NHTSA'S INITIAL EVALUATION OF CHILD SIDE IMPACT TEST PROCEDURES

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ABSTRACT

This paper details the National Highway Traffic Safety Administration's (NHTSA) initial research to evaluate potential child side impact test procedures. Federal Motor Vehicle Safety Standard (FMVSS) No. 213, "Child Restraint Systems" currently only requires that U.S. marketed child restraints meet dynamic testing simulating a 48.3 kph (30 mph) frontal impact. NHTSA is evaluating test parameters and potential methodologies to replicate a representative side impact scenario that could potentially be developed into a future child restraint dynamic side impact test procedure. This paper will discuss (1) testing conducted using the side impact sled buck designed by TK HOLDINGS INC. (Takata), and (2) side impact moving deformable barrier (MDB) into vehicle crash tests, which were performed in an effort to refine sled buck test parameters. This study is limited to one generic sled test buck design concept and side impact tests involving small passenger vehicles. It was observed that the sled buck concept was repeatable and able to distinguish between child restraint system (CRS) models. The design of the CRSs' seat back side wing is an important element for providing side impact protection, particularly when impact angles are varied. Trends in injury response values between sled and crash tests were similar for the two CRS models used in both types of testing.

INTRODUCTION

This study looks at the use of dynamic generic sled simulations to replicate the performance observed during vehicle crash tests of a properly restrained 3-year-old child dummy. With only a side impact child dummy representative of a 3-year-old currently available, the 1- to 3-year-old age group was the primary focus for the agency's initial evaluation of child restraint systems during side impact crashes. The TNO Q3 side (Q3s) dummy and the Hybrid III 3-year-old dummy, with a side impact neck (H3Cs), were used as Anthropomorphic Test Devices (ATDs).

Children represent more than 50% of the rear seat occupants in motor vehicle crashes. Side impacts are the second most frequent collisions resulting in child occupants sustaining serious to life-threatening head, neck and chest injuries. Using NHTSA's National Automotive Sampling System – Crashworthiness Data System (NASS-CDS) database (1995-1996, 1998-2004), it was determined that side impacts account for 27% of the crashes involving 0-12 year old occupants. For those side impacts, 42% involved children 0-3 years old, 36% involved 4-8 year olds and 22% involved 9-12 year olds. [1]

For children 1-3 years old, 9% of those with survivable injuries were unrestrained (NASS-CDS) and 46% of the fatally injured were unrestrained (FARS 1994-2003). Using unweighted values, due to the paucity of NASS-CDS data for the 1-3 years age group, side impacts with a $\Delta V \geq 30$ kph (18.7 mph) provided 28 children with 104 injuries. For this subset, it was observed that:

- The PDOF of the subject side impact crashes was approximately 30° off lateral,
- Near-side and center occupants suffered more severe injuries (AIS2+) than far-side occupants, and
- Direct contact with the vehicle interior accounted for 45% (47) of the injuries, while 14.4% (15) were due to contact with the child restraint system (CRS). Of these 104 injuries, 57% were to the head, 21% to the torso and 6% to 9% were to the neck and the upper and lower extremities.

HYGE SLED TEST SERIES

Sled Buck Configuration

The sled buck used was a side impact buck designed by Takata, which consists of a sliding "vehicle" seat mounted to a rail system along with a "side door" structure rigidly mounted to the sled buck structure. A specific density of aluminum honeycomb is mounted below the "door" structure. The sliding "vehicle" seat is positioned sufficiently away from the "side door" to allow the sled to reach a desired velocity prior to the sliding "vehicle" seat coming into contact with the "side door" and aluminum honeycomb. The principle of this design is that the sliding "vehicle" seat and CRS impact the side

"door" structure at a desired speed, at which time the aluminum honeycomb begins to crush, replicating the intrusion velocity of the "door" that the CRS would experience during an actual vehicle crash. Figure 1 shows a schematic of the Takata side impact buck configuration. A photo of the actual set-up used by NHTSA is shown in Figure 2.

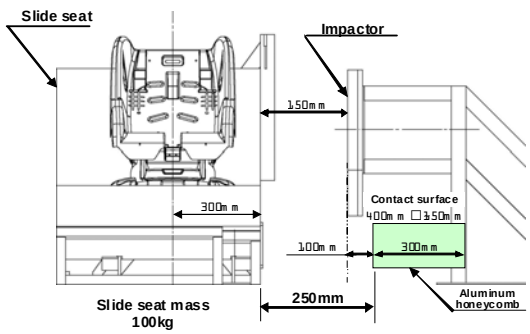

Figure 1. Takata's Side Impact Sled Buck.

Figure 2. NHTSA's Side Impact Sled Buck Set-up.

Two differences between the Takata buck and the NHTSA buck set-ups are notable. First, the ECE Regulation No. 44 seat cushion foam used by Takata was replaced with the cushion foam used in the FMVSS No. 213 seat fixture. Secondly, the initial seat to honeycomb distance was increased from 250 mm to 260 mm for the NHTSA tests. The distance was increased in order to obtain the desired impact velocity while preventing the sliding seat from bottoming out against the support structure behind the honeycomb.

Initial Sled Test Parameters Used by NHTSA

The agency chose to look at small vehicles to develop the test parameters. The vehicle models selected were previously tested in accordance with FMVSS No. 214 "Side Impact Protection" Moving Deformable Barrier (MDB) test procedure. As noted earlier, the Takata buck design is unique in that it has two moving fixtures – the sled buck itself and the seat on which the child restraint is attached. The critical factor for the sled buck is to have the "door" structure reach the desired velocity prior to its contact with the sliding "vehicle" seat. The desired door velocity and sliding seat acceleration pulse were determined in order to determine these parameters.

Determination of Sliding Seat Acceleration Pulse – The target acceleration pulse for the sliding seat was determined by evaluating the right rear sill Y-axis accelerometers in ten small vehicles that were tested per FMVSS No. 214. There was a negligible difference between the acceleration pulses obtained from use of the X-Y resultant and that from use of only the Y-axis accelerations. Therefore, only the Y-axis accelerometers were used in this analysis. Each of these vehicles had a 50th percentile adult male and/or a 5th percentile adult female dummy in the rear seat. Those vehicles* were:

- 2005 Toyota Corolla
- 2005 Toyota Corolla
- 2005 Subaru Forester
- 2005 Suzuki Forenza
- 2005 Subaru Forester
- 2003 PT Cruiser
- 2003 Mazada Protégé
- 2003 Suzuki Aerio
- 2005 Saturn Ion
- 2005 Saturn Ion

*(See Appendix for the FMVSS No. 214 Vehicle Database test numbers and dummy types)

The right rear sill values were averaged together to derive a typical acceleration level for a small sized vehicle. The dotted black line shown in Figure 3 represents this average. The upper and lower boundaries (blue lines) of sliding seat pulse were based on the maximum and minimum values of the cluster of acceleration curves when the individual curves for the ten vehicles were overlayed on one plot. The red line is representative of the actual sliding seat acceleration pulse obtained in the tests reported in this paper. The data channels were filtered with a Class 60 filter.

