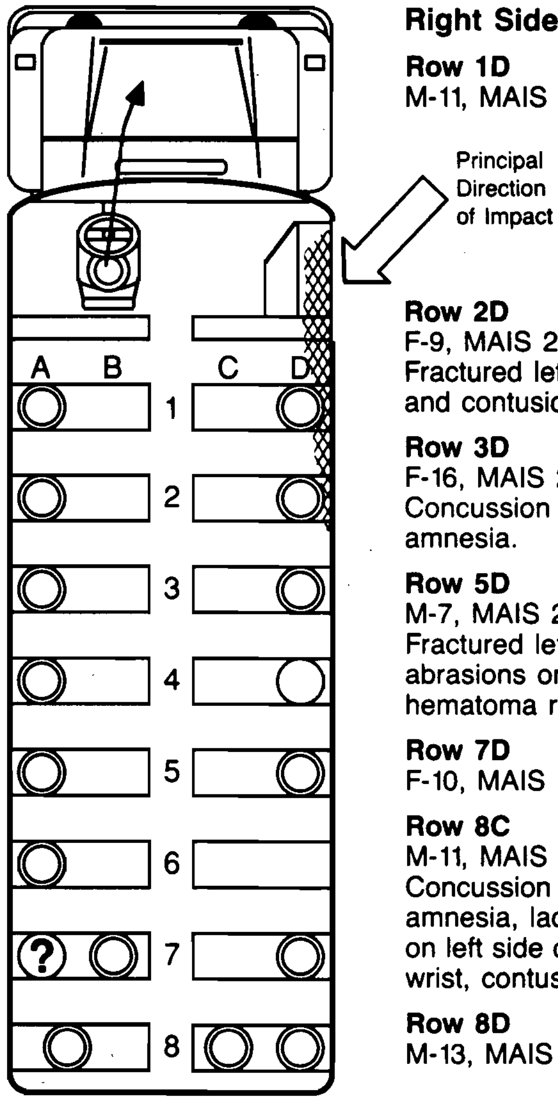
Row 5A
F-15, MAIS 1

Row 6A
M-18, MAIS 1

Row 7A
M-NK, MAIS 9 (Unknown if injured)

Row 7B
M-7, MAIS 1

Row 8 (Center)
F-12, MAIS 1



Right Side of Bus

Row 1D
M-11, MAIS 1

Row 2D
F-9, MAIS 2
Fractured left wrist, wrist abrasions and contusions to neck and head.

Row 3D
F-16, MAIS 2
Concussion with retrograde amnesia.

Row 5D
M-7, MAIS 2
Fractured left clavicle, multiple abrasions on right side of face, hematoma right side of scalp.

Row 7D
F-10, MAIS 1

Row 8C
M-11, MAIS 2
Concussion with retrograde amnesia, laceration and contusion on left side of forehead and on right wrist, contusion on right arm.

Row 8D
M-13, MAIS 1

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 — Male, Age 17; MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

Case No.: 21
DCA-85-SH-001

Accident Location: Intersection of Route 13 with Route 30, Woodside, Delaware

Date and Time: September 11, 1985, 3:30 p.m.

Description of Schoolbus: 66-passenger poststandard schoolbus:
1985 Chevrolet chassis with a Blue Bird body

Type of Accident: Multiple collision; right side impact followed by minor left side impact

Accident Severity: Moderate to severe

Summary of Events: A schoolbus transporting 42 junior high and high school students home from school was travelling on a 4-lane, divided asphalt highway. When the schoolbus attempted to make a left turn onto a highway, it was struck on the right side by an oncoming tractor-semitrailer. The tractor-semitrailer then pushed the schoolbus sideways for a distance of over 50 feet into the left front side of a van stopped at a traffic light. After the second impact, the schoolbus rotated clockwise about 120° and came to rest upright, lodged on a traffic island facing oncoming traffic, .

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 42 passengers, aged 11 to 16, 3 were uninjured, 33 sustained minor (ASI 1) injuries, and 6 sustained moderate (AIS 2) injuries. The 48-year-old unrestrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Extensive damage occurred to the right side sheet metal extending from behind the front entrance door to the rear wheels. The truck pushed the sidewall in at seat rows 4, 5, 6, and 7, pushing the seats together such that the right side seat benches of rows 5 and 6 were almost touching the left side seats. No room was left to walk through the aisle. This hindered emergency evacuation because the occupants in the front half of the bus had to climb over the seats in the middle to get out. The floor buckled in this area causing the seat legs and bolts to pull out of the floor.

The schoolbus body also shifted on the chassis during impact. At rows 5 and 6 the access panel just above the window came apart. There are no cuts or lacerations, however, documented sustained by passengers seated in this area. At row 8 seat F, a passenger received a laceration on the right side of his head; the source is not known. He would have had to move two rows forward to strike the side panel.

Evaluation of Bus Performance: Considering that the bus was struck by a much larger vehicle, the impact was of moderate severity and the impact was focused on a relatively weak part of the bus, the schoolbus did extremely well in maintaining its integrity and protecting the occupants from serious injury.

Injury Analysis

Passengers: Six students sustained moderate (AIS 2) injuries which included two pelvic fractures, three closed head injuries, and one ankle fracture. The two pelvic fractures occurred in the left rear area of the bus, at the center position of row 10 and the aisle position of row 11, when these passengers were displaced from their seats into the center aisle area of the bus. The probable contact points for these fractures were either the lower structure of the right side bench seats or the bus aisle floor. One of the closed head injuries also occurred in the left rear area of the bus at the aisle side of row 10; this injury is attributed to contact between occupants. The remaining two closed head injuries occurred in the center area of the bus, at the window position of row 6 left side and at the aisle position of row 5 right side. The injury to the passenger at row 6 left side probably resulted from occupant to occupant contact while the row 5 right side passenger probably contacted the interior sidewall of the bus. The passenger seated at row 1, right side window position, attributed his ankle fracture to the lower framework of the modesty panel.

The remaining injuries, all minor (AIS 1) contusions, abrasions, lacerations, and strains, occurred at various seating positions within the bus. All occurred when passengers struck parts of the bus interior and/or other occupants. One passenger, seated on an overturned trashcan in the rear aisle area, was thrown into the open area behind the last bench of the right side. This passenger received only a minor head injury.

While lap belt use would have prevented the two pelvic fractures (AIS 2), the remaining four moderate injuries, (a fractured ankle and three closed head injuries), probably still would have occurred. The contact points within the bus interior which produced the head injuries and fractured ankle would remain within reach of lap-belted passengers. Passengers who unrestrained sustained pelvic fractures, could if lap belted sustain other types of moderate injuries.

It is possible that lap belt use by passengers in this accident might have increased the severity of injuries, particularly head injuries. When unrestrained, an occupant's entire body is free to move in reaction to an applied outside force. Then, when the occupant contacts a rigid interior surface, the force usually is not concentrated on a small area of his body. When an occupant is lap belted, the upper torso and head pivots from the restrained pelvic area, possibly resulting in the entire interior contact force being concentrated at a small area of their body, such as their head. Injury severity usually increases as the force concentration area becomes smaller. With the severe side impact force and resultant rotation that occurred in this collision, a violent upper body pivot would have resulted at most of the seating positions.

Schoolbus Driver: Available lap belt not used. Driver received minor (AIS 1) injury: bruised right arm.

Outcome for Occupants of Other Vehicle

Vehicle No. 1 Description: 1973 International tractor with a 1972 Fruehauf cargo tank.
Damage to Vehicle:—The tractor front end and left front damage.
Occupant Restraint Use and Injury:--No restraint used; not injured.

Vehicle No. 2 Description: 1976 van
Damage to Vehicle: Damage to the front and left front side.
Occupant Restraint Use and Injury: Unknown if restraint used; not injured.

Woodside Delaware
Case No. 21

Left Side of Bus

Driver
M-43, MAIS 1

Row 1A
M-13, MAIS 1

Row 1C
F-16, MAIS 1

Row 2A
F-14, MAIS 1

Row 3A
F-12, MAIS 1

Row 3C
F-14, MAIS 1

Row 4A
M-14, MAIS 1

Row 5A
F-14, MAIS 1

Row 5C
F-14, MAIS 1

Row 6A
M-13, MAIS 1

Row 7A
F-14, MAIS 1

Row 7C
F-11, MAIS 1

Row 8A
F-15, MAIS 1

Row 8C
M-13, MAIS 1

Row 9A
F-16, MAIS 1

Row 9C
M-11, MAIS 1

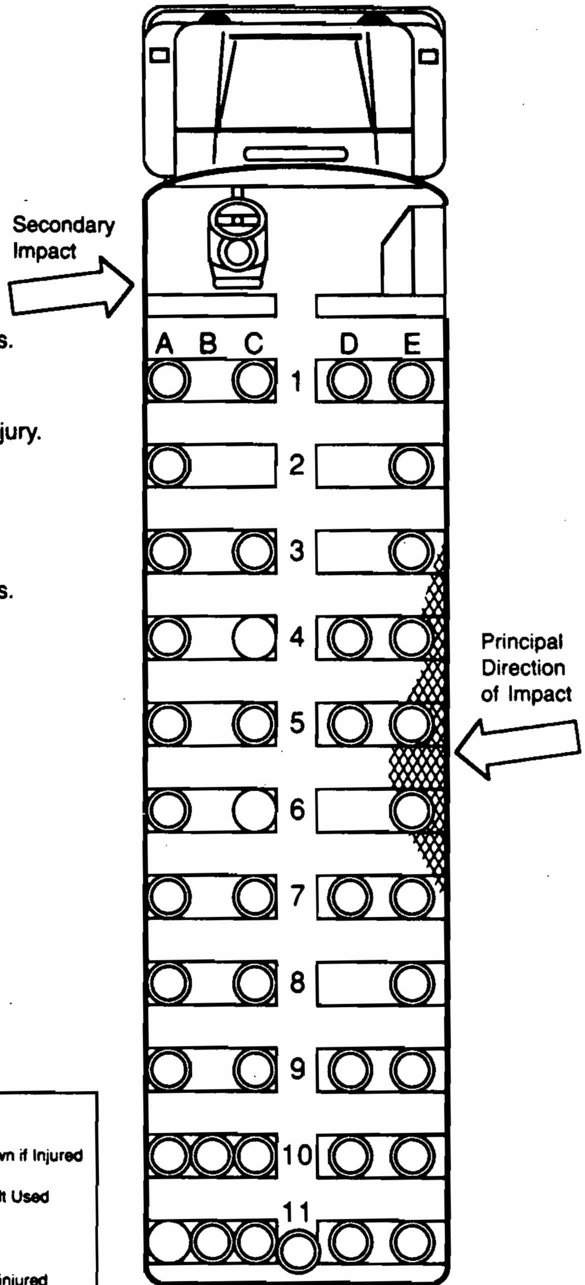
Row 10A
F-14, MAIS 1

Row 10B
F-12, MAIS 2
Fractured pelvis.

Row 10C
F-15, MAIS 2
Closed head injury.

Row 11B
F-14, MAIS 1

Row 11C
F-15, MAIS 2
Fractured pelvis.



Right Side of Bus

Row 1D
F-14, MAIS 1

Row 1E
M-12, MAIS 2
Fractured right ankle.

Row 2E
F-15, MAIS 1

Row 3E
F-13, MAIS 1

Row 4D
M-13, MAIS 1

Row 4E
M-13, MAIS 1

Row 5D
M-13, MAIS 2
Closed head injury.

Row 5E
M-13, MAIS 1

Row 6E
M-16, MAIS 1

Row 7D
M-11, MAIS 1

Row 7E
M-15, MAIS 1

Row 8E
F-15, MAIS 1

Row 9D
M-12, MAIS 1

Row 9E
F-14, MAIS 1

Row 10D
F-13, MAIS 1

Row 10E
F-14, MAIS 1

Row 11D
M-11, MAIS 1

Row 11E
M-15, MAIS 1

Row 11
F-15, MAIS 1
Seated on overturned trash can in aisle.

LEGEND

Uninjured — Unknown if Injured
Injured — Lap Belt Used
Fatally Injured

Example: M-17 (Male, Age 17) MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

<u>Case No.: 22</u>
MKC-86-H-SB03

Accident Location: I-270 off ramp to Manchester Road, Des Peres, Missouri

Date and Time: February 4, 1986, 8:34 a.m.

Description of Schoolbus: 47-passenger poststandard bus:
1984 Ford chassis with Blue Bird body

Type of Accident: Noncollision rollover (90°)

Accident Severity: Minor; (low speed rollover).

Summary of Events: A schoolbus, transporting 13 special education students to school, was travelling on an interstate highway exit ramp. The exit ramp, wet from rain, was on an approximate 5 percent upgrade and was without improved shoulders. As the bus proceeded up the ramp, the bus veered to the right and tires on the right side of the bus dropped off of the road surface onto the soft shoulder. At this point, the ground sloped away from the road, dropping approximately 30 inches over a distance of 7 to 8 feet. After travelling up the road for over 100 feet, the busdriver was able to steer the bus so that its right front tire regained the road. The right rear tires remained off the road; however, and continued to dig progressively deeper into the soft shoulder, eventually causing the bus to rollover onto its right side. The bus then slid upon its right side for several feet before coming to rest.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 13 passengers, aged 5 to 15, 8 were uninjured, 3 sustained minor (AIS 1) injuries, and 2 sustained moderate (AIS 2) injuries. The 34-year-old restrained driver was uninjured.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The schoolbus received damage to its right side due to the rollover and surface impact. Minor collapse of the upper right roof structure occurred and the top front shifted toward the left approximately 3 inches. One pane of each window, 3, 6, and 7, on the right side were broken. No interior damage was noted.

Evaluation of Bus Performance: The schoolbus body performed well in this low speed rollover.

Injury Analysis

<u>Passengers:</u> Five of the 13 passengers were injured; the worst injury was a moderate (AIS 2) injury.

The two moderate injuries, both fractured clavicles, were sustained by passengers seated precrash on the left side of the bus and probably were due to contact with interior fixtures as they fell onto the right interior during overturn. The three remaining injuries, all AIS 1, were minor sprains, contusions, and lacerations, also attributable to the bus rollover and ground impact. Accurate speculation as to occupant contact points or, for that matter, seating positions is difficult. A witness stated that several students were standing in the aisle of the bus immediately before the accident.

Des Peres, Missouri
Case No. 22

It is probable that lap belt use would have prevented the two moderate injuries in this low speed rollover accident. It cannot be said with certainty that these passengers would not have received other contact-induced moderate injuries if lap belted. The type or severity of the minor injuries probably would not have been altered by use of lap belts.

A 5-year old passenger, seated on the left side of row 6, was restrained by an aftermarket upper torso restraint. This restraint reportedly consisted of a belt looped around the seatback cushion and passed between the junction of the lower and upper cushion, forming a diagonal loop about the occupant's upper torso. The Safety Board investigator reported that the restrained passenger was held in his seat, on the upper side of the bus, as the overturn and ground impact occurred. No injury was reported. Since unrestrained passengers seated on the left side of the bus also were uninjured, no statement as to the benefit of the "loop belt" can be made. "Loop belts" are not considered safety belts.

Schoolbus Driver: Available lap belt used; no injuries.

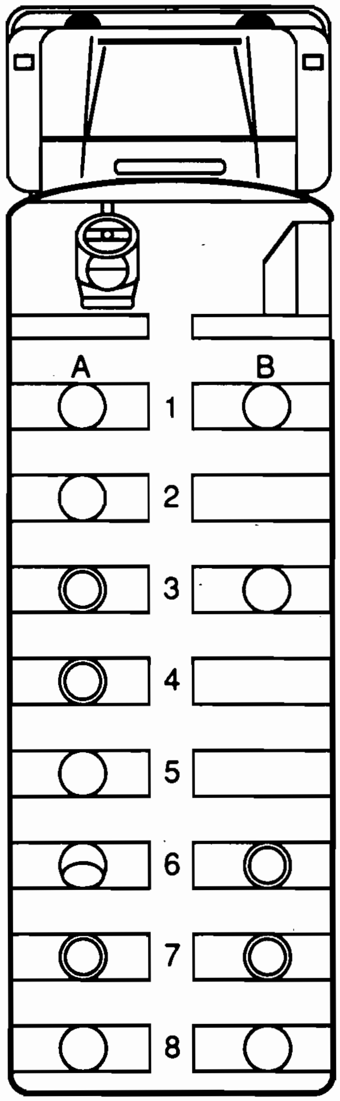
Des Peres, Missouri
Case No. 22

Left Side of Bus

Row 3A
M-13, MAIS 1

Row 4A
M-12, MAIS 2
Fractured left clavicle.

Row 7A
F-14, MAIS 2
Fractured left clavicle.



Right Side of Bus

Row 6B
F-13, MAIS 1

Row 7B
F-13, MAIS 1

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used
- Wheel Chair
- Loop Belt Used

Example: M-17 — Male, Age 17

MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Note:
The passenger in 6A was restrained by an aftermarket "loop belt."

The school bus shown is representational only.

Case No.: 23
MKC-84-H-SB24

Accident Location: U.S. Route 160, Rueter, Missouri

Date and Time: May 7, 1984, 11:15 a.m.

Description of Schoolbus: 48-passenger poststandard bus:
1980 Chevrolet chassis with 1980 Thomas Built body

Type of Accident: Noncollision rollover (90°)

Accident Severity: Minor

Summary of Events: A schoolbus transporting 11 high school students and one teacher on an activity trip was travelling about 40 mph down a 3 percent grade on a wet, 2-lane, 2-way asphalt road. The bus failed to negotiate a left curve, and skidded several feet before the right tires went into a drainage ditch. The schoolbus rolled slowly over onto its right side and slid before coming to rest.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 12 passengers, aged 17 to 38, 10 were uninjured, and 2 sustained minor (AIS 1) injuries. The 45-year-old unrestrained driver was uninjured.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Very minor. Sheet metal stripping on lower portion of boarding door bent rearward. The speed of the rollover was extremely low.

Evaluation of Bus Performance: The bus performed well in this low speed rollover.

Injury Analysis

Passengers: The two injured passengers received their minor (AIS 1) injuries when the bus rolled to its side, and passengers moved to the right.

A girl seated by the left window in row 5, fell on top of a boy seated across the aisle in row 5, injuring his back (cervical sprain, AIS 1) and propelling him into the person seated next to him. (This person, however, was not injured.) The girl continued to fall to the right, striking the window in row 4, breaking the glass. She sustained a cervical strain (AIS 1) when she initially fell on the boy and cuts and abrasions (AIS 1) from striking the window and frame when she came to rest.

Another passenger, seated in row 2 on the left window seat, was flung to the right during the rollover, striking the passenger seated in row 1 by the window. Neither student was injured.

Use of a lap belt certainly would prevent passengers from being flung around the bus during a rollover. Lap belt use cannot guarantee, however, that no passengers would have sustained minor injuries in this rollover. The five passengers seated on right by the windows still could be injured by contact with the windows during rollover and the two with passengers seated next to them could be injured by flailing limbs and head contact.

Rueter, Missouri
Case 23

Schoolbus Driver: Lap belt available but not used. Driver was not injured.

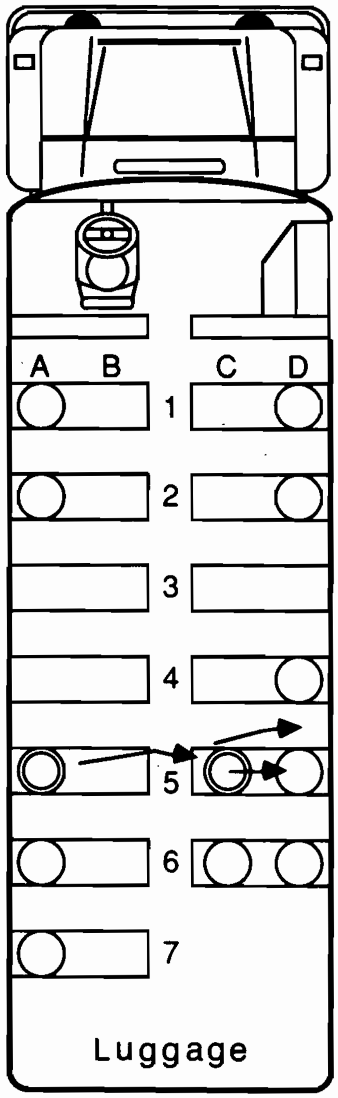
Special Notes on the Accident

Prior to the trip, the rear seat on the left and the two rear seats on the right had been removed to make room for luggage storage. The suitcases stored in this space were not secured and pose a potential danger. Loose suitcases conceivably could injure passengers in another accident scenario, i.e., 360° rollover. They also could block use of emergency exit.

Rueter, Missouri
Case 23

Left Side of Bus

Row 5A
F-18, MAIS 1



Right Side of Bus

Row 5C
M-17, MAIS 1

LEGEND

Uninjured

Unknown if Injured

Injured

Lap Belt Used

Fatally Injured

Example: M-17 — Male, Age 17

MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

<u>Case No.: 24</u>
MKC-85-H-SB31

Accident Location: Leavenworth, Kansas

Date and Time: October 15, 1984, 7:20 a.m.

Description of Schoolbus: 65-passenger poststandard bus:
1981 International chassis with Thomas Built body

Type of Accident: Noncollision rollover (90°)

Accident Severity: Minor to Moderate

Summary of Events: A schoolbus just beginning its morning run to pickup students for classes was transporting two children. The driver of the bus was the mother of the two passengers (one of preschool age). As bus traveled down a slight grade on a wet, gravel, 2-lane roadway at approximately 30 mph, the bus went off the road into a small ditch on the right. Evidence indicates the bus traveled 118 feet with the right front and right rear tire inside the ditch. The driver then apparently steered to the left, causing the bus to roll over onto its right side and slide across the gravel road for 60 feet before coming to rest. One passenger was partially ejected.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 2 passengers, aged 4 to 11, 1 was uninjured, and 1 sustained serious (AIS 3) injuries. The 30-year-old restrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The right front windshield was broken. The right front boarding door was crushed inboard and the roof was scraped at the right front and right rear corners. The top window pane of the first window after the right front boarding door was broken.

Evaluation of Bus Performance: The bus sustained minor damage to the right front during a slow 90° rollover onto its right side. No interior damage. The bus performed well.

Injury Analysis

<u>Passengers:</u> A 4-year-old girl, seated in row 1, directly behind the driver, was flung to the right side of the bus as the bus rolled over. Her right arm went through the upper window glass of the forward most right side window and remained outside of the passenger compartment as the bus slid several feet along the gravel roadway surface. This resulted in serious (AIS 3) injuries to her arm which ultimately necessitated amputation above the elbow. An 11-year-old child, the injured girl's sister, was seated in the left rear area of the bus. This passenger, although undergoing collision forces similar to those acting upon her younger sister, reportedly was uninjured. Had a lap belt restraint or child safety seat been available for use by the 4-year-old, the disfiguring arm injury would have been prevented. This accident is puzzling because the only school-age child present in the schoolbus was not injured in the rollover.

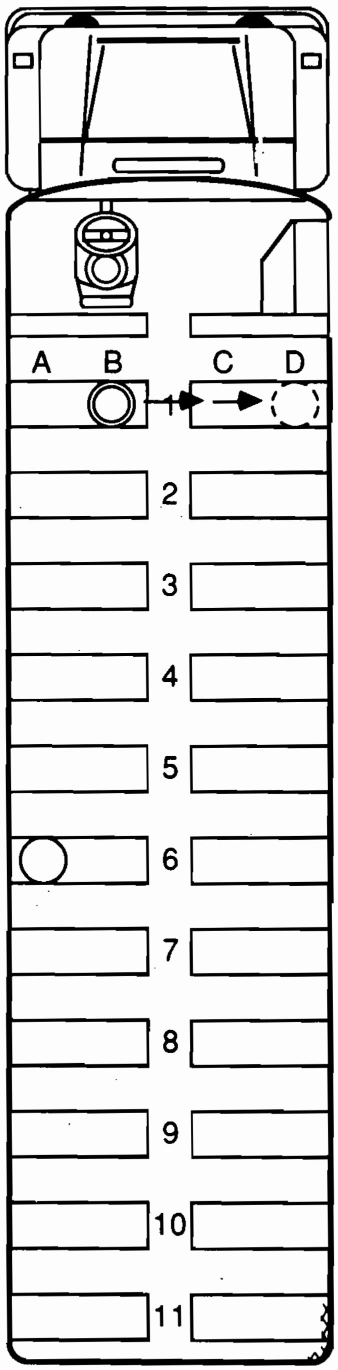
<u>Schoolbus Driver:</u> Available lap belt used. Driver received minor injuries (AIS 1): details unknown.

Leavenworth, Kansas
Case 24

Left Side of Bus

Driver
F-30, MAIS 1

Row 1B
F-4, MAIS 3
Partial amputation with severe crushing and lacerations of right arm.



Right Side of Bus

No Injuries

LEGEND

- Uninjured
- Unknown if Injured
- Injured
- Lap Belt Used
- Fatally Injured

Example: M-17 (Male, Age 17)

MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Note:
The bus rolled over and slid on its right side. The passenger in Row 1B was thrown against the right side windows. Her arm penetrated the window and was crushed beneath the sliding bus.

The school bus shown is representational only.

Case No.: 25
CHI-85-H-SB01

Accident Location: State Route 62, outside Point Pleasant, West Virginia

Date and Time: October 2, 1984, 8 a.m.

Description of Schoolbus: 65-passenger poststandard bus:
1983 Ford chassis with 1983 Blue Bird body

Type of Accident: Noncollision rollover (270°)

Accident Severity: Moderate

Summary of Events: A schoolbus transporting 53 students to school was travelling at a driver-estimated speed of 15 to 20 mph on a wet, 2-lane, opposing traffic, asphalt road. As the schoolbus entered a curve, an oncoming tractor-trailer combination crossed the centerline into the path of the bus. The schoolbus driver steered to the right to avoid collision and braked. The schoolbus went onto the shoulder, slid down an embankment which partially collapsed, and overturned onto its right side. The schoolbus continued to roll down the embankment, completing a three-quarter revolution, before coming to rest on its left side, 14 feet below the road surface.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 53 passengers, aged 11 to 17, 17 were uninjured, 32 sustained minor (AIS 1) injuries, and 4 sustained moderate (AIS 2) injuries. The 29-year-old restrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: No major damage. The right front fender, right front roof and left side roof were damaged. Third left side passenger window broken out of frame. No bus body joint separation or significant intrusion into bus interior was noted. Fuel system not damaged.

Evaluation of Bus Performance: This was a low-speed rollover. Roof and sides of bus withstood loading which occurred during rollover. Integrity of bus body was maintained by structural strength. Seat padding required by FMVSS mitigated severity of occupant injuries.

Injury Analysis

Passengers: This was a low speed rollover, but it is still surprising 17 students sustained no injuries during the 270° rollover. Thirty-three students received minor injuries and four students sustained moderate injuries. All passengers were conscious and able to evacuate the bus after it came to rest. Students seated on the right side of the bus were more apt to be uninjured (12 of the 17) than those on the left, but AIS 2 injuries were equally divided between both sides.

Three of the students who sustained moderate injuries received concussions; the fourth had a hairline fracture of the left forearm.

Point Pleasant, West Virginia
Case 25

Lap belt use probably would not have affected the injury outcome of this accident. Two of the four students who received AIS 2 injuries were seated on the right, next to the windows. As the bus turned over onto its right side, beginning the rollover, these students even if lap belted could have sustained an AIS 2 concussion or fractured forearm from contact with window and side wall. The third student who received a concussion was seated on the left, next to the window. She also could contact the window or sidewall if lap belted when the bus came to rest or by contact with the student seated next to her during the rollover. The fourth student with AIS 2 injuries was seated in the first row, in between two other students. She could still sustain a concussion if lap belted by striking the neighboring passengers or the restraining barrier

Schoolbus Driver: Available lap belt used. Driver received minor (AIS-1) injuries: bruised left and right shoulder and sprained knee (received while evacuating the bus), and a bruised upper left and right thigh (sustained from contact with steering wheel rim during rollover). Driver remembers being held in place by lap belt during rollover.

Special Notes on the Accident

According to witnesses, two seat cushion bottoms came loose during rollover.

Seating position of one passenger unknown.

Point Pleasant, West Virginia
Case 25

Left Side of Bus

Driver
F-29, MAIS 1

Row 1A
F-13, MAIS 1

Row 1B
F-13, MAIS 2
Concussion, bruised left ribs, abrasion on right ear.

Row 1C
F-15, MAIS 1

Row 2C
M-13, MAIS 1

Row 3A
F-14, MAIS 1

Row 3C
M-13, MAIS 1

Row 4A
M-15, MAIS 1

Row 4C
M-15, MAIS 1

Row 5A
M-12, MAIS 1

Row 5C
F-13, MAIS 1

Row 6A
F-13, MAIS 2
Concussion

Row 6C
F-12, MAIS 1

Row 7A
M-7, MAIS 1

Row 7B
F-17, MAIS 1

Row 8A
F-NK, MAIS 1

Row 8B
F-16, MAIS 1

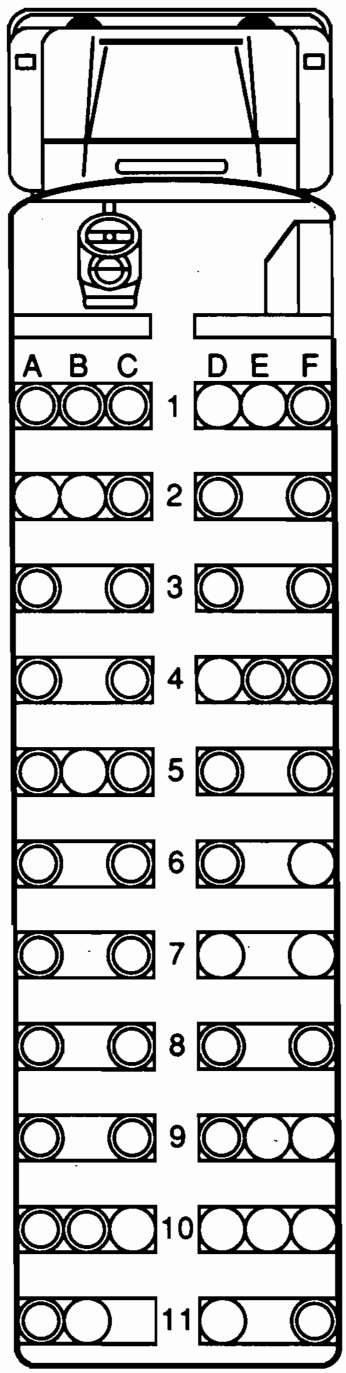
Row 9A
F-NK, MAIS 1

Row 9B
F-17, MAIS 1

Row 10A
F-NK, MAIS-1

Row 10B
M-13, MAIS 1

Row 11A
F-16, MAIS 1



Right Side of Bus

Row 1F
F-12, MAIS 2
Concussion.

Row 2D
F-11, MAIS 1

Row 2F
F-11, MAIS 2
Hairline fracture left forearm.

Row 3D
M-14, MAIS 1

Row 3F
M-12, MAIS 1

Row 4E
M-12, MAIS 1

Row 4F
M-12, MAIS 1

Row 5D
M-NK, MAIS 1

Row 5F
M-13, MAIS 1

Row 6D
F-13, MAIS 1

Row 8D
F-17, MAIS 1

Row 8F
F-17, MAIS 1

Row 9D
M-18, MAIS 1

Row 11F
M-16, MAIS 1

LEGEND

- ○ Uninjured
- ◎ Injured
- ● Fatally Injured
- ? Unknown if Injured
- ⊖ Lap Belt Used

Example: M-17 (Male, Age 17)

MAIS-2 (Used for injured occupants only) Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Note:
Seating position for F-13, MAIS 1, is unknown.

The school bus shown is representational only.

<u>Case No.: 26</u>
DEN-86-H-SB02

Accident Location: Lea County Road 76, outside Hobbs, New Mexico

Date and Time: October 16, 1985, 8:15 a.m.

Description of Schoolbus: 47-passenger poststandard bus:
1985 International Harvester chassis with a Blue Bird body

Type of Accident: Noncollision rollover (450°)

Accident Severity: Moderate

Summary of Events: A schoolbus was travelling at a driver-estimated speed of 20 to 25 mph on a wet, dirt road which was full of pot holes and very "washboardy," picking up students en route to school. A light rain was falling. As the schoolbus rounded a slight left curve, the driver accelerated and lost control of the bus. The vehicle's right wheels left the road, entered a shallow ditch, and travelled approximately 175 feet in the ditch before the driver was able to return the bus to the road. After a short distance, the rear end of the bus fishtailed to the left, the bus skidded sideways, rotated clockwise approximately 100° and rolled over 1 1/4 times. The driver stated she was going about 20 to 25 mph when she lost control of the schoolbus. The rollover probably occurred when the bus was travelling approximately 20 mph. The bus came to rest on its left side, facing the opposite direction it had been travelling.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 11 passengers, aged 12 to 16, 5 sustained minor (AIS 1) injuries, and 6 sustained moderate (AIS 2) injuries. The 30-year-old restrained driver received minor (AIS 1) injuries.

Damage to Schoolbus: The schoolbus roof was pushed down 20 inches in the front from the impact with the ground as it rolled over. There was a 15-inch outward bowing of the front portion excluding the hood diminishing to 3 inches toward the rear of the bus. The bus body bowed over toward the right. There was no deformation to the seat frames and the body seams remained intact. Fuel tank retained integrity. The windshield shattered and fell out of the bus (due to the bowing). The front entrance door was also bent outward (again due to the bowing) and was inoperable.

All windows on the left side were broken but most remained in place. Some windows were broken not during crash, but following the crash, when passengers walked on the glass panes during evacuation.

Evaluation of Bus Performance: The schoolbus performed well in maintaining its integrity during this overturn considering the speed of the rollover.

Injury Analysis

<u>Passengers:</u> Every passenger on the bus was injured in this accident. The number of students who sustained moderate (AIS-2) injuries as their most severe injury was almost equaled by the number who received minor (AIS 1) injuries as their most severe. Considering the bus rolled over 1 1/2 times at moderate speed, injuries were less than might have been expected.

Injuries assuredly would have been less severe if the schoolbus interior had been without metal luggage racks. Contact with the overhead luggage rack contributed to many of the minor injuries and all, but, one of the moderate injuries. Nine of the 11 passengers specifically told the Safety Board investigator (or he later reconstructed) that they hit or landed on the luggage rack during the rollover. Two students received contusions (AIS 1) on their backs which mirrored the luggage rack rails, elongated ("line-type") deep bruises spaced 3 to 4 inches apart; other AIS 1 injuries attributable to contact with the racks were contusions to heads, elbows, and shoulders.

Luggage rack contact also was the probable source of the following AIS 2 injuries: compression fractures of T-12 vertebra, fractured left clavicle, compression fracture of L-3 vertebra, compression fracture T-12 vertebra, fracture of transverse process L1-S1 (pelvis), and fractured left clavicle. (Note: one student sustained two AIS 2 injuries.)

The remaining AIS 2 injury, a fracture of the proximal left humeral metaphysis (upper arm), probably was caused by contact with the window frame on left side of bus; the student had been seated on the left side.

Contact with seat backs, window frames, and interior walls accounted for remaining injuries.

Contact with other students apparently did not cause injuries. When the bus came to rest, three students were piled on one another. All three sustained minor (AIS 1) injuries, but these injuries were not attributed by the students, or by the Safety Board investigator, to contact with one another but rather to contact with an overhead rack, seat back, or window.

Lap belt use certainly could have prevented some of the specific injuries (i.e., back injury from contact with luggage rack). Belt use would not have helped the student who fractured her arm (AIS 2) by striking the window frame. She conceivably still could have broken her arm if lap belted since her arms would be free to flail. Passengers would not have contacted the overhead luggage racks, the probable source of the majority of their injuries, if they had been wearing lap belts during the rollover.

Lap-belted passengers, however, still could sustain minor, even moderate, injuries in a rollover accident of this type —a 450° revolution.

Removal of the luggage racks would have dramatically affected injury outcome. Contact with the metal edges of the luggage rack during rollover would produce more severe injuries than contact with the sloping interior roof. Any time a force is concentrated rather than spread out over a larger body area, it is more injurious.

Schoolbus Driver: Available lap belt used. Driver sustained minor injury (AIS 1): Laceration of right hand (contact with side window).

Hobbs, New Mexico
Case No. 26

Left Side of Bus

Driver
F-30, MAIS 1

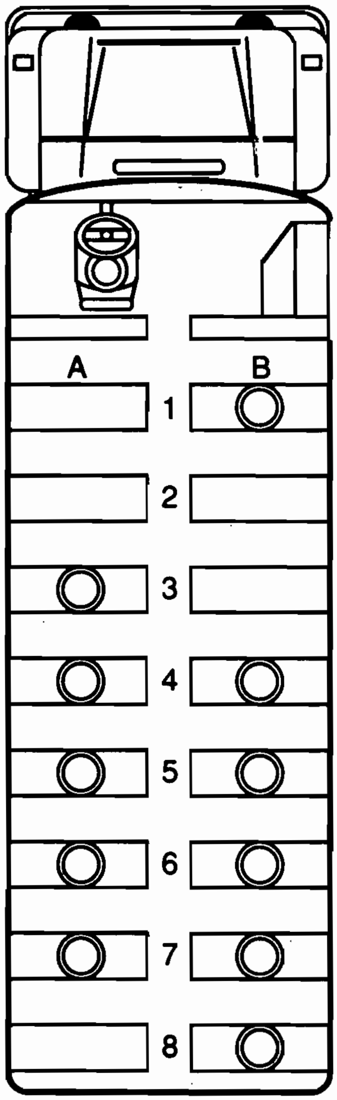
Row 3
M-13, MAIS 1

Row 4
F-14, MAIS 2
Compression fracture T-12 vertebra, contusion of left elbow and mid-back.

Row 5
M-13, MAIS 2
Compression fracture of L-3 vertebra and contusion on left side of head.

Row 6
M-14, MAIS-2
Fracture of left humeral metaphysis, contusion on left cheek.

Row 7
F-12, MAIS 1



Right Side of Bus

Row 1
M-13, MAIS 1

Row 4
F-16, MAIS 2
Fractured left clavicle, contusion on right hip and posterior.

Row 5
F-16, MAIS 2
Compression fracture T-12 vertebra, fracture of the transverse process L-1-S1, contusion on left hip and side.

Row 6
F-14, MAIS 2
Fractured left clavicle, contusion on left shoulder and lower back.

Row 7
M-13, MAIS 1

Row 8
F-14, MAIS 1

Special Note:
The passenger in Row 5A was lying down in the seat.

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 (Male, Age 17) MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

<u>Case No.: 27</u>
DCA-86-SH-002

Accident Location: Baltimore-Washington Parkway, outside Bladensburg, Maryland

Date and Time: January 10, 1986, 8:15 a.m.

Description of Schoolbus: 50-passenger poststandard bus:
1979 International Harvester chassis with 1979 Superior body

Type of Accident: Noncollision rollover (270°)

Accident Severity: Moderate

Summary of Events: A schoolbus transporting 51 high school students to school was travelling in the center of three southbound lanes on a divided, asphalt highway. As the bus approached a Y-junction, a passenger car suddenly changed lanes from the extreme right to the center lane, directly into the path of the bus. The bus driver steered sharply to the left and braked, locking the rear brakes, which initiated a rapid counterclockwise rotation of the schoolbus. The travel path of the bus was redirected toward the east curb while the rotation continued and as the left front tire mounted the curb, the bus began a rollover onto its right side. The rollover continued as the bus rotated onto its top, then onto its left side before coming to rest on the grassy center median. In all, the schoolbus made a three-quarter revolution, while rotating longitudinally about 120°.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 51 passengers, aged 14 to 18, 4 were uninjured, and 47 sustained minor (AIS 1) injuries. The 46-year-old unrestrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Damage was confined to the passenger door, broken windshield (driver's side), two broken windows (right side), dented roof and ceiling, slightly compressed ceiling, and bus side ceiling separation on the right bus side.

Evaluation of Bus Performance: The schoolbus body and chassis remained securely attached. Interior body panels separated in numerous places. Access panels, not covered by Federal standards, also showed separation. All bottom seat cushions came loose and were tossed around the bus. This occurred because seats were not secured to their rails after the cushions were recovered with plastic material. Indeed, the new covering material was stapled over the latches in some cases.

The seat backs and floor and wall anchorages remained in position.

Injury Analysis

<u>Passengers:</u> All students except one were seated at the beginning of the accident sequence. The exception was the student standing in the aisle near row 7. He sustained a minor scalp contusion (AIS 1) when he struck the ceiling during rollover.

Bladensburg, Maryland
Case No. 27

The rollover occurred at a relatively low speed but as the bus made its three-quarter revolution, all passengers tumbled around in the bus interior. Students mentioned hitting their heads, necks, shoulders and back during the rollover. In some cases, these contacts did not produce an injury per se in the body region struck; passengers who were injured received only minor injuries. The slowness of the rollover no doubt contributed to the lack of more serious injuries.

Probable source of the minor soft tissue injuries (contusions and lacerations to legs, arms, ribs, scalp and back) which were sustained include contact with the ceiling, walls, other passengers, loose bottom seat cushions, and contact with exposed bottom seat cushion support rails. Flying books and loose items also caused injuries.

