

EVALUATION OF INJURY RISK FROM SIDE IMPACT AIR BAGS

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ABSTRACT

Several thoracic and head protection side impact air bag systems (SAB) are emerging in the U.S. market and are projected to become prevalent in the fleet. These systems appear to offer superior protection in side crashes. However, concerns have been raised as to their potential for causing injury to out-of-position (OOP) occupants. This paper describes the National Highway Traffic Safety Administration (NHTSA) program for evaluation of the SAB systems for OOP occupants and provides a status report on the current research. The industry's Side Airbag Out-of-Position Injury Technical Working Group (TWG) recommended procedures for 3 year old and 6 year old occupants are evaluated. Additional test procedures are described to augment the TWG procedures for these occupants and 12 month old infants.

1.0 INTRODUCTION:

Several thoracic and head protection side impact air bag systems (SAB) are emerging in the U.S. market and are projected to become prevalent in the fleet (Figure 1). These inflatable side countermeasures vary widely in designs, sizes, mounting locations and methods, inflation systems, and areas of coverage. In particular, there are several seat and door mounted thorax air bag systems; various versions of a window curtain type head protection air bag systems, an inflatable tubular structure head protection system, combination head/thorax seat mounted air bag systems etc. These systems appear to offer superior protection in side crashes. NCAP tests on forty five four door cars show that the eleven vehicles with SAB got higher star ratings (for the driver) than those without SAB. Also, the average TTI values for the driver of the SAB equipped vehicles was lower than for those without SAB.

As of January 1, 2001 NHTSA Special Crash Investigations (SCI) program had studied 48 crashes involving SAB [1]. There were no serious injuries (AIS-3 or higher) attributed to SAB in the majority of the cases. In a single exception, the driver received an AIS-3 thorax injury from the SAB cover flap in a door mounted thorax

SAB system [1]. However, concerns have been raised as to their potential for causing injury to out-of-position (OOP) occupants, especially as the usage of SAB systems increase in the coming years.

The need to understand the benefits and potential for harm to OOP occupants (and certain in-position occupants, e.g., properly restrained infants in child restrained systems) is especially important considering the growth in the number of SAB systems in the past few years and the projected trend for the prevalence of such systems, standard or optional, in the coming years (Figure 1).

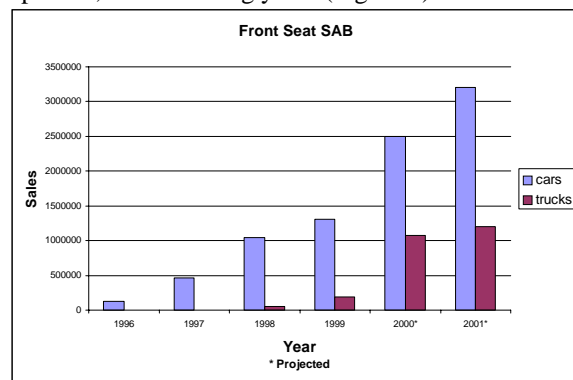


Figure 1. Use of Front Seated Position SAB.

This paper describes the National Highway Traffic Safety Administration (NHTSA) program for evaluation of the SAB systems for OOP occupants. The Side Airbag Out-of-Position Injury Technical Working Group (TWG) recommended procedures for the 3 year old and 6 year old occupants are evaluated.

Additional test procedures are described to augment the TWG procedures. This includes assessment of in-position 12 month CRABI dummy in forward and rear facing child restraint systems, which is not addressed by the current TWG procedures. This paper focuses on seat mounted and door mounted SAB systems for thorax and head protection. Additional research is ongoing into the evaluation of adult OOP dummies, roof mounted air bag systems, and repeatability of all the test procedures.

2.0 BACKGROUND

The agency is aware of the potential for injury from side air bags, considering that front air bags have been the cause of injury and fatalities in certain low severity impacts. The agency initiated research in fall of 1998 into 3 year old child OOP interactions with SAB [2]. The study concluded that some SAB systems had the potential for causing injury to the head-neck and chest of OOP children, although less aggressive airbags reduced that potential. The results were sensitive to the positioning of the dummy and had some test-to-test variability because of variability in the deployment characteristics of the bags.

Research was also initiated by Transport Canada in 1998 to examine the most appropriate and effective means of minimizing injury risks to children under “off-design” conditions [3]. The research concluded that while SAB have the potential for benefit in side crashes, they also have the potential for causing injury to OOP children.