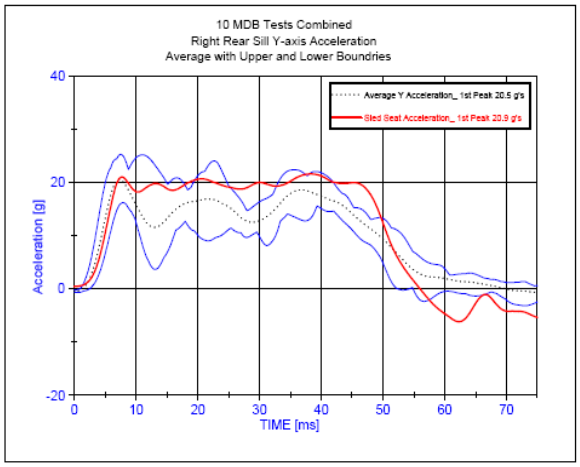

Figure 3. Sliding Seat Pulse with Boundaries.

Determination of Sliding "Vehicle" Seat Velocity – The aforementioned ten vehicles were also used to determine the desired sliding seat velocity. The accelerometers were integrated to calculate the velocity and then averaged together. The derived velocity was approximately 27 to 29 kph (17 to 18 mph).

Determination of "Door" Velocity – The determination of the door velocity was from four small vehicles tested under FMVSS No. 214. The four vehicles* used for this derivation were:

- 2005 Subaru Forester
- 2005 Toyota Corolla
- 2005 Suzuki Forenza
- 2005 Saturn Ion

*(See Appendix for the FMVSS No. 214 Vehicle Database test numbers)

The derived average velocities (Y-axis) ranged from 31.4 kph at the upper centerline of the door to 33.0 kph at the mid centerline. Therefore, 32 kph (20 mph) was selected as the target speed of the door on the sled buck. The shape of the acceleration pulse for the sled/door was not critical, but it should be at peak speed prior to the honeycomb contacting the sliding seat structure. This was achieved using a half-sine acceleration pulse for the sled/door, with a peak acceleration of about 28 G's and a duration of about 55 milliseconds.

Figure 4 shows the sled/door velocity (red line) and the sliding seat velocity (blue line) for a typical sled test. As can be seen, the actual sliding seat velocity exceeded the desired speed of 27 to 29 kph (17 to 18 mph) derived from crash tests. This is due to the mass of the sliding seat being small compared to that of the sled, as compared to in the crash tests, where the mass of the struck vehicles and the MDB were more similar. Based on engineering judgment, maintaining a door velocity of about 32 kph (20 mph) and a sliding seat acceleration pulse that matched the corridors shown in Figure 3 were deemed more critical than achieving the desired seat velocity. The large mass difference between the sliding seat and sled would require adding significant weight to the sliding seat in order to reduce the seat velocity.

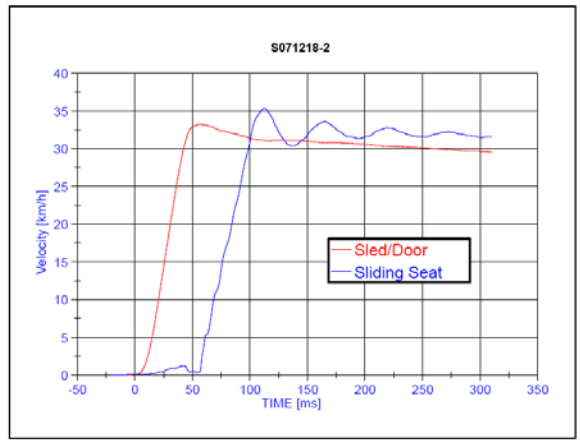

Figure 4. Typical "Door" and Seat Velocities.

Determination of Sled Buck Angle – The ten vehicles which were used to derive the test pulse boundaries and the door velocity were used to determine the impact angle of the sled buck. The right rear side sill X-axis and Y-axis accelerations were integrated to obtain the corresponding component velocities. These were then used to calculate the angle of the resultant deceleration with respect to the lateral axis of the vehicle during the crash event. The time period of interest was determined to be five to 60 milliseconds, which represents the typical time from initial motion of the struck vehicle through peak loading on the near-side occupant. A reference frame was used in which a pure left-to-right lateral impact was zero degrees and a pure frontal impact was 90 degrees. The mean angles over the time period of interest for the ten vehicles ranged from four to 15 degrees, while the angle at any specific time ranged from -8 to 22 degrees across the ten vehicles. Based on this, it was decided to consider the range from 0 to 20 degrees for the test program reported here.

Summary of Test Parameters – The following test parameters were used for the sled tests:

- Sled pulse – ½ sine, 28 G peak, 55 msec duration
- Sled velocity – 32 kph (20 mph)

- Honeycomb dimensions (2.3 PCF, 3/8" cell wall): 300 mm thick x 342 mm wide x 125 mm long
- Sliding seat initial position – 260 mm from honeycomb
- Sliding seat acceleration – matches corridors in Figure 3, 20 G peak, 55 msec duration
- Door padding - 5 cm foam thickness
- Lateral (0°) and oblique (10°, 15° and 20°) impact angles

Sled buck and test parameters, such as initial seat to door spacing, honeycomb stiffness and/or dimensions, door padding and sled speed, can be altered in order to fine-tune results.

Discussion of Side Impact Sled Test Results

CRS Models Tested – It was desirous to test models of CRS that meet FMVSS No. 213 and/or ECE Regulation No. 44 requirements. In addition to testing U.S. compliant CRS models, it was of interest to test models that meet the European restraint standard. For this initial evaluation of the test configuration, a total of five CRS models were selected:

- Graco SafeSeat Step2 Toddler
- Evenflo Triumph Advance DLX
- Safety 1st All-in-One Convertible
- Maxi-Cosi Priori (SIP)
  (meets both FMVSS No. 213 & ECE Reg. 44)
- Graco Logico M (SIP)
  (meets only ECE Reg. 44)

All of the CRS models were tested in the forward-facing mode with the 3-year-old Q3s side impact dummy. The LATCH system was used to install the seats, except for the Graco Logico M. By being compliant only with ECE Reg. 44, the Logico M does not have ISOFIX hardware. It was installed with a lap/shoulder belt restraint (no top tether).

