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School Bus Restraints for Small Children in Canada

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16. Abstract

In an effort to assess the safety of preschool-aged children travelling in school buses, Transport Canada conducted tests to evaluate their safety if the bus is involved in a collision. The study has demonstrated that:

- Pre-school-aged children would benefit from being restrained in child restraints appropriate to their height and weight while travelling in a school bus.
- Older children continue to be well protected by school bus compartmentalization.

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16. Résumé

Dans le but d'évaluer la sécurité des enfants préscolaires qui voyagent en autobus scolaire, Transports Canada a effectué des essais pour déterminer leur niveau de sécurité si l'autobus est impliqué dans une collision.

L'étude a démontré les faits suivants :

- Les enfants d'âge pré-scolaire bénéficieraient de l'utilisation d'ensembles de retenue qui sont appropriés à leur taille et leur poids lorsqu'ils voyagent en autobus scolaire.
- Les enfants plus âgés sont toujours bien protégés par le compartimentage des autobus scolaires.

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School Bus Restraints for Small Children In Canada

Prepared by the Standards and Regulations Division, Road Safety and Motor Vehicle Regulation Directorate, Transport Canada – November 16, 2004

1. BACKGROUND

Historically, school buses have been used to transport school-aged children to and from school or other activities. Transport Canada has conducted several studies and investigations that determined that school buses are the safest means of road transportation for school-aged children [1] [2] [3] [4] [5] [6] [7] [8].

One of the features that make school buses safe for school-aged children is "compartmentalization." Compartmentalization is a means of providing passive protection by deformable and energy-absorbing seats, as well as optimized seat spacing and seat back height. In a collision, the body of the passenger moves forward, contacting and deforming the energy-absorbing seat back in front, distributing the force across the entire upper body area. This system has proven to be very effective in protecting school-aged children. Other features that make school buses safe are their strong body joints, window retention, roof intrusion protection, emergency exits and distinctive colour and lights, which make them conspicuous on our roads.

Parents, daycare centres and those responsible for transporting preschool-aged children are increasingly requesting information from Transport Canada on how to safely transport preschool-aged children in school buses. Some provinces have a networked daycare system where young children are transported from one building to another, to and from activities or playgroups. In some jurisdictions, children start school at 4½ years of age or younger.

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[1] *School Bus Collision Tests*, Transport Canada, Traffic Safety Standards and Research, Standards and Regulations, 1985, Technical Memorandum (TSRS).
[2] G.N. Farr, *School Bus Seat Development Study*, Transport Canada, Road Safety Standards and Research, 1987, TP8445E.
[3] P. Gutoskie, T.M. Burtch and G. Farr, *Background Paper on School Bus Occupant Protection in Canada*, Transport Canada, Traffic Safety Standards and Research Branch, 1989, TP 8013E.
[4] M. McHattie, *Review of Bus Safety Issues*, Transport Canada, Road Safety and Motor Vehicle Regulation Directorate, 1998, TP13330E.
[5] W.T. Gardner and S. Ste Marie, *School Bus Collision Summary, Canada, 1989-1997*, Multi-Disciplinary Road Safety Conference XI, Halifax, Nova Scotia, 1999.
[6] J.-F. Bruneau, *Comparison of Two Advance Stop Signalling Systems Used on Canadian School Buses: Amber Lights and Red Lights*, Transport Canada, Transportation Development Centre, 2002, TP13903E.
[7] G.N. Farr, *School Bus Safety Study, Volumes 1 & 2*, Transport Canada, Traffic Safety Standards and Research, 1985, TP6222E.
[8] *School Bus Collisions 1992-2001*, Transport Canada, Road Safety and Motor Vehicle Regulation Directorate, June 2004, TP2436E, RS2004-02E.

In an effort to assess the safety of preschool-aged children travelling in school buses, Transport Canada conducted tests to evaluate their safety if the bus is involved in a collision. The heads of preschool-aged children are proportionately larger than those of older children and make contact with the seat back in front in a different manner. In addition, their bodies may not weigh enough to take full advantage of the energy-absorbing seat backs.