In December 1998, then NHTSA Administrator, Ricardo Martinez, M.D., wrote to the automobile manufacturers indicating that the SAB had significant safety potential, and encouraged the manufacturers to confirm that the current and projected applications of advanced technologies did not pose safety risks. The letter also indicated a willingness to work jointly with the industry to establish rigorous internal design protocols to address this possibility. The results from the above NHTSA research and Transport Canada study was presented at a public meeting in April 1999 [4]. In May 1999, Dr. Martinez, in a letter to the Alliance of Automobile Manufacturers (Alliance) and Association of International Automobile Manufacturers (AIAM), asked the industry to develop a comprehensive, open, and timely public standard for the industry to follow, which would ensure that future side air bags would not pose any injury risk to occupants [5].

In August 2000, TWG, comprised of representatives from the Alliance, AIAM, Automotive Occupant Restraints Council (AORC), and Insurance Institute for Highway Safety (IIHS), proposed test devices, performance criteria, and test procedures for assessing SAB deployment injury risks [6]. These findings were based on the input from Working Group 3 of the International Organization of Standards (ISO) Technical Committee 10 which also developed procedures for evaluating SAB [7]. The TWG procedures provided a framework for the agency’s research activities described in this paper.

In the summer of 1999, research was initiated at the Vehicle Research and Test Center (VRTC) to study the

potential for injury to OOP occupants and to evaluate the benefits of SAB in side impacts. The first phase of this research was to evaluate the TWG procedures and propose any additional procedures or modifications, if necessary, to assess the injury to OOP children and verify the reduced risk to properly restrained children in child restraints and booster seats. That research is in progress, and the partial interim findings from that study are presented in this paper. The study of the efficacy of SAB in protecting occupants in side crashes is expected to begin in 2001 and will be reported in a future publication.

3.0 TEST CONDITIONS

3.1 Vehicle Selection:

The following vehicles with seat and door mounted SAB (front seating position, unless specified otherwise) were chosen:

Table 1. Vehicle Selection

Seat Mounted		Door Mounted	Roof Mounted
Thorax bags	Head/Thorax bags		
1999 Geo Prizm	1999 Windstar	1999 Cadillac Deville	1999 Volvo S80
1999 VW Jetta	1999 Mercury Cougar	2000 Mercedes S430 (front and rear)	2000 Mercedes S430
1999 Saab 95	2000 Nissan Maxima	2000 BMW 528i (front and rear)	2000 BMW 528i
1999 Volvo S80	2000 Audi A6 (front and rear)		2000 Audi A6
2000 Cadillac Deville (rear)			2001 Saturn L200.

The initial selection of vehicles was done in the Spring of 1999. Vehicles were chosen based on the availability of the SAB as standard or optional equipment in vehicles at that time. Additional vehicles were added to the matrix as SAB became available for those vehicles.

The goal was to have a range of airbags in the test matrix: head/thorax bags, thorax bags, head bags, seat mounted, door mounted, and roof mounted systems for a wide selection of vehicles with production side air bag systems. Although not prevalent, vehicles with side air bags in the rear seats were especially selected because of the need to evaluate the risks to properly restrained children in the rear seat.

3.2 Test positions

The Technical Working Group (TWG) Out of Position (OOP) Seating Procedures [6] were used as the basis for selecting test positions. High speed videos of “blank deployments” (deployments of the air bags without any occupants in the seated positions) were studied to estimate any other position (for example, positions used in Medical College of Wisconsin (MCW) study [2]) or variations to TWG positions that might result in high loads to the head and chest. The goal was to understand the location of the bag deployment opening, deployment path, bag volume, etc. This was used as a guide for finding the positions for the most severe loads for dummies of various sizes

A test matrix was set up based on the above study on 12 test vehicles. The vehicles had different types of side airbags; door mounted, seat mounted, thorax and head-thorax combination bags. The objective of these tests was to evaluate out-of-position (OOP) three-year-old, the six-year-old, and the properly restrained 12-month-CRABI dummies. Some of the positions for booster seats (not covered by the TWG procedures) were verified with a small child occupant.

There were several modified positions that were used to evaluate the seat mounted side airbags. These are listed in Table 2 and described below.

3.2.1 Three-Year-Old Seat Mounted Seating Positions

- NHTSA Seat-01-3: Chest against the seatback with the upper rib at upper airbag module with the arm out of the way to get the dummy closer to the edge of the seat.
- NHTSA Seat-04-3: Lying across the seat with the head on armrest with the body rotated until head touches the seatback, armrest and/or door.