Evaluation of Test Methodology – The first series of sled tests consisted of conducting tests with the five CRS models at a simulated 0° impact angle. Each CRS model was tested at least twice; two of the models, the Graco SafeSeat Step2 and the Safety 1st All-in-One, were tested six and four times, respectively.

Five different dummy responses were used to evaluate the repeatability of the test procedure: HIC_{15}, upper neck tension, spine y-axis acceleration, pelvis y-axis acceleration and chest lateral displacement. Because there are currently no established injury assessment reference values (IARV) for the child side impact dummies, the test results were used solely for comparative purposes and not to ascertain "pass/fail" conditions.

Figure 5 contains the mean HIC_{15} values for each of the CRS models, while Figure 6 contains the mean neck tension values.

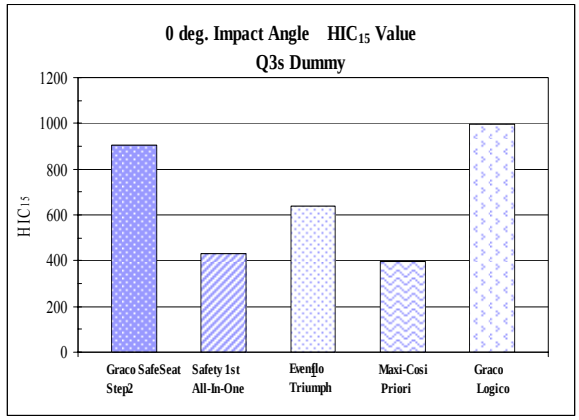

Figure 5. Mean HIC_{15} Values at 0° Impact Angle.

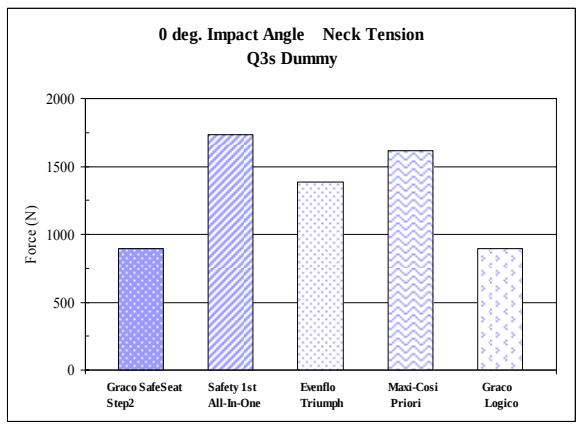

Figure 6. Mean Neck Tension at 0° Impact Angle.

It is noted that there appears to be a trend between HIC_{15} value and neck tension; as one value increases, the other decreases. The HIC_{15} value tends to be higher when there is a more pronounced lateral component to the dummy's head motion (i.e., more direct lateral contact with CRS side wing). If the forward component of the dummy's head motion is more pronounced, the contact force on the head decreases while the inertial loading on the neck from the head increases. This tends to result in higher neck tensions and lower HIC_{15} values.

The mean values for the spine and pelvis Y-axis accelerations are shown in Figures 7 and 8,

respectively, and the mean chest displacement values are shown in Figure 9 for the five CRS models tested at 0° impact angle.

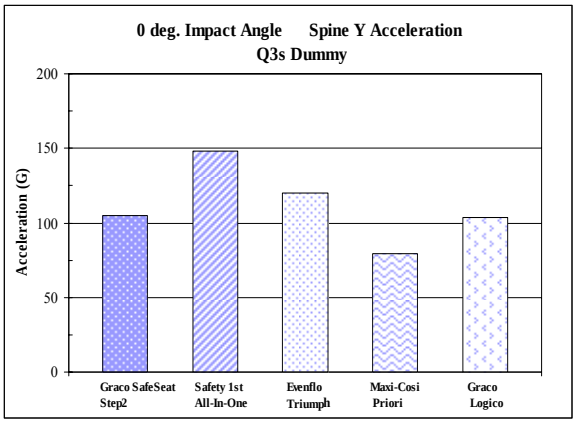

Figure 7. Mean Spine Y-axis Acceleration at 0° Impact Angle.

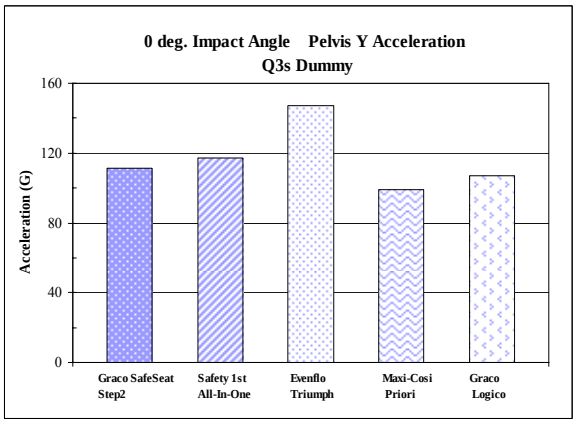

Figure 8. Mean Pelvis Y-axis Acceleration at 0° Impact Angle.

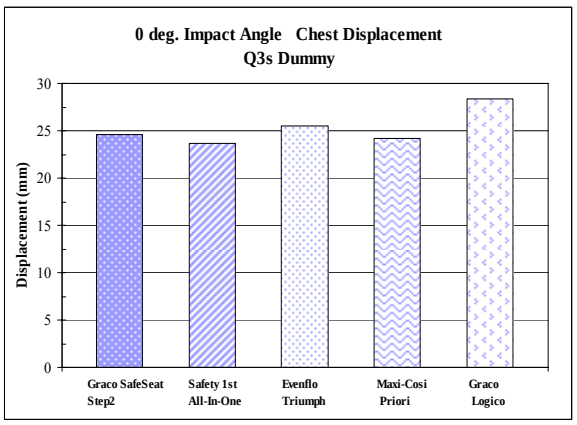

Figure 9. Mean Chest Lateral Displacement at 0° Impact Angle.

Evaluation of Impact Angles – Subsequent to the 0° impact angle tests, a series of tests were performed with the sled buck rotated to simulate impacts at 10°, 15° and 20^0. This series was conducted in an effort to evaluate the effect of the buck's impact angle on dummy kinematics. In addition to replicating dummy injury responses, it is also desirous to replicate the dummy's kinematics observed in side impact crashes.