Even if students were lap belted, it's probable they still would sustain minor injuries in a rollover. Indeed, since the bottom seat cushions of the bench seats of this bus were not secured, lap-belted students conceivably could sustain more serious injuries should cushions come off during rollover since they then will impact the exposed seat rails with their "tail bones" or fall between the railings.

Schoolbus Driver: Lap belt available but not used. The schoolbus driver told the Safety Board investigator, she was wearing her safety belt at the time of the accident. The lap belt, however, was found by the Safety Board investigator and Park Police to be fastened across the driver's seat back. Dirt and debris on the belt indicated it had not been used recently. Prince George's County Board of Education requires schoolbus drivers to wear their belts when the vehicle is in motion. Driver probably sustained minor (AIS 1) injuries: complained of back spasms.

Special Notes on the Accident

Flying seat cushions caused some injuries, and the detached cushions lying within the lower side of the overturned bus hindered bus evacuation.

This accident illustrates the problems inherent of relying on newspaper or radio accounts to gauge the severity of injuries sustained by students in a particular schoolbus accident. News accounts reported that a police helicopter transported two students with suspected serious injuries to the Washington Hospital Center and that all students were taken to local hospitals. In actuality, 2 students (of the 51 students) were kept in the hospital for 1 1/2 days for observation; students without obvious injuries were transported to hospitals for a precautionary medical examination. The outcome of the accident: students who were injured sustained minor injuries only.

Bladensburg, Maryland
Case No. 27

Left Side of Bus

Row 1A
F-14, MAIS 1

Row 1B
F-14, MAIS 1

Row 1C
F-14, MAIS 1

Row 3A
M-15, MAIS 1

Row 3B
M-14, MAIS 1

Row 3C
M-17, MAIS 1

Row 4A
F-18, MAIS 1

Row 4B
F-17, MAIS 1

Row 5A
F-16, MAIS 1

Row 5B
F-16, MAIS 1

Row 5C
M-15, MAIS 1

Row 6A
M-14, MAIS 1

Row 6B
M-16, MAIS 1

Row 6C
M-15, MAIS 1

Row 7A
F-15, MAIS 1

Row 7B
F-17, MAIS 1

Row 7 Aisle (Standing)
M-15, MAIS 1

Row 8A
M-15, MAIS 1

Row 8B
M-16, MAIS 1

Row 8C
M-17, MAIS 1

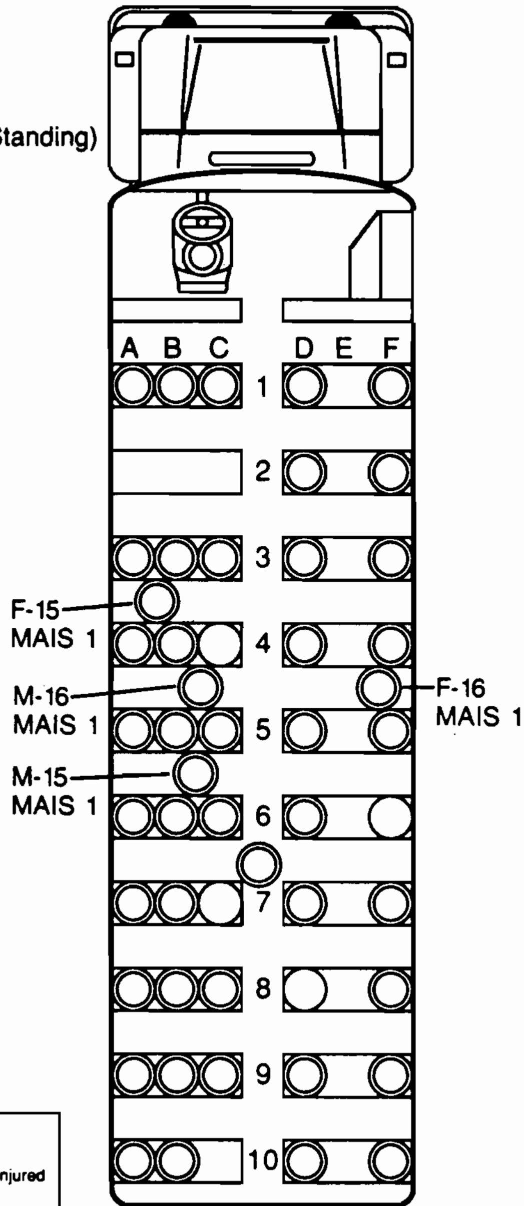
Row 9A
M-16, MAIS 1

Row 9B
F-16, MAIS 1

Row 9C
M-16, MAIS 1

Row 10A
F-14, MAIS 1

Row 10B
M-16, MAIS 1



LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 — Male, Age 17

MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Right Side of Bus

Row 1D
M-16, MAIS 1

Row 1F
F-14, MAIS 1

Row 2D
M-15, MAIS 1

Row 2F
F-15, MAIS 1

Row 3D
F-16, MAIS 1

Row 3F
F-15, MAIS 1

Row 4D
M-15, MAIS 1

Row 4F
M-15, MAIS 1

Row 5D
F-16, MAIS 1

Row 5F
M-14, MAIS 1

Row 6D
F-14, MAIS 1

Row 7D
F-14, MAIS 1

Row 7F
F-15, MAIS 1

Row 8F
F-16, MAIS 1

Row 9D
M-16, MAIS 1

Row 9F
F-15, MAIS 1

Row 10D
F-15, MAIS 1

Row 10F
M-15, MAIS 1

Special Notes:
One student standing in aisle near Row 7.

Four students were sharing seats that were already filled to capacity: Row 4L, 5L, 6L, and 5R.

The school bus shown is representational only.

Case No.: 28
DCA-85-MH-003

Accident Location: State Route 88, outside Jefferson, North Carolina

Date and Time: March 13, 1985, 12:20 p.m.

Description of Schoolbus: 54-passenger poststandard bus:
1980 Chevrolet chassis with 1980 Thomas Built body

Type of Accident: Noncollision rollover (360°)

Accident Severity: Moderate

Summary of Events: A schoolbus transporting 22 high school students to afternoon classes was travelling on a 2-lane, 2-way asphalt road up a hill at about 20 mph. As it approached a left curve in the roadway, the bus went off the right edge of the road onto a shoulder and overturned, rolling one full revolution down a steep embankment before coming to rest upright against two trees. Slow rollover (estimated speed 5.6 mph). Final impact into trees at bottom of embankment is estimated at 15.5 mph.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 22 passengers, aged 16 and 17, 20 sustained minor (AIS 1) injuries, 1 sustained moderate (AIS 2) injuries, and 1 received serious (AIS 3) injuries. The 17-year-old restrained driver was not injured.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Superficial damage to right side of bus including dents, scrapes, scratches, and dirt and tree bark embedded. The left rear tires were ripped and the rims bent. All other areas remained undamaged except for minor scrapes and scratches. No intrusion into passenger compartment. No separation of body panels.

Evaluation of Bus Performance: The schoolbus performed extremely well. Despite the 360° rollover, it could be driven from the accident scene to the school garage. Damage was confined mainly to the right side.

Injury Analysis

Passengers: Most students did not remember what they struck or what caused their injuries. The student seated in the fifth row window seat on the right side of the bus who sustained a broken clavicle (AIS 2) believed she received her injury when she struck the bus floor. The most seriously injured student (AIS 3), seated in the ninth row window seat on the right, did not know what she struck or how she received her bruised liver. The remaining 19 passengers who were injured received minor injuries (AIS 1), but only a few could identify what they had struck. Some students mentioned that they struck the roof, windows, and seatbacks (two mentioned striking the metal bar inside the seatback cushion) and that other students fell on them. One student seated in the first row recalled that his feet hit the windshield, and another also seated in the first row stated that his right arm struck the bar connected to the front door handle (he received a bruise).

Most of the minor injuries were confined to the passengers' extremities and probably occurred as the bus rolled over and the flailing arms and legs of the students struck seats, windows, roof, and each other. Head contusions also were common.

Installation and use of lap belts might have reduced the severity of the injuries sustained by the passenger with the broken clavicle (AIS 2) and the passenger with the bruised liver (AIS 3). However, it is less likely that lap belt use would have resulted in a substantial reduction in the number and nature of the minor injuries (AIS 1) incurred by the other passengers.

Twenty of the 22 passengers involved sustained minor injuries during the rollover. If lap belts had been available for all occupants at the time of the accident, passengers would not have hit the roof during the rollover, or fallen from their seats onto the floor or on top of other passengers. Nonetheless, had the passengers been wearing lap belts, they probably still would have sustained similar types of minor to moderate injuries (abrasions, contusions, and fractured fingers and noses) during the rollover by contacts with the person seated next to them and the seatbacks in front of them. Passengers seated by the windows still would have struck the sidewalls and windows.

It is difficult to evaluate the effect lap belt use would have had on the students who were more seriously injured. If the student seated in the right rear window seat sustained her bruised liver as result of being fallen on or stepped on by another passenger, or by falling across a seatback, lap belt use might have prevented her injury. She did not know how she was injured, however. If the student seated in the fifth row window seat received her broken clavicle from striking the floor as she remembers, lap belt use could have prevented this injury. She still could have received some similar level of injury though, even if restrained, by striking the window, window frame, and side wall during the rollover or by contact with the person seated next to her.

Schoolbus Driver: Available lap belt used. Driver stated he was uninjured although he struck the left sidewall of the bus just above the window.

Special Notes on the Accident

Tire chains secured to the legs of the two rear seats of the schoolbus were a potential source of injury.

Jefferson, North Carolina
Case No. 28

Left Side of Bus

Row 1A
M-16, MAIS 1

Row 1B
M-17, MAIS 1

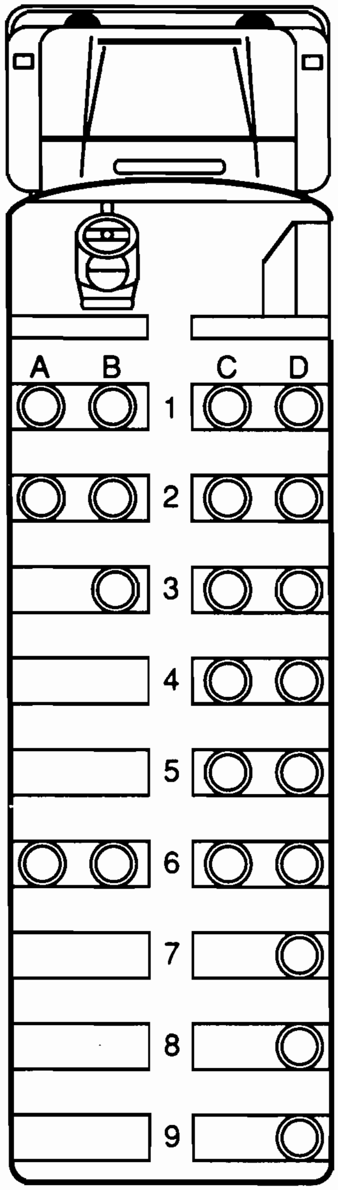
Row 2A
M-16, MAIS 1

Row 2B
M-16, MAIS 1

Row 3B
M-16, MAIS 1

Row 6A
M-16, MAIS 1

Row 6B
M-17, MAIS 1



Right Side of Bus

Row 1C
M-16, MAIS 1

Row 1D
M-16, MAIS 1

Row 2C
M-17, MAIS 1

Row 2D
F-16, MAIS 1

Row 3C
F-17, MAIS 1

Row 3D
F-17, MAIS 1

Row 4C
M-17, MAIS 1

Row 4D
M-16, MAIS 1

Row 5C
M-17, MAIS 1

Row 5D
F-16, MAIS 2
Fractured left clavicle, contusions on legs, head, and hip.

Row 6C
F-17, MAIS 1

Row 6D
M-17, MAIS 1

Row 7D
M-16, MAIS 1

Row 8D
F-16, MAIS 1

Row 9D,
F-16, MAIS 3
Contused liver and intestines;
MAIS 1: contusions on forehead, hips, back, and left ankle.

LEGEND

- Uninjured
- Unknown if Injured
- Injured
- Lap Belt Used
- Fatally Injured

Example: M-17 (Male, Age 17) MAIS-2 (Used for injured occupants only) Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

Case No.: 29
MKC-86-H-AB05

Accident Location: U.S. Highway 70, outside Swink, Oklahoma

Date and Time: March 6, 1986, 7:15 a.m.

Description of Schoolbus: 72-passenger poststandard bus:
1982 Ford chassis with 1983 Wayne body

Type of Accident: Noncollision rollover (360°)

Accident Severity: Moderate to severe

Summary of Events: A schoolbus, transporting 32 high school band members and an adult chaperone on an activity trip, was travelling at a driver-estimated speed of approximately 40 mph on a rural 2-lane, 2-direction road. The driver allowed the right front tire of the bus to drop off the unimproved asphalt edge of the right side shoulder and, as the driver attempted to regain the travel lane, the bus began a counterclockwise rotation with the rear of the bus sliding down the cross slope of the roadside. After travelling approximately 57 feet, with the right rear tires digging progressively deeper into the dirt, the bus began to overturn, eventually completing a full 360° rollover before coming to rest upright. Four students reported they were ejected out the front windshield.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 33 passengers, aged 14 to 39, 6 were uninjured, 24 sustained minor (AIS 1) injuries, and 3 sustained moderate (AIS 2) injuries. The 23-year-old restrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The ground impacts during rollover resulted in substantial distortion of the schoolbus roof structure. The top structure, from the side window framework upward, was pushed toward the right of the body's longitudinal centerline a distance of 15 inches at the front, resulting in several inches of compartmental compression at the extreme front, and 2 inches at the extreme rear. Only two of the side windows remained intact on the right side of the bus. Ten top windows and three bottom windows were not broken on the left side. Both components of the front windshield were displaced from their framework and the passenger loading door was rendered inoperative due to structural collapse. Although the rear emergency exit was damaged and inoperative from the schoolbus interior, the driver was able to open it from the outside for passenger exit and evacuation.

All of the bench seat lower cushions were reportedly displaced from the seat frameworks during the rollover. The investigator noted that seven of the seat bottom frame clamps were bent backwards, rendering them ineffective for holding the cushions in place.

Evaluation of Bus Performance: The schoolbus body probably performed as well as could be expected considering the dynamics of this rollover. The structural collapse that occurred apparently did not influence severity of injuries sustained by the occupants. It is highly probable, however, that the seat cushion displacement contributed to various injuries to the student passengers. Again, considering the dynamics of this complete rollover, the cushions probably only altered the type of injuries sustained, not the severity. The major problem resulting from the seat bottom cushion displacement appears to have been the obstruction presented to passengers attempting to exit from the bus.

Swink, Oklahoma
Case No. 29

Injury Analysis

Passengers: Minor (AIS 1) injuries sustained by 24 passengers in this accident consisted of lacerations, contusions, abrasions, and both lumbar and cervical strains. Three passengers received moderate AIS 2 injuries: a nondisplaced fracture of the fifth cervical vertebra; a fracture of the right clavicle; and a 2 1/2-inch forehead laceration. A fourth passenger was hospitalized overnight for observation but was reported by medical records to have sustained only minor (AIS 1) injuries.

Injuries sustained by passengers in this bus occurred at various times within the rollover sequence due to a variety of contact points. Band instruments were stored loosely at numerous locations within the passenger compartment and came loose, hitting passengers during the accident. It was reported that every bottom seat cushion was displaced during the rollover and several passengers stated they were injured by these loose cushions. Four students reported ejection through the displaced front windshield, however, the highest level injury sustained was a moderate (AIS 2) laceration.

Lap belt use, in this accident, might have altered the type of injuries, but probably would not have had effect on the injury severity. If four students actually were ejected were from the bus, any type restraint would prevent those ejections. No serious injuries resulted from the ejections, however, and AIS 2 injuries can be sustained by lap-belted occupants during a 360° rollover.

Schoolbus Driver: Available lap belt used but reported as adjusted improperly. Minor (AIS 1) injuries: a minor contusion and laceration to right frontal forehead and abrasion to lower right leg.

Special Notes on the Accident

The restraint system furnished at the driver's position is equipped with nonlocking retractors, their only function being the stowage of belt webbing. In this case, as has occurred in other Safety Board investigated accidents, the nature of this type system is apparently confusing to the bus driver. The confusion results in a driver simply fastening the buckle/latchplate connection, expecting either an emergency locking or an automatic locking function. Neither function is provided by this system, resulting in the retractors simply unspooling the stored webbing upon loading by the driver's weight. This leaves the driver free to travel forward into contact with the frontal interior or to be displaced from his seating position in a rollover situation.

Swink, Oklahoma
Case No. 29

Left Side of Bus

Driver
M-23, MAIS 1

Row 1A
M-15, MAIS 1

Row 1B
M-16, MAIS 1

Row 3A
F-16, MAIS 1

Row 3B
F-15, MAIS 1

Row 4A (Ejected)
F-16, MAIS 1

Row 5A
F-15, MAIS 1

Row 6A (Ejected)
F-15, MAIS 1

Row 6B
F-15, MAIS 1

Row 7A
M-15, MAIS 1

Row 8A
F-16, MAIS 1

Row 9A
F-15, MAIS 1

Row 9B
F-15, MAIS 1

Row 11A
F-16, MAIS 1

Row 11B
F-16, MAIS 2
Fractured cervical vertebra.

LEGEND

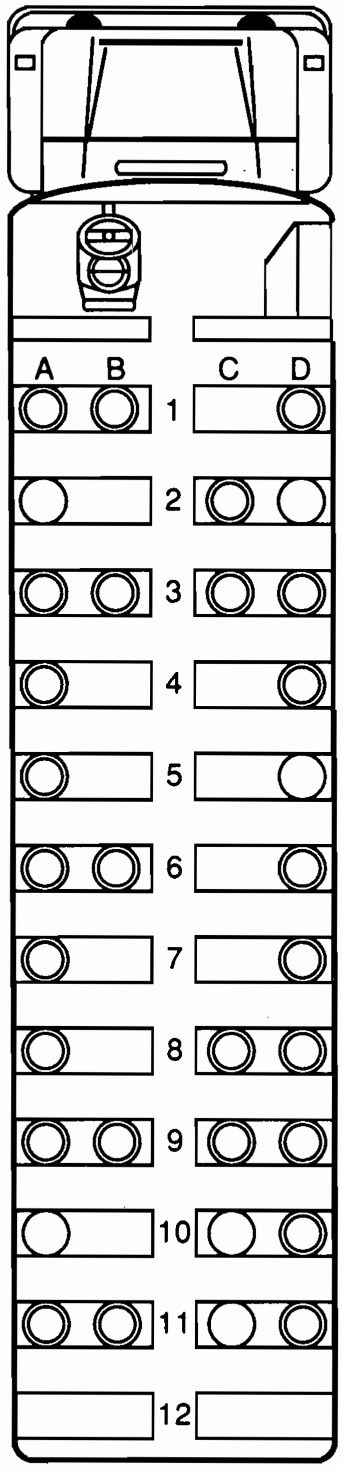
- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 (Male, Age 17); MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)



Right Side of Bus

Row 1D (Ejected)
F-39, MAIS 2
Forehead laceration.

Row 2C
F-15, MAIS 1

Row 3C
F-15, MAIS 1

Row 3D
F-15, MAIS 2
Fractured clavicle.

Row 4D (Ejected)
M-16, MAIS 1

Row 6D
M-16, MAIS 1

Row 7D
M-15, MAIS 1

Row 8C
F-15, MAIS 1

Row 8D
D-16, MAIS 1

Row 9C
F-15, MAIS 1

Row 9D
M-15, MAIS 1

Row 10D
F-16, MAIS 1

Row 11D
F-16, MAIS 1

Special Notes:

The bus driver was restrained, but the lap belt was improperly adjusted, resulting in his displacement and injury during rollover.

The injured passenger in Row 11B had been involved in a previous accident; this may have affected her injury.

The school bus shown is representational only.

Case No.: 30
CHI-84-H-FR06

Accident Location: U.S. 119 outside Julian Boone, West Virginia

Date and Time: November 7, 1983, 7:40 a.m.

Description of Schoolbus: 72-passenger poststandard bus:
1983 International chassis with 1983 Amtran body

Type of Accident: Front angle collision (principal direction of impact at 1 o'clock) with rollover (90°)

Accident Severity: Minor

Summary of Events: A schoolbus transporting 29 elementary students to school was travelling at a driver-estimated speed of 40 mph on a concrete, 2-lane, divided rural highway. The driver failed to steer the bus around a gentle curve. The schoolbus continued straight ahead, left the road, went onto the right shoulder, and struck a break-away sign post. After impact, the driver turned sharply to the left in an attempt to get the schoolbus back onto the road. As the schoolbus regained the road, it overturned onto its right side and slid 175 feet on the concrete roadway before coming to rest.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 29 passengers, aged 5 to 12, 7 were uninjured, 21 sustained minor (AIS 1) injuries, and 1 sustained moderate (AIS 2) injuries. The 42-year-old restrained driver was uninjured.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Bent right A-pillar and boarding door scratches and dents on right side above windows.

Evaluation of Bus Performance: The poststandard schoolbus performed very well in the accident, retaining its structural integrity without interior damage which could cause occupant injury.

Injury Analysis

Passengers: All but one of the injured students received minor (AIS 1) injuries only. The minor injuries sustained by 21 of the 29 schoolbus passengers consisted of contusions and abrasions, confined primarily to heads and extremities. Seating position appeared to have no influence on minor injuries; students who received these injuries were seated throughout the bus.

The student who received the only moderate (AIS 2) injury, a fractured wrist, was seated in the approximate center left side.

It is unlikely lap belt use would have altered either the type or severity of injuries sustained in this accident.

Schoolbus Driver: Available lap belt used; driver was reportedly uninjured.

Julian Boone, West Virginia
Case No. 30

Left Side of Bus

Row 1A
M-5, MAIS 1

Row 1C
M-5, MAIS 1

Row 3A
M-8, MAIS 1

Row 5A
M-8, MAIS 1

Row 5B
M-9, MAIS 1

Row 5C
M-8, MAIS 1

Row 6A
M-8, MAIS 1

Row 6B
M-8, MAIS 1

Row 6C
M-9, MAIS 1

Row 7C
M-9, MAIS 2
Fractured left wrist.

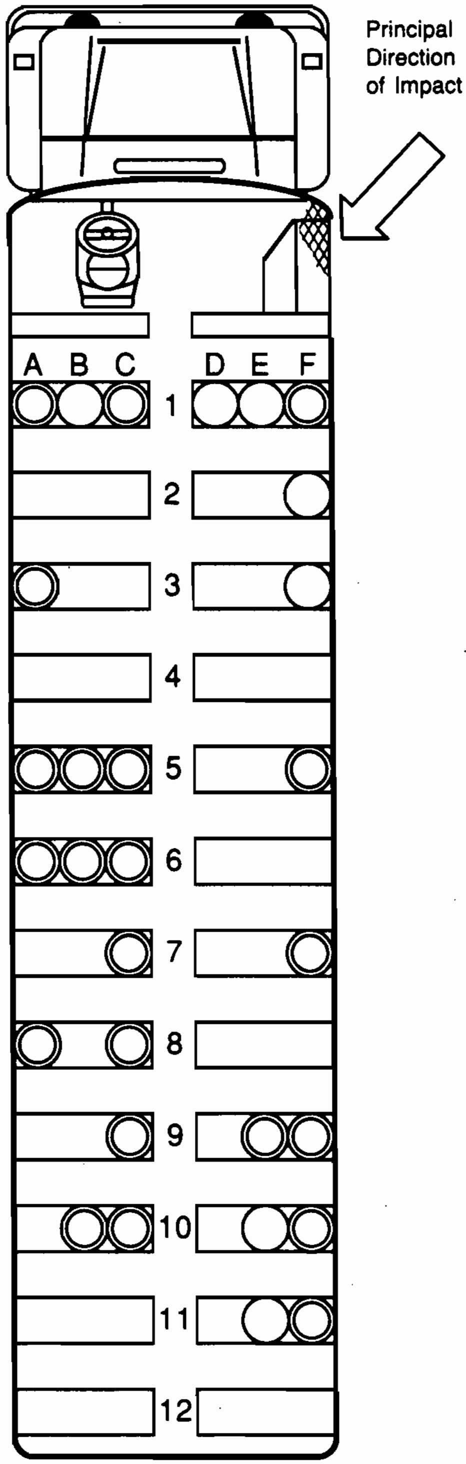
Row 8A
M-11, MAIS 1

Row 8C
M-10, MAIS 1

Row 9C
M-11, MAIS 1

Row 10B
M-11, MAIS 1

Row 10C
M-12, MAIS 1



Right Side of Bus

Row 1F
F-5, MAIS 1

Row 5F
F-8, MAIS 1

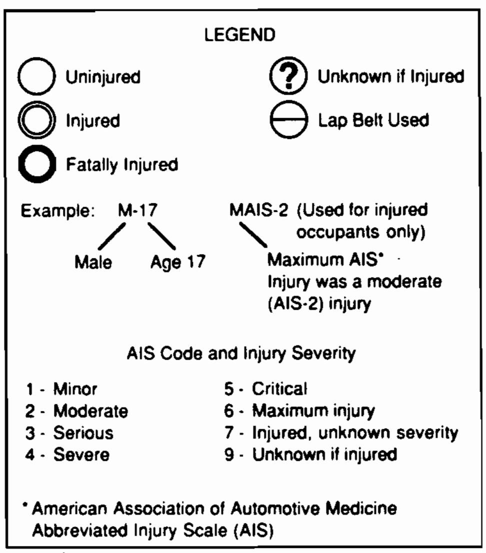
Row 7F
F-9, MAIS 1

Row 9E
F-9, MAIS 1

Row 9F
F-10, MAIS 1

Row 10F
F-10, MAIS 1

Row 11F
F-11, MAIS 1



The school bus shown is representational only.

Case No.: 31
CHI-85-H-SB28

Accident Location: U.S. 67, outside Greenfield, Illinois

Date and Time: September 25, 1985, 8 a.m.

Description of Schoolbus: 59-passenger poststandard bus:
1978 Ford chassis with 1977 (November) Wayne body

Type of Accident: Rear-end collision followed by rollover (90°)

Accident Severity: Moderate

Summary of Events: A schoolbus transporting 32 students to school was travelling about 10 to 15 mph, getting ready to make a left hand turn onto a gravel road. As the bus turned left, it was struck in the rear by a tractor-trailer travelling behind it. The truck jackknifed and the right rear corner of the bus was struck by the left front of the tractor as well as the left front of the trailer. The rear of the bus was pushed counterclockwise and the bus went off the road, struck a ditch, and turned over onto its right side. One passenger was totally ejected and another was partially ejected. (Bus driver estimated schoolbus preimpact speed at 10 to 15 mph; Safety Board investigator estimates truck speed at 35 to 40 mph.)

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 32 passengers, aged 5 to 17, 9 were uninjured, 19 sustained minor (AIS 1) injuries, 3 sustained moderate (AIS 2) injuries, and 1 sustained serious (AIS 3) injuries. The 53-year-old restrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The rear of the bus and right rear corner were damaged from impact with the tractor and semitrailer. The right rear corner had collapsed inward 11 inches and was bowed out to the right about 2 inches (probably more, but it was pushed back in by rollover damage). The top hinge of the emergency door completely separated and the bottom hinge was partially separated. Induced damage caused the left rear corner of the bus to collapse inward 2 inches. Direct damage to the right side (the side it rolled over on) was confined to rippling of the sheet metal from roadway contact, broken windows from roadway and occupant contact, and some minor dents to the interior sheet metal. The only seat deformed from the collision was row 10 on the right side (impact area) which was pushed forward and rotated upward reducing the distance from seatback to seatback by 15 inches. The sole occupant of this seat was ejected through the right side window. (See special notes for comments on seat cushions.)

Evaluation of Bus Performance: The bus performed well in the crash. Although the right rear corner of the bus intruded inward, the vehicle that struck the bus was substantially larger, heavier, and travelling faster than the bus. The bus also performed well during the 90° rollover, limiting damage to sheet metal rippling and broken windows.

Injury Analysis

Passengers: Twenty-three of the 32 passengers were injured in this accident. The majority (19) of those injured received minor (AIS 1) injuries, primarily due to contact with various points within the vehicle interior during the initial bus/truck impact and subsequent rollover as the right side of the bus struck the ground.

One passenger, seated at the extreme right rear position within the bus, was reportedly ejected at the initial collision through an opening created when the right rear side glass was displaced from its framework. The ejection more probably occurred as the bus rolled onto its right side and struck the ground. The passenger landed in the bottom of a ditch and sustained minor injuries only. Moderate to serious injuries probably were prevented by the soft dirt he fell upon and the fact that the depressed nature of the ditch allowed a survivable space between the bus sidewall and the ground.

Three passengers received moderate (AIS 2) injuries. One of the moderate injuries, a fractured clavicle, probably occurred as the student fell from the left side of the bus to the right side interior due to the rollover and ground impact. The remaining two moderate injuries, a low level concussion and a compression fracture of the L, L2 vertebra, probably occurred during the initial bus/truck impact as the two passengers were forced rearward, downward, and to the left due to the direction of principal impact forces.

The single serious (AIS 3) injury probably occurred when a passenger's arm was partially ejected through a window as the bus struck the ground surface on its right side, rolled past 90°, then settled back onto its right side. An open displaced fracture of the passenger's right arm resulted as he fell from a aisle seat on the right side onto the right side window, penetrating the window glass with his arm.

The 19 minor (AIS 1) injuries which occurred in this accident would not have been prevented by the use of passenger lap belts. Lap belts cannot prevent injury-producing contact between occupants nor contact with interior components of the bus.

While the use of a lap belt would have prevented the ejection of the extreme right rear passenger, that use also would have secured him within the only area of interior compression and deformation. It is almost a certaintly that this passenger, had he been restrained, would have sustained serious to severe lower leg injuries due to the compression of his seating area. His seat was pushed forward by the rear-end impact to within 15 inches of the seatback in front of him. The possibility of head injuries also should be considered as his lower body would have been held in place, allowing his torso and head to react rearward and into the direct impact induced collapse. Being unrestrained, he was allowed to react both rearward and toward the left interior, reducing the forces which acted on his entire body.

Lap belt use probably would not have prevented the moderate (AIS 2) injuries sustained by the left side, ninth row passengers. These two injuries, a minor concussion and a compression fracture of L, L2 vertebra, most likely occurred due to rearward reactive forces, not from being displaced out of their seats by the rollover.

The remaining AIS 2 injury could have been prevented by lap belt use. The fractured clavicle most likely resulted when this passenger fell onto the right side interior of the bus during rollover, an action which would not have occurred had a lap belt been used.

The serious (AIS 3) injury also could have been prevented by lap belt use. The reactive forces which acted upon this passenger, seated on right side of row 7, probably would have been altered by use of a lap belt. Had his lower body been properly restrained or secured to the bench seat, his 62-inch height would not have allowed him to penetrate the side window with his right arm, thus preventing the open displaced fracture (AIS 3) of his arm.

Schoolbus Driver: Available lap belt used. Minor (AIS 1) injuries: bruises on left and right hips (from lap belt), bruises on left arm, ankle and right knee, and small laceration on left ankle.

When the schoolbus came to rest on its right side, the driver was trapped suspended by her belt. She was unable to release the lap belt and direct evacuation until two high school students lifted her up, removing her weight from the belt. The driver was then able to push the buckle release button and release the latchplate.

Outcome for Occupants of Other Vehicle:

Vehicle Description: 1985 Ford conventional tractor with Great Dane van trailer.

Damage to Vehicle: Tractor-trailer rolled over following impact. The entire left front corner of the trailer, from top to bottom, was smashed in from impact with the bus. The left front fender was torn apart and the driver's door and left side mirror were smashed on the tractor. There were scratches, abrasion, and creases on the left side and roof of the trailer from the overturn.

Occupant Restraint Use and Injury: Driver was restrained. He received minor (AIS 1) injuries: contusions to the left arm.

Special Notes on the Accident

After this accident, 15 of 20 seat cushions were not locked in place. Eight of these were on the left side of the bus. The investigator interviewed the bus mechanic who was aware of the problem. He stated that he had been periodically retightening the retaining clip bolts, but they still loosened up. Three students stated that they had been struck by seat cushions during the accident.

Greenfield, Illinois
Case No. 31

Left Side of Bus

Driver
F-53, MAIS 1

Row 1A
F-5, MAIS 1

Row 1B
M-7, MAIS 1

Row 2A
F-6, MAIS 1

Row 2C
F-7, MAIS 1

Row 3A
M-11, MAIS 2
Fractured right clavicle.

Row 3C
M-8, MAIS 1

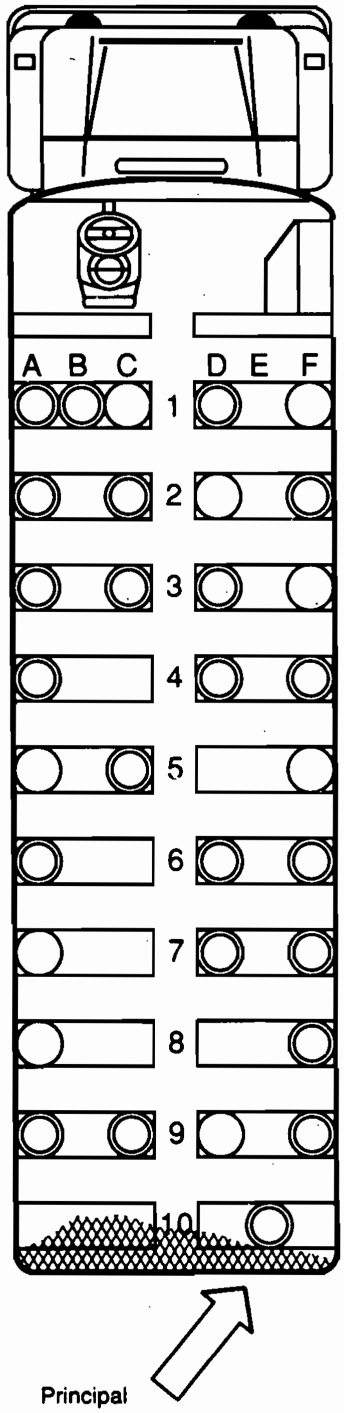
Row 4A
F-11, MAIS 1

Row 5C
M-8, MAIS 1

Row 6A
M-12, MAIS 1

Row 9A
F-15, MAIS 2
Compression fracture L-1-L-5, minor laceration on right of mouth.

Row 9C
F-16, MAIS 2
Concussion, contusions on head and left scapula.



Principal Direction of Impact

Right Side of Bus

Row 1D
M-9, MAIS 1

Row 2F
F-6, MAIS 1

Row 3D
M-12, MAIS 1

Row 4D
M-8, MAIS 1

Row 4F
M-8, MAIS 1

Row 6D
M-11, MAIS 1

Row 6F
M-10, MAIS 1

Row 7D
M-10, MAIS 3
Fractured humerus of right arm (open—displaced), fractured right finger. (Partial ejection.)

Row 8F
M-16, MAIS 1

Row 9F
M-17, MAIS 1

Row 10E
M-14, MAIS 1
(Ejected out of right side window.)

LEGEND

Uninjured — Unknown if Injured
Injured — Lap Belt Used
Fatally Injured

Example: M-17 — Male, Age 17; MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

<u>**Case No.: 32**</u>
FTW-85-H-SB32

Accident Location: Farm to Market Road No. 1362, outside Caldwell, Texas

Date and Time: April 23, 1985, 4:50 p.m.

Description of Schoolbus: 59-passenger poststandard bus:
1978 International Harvester chassis with 1978 Wayne body

Type of Accident: Front angle collision (principal direction of impact at 1 o'clock), followed by rollover (90°)

Accident Severity: Moderate

Summary of Events: A schoolbus transporting 16 elementary students home from school was travelling about 40 mph on a dry, 2-lane, asphalt rural road. Driver-estimated preimpact speed of bus was 40 mph; investigator-calculated impact speed at 30 mph. When the driver failed to negotiate a slight curve in the road, the bus left the road and went onto the soft right shoulder, and the driver lost control. The left front tire never left the road. The bus then veered to the left as the driver attempted to regain control, went across the road to the left side, and collided with the bank of a 3-foot-deep ditch. The schoolbus hit the bank with its right front, turned over onto its right side, caught on fire and burned. A student was partially ejected but extricated before the fire reached her.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 16 passengers, aged 6 to 18, 9 were uninjured, 5 sustained minor (AIS 1) injuries, 1 sustained moderate (AIS 2) injuries, and 1 sustained injuries of unknown severity (AIS 7). The 41-year-old restrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Impact damage to the front of the bus was substantial with rearward displacement of structural components reaching 20 inches at the extreme right front. The right side front wheel and suspension were torn from attachment points and displaced rearward into contact with the right front corner of the bus passenger compartment. The bolts connecting the front of the right side spring hanger were sheared off. Damage continued to the right side of the bus as it continued plowing forward through the roadside material as it overturned. The extreme right front of the passenger body was deformed rearward 14 inches at its bottom, rendering the passenger loading door inoperative due to collapsed framework. The collapsed framework was not a factor in the accident as the bus came to rest lying upon its right side. Overturn damage was also noted at the upper right front of the bus body, directly above the position of the passenger loading door. The upper structure of the bus body, from the lower window line upward, was shifted toward the left 5 inches at the extreme front and 3 inches at the extreme rear. The rear emergency exit door remained fully operational despite the shifted structure.

As the bus settled to its final resting position, lying upon its right side, a fire erupted in the engine compartment. The busdriver related that within 1 to 2 minutes of the crash, she had used the contents of an on-board 5-pound fire extinguisher in an attempt to put out the fire. However, just as the extinguisher's contents were exhausted, the fire restarted. All combustible materials within the passenger compartment of the bus were eventually consumed by the fire. All underhood, nonmetallic hoses and lines were also consumed while a major portion of aluminum components were melted away by the intense heat. Safety Board investigators could not determine the origin of the fire.

Evaluation of Bus Performance: Bus did not display any seam separations from the 30 mph impact.

Injury Analysis

Passengers: Due to unusually warm weather, a large number of side windows in the schoolbus were open. Just before the accident occurred, a high wind gusted through the open windows, displacing papers placed in the overhead parcel carriers. Several students were standing up and gathering scattered books and papers when the bus overturned. Standing students in the rear of the bus received the majority of injuries sustained in this accident.

The most seriously injured student, a 15-year-old girl, had been standing in the aisle between row 9 and 10 picking up papers when the bus went out of control and overturned. She was partially ejected during the overturn and trapped with her leg jammed between the frame of the third side window from the rear and the ground. It took the driver and passengers about 5 minutes before the trapped leg could be freed. Finally, a jack had to be used to raise the side of the bus. By the time the student was extricated, the fire had reached the second row of seats, a distance of only 11 to 12 feet from the student. This student received moderate soft tissue injuries and deep abrasions (AIS 2) to her right leg. The X-rays of femur, knee, and the tibia showed no fractures or dislocations.

A 9-year-old, seated by the left window in row 4, received scratches on his chest (severity unknown) and an unspecified injury to his lower right leg from interior contacts. More information was not available from the student or medical records so this student's injuries could be coded only as AIS 7, injuries of unknown severity.

The five students who sustained minor (AIS 1) injuries received small lacerations, superficial abrasions, and soft tissue injuries from contact with side walls and flying glass. Glass fragments also caused a corneal abrasion for one student. Two students burned the soles of their feet (AIS 1) during the fire, perhaps when they helped extricate the trapped student.

Seated passengers received minor injuries or no injuries. Lap belt use probably would not alter this outcome. Standing passengers sustained the majority of injuries. Had lap belts been available on this bus, these students probably still would have been unrestrained at the moment the bus overturned, having unbuckled their belts to stand-up and retrieve fallen papers.

Schoolbus Driver: Available lap belt used. Seat belt use by the busdriver prevented serious injury and allowed her to direct and assist in the evacuation of student passengers. Had the busdriver been disabled, it is very possible the trapped student would not have survived the postcrash fire. Driver received minor (AIS 1) inuries: soft tissue injury to left ankle and smoke inhalation. The schoolbus driver did not injure her ankle in the collision, but rather was injured during evacuation.