The following positions were used to get the head closer to the seatback and to locate the head and neck near the airbag module:

- NHTSA Seat-02-3: Sitting at seat edge on foam booster slide the pelvis forward until the head touches the

seatback

- NHTSA Seat-03-3: Same setup as the TWG 3.3.3.1, but without the foam booster block
- NHTSA Seat-07-3: MCW Procedure - sitting at seat centerline and leaning sideways with the head CG at the centerline of the airbag module
- NHTSA Seat-08-3: MCW Procedure on a foam booster with the head CG at the top of the airbag module

The last two positions, NHTSA Seat-05-3 and NHTSA Seat-06-3 are in booster seats. Booster seats are not addressed by TWG procedures.

- NHTSA Seat-05-3: Properly restrained in a booster seat
- NHTSA Seat-06-3: Properly restrained with the dummy lying sideways with the belt under it’s arm and resting it’s head on the door edge.

3.2.2 Six-Year-Old Seat Mounted Seating Positions

The following positions allow the dummy to be at different heights along the airbag module.

- NHTSA Seat-01-6: Back against the seat bolster with head/torso junction at the upper airbag without foam booster block
- NHTSA Seat-02-6: Back against the seat bolster sitting on the seat, slide pelvis forward until the Head CG at the upper airbag module
- NHTSA Seat-03-6: MCW Procedure - sitting at seat center and leaning sideways with the head CG at the top of the airbag module
- NHTSA Seat-04-6: MCW Procedure - sitting at seat center and leaning sideways with the head CG at the centerline of the airbag module

The door mounted systems had similar variations used. The positions are listed in Table 3 and described below.

Table 2. Test Positions for Seat Mounted Air Bags

TWG Positions			NHTSA's Modifications	Change from TWG position
TWG 3.3.2.1	3YO	Leaning sideways	NHTSA Seat-02-3	Gets head closer to seatback
			NHTSA Seat-03-3	Places head at a different location along the seatback
			NHTSA Seat-07-3	Gets head closer to seatback and places head at a different location along the seatback
			NHTSA Seat-08-3	Gets head closer to seatback and places head at a different location along the seatback
TWG 3.3.2.2	3YO	Peek-a-Boo	NHTSA Seat-01-3	Gets dummy closer to the edge of the seat
TWG 3.3.2.3	3YO	Lying across seat	NHTSA Seat-04-3	Gets head closer to the seatback
TWG 3.3.2.4	3YO	Lying Flat on seat	None	
N/A	3YO	Booster Seat	NHTSA Seat-05-3	Not addressed by TWG
			NHTSA Seat-08-3	Not addressed by TWG
TWG 3.3.2.5	6YO	Leaning sideways	NHTSA Seat-01-6	Places head at a different location along the seatback
			NHTSA Seat-02-6	Gets head closer to seatback and places head at a different location along the seatback
			NHTSA Seat-03-6	Gets head closer to seatback and places head at a different location along the seatback
			NHTSA Seat-04-6	Gets head closer to seatback and places head at a different location along the seatback
N/A	12 mo CRABI	Booster seat	NHTSA Seat-01-12	Booster seats are not addressed by TWG
			NHTSA Seat-02-12	Booster seats are not addressed by TWG

Table 3. Test Positions for Door Mounted Air Bags

TWG Positions			NHTSA's Modifications	Change from TWG position
TWG 3.3.3.1	3YO	Kneeling at Window	NHTSA Door-01-3	Brings chest closer to the airbag module
			NHTSA Door-02-3	Aligns chest to center of air bag module
TWG 3.3.3.2	3YO	Back at Door	NHTSA Door-03-3	Places neck at a higher location on the air bag module
TWG 3.3.3.3	3YO	Head on Armrest	None	
TWG 3.3.3.4	3YO	Lying on Seat	None	
N/A	3YO	Leaning Sideways	NHTSA Door-04-3	Leaning sideways is not addressed by TWG
			NHTSA Door-05-3	Leaning sideways is not addressed by TWG
			NHTSA Door-06-3	Leaning sideways is not addressed by TWG
N/A	3YO	Booster	NHTSA Door-07-3	Booster seats are not addressed by TWG
			NHTSA Door-08-3	Booster seats are not addressed by TWG
N/A	6YO	Back at Door	NHTSA Door-01-6	6 YO not addressed by TWG
N/A	6YO	Leaning Sideways	NHTSA Door-02-6	6 YO not addressed by TWG
			NHTSA Door-03-6	6 YO not addressed by TWG
			NHTSA Door-04-6	6 YO not addressed by TWG
			NHTSA Door-05-6	6 YO not addressed by TWG
N/A	12 mo CRABI	Booster	NHTSA Door-01-12	Booster seats are not addressed by TWG
			NHTSA Door-02-12	Booster seats are not addressed by TWG

3.2.3 Three-Year-Old Door Mounted Seating Positions

- NHTSA Door-01-3: Kneeling at the edge of the seat facing out the window with the knees touching the door
- NHTSA Door-02-3: Kneeling on the seat facing out the window with the center of the chest inline with the horizontal centerline of the airbag module
- NHTSA Door-03-3: Sitting on the seat facing inward with head/torso junction to the upper airbag module

TWG did not consider leaning the dummy sideways for door mounted systems. The following positions locate the head/neck near the door mounted air bag for such leaning sideways positions.