The three CRS models tested in this series – Graco SafeSeat Step2, Evenflo Triumph and Maxi-Cosi Priori – were selected primarily because of their seat back side "wing" design. The SafeSeat Step2 and the Maxi-Cosi Priori have wings that are essentially perpendicular to the CRS seat back. The wings on the Evenflo Triumph are slightly more angled outward relative to the seat back (see Appendix for photos of CRS models). The Safety 1st All-in-One was not chosen for this series because dummy head contact with the side "door" structure had been observed when the buck was oriented at 0°; testing at angles greater than 0° with this CRS model would not have garnered pertinent information with regard to effect of impact angle. Also, the Graco Logico was not tested at impact angles greater than 0° because the CRS was not available at the time of the test series.

The HIC_{15} values for the three CRS models at the four different sled buck orientations are shown in Figure 10. Two of the CRS models (SafeSeat Step2 and Maxi-Cosi Priori) exhibited a trend of decreasing HIC value with increasing impact angle, while the third CRS (Evenflo Triumph) exhibited the reverse trend – increasing HIC value with increasing impact angle. For all three CRS models, the dummy's upper torso and head increasingly rotated forward in the CRS as the impact angle increased. Although the dummy kinematics were similar for all three seats, the design of the seat back side wings appears to affect the head responses (see Figure 11 for photos of Graco SafeSeat Step2 and Evenflo Triumph CRS, respectively). The SafeSeat Step2 and Maxi-Cosi Priori's more straight forward wing design better contained the head throughout the event, allowing the head velocity to dissipate during the dummy's forward rotation. This was not the case for the Evenflo Triumph. Because the wing design for this CRS is slightly more outward relative to the seat back than the other CRS models, the dummy's head contacted the side wing and then rotated outward along the edge of the wing resulting in more pronounced head rotation and excursion than observed for the other two models.

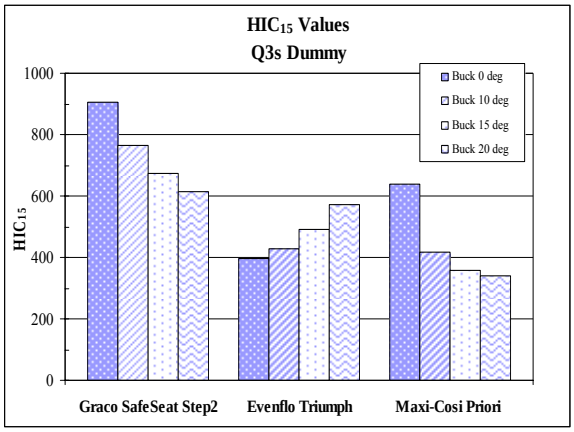

Figure 10. HIC_{15} Values for 0°, 10°, 15° and 20° Sled Impact Angles.

Figure 11. Examples of Wing Designs (Graco SafeSeat Step2 [left] and Evenflo Triumph [right]).

The dummy's peak neck tension values for the three CRS models at each impact angles are shown in Figure 12. As anticipated, neck tension generally tended to increase as the impact angle increased due to the forward rotation of the upper torso and head. Note that for the Evenflo Triumph, the neck tension significantly increased once the impact angle was greater than 0°. The CRS model's wing design appears to have an effect on the increase in tension values, as previously discussed.

Figures 13 and 14 show the spine and pelvis Y-axis accelerations, respectively, for the four sled test impact angles. The accelerations tended to be greater when tested at the 0° impact angle for the SafeSeat Step2 and Triumph, while they were virtually identical across the impact angle range for the Maxi-Cosi Priori.

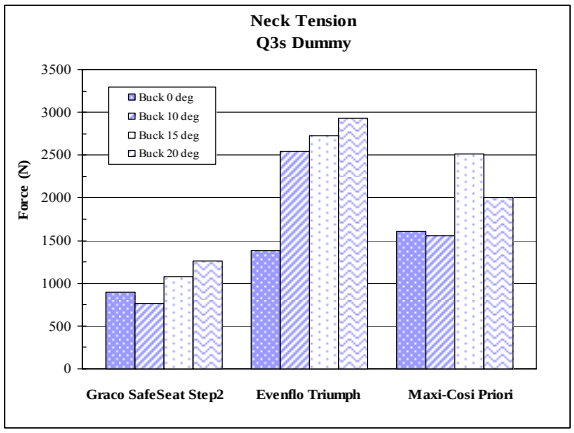

Figure 12. Neck Tension for 0°, 10°, 15° and 20° Sled Impact Angles.

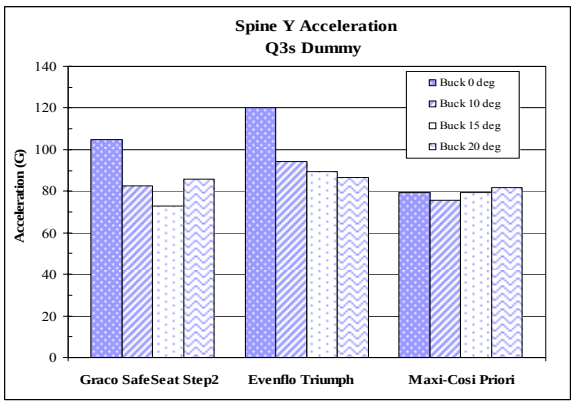

Figure 13. Spine Y-axis Acceleration for 0°, 10°, 15° and 20° Sled Impact Angles.

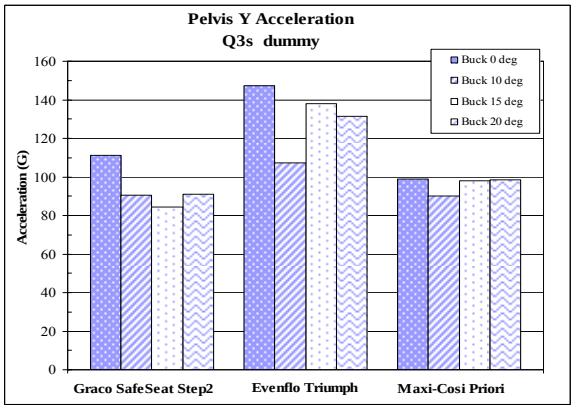

Figure 14. Pelvis Y-axis Acceleration for 0°, 10°, 15° and 20° Sled Impact Angles.

The dummy's lateral chest displacement for the four impact angles are shown in Figure 15. No specific trend appeared for the three CRS models. For the SafeSeat Step2, displacement values varied by approximately 6 mm, while displacement varied approximately 3 mm for the other two models.