Caldwell, Texas
Case No. 32

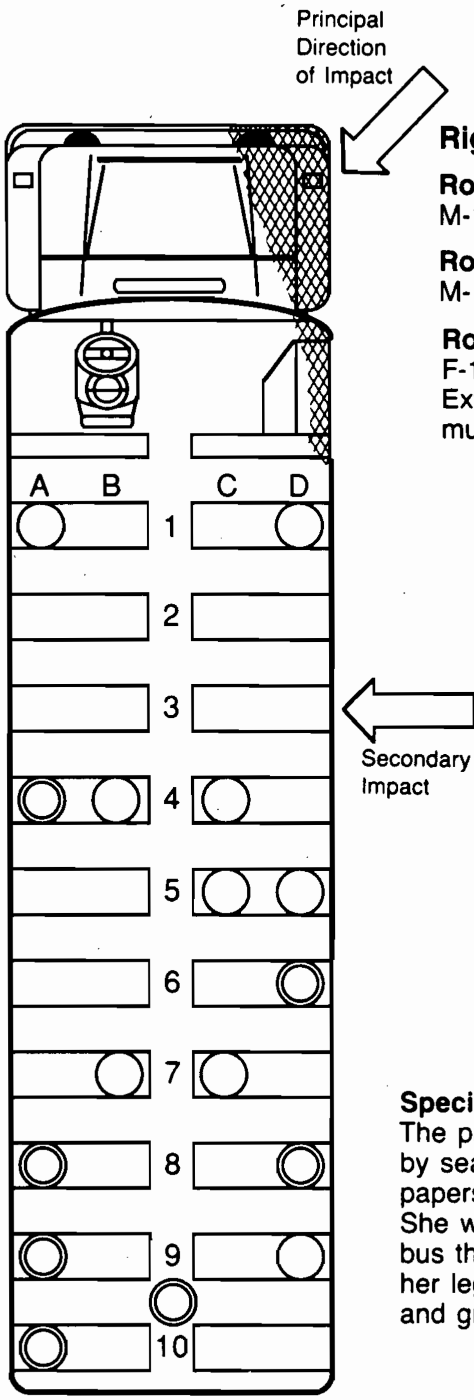
Special Notes on the Accident

This schoolbus was furnished with overhead parcel carriers which extended 19 inches out from the sidewall and 11 1/2 inches from the ceiling. Beginning at the extreme rear of the bus, the carriers continued forward to a point directly above the seat back cushions of the front row seats. An upturned rim, approximately 2 inches high, formed the carrier's edges but an open space approximately 1 inch wide was left between the edge and the bus sidewall. The overhead carriers were used by students to store books, folders, and papers but no provisions were made for securing these items. According to school district officials, it was common for items to fall from the carriers during sudden changes in vehicle motion, and instances of items falling out of the carriers through the outboard space, and out the side windows also had been reported. School district officials had not requested the parcel carriers when the bus was ordered and stated that they would be willing to remove the carriers if they could be sure removal would not diminish the structural integrity of the bus.

According to the busdriver, a large number of seat cushions were displaced from their frames during the accident. These cushions fell into the lower area of the bus and obstructed evacuation. The exact method by which the seat cushions were attached to the seat frames could not be documented since all cushions except one were destroyed in the fire.

In Wayne bus bodies of the accident bus' make and model, seat cushions normally are attached to the rear frame rail by two clips and to the front frame rail by two half clips. Wayne has recently changed the method of securing seat cushions: front clips now extend fully around the front seat rails and tools are required to remove the cushion.

Caldwell, Texas
Case No. 32



Left Side of Bus

Driver
F-41, MAIS 1

Row 4A
M-9, MAIS 7
(Injured, unknown severity)

Row 8A
F-11, MAIS 1

Row 9A
F-12, MAIS 1

Row 10A
F-14, MAIS 1

Right Side of Bus

Row 6D
M-14, MAIS 1

Row 8D
M-16, MAIS 1

Row 10 (Aisle)
F-15, MAIS 2
Extensive soft tissue injury with multiple abrasions to right leg.

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 (Male, Age 17) MAIS-2 (Used for injured occupants only) Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

* American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Note:
The passenger standing in the aisle by seat 10 was retrieving fallen papers at the moment of impact. She was partially ejected from the bus through an open window and her leg was crushed between bus and ground.

The school bus shown is representational only.

Case No.: 33
NYC-86-HSB-07

Accident Location: Intersection of W. Alpine Street and Johnson Avenue, Newark, New Jersey

Date and Time: March 18, 1985, 2:16 p.m.

Description of Schoolbus: 30-passenger poststandard bus: 1979 International Harvester chassis with Superior body

Type of Accident: Left side impact followed by rollover (90°)

Accident Severity: Moderate

Summary of Events: A schoolbus, equipped with lap belts for all occupants, was transporting eight grade school students and an adult attendant home from school, travelling about 20 mph on a residential street. At least six of the eight students were wearing the available lap belts. The driver and adult aide were unrestrained. As the schoolbus crossed an intersection, it was struck on the left side by a car. At impact, the bus rotated counterclockwise, turned over onto its right side, and came to rest. Bus speed at rollover was about 20 mph.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 9 passengers, (8 students, aged 6 to 10, and an adult aide, age 25), 8 were uninjured, and 1 sustained minor (AIS 1) injuries. The injured passenger was the unrestrained aide. The 26-year-old unrestrained driver received moderate (AIS 2) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The left side of the rear axle was displaced rearward about 4 inches; the lower exterior panel on the left side, between the front and rear wheels were displaced about 10 inches inboard. The front windshield popped out of the frame. The right side of the bus, from window to roof, was displaced inboard about 4 inches.

The ceiling panels separated at the seam in several areas. Separations ranged between 1/16 inch to 1/4 inch. The front portion of the tag leaf springs on the left side broke loose from the support.

Evaluation of Bus Performance: The exterior performance of the schoolbus was fair; the interior performance good. The only noticeable interior damage was ceiling panel separation, but this does have injury potential.

Injury Analysis

Passengers: The students were learning disabled and required by school policy to be restrained when transported by schoolbus; the schoolbus driver and adult attendant share responsibility to ensure students are restrained. At least six of the eight student passengers were wearing the available lap belts. The adult aide was unbelted, as was the driver.

When the schoolbus came to rest on its right side, five children restrained by their lap belts were suspended by their lap belts on the left side (top). The schoolbus driver unbuckled the children and helped them evacuate the bus. Had these children been unrestrained, they might have been injured in the accident since they would have been flung to the right as the bus turned over.

The unrestrained adult aide was seated in first seat on the right (bottom) and sustained minor injuries from contact with side wall and window frame. It is uncertain at this time if the two children seated in the second seat on the right (bottom) were restrained or not. The child in row 3 on the right (bottom) probably was restrained. All three children seated on the right were uninjured. Restraint use/nonuse probably made little difference in the injury outcome for the bus occupants seated on the right side of the bus.

Schoolbus Driver: Available lap belt not used. Driver sustained moderate (AIS 2) injuries: contusion to left forearm, right side of right thigh, right eyebrow; laceration and contusion to left temple; contusions to right side of back; mild concussion (contact with front interior and passenger door). The driver was the most seriously injured occupant in the bus.

Outcome for Occupants of Other Vehicle

Vehicle Description: 1980 Chevrolet, 4-door sedan police car.

Damage to Vehicle: Front end damage.

Occupant Restraint Use and Injury: Unknown at this time if driver and passenger were restrained. The driver received minor (AIS 1) injuries: laceration of left knee. Passenger complained of head and neck pain.

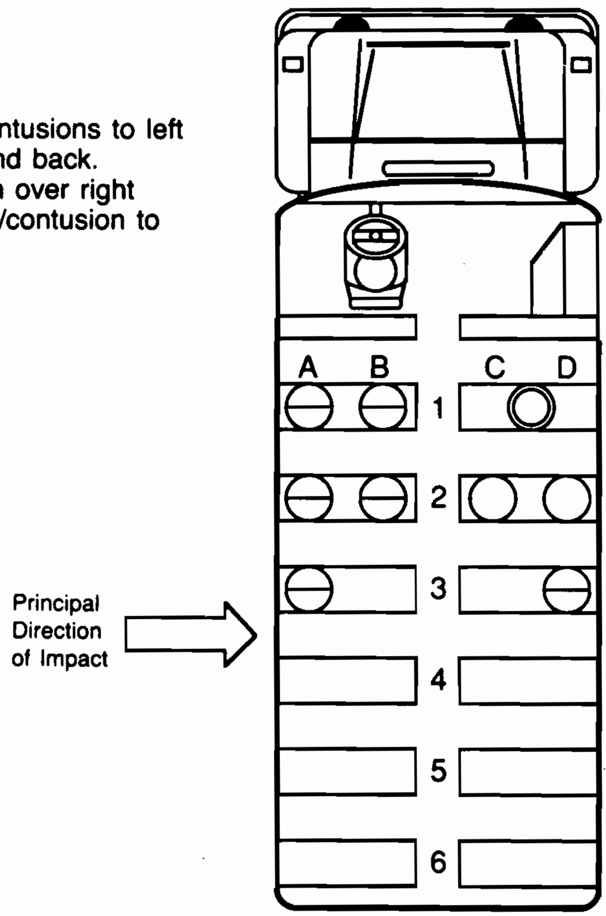
Special Notes on the Accident

It is unknown if the two schoolbus passengers seated in the second seat on the right were restrained at the time of the accident. When the Safety Board investigator examined the schoolbus, both lap belts at this seated position were buckled across the seat. All of the remaining lap belts which had been used were unbuckled and hanging loose. Independent witnesses are lacking to confirm restraint use/nonuse by these two passengers.

Newark, New Jersey
Case No. 33

Left Side of Bus

Driver
F-26, MAIS 2
Mild concussion, contusions to left forearm, right leg and back. Laceration/contusion over right eyebrow. Laceration/contusion to left temple.



Right Side of Bus

Row 1C-D
F-25, MAIS 1

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 (Male, Age 17)

MAIS-2 (Used for injured occupants only) Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Note:
It is uncertain whether the passengers in Row 2C and D were restrained. (In report text tables, however, these passengers are included among the restrained.)

The school bus shown is representational only.

Case No.: 34
ATL-85-H-SB13

Accident Location: Intersection of Metro Parkway and Colonial Boulevard in Fort Myers, Florida

Date and Time: May 8, 1985, 2:22 p.m.

Description of Schoolbus: 65-passenger poststandard bus: 1978 GMC chassis with 1979 Ward body

Type of Accident: Left side impact (direction of force at 5 o'clock), followed by rollover (90°)

Accident Severity: Moderate

Summary of Events: A schoolbus transporting 17 high school students home from school was in the middle of an intersection when a passenger car ran a red light and crashed head-on into the left side of the bus. Police estimated schoolbus preimpact speed at 30 mph; car preimpact speed at 50 mph. The car impacted the schoolbus about 7 feet ahead of the left rear wheel and then crushed rearward until the car was embedded against the wheel. The collision caused the schoolbus to rotate 90° counterclockwise, overturn onto its right side, and skid a short distance before coming to rest.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 17 passengers, aged 14 to 19, 1 was uninjured, and 16 sustained minor (AIS 1) injuries. The 48-year-old driver, restraint use unknown, received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Postcrash inspection revealed considerable damage to the exterior of the bus and no damage to the interior. The driver's windshield was broken out and shattered on the right side. Except for one panel, all passenger windows on the right side were either cracked, shattered or broken out; two windows on the left side were similarly damaged. Many windows on the right side had been broken when the students walked on them during evacuation. The frames of 7 of the 10 broken windows on the right side were deformed outward. Frames of the two broken windows on the left side were similarly deformed.

Damage from the car impact was evident on the left side of the bus. Paneling below the flooring on the left side was deformed inward for a distance that began about 7 feet ahead of the left rear well and ended 30 inches past the wheel. The left rear wheel was forced rearward and the leaf spring assembly for that wheel was broken away from its U-bolt axle securement. Damage sustained from the overturn was evident on the right side of the bus. The right side of the windshield frame was crushed inward and minor pavement scrape marks were evident along the right side.

Inspection of the bus interior revealed no damage but markings in the roof area indicated strikes by the passengers during the overturn. All the seats remained intact. Hair and blood stains were on the ceiling above the right passenger windows indicating that some passengers struck that area.

Fort Myers, Florida
Case No. 34

Evaluation of Bus Performance: Neither the overturn nor collision violated integrity of passenger compartment. All bus seats remained secured.

Injury Analysis

Passengers: Impact forces in this collision were dissipated underneath the passenger compartment when the car underrode the bus. Minor injuries (AIS 1), were the most severe injury sustained. Many students received multiple minor injuries from multiple contact sources: i.e., window frame, ceiling, other students, etc. One student sustained seven AIS 1 injuries, but the norm was two.

Except for the passenger seated in row 4B, all passengers seated on the left side of the bus were thrown from their seats and onto the right ceiling and/or onto seats and passengers on the right side. They sustained a variety of minor injuries such as abrasions, lacerations and contusions. Muscle sprains also were common. Students on the right side of the bus received minor injuries from contact with sidewalls and other students landing on them. Five students had been asleep and/or lying down, stretched across the seat at the moment of initial impact. These students sustained only minor injuries. The one uninjured student, in row 10E, had a student from across the aisle land on him, but he was not hurt by the impact.

Lap belt use might possibly have reduced the number of AIS 1 injuries sustained by individual passengers, i.e., a student might sustain two AIS 1 injuries rather than three, by eliminating the minor injuries caused by contact with the bus ceiling. It would not, however, guarantee that more students would be uninjured. There were at least three injury-causing events in this accident: the side impact, 90° counterclockwise rotation, and the overturn.

Schoolbus Driver: Restraint use unknown. The driver states she was wearing her lap belt at the time of the accident and that the buckle opened during the overturn and she was thrown from her seat into the stairwell. Driver sustained minor (AIS 1) injuries: muscle strain to forearm and upper arm; contusions to right elbow and right buttock; muscle strain to right thigh and leg.

Outcome for Occupants of Other Vehicle

Vehicle Description: 1981 Oldsmobile Delta '88, 2-door sedan.

Damage to Vehicle: Full front crushed in; vehicle totalled.

Occupant Restraint Use and Injury: Available restraint not used. Driver sustained minor (AIS 1) injuries; treated and released by hospital. No further information available.

Fort Myers, Florida
Case No. 34

Special Notes on the Accident

Some bottom seat cushions became dislodged.

The lap belt that failed at the schoolbus driver's seat was as "Beam 300" manufactured by Beam Industries, Inc., Oklahoma City, Oklahoma. The restraint system consisted of a static-type lap belt anchored to the floor at each side of the driver's seat, with a latch-type release buckle and a sliding latchplate.

Due to the schoolbus driver's report of a restraint system failure, involving a complete separation of the buckle/latchplate connection, the Safety Board initiated an analysis of the failed components. The complete restraint system was removed from the schoolbus driver's position and shipped to the Safety Board's laboratory in Washington, D.C., where it was examined and tested by a Safety Board metallurgist. The following is a synopsis of the metallurgist's factual report.

Components Examined: Latchplate, buckle, and belting from the driver's lap belt.

Details of the Examination: Information submitted with the belt indicated that the fastened latchplate could be released from the buckle when the underside of the buckle was impacted. Testing in the laboratory verified this separation mode. It was also discovered that the latchplate could be manually pulled from the buckle by pulling sharply on the belting.

When inserted into the buckle, the latchplate is normally held in place by two latch ears. These latch ears are slightly rounded. The latch ears and the release plate spring-loaded in relation to the release plate hinge pin. However, when first received, information in the release plate created binding between the release plate and the body of the buckle. Because of this binding, the spring force was insufficient to return the release plate to the closed position. The plate was bent toward the hinge pin along its entire width. Midway between the hinge pin ends, the release plate was deformed inward approximately 0.07 inch.

In the laboratory, the binding between the release plate and the buckle body was relieved by deforming the plate away from the hinge pin at the midpoint. This action allowed the spring to work upon the plate and quickly snap the plate to the closed position when released. Further testing of the fastened and closed latch assembly showed that the latch plate could still be easily released from the buckle when the underside of the buckle was impacted or when the belting was sharply pulled.

Examination of the areas of contact between the latch plate and the latch ears revealed some areas of minor wear but no significant areas of damage.

Fort Myers, Florida
Case No. 34

Left Side of Bus

Driver
F-48, MAIS 1

Row 1A
F-19, MAIS 1

Row 2A
F-17, MAIS 1

Row 3A
F-18, MAIS 1

Row 4A
F-14, MAIS 1

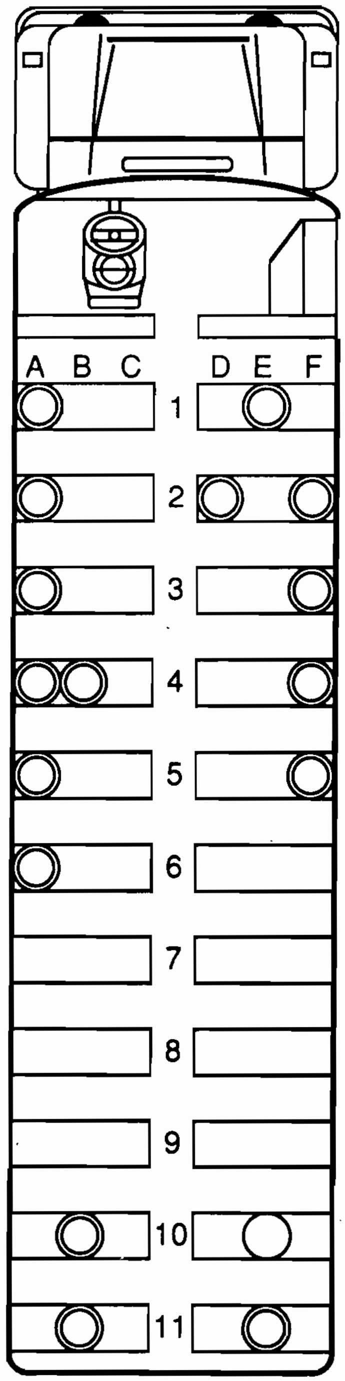
Row 4B
F-15, MAIS 1

Row 5A
F-15, MAIS 1

Row 6A
F-16, MAIS 1

Row 10B
M-16, MAIS 1

Row 11B
M-15, MAIS 1



Right Side of Bus

Row 1E
M-18, MAIS 1

Row 2D
F-16, MAIS 1

Row 2F
F-17, MAIS 1

Row 3F
F-16, MAIS 1

Row 4F
F-15, MAIS 1

Row 5F
F-15, MAIS 1

Row 11E
M-16, MAIS 1

LEGEND

Uninjured
Unknown if Injured
Injured
Lap Belt Used
Fatally Injured

Example: M-17 — Male, Age 17
MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Note:
The driver's restraint system failed during the accident by coming unlatched.

The school bus shown is representational only.

Case No.: 35
DEN-85-H-SB08

Accident Location: County Road 213, outside Durango, Colorado

Date and Time: December 11, 1984, 7:30 a.m.

Description of Schoolbus: 65-passenger poststandard bus:
1979 International Harvester chassis with 1979 Thomas Built body

Type of Accident: Right sideswipe followed by rollover (90°)

Accident Severity: Moderate

Summary of Events: A schoolbus transporting 15 students to school was travelling at a driver-estimated speed of 30 mph on a wet, slushy, asphalt, 2-lane highway. The driver lost control, and the bus skidded off the right side of the road, and sideswiped an outcropped large boulder with its top right side. The bus then went to the left, crossed the road, and travelled a short distance along the shoulder before sliding down a 40-foot river embankment into the river. The bus rolled over onto its left side and came to rest on the rocky riverbed in about 2 feet of water.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 15 passengers, aged 5 to 17, 1 was uninjured, 10 sustained minor (AIS 1) injuries, 3 sustained moderate (AIS 2) injuries, and 1 sustained serious (AIS 3) injuries. The 31-year-old restrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Sideswipe damage to roof above windows. Moderate damage to left side. (Note: roof and ceiling damage above window No. 7 on right side could have been sustained during recovery operations.) Maintenance access panel separation above right side windows.

Evaluation of Bus Performance: No seams separated; bus conformed to FMVSS 221 and 222.

Injury Analysis

Passengers: Schoolbus passengers were subjected to at least two impacts (collision with the boulder and impact with the ground when bus turned over), with each of the impacts probably contributing to occupant injury.

Fourteen of the 15 students sustained injury; the most serious injury was the multiple fracture of the leg of the passenger seated precrash in right side of row 10. It is possible that tire chains, stored unsecured beneath the extreme right rear seat (row 11), contributed to this passenger's serious (AIS 3) injury by creating unusual loading on his leg's bone structure during the rollover and subsequent ground impact. These tire chains would have been displaced forward by the nature of the boulder impact and might have pinned the passenger's leg under the framework of the right side row 9 bench, before the bus overturn. Another possibility is that the passenger slid forward at the time of the boulder impact so his leg was under the row 9 seat during the overturn. This action also would have created an unusual loading of his bone structure.

The three students sustained moderate (AIS 2) injuries: a concussion sustained by the row 9 right side passenger, a compression fracture of the T11 vertebra sustained at row 11 left side, and a fractured left clavicle sustained at the row 2 right side position, probably all occurred during the ground impact which followed the rollover. It must be remembered, however, that none of the bus passengers probably were seated properly when the rollover occurred. Several different forces had already acted upon their bodies: the boulder impact, the side swerve both before and after the boulder strike, and the descent down to riverbed. These forces in combination had most likely displaced many of the passengers from their seats.

The AIS 1 injuries sustained by 10 passengers, seated throughout the bus, consisted of bruises, abrasions, and lacerations from contact with seatbacks, sidewalls, and windows. Window glass, loose objects within the bus, and contact with a rock in the riverbed also caused student injuries.

The most seriously injured student (AIS 3), probably would not have fractured three bones in his right leg had he been wearing a lap belt. Lap belt use would have prevented him from sliding off the seat and ending up under the seat in front of him. Lap belt use would not have reduced the number of minor injuries.

Schoolbus Driver Injuries: Available lap belt used. Driver received minor injuries (AIS 1): three fractured ribs, and contusions of the left elbow, knee, ankle, and right ankle from contact with the control console on the left side.

Special Notes on the Accident

Loose tire chains were stored under right rear seats. Some seat backs were torn before the accident and the padding was missing. Loose chains and missing padding have injury potential.

Durango, Colorado
Case No. 35

Left Side of Bus

Driver
F-31, MAIS 1

Row 1B
F-5, MAIS 1

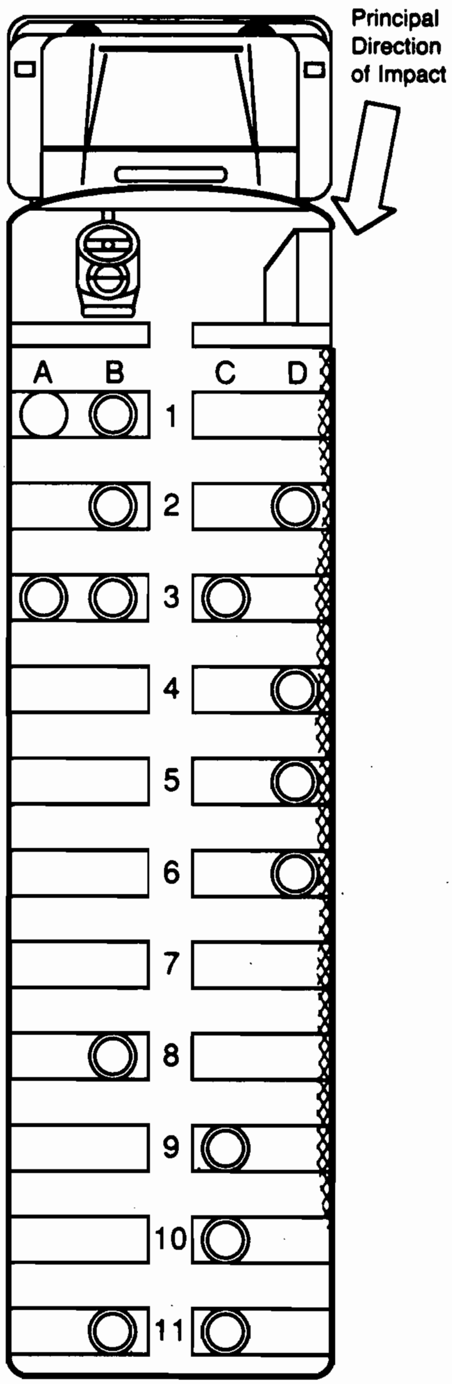
Row 2B
M-8, MAIS 1

Row 3A
M-13, MAIS 1

Row 3B
M-11, MAIS 1

Row 8B
F-7, MAIS 1

Row 11B
M-17, MAIS 2
Compression fracture of the thoracic spine, laceration left check, contusion left forearm, abrasion right knee; injuries sustained from seatback and left sidewall and windows.



Right Side of Bus

Row 2D
M-8, MAIS 2
Fractured right clavicle.

Row 3C
M-7, MAIS 1

Row 4D
M-9, MAIS 1

Row 5D
F-5, MAIS 1

Row 6D
F-17, MAIS 1

Row 9C
M-10, MAIS 2
Concussion caused by seatback.

Row 10C
M-13, MAIS 3
Fractured right femur, fractured right fibula and tibia.

Row 11C
M-14, MAIS 1

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 — Male, Age 17; MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

Case No.: 36
CHI-86-H-SB02

Accident Location: State Route 350, outside Wilmington, Ohio

Date and Time: October 28, 1985, 8:40 a.m.

Description of Schoolbus: 30-passenger poststandard bus: 1980 Ford chassis with Wayne body

Type of Accident: Front angle collision followed by rollover (270°)

Accident Severity: Moderate

Summary of Events: A schoolbus, equipped with restraints for all occupants, was transporting 16 developmentally disabled passengers on a rural 2-lane highway when its right tires left the road. The right tires tracked off the roadway for approximately 90 feet before regaining the asphalt pavement. From the point of highway reentry, the schoolbus yawed counterclockwise as it crossed both lanes and left the roadway. The bus then struck a dirt embankment with its right front, overturned 270° (a three-quarter revolution), and came to rest on its left side. Total travel distance from the initial start of the overturn to the point of final rest was approximately 25 feet. Total counterclockwise rotation, from the initial loss of directional control, was approximately 100°. (Embankment impact was probably less than 20 miles per hour.)

Of the total bus occupants, five were restrained by lap belts, two were restrained within a single loop restraint (aftermarket addition to schoolbus; not considered a safety belt), and two were secured in their wheelchairs at designated positions within the specially equipped bus. The driver and remaining seven passengers were unrestrained although lap belts were available at their seating position.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 16 passengers, aged 5 to 79, 5 were uninjured, 10 sustained minor (AIS 1) injuries, and 1 sustained serious (AIS 3) injuries. The 58-year-old unrestrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The schoolbus body received damage to the right front, left front, and top due to the embankment impact and rollover. No interior damage was noted.

However, several seat cushion bottoms became dislodged at some point within the collision dynamics. The investigator did not attribute any passenger injury to loose cushions.

Evaluation of Bus Performance: The schoolbus performed well in this moderate speed impact and 360° rollover. All significant damage was confined to the bus body exterior. There were no noted failures of the body panel joints.

Wilmington, Ohio
Case No. 36

Injury Analysis

Passengers: All but one of the injured passengers sustained minor injuries only. The minor (AIS 1) injuries sustained by passengers in this accident consisted of contusions, abrasions, minor lacerations, and strains. These minor injuries were sustained by both belted and unbelted passengers alike. The one passenger's serious (AIS 3) injury was a compression of the lower thoracic spine, most likely received at some point during the multiple rollover dynamics and ground impacts. The passenger who sustained this serious injury was unrestrained although a lap belt was available at his seating position, row 1, left side seat.

Had a lap belt been used by the passenger who sustained the serious injury, it is very likely the compressive fracture of the thoractic vertebrae would have been prevented. Lap belt use by the remaining bus passengers probably would not have resulted in any reduction of injury severity.

Schoolbus Driver: Lap belt available but not used. Minor (AIS 1) injuries: minor contusions and superficial abrasions.

Wilmington, Ohio
Case No. 36

Left Side of Bus

Driver
M-58, MAIS 1

Row 2
F-6, MAIS 1

Row 4A
F-54, MAIS 1

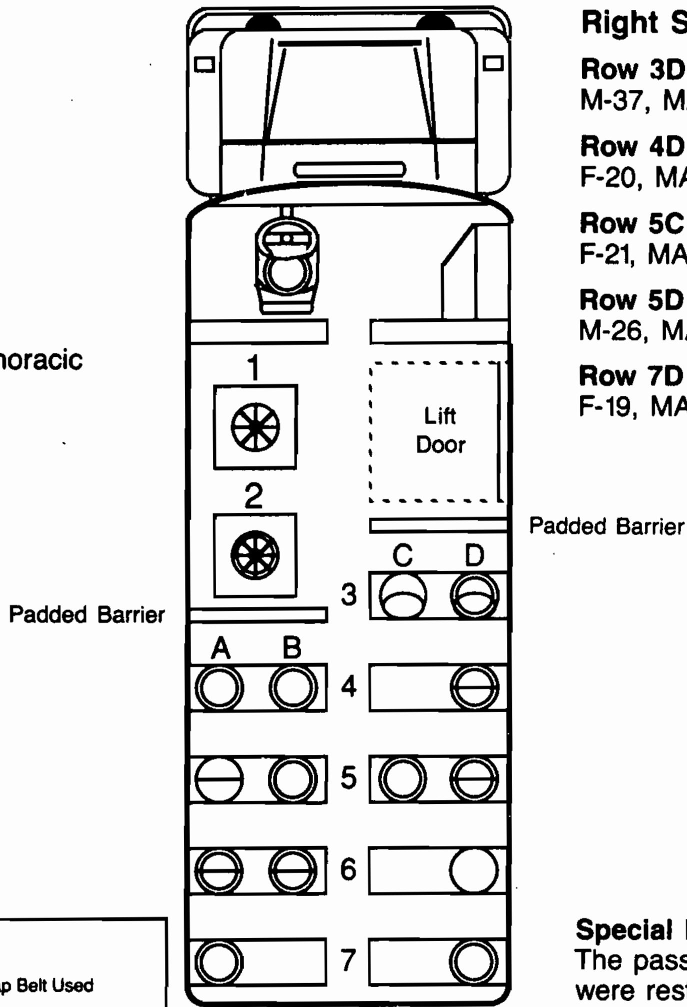
Row 4B
F-25, MAIS 3
Compressive fractures of thoracic spine.

Row 5B
M-20, MAIS 1

Row 6A
M-26, MAIS 1

Row 6B
M-79, MAIS 1

Row 7A
M-28, MAIS 1



Right Side of Bus

Row 3D
M-37, MAIS 1

Row 4D
F-20, MAIS 1

Row 5C
F-21, MAIS 1

Row 5D
M-26, MAIS 1

Row 7D
F-19, MAIS 1

LEGEND

Uninjured
Injured
Fatally Injured
Unknown if Injured
Lap Belt Used
Wheel Chair
Loop Belt Used

Example: M-17 (Male, Age 17) MAIS-2 (Used for injured occupants only) Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

Special Notes:
The passengers in Row 3C and D were restrained together in a single loop belt. The belt was bolted to each end of the seat. This is not a safety belt.

Every occupant of the bus had some form of restraint available at their seating position.

The school bus shown is representational only.

<u>Case No.: 37</u>
FTW-85-H-SB33

Accident Location: Georgetown, Texas

Date and Time: April 16, 1985, 9:31 p.m.

Description of Schoolbus: 48-passenger poststandard bus:
1983 Chevrolet chassis with a Carpenter body

Type of Accident: Multiple collision with rollover (90°)

Accident Severity: Moderate

Summary of Events: A schoolbus was transporting members of a high school basketball team home from an evening athletic event when an oncoming car crossed the center line and struck the left front of the schoolbus. A portion of the car travelled underneath the left side of schoolbus, causing the bus to turn over onto its right side. The schoolbus then slid on its right side across the center line, rotated 180° counterclockwise over a distance of 288 feet, before being struck in the rear at the right roofline/sidewall by another car coming from the opposite direction. The bus came to final rest at the location of the second impact.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 14 passengers (12 members of team, the scorekeeper and her child), aged 9 to 18, 5 were uninjured, 7 sustained minor (AIS 1) injuries, and 1 sustained serious (AIS 3) injuries. One student had to be coded AIS 7, injured, unknown severity, due to lack of sufficient medical information. The 23-year-old unrestrained driver was uninjured.

(See the schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The schoolbus was subjected to a 90° rollover and two vehicle impacts (a frontal and rear-end collision). The first impact damaged the left front bumper, fender, tire rim and the rollover damaged the left side lower sheet metal. Right side of bus (paint removed) and ground-off rivets and two windows were broken. A-pillar was bent rearward, overlapping bus doors. The second impact damaged the right rear and deformed the right side of the roof 28 inches. The right rear window was broken and the emergency door was separated from the bus body. Left rear axle was displaced rearward.

Evaluation of Bus Performance: The bus performed well, with the exception of the seat cushion attachments. (Nine cushions were loose.) The fasteners apparently were not secured properly. Seat frame supports maintained integrity. Fuel tank remained intact.

Injury Analysis

<u>Passengers:</u> Only one passenger sustained more than a minor injury. This student, seated before the crash in the right rear of the bus, probably sustained his serious (AIS 3) injury, a contused kidney, during the second collision when a car struck the rear of the bus as it slid on its right side. He would have been in the direct impact zone and the force of this collision deformed the right rear of the bus at this student's seating position. His injury could have resulted from penetration or contact with seat back in front of him or rear wall, or a combination of these events.

Georgetown, Texas
Case No. 37

Lap belt use probably would not have reduced the severity of the serious (AIS 3) injury sustained by the person seated precrash in the last seat on the right. He still would have been in the area of the second impact as the crash forces came through the back of the bus and the sheet metal deformed and intruded at this position. Lap belt use also would not reduce the number of minor injuries (bruises, abrasions, and contusions) sustained in the accident.

Schoolbus Driver: Lap belt available but not used.
Description of Injuries--Driver was reported to be uninjured.

Outcome for Occupants of Other Vehicle

Vehicle No. 1 Description: 1980 Honda Accord 4 door sedan

Damage to Vehicle: Total destruction of front and side.

Occupant Restraint Use and Injury: Driver unrestrained. Injuries described as "serious." No further information available.

Vehicle No. 2 Description: 1983 Chevrolet Caprice Classis 4 door

Damage to Vehicle: No information or photographs available about damage. Car had to be towed away.

Occupant Restraint Use and Injury: Driver and passenger unrestrained. Injuries described as "serious."

Special Notes on the Accident

The Safety Board investigator found nine seat cushions disconnected from their mountings. The single rear mounting fastener on each of these seat cushions was bent and turned to the open position. An examination of the remaining secured seat cushions revealed that the nut and bolt attaching the fastener to the cushion bottom were loose. The fastener could be easily turned releasing the cushion from its secured position. No injuries could be attributed to loose seat cushions in this accident, but they do have injury potential. Loose cushions could become flying missiles during a crash, more likely in rollovers of more than 90°, and occupants also could be hurt by contact with the exposed metal seat frame.

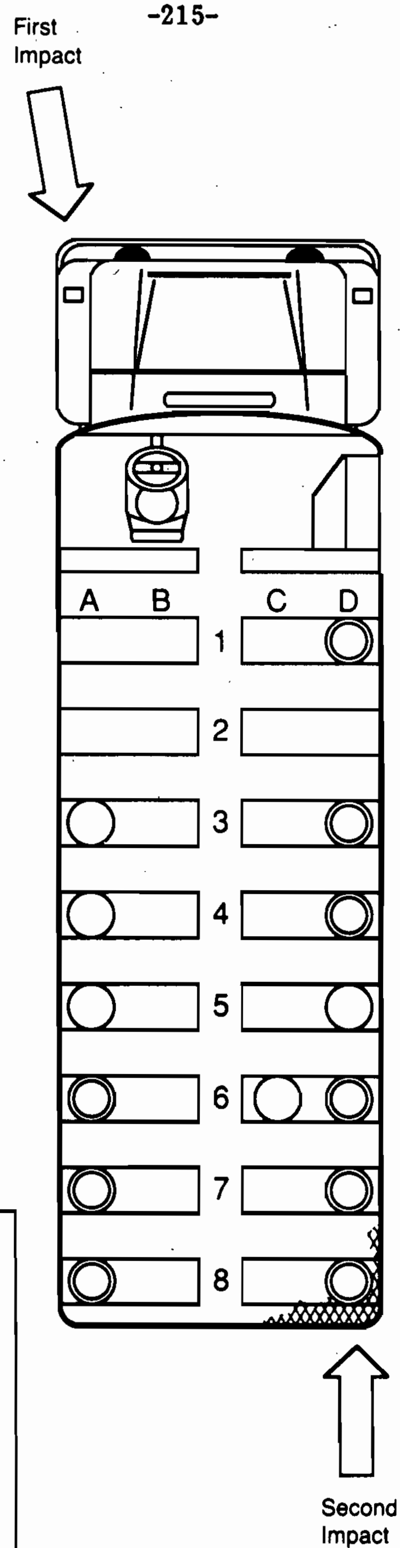
Georgetown, Texas
Case No. 37

Left Side of Bus

Row 6A
M-17, MAIS 7
(Injury of unknown severity).

Row 7A
M-16, MAIS 1

Row 8A
M-15, MAIS 1



Right Side of Bus

Row 1D
F-46, MAIS 1

Row 3D
M-9, MAIS 1

Row 4D
M-18, MAIS 1

Row 6D
M-17, MAIS 1

Row 7D
M-16, MAIS 1

Row 8D
M-18, MAIS 3
Probable contused kidney with hematuria, contact point unknown but occurred during second collision. MAIS 1 laceration and contusion of left elbow and lacerations due to glass.

LEGEND

Uninjured
Unknown if Injured
Injured
Lap Belt Used
Fatally Injured

Example: M-17 (Male, Age 17) MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor
2 - Moderate
3 - Serious
4 - Severe
5 - Critical
6 - Maximum injury
7 - Injured, unknown severity
9 - Unknown if injured

* American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

<u>Case No.: 38</u>
MKC-85-H-SB01

Accident Location: County Road 27, outside Cherokee, Iowa

Date and Time: November 10, 1984, 7:50 a.m.

Description of Schoolbus: 53-passenger poststandard schoolbus: 1984 GMC chassis with 1984 Ward body

Type of Accident: Head-on collision with rollover (450°)

Accident Severity: Moderate to severe. (Collision was moderate but vehicle dynamics following crash resulted in severe forces acting on occupants.)

Summary of Events: A schoolbus, transporting 13 members of high school athletic team to a practice game at a distant school, was travelling on a rural 2-lane highway. One team coach drove the bus and a second coach was a passenger. As the schoolbus crossed an intersection, a car drove into its path. The bus collided front first into the right side of the car, and following the impact, both vehicles travelled in the same direction approximately 25 to 30° from the original travel direction of the schoolbus. The schoolbus rotated approximately 135° clockwise and underwent a 450° rollover at the same time as it continued to travel well over 100 feet from the initial contact area. The schoolbus came coming to rest on its left side. In all, the bus rolled over 1 1/4 times.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 14 passengers, aged 14 to 27, 2 were uninjured, 8 sustained minor (AIS 1) injuries, 2 sustained moderate (AIS 2) injuries, and 2 sustained serious (AIS 3) injuries. The 38-year-old restrained driver received minor (AIS 1) injuries.

(See the schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The schoolbus sustained substantial front structural damage from the initial impact into the side of the passenger car. As it then continued from the initial impact, it received additional substantial damage to the upper left side, that area deformed inward several inches due to ground contact. Only moderate damage was induced along the right side of the bus from the rollover. The interior retained its structural integrity with the single exception of the upper left side wall. All seats remained secured at their original position. The window framework along both the right and left side was deformed outward at several locations, most likely due to occupant contact.

Evaluation of Bus Performance: Schoolbus body performed very well in this 450° rollover accident. Bus body failure did not contribute to occupant injuries.

Injury Analysis

<u>Passengers:</u> All but one of the moderate (AIS 2) and serious (AIS 3) injuries were sustained by passengers seated precrash in the right side center area of the bus. The remaining serious (AIS 3) injuries occurred toward the left rear where the occupant was seated precrash on the inboard or aisle side of the bench seat. This accident involved a head-on collision, a 135° clockwise rotation, and a 450° rollover (a complete revolution followed by a roll onto the left side for the second time). It is highly improbable that many bus passengers were able to retain their precrash seating positions

throughout the initial impact and rotational dynamics, up to the time where the bus rollover began. However, it is most likely that the moderate and serious injuries, all head injuries, occurred at the beginning of the rollover as the left side of the bus struck the ground with a force great enough to deform substantially the upper left side structure.

Given the tremendous variation in force directions which acted upon occupants of this bus, along with the fact that an occupant seated at any position upon the approximately 36-inch wide bus bench set is well within reach of a rigid side walls, it is highly improbable that the use of lap belts in this accident would have reduced nor prevented the type of injuries sustained. Discounting the possibility of injuries induced by the lap belt itself, none of the passengers would have been prevented from having violent head contacts with the bus interior side walls nor from contacts with other occupants. It is possible that the use of lap belts could have increased the number and severity of head injuries in this rollover accident due to the upper torso and head acceleration resulting from the lower body restraint.

Schoolbus Driver: Available lap belt used. Minor (AIS 1) injury: the only injury reported by the driver was a minor contusion to his left knee (probably occurred at initial impact). During rollover, driver may have braced himself by holding onto steering wheel.

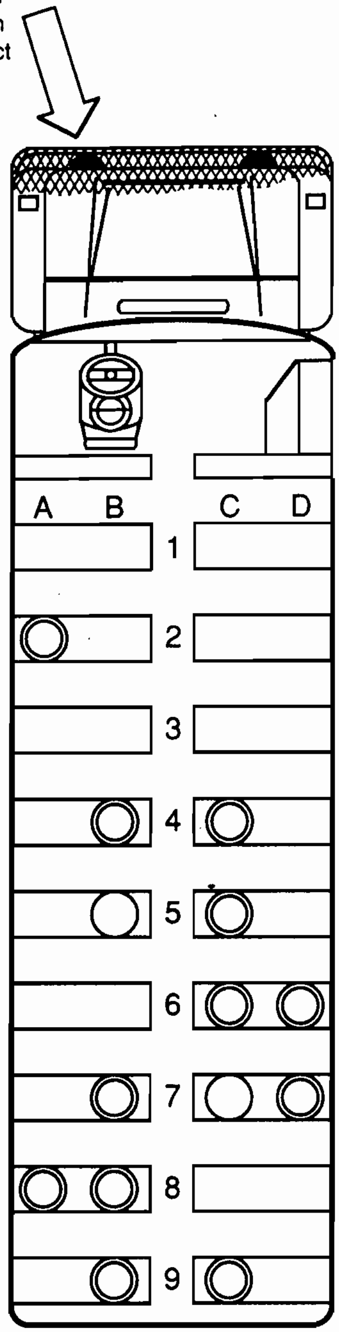
Outcome for Occupants of Other Vehicle

Vehicle Description: 1984 Ford Escort Stationwagon.

