STATUS OF NHTSA MOTORCOACH SAFETY PLAN

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ABSTRACT

The United States Department of Transportation, National Highway Traffic Safety Administration (NHTSA), has been actively researching ways to improve bus safety for several years. In 2007, NHTSA completed a broad review of motorcoach safety issues in the United States and developed an approach that would be pursued to most expediently address those issues. This paper discusses the priority areas that are being investigated for improvements, presents the approach that is being taken in each priority area, and summarizes the status and research results obtained thus far.

While there are a number of agency programs that encompass motorcoaches, the agency has decided to pursue these efforts as priorities: passenger ejection, roof strength, fire safety, and emergency evacuation.

For passenger ejection, incorporation of seat belts has been pursued as the most expedient way to mitigate ejection. A full scale frontal 30 mph barrier crash test was conducted to measure the occupant responses for both belted and unbelted conditions, and sled testing under a variety of configurations was completed to assess seat anchorage and seat belt load experienced under these conditions.

Regarding roof strength, tests on four motorcoaches were conducted to assess and compare European and U.S. requirements for roof strength in buses. Survival space and emergency exit operation were studied for both test conditions.

To address emergency evacuation on motorcoaches, studies and human evacuation simulations are being conducted. Various emergency exit scenarios including windows, rear stairs/door, existing wheelchair exit doors, airplane style portals, and roof exits are being evaluated. Minimum strength requirements for opening emergency exits based on the age of the occupant are also being examined.

As for fire safety, NHTSA is conducting research to examine how a motorcoach fire spreads from the wheel well to and through the passenger compartment. The flammability of interior and exterior materials will be investigated, as well as detection systems to warn the driver of an external fire along with automatic suppression systems to quell a fire before it spreads.

INTRODUCTION

Motorcoach transportation has been a very safe form of transportation in the United States. On average, about 14 fatalities have occurred annually to occupants of motorcoaches in crash and rollover events, with about 2 of the fatalities being drivers. Approximately one-third of the fatal crashes resulted in rollover. Ejection of passengers from motorcoaches accounts for approximately one-half of passenger fatalities. Among all motorcoach crashes, about two-thirds are single vehicle events and involve running off the road, hitting roadside objects, or rolling over.

In addition to the fatal crashes, there have been a number of fire incidents, including a tragic incident in Wilmer, Texas [NSTB, 2007] resulting in the death of twenty-three occupants when a fire erupted to engulf the motorcoach.

In 2007, following completion of several studies relevant to motorcoach safety, NHTSA conducted a comprehensive review of those studies and motorcoach safety issues in the United States, and then developed an approach that would be pursued to most expediently address those issues [NHTSA, 2007]. This paper discusses the priority areas that are being investigated for improvements, presents the approach that is being taken in each priority area, and summarizes the status and research results obtained thus far.

PASSENGER EJECTION

Passenger ejections can be reduced by using a number of different technologies, e.g., reducing openings by using stronger window retention methods, improvements to the integrity of window and other glazing areas, use of safety belts etc. Crash and sled tests to study the effects of using safety belts are described in the following sections.

For passenger ejection, a full scale frontal 30 mph barrier crash test was conducted to measure the occupant responses for both belted and unbelted conditions, and sled testing under a variety of configurations was completed to assess seat anchorage and seat belt load experienced under these conditions. These tests are described in the following.

Crash Test

The agency conducted a crash test in December 2007 at the NHTSA Vehicle Research and Test Center in E. Liberty, Ohio (Test # 6294 in NHTSA Vehicle Crash Test Database). Figure 1 shows the motorcoach used in the test. It was a 2000 MCI 102EL3 Renaissance with a Series 60 diesel engine and B500 Allison Automatic transmission. The coach was 45 ft long, 12 ft 6 inches tall, with 54 seats (34 inches apart longitudinally). The weight as tested (including dummies and equipment) was 42,720 lbs.

Figure 1. Motorcoach Used for Crash Test

The coach had unbelted seats from American Seating Co, seats with 2 and 3-point belts from Amaya/Fainsa and a seat with 3-point belts from Freedman Seating Co.

The crash test speed was 30 mph (48.3 kph) into a fixed rigid barrier at 0 degrees, full overlap condition. The test collected data from 355 dummy channels and 26 vehicle channels at 12,500 samples/sec. Figure A1 in Appendix A shows the crash pulse (deceleration) from three locations in the middle and rear of the coach, away from the crush zone.

The coach had the following dummies on-board:
- •Hybrid III 50th male – 17 dummies
- •Hybrid III 5th female – 3 dummies
- •Hybrid III 95th male – 2 dummies

Each dummy had accelerometers in head and chest, load cells in upper neck and femur, and a chest displacement potentiometer. The dummies were seated at locations shown in Figure 2.

Crash Test Observations

Unbelted dummies had high head accelerations and neck injury values (Nij), as did the dummies with 2-point (lap) belts. The highest readings of the Head Injury Criteria (HIC15) and Nij in unbelted dummies were approximately twice the Injury Assessment Reference Value (IARV) (1.9 and 2.1 respectively). The corresponding ratios of the highest HIC15 and Nij for dummies with lap belts were 1.9 and 4.7 respectively.