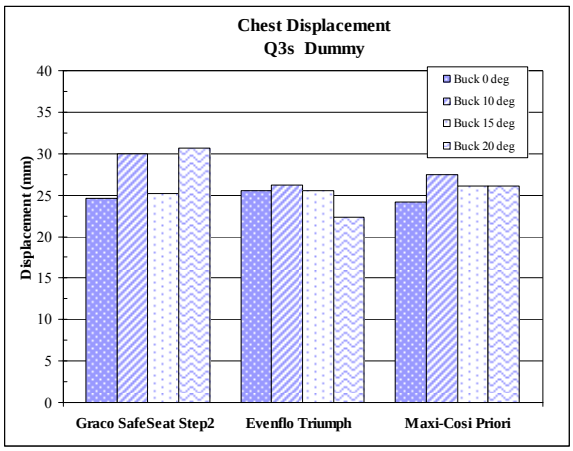

Figure 15. Chest Lateral Displacement for 0°, 10°, 15° and 20° Sled Impact Angles.

FULL-SCALE SIDE IMPACT CRASH TESTS

Subsequent to the sled testing, a series of four full-scale crash tests were conducted to better define sled parameters in an effort to more realistically replicate real-world crashes.

Two vehicles, a 2008 Nissan Sentra and 2008 Nissan Versa, were subject vehicles, and the FMVSS No. 214 standardized MDB was the striking vehicle. The targeted impact velocity was 52.8 kph (32.8 mph), with impact occurring on the left side of the vehicle. For the first test, Sentra test #v06634, the impact location was that specified in FMVSS No. 214D [2]. For the remaining three tests, the impact location on the subject vehicle was moved rearward 229 mm (9 inches) to provide for more direct contact of the MDB with the child restraint. Although both the Sentra and Versa had side curtain air bags in the rear compartment, the air bags were disconnected for the crash tests to allow for a direct comparison with the sled, which does not have a side curtain fixture.

Two ATDs representing a 3-year-old child – the Q3s and a Hybrid-III 3Cs (H3Cs) – were seated in the left and right rear passenger locations, respectively. The H3Cs dummy is the standard HIII 3-year-old dummy with a prototype neck designed for use during side impacts. Only the results of the Q3s dummy will be discussed in this paper. Each dummy was restrained in a forward-facing child restraint which had been properly installed in the vehicle using the LATCH system. The two CRS models chosen for these tests were the Graco SafeSeat Step2 and the Maxi-Cosi Priori. The matrix of crash tests is contained in Table 1.

Table 1.
CRS Side Impact Crash Test Matrix

Test No.	Vehicle	Near-side Q3s	Far-side H3Cs	Impact Location
v06634	2008 Nissan Sentra	Graco SafeSeat Step2	Graco SafeSeat Step 2	TP-214D-08
v06635	2008 Nissan Sentra	Graco SafeSeat Step2	Graco SafeSeat Step 2	228.6 mm rear of TP-214D-08
v06636	2008 Nissan Versa	Graco SafeSeat Step2	Graco SafeSeat Step 2	228.6 mm rear of TP-214D-08
v06637	2008 Nissan Versa	Maxi-Cosi Priori	Maxi-Cosi Priori	228.6 mm rear of TP-214D-08

The following sections will compare and discuss the results from the sled tests, conducted at the four impact angles, and the crash tests.

Comparison of Sled and Crash Test Results with Graco SafeSeat Step2 Child Restraint System

The HIC_{15} results from the sled tests at the four angles and the three crash tests for the dummy seated in the SafeSeat Step2 are shown in Figure 16. As noted previously for this CRS model, the HIC_{15} values decreased as impact angle increased during sled tests. For all three crash tests, the HIC_{15} values were lower than those from the sled tests. The values from the two Sentra tests were essentially identical, regardless of the fact that for test #v06635, the MDB's impact location was 229 mm (9 inches) rearward of where it was in test #v06634. Among the two vehicle models, the HIC_{15} value for the Versa test #v06636 was approximately 20% lower than those for the two Sentra tests.

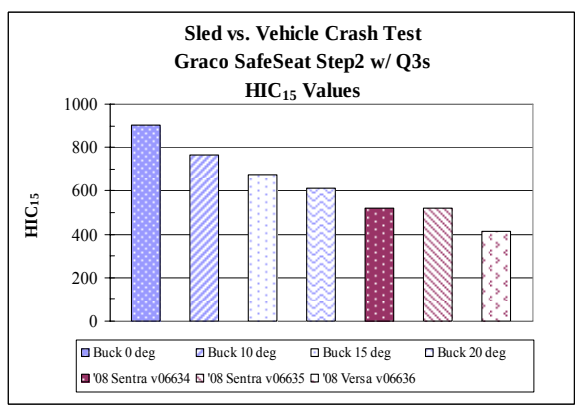

Figure 16. Comparison of HIC_{15} Values from Sled Tests at Various Side Impact Angles and Crash Tests.

Figure 17 contains the neck tension results for the sled and crash tests. The peak neck loads when the

SafeSeat Step2 was tested at 15° and 20° tended to be more comparable to those observed in the three crash tests. The 15° sled test result was consistent with the result from the Sentra test in which the MDB was positioned at the standard FMVSS No. 214 impact location. The 20° sled test result agreed with the crash test results when the MDB was moved rearward to provide for more direct contact with the CRS, regardless of vehicle model.

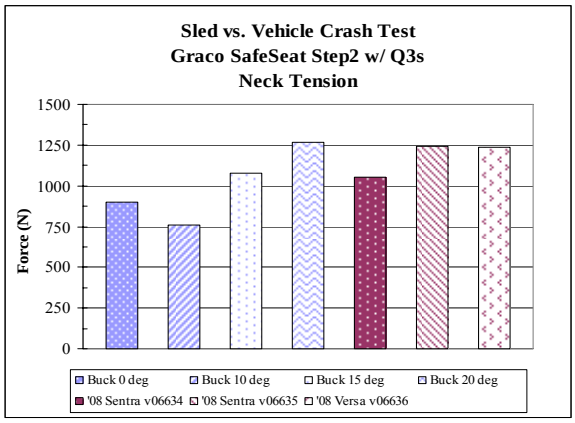

Figure 17. Comparison of Neck Tension from Sled Tests at Various Side Impact Angles and Crash Tests.

Figures 18 and 19, respectively, contain the spine and pelvis Y-axis accelerations for the sled and crash tests. As noted previously, both the spinal and pelvic accelerations were the highest during the sled tests when the impact angle was 0°. There were no definitive trends observed for the spine accelerations; the angled sled tests' and the crash tests' results were similar, ranging from 73 G's to 92 G's.