Damage to Vehicle: Destroyed. Entire passenger compartment was violated by penetration of the schoolbus into the small car's right side.

Occupant Restraint Use and Injury: All four occupants were unrestrained. Three were fatally injured and one sustained critical injuries. Police reported that three of the Ford occupants were ejected from the vehicle.

Cherokee, Iowa
Case No. 38



Left Side of Bus

Driver
M-38, MAIS 1

Row 2A
M-27, MAIS 1

Row 4B
F-14, MAIS 1

Row 7B
F-18, MAIS 3
Cerebral contusion from contact with interior sidewall during rollover, laceration of gums and facial abrasions.

Row 8A
F-17, MAIS 1

Row 8B
F-16, MAIS 1

Row 9B
F-17, MAIS 1

Right Side of Bus

Row 4C
F-15, MAIS 3
Cerebral contusion, contusion to right periorbital area with transient diplopia, abrasion to back.

Row 5C
F-16, MAIS 2
Cerebral concussion and cervical strain.

Row 6C
F-14, MAIS 1

Row 6D
F-14, MAIS 2
Mild concussion.

Row 7D
F-16, MAIS 1

Row 9C
F-17, MAIS 1

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 (Male, Age 17) MAIS-2 (Used for injured occupants only) Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

Case No.: 39
MKC-85-H-SB19

Accident Location: Intersection of State Route 65 and Aitkin County Road No. 26, outside McGrath, Minnesota

Date and Time: April 22, 1985, 7:10 a.m.

Description of Schoolbus: 53-passenger poststandard bus:
1984 International chassis with 1984 Carpenter body

Type of Accident: Side impact (principal direction of impact at 3 o'clock), followed by rollover (90°)

Accident Severity: Severe; 38.5 lateral Delta V for schoolbus.

Summary of Events: A schoolbus transporting seven students to school stopped at a stop sign at an intersection, then pulled onto a State highway directly into the path of an oncoming tractor-trailer. The schoolbus was struck in the right side, just to the rear of the approximate longitudinal center of mass. This contact resulted in a clockwise rotation of the bus as it rode up over the front structure of the truck tractor. The bus probably was carried for several feet before it continued rotating off the front of the truck tractor, eventually overturning onto its left side in the road side ditch. Total longitudinal rotation of the bus, from point of impact to final rest, was approximately 95°.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 7 passengers, aged 8 to 17, 3 sustained minor (AIS 1) injuries, 2 sustained moderate (AIS 2) injuries, 1 sustained serious (AIS 3) injuries, and 1 sustained severe (AIS 4) injuries which proved fatal. The 34-year-old restrained driver was uninjured.

(See the schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Primary damage was to the right side starting at front passenger to the right rear wheel, an area of 160 inches. The impact of the truck deformed the right side of the bus body inward 22 inches at its maximum point and caused the left side to bow out 18 inches. The floor was deformed which in turn deformed the seat frames. Consequently, 15 of the 18 passenger seat bottom retainer clips were torn loose and 5 of the 15 loose seat bottoms broke free from the frames and were thrown around the bus.

The ceiling was slightly rippled from induced pressure from the impact. The windshield remained intact, but all but one window on each side was broken. The gasoline tank was penetrated by members of its frame, which twisted due to the force of impact.

Evaluation of Bus Performance: Body panel of the passenger compartment did not separate despite violence of crash, preventing possible ejection of occupants. Passenger seats remained fastened to the floor.

Injury Analysis

Passengers: The fatally injured passenger, seated in the right rear of the bus in row 9, died from multiple trauma. She sustained a closed head wound, abdominal trauma, fractured pelvis, and was unconscious for more than an hour. Contact with the window frame was the probable source of her head injury; she had been seated near the aisle and probably was flung toward the window at impact and during rotation. The probable source of her fractures could not be determined.

One passenger seated in row 5 on the right side, sustained serious (AIS 3) lacerations to his hand from contact with the collapsed sidewall and window glass; he was seated in the impact zone of the initial collision.

Two passengers received moderate (AIS 2) injuries. One was seated by the left window in row 2 and sustained a concussion from contact with window frame. The other was in row 1, on right, and fractured her left clavicle from contact with side wall. Minor injuries (AIS 1) sustained by three passengers mainly were lacerations from broken window glass.

The Safety Board cannot determine the effect of lap belt use for the fatally injured passenger. Lap belt use might have prevented some injuries but the passenger still would have been injured. The fatally injured passenger was seated in the rear of the bus on the right. An occupant seated at this position would accelerate toward the right interior sidewall due to the severe impact forces and rotation. Her reaction to the impact would have been intensified at her position due to the clockwise rotation (i.e., she was at the end of a "crack the whip" effect). If lap belted, her head still could have made violent contact with the interior side wall, possibly still resulting in death.

It's less probable that lap belt use would have eliminated the moderate (AIS 2) or serious (AIS 3) injuries. Lap belt use cannot prevent severe lacerations or other injuries to upper limbs if a student is seated near an area of penetration; the upper torso is free to move in response to crash forces even if the pelvis is secured by belt. Students still could receive concussions (AIS 2) or fractures when lap belted as the bus rolled over, rotated, or at initial impact by striking side walls and seat backs in front of them. Lap belt use would not have benefited the three students who received minor injuries. Restraint use cannot protect against injury from flying glass.

Schoolbus Driver: Available lap belt used; driver was uninjured.

Outcome for Occupants of Other Vehicle

Vehicle Description: 1972 International Tractor with semi-trailer.

Damage to Vehicle: Full front of tractor was crushed in.

Occupant Restraint Use and Injury: Driver was unrestrained. He received moderate (AIS 2) injuries: multiple facial lacerations.

McGrath, Minnesota
Case No. 39

Special Notes on the Accident

This was a very violent collision for the schoolbus due to difference in vehicle mass between the schoolbus and the semi-truck (1:4.3). The truck was slowed only slightly by the impact.

Bottom seat cushions in the schoolbus came loose and the bus gas tank was punctured. See vehicle damage description.

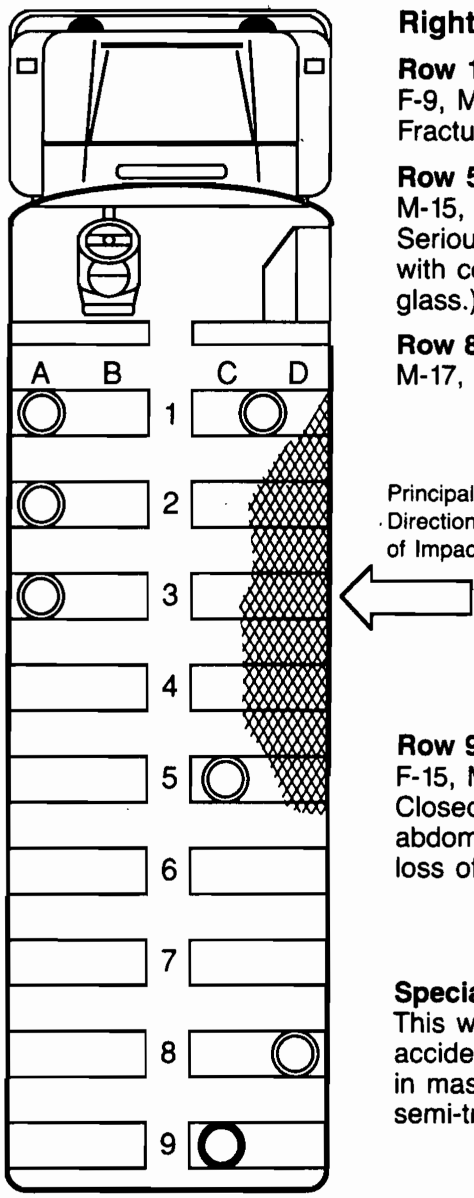
McGrath, Minnesota
Case No. 39

Left Side of Bus

Row 1A
F-8, MAIS 1

Row 2A
M-9, MAIS 2
Concussion

Row 3A
M-9, MAIS 1



Right Side of Bus

Row 1C-D
F-9, MAIS 2
Fractured left clavicle.

Row 5C
M-15, MAIS 3
Serious laceration to hand. (Contact with collapsed sidewall and window glass.)

Row 8D
M-17, MAIS 1

Row 9C
F-15, MAIS 5 (Fatal)
Closed head injury. Acute abdominal trauma. Fractured pelvis, loss of consciousness.

Special Note:
This was an extremely violent accident because of the difference in mass between the bus and the semi-truck (1:4.3).

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

Example: M-17 — Male, Age 17; MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

Case No.: 40
ATL-86-H-SB03

Accident Location: U.S. Highway 84, outside Brunswick, Georgia

Date and Time: January 14, 1986, 7:33 a.m.

Description of Schoolbus: 66-passenger poststandard bus:
1984 Ford chassis with 1984 Blue Bird body

Type of Accident: Rear-end collision followed by rollover to left (100°), then end-over-end rotation, then rollover to right (90°)

Accident Severity: Severe

Summary of Events: A schoolbus transporting 10 students to school was stopped in the right lane of a level, 2-lane asphalt highway to pick up a student. The schoolbus had its flashers and stop arm activated when it was struck in the rear by a tractor semi-trailer travelling at a driver-estimated speed of 50 to 55 mph. The truck crushed into the back of the schoolbus, pushed the bus forward for about 100 feet, and then disengaged. The schoolbus continued off the road onto a sloping shoulder and down into a drainage ditch, which paralleled the road 41 inches below the road surface. As the bus travelled into the ditch, it first rolled (about 100°) onto its left side and then pitched forward, embedding the left roof corner into the ground. The embedded roof corner acted as a pivot, lifting the rear-end forcefully skyward, and the bus flipped over, end-over-end in a 180° arc. The bus then landed on its right side at the bottom of the ditch and came to rest.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 10 passengers, aged 12 to 18, 6 sustained minor (AIS 1) injuries, 1 sustained moderate (AIS 2) injuries, and 3 sustained serious (AIS 3) injuries. The 33-year-old unrestrained driver received moderate (AIS 2) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The schoolbus received severe crush damage at the front roofline, left side roofline and window frames that extended rearward from the front corner to the fifth passenger window, the right passenger door and the entire rear end. Almost all of the outer shell of the passenger compartment revealed either direct crush or induced damage. The windshield and all rear glass panels as well as five windows along the left side and three windows along the right side were broken out.

The most severe damage was noted at the rear end of the schoolbus. The front of the truck crushed forward into the rear of the passenger compartment for a distance of approximately 85 inches. The truck's wedging type entry into the bus caused the passenger compartment to separate at its chassis frame securement from the rear end forward to a location just below the driver's position. The rear flooring below the last four passenger sets was rumpled forward and deformed upward and the rear roofline was forced down in close proximity to the top of the seatbacks. The last four left rear passenger seats and the last three right rear passenger seats were accordioned forward and the seat cushions were in contact with the next seats ahead.

Brunswick, Georgia
Case No. 40

Evaluation of Bus Performance: Considering the severe impact forces and subsequent dynamics, the integrity of the schoolbus passenger compartment and its components were maintained admirally. Except at direct crush areas, the body joints and the glass panels remained intact. The rear flooring was rumpled forward but it did not splinter. All of the seat anchorages remained secured to the floor and the seat backs and cushions did not deform.

Injury Analysis

Passengers: All passengers were injured in this accident; four received more than minor injuries.

Nine of the 10 passengers were ambulatory following the crash; the remaining passenger was unconscious for over 24 hours. All were examined at a local hospital shortly after the accident and hospital records for the passengers revealed that as a group they received a total of 41 injuries: 31 AIS 1 injuries; 7 AIS 2 injuries; and 3 AIS 3 injuries. An analysis of injury by affected body region found 9 of the 10 moderate to serious (AIS 2 and -3) injuries were to the upper body (between head and shoulders); an injury to the abdomen was the sole exception. Twenty-three of the 31 minor (AIS 1) injuries were to the upper body; 8 were to the lower body.

Passengers were seated in three general areas of the bus. Three were seated at the right front, two were seated on opposite sides of the aisle near the center, and five were seated on the three rearmost seat rows. Three of the five rear passengers were seated on the left side of the aisle and two were on the right side. When the truck impacted the rear compartment, it crushed the area where the five rear passengers were seated; the crush was more severe on the left than the right. Thirty of the total of 41 injuries occurred to passengers in the rear area crushed by the initial impact. The three passengers seated at the left rear received AIS 1 to -3 injuries; one of the right rear passengers received AIS 1 to 2 injuries while the other one at that location received a single AIS 1 injury. The remaining five passengers seated forward from the rear received only AIS 1 injuries.

All of the AIS 2 and 3 injuries were attributed to the rear end impact forces and the subsequent compartment crushing in that area. Except for flying glass lacerations, all passengers who received only AIS 1 injuries were hurt when they were thrown from their seats during impact or rollover forces, and contacted interior components such as the roof, seats, and side walls.

Lap belt use would not have decreased the number of moderate to serious injuries sustained in this crash. Indeed, lap belt use might have increased the number of serious injuries. The four unrestrained passengers who sustained AIS 2 and -3 injuries in this crash were originally seated in the rear-most severely crushed area of the passenger compartment. The severity of their existing injuries was due to crush; collapsing roof, crushed-in window frames and flying glass. The rear roof was forced down in close proximity to these seatbacks. More serious injuries could have resulted had these passengers been lap belted and held in place as the roof crushed down.

Lap belt use would have eliminated the specific minor (AIS 1) injuries sustained by passengers when they were thrown out of their seats, but lap-belted passengers still could sustain minor injuries during impact, rotation, and rollover.

Brunswick, Georgia
Case No. 40

Schoolbus Driver: The schoolbus driver stated that he was lap belted when the truck struck the rear of his stopped bus, but he released the lap belt buckle immediately after the initial impact so that he would be free to aid the passengers when the bus stopped. He stated he was then thrown about during the subsequent crash events. The Safety Board finds this sequence of events improbable at best. The time available between the initial impact and first rollover probably was too short to allow such action by the driver.

The driver's seat was equipped with a floor-anchored lap belt. Both belts were equipped with webbing storage retractors. The end of the left belt was equipped with a clasp-type locking buckle by which the length of the left belt could be adjusted; the right belt was equipped with a metal latchplate. Postcrash inspection of the lap belt system revealed that the left belt was adjusted to its full length at the buckle. The retractors on both belts showed no sign of lockup when they were rotated quickly by extending the belt or when outside force was applied to the retractor housing.

The Safety Board investigator suspects the driver was unrestrained throughout the entire accident: the driver had no abdominal injury, the lap belt was adjusted to its full length, and the driver was thrown from his seat during the accident.

The driver sustained moderate (AIS 2) injury. He reported that he was thrown from his seat and was in the aisle between the fourth and fifth row of passenger seats when the bus came to rest. According to the hospital records, his only injury was a sprained left knee (AIS 2).

Outcome for Occupants of Other Vehicle

Vehicle Description: 1984 conventional cab Peterbilt truck tractor and a 40-foot-long flatbed type semitrailer loaded with pine stumps.

Damage to Vehicles

Vehicle No. 1 Description: Tractor—The tractor was destroyed by front end crush damage. The steering axle was stripped away and completely separated from the vehicle. The front frame members were severely deformed and the fenders and hood were torn away. The left side of the forward cab and dashboard were crushed rearward into the driver compartment. The steering wheel post was forced down and the steering wheel rim was in contact with the driver's seat cushion. The engine and transmission were damaged beyond repair. Only the rear section of the tractor remained without serious damage.

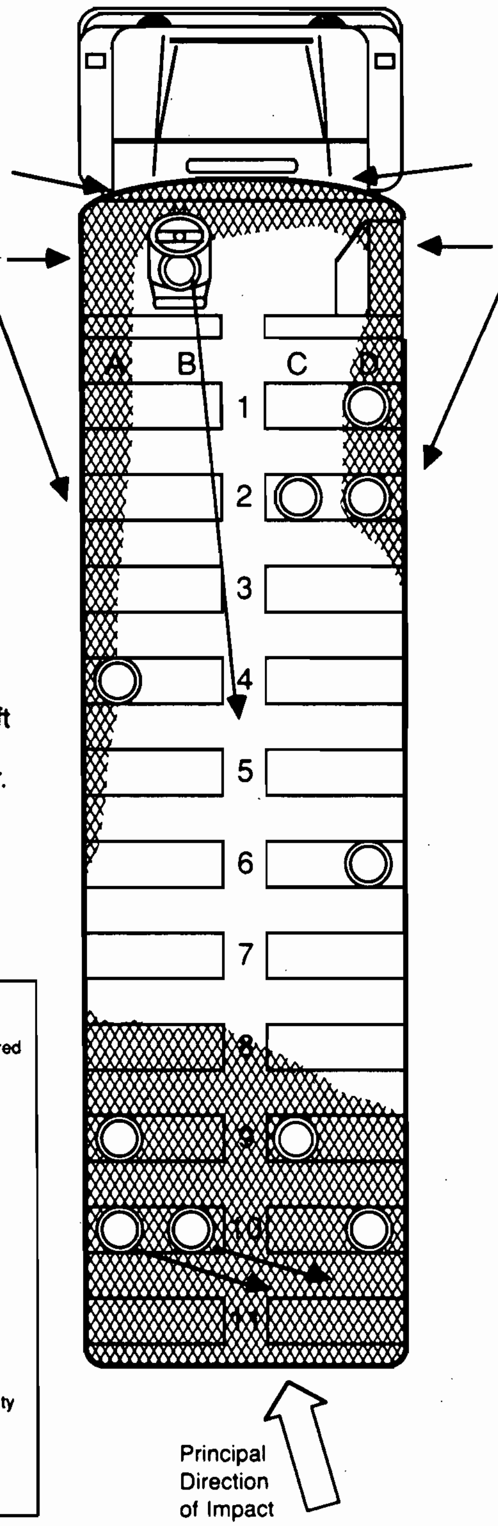
Vehicle No. 2 Description: Semitrailer--The upper fifth wheel plate, welded beneath the forward frame was ripped away and remained attached to the tractor; this caused the trailer separation from the tractor during the accident.

Occupant Restraint Use and Injury: Driver was unrestrained. Moderate (AIS 2) injury: deep laceration to chin and jaw (AIS 2) and chest contusion (AIS 1).

Brunswick, Georgia
Case No. 40

Left Side of Bus

Right Side of Bus



Row 4A
F-17, MAIS 1

Row 9A
M-14, MAIS 3
Cerebral contusion with antigrade and retrograde amnesia; lacerated scalp; abrasions and contusions to left shoulder; strained spine.

Row 10A
F-13, MAIS 3
Cerebral contusion, laceration to left neck, laceration to face, scalp laceration, and laceration to left ear.

Row 10B
M-15, MAIS 3
Deep laceration of right forehead, spinal strain, contusion to the kidneys.

Row 1D
M-13, MAIS 1

Row 2C
M-12, MAIS 1

Row 2D
M-18, MAIS 1

Row 6D
M-12, MAIS 1

Row 9C
M-13, MAIS 1

Row 10D
M-16, MAIS 2
Fractured right clavicle.

LEGEND

Uninjured
Injured
Fatally Injured
Unknown if Injured
Lap Belt Used

Example: M-17 — Male, Age 17
MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

<u>Case No.: 41</u>
DCA-84-HF-005

Accident Location: State Route 44, Rehoboth, Massachusetts

Date and Time: January 10, 1984, 11:45 a.m.

Description of Schoolbus: 65-passenger poststandard bus:
1979 International Harvester chassis with Wayne body

Type of Accident: Left front impact followed by rollover (180°)

Accident Severity: Extremely severe

Summary of Events: A tow truck was turning right from a driveway onto a highway when the car in tow was struck by an oncoming tractor-semitrailer. The tractor-semitrailer then crossed the centerline of the 2-lane, 2-way highway, and struck the left front of a schoolbus transporting 15 students. Tractor-semitrailer preimpact speed 45 to 55 mph; schoolbus preimpact speed 31 mph. The force of the collision partially separated the schoolbus body from its frame and pushed the schoolbus approximately 80 feet off the roadway. The schoolbus overturned and came to rest on its roof.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 15 passengers, aged 5 to 6, 2 were uninjured, 9 sustained minor (AIS 1) injuries, 1 sustained moderate (AIS 2) injuries, 1 sustained serious (AIS 3) injuries, 1 sustained severe (AIS 4) injuries, and 1 sustained critical (AIS 5) injuries which proved fatal. The 49-year-old driver, restraint use unknown, received critical (AIS 5) injuries which proved fatal.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: Extensive collision damage was found on the left side of the body starting immediately to the rear of the left front of the bumper and extending rearward for 16 feet. Maximum penetration into the sidewall of the schoolbus body was 18 inches at the rear of the barrier between the driver's seat and the first passenger seat on the left side.

After the accident the body of the schoolbus was partially detached from the frame and the entire steering axle assembly was torn from the frame. The left front tire was deflated and the right front tire was inflated.

The right and left front roof support pillars were displaced to the right and were broken away from the roof at the roof joint. The left front roof support pillar was displaced into the area normally occupied by the driver at an angle of approximately 45° to the longitudinal axis of the vehicle.

There were no body panel penetrations or separations except in the major area of impact. There was some minor penetration of the exterior body panels on the left side behind the driver's seat. Also, there was some separation of the interior panel at the bottom of the lower horizontal sash frames of the first three passenger windows behind the driver.

The floor panels buckled across the width of the bus at four locations: between the seat legs of rows 1, 2, and 3, and between the rear seat legs of row 3 and the forward legs of row 4. The height of the floor buckles were 8, 6, 3, and 6 inches, respectively.

Rehoboth, Massachusetts
Case No. 41

Evaluation of Bus Performance: Based on the evidence, the Safety Board believes that the crushing and displacement of the left and right front corner roof support posts of the schoolbus occurred during the initial collision with the truck and substantially weakened the front roof support structure before vertical loads were applied during the subsequent rollover. The crash performance of the schoolbus, therefore, cannot be evaluated strictly in terms of its compliance with the vertical load testing requirements specified in FMVSS 220.

With both front corner support posts displaced, the front of the bus roof collapsed and made contact with the firewall when the vehicle rolled over. However, after the bus rolled over onto its top, the roof was subjected to vertical loading, and it did perform in a crashworthy manner with respect to the requirements of FMVSS 220. Except where the roof collapsed in front, the maximum vertical penetration of 4 1/2 inches occurred on the exterior panels of the roof with only minor buckling of the interior panels. The roof reacted to these forces as a unit, which allowed the vertical forces on the roof to be uniformly distributed. Also, the schoolbus body retained its basic shape, except in the area of maximum engagement with the truck, which provided survivable occupant space given the size of the passengers who were occupying the bus at the time of the accident. If larger, high-school aged passengers had been seated in the front of the bus, they might have suffered serious or fatal head injuries when the front of the roof collapsed during the rollover.

The schoolbus body damage and distortion to the left front, to the right rear corner of the roof, and to the right sidewall did not prevent the rear emergency exit from being fully operable. This exit was used by rescuers to evacuate most of the children from the bus. Panel separations occurred only in the major impact area which is to be expected. The schoolbus retained its basic shape except in the area of maximum engagement with the truck thereby performing in a crashworthy manner in respect to the rollover protection requirements. Despite the severe damage the emergency exit door was operable. There was floor buckling and seatleg separation due to the severe crash forces. The fuel tank was not significantly damaged. The schoolbus body separated from the chassis which is believed to have provided good results by absorbing some of the crash energy.

The crash performance of the poststandard schoolbus body in this accident is a significant improvement over the crash performance of schoolbuses in accidents investigated by the Safety Board before the promulgation of FMVSS 220, 221, and 222.

Injury Analysis

Passengers: The driver reportedly required passengers to sit in the first six rows of the schoolbus so that she could monitor their activities. The most seriously injured passengers were sitting in the first three rows of the schoolbus. The fatally injured passenger also was seated in the front of the bus on the left side, near the area of maximum intrusion. None of the occupants were ejected from the bus.

It could not be determined whether the two passengers who were in the first seat behind the driver were sitting as shown in in the seating chart or vice versa. However, based on the severity of injury, it is believed that the fatally injured passenger was sitting near the window and that the injury most likely was caused by severe impact forces as the passenger was propelled forward into the barrier to the front and the crushed left side wall of the bus as the tractor forced the schoolbus body off its chassis. These crash forces were concentrated in the major impact area adjacent to where the child was sitting.

The passenger who is believed to have been sitting on the aisle side in the same seat as the fatally injured passenger experienced the same kinematics and suffered severe head injuries. However, the passenger's injuries were not fatal because the passenger was seated farther away from the major impact area and probably did not come in contact with the left side wall of the bus. The same is true of the passenger in the second seat behind the driver who was sitting on the aisle to the right of the major impact area and who suffered minor head contusions on the left side and a bruised knee.

The passenger who was in the third seat on the driver's side by the window was located in the major impact area and suffered a fracture of the left femur. The passenger in the sixth seat behind the driver sustained no injuries. This passenger was seated away from the major impact area.

In sum, for the passengers seated on the left side of the bus, the severity of their injuries was directly related to their proximity to the major impact area where the crash forces would have been the greatest. While most of the passengers' minor injuries probably occurred after the bus rolled onto its top, the fatal and most severe injuries are believed to have occurred during initial impact with the tractor-semitrailer.

The passenger who was seated in the first seat in the right side next to the window recalled being propelled into the barrier to the front. He suffered a fractured left clavicle which is consistent with the occupant kinematics of being propelled forward and to the left. The eight passengers who sustained minor injuries and the passengers who were not injured did not experience the severe crash forces experienced by those who were sitting in the first three rows on the left side of the bus. The injuries to passengers seated on the right side of the bus probably occurred while the bus was rolling over when they contacted the right side windows, the sidewall, and the roof of the bus.

Lap belt use would not have prevented student fatality or the serious or severe injuries of the surviving passengers. The use of lap belts by passengers in window seats of rows 1 and 3 on the left of the schoolbus would not have benefited them because of the degree of crush at their occupant spaces in the major impact area. The use of lap belts by all other occupants with minor or moderate injuries would have prevented them from being thrown out of their seats and onto the ceiling as the bus collided with the truck and rolled over. However, if the children seated away from the major impact area had been wearing lap belts, their injuries may have been different, but not necessarily less severe because passengers sitting in the outboard seats still would have contacted the seat backs, the side walls, windows, and the roof either during the initial collision with the truck, during the rollover, or both.

<u>Schoolbus Driver:</u> Restraint use unknown. Driver sustained critical (AIS 5) injuries which proved fatal: ruptured heart, compound fracture of the right lower leg, fracture of the left leg and right wrist; contusions and abrasions to the hands and left side of the abdomen, face, forehead, nose, lips, and lacerations and contusions on both legs and thighs. Use of a lap belt would not have benefited the driver because of the degree of crush at his seating position; he was in the major impact area.

Rehoboth, Massachusetts
Case No. 41

Outcome for Occupants of Other Vehicles: Two moving vehicles besides the schoolbus were involved were involved in this accident.

Vehicle No. 1 Description: Tractor-semitrailer--1978 Kenworth with a 1979 Transcraft flatbed semitrailer. The left side of cab was displaced 4 feet rearward and 5 feet to the left - headerboard of the trailer was displaced forward about 1 foot on the left. The right side rail was torn out for about 6 feet starting 8 feet from the front of the trailer.

Vehicle No. 2 Description: Tow Truck--1975 Ford towing a car. The two truck was not damaged but the towed car was.

Occupant Restraint Use and Injury: It is not known if the truckdriver or the towtruck driver were restrained. The truckdriver died of a ruptured heart but restraint use in his case is immaterial since his living space was compromised. The towtruck driver was uninjured.

Special Notes on the Accident

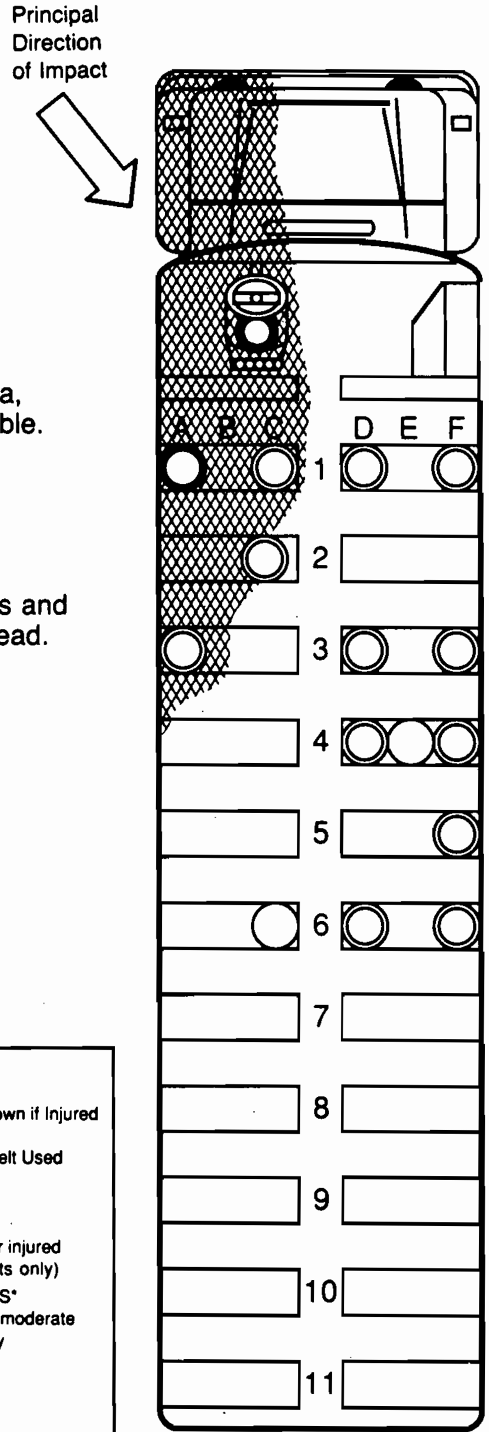
One undesirable crashworthiness factor noted in this accident was that a number of seat cushions came loose from the seats during the bus rollover. FMVSS Standard 222 requires that ". . .the seat cushion shall not separate from the seat at any attachment point when subjected to an upward force of five times the seat cushion weight. . . ." In this accident, the seat cushions came free because the clips at the rear of the cushion were free to rotate and, therefore, did not secure the cushion to the rear of the seat frame. It is possible that some of the movable seat cushion clips were not secured onto the seat frames before the accident, or that the clips rotated to the unsecured position during the rollover.

Loose seat cushions are a hazard during a crash. As the bus rolled over, the loose 13-pound cushions became missiles and may have contacted and injured some of the passengers. In addition, the loose cushions could have concealed small unconscious passengers and prevented them from being readily observed by rescuers. The Safety Board believes that an improved method of fastening the seat cushion to the frame is required to prevent seat cushion separation during impacts or rollovers.

The 13-pound seat cushions were constructed of polyurethane foam on a 1/2-inch plywood base. The seat cushions were attached to the seat frame by two retaining clips on the front and the rear of each cushion. To install, each seat cushion was dropped perpendicularly onto the frame to engage the fixed front clips and then rotated toward the seat back. After emplacement of the seat cushion, the two retaining clips at the rear were rotated 90° to engage the seat frame. Photographs showed that at least seven seat cushions came loose from their mountings and were lying on the inside roof panels of the bus after it overturned.

Wayne has since altered its seat cushion attachment design to render seat cushions permanently attached.

Rehoboth, Massachusetts
Case No. 41



Left Side of Bus

Driver
F-49, MAIS 5 (Fatal)

Row 1A
M-5, MAIS 5 (Fatal)

Row 1C
F-6, MAIS 4
Head injuries with seizures, unconscious, transient hypoxia, broken teeth, fractured mandible.

Row 2C
M-5, MAIS 1

Row 3A
M-6, MAIS 3
Fractured left femur, abrasions and contusions on face and forehead.

Right Side of Bus

Row 1D
M-6, MAIS 1

Row 1F
M-6, MAIS 2
Fractured left clavicle.

Row 3D
M-5, MAIS 1

Row 3F
M-5, MAIS 1

Row 4D
M-6, MAIS 1

Row 4F
M-6, MAIS 1

Row 5F
F-6, MAIS 1

Row 6D
F-5, MAIS 1

Row 6F
F-5, MAIS 1

LEGEND

Uninjured
Injured
Fatally Injured
Unknown if Injured
Lap Belt Used

Example: M-17 — Male, Age 17
MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

The school bus shown is representational only.

Case No.: 42
DCA-84-AH-008

Accident Location: State Route 615, outside Carrsville, Virginia

Date and Time: April 12, 1984, 3:25 p.m.

Description of Schoolbus: 65-passenger poststandard bus:
1980 Ford chassis with Blue Bird body

Type of Accident: Right side impact (direction of principal impact at 3 o'clock) followed by rollover (270°)

Accident Severity: Extremely severe

Summary of Events: A schoolbus transporting 26 students home from school, was stopped at a railroad crossing when the bus was struck by a freight train travelling about 49 mph. The train impacted the schoolbus in front of the right side door tearing away the front of the schoolbus forward of the driver's seat. At the initial impact, the schoolbus body and steering axle separated from the chassis and the bus body rotated 180° counterclockwise. The right rear of the schoolbus struck the side of the train as it rotated around, and the schoolbus body made a three-quarter revolution to the right and came to rest on its left side, approximately 80 feet from the crossing. The schoolbus chassis, with the engine still mounted, came to rest upside down between the bus body and the crossing, and a fire started in the bus engine. The train remained on the track.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 26 passengers, aged 5 to 14, 23 sustained minor (AIS 1) injuries, 1 sustained moderate (AIS 2) injuries, and 2 sustained serious (AIS 3) injuries. The 44-year-old restrained driver received serious (AIS 3) injuries which proved fatal.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The padded barriers in front of the first-row passenger seats were intact after the accident. The floor of the bus was buckled at the last row of seats. Although the buckling induced cracks in the rear seat legs of the seats in the last row at their point of attachment to the schoolbus floor, the seat legs did not separate from the schoolbus floor. The frame of the driver's seat remained attached to the floor, the seat cushion was missing, and the seatbelt was found stowed in its retractors. The floor under the driver's seat was displaced 12 inches upward.

Some of the photographs show the seat cushions displaced, but it is not known if this occurred due to rescue operations or during the rollover.

Evaluation of Bus Performance: The separation of the chassis from the schoolbus body had positive safety results in that the crash forces which otherwise would have been transmitted to the schoolbus body were expanded when the body was forced off the chassis.

The minor deformation of the exterior roof panel at the right rear of the schoolbus body occurred when this portion of the roof contacted the ground during the rollover. After this contact and as the bus continued to roll over 270° to the right, the roof was subjected to vertical loading, and it performed in a crashworthy manner with respect to the requirements of FMVSS 220. The roof reacted to the crash forces as a unit, and the schoolbus body retained its basic shape which provided survivable occupant space.

The damage sustained at the right rear during the secondary impact of the bus with the train and the crash forces experienced during the subsequent rollover did not prevent the rear emergency exit from being operable. It appears that post-1977 construction methods are substantially better than construction methods in use before the promulgation of FMVSS 221. In this accident there was no interior body panel separation, and the only exterior body panel penetration noted was at the lower right rear of the bus where it collided with the train. Although the collision of the right rear of the bus with the train induced cracks in the rear seat legs in the last row of seats, there were no seat leg separations, and all the passenger seats retained their original spacing and provided for survivable space.

Injury Analysis

Passengers: Two of the 26 schoolbus passengers were seriously injured (AIS 3 injuries): 10-year-old occupant sitting in the window seat behind the driver next to the window sustained head trauma and a depressed skull fracture on the left side of the head and 14-year-old occupant sitting in the last aisle seat on the right sustained a fracture at the base of the skull with mild brain injury as well as severe left facial abrasions.

A 6-year-old child occupying the same seat as the second child was lying prone with her head on the 14-year-old's lap. The 6-year-old child suffered minor (AIS 1) injuries including cuts to the left side of the head requiring stitches with scratches and bruises on her back, arms, and legs.

The schoolbus passenger in the third row window seat on the right had moderate (AIS 2) injuries including bruising and abrasions across the zygomata (the bony arch below the eyes) and bruising on the lower extremities.

Twenty three of the 26 schoolbus passengers suffered minor AIS 1 injuries which included multiple lacerations, cuts/abrasions, bruises, and contusions. The head and the face were the predominant body parts injured in all categories (26 total AIS 1 injuries to head and face). Arms and hands were the next most commonly injured body region, followed by legs (mostly shins). Eleven children had extensive head lacerations; five of these children required stitches. Another six children had numerous head cuts, abrasions, bruises, and contusions. Three children suffered facial lacerations; another seven children had facial cuts, abrasions, bruises and contusions. Four children had eye injuries. All of these injuries just described are coded as minor (AIS 1) injuries. Multiple AIS 1 injuries were common. One child had 7 minor injuries, 4 had 6, 2 had 4, 8 had 3, 5 had 2, and only 3 children had 1 injury.

The 10-year-old child sitting in the first seat behind the driver and the 14-year-old child sitting in the rear aisle seat on the right were the most seriously injured. The child sitting behind the driver was close to the area of the first impact with the train and probably was thrown head-first toward the right side of the bus when the train struck the front right side. This child sustained head trauma, including a depressed skull fracture. The installation and use of a seat belt by this child probably would have prevented or mitigated this injury.

The 14-year-old child sitting in the rear aisle seat on the right, and a 6-year-old lying prone on the same seat with her head in her 14-year-old sister's lap, were seated immediately in front of the second impact area at the right rear of the bus. The force of the second impact initially would have propelled both of these children to the right rear. Because of her size and initial seating position, the 14-year-old child sustained her basilar skull fracture when her head, which was above the padded seat back, probably contacted the frame of the emergency door at the right rear of the bus. Use of a lap belt would not have prevented the 14-year-old's basilar skull fracture. Because of her prone position in the seat, the 6-year-old was propelled into the padded seat back instead of the hard interior surfaces above the back of the right rear seat. The 14-year-old also sustained facial abrasions to the left side of her face, and the 6-year-old sustained cuts on the upper left side of the head and scratches and bruises on her hands, arms, and legs. It is believed that these less-serious injuries were sustained when the bus rolled over.

Most of the children who were seated next to the side wall on the right side of the bus at the time of the collision sustained lacerations, bruises, or abrasions to the right sides of their heads or upper torsos. Although it is possible that some of these injuries may have been sustained when the bus rolled over, the Safety Board believes that the majority of these injuries were sustained when the train initially struck the bus and these children were propelled to the right and contacted the right side wall, windows, and window frames on the right side of the bus. The installation and use of lap belts by the children seated by the sidewall on the right side would not have prevented or mitigated most of these minor to moderate injuries.

The children who were seated away from the major impact areas sustained minor injuries. It is believed that these injuries occurred when these children contacted the side walls, the windows and frames, and the roof when they were thrown about the interior of the bus during the initial impact and the subsequent rotation and rollover.

If the train had struck the right side of the schoolbus in the passenger seating area rather than in front of the firewall, the accident would have been much more severe. There would have been more penetration into the occupant space and probably a higher number of serious to fatal injuries in or near the area of impact.

Schoolbus Driver: Available lap belt used. As the train struck the front right side of the bus, the entire front of the bus body forward of the driver's seat was torn away when the schoolbus body separated from the chassis. If the driver had not been wearing her seat belt, she probably would have been ejected through the opening in the right front of the bus created by the collision and possibly crushed between the schoolbus body and the train during the collision or subsequent rotation. Serious (AIS 3) injuries: fractured right forearm, fracture of the right femur, amputation of the left leg below the knee, pelvic fracture and an amputation of the right foot. The driver had been seated closest to the first major impact area and she died of her injuries 5 days after the accident after refusing blood transfusions or blood products for religious reasons.

Outcome for Occupants of Other Vehicle

Vehicle Description: Chesapeake and Ohio freight train: 3 locomotives, 108 cars, and caboose

Damage to Vehicle: Extremely minor; a bent handrail and bent uncoupling lever.

Occupant Restraint Use and Injury: The three members of the traincrew were unrestrained and were not injured.

Carrsville, Virginia
Case No. 42

Left Side of Bus

Driver
F-44, MAIS 3 (Fatal)
Fractured right forearm, fracture of right femur, an amputation of the left leg below the knee, a pelvic fracture, and an amputation of the right foot.

Row 1A
F-10, MAIS 3
Head trauma, depressed skull, fracture in left parietas occipital area.