The study reviewed the compartmentalization protection offered by school bus seats and properly installed child restraints. The analysis targeted forward-facing child restraints. Other studies have extensively investigated the benefits of rear-facing restraints for infants [9] [10] [11]. A review of these studies has determined that the benefits of rear-facing restraints for infants would also apply when these restraints are used in school buses.

This report compares dummy response for the 18-month, 3-year and 6-year old dummies[12] using compartmentalization and properly installed forward-facing child restraints in forward simulated impacts.

Canadian regulations[13] currently require that all new small buses[14] be equipped with two sets of lower universal anchorages, which allow for the base of a child seat to be installed in the bus. Every child restraint manufactured since September 2002[15] must be equipped with connectors compatible with lower universal anchorages and a tether in the case of forward-facing child restraints.

Transport Canada has developed an information package about the safe travel of children in passenger vehicles. This package, known as Car Time 1-2-3-4,[16] divides the safe travel of children into simple stages. The dummies used and the conclusions reached in this study make reference to these stages.

2. STUDY OBJECTIVE

The objective of the study was to investigate the relative safety offered to children of different ages by compartmentalization and by child restraints in the context of travelling in school buses. Testing on an acceleration sled using dummies representing children of different ages, mass and heights was performed in order to achieve this.

[9] F. Legault and D. Stewart, *Towards Improved Infant Restraint System Requirements*, ESV Conference Paper Number 98-S10-O-10, Windsor, Canada, 1998.

[10] G. Carlsson, H. Norin and L. Ysander, *Rearward-facing Child Seats – The Safest Car Restraint for Children,* Accident Analysis and Prevention, Vol. 23, Nos. 2/3, pp. 175-182, 1991.

[11] B. Kamren, M.V. Koch, A. Kullgren, A. Lie, C. Tingvall, S. Larsson and T. Turbell, *The Protective Effects of Rearward Facing CRS: An Overview of Possibilities and Problems Associated with Child Restraints for Children Aged 0 - 3 Years*, SAE 933093, SP-986, Child Occupant Protection, San Antonio, 1993.

[12] The word "dummy" refers to anthropometric test devices that surrogate humans in laboratory tests.

[13] SOR/2002-205, May 30, 2002; SOR/2003-272, July 24, 2003.

[14] GVWR of 4 536 kg or less.

[15] SOR/2002-206, May 30, 2002.

[16] *Keep Kids Safe: Car Time 1-2-3-4*, Transport Canada, TP 13511E, Revised June 2001.

3. SUMMARY OF FINDINGS

This study has demonstrated that:

- Children whose mass is 18 kg (40 lb.) and under, or until they reach approximately 4½ years, would benefit from being restrained in child restraints appropriate to their height and weight while travelling in a school bus. Proposing an amendment to the universal lower and tether anchorage regulations to extend their applicability to all new school buses would facilitate the installation of child restraints in school buses.
- Older children continue to be well protected by school bus compartmentalization.

4. REGULATORY CONSIDERATION

Based on this study, the Department is proposing to amend the *Motor Vehicle Safety Regulations* to make the requirements of CMVSS 210.1 “User-Ready Tether Anchorages for Restraint Systems”[17] and CMVSS 210.2 “Lower Universal Anchorage Systems for Restraint Systems”[18] applicable to all new school buses. The proposed amendments would introduce a requirement for all new school buses to be equipped with user-ready tether and lower universal anchorages on every bench seat: one set of user-ready tether and lower universal anchorages for each school bus bench seat whose width is 762 mm or less, or two sets for school bus bench seats wider than 762 mm.

Currently, the regulation requires that two forward-facing designated seating positions be equipped with lower universal anchorages in all new buses whose gross vehicle weight rating (GVWR) is 4 536 kg or less.

5. TEST METHODOLOGY

Tests were performed with three state-of-the-art fully instrumented dummies. Two dummies were selected to represent preschool-aged children, while one represented a small school-aged child. These dummies and the size of children they represent are presented below.

The head and chest accelerations of the dummies were measured for each test. Because injury reference levels have not been adopted for children,[19] the upper and lower neck forces and moments and shoulder loads were not analyzed.

Two tests each were conducted for the 18-month dummy using compartmentalization and child restraints, two tests each were conducted for the 3- and 6-year old using compartmentalization, and three tests were conducted for the 3-year old using child restraints.