The injury criteria and the IARV are described on the Advanced Air Bag Technology page on the NHTSA web site.
http://www-nrd.nhtsa.dot.gov/

The dummies restrained by 3-point belts had low injury assessment values for head and neck. The highest HIC15 and Nij in dummies with lap and shoulder belts were 0.6 and 0.8 respectively. All dummies had low chest accelerations, chest displacements and femur loads (worst case condition of about half of the IARV).

Unbelted dummies typically made head contact with the seatback in front within 150-180 ms. The unbelted dummies in the aisle seat ended up in the aisle, while those in the window seat ended up in the row in front or on the floor.

Structurally, all seats remained attached to the bus at all seat anchor locations. One baseline (unbelted) seat had a failure of the seat frame at

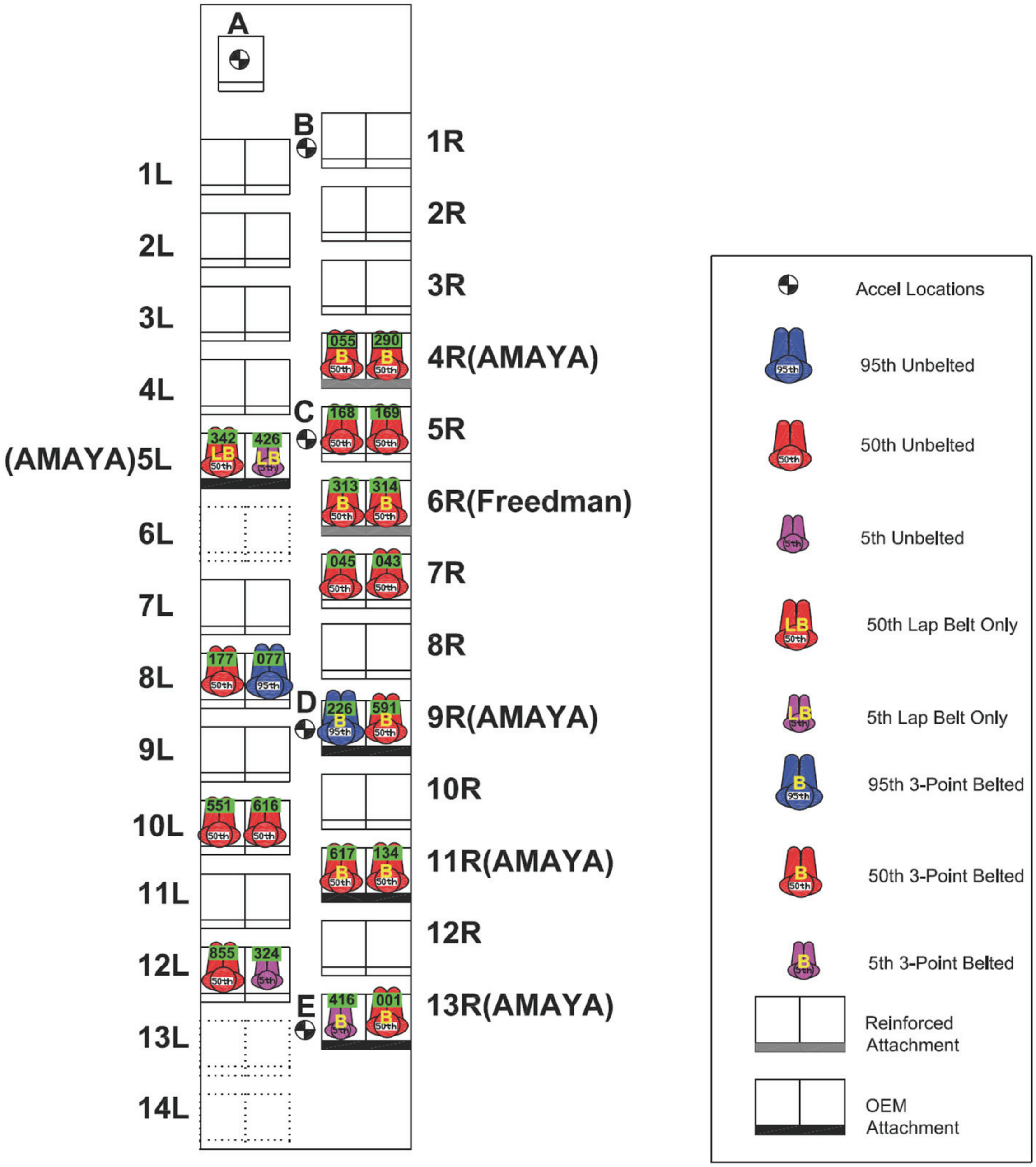

Figure 2. Motorcoach Crash Test Dummy Seat Diagram

the floor attachment. This unoccupied seat had unbelted 50th M and 95th M in the row behind it. Baseline seats and the Freedman seat had bent/broken seatbacks when impacted by unbelted dummies in the seat behind it. Figure 3 is an image from the crash test.