Row 2B
M-12, MAIS 1

Row 3A
F-11, MAIS 1

Row 3B
F-9, MAIS 1

Row 4A
M-6, MAIS 1

Row 5B
M-9, MAIS 1

Row 6A
M-5, MAIS 1

Row 7A
F-6, MAIS 1

Row 7B
F-7, MAIS 1

Row 8B
M-7, MAIS 1

Row 9A
F-9, MAIS 1

Row 9B
M-12, MAIS 1

Row 10A
F-13, MAIS-1

Row 10B
F-13, MAIS 1

Row 11A
F-12, MAIS-1

LEGEND

- Uninjured
- Injured
- Fatally Injured
- Unknown if Injured
- Lap Belt Used

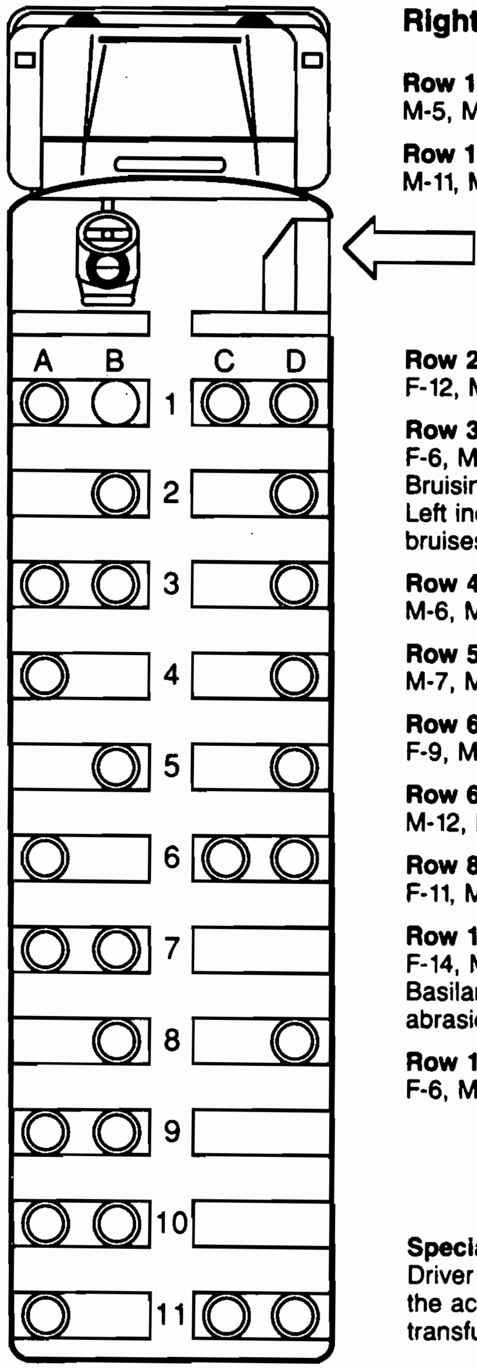
Example: M-17 — Male, Age 17

MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)



Right Side of Bus

Row 1C
M-5, MAIS 1

Row 1D
M-11, MAIS 1

Row 2D
F-12, MAIS 1

Row 3D
F-6, MAIS 2
Bruising and abrasion across zygomata. Left index finger bruised with other bruises on lower extremities.

Row 4D
M-6, MAIS 1

Row 5D
M-7, MAIS 1

Row 6C
F-9, MAIS 1

Row 6D
M-12, MAIS 1

Row 8D
F-11, MAIS 1

Row 11C
F-14, MAIS 3
Basilar skull fracture, severe facial abrasions.

Row 11D
F-6, MAIS 1

Special Note:
Driver died of her injuries 5 days after the accident after refusing blood transfusions or blood products.

The school bus shown is representational only.

<u>**Case No.: 43**</u>
<u>DCA-85-MH-006</u>

Accident Location: U.S. 160, outside Tuba City, Arizona

Date and Time: April 29, 1985, 3:14 p.m.

Description of Schoolbus: 84-passenger poststandard bus: with May 1977 Blue Bird body and chassis

Type of Accident: Rear-end collision followed by rollover (90°)

Accident Severity: Extremely severe; 44 mph Delta V for schoolbus.

Summary of Events: A schoolbus transporting 32 passengers home from school was stopped with its warning lights flashing in the eastbound lane of a two-lane highway to discharge passengers when as tractor-semitrailer travelling about 59 mph crashed into its rear. The rear of the schoolbus was lifted up by the force of the collision. After impact, the schoolbus, which remained upright, was pushed forward for approximately 136 feet. It rotated 155° clockwise as it was pushed and left the road to the right. The bus then overturned onto its left side and slid about 18 feet before coming to rest.

Outcome for Schoolbus Occupants by Most Severe Injury: Of the 32 passengers, aged 5 to 21, 4 were uninjured, 18 sustained minor (AIS 1) injuries, 4 sustained moderate (AIS 2) injuries, 4 sustained serious (AIS 3) injuries, and 2 were fatally injured. The 49-year-old restrained driver received minor (AIS 1) injuries.

(See schoolbus occupant seating position and injury chart.)

Damage to Schoolbus: The right rear of the schoolbus was displaced forward and about 2.5 feet to the left, and the left rear was displaced forward about 9.7 feet. There were no exterior body panel separations between the roof and the rear body side panels. The extensive crush prevented inspection of all the side body panel joints at the left rear. However, of the joints that were visible, no exterior body panel separations were noted at this location. The rear 11 feet of both the longitudinal frame rails which formerly ran the entire length of the vehicle were bent 37 inches to the left. The emergency door at the rear was inoperable due to collision damage.

The padded restraining barrier installed in front of the first passenger seat on the right side was displaced rearward 12 inches on the aisle side. The padded left front restraining barrier was not damaged or displaced from its preaccident location. The remaining damage to the interior of the schoolbus was confined to the area containing the last four rows of seats. The floor was buckled upward in four places at these seats, and the seat legs on the last three rows of seats were torn from the floor. The seats of the last three rows were crushed forward with no space between the seat cushion and the seat back of the next row forward. The seat on the left side was displaced upward to within about 8 inches from the interior ceiling body panel.

No separation of the major interior body panels was noted at the rear of the schoolbus. The schoolbus had interior maintenance access panels installed along both sides above the windows. The maintenance access panels along the left side of the schoolbus contained the wiring for the interior dome lights, the sidemarker lamps, and the rear tail, stop, and flashing red stop lamps. These maintenance access panels were joined to their adjacent interior body parts by sheet metal screws located at each corner of the panel. Joint separations were noted at the connections joining the left and right maintenance access panels to the interior body sidewall panels at the rear. Above the 13th row of seats, where the separation of the maintenance access panel left the bottom edge of the body panel exposed, a quantity of blood, hair, and tissue was present on the edge of the body panel.

Evaluation of Bus Performance: The schoolbus demonstrated the crashworthiness required by FMVSS 221. Joint separations of interior maintenance access panels with the resultant exposure of metal edges pose a hazard to schoolbus occupants during crashes.

Injury Analysis

Passengers: The bus was stopped to discharge passengers at the time of the collision. Passengers in the rear row of seats were standing up and stretching, and some of the other passengers were standing up either to exit the schoolbus or change seats.

The two schoolbus passengers who sustained fatal injuries were occupying the left rear window seat and the right rear seat and were reported to be standing when the truck struck the bus. The amount of crush damage in their area did not provide survivable space.

Three of the four schoolbus occupants who sustained serious (AIS 3) injuries also were occupying the last four rows of the schoolbus where the crash forces were the greatest. The 21-year-old male occupant of the left window seat in the 13th row probably sustained his head laceration when he contacted the edge of the body panel joint which was exposed due to the joint separation of the adjacent maintenance access panel. The remaining passenger who sustained serious injuries was occupying the seat in the second row behind the schoolbus driver before the collision. This passenger was about to exit the schoolbus at the stop where the collision occurred and sustained his basilar skull fracture because he probably was standing up in the aisle and was thrown backward by the force of the collision, striking his head on some object inside the schoolbus when the collision occurred.

Four passengers sustained moderate injuries including humerus and clavicle fractures and an abdominal contusion. Minor injuries sustained by 18 students included sprains, contusions, bruises, and abrasions.

The installation and use of lap belts would not have prevented the fatalities or serious injuries sustained by the passengers in the last row of seats. The amount of crush in this area did not provide survivable space between the seat backs. The passenger in the aisle seat in the last row of seats on the left side probably was standing in the aisle at the time of the collision and therefore avoided being crushed between the seats.

Tuba City, Arizona
Case No. 43

The passenger in the window seat on the left side in the 13th row of seats sustained serious injuries. This seat was pushed up and to within about 8 inches of the ceiling of the schoolbus, and the use of a lap belt would not have prevented his injuries.

The passenger in the window seat on the left side in the second row who was seriously injured probably was standing up to exit the schoolbus at the time of the collision. A lap belt would not have been in use. The remaining passenger who was seriously injured was occupying the window seat on the right side in the 11th row. This person probably sustained his serious injury when he contacted the sidewall, the occupant next to him, or the ceiling of the schoolbus during the collision, the rotation of the schoolbus body, and/or the subsequent 90° overturn. The lack of available evidence concerning what object this person struck and what caused his injury prevents the Safety Board from determining whether this person's serious injury may have been prevented by the use of a lap belt.

The remaining passengers in the schoolbus sustained minor to moderate injuries. If lap belts had been available and in use by all seated occupants, they would not have contacted the ceiling and would not have fallen or been ejected from their seats during the rotation and 90° rollover. However, the use of lap belts would not have prevented the occupants from contacting the sidewalls, the windows, the seatbacks in front or behind them, or the persons sitting next to them. These passengers probably would have sustained similar types of injuries, such as abrasions and contusions, if lap belts had been in use.

Schoolbus Driver: Available lap belt used. Driver sustained minor (AIS 1) injury: paraspinal muscle spasm.

Outcome for Occupants of Other Vehicle

Vehicle Description: 3-axle 1983 cab-over-engine Freightliner trucktractor with 2-axle 1984 Wilson double-deck livestock semitrailer; estimated loaded gross weight 79,520 pounds.

Damage to Vehicle: Damage extended across the entire front of the truck tractor. The top of the cab was displaced about 4 feet rearward and about 4 feet leftward. The right side of the cab and the right steering axle wheel were displaced 1 1/2 feet farther rearward than the same components on the left side of the vehicle. The top of the roof was crushed downward about two feet.

Occupant Restraint Use and Injury: Restraint use unknown. Minor (AIS 1) injuries.

Tuba City, Arizona
Case No. 43

Left Side of Bus

Driver
M-45, MAIS 1

Row 2A
M-13, MAIS 3
Basilar skull fracture and concussion, right flank contusion and abdominal blunt trauma.

Row 3A
F-14, MAIS 1

Row 4A
M-5, MAIS 1

Row 4B
M-9, MAIS 1

Row 5A
F-17, MAIS 1

Row 5B
M-18, MAIS 1

Row 7A
M-11, MAIS 2
Abdominal contusion, abrasions on left lower rib cage, neck strain.

Row 7B
M-11, MAIS 1

Row 8A
F-13, MAIS 1

Row 9B
M-13, MAIS 2
Fractured right clavicle.

Row 10A
M-17, MAIS 1

Row 10B
F-14, MAIS 1

Row 11A
M-14, MAIS 1

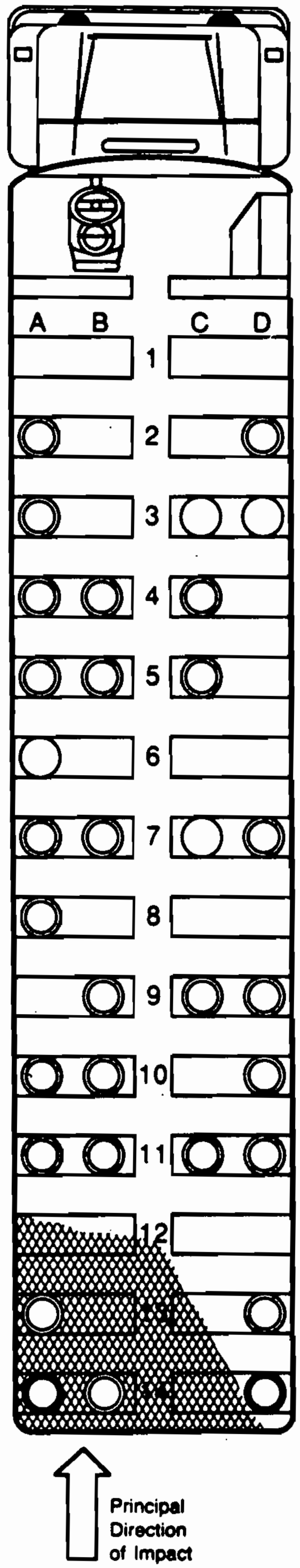
Row 11B
M-14, MAIS 1

Row 13A
M-21, MAIS 3
Fracture of left femur, laceration of right forehead, multiple bruises and abrasions.

Row 14A
M-15 (Fatal) (Probably MAIS 6)
Multiple fractures, massive internal injuries.

Row 14B
M-17, MAIS 3
Bilateral femoral fractures, scalp and facial lacerations, left 2nd, 3rd, and 4th metatarsals fracture.

The school bus shown is representational only.



Principal Direction of Impact

Right Side of Bus

Row 2D
F-21, MAIS 2
Distal clavicle fracture.

Row 4C
F-16, MAIS 1

Row 5C
M-15, MAIS 2
Left humerus fracture, soft tissue injury to left knee, abrasions on left elbow and back.

Row 7D
F-11, MAIS 1

Row 9C
F-16, MAIS 1

Row 9D
F-14, MAIS 1

Row 10D
M-15, MAIS 1

Row 11C
M-16, MAIS 1
Left renal contusion, left pneumothorax.

Row 11D
M-16, MAIS 3

Row 13D
M-17, MAIS 1

Row 14D
M-11 (Fatal) (Probably MAIS 6)
Closed head injury with occipital skull fracture, fractures of right and left femurs, right tibia, and left humerus, diastatis pubis.

Special Note:
Passengers, in Rows 2A, 3A, 4C, 14A, 14B, and 14D are reported to have been standing when the accident occurred.

LEGEND

- Uninjured
- Unknown if Injured
- Injured
- Lap Belt Used
- Fatally Injured

Example: M-17 — Male, Age 17
MAIS-2 (Used for injured occupants only) — Maximum AIS* Injury was a moderate (AIS-2) injury

AIS Code and Injury Severity

1 - Minor	5 - Critical
2 - Moderate	6 - Maximum injury
3 - Serious	7 - Injured, unknown severity
4 - Severe	9 - Unknown if injured

*American Association of Automotive Medicine Abbreviated Injury Scale (AIS)

APPENDIX B

ABBREVIATED INJURY SCALE

Motor vehicle occupant injuries were coded in the schoolbus safety study according to the 1980 Abbreviated Injury Scale (AIS). 1/ Injuries are described in the text of case summaries in terms of the maximum AIS level injury sustained by an occupant. Hence, if an individual sustained two AIS 3 injuries, one AIS 2, and seven AIS 1 injuries, the individual is described as receiving an MAIS 3 injury.

A University of Michigan study substantiated that approximately 98 percent of multiply injured persons would be properly assessed using their most severe injury as an index. 2/ Description of all the injuries, however, incurred by a schoolbus occupant with a MAIS greater than or equal to 2, is included on the bus seating charts.

The AIS codes used in the study were:

AIS Code	Description	Examples
1	Minor	Bruises, abrasions, superficial lacerations (less than 2 inches on face or 4 inches on body provided they do not extend into subcutaneous tissue), fractured finger, sprained wrist, fractured nose
2	Moderate	Deep laceration, mild concussion, head injury with amnesia about accident and no neurological damage, fractured clavicle ("collar bone"), sprained knee, fractured foot, fractured ulna in arm
3	Serious	Fractured femur, dislocated hip, brain swelling, contused bladder, fractured pelvis, crushed forearm, hand amputation, head injury with prior unconsciousness with neurologic deficit
4	Severe	Ruptured spleen, amputation of leg above knee, brain hemotoma less than 100 cc

1/ AIS is a standardized, universally accepted system for assessing impact injury severity by coding individual injury codes. The first AIS was published in 1971 under sponsorship of a joint committee of the American Medical Association, the American Association for Automotive Medicine, and the Society of Automotive Engineers. Since 1973, the American Association for Automotive Medicine has been the parent organization.

2/ Huang, L.C., and March, J.C., "AIS and Threat to Life", Proceedings, American Association for Automotive Medicine 22; 242-254, 1978.

AIS Code	Description	Examples
5	Critical	Pulmonary artery laceration, complete spinal cord lesion (quadriplegia or paraplegia), ruptured liver, unconsciousness more than 24 hours or penetrating skull injury, brain hematoma more than 100 cc
6	Maximum injury, virtually unsurvivable	Torso transection, massive skull crush, spinal cord crush with total transection C-3 or above, crushed brain stem
7	Injured, unknown severity	Insufficient information is available or outcome rather than injury is described, i.e. arm trauma, closed head injury, kidney injury
9	Unknown if injured	Medical report states "redness over eye," "suspicion of ________," or no information is available

APPENDIX C

ACCIDENT SEVERITY SCALE

Accident severity in the table in appendix D and in the accident summaries in appendix A is expressed solely in terms of the schoolbus, not the other vehicle(s), if any, involved in the accident. This is an important distinction since an accident classified as "minor" for a schoolbus may well be "severe" for a passenger car involved.

The Safety Board investigators were unable to calculate Delta V, the best single measure of crash severity, for most of the schoolbus accidents in the study. Delta V measures the sudden change in vehicle velocity that occurs in a fraction of a second during a collision while primary vehicle damage is occurring.

Delta V in multivehicle accidents is normally determined by the difference in velocities of the vehicles, and the ratio of the vehicle weights. Such data often were not available to the Safety Board investigators, and computer-based shortcuts to calculate Delta V in schoolbus accidents are not available. Passenger cars have been barrier crash-tested for years, yielding vast amounts of data correlating Delta V with vehicle crush; schoolbus crush data has not been correspondingly collected.

Even if data had been available, many schoolbus accidents are, by their nature, not suitable to use Delta V as an index of accident severity. Delta V is an excellent tool for measuring the severity of a collision between two objects, but it is not a good measure of collision severity for accidents involving rollover, sideswipes, or violent rotation. More than half of all schoolbus cases in this study fall in these categories. Two separate accident severity scales were devised for this study since rollover accidents are so different from nonrollover accidents. Each consider the degree and type of damage to the schoolbus body and the estimated complexity and severity of crash forces acting on bus occupants. (In a rollover, these crash forces would include the speed of the rollover and degree of overturn.) Each factor, damage and crash force, is important in accident severity and must be considered in conjunction with the other. A single factor taken by itself might result in a misleading estimate of accident severity.

Injury outcome alone does not accurately reflect crash severity. For example, the fatal schoolbus accident involving a Mahopac school district in Carmel, New York, (case 1) was a minor, not severe, accident. The bus ran off the road twice, and came to rest after striking a small tree. The schoolbus body was only slightly damaged, and crash forces acting on the occupants were slight. Of the 15 passengers on the bus, more than half were uninjured; the rest, except for the fatally injured passenger, received minor injuries. Yet, one passenger sustained a severely lacerated liver and died as a result, which could lead some to assume this must have been a severe accident.

In addition, accident severity itself is a good, but not absolute, predictor of injury outcome. Many additional factors can influence the chance of injury. In one accident investigated for this study, for instance, the fact that all passengers were seated in the front of the bus enhanced their chance of survival when the moving bus was struck by an oncoming train. The train hit the bus between rows 12 and 13, tearing a gaping hole in the bus, but no passenger was seated in these rows. Few passengers were injured, and those that were sustained minor injuries only. Thus, the crash potentially could have resulted in fatalities, but passenger injuries, in fact, were minor.

APPENDIX D

MAXIMUM INJURY SUSTAINED BY SCHOOLBUS PASSENGERS IN EACH SAFETY BOARD INVESTIGATION IN THE STUDY

(Based on the most severe injury sustained by each of the 1,166 schoolbus passengers (restrained and unrestrained) on the 44 large poststandard school-buses involved in accidents investigated by the Safety Board for this study. Accidents are presented in the table in the same order as their case summaries in the report.)

Nonrollover Accidents			Outcome for Schoolbus Passengers: Number by Most Severe Injury								
Location	Accident Severity	No. of Schoolbus Passengers	Uninjured	Minor (AIS-1)	Moderate (AIS-2)	Serious (AIS-3)	Severe (AIS-4)	Critical (AIS-5)	Maximum (AIS-6)	(AIS-7)	(AIS-9)
1. Carmel (Mahopac), NY*	Minor	15	8	4				1		1	1
2. Chanute, KS	Minor	4	4								
3. Cornelius, OR	Minor	46	40	6							
4. Little Rock, AR	Minor	46	38	7	1						
5. Healdton, OK	Minor	15-20	14-19	1							
6. Pasedena, MD	Moderate	18	11	7							
7. Tecumseh, OK	Moderate	55	36	19							
8. Bloomfield Township, OH	Moderate	54	48	6							
9. Lanconia, NH	Moderate	14	3	9	1					1	
10. Frankston, TX	Moderate	44	28	6						10	
11. Palmyra, NE	Moderate	20	11	9							
12. Sour Lake, TX	Moderate	30	22	8							
13. St.-Louis, MO*/***	Ext. Sev.	13		8	2	1	1	1			
14. Snow Hill, NC*	Ext. Sev.	27		8	7	3	7	2			
15. Key Largo, FL**	Minor	109	65	44							
16. Greenburgh, NY***	Ext. Min.	29	29								
17. Snyder, OK	Minor	48	43	4	1						
18. Stephenson, WV	Moderate	61	53	8							
19. Kerrick, TX	Moderate	5	1	4							
20. Hecla, SD	Moderate	17	2	9	5	1					
21. Woodside, DE	Mod.-Sev.	42	3	33	6						

Rollover Accidents

Location	Accident Severity	No. of Schoolbus Passengers	Outcome for Schoolbus Passengers: Number by Most Severe Injury: Uninjured	Minor (AIS-1)	Moderate (AIS-2)	Serious (AIS-3)	Severe (AIS-4)	Critical (AIS-5)	Maximum (AIS-6)	(AIS-7)	(AIS-9)
22. Des Peres, MO***	Minor	13	8	3	2						
23. Rueter, MO	Minor	12	10	2							
24. Leavenworth, KS	Min.-Mod.	2	1			1					
25. Point Pleasant, WV	Moderate	53	17	32	4						
26. Hobbs, NM	Moderate	11		5	6						
27. Bladensburg, MD	Moderate	51	4	47							
28. Jefferson, NC	Moderate	22		20	1	1					
29. Swink, OK	Mod.-Sev.	33	6	24	3						
30. Julian Boone, WV	Minor	29	7	21	1						
31. Greenfield, IL	Moderate	32	9	19	3	1					
32. Caldwell, TX	Moderate	16	9	5	1					1	
33. Newark, NJ***	Moderate	9	8	1							
34. Fort Myers, FL	Moderate	17	1	16							
35. Durango, CO	Moderate	15	1	10	3	1					
36. Wilmington, OH***	Moderate	16	5	10		1					
37. Georgetown, TX	Moderate	14	5	7		1				1	
38. Cherokee, IA	Mod.-Sev.	14	2	8	2	2					
39. McGrath, MN*	Severe	7	0	3	2	1	1				
40. Brunswick, GA	Severe	10		6	1	3					
41. Rehoboth, MA*	Ext. Sev.	15	2	9	1	1	1	1			
42. Carrsville, VA	Ext. Sev.	26		23	1	2					
43. Tuba City, AZ*	Ext. Sev.	32	4	18	4	4			2		

* Fatally injured schoolbus passenger(s). NTSB investigated six crashes of large poststandard school buses which involved schoolbus passenger fatalities. A total of 13 school bus passengers were fatally injured. Overall, 16 schoolbus occupants died in 8 crashes. In two accidents (Palmyra, NE, and Carrsville, VA), the schoolbus driver was the only bus occupant to die. If fatally injured occupants of other vehicles are included, the number of fatal schoolbus accidents is 10 and the number of motor vehicle occupant fatalities represented in this study is 22.

** Key Largo, FL, crash involved two large poststandard schoolbuses.

*** Some form of restraint was available for all, or some, schoolbus passengers.

APPENDIX E

NATIONAL TRANSPORTATION SAFETY BOARD
SCHOOLBUS INVESTIGATIONS INVOLVING LOOSE BOTTOM SEAT CUSHIONS

Location	Accident No.	Bus Body	Type of Accident	Cushion Attachment
Chanute, KS (case 2)	MKC-84-H-SB-26	1983 Blue Bird	Head-on collision	Several cushions only partially secured to the seat frame; metal retainer clips out of position.
Bloomfield Township, OH (case 8)	CHI-84-H-SB15	1984 Carpenter	Head-on collision	All bottom seat cushions unsecured; no seat cushion came loose.
Lanconia, NH (case 9)	NYC-84-H-SB03	1983 GMC	Head-on collision	Eight cushions came loose; 12 of 24 seats had bottom seat cushion rear lock open or missing. (Nine were missing rear lock.)
Palmyra, NE (case 11)	MKC-85-H-SB02	1983 Wayne	Left-front angle collision	All bottom seat cushions were unlatched. One seat impossible to latch because latch not installed properly.
St. Louis, MO (case 13)	DCA-86-MH-002	1979 Ward	Front angle collision	Four cushions displaced.
Des Peres, MO (case 22)	MKC-86-H-SB03	1984 Blue Bird	Noncollision rollover (90°)	Seat cushions detached in rows 4, 6, and 7 on left side of bus and thrown around in bus.

Location	Accident No.	Bus Body	Type of Accident	Cushion Attachment
Point Pleasant, WV (case 25)	CHI-85-H-SB01	1983 Blue Bird	Noncollision rollover (270°)	Two seat cushions came loose.
Bladensburg,MD (case 27)	DCA-86-SH-002	1979 Superior	Noncollision rollover (270°)	Loose seat cushions cause some injuries. All bottom seat cushions came loose. Cushions were not secured to frame rails after recovering.
Swink, OK (case 29)	MKC-86-H-AB05	1982 Wayne	Noncollision rollover (360°)	All seat cushions loose; never relatched after sweeping under seats. Some cushions struck passengers causing injuries.
Greenfield, IL (case 31)	CHI-85-H-SB28	1978 Wayne	Rear-end collision with rollover (90°)	Fifteen bottom seat cushions unlocked and fell off seat frames during rollover. Some passengers injured by loose cushions.
Caldwell, TX (case 32)	FTW-85-H-SB32	1978 Wayne	Front angle collision with rollover (90°)	Large number of cushions came loose and obstructed evacuation.
Fort Myers, FL (case 34)	ATL-85-H-SB13	1978 Ward	Side impact with rollover (90°)	Some seat cushions dislodged.
Georgetown, TX (case 37)	FTW-85-H-SB33	1983 Carpenter	Multiple collision with rollover (90°)	Nine cushions loose. Fasteners not secured properly.

Location	Accident No.	Bus Body	Type of Accident	Cushion Attachment
McGrath, MN (case 39)	MKC-85-H-SB19	1984 Carpenter	Side impact with rollover (90°)	Some bottom seat cushions came loose.
Rehoboth, MA (case 41)	DCA-84-HF-005	1979 Wayne	Left front impact with rollover (180°)	Seven cushions loose.
Carrsville, VA (case 42)	DCA-84-AH-008	1980 Blue Bird	Side impact with rollover (270°)	Some cushions displaced (possibly during rescue operations)

APPENDIX F

NATIONAL TRANSPORTATION SAFETY BOARD SAFETY RECOMMENDATIONS RELATING TO SEAT BELTS ON SCHOOLBUSES

1972

Schoolbus Driver Restraint Installation

Recommendation Number: H-72-001
Issue Date: 5/19/72
Addressee: All States
Status: Closed—Acceptable Action

The Safety Board recommends that all States: Enact requirements for school districts or Administrations within their jurisdiction, through State funding assistance or any other appropriate authority, for the installation of suitable restraint systems (seatbelts or other approved devices) at the driver's position in all schoolbuses, and for the wearing of such restraints (or the use of such devices) at all times when persons are being transported in such schoolbuses.

1973

Seatbelt Use Demonstration Project

Recommendation Number: H-73-014
Issue Date: 6/21/73
Addressee: NHTSA
Status: Closed—Acceptable Action

The Safety Board recommends that the National Highway Traffic Safety Administration: Assess the human factors involved in seatbelt usage in schoolbuses through a demonstration project. The project should include a number of buses equipped with seatbelts and highback, padded seats, which are engaged in pupil transportation. (Findings from this project will be useful for evaluation of the provisions found in the proposed vehicle safety standard (docket No. 73-3), bus passenger seating and crash protection.

Seatbelts on Activity Buses

Recommendation Number: H-73-019
Issue Date: 5/22/73
Addressee: NHTSA
Status: Closed—Acceptable Alternate Action

The Safety Board recommends that the National Highway Traffic Safety Administration: Require, for the schoolbus category, the cushioning performance called for in the first performance option along with the seat strength performance and seatbelt anchorages at each seat location proposed in the second performance option. The warning system should not be required. Consideration should also be given to establish a separate category of schoolbus for intermittent higher-speed or interstate-highway operation which would require seatbelts to be installed.

1983

Drivers and Passengers of Small Schoolbuses and School Vans to Use Available Restraints

Recommendation Number: H-83-039
Issue Date: 9/23/83
Addressee: All States and D.C.
Status: Open—Acceptable Action

The Safety Board recommends that the Governors of the 50 States and the Mayor of the District of Columbia: Review State laws and regulations and take any necessary legislative action, to ensure that passengers in small (more than 10 passengers and less than 10,000 GVWR) schoolbuses and school vans are required to use available restraint systems whenever the vehicle is in motion; ensure that all users of such vehicles are aware of and comply with these provisions.

Recommendation Number: H-83-041
Issue Date: 9/28/83
Addressee: All States and D.C.
Status: Open—Acceptable Action

The Safety Board recommends that the Governors of the 50 States and the Mayor of the District of Columbia: Review State laws and regulations and take any necessary legislative action, to ensure that drivers of schoolbuses are required to wear their seatbelts whenever the vehicle is in motion, that all schoolbus drivers are made aware of this requirement, and that periodic monitoring of schoolbus driver seatbelt use is conducted.

National Transportation Safety Board Recommendations Not Specifically Connected with Seat Belts on Schoolbuses, but Related

1973

Seatbelts on Intercity Buses

Recommendation Number: H-73-018
Issue Date: 5/22/73
Addressee: NHTSA
Status: Closed—Unacceptable Action

The Safety Board recommends that the National Highway Traffic Safety Administration: Require, for the interstate-bus category, the cushioning performance called for in the first performance option in order to provide a defined level of protection for those passengers who do not use an installed restraint. The seat strength performance and seatbelts called for in the proposed rulemaking's second performance option should also be required. The warning system should not be required.

1975

Schoolbus Rollover Testing

Recommendation Number: H-75-022
Issue Date: 9/18/75
Addressee: NHTSA
Status: Closed--Acceptable Action

The Safety Board recommends that the National Highway Traffic Safety Administration: Initiate a program of dynamic rollover testing of schoolbuses to provide data, in combination with data already obtained from static testing, to be used to develop a performance requirement that will ensure reasonable structural integrity in rollover environments.

1978

Evaluation of Schoolbus Seating Standards

Recommendation Number: H-78-011
Issue Date: 03/08/78
Addressee: NHSTA
Status: Open—Acceptable Action

The Safety Board recommends that the National Highway Traffic Safety Administration: Review available accident statistics involving 1975 and later model schoolbuses equipped with seating arrangements that comply with Federal Motor Vehicle Safety Standards No. 222 to determine if the specific seating, restraining barrier, and impact zone requirements for schoolbuses have reduced the injuries sustained by occupants on these schoolbuses when involved in collisions and rollovers. A report of the findings should be submitted to the National Transportation Safety Board at the earliest opportunity.

1983

Vehicles Used for School-Type Purposes Should Meet Schoolbus Safety Standards

Recommendation Number: H-83-040
Issue Date: 9/28/83
Addressee: All States and D.C.
Status: Open—Acceptable Action

The Safety Board recommends that the Governors of the 50 States and the Mayor of of the District of Columbia: Review State laws and regulations and take any necessary legislative action, to ensure that vehicles designed to carry more than 10 passengers and weighing less than 10,000 pounds GVWR, used to transport children to and from school, school-related events, camps, day care center, or similar purposes meet all Federal Motor Vehicle Safety Standards applicable to small schoolbuses.

APPENDIX G

NATIONAL TRANSPORTATION SAFETY BOARD
SAFETY RECOMMENDATIONS RELATING TO SCHOOLBUS STRUCTURE AND DESIGN
(1968-1985)

1968

Recommendation Number: H-68-009
Issue Date: 11/08/68
Addressee: FHWA
Status: Closed—Acceptable Action

The Safety Board recommends that the Federal Highway Administration: Consider the need for requirements for structural strength of schoolbus bodies in connection with its study of desirable standards for protection of schoolbus occupants. In particular, the Safety Board recommends that program A.1.1.4 of the National Highway Safety Bureau, titled "Design, Fabrication, and Test of a Safe School Bus Interior," be expanded in scope to include consideration of structural integrity and intrusion into the school bus interior.

1970

Recommendation Number: H-70-014
Issue Date: 8/22/70
Addressee: NEA
Status: Closed—No Longer Applicable

The Safety Board recommends that the National Education Association and the schoolbus manufacturing industry: Adopt a policy of using fastening methods which inhibit the raising of sharp edges and which provide much greater efficiency of joints to prevent the disintegration of schoolbus bodies. This policy might well be implemented by voluntary specifications adopted by the National Education Association and used by schoolbus purchasers and manufacturers.

Recommendation Number: H-70-015
Issue Date: 8/22/70
Addressee: NHTSA
Status: Closed—Acceptable Action

The Safety Board recommends that the National Highway Safety Bureau: Include in its accident research investigations and studies a search for evidence of the nature of schoolbus disintegration and the significance of the disintegration phenomena in injury causation.

Recommendation Number: H-70-016
Issue Date: 8/22/70
Addressee: NHTSA
Status: Closed—Acceptable Action

The Safety Board recommends that the National Highway Safety Bureau: Continue its consideration of the recommendation concerning schoolbus safety made by the Safety Board in its report of the grade-crossing accident at Waterloo, Nebraska, which occurred October 2, 1967.

1971

Recommendation Number: H-71-033
Issue Date: 4/22/71
Addressee: NHSTA
Status: Closed—Acceptable Action

The Safety Board has discussed its Special Study "Inadequate Structure Assembly of Schoolbus Bodies with the Vehicle Equipment Safety Commission (VESC), officers and members of the Schoolbus Manufacturing Institute and of the Ward Company. VESC will issue standards, Ward Schoolbus Manufacturing Company indicated they would welcome a NHTSA standard specifying joint strength and schoolbus body strength. The Safety Board urges the NHSTA to move expeditiously in this field.

Recommendation Number: H-71-033A
Issue Date: 8/26/70
Addressee: NEA
Status: Closed—No Longer Applicable

The Safety Board recommends that the National Education Association and the schoolbus manufacturing industry: Adopt a policy of using fastening methods which inhibit the raising of sharp edges and which provide much greater efficiency of joints to prevent the disintegration of schoolbus bodies. This policy might well be implemented by voluntary specifications adopted by the National Education Association and used by schoolbus purchasers and manufacturers.

1972

Recommendation Number: H-72-002
Issue Date: 5/19/72
Addressee: NHTSA
Status: Closed—Acceptable Action

The Safety Board recommends that the National Highway Traffic Safety Administration and the Vehicle Equipment Safety Commission: In consideration of the unnecessary hazards posed by locating schoolbus fuel tanks adjacent to service doors, act promptly to determine the "best" and "safest" location for schoolbus fuel tanks and to specify such location, as well as any protective shield or structural changes, to minimize the likelihood that a collision which might disable the service door or the emergency exit will also initiate a schoolbus fuel tank fire, and vice versa.

Recommendation Number: H-72-003
Issue Date: 5/19/72
Addressee: NHTSA
Status: Closed—Acceptable Action

The Safety Board recommends that the National Highway Traffic Safety Administration and the Vehicle Equipment Safety Commission: In consideration of the hazards posed by schoolbus service doors which open in such a fashion that the pressure of persons from within the bus might hamper or prevent the expeditious opening of such doors in an emergency, act promptly to determine the safest mode of service door opening and to specify such mode of opening in appropriate standards.

Recommendation Number: H-72-30
Issue Date: 9/22/72
Addressee: NHTSA
Status: Closed—Acceptable Action

The Safety Board recommends that the National Highway Traffic Safety Administration: Expeditiously adopt a Federal Motor Vehicle Safety Standard to control the strength of structural joints of schoolbuses. In this connection careful consideration should be given to requirement 5.6 Body Structure, of the Vehicle Equipment Safety Commission. This standard should also apply to the strengthening of the window columns of schoolbuses.

1973

Recommendation Number: H-73-016
Issue Date: 5/22/73
Addressee: NHTSA
Status: Closed—Acceptable Action

The Safety Board recommends that the National Highway Traffic Safety Administration: Establish separate vehicle-type classes for transit buses, interstate buses, and schoolbuses, based upon exact definitions of the intended use and performance of the buses in defined highway environments. Factors which should be considered include at least the number and classes of passengers carried, the maximum intended speed of operation, the classes of highways over which operation is intended, the luggage-carrying capability, the duration of trips, and the intent to provide for standing and/or seated passengers.

Recommendation Number: H-73-017
Issue Date: 5/22/73
Addressee: NHTSA
Status: Closed—No Longer Applicable

The Safety Board recommends that the National Highway Traffic Safety Administration: Require, for the transit-bus category that seats have the characteristics of the proposed rulemaking's first performance option only. Steps should be taken later to provide crashworthiness features in the structural area or to meet other needs typical of the stated and defined utility performance, e.g., the need to accommodate standing passengers.

1974

Recommendation Number: H-74-009
Issue Date: 4/30/74
Addressee: FHWA
Status: Closed—Acceptable Action

The Safety Board recommends that the Federal Highway Administration: Develop a precise technical definition of crash cushions on the basis of minimum performance criteria. The factors defined should include not only classes of vehicles, but also velocities and angles of attack, so that standards can be established to require the most effective use of crash cushions on Federal-aid highways. Such standards would describe speeds and impact directions at which vehicle types will be adequately handled.

Recommendation Number: H-74-010
Issue Date: 4/30/74
Addressee: NHTSA
Status: Closed—Unacceptable Action

The Safety Board recommends that the National Highway Traffic Safety Administration: Proceed with the notice of proposed rulemaking (Docket 73-3 Notice 1), to provide for (1) increased strength of seat anchorages which more fully uses the abilities of structures to protect passengers and (2) more protection against gross seat deflection which can permit seats to be carried away.

Recommendation Number: H-74-011
Issue Date: 4/30/74
Addressee: NHTSA
Status: Closed—Acceptable Action

The Safety Board recommends that the National Highway Traffic Safety Administration: Identify types of bus seat anchorages which are substantially below the strengths obtainable by such simple changes as substituting a bolt for a sheet metal screw. If it is possible to identify such buses by visual inspection, steps should be taken to inform owners of the possible change for local retrofit purposes.

1978

Recommendation Number: H-78-010
Issue Date: 3/08/78
Addressee: NHTSA
Status: Closed—Acceptable Alternate Action

The Safety Board recommends that the National Highway Traffic Safety Administration: Modify Federal Motor Vehicle Safety Standard No. 217 to provide for additional emergency exit points to facilitate escape from and access to schoolbuses regardless of the vehicle's attitude following a collision or overturn. Such exits shall be in addition to the current options set forth in FMVSS No. 217.

1980

Recommendation Number: H-80-067
Issue Date: 10/24/80
Addressee: DOT
Status: Closed—Acceptable Alternate Action

The Safety Board recommends that the secretary of the Department of Transportation: Establish a task force to examine the problem of front wheels on small front-wheel drive vehicles being snagged and torn from the vehicle when impacting traffic barriers, as well as the failure of front axles and wheels of schoolbus-type vehicles in such impacts. The task force should determine what additional research is needed to further define the problem. A cooperative effort with the NHTSA, the FHA, the AASHTO, and the automobile industry should be initiated to resolve any identified problem.

Recommendation Number: H-80-068
Issue Date: 10/24/80
Addressee: Motor Vehicle Manufacturers
Addressee: Truck Body and Equipment Association
Addressee: Automobile Importers of America
Status: Open—Acceptable Action

The Safety Board recommends that the Motor Vehicle Manufacturers Association, Truck Body and Equipment Association, Inc., and Automobile Importers of America: Cooperate with DOT in determining the nature of the hazard posed by front wheels of small front-wheel-drive vehicles being snagged when impacting traffic barrier systems and the failure of front axles and wheels of schoolbus-type vehicles in such impacts.

1982

Recommendation Number: H-82-038
Issue Date: 10/06/82
Addressee: NHTSA
Status: Closed—Acceptable Action

The Safety Board recommends that the National Highway Traffic Safety Administration: Examine the crash performance of vans in rollovers and all accident types, through its crash testing and accident investigation programs, to determine if there is any tendency for doors and other escape areas to unnecessarily jam or be blocked in low-speed crashes. If necessary, establish additional crash performance standards for van escape area, especially those used for public transportation.