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[17] Canada Gazette references to follow.

[18] Canada Gazette references to follow.

[19] United States Federal Register: Rules and Regulations; *FMVSS 213 – Child Restraint Systems*, Vol. 68, No. 121, June 24, 2003; pp. 37619-37658.

5.1. TEST FACILITIES

School bus seats meeting CMVSS 222[20] "School Bus Passenger Seating and Crash Protection" were installed and secured to a HyGe sled. In the case of compartmentalization tests, a cage was installed around the test equipment to retain the dummies.

Figure 1 – Typical test setup

The tests were conducted in accordance with the prescriptions of "Test Method 213 – Child Restraint Systems."[21] The change of velocity of the test sled (δV) was 48 km/hr, while the deceleration pulse of 20 "g" was attained within 11 milliseconds and maintained until 48 milliseconds after the start of the test. The ambient test conditions, specifications for atmospheric soaking and test preparation, were also those specified in the Test Method.

[20] SOR/80-161, February 21, 1980; SOR/86-453, April 17, 1986; SOR/91-593, October 24, 1991.
[21] Issued April 1, 1982, and revised in October 2001.

5.2. TEST DUMMIES

The 18-month CRABI[22] and 3-[23] and 6-year[24] Hybrid III dummies were used in this test program. The mass for each dummy is given in Table 1.

The 18-month dummy represents a child whose mass is slightly over that of an older Stage 1 child (from birth to about one year old), the 3-year dummy that of a Stage 2 child (from about one year to about 4½ years) and the 6-year dummy that of a young Stage 3 child (from about 4½ to about eight years). The stages corresponding to the dummy sizes used in this study are also given in Table 1.

Table 1 – Test dummy information

Test Dummy	*Mass (kg)*	*Mass (lb.)*	*Corresponding Stages in Car Time 1-2-3-4*	*Targeted bus occupant population*
CRABI 18-month	11.5	25.3	Slightly above that of Stage 1	Smallest-size child potentially taking part in daycare activities and trips
3-year Hybrid III	15.5	34.0	Stage 2	Average-size child potentially taking part in daycare activities and trips
6-year Hybrid III	23.5	51.6	Stage 3	Youngest grade school child transported on school buses

The specifications for the head and chest accelerometers that recorded the data analyzed in this report are consistent with Society of Automotive Engineers Recommended Practice SAE J211.[25] The dummies were clothed as specified in Test Method 213, with clothing size adjustments made for their respective stature.

[22] CRABI 18 Month Old Child Dummy, First Technology, part no. 93091-000.
[23] United States Code of Federal Regulations, Title 49, Transportation, Part 572 – Sub-Part “P.”
[24] United States Code of Federal Regulations, Title 49, Transportation, Part 572 – Sub-Part “N.”
[25] Society of Automotive Engineers Recommended Practice (SAE) J211, Instrumentation for Impact Tests (MAR95).

5.3. RESTRAINTS

Every school bus seat and child restraint used in this testing was either a commercially available product or a prototype designed by seating or restraint manufacturers.

6. DATA RECORDING AND ANALYSIS

6.1. DATA RECORDING EQUIPMENT

Each test was recorded and the data were analyzed using the following equipment:

- Transducers on the sled were supplied with 3.33 volt DC from local sled-mounted power supplies. Outputs were fed to off-board active analog filters (via a low-noise multi-coaxial umbilical cable), which filtered the data according to the SAE J2111.
- The signals were then digitized at a sampling rate of 10,000 samples per second using a series of four National Instruments MIO-6070E multifunction boards containing 12-bit A/D converters, which provided direct memory access to the RAM of a National Instruments PXI 8156 computer system where the data was initially stored, with final indefinite storage on CD-ROM.
- Digital post-filtering was carried out from the data in RAM using custom-designed National Instruments Labview software as specified for the filter class by SAE J2111. The Labview software was further used to perform scaling, processing and plotting functions.