Figure 3. Belted Dummies (on left) Remained in Their Seats; Unbelted Dummmies (on right) Did Not.

Sled Tests

Fifteen crash simulations (sled tests) were run using a representation of the crash pulse from the crash test at VRTC (VRTC Pulse). Additionally, five sled tests were run using the European ECE Regulation 80 tests of seats and anchorages (EU Pulse). The crash test acceleration, VRTC Pulse and the EU Pulse, including the corridors used to define the EU pulse requirements, are shown in Figure A2 in Appendix A. The approximate velocity change for the VRTC pulse was 25 mph (40.2 kph) and for the EU pulse was 20 mph (32.2 kph). These tests are available in NHTSA Vehicle Crash Test Database as test # 6559 through 6578.

Three types of seats were used in the sled tests.

1. Baseline (American Seating)
    a. No belts

2. M3 belted seats (Amaya/ FAINSA)
    a. 3-point belts
    b. 2-point belts

3. M2 belted seats (Amaya/ FAINSA)
    a. 3-point belts

Baseline seats without seat belts were obtained from the 2000 MCI 102EL3 Renaissance Series tested bus and the seat supplier, American Seating Company (Amer Seat).

Three different seats with seatbelts, supplied by Amaya/FAINSA, were used in the sled tests. These seats were designed to meet ECE Regulation 14 and TRANS/WP.29/78/Rev.1/Amend2

M3: These seats are designed for mass transportation vehicles having a mass exceeding 5 tonnes (11,023 lbs). This uses a load equivalent to 6.6g. (referred to as “7G seats” in Figure 4).

M2: These seats are designed for mass transportation vehicles, having a mass not exceeding 5 tonnes (11,023 lbs). This uses a load equivalent to 10g. (referred to as “10G seats”). All such seats used had 3-point seat belts and are similar in appearance to the M3 seats.

The test matrix is shown in Figure 4. The test setup consists of three rows of seats with the middle row, subject seat, having load cells at all the seat anchor locations. Figure 5 shows a typical buck setup. The occupants at the 6 possible seating locations are as shown in Figure 4 along with crash pulse and the type of belted seat used. The test numbers used are as follows:

TEST N
Test # YYMMDD - Test sequence for that day

where N is the chronological sequence of tests in the order they were run (1 through 20).

0 DEGREE BUCK ANGLE

TEST Type / *Test Obsevation*	*ROW*	*SEAT*	*DUMMY LOCATIONS Restraint* Left	Right	TRC Test # 7G seats VRTC pulse	7G seats EU pulse	10G seats VRTC pulse
1	Front	Amer Seat	--	--	TEST 4	TEST 16	TEST 15
Seat Forces	Middle	Amaya/FAINSA	95th 3pt	95th 3pt	Test # 080721-1	Test # 080820-1	Test # 080819-1
Maximum	Rear	Amer Seat	95th unbelt	95th unbelt			
2	Front	Amer Seat	--	--	TEST 5	TEST 17	TEST 13
Seat Forces	Middle	Amaya/FAINSA	50th 3pt	50th 3pt	Test # 080722-1	Test # 080821-1	Test # 080815-2
Medium	Rear	Amer Seat	50th unbelt	50th unbelt			
3	Front	Amer Seat	--	--	TEST 3	TEST 18	
Seat Forces	Middle	Amaya/FAINSA	50th 3pt	50th 3pt	Test # 080716-2	Test # 080821-2	
Average	Rear	Amer Seat	--	--			
4	Front	Amer Seat	--	--	TEST 2	TEST 19	
Seat Forces	Middle	Amaya/FAINSA	50th 3pt	5th 3pt	Test # 080716-1	Test # 080822-1	
Minimum	Rear	Amer Seat	--	--			
5	Front	Amer Seat	--	--	TEST 1	TEST 20	
Lap Belts	Middle	Amaya/FAINSA	50th 2pt	5th 2pt	Test # 080715-1	Test # 080822-2	
	Rear	Amer Seat	--	--			
6	Front	Amer Seat	--	--	TEST 7		
Compartmentalization	Middle	Amer Seat	95th unbelt	95th unbelt	Test # 080724-2		
Current	Rear	Amer Seat	5th unbelt	5th unbelt			
7	Front	Amaya/FAINSA	--	--	TEST 6		
Compartmentalization	Middle	Amer Seat	50th unbelt	5th unbelt	Test # 080724-1		
Seat Effects	Rear	Amer Seat	50th unbelt	5th unbelt			
7b	Front	Amaya 10G	--	--			TEST 14
Compartmentalization	Middle	Amaya 7G	50th unbelt	5th unbelt			Test # 080818-1
Seat Effects 10 G	Rear	Amer Seat	50th unbelt	5th unbelt			
10	Front	Amaya/FAINSA recl	--	--	TEST 12		
Reclined	Middle	Amaya/FAINSA recl	5th 3pt	50th 3pt	Test # 080815-1		
Belted	Rear	Amer Seat	50th unbelt	50th unbelt			
11	Front	Amaya/FAINSA	--	--	TEST 10		TEST 11
Max Rear Loading	Middle	Amaya/FAINSA	5th 3pt	50th 3pt	Test # 080813-1		Test # 080814-1
Belted	Rear	Amer Seat	95th unbelt	95th unbelt			