- NHTSA Door-04-3: MCW Procedure-sitting at seat centerline leaning sideways with the head CG at the vertical centerline of the airbag module
- NHTSA Door-05-3: MCW Procedure-sitting at seat center and leaning sideways with the seat in the rearmost position with the head resting at the airbag (wherever it hits the module)
- NHTSA Door-06-3: MCW Procedure-sitting on seat leaning sideways with the head CG at the horizontal centerline of the airbag module

The last two positions are with the booster seat.

- NHTSA Door-07-3: Properly restrained in a booster seat
- NHTSA Door-08-3: Properly restrained with the dummy lying sideways with the belt under it's arm and resting it's head on the door edge.

3.2.4 Six-Year-Old Door Mounted Seating Positions

TWG did not look at the door mounted systems with the six year old. The test positions that were picked were based on the three year old positions.

- NHTSA Door-01-6: Sitting at the edge of the seat facing inward with head/torso junction at upper airbag module

The others are based on the MCW procedure, with the dummy in the center of the seat leaning sideways, but at various heights depending on the position. These positions help isolate the head and neck for the door mounted SAB.

- NHTSA Door-02-6: MCW Procedure-sitting at seat center and leaning sideways with the seat in the rearmost position with the head resting at the airbag (wherever it hits the module)

- NHTSA Door-03-6: MCW Procedure-sitting at seat center and leaning sideways with the head CG at the horizontal centerline of the airbag module
- NHTSA Door-04-6: MCW Procedure-sitting at seat center and leaning sideways with the head CG at the vertical centerline of the airbag module
- NHTSA Door-05-6: MCW Procedure-sitting at seat center and leaning sideways with the top of the head at the horizontal centerline of the airbag module

3.2.5 Twelve Month CRABI Seat and Door Mounted Seating Positions

The positions for the 12-month-CRABI were with a properly restrained infant in two different child seats, a rearward facing infant seat and a child seat with a flip over tray. The seat was properly installed according to the manufacturer's instructions and the airbag was deployed.

- NHTSA Seat(Door)-01-12: Properly restrained in a booster seat with the flip over tray
- NHTSA Seat(Door)-02-12: Properly restrained in a rear facing infant seat.

3.3 Dummies and instrumentation

The Hybrid III three-year-old dummy used in the testing had the following instrumentation: a head triaxial accelerometer, upper and lower 6-axis neck load cells, left and right biaxial shoulder accelerometers, T01 triaxial accelerometer, T12 triaxial accelerometer, chest triaxial accelerometer, chest displacement potentiometer, rib three uniaxial accelerometers, upper and lower sternum uniaxial accelerometers, 6-axis lumbar load cell, pelvis triaxial accelerometer, biaxial pubic load cell, and right and left biaxial ASIS load cells.

The Hybrid III six-year-old dummy had the following instrumentation: a head triaxial accelerometer, upper and lower 6-axis neck load cells, chest triaxial accelerometer, chest displacement potentiometer, upper and lower spine uniaxial accelerometers, upper and lower sternum uniaxial accelerometers, pelvis triaxial accelerometer, and right and left biaxial ASIS load cells.

The 12-month-CRABI dummy had the following instrumentation: a head triaxial accelerometer, upper and lower 6-axis neck load cells, chest triaxial accelerometer, 6-axis lumbar load cell, and pelvis triaxial accelerometer. The body coordinate system used the X-axis as back to front, the Y-axis as left to right, and the Z-axis as top to bottom.

4.0 DEVELOPMENT OF THE TEST MATRIX

The following baseline tests were performed on most of the vehicles with the Hybrid III three-year-old dummy; TWG 3.3.2.2 - peek-a-boo, TWG 3.3.2.1 - leaning sideways with booster, and TWG 3.3.2.3 - lying across the seat with head on armrest. If the review of the high speed films indicated an alternative seating position that would be more likely to produce higher loads, then additional tests were conducted in positions derived from varying the TWG positions. The following seating procedures variations were tested on several of the vehicles: peek-a-boo with arm out of the way and the side touching armrest, on foam booster leaning sideways with pelvis forward until head touches seatback, leaning sideways without a foam booster, lying across seat at an angle with head on armrest, belt position booster (BPB), where the dummy is in a booster seat sitting properly, BPB leaning sideways, the MCW procedure, where the dummy is seated in the center of the seat and leaning sideways[2] and MCW position on a booster. The BPB used in all tests was the Fisher Price Booster Model # 79750.