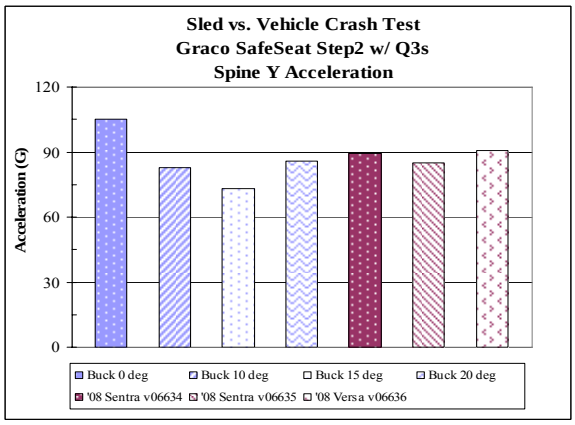

Figure 18. Comparison of Spine Y-axis Acceleration from Sled Tests at Various Side Impact Angles and Crash Tests.

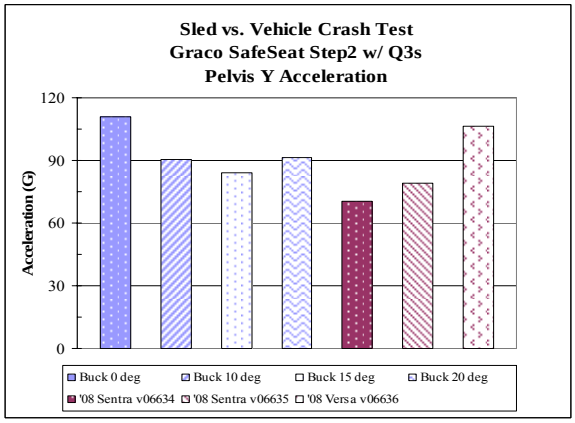

Figure 19. Comparison of Pelvis Y-axis Acceleration from Sled Tests at Various Side Impact Angles and Crash Tests.

The pelvic results for the three angled sled tests and crash tests did differ somewhat, with the results being slightly lower in the two Sentra tests. However, the pelvis response in the Versa crash test was very similar to the 0° sled test response. It was noted from the test footage that interaction with the armrest in the vehicle crash tests appeared to result in a more pronounced inboard rotation of the CRS base than was observed in the sled tests. The angular intrusion of the front edge of the door (near B-pillar) also appeared to contribute to the CRS base inboard rotation. A frame from a digital high speed imager of the near-side Q3s dummy, seated in the SafeSeat Step2 seat, at 57.5 ms into the crash event is shown in Figure 20. This typifies the more pronounced inboard rotation of the CRS base and the angular intrusion of the door observed in the crash tests.

Figure 20. Near-side Dummy (Test #v06635, Sentra); Example of CRS Base Rotation and Angular Door Intrusion.

For each of the crash tests, the following three locations on the CRS were translated to the side door structure:

- "seat bight" of the CRS's back and cushion
- CRS base, approximately mid fore-aft of base
- front edge CRS base

These three points are designated as "4", "3" and "2", respectively, in Figure 21.

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Figure 21. Measured Locations on CRS and Child Dummy.

Photographs of the struck side rear door panel, pre-test and post-test respectively, for Sentra test #v06635 are shown in Figures 22 and 23. Similar photographs for Versa test #v06636 are shown in Figures 24 and 25. For both vehicles, the armrest and, to a certain extent, the lower door panel protruded into the vehicle more than did the upper portion of the door panel, thereby resulting in the lower portion of the CRS structure being contacted earlier than the remainder of the CRS. The "door" structure used in the agency's initial series of sled tests was essentially a flat wall configuration.

Figure 22. Sentra #v06635 Struck Side Door Panel, Pre-test.

Figure 23. Sentra #v06635 Struck Side Door Panel, Post-test.

Figure 24. Versa #v06636 Struck Side Door Panel, Pre-test.

Figure 25. Versa #v06636 Struck Side Door Panel, Post-test.

Sled versus crash tests comparison of the lateral chest displacement, when the Q3s was restrained in the SafeSeat Step2, is shown in Figure 26. Regardless of sled impact angle, the results observed in the sled tests were greater than those observed during the three crash tests. It is believed that this disparity in values is primarily due to the difference in the side door configuration and stiffness. Because the dummy's pelvis and lower torso were engaged earlier

in the crash event than was the upper torso, due to the armrest/lower door panel configuration, the thoracic displacements were not as large as those observed during the sled tests.

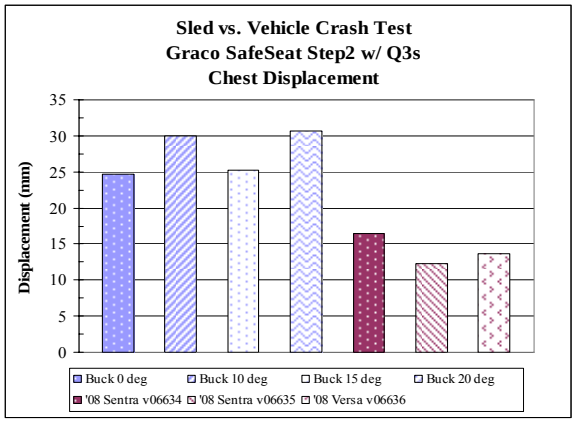

Figure 26. Comparison of Chest Lateral Displacement from Sled Tests at Various Side Impact Angles and Crash Tests.

Comparison of Sled Tests and Crash Test with Maxi-Cosi Priori Child Restraint System

Figure 27 shows the HIC_{15} results from the sled tests at the four angles and the one crash test (Versa #v06637) conducted with the dummy seated in the Maxi-Cosi Priori. This CRS model exhibited a trend of decreasing HIC_{15} values as the impact angle increased. For the one crash test conducted with this CRS model, the Q3s dummy's HIC_{15} value was approximately 50% less than the values observed for the three non-zero angled sled tests.

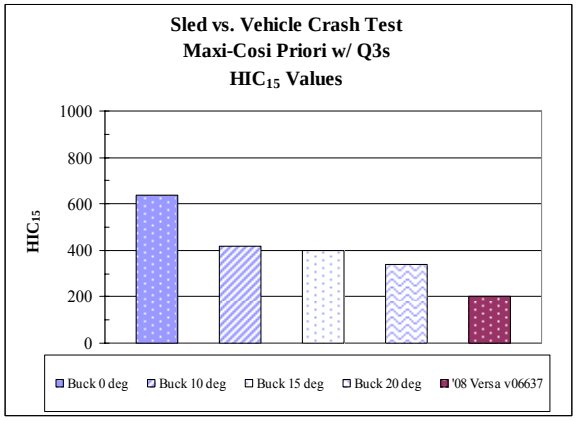

Figure 27. Comparison of HIC_{15} Values from Sled Tests at Various Side Impact Angles and Crash Test.