15 DEGREE BUCK ANGLE

TEST Type / *Test Obsevation*	*ROW*	*SEAT*	Left	Right	7G seats VRTC pulse	7G seats EU pulse	10G seats VRTC pulse
8	Front	Amaya/FAINSA	--	--	TEST 8		
Compartmentalization	Middle	Amer Seat	5th unbelt	50th unbelt	Test # 080729-1		
Current	Rear	Amer Seat	5th unbelt	50th unbelt			
9	Front	Amer Seat	--	--	TEST 9		
Compartmentalization	Middle	Amaya/FAINSA	5th 3pt	50th 3pt	Test # 080730-1		
Belted	Rear	Amer Seat	5th unbelt	50th unbelt			

(green shading) = The test condition was replicated in the crash test

	Front row	--	--	--
↑	Middle Row	--	--	--
Direction of impact	Rear Row	--	--	--

This row has seat anchor load cells

Test #: YYMMDD - Test sequence #

Test 11 used 10g seat in the middle row, 7g seat in the front row

Figure 4. Motorcoach Sled Test Matrix

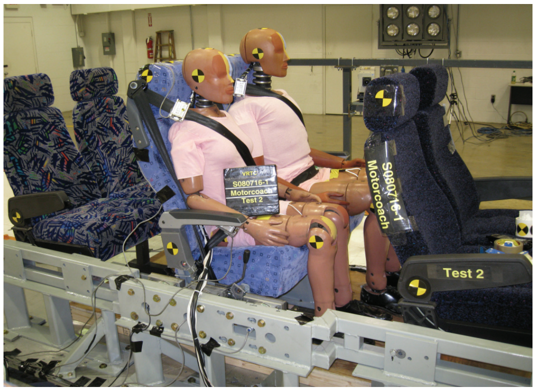

Figure 5. General Sled Buck Setup

Each seat was attached at 4 locations; 2 on the floor, and 2 on the side. These are marked in Figure 6 as locations A, B, C, D, respectively. For the sled test program, the center row seat was mounted at the 4 locations with rigid attachments with 3-axis load cells. Forces in 3 directions were measured at each of the seat anchor locations.

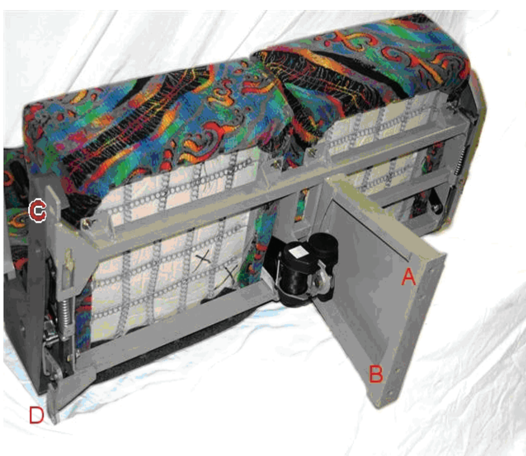

Figure 6. Motorcoach Seat Anchor Locations

Sled Test Observations

Higher dummy injury assessment values were mostly limited to HIC and Nij. The 3-point belted seats prevented critical injury values in almost all configurations with VRTC crash pulse. No 3-point belted dummy recorded a critical Nij across all test conditions

Unbelted dummies loading the target seat from the rear often increased the injury values of the 3-point belted dummy in the target seat, when compared to tests that had no rear dummy loading.
The EU pulse has a shorter duration and higher peak G than the VRTC pulse. EU pulse tests resulted in higher HIC when compared to VRTC crash test pulse. Three-point belted dummies with the EU pulse reached critical injury values in tests.

Dummy injuries values (HIC and Nij) reached critical thresholds with 2-point (lap only) belt tests. The 5th female dummy consistently recorded higher injury numbers when compared to the larger occupants in 2-point and unbelted conditions.

Low injury numbers were recorded for 15 degree angled testing. However, the unbelted dummies were not contained between the seats and often fell into the 'aisle.'

For similar tests with the Amaya M2 and M3 seats, the injury values were relatively similar.

ROOF CRUSH/ROLLOVER TESTING

Roof crush/rollover testing was performed on two different motorcoach models. The testing was done to evaluate two existing roof crush/rollover test procedures on four older motorcoaches: Federal Motor Vehicle Safety Standard (FMVSS) No. 220 and Economic Commission for Europe (ECE) R.66 complete vehicle test.

The agency tested two 12,200 mm (40 feet) 1992 Motor Coach Industries (MCI) model MC-12 and two 1991 Prevost model LeMirage motorcoaches. MCI and Prevost vehicles were selected to "bracket" the roof strength characteristics for similar sized motorcoaches in the fleet. The most evident structural difference was that the Prevost LeMirage had smaller side windows and more roof support pillars than the MCI MC-12. Table 1 presents information about each of the buses.