6.2. FILM RECORDING AND ANALYSIS

Video recordings were used to perform the kinematics analysis for each test. This information was recorded using:

- a Kodak EM Ektapro Motion Analyzer system;
- a Kodak high-gain imager (video camera);
- a Kodak EM Processor (model 1012) producing black and white motion pictures with X-Y electronic crosshair calculation capability;
- a frame rate of 500 frames per second; and
- a shutter speed of 1/1000 sec.

6.3. VARIABLES EXPLORED IN THE STUDY

The variables explored in the present study are the following:

6.3.1. *Dummy/Child Size*

CRABI 18-month old and Hybrid III 3-year old and 6-year old dummies were used to simulate child occupants.

6.3.2. *Configuration of Restraint System*

The compartmentalization tests provide a baseline for the measurements for the different dummies. Child restraints used in the testing all had the same shell and harness design.

6.4. DATA SCREENING

The data were examined for errors in data entry and to identify any outliers in the test results. No such occurrences were identified. Every test was also subjected to extensive photographic analysis.

7. RESULTS

The results are presented in Figures 2 and 3. For conciseness, these figures use “CRS” to refer to child restraint system and “passive” to refer to compartmentalization. The numerical results for each test appear beside the corresponding data point in the graphs. For the purposes of this paper, maximum values for head and chest accelerations are reported and analyzed.

The grey data bars in the graphs represent tests performed for properly installed child restraints securing the 18-month and 3-year dummies, whereas the white data bars represent tests performed with compartmentalization for the 18-month, 3-year and 6-year dummies.

For reference purposes, the acceptable levels for head and chest accelerations are 80 g and 60 g respectively (the horizontal line in Figures 2 and 3). These acceptable levels were adopted from the criteria for the 3-year dummy as specified in CMVSS 213.4 “Built-in Child Restraint Systems and Built-in Booster Cushions”[26] and CMVSS 213 “Child Restraint Systems.”[27]

[26] SOR/94-669, October 25, 1994.

[27] Schedule 3 of Motor Vehicle Restraint Systems and Booster Cushions Safety Regulations (RSSR); SOR/98-159, March 12, 1998; SOR/98-524, October 22, 1998; SOR/2000-89, March 2, 2000; SOR/2001-341, September 20, 2001; SOR/2002-206, May 30, 2002.

7.1. HEAD ACCELERATION

Figure 2 presents head acceleration according to dummy size and the type of restraint system used. The head acceleration for every test for the 18-month dummy using a child restraint (two tests), the 3-year dummy using a child restraint (three tests) and the 6-year dummy using compartmentalization (two tests) were below the 80 g criterion, whereas every test for the 18-month dummy using compartmentalization (two tests) and the 3-year dummy using compartmentalization (two tests) were above the criterion. This indicates that children in Stages I and II would benefit from using a properly installed child restraint while travelling in a school bus.

7.2. CHEST ACCELERATION

Figure 3 presents chest acceleration according to dummy size and the type of restraint system used. The chest acceleration for every test for the 18-month dummy using a child restraint (two tests), the 3-year dummy using a child restraint (three tests) and the 6-year dummy using compartmentalization (two tests) were below the 60 g criterion, whereas one of the two tests for the 18-month dummy and one of the two tests for the 3-year dummy using passive protection were above the criterion. This also indicates that children in Stages I and II would benefit from using a properly installed child restraint while travelling in a school bus.

8. CONCLUSIONS AND SUMMARY

The 6-year old dummy was well protected by compartmentalization. The 3-year and 18-month old dummies would benefit from a properly installed child restraint.

The analysis of the data in this study suggests that children corresponding to Stages 1 and 2 would benefit from the use of properly installed children's restraint systems while travelling in a school bus.