1983

Recommendation Number: H-83-067
Issue Date: 12/14/83
Addressee: California Department of Education
Addressee: Washington State Board of Education
Status: Open—Acceptable Alternate Action

The Safety Board recommends that the California Department of Education, and the Washington State Board of Education: Initiate a program to retrofit (except where the design makes retrofitting economically prohibitive) all transit-type schoolbuses within your fleet that are not equipped with Federal Motor Safety Standard (FMVSS) 222 approved seats with FMVSS 222 approved seat and restraining barriers if these schoolbuses are refurbished during their normal service life.

1984

Recommendation Number: H-84-08
Issue Date: 4/14/84
Addressee: Alabama, Governor
Status: Open—Acceptable Alternate Action

The Safety Board recommends that the Governors of the 50 States and the Mayor of the District of Columbia: When purchasing buses of the types designed to meet the Federal standards for schoolbuses built after April 1977, which are intended for special-purpose uses in which the standards are not mandatory, conduct an evaluation of any proposed modifications for their possible adverse effects on the safety of the intended passengers.

Recommendation Number: H-84-075
Issue Date: 10/05/84
Addressee: NHTSA
Status: Open—Acceptable Alternate Action

The Safety Board recommends that the National Highway Traffic Safety Administration: For newly manufactured vehicles, revise Federal Motor Vehicle Safety Standard 222 to include a requirement that schoolbus seat cushions be installed with fail safe latching devices so as to ensure they remain in their installed position during impacts and rollovers.

1985

Recommendation Number: H-85-017
Issue Date: 8/27/85
Addressee: 16 States and D.C.
Status: Open—Acceptable Alternate Action

The Safety Board recommends that the States of Arkansas, Colorado, Idaho, Kentucky, Louisiana, New Hampshire, New Mexico, North Carolina, Oklahoma, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, Washington, Wisconsin, and the District of Columbia: Prohibit the operation of nonpublic schoolbuses while deadbolt or similar supplemental locks on emergency doors are engaged.

Recommendation Number: H-85-018
Issue Date: 8/27/85
Addressee: 11 States and D.C.
Status: Open—Acceptable Alternate Action

The Safety Board recommends that the States of Alabama, Alaska, Arizona, California, Florida, Georgia, Mississippi, Nebraska, South Carolina, West Virginia, and Wyoming: Prohibit the operation of public and nonpublic schoolbuses while deadbolt or similar supplemental locks on emergency doors are engaged.

APPENDIX H

NATIONAL TRANSPORTATION SAFETY BOARD PUBLISHED HIGHWAY ACCIDENT REPORTS INVOLVING SCHOOLBUSES 1/ (1968 THROUGH APRIL 1987)

Poststandard Large Schoolbuses

(Schoolbuses more than 10,000 pounds manufactured after April 1, 1977.)

"Schoolbus" as used by the Safety Board in compiling this list was defined by vehicle type, not function, so church buses, activity buses, and schoolbuses used for regularly scheduled school transportation are represented. Safety Board investigations of crashes involving intercity buses, coach-type buses, municipal buses or other buses with bodies substantially different from schoolbuses are not included in this list. Examples of the latter include the tour bus crash at Denali National Park in Alaska, June 15, 1981, and the chartered bus crash near New Smithville, Pennsylvania, July 15, 1970. The design and crashworthiness of the vehicles involved in these accidents were quite dissimilar to that of a schoolbus, i.e., these buses had long picture windows or reclining seats. It is not correct to assume injuries sustained by occupants of these buses would be similar to that sustained by occupants of a schoolbus. Ejection, for example, is far more likely to occur in buses with transit-type windows which open often during rollover.

Report Number	Adopted Date	Title	NTIS Order Number 2/
NTSB/HAR-84-05	9/05/84	Collision of G & D Auto Sales, Inc., Tow Truck Towing Automobile, Branch Motor Express Company Tractor-Semi-Trailer, Rehoboth, Massachusetts, January 10, 1984	PB84-916205
NTSB/HAR-85-02	1/25/85	Collision of Isle of Wight County, Virginia Schoolbus with Chesapeake and Ohio Railway Company Freight Train, State Route 615 near Carrsville, Virginia, April 12, 1984	PB85-916202
NTSB/HAR-85-05	12/10/85	Schoolbus Rollover, State Route 88 near Jefferson, North Carolina, March 13, 1985	PB85-916206

1/ Not all Safety Board investigations result in a published report. This list consists only of major schoolbus investigations which resulted in Safety Recommendations. Such investigations are published while others exist only as midlevel accident reports and are maintained in a public docket.

2/ Copies of the Safety Board's highway accident reports are available from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161. Please refer to the NTIS order number when ordering a specific report.

Report Number	Adopted Date	Title	NTIS Order Number 2/
NTSB/HAR-85-06	12/10/85	Collision of Tuba City School District Schoolbus and Bell Creek, Inc., Tractor-Semitrailer, U.S. 160 near Tuba City, Arizona, April 29, 1985	PB85-912607
NTSB/HAR-86/02	08/05/86	Multiple Vehicle Collision and Fire, U.S. 13 Near Snow Hill, North Carolina, May 31, 1985	PB86-916202
NTSB/HAR-87/2	04/14/87	Schoolbus Loss of Control and Collision with Guard Rail and Sign Pillar, U.S. Highway 70 Near Lucas and Hunt Road, St. Louis, Missouri, November 11, 1985	PB87-916203
		Prestandard Large Schoolbuses 3/	
NTSB/SS-R/H-3	9/18/68	Waterloo, Nebraska, Public School School Bus and Union Pacific Railroad Company Freight Train Accident, Waterloo, Nebraska, October 2, 1967	PB-190204
NTSB/RHR-73-01	3/21/73	Penn Central Freight Train/ Schoolbus Collision, near Congers, New York, March 24, 1972	PB-221137
NTSB/RHR-75-01	7/07/75	Collision of the Southern Railway Work Train with a Polk District Schoolbus at Aragon, Georgia, October 23, 1974	PB-244467/AS
NTSB/HAR-72-02	4/12/72	Schoolbus/Automobile Collision and Fire, near Reston, Virginia, February 29, 1972	PB-209260

3/ The level of crashworthiness and occupant protection provided by a schoolbus manufactured before 1977 (the year Federal schoolbus safety standards became effective) is markedly inferior to that offered by a schoolbus manufactured after that date. It is not correct to assume that injuries sustained by passengers of prestandard schoolbuses would be sustained by passengers of poststandard schoolbuses in a similar crash. The interior bus components, in particular, are quite different. In addition, joint strength in many prestandard school buses is considered weaker so panel separations occur more often, and with body failure, ejection is more common.

Prestandard Large Schoolbuses
(continued)

Report Number	Adopted Date	Title	NTSB Order Number 2/
NTSB/HAR-75-01	3/05/75	Jesus Ayala Schoolbus Type Run off Roadway/Drainage Ditch Submergence, Blythe, California, January 15, 1974	PB-241749/AS
NTSB/HAR-76-01	1/07/76	Sisiyou Union High School District Schoolbus/Automobile Collision and Rollover, I-5, Ashland, Oregon, May 9, 1975	PB-250050/AS
NTSB/HAR-77-02	9/29/77	Student Transportation Lines, Inc., Charter Bus Climbing of Bridge Rail and Overturn near Martinez, California, May 21, 1976	PB-275193/AS
NTSB/HAR-78-01	2/23/78	Tractor-Semitrailer/Schoolbus Collision and Overturn, Rustburg, Virginia, March 8, 1977	PB-277990/AS
NTSB/HAR-79-02	3/08/79	Overturn of a Ypsilanti, Michigan, Boys Club Bus, I-75 near Tifton, Georgia, April 11, 1978	PB-294004/AS
NTSB/HAR-80-06	9/29/80	B & J Trucking Company Truck Tractor/Coachella Valley Unified School District Schoolbus Collision, State Route 86 near Coachella, California, April 23, 1980	PB-81-114007
NTSB/HAR-82-02	4/26/82	Herman Duvall Tractor-Pole Semi-Trailer/SL & B Academy, Inc., Schoolbus Collision, U.S. Route 45, near Waynesboro, Mississippi, October 12, 1981	PB82-916202
NTSB/HAR-83-02	5/03/83	J.C. Sales, Inc., Tractor-Semi-Trailer/Calvary Baptist Church Van Collision, State Route 198 at 19th Avenue near Lemoore, California, October 8, 1982	PB83-916202
NTSB/HAR-83-03	9/20/83	Jonesboro School District Schoolbus Run-Off Road and Overturn, State Highway 214 at State Route 18, near Newport, Arkansas, March 25, 1983	PB83-916203

Prestandard Large Schoolbuses
(continued)

Report Number	Adopted Date	Title	NTSB Order Number 2/
NTSB/HAR-83-9	12/05/83	Collision of Humbolt County Dump Truck and Klamath Trinity Unified District Schoolbus, State Route 96 near Willow Creek, California, February 24, 1983	PB83-916205
NTSB/HAR-84-06	9/05/84	Activity Bus/Tractor-Cargo Tank Semi-Trailer Collision, State Route 61 near Devers, Texas, December 23, 1983	PB84-916206
NTSB/HAR-85-01	3/05/85	Church Bus Loss of Control on Long Steep Grade, State Route 155 near Wofford Heights, California, July 7, 1984	PB85-916201
NTSB/HAR-85-03	5/02/85	Schoolbus Loss of Control Accident in Miami, Florida, September 28, 1983	PB85-916204
NTSB/HAR-85-03	4/12/84	Schoolbus Loss of Control Accidents in Birmingham, Alabama, April 12, 1984	PB85-916204
NTSB/HAR-85-04	6/25/85	Fatigue-Related Commercial Vehicle Accident, Junction City, Arkansas, October 19, 1984	PB85-916204
NTSB/RHR-85-01	06/12/85	Grade Crossing Collision of a Florida East Coast Railway Company Freight Train and an Indian River Academy Schoolbus, Port St. Lucie, Florida, September 27, 1984	PB85-917007

Other Types of School Vehicles

NTSB/HAR-82-05	09/22/82	Pattison Head Start Center School Van Run off Bridge and Fire, near Hermanville, Mississippi, December 17, 1981 (schoolvan)	PB82-915205
NTSB/HAR-84-01	04/03/84	Valley Supply Company Truck Towing Farm Plow Anchor Motor Freight, Inc. Car Carrier Truck/NY State Association Bus for Retarded Children, near Holmesville, New York, April 5, 1983 (Although the bus was manufactured in 1982, it was not required to, nor did it, meet Federal schoolbus standards since it was used for "special purposes," not school transportation. It did meet New York State Standards, however.)	PB84-916201

SUMMARY I

SUMMARY OF TRANSPORT CANADA SCHOOLBUS FRONTAL CRASH TESTS, 1984

DUMMY NUMBER	LOCATION IN BUS	SEAT SPACING (inch)	LAP BELTED	UNBELTED	HIC	CHEST ACCELERATION (g)	
1	Front LH	21		X	*	60.4	LARGE SCHOOLBUS (more than 10,000 GVWR) BLUEBIRD 66 PASSENGER
2	Front RH	21	X		649	40.8	
3	Centre LH	27 1/8	X		629	28.1	Vehicle Wt 17923 lbs. Vehicle Velocity 30.5 MPH Vehicle Decel. 15 g Dynamic Crush 54.0 in. Body Slide 30½ in.
4	Centre RH	27 1/8		X	220	34.2	
5	Rear LH	24		X	205	48.2	
6	Rear RH	24	X		731	25.0	*Data not valid due to technical problems
1	Front LH	21	X		2,505	40.1	SMALL SCHOOLBUS (less than or equal to 10,000 GVWR) THOMAS MINOTOUR 22 PASSENGER
2	Front RH	21		X	893	47.9	
3	Centre LH	26½	X		1,144	38.6	
4	Centre RH	26½	/	X	741	59.8	Vehicle Wt 8,874 lbs. Vehicle Velocity 29.42 MPH Vehicle Decel. 19.5 g Dynamic Crush 28.7 in. Body Slide 15 in.
5	Rear LH	24	X		1,173	42.4	
6	Rear RH	24		X	494	44.9	
1	Front LH	21 1/8	X		2,016	32.5	SCHOOL VAN BUILT RE SCHOOLBUS STANDARDS (van conversion) CAMPWAGON 20 PASSENGER
2	Front RH	20½		X	369	21.1	
3	Centre LH	26½	X		2,195	32.2	
4	Centre RH	27		X	946	42.0	Vehicle Wt 6724 lbs. Vehicle Velocity 29.44 MPH Vehicle Decel. 49 g Dynamic Crush 19.5 in. Body Slide 0
5	Rear LH	24½	X		1,711	37.5	
6	Rear RH	24½		X	607	24.4	

HIC is a measure of the forces the head experiences during the crash. It does not measure injury to the neck or facial laceration. The higher the HIC score, the greater the likelihood of serious or fatal injuries. The Federal government requires that cars equipped with automatic restraints not exceed a HIC of 1,000 in 30 mph crash tests. However, individuals have a wide range of tolerance to injury. Consequently, although there are relationships between dummy test results and actual injuries, there is no single cutoff point for serious injury or death -higher scores indicate a higher potential risk and lower scores indicate a lower potential risk.

Chest deceleration is a measure of the amount of force the belted dummy's chest experiences during the crash impact. Higher chest deceleration scores indicate that it is more likely that occupants will sustain serious internal injuries. The score is given in gravitational units (G's). Cars equipped with automatic restraints must not exceed 60 G's in the 30 mph compliance tests.

APPENDIX J

THOMAS BUILT BUSES SIDE IMPACT CRASH TESTS

During April and May 1985, Thomas Built Buses in cooperation with Arvin Calspan of Buffalo, New York, conducted three schoolbus crash tests: (1) a head-on crash into a frontal barrier at 30 mph; (2) a left side impact by a 4,000-pound moving barrier at 30.4 mph; and (3) a right side impact by the same moving barrier at 30.8 mph. The last two tests marked the first time a poststandard schoolbus had been crash-tested for side impact tolerance since the new schoolbus standards were implemented.

The head-on crash test involved no instrumented dummies. The second test, a left side impact, did, but data from three of the six instrumented dummies were lost. The test was then repeated by striking the other side of the bus and data from this third test are presented on the next page.

The same vehicle, a 16-passenger 1985 Thomas Minotour schoolbus was used for all three tests. The small schoolbus weighed less than 10,000 GVWR and thus was required by Federal schoolbus standards to be equipped with lap belts for all passengers.

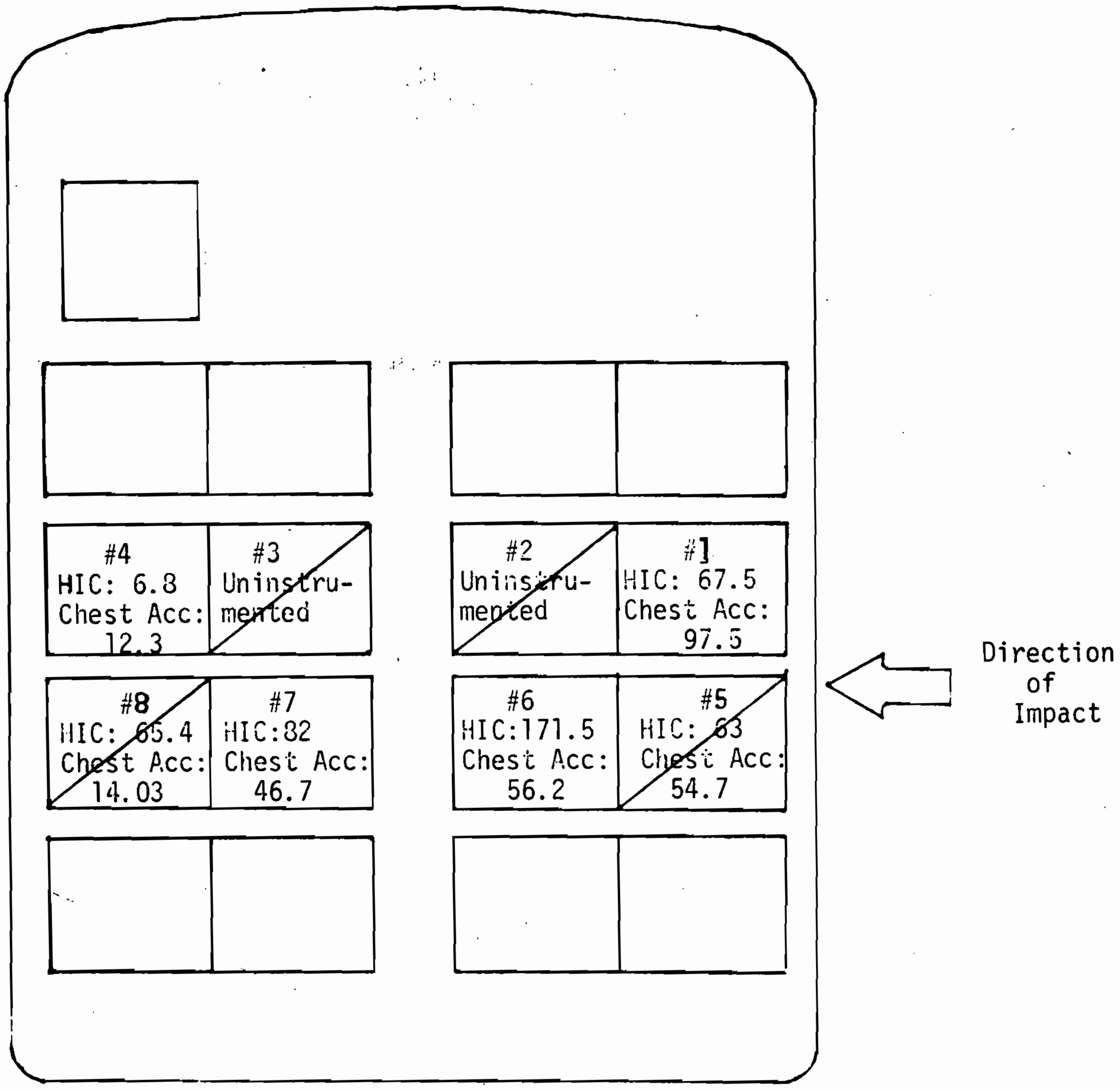
In his cover memo presenting test data, Morris Adams, Vice President for Corporate Affairs, Thomas Built Buses, explained why the Minotour was chosen: "This size bus was chosen over the larger buses with the feeling that this would be the most extreme situation and would give us the most violent results, and if things went satisfactorily in this size bus, we could feel assured that it would be even better in the larger buses."

The school bus had six instrumented 50th percentile dummies, one uninstrumented 6-year-old dummy, and one uninstrumented 5th percentile dummy. Four dummies were lap belted; the other four were unrestrained.

The test results are shown on the next page.

Both restrained and unrestrained dummies were recorded as sustaining nonlife threatening chest and head crash forces during the side impact. Thomas Built Buses concluded that "compartmentalization works as it was designed to work in frontal or side impacts. These tests also indicate that in the case of the side impact there seems to be very little significant difference between the belted and unbelted dummies in these test conditions relating to head and chest injuries."

The Safety Board believes the Thomas Built Buses crash tests provide an indication of what can be expected from a 30 mph side impact involving a schoolbus transporting both lap belted and unrestrained passengers. Since a belted dummy was seated to an unbelted dummy during the test, test results do not necessarily provide an indication of the head or chest injuries to be expected if a small schoolbus transporting all lap belted passengers is involved in a side impact, nor for that matter, what to expect if all passengers are unrestrained.



Key to dummies used:

Position 1: 50% instrumented, unrestrained
Position 2: 6-year-old restrained by lapbelt (uninstrumented)
Position 3: 5% belted (uninstrumented)
Position 4: 50% instrumented, unrestrained
Position 5: 50% instrumented, restrained by lapbelt
Position 6: 50% instrumented, unrestrained
Position 7: 50% instrumented, unrestrained
Position 8: 50% instrumented, restrained by lapbelt

APPENDIX K

NATIONAL SAFETY COUNCIL SCHOOLBUS ACCIDENT STATISTICS

School bus accidents, 1985

School bus transportation accidents killed about 125 persons in the school year 1984-1985, including 45 pupils, 5 bus drivers and 70 other persons.

Of the pupils killed, about 15 were passengers on school buses and 30 were pedestrians either approaching or leaving a loading zone. More than half of the pupil pedestrian victims were struck by the school bus which they were entering or leaving. States that reported on-board pupil fatalities and the number of fatalities are as follows: Ariz. (2), Calif. (1), Mass. (6), Minn. (1), Mo. (1), N.C. (6), and Pa. (1). (pedestrians)

Injuries in school bus related accidents totalled about 10,400 of which 6,700 were students.

The table on page 91 shows certain details of the injury and property damage accidents which occurred in calendar year 1985. Types of school bus accidents not itemized include an estimated 300 pedestrian, 120 bicycle, and 5 railroad accidents. About eight out of ten accidents involved property damage with no injuries.

Characteristics of school bus transportation

Interpretation of school bus accident data is complicated by the many variations between state operations, by lack of standard definitions of terms, and by lack of comparable reporting by states.

The state totals in the table on page 91 are shown as reported by the states. The U.S. totals are National Safety Council estimates developed by inflating the total from reporting states to compensate for the portion from missing states. State figures are weighted based on the number of pupils transported in that state.

Terms and reporting classifications

Vehicles. Included are regular school buses and other nonfamily-owned vehicles used in transporting pupils.

Annual bus mileage. Total mileage includes deadheading (traveling with no pupil passengers) and extracurricular activity trips. Data from nine states indicate that deadheading may average about 19 per cent of total mileage, ranging from practically none in some states, up to one fourth of the total bus mileage in others, depending on arrangements for driver and bus storage. Extracurricular mileage, based on 22 states, is indicated to be about 8 per cent of total mileage, also with a wide range among states. Such mileage includes athletic and field trips, shuttle service, and so on.

Pupils transported daily. A pupil is counted only once for each day transported, although usually two one-way trips or more are made daily.

Pupil passenger miles and average bus occupancy. Total pupil passenger miles cannot be computed directly from total bus mileage and pupils transported. Reports indicate average bus occupancy as upwards of 35 pupils, but it may rise or fall several times on a single route trip, as a bus in some instances may serve several schools along the route. Average occupancy for all bus mileage, including deadheading, may be only about 40 per cent of capacity. The National Safety Council estimate of total pupil passenger miles for 1985 is 70.0 billion.

Route trip. A route trip may represent (1) a one-way trip from the point where the first pupil boards the bus to the point where the last pupil leaves it, (2) a round trip, or (3) several separate trips ending at the same school(s). Miles per route trip reported for 18 states ranged from 15 to 50, averaging 30 miles. Pupils carried per route trip ranged from 21 to 79, averaging 50 pupils. Route trips per bus ranged from 1 to 4, averaging 2.2 trips daily.

School Bus Accidents by State

State	Vehicles	Annual Bus Mileage (000)	Pupils Transp. Daily	Type of School Bus Accident: Total[a]	Other Veh.	Non-coll.	Fixed Obj.	Prop. Damage Only Acc.	Persons Injured: Total	Pupils
U.S.[b]	350,000	3,400,000	21,800,000	28,000	23,000	500	2,000	23,000	10,400	6,700
Alabama	7,048	54,077	403,881	312	288	3	7	290	100	88
Alaska	600	7,200	40,000	95	75	0	18	79	...	...
Arizona	3,500	32,108	194,529	202	192	1	6	136	173	80
Arkansas	4,182	40,649	265,916	230	78	1	...	201	56	46
California	17,248	261,603	882,541	1,737	1,171	79	135	1,347	787	592
Colorado	5,085	41,282	223,640	299	280	6	13	283	124	82
Connecticut	4,629	...	215,497	940	910	1	21	800	213	90
Delaware	1,251	15,632	81,043	75	59	0	7	62	100	87
Dist. of Col	151	1,800	2,475	65	31	0	0	65	1	0
Florida	8,240	139,353	744,185	938	720	32	171	771	428	311
Georgia	9,495	84,338	814,822	991	712	...	133	...	306	249
Hawaii	730	11,342	38,900	...	...	...	...	...	...	...
Idaho	1,998	18,989	122,000	135	108	6	0	126	34	19
Illinois	15,523	180,784	889,734	2,414	1,882	18	38	1,987	794	276
Indiana	10,356	59,529	647,801	856	...	...	...	723	262	107
Iowa	6,801	63,087	248,368	500	333	26	121	443	137	81
Kansas	5,038	41,358	158,766	248	221	8	10	190	94	21
Kentucky	6,887	72,422	453,207	914	724	26	57	758	246	175
Louisiana	7,467	64,156	576,516	777	741	12	10	393	384	301
Maine	2,287	27,235	165,183	192	185	0	5	149	83	44
Maryland	4,933	75,843	442,387	1,065	944	14	104	...	98	27
Massachusetts	7,421	58,699	507,035	1,060	585	0	85	918	153	129
Michigan	13,648	107,683	964,293	30	9	0	1	10	20	1
Minnesota	10,580	93,138	831,214	723	686	5	12	698	...	...
Mississippi	5,526	42,159	359,435	382	362	4	15	3[illegible]	90	59
Missouri	9,343	96,909	451,090	632	548	0	39	520	251	174
Montana	1,342	16,678	58,643	74	67	2	5	67	7	7
Nebraska	3,495	30,585	56,151	123	115	1	4	92	31	30
Nevada	874	11,278	55,174	62	54	0	3	41	21	15
New Hampshire	1,926	11,873	96,371	166	141	0	19	130	55	28
New Jersey	12,624	128,037	629,004	582	448	41	44	272	308	202
New Mexico	2,038	28,127	131,082	233	190	11	28	188	45	31
New York	26,304	168,778	1,658,063	466	402	4	18	282	376	261
North Carolina	12,915	111,945	712,478	1,168	940	7	7	802	947	572
North Dakota	2,175	25,805	49,075	28	20	0	2	18	6	4
Ohio	15,673	157,526	1,310,660	1,354	...	...	...	1,036	318	318
Oklahoma	6,385	50,637	296,349	427	358	1	48	367	121	60
Oregon	4,327	40,854	222,899	343	274	1	61	318	32	10
Pennsylvania	19,703	239,846	1,382,337	1,752	1,505	46	162	...	461	160
Rhode Island	...	...	...	...	...	...	...	...	...	...
South Carolina	5,956	61,789	442,384	796	745	15	16	777	671	629
South Dakota	1,215	...	46,318	75	61	1	6	64	37	29
Tennessee	6,306	66,144	556,484	831	637	26	66	715	154	148
Texas	22,481	181,000	1,000,000	1,228	1,084	1	21	898	651	557
Utah	1,483	16,482	116,189	102	99	0	1	91	21	2
Vermont	...	...	...	...	...	...	...	...	...	...
Virginia	9,130	80,759	725,333	686	615	16	29	547	279	163
Washington	6,107	63,367	384,627	310	294	2	7	217	140	28
West Virginia	2,973	37,372	285,650	665	467	0	195	650	19	6
Wisconsin	6,983	75,445	464,548	866	650	0	142	675	357	140
Wyoming	1,411	13,680	40,791	34	30	1	1	24	36	19

Source: National Safety Council survey of state departments of education and state traffic authorities. Most reports cover 1984-1985 school year or 1985 calendar year. U.S. totals are Council estimates for the calendar year 1985.
[a]Totals include additional accident types not shown separately.
[b]Procedures for estimating U.S. totals were revised for the 1985 edition. U.S. totals in this edition are not comparable to estimates prior to the 1985 edition.

SCHOOL-COLLEGE ACCIDENTS, 1985

Accidental deaths and death rates of children 5-14 years

	1985 Deaths	Rate[a]
TOTAL	4,000	11.8
Motor-vehicle	2,100	6.2
Pedestrian	1,000	2.9
Home	800	2.4
Public nonmotor-vehicle	1,000	2.9
Work	100	0.3

[a]Deaths per 100,000 population.

Accidental Deaths by Type of Accident, Ages 5-22, 1983

Almost 20,000 school and college aged children and young adults died accidentally in 1983 according to the latest detailed information from the National Center for Health Statistics (see table below). Motor-vehicle accidents are the leading cause and drowning is the second leading cause of accidental death for all individual ages from 5 to 22. Fire deaths rank third for ages 5 to 11 and age 13, while firearms deaths are third highest for age 12 and ages 14 to 22.

Age	All Accidents	Motor-Vehicle	Drown-ing	Fires, Burns	Fire-arms	Falls	Poison (solid, liquid)	Poison by Gas	Mechanical Suffo-cation	Other Accident
5 to 22 years	**19,883**	**13,663**	**2,033**	**727**	**657**	**374**	**288**	**250**	**232**	**1,881**
5 years	465	216	82	82	11	5	1	5	10	53
6 years	420	222	67	50	5	7	1	2	8	58
7 years	438	215	74	63	17	6	1	3	8	51
8 years	349	198	64	36	3	4	0	3	7	36
9 years	315	177	46	31	9	6	0	3	15	28
10 years	337	168	60	28	22	9	1	1	9	39
11 years	370	192	54	34	28	3	1	4	11	43
12 years	462	234	77	30	32	8	1	1	21	58
13 years	526	280	83	46	40	10	10	3	15	59
14 years	639	361	104	22	36	12	6	9	22	67
15 years	840	519	101	18	58	14	15	10	16	89
16 years	1,293	950	133	21	44	17	9	14	16	89
17 years	1,717	1,308	171	23	53	25	22	31	4	80
18 years	2,268	1,745	179	43	49	39	23	30	8	152
19 years	2,457	1,877	181	38	57	48	30	30	21	175
20 years	2,364	1,747	196	51	54	45	47	35	11	178
21 years	2,350	1,697	173	51	69	64	58	33	13	192
22 years	2,273	1,579	188	60	70	52	60	33	17	214

Source National Center for Health Statistics, 1983 data

Injuries at school and school days lost. Over 6 million persons (both students and nonstudents) suffer injuries in and around schools and colleges each year that are medically attended or that cause at least one day of restricted activity, according to 1980 and 1981 figures from the National Health Interview Survey. Injuries at schools and colleges cause an average of about 7 days of restricted activity and slightly less than 1 day of bed disability per case.

About 14 million days of school are lost by students aged 6 to 16 each year due to accidents in all locations.

Source National Center for Health Statistics, J.G. Collins, Persons injured and disability days due to injuries, United States, 1980-81. *Vital and Health Statistics*, Series 10, No. 149, DHHS Pub. No. (PHS) 85-1577. Public Health Service. Washington, D.C. Government Printing Office, Mar. 1985.

Student Accident Rates by School Grade

The table below summarizes more than 8,600 school jurisdiction accidents[a] reported to the National Safety Council for the 1983-84 school year. The rates are accidents per 100,000 student days. In the TOTAL column only, a rate of 0.10 is equivalent to about 8,000 accidents among the nation's enrollment.

The rates indicate principal accident types and locations within grade groups. Since reporting is voluntary, the experience may not be representative of the national accident picture. These rates are not comparable to rates of previous years due to a decrease in the number of schools included. See footnotes.

Location and Type	TOTAL[b]	Kgn.[c]	1-3 Gr.	4-6 Gr.	7-9 Gr.	10-12 Gr.	Days Lost per Inj.
Enrollment Reported (000)	*880*	*56*	*210*	*199*	*218*	*178*	
Total School Jurisdiction	**5.72**	**4.67**	**3.57**	**6.54**	**7.56**	**5.51**	**1.51**
Shops and labs	**0.25**	**0.00**	(d)	**0.03**	**0.47**	**0.50**	**1.13**
Homemaking	0.02	0.00	0.00	0.01	0.03	0.03	1.38
Science	0.02	0.00	0.00	0.00	0.04	0.06	1.04
Vocational, ind. arts	0.19	0.00	0.00	0.01	0.35	0.43	1.17
Other labs	0.02	0.00	(d)	0.01	0.03	0.03	0.97
Other shops	0.01	0.00	0.00	(d)	0.02	0.04	1.03
Building—general	**1.43**	**1.67**	**1.66**	**1.48**	**1.97**	**1.11**	**1.40**
Auditoriums and classrooms	0.49	0.91	0.45	0.61	0.52	0.27	1.36
Lunchrooms	0.08	0.12	0.05	0.10	[illegible]	0.06	1.51
Corridors	0.27	0.22	0.19	0.22	0.46	0.22	1.18
Lockers (room and corridor)	0.05	0.00	0.01	0.03	0.10	0.09	0.83
Stairs and stairways (inside)	0.22	0.04	0.08	0.18	0.41	0.24	1.75
Toilets and washrooms	0.07	0.16	0.09	0.09	0.04	0.02	0.96
Grounds—unorganized activities	**0.93**	**1.23**	**1.30**	**1.98**	**0.31**	**0.08**	**1.42**
Apparatus	0.19	0.58	0.36	0.31	0.02	(d)	1.36
Ball playing	0.16	0.02	0.08	0.43	0.12	0.03	1.14
Running	0.21	0.18	0.31	0.44	0.06	0.01	2.02
Grounds—miscellaneous	**0.40**	**0.62**	**0.36**	**0.66**	**0.36**	**0.19**	**1.60**
Fences and walls	0.02	0.06	0.02	0.05	0.01	0.01	0.72
Steps and walks (outside)	0.12	0.16	0.10	0.17	0.13	0.06	1.48
Physical education	**1.96**	**0.00**	**0.52**	**1.90**	**3.40**	**2.17**	**1.31**
Apparatus	0.13	0.26	0.11	0.14	0.16	0.09	1.46
Class games	0.17	0.16	0.12	0.30	0.16	0.14	1.08
Baseball—hardball	0.02	0.00	0.00	0.01	0.05	0.04	1.19
Baseball—softball	0.06	0.02	0.01	0.07	0.13	0.06	1.39
Football—regular	0.04	0.00	(d)	0.02	0.08	0.05	2.70
Football—touch	0.10	0.00	0.00	0.04	0.20	0.20	0.87
Basketball	0.33	0.00	0.01	0.15	0.74	0.52	1.06
Hockey	0.02	0.00	0.00	0.03	0.04	0.03	1.89
Soccer	0.10	0.00	0.02	0.15	0.17	0.09	1.33
Track and field events	0.09	0.08	0.04	0.11	0.16	0.03	1.53
Volleyball and similar games	0.15	0.00	0.01	0.09	0.25	0.32	0.95
Other organized games	0.17	0.06	0.04	0.22	0.31	0.09	1.07
Swimming	0.04	0.00	0.00	0.01	0.10	0.03	0.81
Showers and dressing rooms	0.05	0.00	0.00	0.02	0.13	0.04	1.29
Intramural sports	**0.07**	**0.00**	**0.00**	**0.01**	**0.14**	**0.13**	**2.85**
Football—regular	0.02	0.00	0.00	(d)	0.04	0.08	1.31
Basketball	0.01	0.00	0.00	(d)	0.03	0.02	1.00
Interscholastic sports	**0.27**	**0.00**	**0.00**	(d)	**0.41**	**0.81**	**1.91**
Football—regular	0.11	0.00	0.00	0.00	0.15	0.34	1.50
Basketball	0.05	0.00	0.00	(d)	0.06	0.15	0.90
Track and field events	0.02	0.00	0.00	0.00	0.04	0.05	1.52
Special activities	**0.07**	**0.02**	**0.02**	**0.10**	**0.08**	**0.08**	**1.60**
Trips or excursions	0.03	0.02	0.02	0.07	0.02	0.02	1.28
Going to and from school (MV)	**0.23**	**0.22**	**0.20**	**0.22**	**0.21**	**0.30**	**2.26**
School bus	0.11	0.08	0.11	0.12	0.13	0.07	1.15
Other mot. veh.—pedestrian	0.06	0.12	0.07	0.08	0.05	0.02	3.73
Other mot. veh.—other type	0.05	0.02	0.01	0.01	0.01	0.21	1.31
Going to, from school (not MV)	**0.11**	**0.22**	**0.12**	**0.13**	**0.13**	**0.06**	**3.59**
Bicycle—not mot. veh.	0.01	0.00	(d)	0.03	0.01	0.01	1.81
Other street and sidewalk	0.06	0.12	0.08	0.06	0.07	0.01	6.79

Source Reporters to the National Safety Council.
[a]Accidents are those causing the loss of one-half day or more of (1) school time or (2) activity during nonschool time, and/or any property damage as a result of a school jurisdictional accident.
[b]Some totals include data not shown separately [c]Adjusted for half day. [d]Less than 0.005

APPENDIX L

OCCUPANT PROTECTION RECOMMENDATIONS FROM 1968 UCLA SCHOOLBUS CRASH TESTS PUBLISHED IN PAPER ENTITLED "SCHOOL BUS PASSENGER PROTECTION" BY SEVERY, BRINK AND BAIRD

SEATING UNITS - Seat designs ranging from frameless air seats to nonpadded hard fiberglass shell seats with tubular frames were evaluated; some seats had no head support, no lateral support and no padded backrest (to protect passengers from the rigid knife-like seatback) while some were safety seats, designed and shown substantially to protect the passengers from abusive collision forces, regardless of direction. Properly designed bus seats provide an inner protective shield around their precious cargo while also compartmentalizing the passengers to reduce the possibilities of their interacting with each other during all but the most devastating of collisions. In general, seats in buses are the initial and very frequently the only structure contacted by passengers during collision. Special attention to their construction can contribute very markedly to bus passenger safety.

1. Low back seat units, seatback height less than 28 in., greatly increase chances of injuries during school bus accidents. Seats most commonly encountered in school buses have seatback heights ranging from 18-20 in. These low back units provide no head support except for very young school children and leave the passenger in an extremely vulnerable condition when the vehicle is rear-ended. In addition, for the head-on collision, the lap-belted passenger, even the 3-year-old in some instances, pivoted about the belt and struck the top horizontal edge of the low seatback ahead in a manner that applied extremely dangerous forces to the face, neck, and chest of the individual.

2. School bus seat anchorages and seat cushion fasteners should not fail from forward decelerations under 30 G and should comply with other related performance criteria that become a part of the Federal Motor Vehicle Safety Standards. The fact that most seat anchorages held during the UCLA 30 mph head-on collision is attributed to the following factors: most of the seats were special units and required individualized techniques to anchor them (UCLA engineers made certain these anchorages would sustain the contemplated impacts so that evaluations of restraints, etc., would not be compromised). The fact that approximately half of the passengers were restrained by systems generally independent of the seat reduced the inertia forces sustained by these seats.* The principal factor is that the bus passenger compartment was subjected to a peak deceleration of only 12 G in the head-on collision because of the bumper mismatch and shifting of bus body-to-frame anchorages. This unusually low deceleration was adversely achieved by the front passenger compartment being crushed from bumper mismatch.

3. Seats not designed to accommodate the added stress of multiple lap belts attached to the seat can be retrofitted with a satisfactory structure to accomplish this modified performance. This modification should not be accomplished unless the seatback height is at least 28 in. It was found that bus seats were not designed to withstand multiple loads from belts attached to the seat. Therefore, a tubular structure with a horizontal belt anchorage manifold was installed in such a manner that it would not impose a trip hazard or complicate cleaning problems. This device was evaluated under collision conditions and effectively carried the restraining loads of these belts through separate floor attachments without adding stresses to the existing seat anchorages. It should be pointed out that retrofit of low seatback units with safety belts is strongly discouraged because low seatbacks greatly intensify and channel impact forces to the face, neck, and chest for passengers thrown against them; these installations also intensify whiplash injuries, owing to the absence of effective shoulder and head support.

4. Seatback strength should include allowance for passengers thrown forward against the backrest. Even when a bus is provided with lap belts, not all passengers will use them. Additionally, lap-belted taller persons will flail their heads and chests against the seatbacks ahead of them during collisions. School bus seatback designs should be of sufficient strength to withstand without failure a 30 G deceleration in the forward direction (head-on) and a 20 G acceleration in the forward direction (rear-end); in addition, a 3000-lb force applied to the backrest longitudinally forward at 16 in. above the seat level for the 30 G deceleration exposure and a 2000-lb force, similarly applied, for the 20 G exposure except in the reverse direction.

5. Elastic rebound of seatbacks increased the chances of passengers sustaining multiple impact injuries. On rebounding from his head impact with the Plymouth windshield, during the rear-end collision, the front seat passenger contacted his seatback with sufficient force to rebound him into the now shattered windshield, striking it forcibly for a second time. This rebound into the windshield would not have occurred for a lap-belted passenger and the severity of his first contact would have been significantly less.

6. Plastic deformation of high seatbacks reduce lap-belted passenger's rebound towards seat ahead in rear-end collisions but greatly increase chances of injury for passengers thrown against them. During the rear-end collision, high backed seats offered adequate support for the head and torso and when the seatback yielded rearward approximately 20 deg. rebound was diminished for the lap-belted passenger. A disadvantage, however, of the low seatback being forced into a semi-reclined position is that the passenger to the rear is more likely to strike it on rebound. This rebound hazard would be intensified if a front-end impact occurred, following the rear-end collision.

7. For the moderately severe collision exposures reported in this paper, it was established that a well-designed safety seat would protect passengers from sustaining more than minor injuries. It is apparent that far safer seats can be provided on the basis of performance guidelines established by this paper. School districts quite properly specify for purchase the least expensive, most durable seats available. However, considering that school buses are used more than a decade, a higher initial investment that provides greatly improved safety and comfort is money well spent.