Previous Related Research

From 2003 to 2006, NHTSA and Transport Canada had a joint program focused on improving glazing and structural integrity of motorcoaches to prevent ejections, using standard coach windows and different variations of glazing and bonding techniques [NHTSA, 2006]. The research focused on finite element modeling of a Prevost model during a rollover. The simulation computed the force applied to the roof during the ECE R.66 rollover test, and during other scenarios such as sliding into fixed objects. The key findings of the research with respect to force on the roof indicated that a force of 1,149,529 N (258,424 lbs) (approximately 7.6 g's average acceleration) with an applied vector angle of 29 degrees relative to the bus longitudinal-transverse plane was achieved during the rollover. It was determined that the average force distribution along the top corner of the bus was approximately 86 N/mm (490 lbs/in) along the length of the bus.

Existing Test Protocols

Two existing roof crush/rollover protection test procedures and their associated performance requirements for buses were examined to determine the feasibility of their application to motorcoaches sold in the United States. One procedure is that specified in FMVSS No. 220, "School Bus Rollover Protection," and the other is that specified in ECE R.66, "Uniform Technical Prescriptions Concerning The Approval Of Large Passenger Vehicles With Regard To The Strength Of Their Superstructure."

FMVSS No. 220 specifies performance requirements for school bus rollover protection. It specifies that when a uniformly distributed load equal to 1.5 times the unloaded vehicle weight (UVW) is applied to the vehicle's roof through a force application plate, the downward vertical movement at any point on the application plate shall not exceed 130 mm and the emergency exits must be operable during and after the test. The force application plate is positioned along the longitudinal centerline of the roof and is 914 mm (36 inches) wide and 305 mm (12 inches) shorter in length than the vehicle roof.

ECE R.66 applies to single-deck, rigid or articulated vehicles, designed and constructed for the carriage of more than 22 passengers in addition to the driver and crew. ECE R.66 requires a complete vehicle test but allows alternative tests which are based on the full vehicle test. The complete vehicle test was conducted for this research program.

In the complete vehicle test, a bus with a blocked suspension is placed on an 800 mm (31.50 in) high tilting platform. The bus is tilted slowly to its side until it reaches its unstable equilibrium and tips onto a horizontal, dry and smooth hard surface.

The performance specifications of ECE R.66 require that the superstructure of the vehicle have sufficient strength to ensure that adequate residual space to survive a rollover is maintained during and after the rollover test. Templates for the ECE R.66 defined residual space are placed inside the vehicle in the front, center and rear of the bus. The requirements are such that no part of the vehicle which is outside the residual space at the start of the test (e.g. pillars, safety rings, luggage racks) shall intrude into the residual space during the test.

Test Results

The testing demonstrated that it is possible to apply the FMVSS No. 220 test or the full vehicle test in ECE R.66 to motorcoaches. The results of the testing are presented below.

For the FMVSS No. 220 tests, neither of the two motorcoaches tested were able to attain the 1.5 x UVW loading that is required according to the specifications in FMVSS No. 220 for school buses. The testing showed that the front sections

Table 1.
Manufacturer's Bus Specifications for Roof Crush Testing

Make	Model	Model Year	Unloaded Vehicle Weight	GVWR	Window Length (mm)	Window Height (mm)
MCI	MC-12	1992	12,474 kg (27,500 lbs)	17,146 kg (37,800 lbs)	1310	685
Prevost	LeMirage	1991	12,426 kg (27,395 lbs)	18,145 kg (40,000 lbs)	815	1040

of these two bus models were weaker than the back. This is most likely because the windshield and service door were located in the front of the bus and offered little resistance to the compressive load. Deformation at the front of both buses was such that the luggage racks entered the residual space as defined in ECE R.66. The front of the MCI bus yielded to the compressive load at 0.91 x UVW, while the front of the Prevost bus yielded at 1.17 x UVW. One of the possible reasons for the differences in the two buses is the number and size of the pillars. The MCI bus had seven pillars, 57 mm (2.24 in) wide, while the Prevost bus had 10 pillars, 205 mm (8.07 in) wide. While other properties such as material and cross-sectional shape play a role in compressive strength, the results tend to indicate a relationship to the number of pillars.

For the ECE R.66 tests, the interior sidewall of both motorcoaches entered the residual space at the front of the occupant compartment. Each bus was positioned on the tilting platform with the driver's side (left) adjacent to the platform's hinge. The platform was raised at a steady rate of less than 5 degrees/second until the vehicle reached its unstable equilibrium and commenced its roll, which occurred at approximately 48 degrees from the horizontal (MCI) and 51 degrees from the horizontal (Prevost). Both buses struck the ground near the left upper edge of the vehicle just above the windows. In both tests, the vehicle windshields lost retention, the emergency roof exits opened, and the front residual template made contact with the left side window. In the MCI bus, the left side luggage rack inboard hangers rearward of the front two hangers broke during the impact, leaving exposed sharp metal edges.