Comparison of the neck tension responses for the four sled angles and one crash test conducted with the Maxi-Cosi Priori are shown in Figure 28. The neck tension values observed in the crash test were comparable to the values observed during the 15° and 20° angled sled tests. This trend is similar to that observed with the SafeSeat Step2.

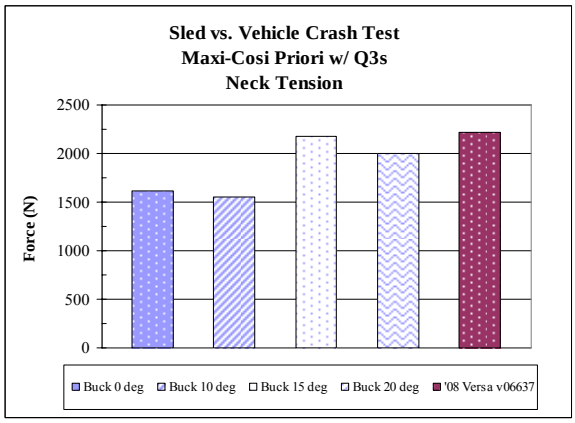

Figure 28. Comparison of Neck Tension from Sled Tests at Various Side Impact Angles and Crash Test.

Although the Q3s dummy's head rotated sufficiently around the CRS side wing to contact the side door upper panel (see Figure 29) during the crash test, the HIC_{15} and neck tension responses were less than or similar to the sled tests' responses.

Figure 29. Q3s Dummy Head Contact, Maxi-Cosi Priori in Versa #v06637.

The spine and pelvis Y-axis accelerations for the sled and crash tests are shown in Figures 30 and 31, respectively. As noted previously, spinal and pelvic accelerations observed during sled tests were essentially identical regardless of impact angle. The spine and pelvis accelerations observed during the crash were similar to those from the sled tests, although tending toward the high end of the response range.

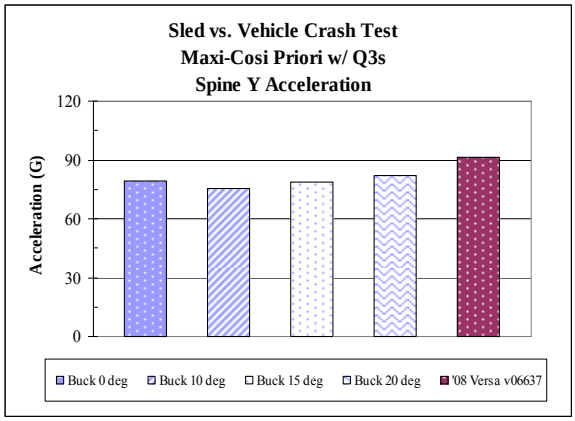

Figure 30. Comparison of Spine Y-axis Acceleration from Sled Tests at Various Side Impact Angles and Crash Test.

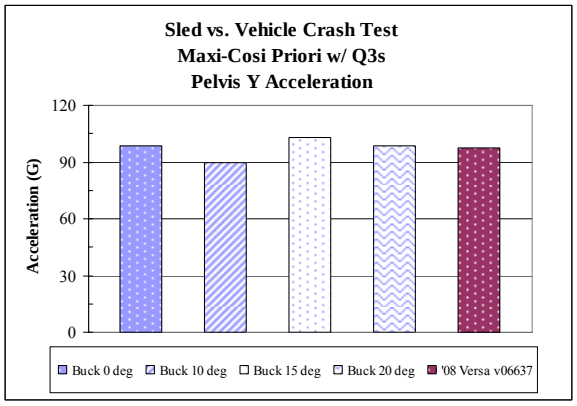

Figure 31. Comparison of Pelvis Y-axis Acceleration from Sled Tests at Various Side Impact Angles and Crash Test

As had been observed with the SafeSeat Step2, the lateral displacement of the Q3s' chest, when restrained with the Maxi-Cosi Priori during the crash test, was significantly less than the displacements observed during the sled test series (see Figure 32).

Comparison of Graco SafeSeat Step2 and Maxi-Cosi Priori Child Restraint Systems Tested in 2008 Nissan Versa Crash Tests

The last two crash tests, v06636 and v06637, enabled an indicant type of comparison of the performance of two different CRS models when crash tested in identical vehicles.

HIC_{15} and neck tension (see Figures 33 and 34, respectively) were the injury responses exhibiting the largest differences between the SafeSeat Step2 and Maxi-Cosi Priori. The spine and pelvis y-axis accelerations and the chest lateral displacements were very similar for both CRS models (see Figures 35, 36 and 37, respectively).

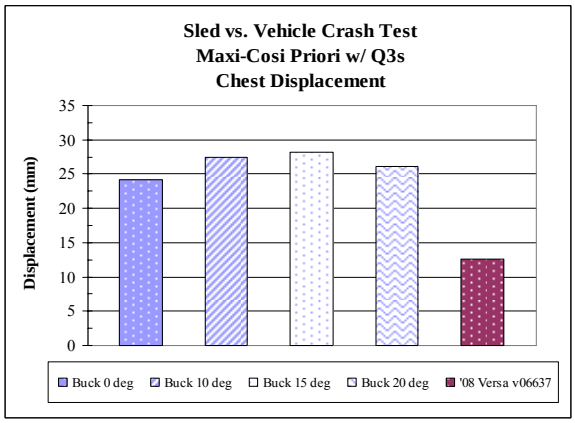

Figure 32. Comparison of Chest Lateral Displacement from Sled Tests at Various Side Impact Angles and Crash Test.

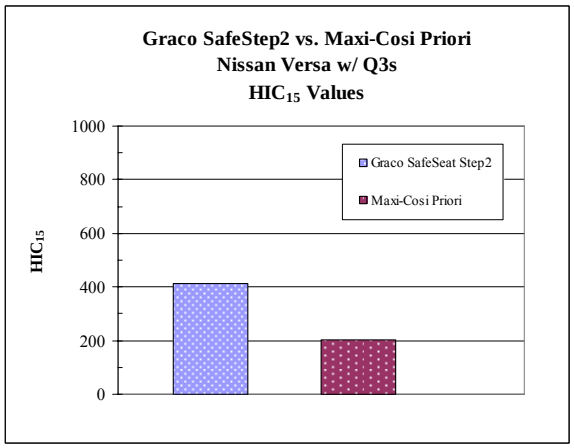

Figure 33. Comparison of HIC_{15} Values for CRS Models in Nissan Versa Crash Tests.