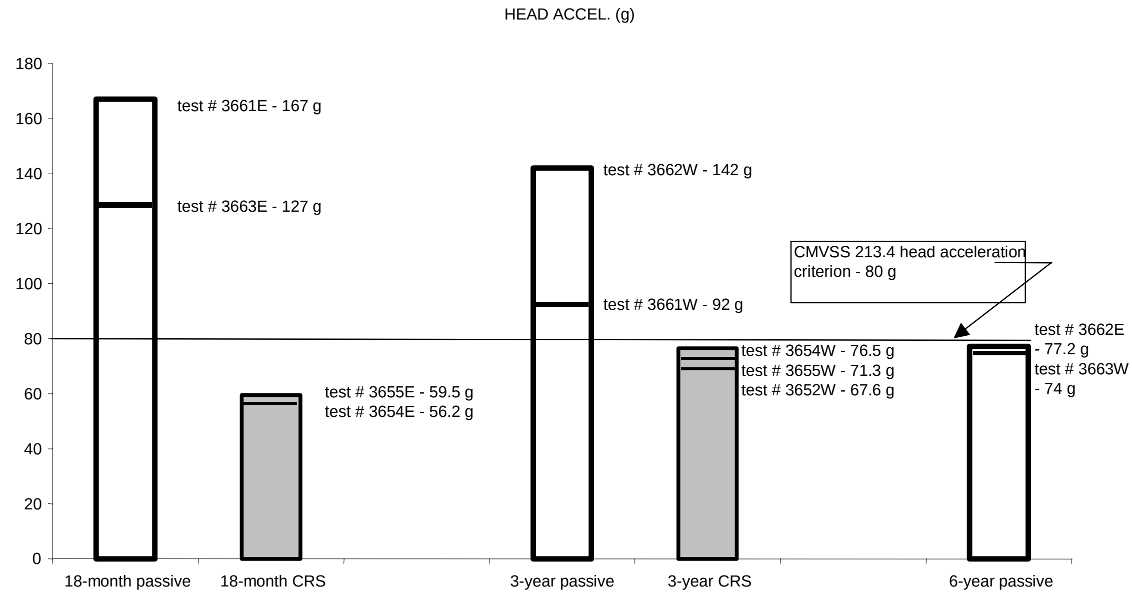

Figure 2 – Head acceleration with respect to test dummy size and restraint use

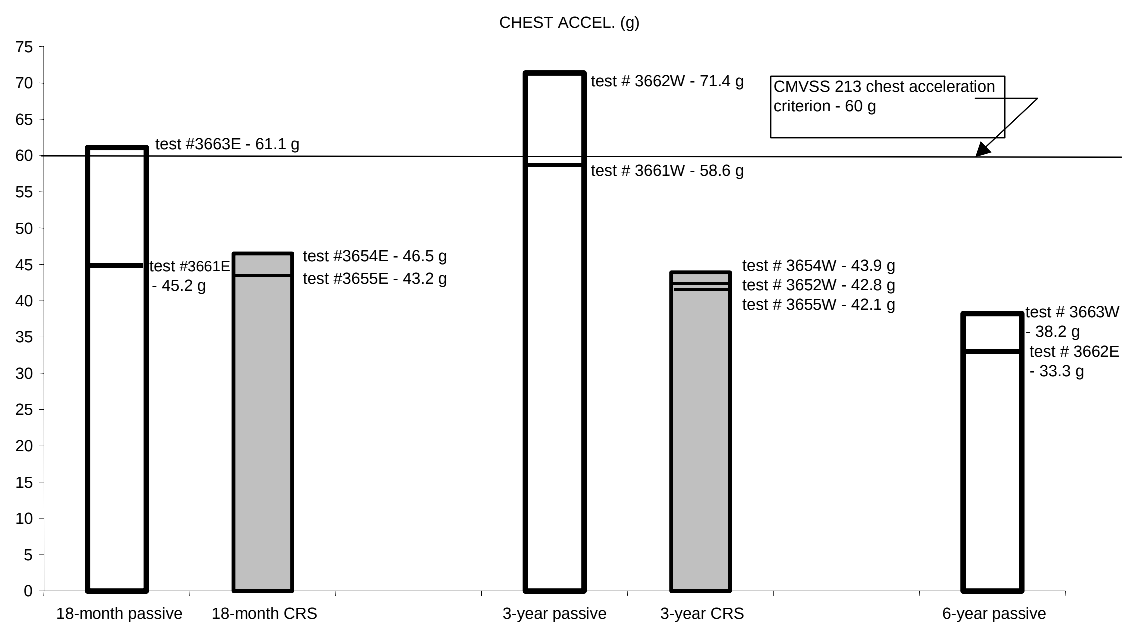

Figure 3 – Chest acceleration with respect to test dummy size and restraint use