Accelerometers were installed on the impact-side interior corner of the roof within the same lateral planes as the residual space templates. The average accelerations along the top of the bus roof when the bus struck the ground surface were calculated. The average accelerations from the roof accelerometers when the buses impacted the ground ranged from 7.59 (MCI) to 8.2 (Prevost) g's. These average acceleration values agree very well with the Transport Canada simulation study that indicated an average roof acceleration of 7.6 g's on a 13,420 mm (44 ft) Prevost bus.

Energy Analysis Quantitative Assessment

In an effort to quantitatively assess the relative stringency between the FMVSS No. 220 and the ECE R.66 tests, a review of the energy absorbed by the buses in each of the two tests was examined. Table 2 presents the energy absorbed by the MCI and Prevost buses in the FMVSS No. 220 and ECE R.66 tests. The energy absorbed by the two buses in the ECE R.66 test is 2.5 to 3 times greater than that at the maximum applied energy in the FMVSS No. 220 test. Both buses experienced vertical displacement of the load application plate that exceeded the maximum allowable level of 130 mm (5 1/8 inches) in the FMVSS No. 220 tests. Additionally, both buses crushed into the ECE R.66 survivable space templates in both the FMVSS No. 220 and the ECE R.66 tests. Since both the buses did not meet the FMVSS No. 220 requirement for school buses sold in the U.S. and ECE R.66 requirements for motorcoaches sold in the EU, it is not possible to objectively assess the relative stringency of these two tests with the available information. Also, since the ECE R.66 test is a dynamic event while the FMVSS No. 220 test is a quasi-static event, and since the load applications in the two tests are significantly different, the absorbed energy cannot be directly compared.

Table 2
FMVSS No. 220 and ECE R.66
Energy Analysis

	Mass (kg)	Energy at 130 mm crush (J)	Energy at Maximum Achievable Load		ECE r.66 Potential Energy ($m*g*\Delta h$)	
			UVW	(J)	CG Δh (m)	Energy (J)
MCI	12,700	4,444	0.91	33,960	0.840	104,653
Prevost	13,381	7,140	1.17	37,599	0.723	94,906

Qualitative Analysis

While it was not possible to quantitatively assess the relative stringency between FMVSS No. 220 and ECE R.66, it is possible to perform a qualitative assessment. From a qualitative basis, it appears that the FMVSS No. 220 criteria for school buses may be more stringent than the rollover requirements in ECE R.66 for buses meeting that regulation. This is based on the observation that neither of these buses was able to support its UVW in the FMVSS No. 220 tests and failed catastrophically prior to reaching 1½ times UVW. Both of the buses crushed approximately 355 mm (14 in) to the top of the ECE R.66 defined residual space template before contact with the luggage rack. The MCI bus reached the 130 mm (5.118 in) maximum displacement criteria for school buses at approximately 70 percent of UVW, and the Prevost bus reached the displacement criteria and continued to displace at 100 percent of the UVW.

During the ECE R.66 rollover tests, imprints from the residual space templates where the front templates struck the side windows in both the MCI and Prevost coaches indicate that only the lateral corner of the templates struck the side window. This suggests that with some design improvements to counteract the lateral forces these buses could pass the ECE R.66 rollover test.

In severe rollover incidents where the bus rolls over more than a quarter turn, school buses meeting FMVSS No. 220 have shown remarkable ability to maintain their structural integrity. Based on the above observations, it appears that the FMVSS No. 220 test protocol may be more stringent that the ECE R.66 requirement. However, these observations are for buses that are over fifteen years old and may not be applicable to the current U.S. fleet.

EMERGENCY EVACUATION STUDY

Several safety recommendations from the National Transportation Safety Board (NTSB) concern egress, emergency exit designs, lighting and signage/marking for motorcoaches (intercity buses). Conducting egress testing to evaluate motorcoach emergency evacuation designs under various post-incident conditions such as fire, smoke and unusable exit situations is also included in the NTSB recommendations.

Research Plan

NHTSA developed a research plan that is being conducted by the Volpe National Transportation System Center. The approach included the following general areas of investigation or activity: 1) Literature review to identify and evaluate relevant studies, modeling efforts, and regulations and standards from other transportation modes (e.g., rail and air) for applicability to motorcoaches, 2) survey and evaluation of various motorcoach emergency egress designs, including signage and marking, 3) conducting controlled evacuation simulations and egress experiments under various conditions and from various types of emergency exits, 4) measure and evaluate emergency exit opening force requirements, and 5) examine performance requirements for FMVSS No. 217 concerning exit opening force levels, signage, marking and lighting.

Preliminary Findings

Pilot studies [Volpe, 2008] have been completed for front door, emergency window, roof hatch, and wheel chair access door egress tests in addition to naturalistic observations of motorcoach egress of passengers. In addition, emergency window exit opening force measurements were made on three different models of motorcoaches (Prevost, Van Hool, MCI).