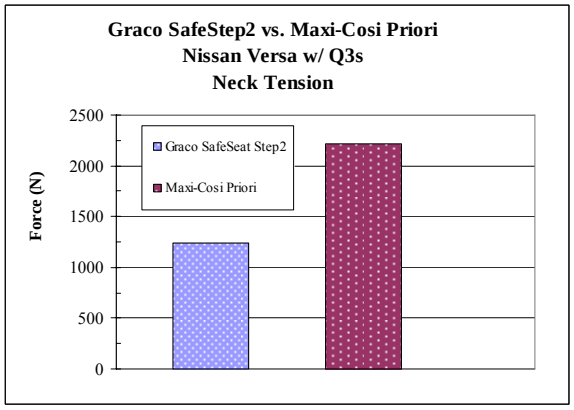

Figure 34. Comparison of Neck Tension for CRS Models in Nissan Versa Crash Tests.

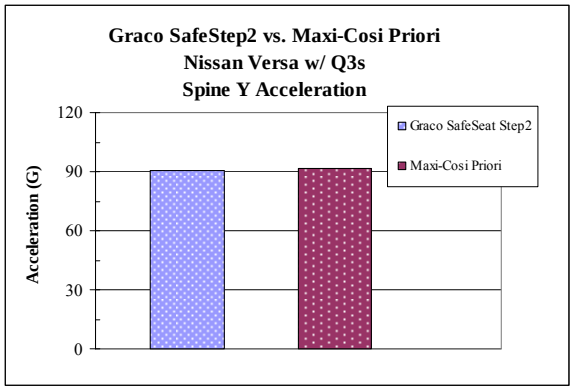

Figure 35. Comparison of Spine Y Acceleration for CRS Models in Nissan Versa Crash Tests.

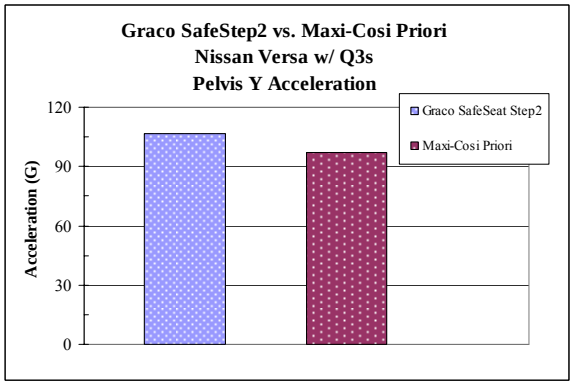

Figure 36. Comparison of Pelvis Y Acceleration for CRS Models in Nissan Versa Crash Tests.

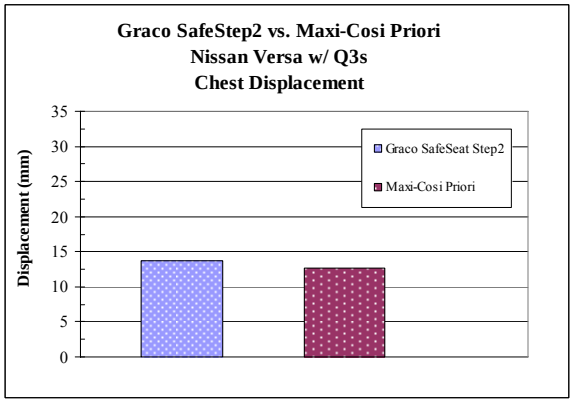

Figure 37. Comparison of Chest Lateral Displacement for CRS Models in Nissan Versa Crash Tests.

Individual test results for the sled and crash tests are available on NHTSA's Vehicle Crash Test Database (http://www-nrd.nhtsa.dot.gov/database/aspx/vehdb/querytesttable.aspx).

CONCLUSIONS

The following conclusions are based on the results from the sled and crash tests:

- The Takata sled buck concept of a sliding seat fixture on a sled appears to be a repeatable test procedure.
- Sled test results indicate that it is feasible to distinguish between child restraint models using some of the injury metrics.
- The impact angle appears to create a definite effect for certain injury metrics, while producing minimal effects for others.
- Based on the limited number of CRS models tested, the design of the CRSs' seat back side wing appears to be an important element for providing side impact protection, particularly when impact angles are varied, as noted in Evaluation of Impact Angles.
- Trends in injury response values between sled and crash tests were similar for the two CRS models used in both types of testing.
- Head and neck injury responses appeared to be more sensitive, during both sled and crash tests, to the type of CRS model used than did spinal and pelvic acceleration and chest displacement responses.

Future sled testing to refine test parameters such as door stiffness and geometry, and to further assess issues such as effect of armrest on CRS kinematics and dummy responses, is planned. Evaluation of additional CRS models within the fleet will also be conducted to validate test methodology.

REFERENCES

[1] McCray, L. et al., "Injuries To Children One to Three Years Old in Side Impact Crashes," Paper Number 07-0186, 20th ESV, June 2007.

[2] FMVSS No. 214D Test Procedure, TP-214D-08.

APPENDIX

FMVSS No. 214 compliance test vehicles used to determine sled pulse and seat velocity

- **2005 Toyota Corolla Test # 5483 ES2re**
- **2005 Toyota Corolla Test # 5491 SIDIIS**
- **2005 Subaru Forester Test # 5485 ES2re**
- **2005 Suzuki Forenza Test # 5575 SIDIIS**
- **2005 Subaru Forester Test # 5480 SIDIIS**
- **2003 PT Cruiser Test # 4614 U.S. SID**
- **2003 Mazada Protégé Test # 4575 U.S. SID**
- **2003 Suzuki Aerio Test # 4574 U.S. SID**
- **2005 Saturn Ion Test # 5460 SIDIIS**
- **2005 Saturn Ion Test # 5461 ES2re**

FMVSS No. 214 compliance test vehicles used to determine "door" velocity

- **2005 Subaru Forester Test # 5480**
- **2005 Toyota Corolla Test # 5483**
- **2005 Suzuki Forenza Test # 5575**
- **2005 Saturn Ion Test # 5460**

Child Restraint System Models

Graco SafeSeat Step2 Toddler

Maxi-Cosi Priori (SIP)

Evenflo Triumph Advance DLX

Graco Logico M (SIP)

Meets only ECE Reg. 44;
Does not use LATCH system

Safety 1st All-in-One Convertible