An adequately designed, properly structured and anchored high back contoured seat (28 in. or higher, well-padded back-

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*Only the driver was restrained in the 1944 Mack-Superior bus and many more of its seats failed during the head-on collision.

rest) provided with well-padded armrests, harness or a lap belt, built into the seat unit with retractable, inertial-lock mechanism, represents the essential features of a safety seat that provides sufficient protection for a bus passenger to sustain, with probably no more than minor injuries, a 30 mph head-on or 60 mph side and rear-end collisions, as reported in this study. The crash performance of seats designed as safety seats represents a decided improvement over conventional seats. This was borne out in a prior series of experiments designed to evaluate the Liberty Mutual safe-seat configuration. (5) As demonstrated by the Cox 6LW contour safety seat with head support and built-in cross-chest lap-belt restraint, the individual from child to adult size can ride out a severe rear-end collision in an uneventful manner. This seat was equally as effective in protecting its occupant from the side-impact forces and the authors are confident that if the rear anchorages for this seat had been adequately attached for the head-on collision experiment, the occupant would have been protected against injury-producing forces for this exposure as well.

8. Seatback height for all school buses should be at least 28 in. While it may be argued that school buses bought exclusively for pre-school activities or exclusively for grade school use should not be required to include high back seats, the purchaser may have no control over its use for special school functions or over its use after it is sold. In rural areas, it is not even acceptable to have part low back and part high back seating within a given bus even though one bus may carry children from the 1st through 12th grades. The adverse interaction of passengers from high back seats thrown against low back seats is clearly documented in this paper.

The high back Superior 26 in. seatback allowed the head of the 13-year-old to contact the top edge of his backrest during the rear-end collision. High back seats (28 in. or more) greatly contribute to the compartmentalization of passengers thereby reducing the chances of injuries sustained by passengers being hurled against one another, regardless of their size.

9. Seat belts recommended for safety seats.* These bus experiments, the many actual school bus accidents investigated by the authors, the many types of collision experiments conducted during the past 16 years by the authors and investigations by others, clearly establish the value in passenger protection of lap belts when used with high back seats. The greatest single contribution to school bus passenger collision safety is the high strength, high back safety seat. Next in importance is the use of a three-point belt, a lap belt or other form of effective restraint. These restraints can be added to the safety seat at very little added cost and their presence provides the continuity needed for proper training of youth concerning habitual use of restraints when riding in any vehicle.

10. Low back seats (backrest less than 28 in.) common to school buses built in 1966 and earlier should not be retrofitted with lap-type safety belts, unless the low backrests are replaced with adequately designed high backrests. During front-end impacts and following rebound from their seatback for rear-end collisions, the lap-belted passenger pivots about his belt and slams his head, face, and, if tall enough, his chest into the seatback ahead. The low back seat presents dangerous surfaces to the belted or unbelted passenger hurled forward against it during collision. In addition, exposure to serious back and neck injuries results when passengers in low back seats experience a rear-end collision. Forces to the passenger as a result of a rear-end collision are increased if a lap belt is worn because it secures the hips thereby intensifying the fulcrum-like action of the seatback forces.

11. Seatbacks and armrests should be designed using well-padded, broad surfaced metal frames designed to provide the required strength and attenuate head impact forces in accordance with the performance specifications of the Federal Motor Vehicle Safety Standard No. 201, S 3.2. As stated in a prior conclusion, within the school bus passenger compartment, seats are the most important single contribution to collision safety, second to none. The seat requires a strong frame to prevent seat inertial forces and free-body impact forces from breaking it free from its mounts. This strength must be designed into the seat so that small surface areas and rigid structures are not encountered during "bottoming-out" type head impacts.

12. The narrow, thin padding covering rigid tubular structures such as the tops of seatbacks, and so forth, represents an unsatisfactory solution to the problem of an inadequate design. Reference to prior discussions in this section sets up guidelines for eliminating these injury-producing structures.

13. Seats should not be provided with rigid protruding structures such as handgrips, handrails and similar injury-producing fixtures. This conclusion is in keeping with prior conclusions and relates to any structure against which a passenger can be thrown.

14. The air seat did not impress the authors as being a practical approach to school bus passenger protection during collisions. The inflated seat, the Martin Air seat tested in this crash series, represents an interesting variation of passenger protective devices. The air seat is readily deformable and could minimize injuries of passengers thrown against it; however, this readily deformable seat in the head-on collision carried the disadvantages of providing a very inexacting restraint to its occupant as well as an inadequate restraint to those passengers thrown against it. Also, during the rear-end collision, no real back support was provided, although the head and back were kept in a good postural relationship as the entire body of the adult flailed into a fully reclined position, bringing the head hard against the knees of the passenger to his rear. From this reclined position, a passenger could readily slip from under the lap belt and become injured as though he were unrestrained. The air seat provides no significant restraint in the lateral direction against the forces of a side impact even when the occupant is con-

*Safety seat, see discussion for conclusion No. 6 for description.

strained by a lap belt, owing to the ease with which the air seat deflects sideways, allowing the passenger to contact the side panel and window of the bus. Without a safety belt, the air seat may bounce its passenger into injury-producing structures. The durability of an inflated seat is certainly questionable and particularly in the presence of school children who would find it difficult to resist the temptation of puncturing the seats.

15. School bus seats at the time of this study are grossly inadequate for protecting passengers. This conclusion is adequately documented by the preceding conclusions and corresponding discussions.

RESTRAINTS - A list of passenger-protective devices would generally show restraints at the top, with the seat a close second The reason passenger seats are regarded as more important than individual restraints for the protection of school bus children is the close proximity of the occupants to school bus seats as contrasted to passenger car seats. The compartmentalization provided by school bus seats, if they are high back seats, serves as a very valuable constraint for all horizontal directions of impact. The performance of safety belts and harnesses in this study followed the lines clearly established in prior experiments. (3-5) Properly designed restraining devices direct collision forces to the strong parts of the body in a manner least likely to produce injuries.

1. Lap-type safety belts would provide substantial additional protection to the school bus passengers, seated in high back seats that have efficient padding on the rear panels of its backrests. The use of a lap belt with a low seatback exposed passengers to extreme hazards of the seatback acting as a fulcrum across the face, neck, or chest when they are jackknifed across the horizontal surface of the seatback ahead of them. Accordingly, where seats with low seatbacks are installed, little benefit, if any, will be derived from use of seat belts for the typical front-end impact. In the head-on and side-impact experiments the passengers flexed at the hips, pitching their heads and upper torsos forward or to the side, striking objects within reach.

For the rear-end collision, lap-belted passengers responded slightly differently from unbelted passengers, but this factor was not nearly as important as was the height of the seatback. Lap belts should not be used for low seatback units because their use substantially increases the highly adverse forces to the spinal column resulting from whiplash and they virtually assure severe head or neck impacts with the low backrests ahead.

In the absence of armrests, the lap belt does provide some hip restraint against sideward movement, thereby reducing the forces that a displaced passenger may apply to a companion seated beside him during a side-impact collision. It is strongly recommended that seat belts not be installed in school buses unless higher seatbacks are also included with appropriate padding applied to all sides of the seatback.

2. The cross-chest lap-belt combination when properly fitted provides significantly more passenger protection than does the use of only a lap belt. A comparison was made between performances of three-point and lap belts in the prior conclusion. In contrast with no belt, the three-point belt allows its wearer to sustain but one-third the crash forces received by an unrestrained passenger of the same size seated beside him. More importantly, the forces are directed by the three-point restraint system to strong parts of the passenger's body in a generally noninjury-producing manner, as contrasted with head and chest injuries commonly sustained for unrestrained passengers on direct impact with the structures around them.

3. The cross-chest lap-belt combination restraint is not recommended for use in school buses. As has been found in prior intersection type collisions where the cross-chest belt has an anchor point to the rear and substantially above shoulder level, the belt passes across the throat in a manner which, during side-impact accelerations, applies injury-producing forces of a lacerative nature to the throat; the forces may be sufficient to cause neck injury and back injury as well. The cross-chest belt should have an anchor point, preferably built into the seat at shoulder level to prevent the belt from passing diagonally across the neck.

Passengers rebounding from the school bus side-impact collision slipped from behind their cross-chest belts, except where the upper anchor point was at their shoulder level; this left the passenger without upper torso restraint should any subsequent collision stresses develop, such as an upset.

During the head-on collision, passengers with higher-than-shoulder level anchor points showed evidence of asymmetrical restraining forces that force their upper torsos to rotate from behind the belt. Thus, an important condition with the effective use of the cross-chest lap-belt unit is to make certain the anchor point is at shoulder level in order to reduce the tendency for the cross-chest belt to injure the necks and to provide a more effective restraint for the head and upper torso against lateral and forward collision forces.

Considering the height variation shown in Table 5, representing the size variation common to school bus passengers, it is apparent that adjustments would have to be provided over a wide range in order to accommodate this requirement. The anchorage ladder necessary to achieve this would provide a rigid structure at shoulder and head level that could be struck by all but the shortest child. The potential gain in the use of cross-chest belts for school bus passengers is too questionable to warrant their further consideration. This position in no way should be construed to extend to passenger vehicles where proper anchorage heights can be obtained that would seldom need to be changed. The smaller passenger car does not provide nearly the passenger safety that is common to buses, making it more important to seek the best possible restraint.

4. Seats having strong but well-padded armrests provide important lateral constraint. Although seats with armrests are a little more difficult to enter, sit down in or exit from, they are more comfortable owing to their additional body support. During the bus side-impact experiment, it was observed that armrests provided a significant improvement in passenger safety by first, preventing individuals from being

ejected from their seats laterally to strike passengers across the aisle, and second, preventing the larger passenger from crushing against a smaller passenger who may be seated in his path. As a minimum requirement, each school bus seat should have an armrest on the aisle side.

5. The restraint bar provides acceptable restraining action against front-end type collisions but does not provide restraint against the lateral forces of a side impact. During the head-on collision, passengers jackknifed over the swing bar in a manner similar to lap-belted subjects. In a side impact the hips of passengers seated together "shift" in unison, with the lead-passenger sustaining the full crushing forces of his companions; the restraint bar does not restrain passengers individually against sideward movement. To be effective for rebound in a rear-end collision, the bar should have a positive latch to fix its position just above the passenger's lap, provided this unit is mounted to a seat with a high backrest.

6. The restraint bars of the type tested in these experiments are not recommended for school buses. The swing bar was positioned next to the lap, tending to prevent passengers from shifting forward during a front-end impact but was not considered a satisfactory restraint, particularly for side impact. In addition to allowing the passengers to shift to the right without restraint from the swing bar, this bar, because of its supports, presents a rigid structure, thereby increasing the chances of injury for a passenger flailed against the firm strut that supports the padded bar.

The restraint bar applies a restraining force to the lap-abdominal area. The thickness of the bar, in order to provide adequate force distribution, may develop back injuries and apply forces to the viscera which could be very injury-producing. There is also a possibility that school children would be injured when the bars are thrown up or thrown down by an overly energetic school child. Accordingly, although this device could be designed to provide some measure of protection for the forward impact, it is of little value in a side impact and for the reasons described above, is an impractical solution, considering the advantages of seat-anchored lap safety belts.

7. The air bag provides good impact attenuation for passengers thrown against it; further research is recommended before a decision can be made concerning its practicality for school buses. The air bag continues to be an interesting, somewhat effective impact moderator. The air bag provides a means for moderating impact forces to the passenger thrown against it. There are certain practical problems associated with its use, as typified by the following:

a. Except under exceptional circumstances, their performance is no better than properly structured, properly padded high back seat units.

b. The device for practical purposes would have to be stored in a folded condition with an external covering relatively impervious to the meddling nature of the school child passengers.

c. The device would have to be rapidly inflated during the onset of collision forces and this precludes the possibility of a centrally stored reservoir of compressed air or gas owing to the time lag common to such manifold systems. The cost of electrical operation of individual air valves, even of the simple life vest cartridge configuration, makes such an installation impractically expensive, both as to initial installation and the frequent maintenance.

d. Inadvertent firing of these devices could produce injuries, particularly f the children were in the process of boarding or leaving the bus when such inadvertent firing occurred.

e. Immediately following a collision, these devices would pose a serious impedance to an expeditious evacuation of injured and unconscious children owing to the tremendous volume they displace when fully inflated.

f. Unless the air bag is provided with a device limiting the build-up pressure during a passenger impact, it performs as an almost perfectly elastic restraining system having the serious disadvantage of rebounding the passenger with great force. To the extent that there is a pressure regulator, the effectiveness of the air bag is reduced because it must operate at a specific pressure level; this tends to limit the higher pressures that would effectively resist impact at higher levels.

The air bags used between the passenger head, chest and the feet in front of him for this experiment appeared to provide good impact attenuation for those individuals thrown against them when the bag did not rupture. In an exceptionally fortuitous sequence of events, one air bag was contacted by four different passengers, owing to their sequential contacts and rebound characteristics.

An air bag was also used in the passenger vehicle for Experiment 87. Taking into account the deceleration of the rear-ending Plymouth, reaching a frame peak of 18 G at 44 msec after the vehicles contacted one another, the right front seat passenger received little value from the air bag positioned between him and the instrument panel, considering his 109 G head impact at 112 msec. A three-point safety belt would have restrained him so that no component of his body would have sustained anything approaching the 109 G value he sustained. The air bag apparently ruptured relatively early during the collision, thereby losing its expected protection.

APPENDIX M

GLOSSARY OF ANATOMICAL AND INJURY TERMS*

abrasion, major
: wearing or rubbing away by friction of skin or mucous membrane into subcutaneous tissue, resulting in profuse bleeding and covering an area greater than 25 cm2 on the face or greater than 50 cm2 on the body

abrasion, superficial
: wearing or rubbing away by friction of the surface of cells or tissues from an area of skin or membrane, resulting in redness but without profuse bleeding; less than or equal to 25 cm2 or less than or equal to 50 cm2 on body body (even if there is profuse bleeding and/or into subcutaneous tissue)

amputation, traumatic
: cutting off a body part, such as a limb, as a result of an injury

aphasia
: loss or impairment of speech (due to trauma)

avulsion
: tearing away of a part of a body structure in which a portion is separated from underlying tissue and adjacent parts, and left hanging as a flap

avulsion, major
: tearing away of subcutaneous tissue and greater than 5 cm (2 inches) on face or greater than 10 cm (4 inches) on body

avulsion, superficial
: a tearing away of tissue not involving subcutaneous tissue regardless of length or involving subcutaneous tissue but less than or equal to 5 cm (2 inches) on face or less than or equal to 10 cm (4 inches) on body

brain stem
: the stemlike portion of the brain connecting it with the spinal cord

cervical
: pertaining to the neck

coma
: a state of unconsciousness with inability to respond, either verbally or through other recognized body motions, even to painful stimuli

comminuted
: broken or crushed into small pieces, as a comminuted fracture

* Excerpts from the 1985 National Accident Sampling System (NASS) Injury Coding Manual Prepared for the U.S. Department of Transportation. NASS investigators use an AIS-code based injury coding system.

compression fracture
a fracture produced by compression (for example, a fracture of vertebrae)

concussion (of the brain)
clinical syndrome characterized by immediate and transient impairment of neural function such as alteration of consciousness, disturbance of vision, etc., due to mechanical forces

contusion (of the brain)
structural alteration of the brain, usually involving the surface, characterized by brain tissue death, and due to mechanical forces

contusion, major (integumentary)
bruise characterized by significant hematoma (greater than 25 cm2 on face, or greater than 50 cm2 on body) and swelling of subcutaneous tissue without a break in the skin or membrane; commonly referred to as "black and blue"

contusion, superficial (integumentary)
bruise of any size characterized by minor hematoma (less than or equal to 25 cm2 on face, or less than or equal to 50 cm2 on body) even with swelling of subcutaneous tissue; with little or no swelling and without a break in the skin; commonly referred to as "black and blue"

decerebrate
a type of movement, spontaneous or induced, characterized by extensor rigidity of one or both upper extremities and indicative of brain stem dysfunction

decorticate
a type of movement, spontaneous or induced, characterized by abnormal, inappropriate flexion of the upper extremity and extension of the lower extremity

detachment
separation of an anatomic structure from its support; most common example is detached retina of the eye, in which retina separates from choroid

disastasis
form of disclocation in which there is separation of two bones normally attached to each other without existence of a true joint (e.g., symphysis pubis)

dislocation
displacement of a bone at a joint from its original anatomical position

dura (also dura mater)
outermost, toughest and most fibrous of the three membranes covering the brain and spinal cord

edema
presence of abnormally large amounts of fluids in the body tissue

epidural
situated upon or outside the outermost and most fibrous of the three membranes (dura) covering the brain and spinal cord

flail chest
term used to describe an abnormal ability for the chest to contract and protract (i.e., respiratory embarrassment) as a result of significant injuries to any one or more of the structures in the thoracic cavity

fracture
break in a bone - see specific fracture for more precise definition

fracture, basilar skull
break in the base of the cranium

fracture, closed
break in a bone that does not produce an open wound in the skin; commonly called a simple fracture

fracture, comminuted
break in a bone in which the bone is splintered or fragmented

fracture, compound - see fracture, open

fracture, depressed skull
break in the skull in which a fragment(s) is pushed inward, causing a change in the normal skull contour

fracture, displaced
break in a bone that causes one segment to be moved out of its normal anatomical relation with the remainder of the bone

fracture, linear
a break in a bone extending lengthwise

fracture, open
break in a bone in which there is an external wound leading to the break; commonly called compound except in the head where "open" implies exposure of dura or brain surface

fracture, ring
a brake in the base of the skull area surrounding forearm magnum (where spinal cord passes into skull); also referred to a "annular basal fracture'

fracture, simple - see fracture, closed

fracture, transverse
break in bone at right angles to the long axis of the bone

fracture, undisplaced
break in bone that does not cause the bone to be moved out of its normal anatomical position

hematoma
collection of blood within a confined area

hemiparesis
a slight paralysis on one side of the body

hemiplegia
paralysis on one side of the body

hemorrhage
blood flowing profusely in a relatively nonconfined space, such as bleeding resulting from a deep laceration

hemothorax
a collection of blood in the thoracic (chest cavity)

ileum
lower portion of the small intestine, extending from the jejunum to the large intestine

infarction, cerebral
an ischemic condition of the brain, producing a persistent focal neurological deficit in the area of one of the cerebral arteries

laceration, deep
a cut or incision into subcutaneous tissue and greater than 10cm (4 inches) on body or greater than 5 cm (2 inches) on face

laceration, superficial
a cut or incision not into subcutaneous tissue, regardless of length or into subcutaneous tissue, but less than 5 cm (2 inches) on face or less than 10 cm (4 inches) on body

Le Fort I fracture
a horizontal segmented fracture of the alveolar process of the maxilla (the supporting bone of the upper teeth), in which the teeth are usually contained in the detached portion of the bone

Le Fort II fracture
unilateral or bilateral fracture of the maxilla, in which the body of the maxilla is separated from the facial skeleton and the separated portion is pyramidal in shape; the fracture may extend through the body of the maxilla down the midline of the hard palate, through the floor of the orbit, and into the nasal cavity

Le Fort III fracture
a fracture in which the entire maxilla and one of more facial bones are completely separated from the brain case

ligament
a band of fibrous tissue that connects bones or cartilages, to support and strengthen joints; a double layer of peritoneum extending from one visceral organ to another

neurological deficit
visible or measurable effects of trauma, such as confusion, relestlessness, visual field defects (blurred/double/tunnel vision), amnesia, paralysis, loss of speech, seizure

paresis
partial paralysis

perforation
a hole through an organ or other body structure resulting from contact with an external force or object

puncture
a wound made by a pointed object - see also perforation

puncture, deep
a perforation into subcutaneous tissue and greater than 10cm (4 inches) on body or greater than 5 cm (2 inches) on face

puncture, superficial
a perforation into subcutaneous tissue regardless of length or into subcutaneous tissue, but less than or equal to 5 cm (2 inches) on face or less than or equal to 10 cm (4 inches) on body

quadriplegia
paralysis of all four extremities simultaneously; also called tetraplegia

rib, "cracked"
a partial fracture, one that does not break the bone through and through

rupture
forcible tearing or breaking of a body structure (i.e., membrane, organ, tendon, etc.)

severance - see transection

sprain
bending of a joint beyond it normal range of motion with partial rupture or other injury to its soft tissue attachments, but without luxation (dislocation) of bones; characterized by rapid swelling, heat, pain and disablement of the joint

strain
an overstretching of a muscle

subarachnoid
situated beneath the middle membrane covering the brain and spinal cord

subcortical
situated beneath the gray matter of the brain

subdural
situated beneath the outermost and most fibrous of the three membranes (dura) covering the brain and spinal cord

tear
a shearing injury — see also laceration, rupture

tetraplegia - see quadriplegia

thorax
: the bony cage consisting of the ribs which give it shape, muscles which cover the ribs and vital organs located within the cage, such as the heart, lungs; commonly called chest cavity

transection, severance
: a cut made across the long axis

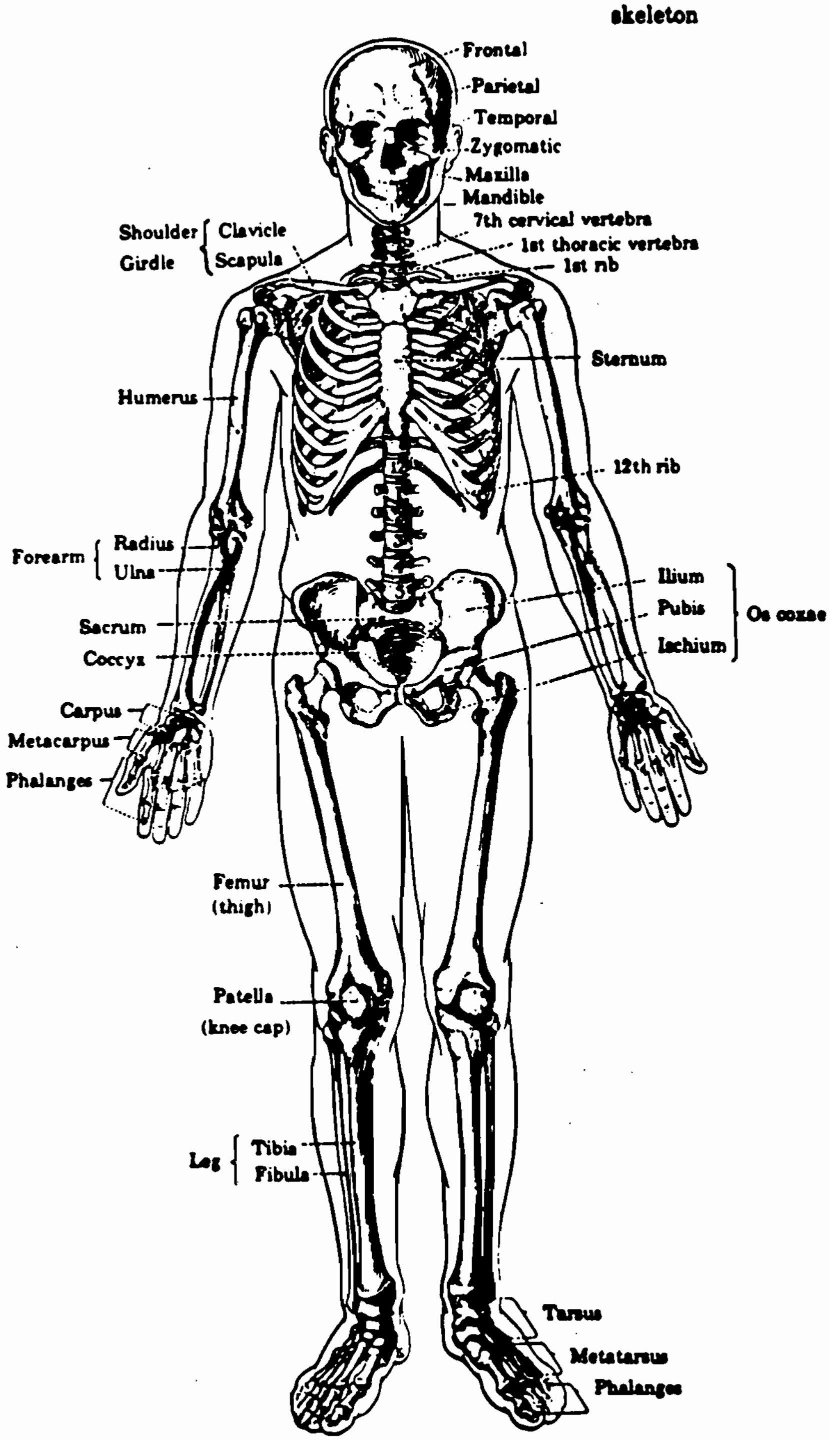
"whiplash"
: a popular term for hyperextension/hyperflexion injuries of the neck (cervical spine); the term should not be used to imply any specific resultant pathologic condition or syndrome

wound, closed
: an injury to the body caused by an outside force in which the skin is not broken

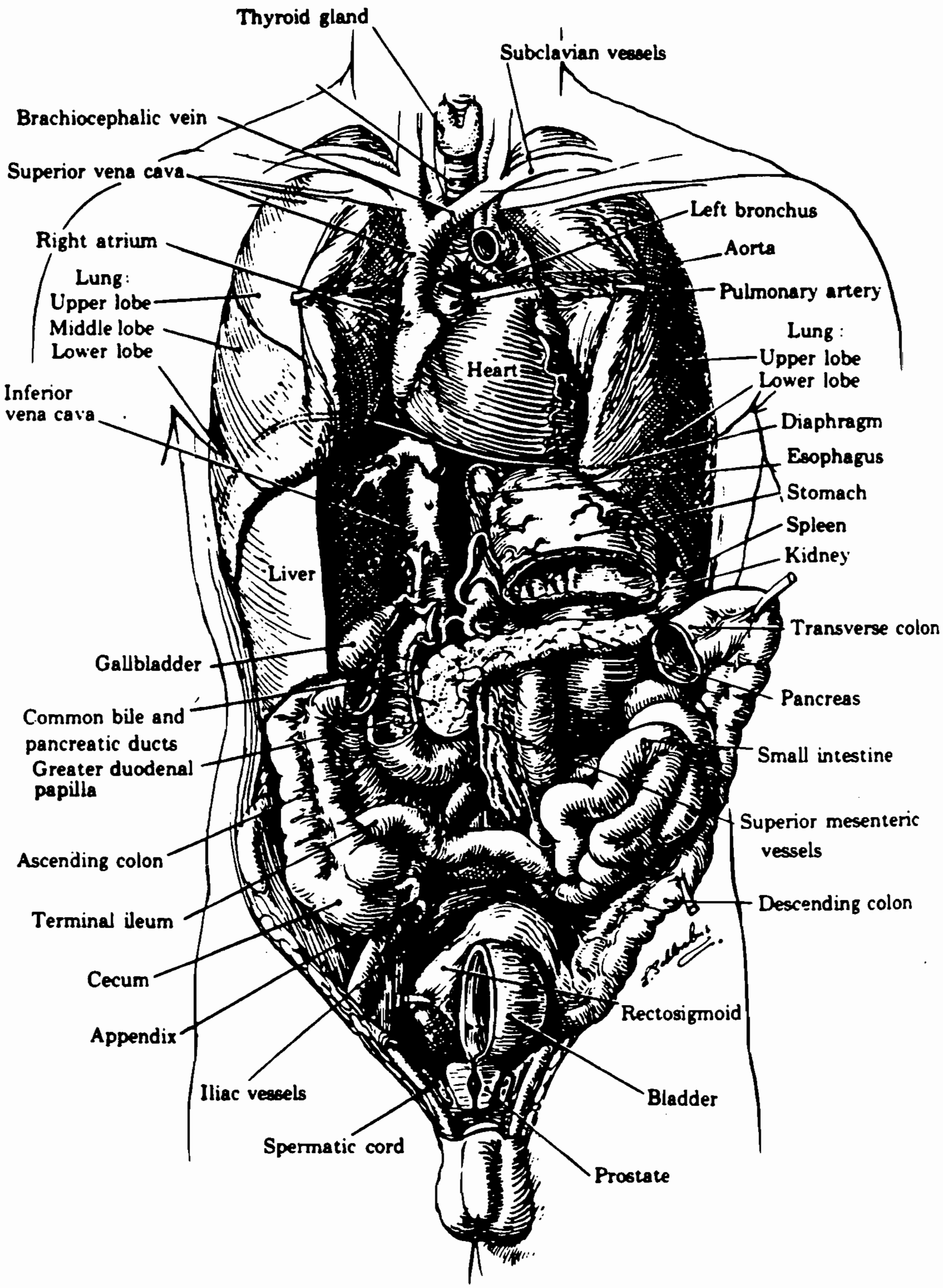
wound, open
: an injury to the body caused by an outside force in which the skin is broken

APPENDIX N

ANATOMICAL DRAWINGS



ANTERIOR VIEW OF HUMAN SKELETON
(King and Showers)

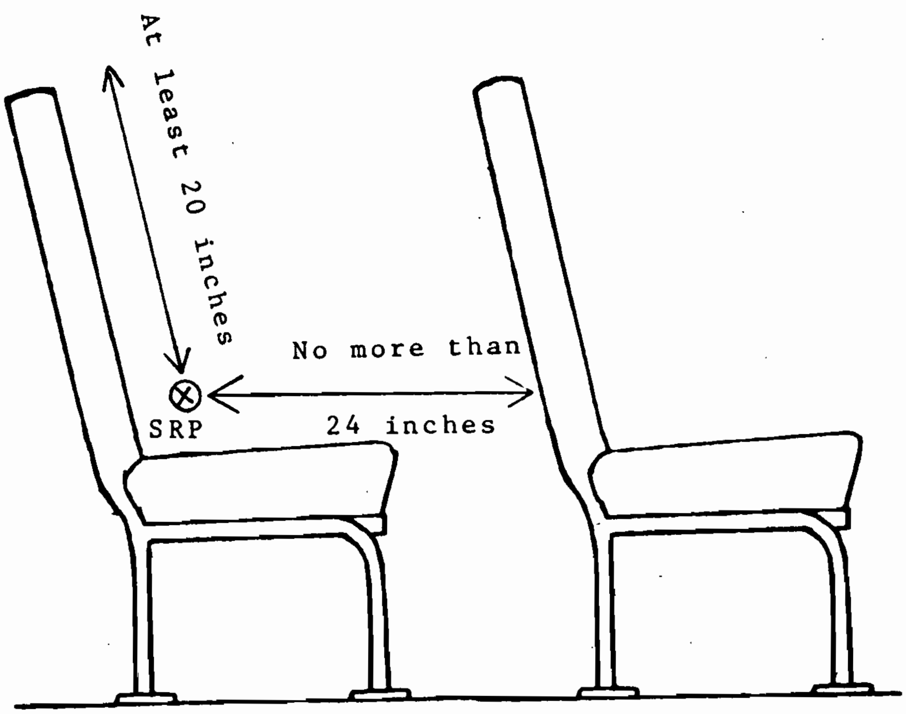


THORACIC AND ABDOMINAL VISCERA

APPENDIX O

ILLUSTRATION OF SEATING REFERENCE POINT AS IT AFFECTS FEDERAL REQUIREMENTS FOR SCHOOLBUS SEAT SPACING AND SEAT BACK HEIGHT

Schoolbus Seatback Height and Seatback Spacing Requirements
(as required by FMVSS 222, "Schoolbus Seating and Crash Protection" as of June 1986)

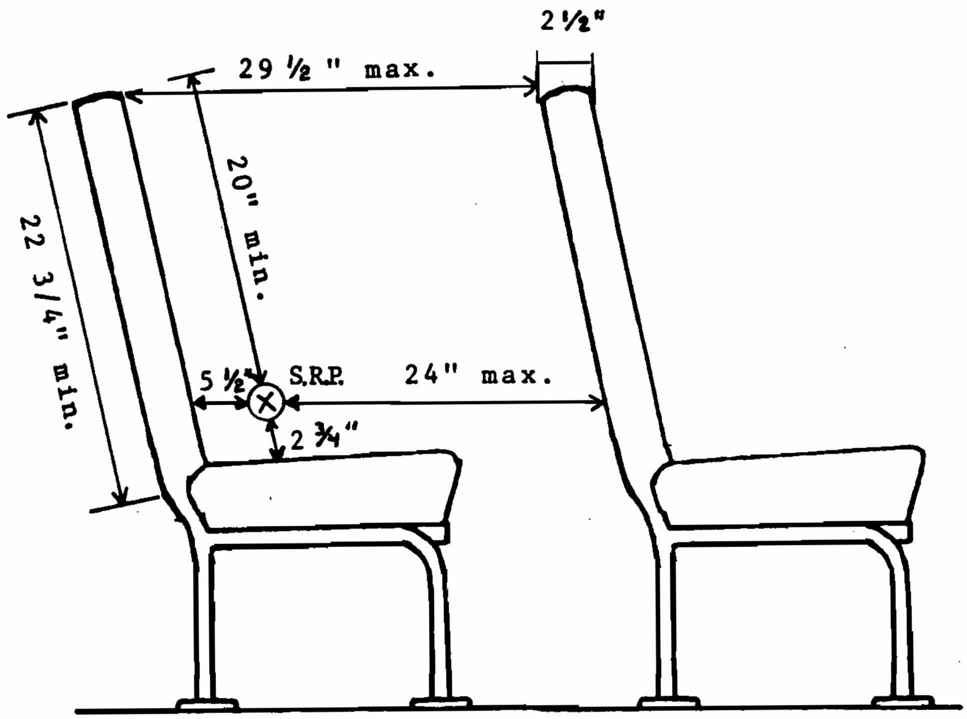


The Federal Government sets certain design parameters which schoolbus manufacturers must follow. One such parameter specifies the maximum width between seats and the minimum seatback height, all in terms of distance from a Seating Reference Point (SRP).

The SRP approximates the pivot center of a human torso and thigh. See the following sketch to find how Federal regulations translate into seatback height and seat spacing criteria as used by one manufacturer.

Note: Federal parameters have changed several times since the inception of FMVSS 222 so not all poststandard schoolbuses were manufactured under the same design restrictions.

Example of Placement of the Seating Reference Point (SRP)
As it Affects Seatback Height and Spacing



Note: Each schoolbus body manufacturer can determine the placement of the Seating Reference Point (SRP) on its seat as long as the pivot center of the human torso and thigh is located in accordance with SAE Standard J826. Hence, the placement of SRP varies slightly from manufacturer to manufacturer.

APPENDIX P

CHRONOLOGY OF FEDERAL SEAT BELT-RELATED RULEMAKING AFFECTING LARGE SCHOOLBUSES (1973 TO 1986, DOCKET N. 73-3)

The chart below outlines some of the Notices of Proposed Rulemaking (NPRM) which were issued in connection with the Federal standard for schoolbus passenger seating and crash protection (FMVSS 222). A proposed standard often is modified many times before it is issued as a final rule; a final rule also can be amended many times. Such is the case with FMVSS 222. Major development relating to lap belts for passengers as well as changes in seat back height and seat spacing are summarized in the chart since seat design interacts with belt performance. These proposals were published in the Federal Register (FR) as shown below. (FMVSS 222 as it now stands appears in appendix R.)

Restraint Requirement	Minimum Seat Back Height from Seating Reference Point (in inches)	Maximum Allowable Seat Spacing from Seating Reference Point (in inches)
Notice #1* (38 FR 4776, 2/22/73)		
Option 1: No restraint necessary but passenger seat must meet performance test requirements.	28	40
Option 2: Each passenger seating position to be equipped with lap belt anchored to seat and warning system to signal both passenger and bus driver if passenger failed to buckle belt after sitting down. Seat performance requirement modified from first option.		
Notice #2 (39 FR 27585, 7/30/74)		
Lapbelt requirement and warning system eliminated in favor of stringent seat strength requirements and passive protection (i.e., "compartmentalization").	24	23
Seat belt anchorages attached to seat frame suitable for lap belt required at each designated seating position.		

* Notice #1 established occupant protection requirements for all buses, not just schoolbuses. Rulemaking that followed restricted FMVSS 222 to schoolbuses and other buses sold for the primary purpose of carrying children to and from school.

Restraint Requirement	Minimum Seat Back Height from Seating Reference Point (in inches)	Maximum Allowable Seat Spacing from Seating Reference Point (in inches)
Notice #4 (40 FR 47141, 10/8/75)		
Seatbelt anchorage provision retained for large schoolbuses (more than 10,000 GVWR).	20	20
Lap belt installation required for all passenger seating positions in small schoolbuses (more than 10,000 GVWR). Lap belts must meet all FMVSS applicable to multipurpose vehicles.		
Notice #5 (41 FR 4016, 1/28/76) Final Rule		
Seatbelt anchorage provisions eliminated for large schoolbuses. Lap belt installation requirement for passengers of small buses retained.	20	20
Effective 10/26/76		
Notice #6 (41 FR 28506, 7/12/76)		
NHTSA denies petition by Physicians for Automotive Safety to: require installation of lap belts for passengers of large buses, issue a separate standard for seat belt assembly anchorages and raise seat back height from 20 to 24 inches as measured from SRP.		
Notice #13 (44 FR 18674-18675, 3/21/79) Amendment		
No change in restraint provisions. Increased maximum allowable seat spacing in school buses from 20 to 21 inches from SRP.	20	21
Effective 3/29/79		
Notice #15 (48 FR 12384, 3/24/83) Amendment		
No change in restraint provisions. Increased seat spacing from 21 to 24 inches.	20	24
Effective 3/24/83		

APPENDIX Q

DEPARTMENT OF TRANSPORTATION OUTLINE OF SAFETY STANDARDS PERTAINING TO SCHOOLBUSES

Thirty of the fifty Federal Motor Vehicle Safety Standards (FMVSS) apply to buses, including school buses. Six of these are of special interest:

(1) FMVSS No. 217 Bus Window Retention and Release.

(2) FMVSS No. 220 School Bus Rollover Protection.

(3) FMVSS No. 221 School Bus Body Joint Strength.

(4) FMVSS No. 222 School Bus Seating and Crash Protection.

(5) FMVSS No. 301 Fuel System Integrity

(6) FMVSS No. 302 Flammability of Interior Materials.

Standards (1) thru (5) were mandated by congress in the "School Bus Act of 74" (P.L. 94-346). Number (6), Flammability of Interior Materials, applies to all vehicles, except motorcycles, and is designed to prevent deaths and injuries from fires originating in the interior of vehicles from sources such as matches and cigarettes. This is done by requiring that all Interior materials have a low burn rate, (4 inches per minute, horizontal), allowing passengers sufficient time to evacuate the vehicle prior to serious fires involvement. Two of these standards were existing standards that were modified to include school buses:

FMVSS No. 217, Bus Window Retention and Release

This standard prescribes the minimum emergency exits; numbers, dimensions and opening characteristics for school buses in both size categories - under 10,000 pounds and over 10,000 pounds. It also provides for,

- Emergency door/starter interlock that prevents starting the school bus if the emergency door(s) are locked.
- An audible warning mechanism indicating the emergency door release mechanism is not in the "closed" position.
- Emergency exit identification, location, and instruction requirements.

FMVSS No. 301 Fuel System Integrity

This standard was fully effective for all vehicles under 10,000 pounds, except motorcycles, on September 1, 1977. It requires that fuel leakage be no more than one ounce per minute from any part of the fuel system when the vehicle is subject to:

(1) a 30 mph fixed barrier frontal collision at an angle of $\pm$ 30 degrees;

(2) a 30 mph rear end moving barrier collision and;

(3) a 20 mph moving barrier lateral collision;

A special test was precribed for large school buses over 10,000 pounds, and utilizes a moving barrier collision at 30 mph at any point (Other requirements such as fuel leakage limitation are the same).

The remaining three standards apply to school buses only:

FMVSS No. 220 School Bus Rollover Protection.

This standard applies to all school buses, and requires that a force of 1 1/2 times the unloaded vehicle weight be applied to the roof of the vehicle body structure. The downward vertical movement of the test plate cannot exceed 5 1/8 inches at any point, and emergency exits must be capable of being opened as specified in FMVSS No. 217.

FMVSS No. 221 School Bus Body Joint Strength

This standard applies only to large school buses over 10,000 pounds. It requires that"...each body panel joint shall be capable of holding the body panel to the member to which it is joined when subjected to a force of 60% of the tensile strength of the weakest joined body panel..."

FMVSS No. 222 School Bus Seating and Crash Protection

This standard applies to all school buses and is the basis of the "compartmentalization" concept of passenger protection.

School buses under 10,000 pounds must meet the following requirements:

- Conform to the restraint requirements of Standards 208, 209, and 210. (This is essentially the requirements for seatbelts (209) and associated anchorages (210).

All school buses must meet the following requirements except school buses over 10,000 pounds which are not required to comply with standards 208, 209, and 210.

- Conform to certain requirements for seatback height and and surface area.

  Each school bus passenger seat shall be equipped with a seat back that, in the front projected view, has a front surface area above the horizontal plane that passes through the seating reference point, and below the horizontal plane 20 inches above the seating reference point, of not less than 90 percent of the seat bench width in inches multiplied by 20.

- Seat backs must exhibit certain strength and deflection requirements, both forward and rearward:

  (The number of seating positions considered to be a bench seat is expressed by th symbol W, and calculated as the bench width in inches divided by 15 and rounded to the nearest whole number).