Some of the preliminary findings [NHTSA, 2009] from the testing and literature review are: the front access door of the motorcoach is the fastest and safest path of egress; the time required for passengers to determine how to open the front access door (in those cases where the motorcoach operator is unavailable) can take longer than the time required for a full load of passengers to evacuate through the door; conspicuous placement of the service door interior release mechanism and operational instructions are critical for passengers; able-bodied bus passengers are capable of egressing through a rear side door without steps (such as a wheel chair access door) at a rate that would allow evacuation of a fully loaded motorcoach in less than three minutes; the time to evacuate a fully loaded motorcoach through emergency exit windows is less than two minutes provided that passengers have the strength and agility to open the windows and climb out, and if methods of holding the windows open are available as shown in Figure 7.

Figure 7. Window Emergency Egress with Support Mechanism

Based upon the results of the pilot studies, construction of a motorcoach mockup for further egress assessment has been initiated for completion in 2009. The additional investigation will include the following general areas of investigation or activity: 1) motorcoach egress under adverse conditions (e.g., darkness); 2) human factors evaluation of egress using alternative options including seated jump and controlled drop from an elevated platform simulating the floor height for wheelchair access door, and a steep rear stairway similar to those used in European motorcoaches; 3) measurement of human strength in applying opening forces in the specific postures required in motorcoaches;
4) experimental determination of the effect of illumination levels on egress rates; and
5) development of performance requirements including interior egress, vehicle safety aids and emergency lighting.

FIRE SAFETY EFFORTS

While motorcoach fires may be relatively rare, they can cause a significant number of fatal or serious injuries during a single event.
Based upon the investigation of the Wilmer, Texas bus fire, it is evident that the fire originated from outside the vehicle cabin due to overheating of a vehicle axle. Additionally, the motorcoach recall data and industry studies indicate that most motorcoach fires start in areas external to the passenger compartment. It is rarely reported that fires start within the passenger compartment.

Of the fires that originate from outside the vehicle cabin, most originate in one of four areas: the engine compartment, the fuel system, the electrical system, or the wheel well. [NFPA, 2006] Causes of these fires range from mechanical failures of the equipment to leaks in hoses, couplings, seals and electrical circuit shorts.

Because numerous fire safety tests and standards already exist, NHTSA's approach is to build upon existing standards and recommended practices rather than develop new test procedures for materials used in construction of motorcoaches. NHTSA's approach also includes potential improvements to motorcoach performance requirements to address fires that originate both within the passenger compartment and those ignited external to it. Resistance to fire propagation is a key component to preventing burn and inhalation injuries, which were identified as the leading cause of death in fires that primarily originate from sources outside the vehicle cabin. Additionally, low flammability of interior components helps provide additional time for motorcoach occupants to evacuate a burning motorcoach and operators to suppress small fires that begin inside the cabin [NBSIR, 1978].

To evaluate potential fire protection tests and standards for relevancy to improving motorcoach safety, NHTSA initiated a research program with the National Institute of Standards and Technology (NIST) to establish an understanding of the development of motorcoach fires and the subsequent spread into the passenger compartment, assess the adequacy of the current FMVSS No. 302 for flammability testing of interior materials for motorcoach applications, recommend potential upgrades to the existing FMVSS No. 302 requirements, determine the feasibility of establishing requirements for fire-hardening or fire resistance of motorcoach exterior components, assess the potential for fire and smoke inhalation injuries to occupants in the event of a motorcoach fire, and identify potential mitigation strategies.

NIST is using the rear section of the motorcoach crash tested in December 2007 to create a mock-up for conducting controlled burn experiments that mimic fires originating in the wheel well area. These mock-up studies will be conducted in two phases. During the initial testing phase, the cabin will be instrumented with thermocouples, calorimeters, and video equipment to ascertain the effects of such fires on the passenger compartment. The tests will record the rate of fire growth, cabin environmental conditions, and cabin visibility vs. time for each ignition source. During the second phase of testing, various potential countermeasures (firewalls, temperature sensors, etc.) will be selected and tested to determine the extent to which each countermeasure improves the detection time, or potential evacuation time allowable for each ignition source.

CONCLUSION

While motorcoach travel in the United States is already very safe, NHTSA has been actively researching ways to improve bus safety for several years. The agency has recently launched a comprehensive program to improve motorcoach safety in a number of priority areas. The priority areas being pursued are seat belts to reduce passenger ejection, roof strength, fire safety, and emergency evacuation. The results of these studies will provide a basis for future NHTSA direction to promote additional improvements for motorcoach occupant protection.

REFERENCES

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APPENDIX A

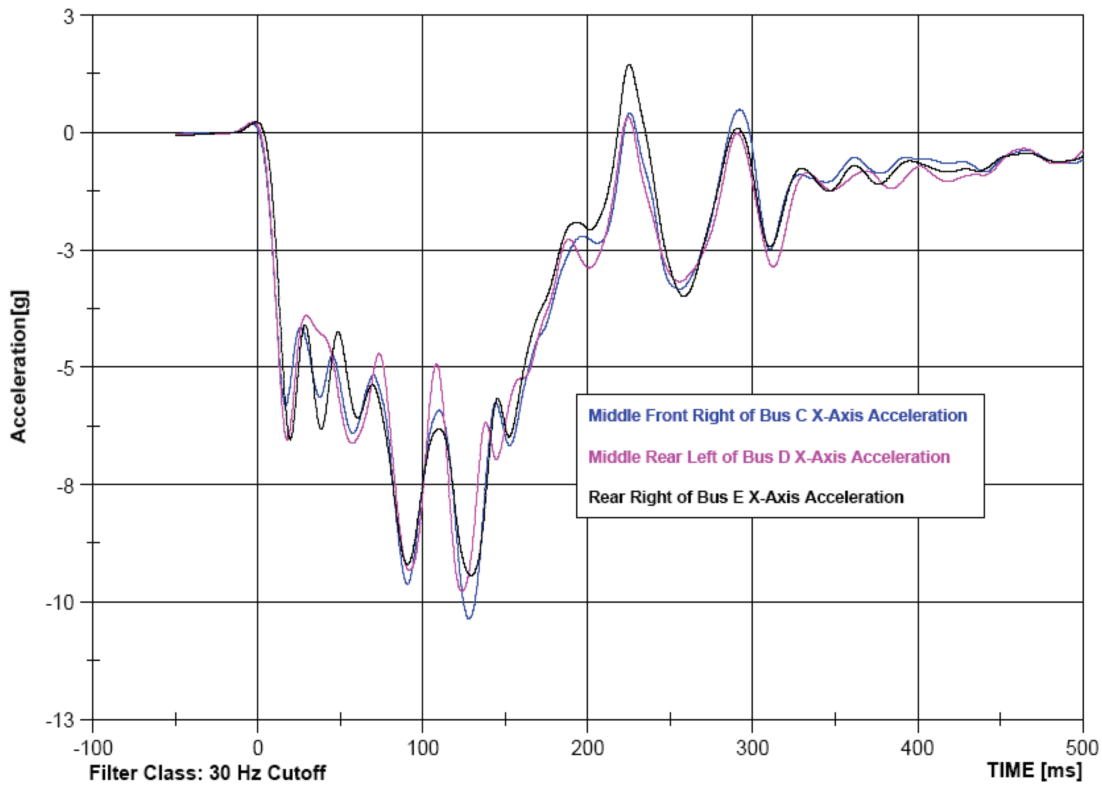

Figure A1. Motorcoach Crash Pulse

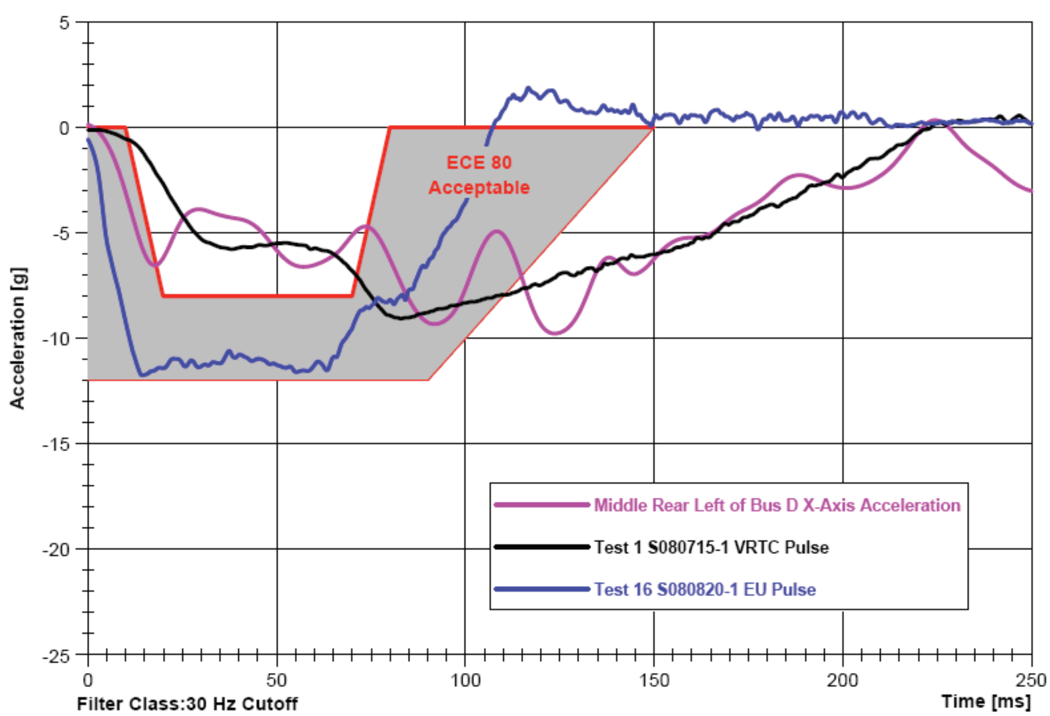

Figure A2. Accelerations for Crash Test (magenta), NHTSA Sled Pulse (black) and EU Pulse (blue)