Seat performance forward

The following requirements must be met under the stated test conditions.

a) The seat back force/deflection curve shall fall within the zone specified.

b) Seat back deflection shall not exceed 14 inches;

c) The seat shall not deflect by an amount such that any part of the seat moves to within 4 inches of any part of another school bus passenger seat or restraining barrier in its originally installed position;

d) The seat shall not separate from the vehicle at any attachment point; and

e) Seat components shall not separate at any attachment point.

Apply a force of 700W pounds horizontally in the forward direction through the loading bar at the pivot attachment point in any horizontal plane $\pm$ 4 inches above or below the seating reference point of the school bus passenger seat behind the test specimen.

Apply additional force horizontally in the forward direction through the upper bar until 4,000W inch-pounds of energy have been absorbed in deflecting the seat back (or restraining barrier).

Seat performance rearward

The following requirements must be met under the stated test conditions.

a) Seat back force shall not exceed 2,200 pounds;

b) [In the case of a school bus manufactured on or after April 1, 1978, seat back deflection shall not exceed 8 inches;

c) The seat shall not deflect by an amount such that any part of the seat moves to within 4 inches of any part of another passenger seat in its originally installed position;

d) The seat shall not separate from the vehicle at any attachment point; and

e) Seat components shall not separate at any attachment point.

Position the loading bar so that it is laterally centered forward of the seat back with the bar's longitudinal axis in a transverse plane of the vehicle kand in the horizontal plane 13.5 inches above the seating reference point of the test specimen, and move the loading bar rearward against the seat back until a force of 50 pounds has been applied, then apply additional force horizontally rearward through the loading bar until 2,800W inch-pounds of energy has been absorbed in deflecting the seat back. Apply the additional load in not less than 5 seconds nor more than 30 seconds.

Seat cushion retention

The seat cushion shall not separate from the seat at any attachment point when subjected to an upward force of five times the seat cushion weight, applied in any period of not less than 1 nor more than 5 seconds, and maintained for 5 seconds.

Seat and Restraining barrier requirements

Each vehicle shall be equipped with a restraining barrier forward of any designated seating position that does not have the rear surface of another school bus passenger seat within 24 inches of its seatign reference point, measured along a horizontal longitudinal line through the seating reference point in the forward direction.

The horizontal distance between the rear of the front adjacent seat or the restraining barrier's rear surface and the seating reference point of the seat in front of which it is required shall be not more than 24 inches, measured along a horizontal longitudinal line through the seating reference point in the forward direction.

Head and Knee Impact Requirements

When any contactable surface of the vehicle within the zones specified is impacted from any direction at 22 feet per second by the head form, the axial acceleration at the center of gravity of the head form shall be such that the head impact criteria (HIC) value shall not exceed 1,000. The head form force distribution shall be such that the energy necessary to deflect the impacted material shall be not less than 40 inch-pounds before the force level on the head form exceeds 150 pounds. When any contactable surface within such zones is impacted by the head form from any direction at 5 feet per second, the contact area on the head form surface shall be not less than 3 square inches.

The head protection zones in each vehicle are the spaces in front of each school bus passenger seat which are not occupied by bus sidewall, window, or door structure and which, in relation to that seat and its seating reference point, are enclosed by the following planes;

a) Horizontal planes 12 inches and 40 inches above the seating reference point;

b) A vertical longitudinal plane tangent to the inboard (aisle side) edge of the seat;

c) A vertical longitudinal plane 3.25 inches inboard of the outboard edge of the seat, and

d) Vertical transverse planes through and 30 inches forward of the reference point.

The leg protection zones of each vehicle are those parts of the school bus passenger seat backs and restraining barriers bounded by horizontal planes 12 inches above and 4 inches below the seating reference point of the school bus passenger seat immediately behind the seat back or restraining barrier. When any point on the rear surface of that part of a seat back or restraining barrier is impacted from any direction at 16 feet per second by the knee form specified, the resisting force of the impacted material shall not exceed 600 pounds and the contact area on the knee form surface shall not be less than 3 square inches.

APPENDIX R

SELECTED FEDERAL MOTOR VEHICLE SAFETY STANDARDS

§ 571.220 Standard No. 220; School bus rollover protection.

S1. *Scope.* This standard establishes performance requirements for school bus rollover protection.

S2. *Purpose.* The purpose of this standard is to reduce the number of deaths and the severity of injuries that result from failure of the school bus body structure to withstand forces encountered in rollover crashes.

S3. *Applicability.* This standard applies to school buses.

S4. *Requirements.* When a force equal to 1½ times the unloaded vehicle weight is applied to the roof of the vehicle's body structure through a force application plate as specified in S5., Test procedures—

(a) The downward vertical movement at any point on the application plate shall not exceed 5⅛ inches; and

(b) Each emergency exit of the vehicle provided in accordance with Standard No. 217 (§ 571.217) shall be capable of opening as specified in that standard during the full application of the force and after release of the force, except that an emergency exit located in the roof of the vehicle is not required to be capable of being opened during the application of the force. A particular vehicle (i.e., test specimen) need not meet the emergency exit opening requirement after release of force if it is subjected to the emergency exit opening requirements during the full application of the force.

S5. *Test procedures.* Each vehicle shall be capable of meeting the requirements of S4. when tested in accordance with the procedures set forth below.

S5.1 With any non-rigid chassis-to-body mounts replaced with equivalent rigid mounts, place the vehicle on a rigid horizontal surface so that the vehicle is entirely supported by means of the vehicle frame. If the vehicle is constructed without a frame, place the vehicle on its body sills. Remove any components which extend upward from the vehicle roof.

S5.2 Use a flat, rigid, rectangular force application plate that is measured with respect to the vehicle roof longitudinal and lateral centerlines,

(a) In the case of a vehicle with a GVWR of more than 10,000 pounds, 12 inches shorter than the vehicle roof and 36 inches wide; and

(b) In the case of a vehicle with a GVWR of 10,000 pounds or less, 5 inches longer and 5 inches wider than the vehicle roof. For purposes of these measurements, the vehicle roof is that structure, seen in the top projected view, that coincides with the passenger and driver compartment of the vehicle.

S5.3 Position the force application plate on the vehicle roof so that its rigid surface is perpendicular to a vertical longitudinal plane and it contacts the roof at not less than two points, and so that, in the top projected view, its longitudinal centerline coincides with the longitudinal centerline of the vehicle, and its front and rear edges are an equal distance inside the front and rear edges of the vehicle roof at the centerline.

S5.4 Apply an evenly-distributed vertical force in the downward direction to the force application plate at any rate not more than 0.5 inch per second, until a force of 500 pounds has been applied.

S5.5 Apply additional vertical force in the downward direction to the force application plate at a rate of not more than 0.5 inch per second until the force specified in S4. has been applied, and maintain this application of force.

S5.6 Measure the downward movement of any point on the force application plate which occurred during the application of force in accordance with S5.5.

S5.7 To test the capability of the vehicle's emergency exits to open in accordance with S4.(b)—

(a) In the case of testing under the full application of force, open the emergency exits as specified in S4.(b) while maintaining the force applied in accordance with S5.4 and S5.5; and

(b) In the case of testing after the release of all force, release all downward force applied to the force application plate and open the emergency exits as specified in S4.(b).

S6. *Test conditions.* The following conditions apply to the requirements specified in S4.

S6.1 *Temperature.* The ambient temperature is any level between 32° F. and 90° F.

S6.2 *Windows and doors.* Vehicle windows, doors, and emergency exits are in the fully-closed position, and latched but not locked.

[41 FR 3875, Jan. 27, 1976, as amended at 41 FR 36026, 36027, Aug. 26, 1976]

§ 571.221 Standard No. 221; School bus body joint strength.

S1. *Scope.* This standard establishes requirements for the strength of the body panel joints in school bus bodies.

S2. *Purpose.* The purpose of this standard is to reduce deaths and injuries resulting from the structural collapse of school bus bodies during crashes.

S3. *Application.* This standard applies to school buses with gross vehicle weight ratings of more than 10,000 pounds.

S4. *Definitions.* "Body component" means a part of a bus body made from a single piece of homogeneous material or from a single piece of composite material such as plywood.

"Body panel" means a body component used on the exterior or interior surface to enclose the bus' occupant space.

"Body panel joint" means the area of contact or close proximity between the edges of a body panel and another body component, excluding spaces designed for ventilation or another functional purpose, and excluding doors, windows, and maintenance access panels.

"Bus body" means the portion of a bus that encloses the bus's occupant space, exclusive of the bumpers, the chassis frame, and any structure forward of the forwardmost point of the windshield mounting.

S5. *Requirement.* When tested in accordance with the procedure of S6., each body panel joint shall be capable of holding the body panel to the member to which it is joined when subjected to a force of 60% of the tensile strength of the weakest joined body panel determined pursuant to S6.2.

S6. *Procedure.*

S6.1 *Preparation of the test specimen.*

S6.1.1 If a body panel joint is 8 inches long or longer, cut a test specimen that consists of any randomly selected 8-inch segment of the joint, together with a portion of the bus body whose dimensions, to the extent permitted by the size of the joined parts, are those specified in Figure 1, so that the specimen's centerline is perpendicular to the joint at the midpoint of the joint segment. Where the body panel joint is not fastened continuously, select the segment so that it does not bisect a spot weld or a discrete fastener.

S6.1.2 If a joint is less than 8 inches long, cut a test specimen with enough of the adjacent material to permit it to be held in the tension testing machine specified in S6.3.

S6.1.3 Prepare the test specimen in accordance with the preparation procedures specified in the 1973 edition of the Annual Book of ASTM Standards, published by the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

S6.2 *Determination of minimum allowable strength.* For purposes of determining the minimum allowable joint strength, determine the tensile strengths of the joined body components as follows:

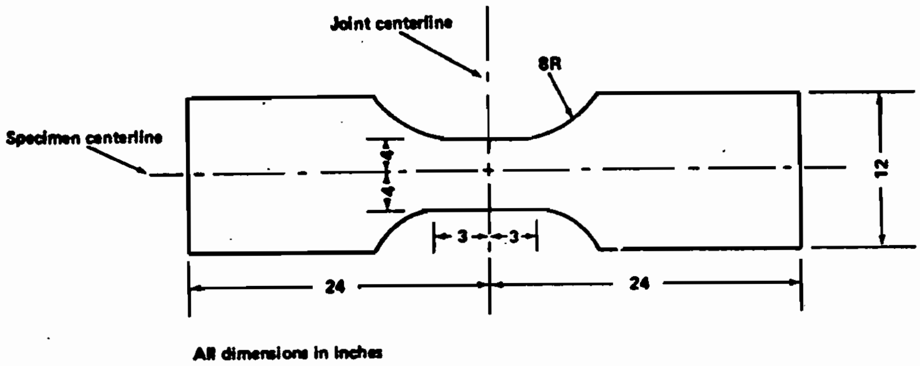


FIGURE 1

(a) If the mechanical properties of a material are specified by the American Society for Testing and Materials, the relative tensile strength for such a material is the minimum tensile strength specified for that material in the 1973 edition of the Annual Book of ASTM Standards.

(b) If the mechanical properties of a material are not specified by the American Society for Testing and Materials, determine its tensile strength by cutting a specimen from the bus body outside the area of the joint and by testing it in accordance with S6.3.

S6.3 *Strength test.*

S6.3.1 Grip the joint specimen on opposite sides of the joint in a tension testing machine calibrated in accordance with Method E4, Verification of Testing Machines, of the American Society for Testing and Materials (1973 Annual Book of ASTM Standards).

S6.3.2 Adjust the testing machine grips so that the joint, under load, will be in stress approximately perpendicular to the joint.

S6.3.3 Apply a tensile force to the specimen by separating the heads of the testing machine at any uniform rate not less than ⅛ inch and not more than ⅜-inch per minute until the specimen separates.

[41 FR 3872, Jan. 27, 1976, as amended at 41 FR 36027, Aug. 26, 1976]

§ 571.222 Standard No. 222; School bus passenger seating and crash protection.

S1. *Scope.* This standard establishes occupant protection requirements for school bus passenger seating and restraining barriers.

S2. *Purpose.* The purpose of this standard is to reduce the number of deaths and the severity of injuries that result from the impact of school bus occupants against structures within the vehicle during crashes and sudden driving maneuvers.

S3. *Application.* This standard applies to school buses.

S4. *Definitions.* "Contactable surface" means any surface within the zone specified in S.5.3.1.1 that is contactable from any direction by the test device described in S6.6, except any surface on the front of a seat back or restraining barrier 3 inches or more below the top of the seat back or restraining barrier.

"School bus passenger seat" means a seat in a school bus, other than the driver's seat or a seat installed to accommodate handicapped or convalescent passengers as evidenced by orientation of the seat in a direction that is more than 45 degrees to the left or right of the longitudinal centerline of the vehicle.

S4.1 The number of seating positions considered to be in a bench seat is expressed by the symbol W, and calculated as the bench width in inches divided by 15 and rounded to the nearest whole number.

S5. *Requirements.* (a) Each vehicle with a gross vehicle weight rating of more than 10,000 pounds shall be capable of meeting any of the requirements set forth under this heading when tested under the conditions of S6. However, a particular school bus passenger seat (i.e., test specimen) in that weight class need not meet further requirements after having met S5.1.2 and S5.1.5, or having been subjected to either S5.1.3, S5.1.4, or S5.3.

(b) Each vehicle with a gross vehicle weight rating of 10,000 pounds or less shall be capable of meeting the following requirements at all seating positions other than the driver's seat: (1) The requirements of §§ 571.208, 571.209, and 571.210 (Standard Nos. 208, 209, and 210) as they apply to multipurpose passenger vehicles; and (2) the requirements of S5.1.2, S5.1.3, S5.1.4, S5.1.5, and S5.3 of this standard. However, the requirements of Standard Nos. 208 and 210 shall be met at W seating positions in a bench seat using a body block as specified in Figure 2 of this standard, and a particular school bus passenger seat (i.e., a test specimen) in that weight class need not meet further requirements after having met S5.1.2 and S5.1.5, or having been subjected to either S5.1.3, S5.1.4, S5.3, or § 571.210 (Standard No. 210).

S5.1 *Seating requirements.* School bus passenger seats shall be forward facing.

S5.1.1 [Reserved]

S5.1.2 *Seat back height and surface area.* Each school bus passenger seat shall be equipped with a seat back that, in the front projected view, has a front surface area above the horizontal plane that passes through the seating reference point, and below the horizontal plane 20 inches above the seating reference point, of not less than 90 percent of the sea bench width in inches multiplied by 20.

S5.1.3 *Seat performance forward.* When a school bus passenger seat that has another seat behind it is subjected to the application of force as specified in S5.1.3.1 and S5.1.3.2, and subsequently, the application of additional force to the seat back as specified in S5.1.3.3 and S5.1.3.4:

(a) The seat back force/deflection curve shall fall within the zone specified in Figure 1;

(b) Seat back deflection shall not exceed 14 inches; (for determination of (a) and (b) the force/deflection curve describes only the force applied through the upper loading bar, and only the forward travel of the pivot attachment point of the upper loading bar, measured from the point at which the initial application of 10 pounds of force is attained.)

(c) The seat shall not deflect by an amount such that any part of the seat moves to within 4 inches of any part of another school bus passenger seat or restraining barrier in its originally installed position;

(d) The seat shall not separate from the vehicle at any attachment point; and

(e) Seat components shall not separate at any attachment point.

S5.1.3.1 Position the loading bar specified in S6.5 so that it is laterally centered behind the seat back with the bar's longitudinal axis in a transverse plane of the vehicle and in any horizontal plane between 4 inches above and 4 inches below the seating reference point of the school bus passenger seat behind the test specimen.

S5.1.3.2 Apply a force of 700W pounds horizontally in the forward direction through the loading bar at the pivot attachment point. Reach the specified load in not less than 5 nor more than 30 seconds.

S5.1.3.3 No sooner than 1.0 second after attaining the required force, reduce that force to 350W pounds and, while maintaining the pivot point position of the first loading bar at the position where the 350W pounds is attained, position a second loading bar described in S6.5 so that it is laterally centered behind the seat back with the bar's longitudinal axis in a transverse plane of the vehicle and in the horizontal plane 16 inches above the seating reference point of the school bus passenger seat behind the test specimen, and move the bar forward against the seat back until a force of 10 pounds has been applied.

S5.1.3.4 Apply additional force horizontally in the forward direction through the upper bar until 4,000W inch-pounds of energy have been absorbed in deflecting the seat back (or restraining barrier). Apply the additional load in not less than 5 seconds nor more than 30 seconds. Maintain the pivot attachment point in the maximum forward travel position for not less than 5 seconds nor more than 10 seconds and release the load in not less than 5 nor more than 30 seconds. (For the determination of S5.1.3.4 the force/deflection curve describes only the force applied through the upper loading bar, and the forward and rearward travel distance of the upper loading bar pivot attachment point measured from the position at which the initial application of 10 pounds of force is attained.)

S5.1.4 *Seat performance rearward.* When a school bus passenger seat that has another seat behind it is subjected to the application of force as specified in S5.1.4.1 and S5.1.4.2:

(a) Seat back force shall not exceed 2,200 pounds;

(b) In the case of a school bus manufactured on or after April 1, 1978, seat back deflection shall not exceed 10 inches; (For determination of (a) and (b) the force/deflection curve describes only the force applied through the loading bar, and only the rearward travel of the pivot attachment point of the loading bar, measured from the point at which the initial application of 50 pounds of force is attained.

(c) The seat shall not deflect by an amount such that any part of the seat moves to within 4 inches of any part of another passenger seat in its originally installed position;

(d) The seat shall not separate from the vehicle at any attachment point; and

(e) Seat components shall not separate at any attachment point.

S5.1.4.1 Position the loading bar described in S6.5 so that it is laterally centered forward of the seat back with the bar's longitudinal axis in a transverse plane of the vehicle and in the horizontal plane 13.5 inches above the seating reference point of the test specimen, and move the loading bar rearward against the seat back until a force of 50 pounds has been applied.

S5.1.4.2 Apply additional force horizontally rearward through the loading bar until 2,800W inch-pounds of energy has been absorbed in deflecting the seat back. Apply the additional load in not less than 5 seconds nor more than 30 seconds. Maintain the pivot attachment point in the maximum rearward travel position for not less than 5 seconds nor more than 10 seconds and release the load in not less than 5 seconds nor more than 30 seconds. (For determination of S5.1.4.2 the force/deflection curve describes the force applied through the loading bar and the rearward and forward travel distance of the loading bar pivot attachment point measured from the position at which the initial application of 50 pounds of force is attained.)

S5.1.5 *Seat cushion retention.* In the case of school bus passenger seats equipped with seat cushions, with all manual attachment devices between the seat and the seat cushion in the manufacturer's designed position for attachment, the seat cushion shall not separate from the seat at any attachment point when subjected to an upward force of five times the seat cushion weight, applied in any period of not less than 1 nor more than 5 seconds, and maintained for 5 seconds.

S5.2 *Restraining barrier requirements.* Each vehicle shall be equipped with a restraining barrier forward of any designated seating position that does not have the rear surface of another school bus passenger seat within 24 inches of its seating reference point, measured along a horizontal longitudinal line through the seating reference point in the forward direction.

S5.2.1 *Barrier-seat separation.* The horizontal distance between the restraining barrier's rear surface and the seating reference point of the seat in front of which the barrier is required shall not be more than 24 inches measured along a horizontal longitudinal line through the seating reference point in the forward direction.

S5.2.2 *Barrier position and rear surface area.* The position and rear surface area of the restraining barrier shall be such that, in a front projected view of the bus, each point of the barrier's perimeter coincides with or lies outside of the perimeter of the seat back of the seat for which it is required.

S5.2.3 *Barrier performance forward.* When force is applied to the restraining barrier in the same manner as specified in S5.1.3.1 through S5.1.3.4 for seating performance tests:

(a) The restraining barrier force/deflection curve shall fall within the zone specified in Figure 1;

(b) Restraining barrier deflection shall not exceed 14 inches; (For computation of (a) and (b) the force/deflection curve describes only the force applied through the upper loading bar, and only the forward travel of the pivot attachment point of the loading bar, measured from the point at which the initial application of 10 pounds of force is attained.)

(c) Restraining barrier deflection shall not interfere with normal door operation;

(d) The restraining barrier shall not separate from the vehicle at any attachment point; and

(e) Restraining barrier components shall not separate at any attachment point.

S5.3 *Impact zone requirements.*

S5.3.1 *Head protection zone.* Any contactable surface of the vehicle within any zone specified in S5.3.1.1 shall meet the requirements of S5.3.1.2 and S5.3.1.3. However, a surface area that has been contacted pursuant to an impact test need not meet further requirements contained in S5.3.

S5.3.1.1 The head protection zones in each vehicle are the spaces in front of each school bus passenger seat which are not occupied by bus sidewall, window, or door structure and which, in relation to that seat and its seating reference point, are enclosed by the following planes;

(a) Horizontal planes 12 inches and 40 inches above the seating reference point;

(b) A vertical longitudinal plane tangent to the inboard (aisle side) edge of the seat;

(c) A vertical longitudinal plane 3.25 inches inboard of the outboard edge of the seat, and

(d) Vertical transverse planes through and 30 inches forward of the reference point.

S5.3.1.2 *Head form impact requirement.* When any contactable surface of the vehicle within the zones specified in S5.3.1.1 is impacted from any direction at 22 feet per second by the head form described in S6.6, the axial acceleration at the center of gravity of the head form shall be such that the expression

$$\left[\frac{1}{(t_2-t_1)}\int_{t_1}^{t_2} a dt \right]^{2.5} (t_2-t_1)$$

shall not exceed 1,000 where a is the axial acceleration expressed as a multiple of g (the acceleration due to gravity), and t_1 and t_2 are any two points in time during the impact.

S5.3.1.3 *Head form force distribution.* When any contactable surface of the vehicle within the zones specified in S5.3.1.1 is impacted from any direction at 22 feet per second by the head form described in S6.6, the energy necessary to deflect the impacted material shall be not less than 40 inch-pounds before the force level on the head form exceeds 150 pounds. When any contactable surface within such zones is impacted by the head form from any direction at 5 feet per second, the contact area on the head form surface shall be not less than 3 square inches.

S5.3.2 *Leg protection zone.* Any part of the seat backs or restraining barriers in the vehicle within any zone specified in S5.3.2.1 shall meet the requirements of S5.3.2.2.

S5.3.2.1 The leg protection zones of each vehicle are those parts of the school bus passenger seat backs and restraining barriers bounded by horizontal planes 12 inches above and 4 inches below the seating reference point of the school bus passenger seat immediately behind the seat back or restraining barrier.

S5.3.2.2 When any point on the rear surface of that part of a seat back or restraining barrier within any zone specified in S5.3.2.1 is impacted from any direction at 16 feet per second by the knee form specified in S6.7, the resisting force of the impacted material shall not exceed 600 pounds and the contact area on the knee form surface shall not be less than 3 square inches.

S6. *Test conditions.* The following conditions apply to the requirements specified in S5.

S6.1 *Test surface.* The bus is at rest on a level surface.

S6.2 *Tires.* Tires are inflated to the pressure specified by the manufacturer for the gross vehicle weight rating.

S6.3 *Temperature.* The ambient temperature is any level between 32 degrees F. and 90 degrees F.

S6.4 *Seat back position.* If adjustable, a seat back is adjusted to its most upright position.

S6.5 *Loading bar.* The loading bar is a rigid cylinder with an outside diameter of 6 inches that has hemispherical ends with radii of 3 inches and with a surface roughness that does not exceed 63 micro-inches, root mean square. The length of the loading bar is 4 inches less than the width of the seat back in each test. The stroking mechanism applies force through a pivot attachment at the centerpoint of the loading bar which allows the loading bar to rotate in a horizontal plane 30 degrees in either direction from the transverse position.

S6.5.1 A vertical or lateral force of 4,000 pounds applied externally through the pivot attachment point of the loading bar at any position reached during a test specified in this standard shall not deflect that point more than 1 inch.

S6.6 *Head form.* The head form for the measurement of acceleration is a rigid surface comprised of two hemispherical shapes, with total equivalent weight of 11.5 pounds. The first of the two hemispherical shapes has a diameter of 6.5 inches. The second of the two hemispherical shapes has a 2 inch diameter and is centered as shown in Figure 3 to protrude from the outer surface of the first hemispherical shape. The surface roughness of the hemispherical shapes does not exceed 63 micro-inches, root mean square.

S6.6.1 The direction of travel of the head form is coincidental with the straight line connecting the centerpoints of the two spherical outer surfaces which constitute the head form shape.

S6.6.2 The head form is instrumented with an acceleration sensing device whose output is recorded in a data channel that conforms to the requirements for a 1,000 Hz channel class as specified in SAE Recommended Practice J211a, December 1971. The head form exhibits no resonant frequency below three times the frequency of the channel class. The axis of the acceleration sensing device coincides with the straight line connecting the centerpoints of the two hemispherical outer surfaces which constitute the head form shape.

S6.6.3 The head form is guided by a stroking device so that the direction of travel of the head form is not affected by impact with the surface being tested at the levels called for in the standard.

S6.7 *Knee form.* The knee form for measurement of force is a rigid 3-inch-diameter cylinder, with an equivalent weight of 10 pounds, that has one rigid hemispherical end with a 1½ inch radius forming the contact surface of the knee form. The hemispherical surface roughness does not exceed 63 micro-inches, root mean square.

S6.7.1 The direction of travel of the knee form is coincidental with the centerline of the rigid cylinder.

S6.7.2 The knee form is instrumented with an acceleration sensing device whose output is recorded in a data channel that conforms to the requirements of a 600 Hz channel class as specified in the SAE Recommended Practice J211a, December 1971. The knee form exhibits no resonant frequency below three times the frequency of the channel class. The axis of the acceleration sensing device is aligned to measure acceleration along the centerline of the cylindrical knee form.

S6.7.3 The knee form is guided by a stroking device so that the direction of travel of the knee form is not affected by impact with the surface being tested at the levels called for in the standard.

S6.8 The head form, knee form, and contactable surfaces are clean and dry during impact testing.

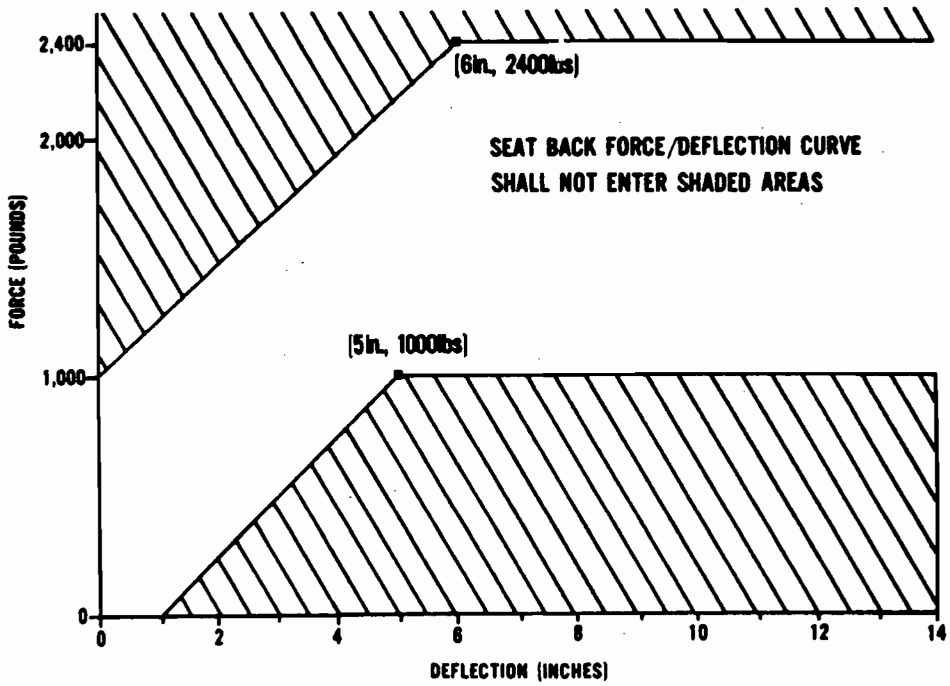


FIGURE 1 - FORCE/DEFLECTION ZONE

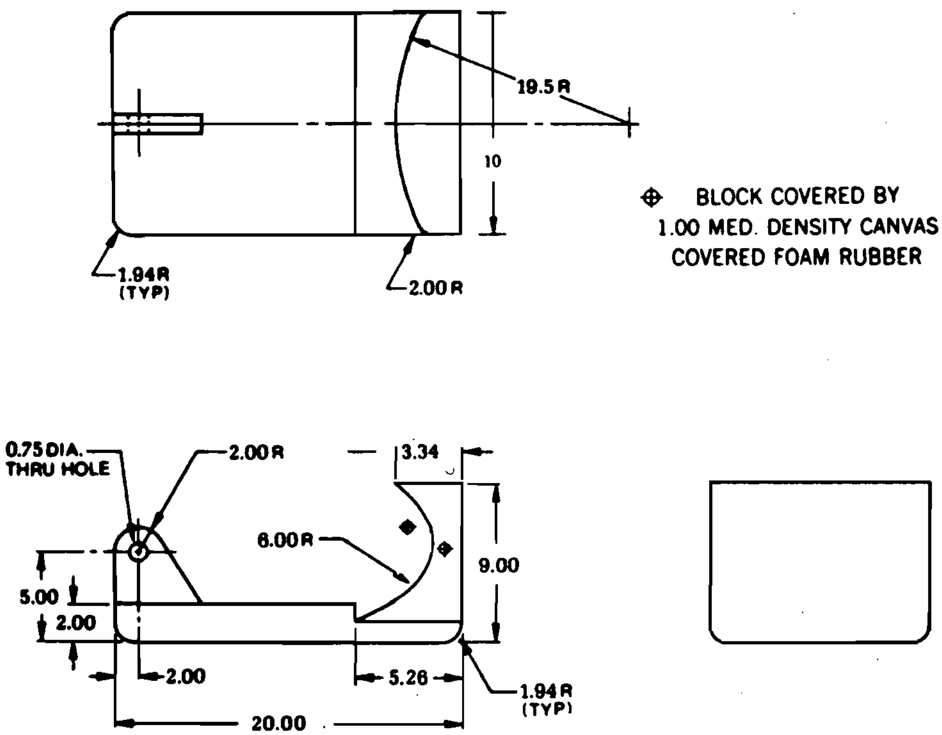


FIGURE 2 – BODY BLOCK FOR LAP BELT

BIHEMISPHERICAL HEAD FORM RADII

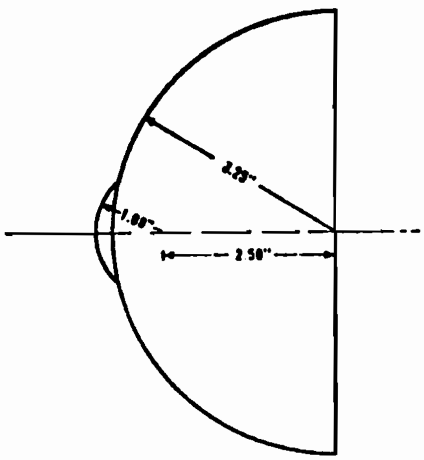


FIGURE 3

[41 FR 4018, Jan. 28, 1976, as amended at 41 FR 28528, July 12, 1976; 41 FR 36027, Aug. 26, 1976; 41 FR 54945, Dec. 16, 1976; 42 FR 64120, Dec. 22, 1977; 43 FR 9150, Mar. 6, 1978; 44 FR 18675, Mar. 29, 1979; 48 FR 12386, Mar. 24, 1983]

§ 571.301 Standard No. 301; Fuel system integrity.

S1. *Scope.* This standard specifies requirements for the integrity of motor vehicle fuel systems.

S2. *Purpose.* The purpose of this standard is to reduce deaths and injuries occurring from fires that result from fuel spillage during and after motor vehicle crashes.

S3. *Application.* This standard applies to passenger cars, and to multipurpose passenger vehicles, trucks, and buses that have a GVWR of 10,000 pounds or less and use fuel with a boiling point above 32° F, and to schoolbuses that have a GVWR greater than 10,000 pounds and use fuel with a boiling point about 32° F.

S4. *Definition.* "Fuel spillage" means the fall, flow, or run of fuel from the vehicle but does not include wetness resulting from capillary action.

S5. *General requirements.*

S5.1 *Passenger cars.* Each passenger car manufactured from September 1, 1975, to August 31, 1976, shall meet the requirements of S6.1 in a perpendicular impact only, and S6.4. Each passenger car manufactured on or after September 1, 1976, shall meet all the requirements of S6, except S6.5.

S5.2 *Vehicles with GVWR of 6,000 pounds or less.* Each multipurpose passenger vehicle, truck, and bus with a GVWR of 6,000 pounds or less manufactured from September 1, 1976, to August 31, 1977, shall meet all the requirements of S6.1 in a perpendicular impact only, S6.2, and S6.4. Each of these types of vehicles manufactured on or after September 1, 1977, shall meet all the requirements of S6., except S6.5.

S5.3 *Vehicles with GVWR of more than 6,000 pounds but not more than 10,000 pounds.* Each multipurpose passenger vehicle, truck, and bus with a GVWR of more than 6,000 pounds but not more than 10,000 pounds manufactured from September 1, 1976, to August 31, 1977, shall meet the requirements of S6.1 in a perpendicular impact only. Each vehicle manufactured on or after September 1, 1977, shall meet all the requirements of S6., except S6.5.

S5.4 *Schoolbuses with a GVWR greater than 10,000 pounds.* Each schoolbus with a GVWR greater than 10,000 pounds manufactured on or after April 1, 1977, shall meet the requirements of S6.5.

S5.5 *Fuel spillage: Barrier crash.* Fuel spillage in any fixed or moving barrier crash test shall not exceed 1 ounce by weight from impact until motion of the vehicle has ceased, and shall not exceed a total of 5 ounces by weight in the 5-minute period following cessation of motion. For the subsequent 25-minute period (for vehicles manufactured before September 1, 1976, other than school buses with a GVWR greater than 10,000 pounds: the subsequent 10-minute period), fuel spillage during any 1-minute interval shall not exceed 1 ounce by weight.

S5.6 *Fuel spillage: Rollover.* Fuel spillage in any rollover test, from the onset of rotational motion, shall not exceed a total of 5 ounces by weight for the first 5 minutes of testing at each successive 90° increment. For the remaining testing period, at each increment of 90° fuel spillage during any 1-minute interval shall not exceed 1 ounce by weight.

S6. *Test requirements.* Each vehicle with a GVWR of 10,000 pounds or less shall be capable of meeting the requirements of any applicable barrier crash test followed by a static rollover, without alteration of the vehicle during the test sequence. A particular vehicle need not meet further requirements after having been subjected to a single barrier crash test and a static rollover test.

S6.1 *Frontal barrier crash.* When the vehicle traveling longitudinally forward at any speed up to and including 30 mph impacts a fixed collision barrier that is perpendicular to the line of travel of the vehicle, or at any angle up to 30° in either direction from the perpendicular to the line of travel of the vehicle, with 50th-percentile test dummies as specified in Part 572 of this chapter at each front outboard designated seating position and at any other position whose protection system is required to be tested by a dummy under the provisions of Standard No. 208, under the applicable conditions of S7., fuel spillage shall not exceed the limits of S5.5.

S6.2 *Rear moving barrier crash.* When the vehicle is impacted from the rear by a barrier moving at 30 mph, with test dummies as specified in Part 572 of this chapter at each front outboard designated seating position, under the applicable conditions of S7., fuel spillage shall not exceed the limits of S5.5.

S6.3 *Lateral moving barrier crash.* When the vehicle is impacted laterally on either side by a barrier moving at 20 mph with 50th-percentile test dummies as specified in Part 572 of this chapter at positions required for testing to Standard No. 208, under the applicable conditions of S7., fuel spillage shall not exceed the limits of S5.5.

S6.4 *Static rollover.* When the vehicle is rotated on its longitudinal axis to each successive increment of 90°, following an impact crash of S6.1, S6.2, or S6.3, fuel spillage shall not exceed the limits of S5.6.

S6.5 *Moving contoured barrier crash.* When the moving contoured barrier assembly traveling longitudinally forward at any speed up to and including 30 mph impacts the test vehicle (schoolbus with a GVWR exceeding 10,000 pounds) at any point and angle, under the applicable conditions of S7.1 and S7.5, fuel spillage shall not exceed the limits of S5.5.

S7. *Test conditions.* The requirements of S5. and S6. shall be met under the following conditions. Where a range of conditions is specified, the vehicle must be capable of meeting the requirements at all points within the range.

S7.1 *General test conditions.* The following conditions apply to all tests.

S7.1.1 The fuel tank is filled to any level from 90 to 95 percent of capacity with Stoddard solvent, having the physical and chemical properties of type 1 solvent, Table I ASTM Standard D484-71, "Standard Specifications for Hydrocarbon Dry Cleaning Solvents."

S7.1.2 The fuel system other than the fuel tank is filled with Stoddard solvent to its normal operating level.

S7.1.3 In meeting the requirements of S6.1 through S6.3, if the vehicle has an electrically driven fuel pump that normally runs when the vehicle's electrical system is activated, it is operating at the time of the barrier crash.

S7.1.4 The parking brake is disengaged and the transmission is in neutral, except that in meeting the requirements of S6.5 the parking brake is set.

S7.1.5 Tires are inflated to manufacturer's specifications.

S7.1.6 The vehicle, including test devices and instrumentation, is loaded as follows:

(a) Except as specified in S7.1.1, a passenger car is loaded to its unloaded vehicle weight plus its rated cargo and luggage capacity weight, secured in the luggage area, plus the necessary test dummies as specified in S6., restrained only by means that are installed in the vehicle for protection at its seating position.

(b) Except as specified in S7.1.1, a multipurpose passenger vehicle, truck, or bus with a GVWR of 10,000 pounds or less is loaded to its unloaded vehicle weight, plus the necessary test dummies, as specified in S6., plus 300 pounds or its rated cargo and luggage capacity weight, whichever is less, secured to the vehicle and distributed so that the weight on each axle as measured at the tire-ground interface is in proportion to its GAWR. If the weight on any axle, when the vehicle is loaded to unloaded vehicle weight plus dummy weight, exceeds the axle's proportional share of the test weight, the remaining weight shall be placed so that the weight on that axle remains the same. Each dummy shall be restrained only by means that are installed in the vehicle for protection at its seating position.

(c) Except as specified in S7.1.1, a schoolbus with a GVWR greater than 10,000 pounds is loaded to its unloaded vehicle weight, plus 120 pounds of unsecured weight at each designated seating position.

S7.2 *Lateral moving barrier crash test conditions.* The lateral moving barrier crash test conditions are those specified in S8.2 of Standard No. 208, 49 CFR 571.208.

S7.3 *Rear moving barrier test conditions.* The rear moving barrier test conditions are those specified in S8.2 of Standard No. 208, 49 CFR 571.208, except for the positioning of the barrier and the vehicle. The barrier and test vehicle are positioned so that at impact—

(a) The vehicle is at rest in its normal attitude:

(b) The barrier is traveling at 30 mph with its face perpendicular to the longitudinal centerline of the vehicle; and

(c) A vertical plane through the geometric center of the barrier impact surface and perpendicular to that surface coincides with the longitudinal centerline of the vehicle.

S7.4 *Static rollover test conditions.* The vehicle is rotated about its longitudinal axis, with the axis kept horizontal, to each successive increment of 90°, 180°, and 270° at a uniform rate, with 90° of rotation taking place in any time interval from 1 to 3 minutes. After reaching each 90° increment the vehicle is held in that position for 5 minutes.

S7.5 *Moving contoured barrier test conditions.* The following conditions apply to the moving contoured barrier crash test.

S7.5.1 The moving barrier, which is mounted on a carriage as specified in figure 1, is of rigid construction, symmetrical about a vertical longitudinal plane. The contoured impact surface, which is 24.75 inches high and 78 inches wide, conforms to the dimensions shown in figure 2, and is attached to the carriage as shown in that figure. The ground clearance to the lower edge of the impact surface is 5.25 ± 0.5 inches. The wheelbase is 120 ± 2 inches.

S7.5.2 The moving contoured barrier, including the impact surface, supporting structure, and carriage, weighs 4,000 ± 50 pounds with the weight distributed so that 900 ± 25 pounds is at each rear wheel and 1100 ± 25 pounds is at each front wheel. The center of gravity is located 54.0 ± 1.5 inches rearward of the front wheel axis, in the vertical longitudinal plane of symmetry, 15.8 inches above the ground. The moment of inertia about the center of gravity is:

$I_x = 271 \pm 13.6$ slug ft.^{2}
$I_z = 3475 \pm 174$ slug ft.^{2}

S7.5.3 The moving contoured barrier has a solid nonsteerable front axle and fixed rear axle attached directly to the frame rails with no spring or other type of suspension system on any wheel. (The moving barrier assembly is equipped with a braking device capable of stopping its motion.)

S7.5.4 The moving barrier assembly is equipped with G78-15 pneumatic tires with a tread width of 6.0 ± 1 inch, inflated to 24 psi.

S7.5.5 The concrete surface upon which the vehicle is tested is level, rigid, and of uniform construction, with a skid number of 75 when measured in accordance with American Society of Testing and Materials Method E-274-65T at 40 mph, omitting water delivery as specified in paragraph 7.1 of that method.

S7.5.6 The barrier assembly is released from the guidance mechanism immediately prior to impact with the vehicle.

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