More variations were tested for the 6 Year old Hybrid III dummy. The baseline test performed for most of the vehicles was TWG 3.3.2.5 - leaning sideways on booster. The following modified seating procedures were performed: leaning sideways without a booster, leaning sideways with head CG at the horizontal center of the airbag module, leaning sideways at the seat's centerline with the pelvis forward and head CG in line with the top of the airbag module, and MCW.

The 12-month-CRABI dummy testing consists of two types of tests using two different types of child restraints. The two types of tests were as follows; forward facing child restraint system (FFCRS) with flip over tray and a Rearward Facing Child Safety Seat (RFCSS). The two car seats that were used were Century Ovation Model # 4665NSK and Fisher Price Safe Embrace Infant Seat Model # 79725, respectively. The car seats were installed according to the manufacturer's instructions. After the test, the car seats were checked for cracks and/or any other noted damage.

The following baseline TWG tests were performed with the Hybrid III three-year-old dummy in vehicles with door mounted systems: TWG 3.3.3.1 - kneeling at window, TWG 3.3.3.2 - back on door facing inward, and TWG 3.3.3.3 - head on armrest. If these did not seem like "worst case" then the following modified tests were done: kneeling at window - knees at the door, back on door - lower neck to upper airbag module, dummy's head CG at

vertical centerline of airbag module (MCW), sitting at seat centerline with seat at rearmost position leaning sideways with head CG at airbag module, sitting at seat centerline leaning sideways with head CG at horizontal centerline of airbag module, BPB, and BPB leaning sideways.

There were no TWG tests with the Hybrid III six-year-old dummy used as baseline tests for the door mounted system. The following tests were performed for the door mounted systems: back on door - lower neck to upper airbag module, dummy's head CG at vertical centerline of airbag module (MCW), sitting at seat centerline leaning sideways with head CG at airbag module, sitting at seat centerline leaning sideways with head CG at horizontal centerline of airbag module, and sitting at seat centerline leaning sideways with top of head at horizontal centerline of the airbag module. The 12-month-CRABI dummy used the same tests as the seat mounted systems: FFCRS and RFCSS.

The dummy positions were documented by taking several measurements from the dummy to the interior parts of the vehicle (tip of dummy's nose to corner of glove box, head CG to side air bag center, lower neck junction to top of seat air bag, head CG to head restraint). Approximately three to four different seating procedures were done per vehicle for each dummy size and seating location (with a side air bag). The tests consisted of deploying the airbag and collecting the data with a digital data acquisition system. All tests were documented with digital still photography and two high speed digital videos at a minimum of 1000 frames per second. The data were collected per J211 specifications.

General Tests Setup

Based on TWG's general guidelines, a set of procedures were adopted for all tests, to provide a consistent test environment. Unless otherwise noted in the procedure for a specific test, these general procedures were as follows:

- The seat was in the rearmost position and the lowest adjustment unless otherwise specified.
- The seatback was at a torso angle of 25 degrees as measured on the SAE J826 H-Point machine.
- The airbag module's top and bottom was marked on the seat or door, for easy reference. The seat was marked at its centerline, for easy reference.
- The head restraint was adjusted to its full-down position or removed if it was interfering.
- The safety belt anchor was in its highest position.

- Most of the tests were performed with the window down, for easier access to the dummy for positioning. Reviews of the high speed video did not show any potential interaction of the deploying air bag with the window opening.

5.0 INJURY CRITERIA AND IARVs

A thorough evaluation of the injury criteria and the corresponding injury assessment reference values (IARV) for the various loads on the different sized dummies is planned by NHTSA. In the interim, to facilitate a comparison of the positions considered in this paper, the injury criteria and research values included in the TWG procedures were evaluated. The injury criteria for the 3 year old chest deflection and 6 year old HIC was as per the NHTSA interim final rule for FMVSS 208. The injury criteria values and the research values used in this paper are listed in Table 4.

6.0 THE TEST MATRIX

All of the tests that are planned have not been completed. The tests for the 3 year old and 6 year old child dummies, for both seat mounted and door mounted air bags, have been completed. A small number of the tests for the 12-month-CRABI have been completed and the remainder are planned. The rest of the test combinations were considered unlikely to cause high loads on the dummies based on the dummy positions and the bag deployment characteristics (as determined by the blank deployments).

Research is ongoing into the evaluation of additional child OOP seated positions, adult OOP dummies, roof mounted air bag systems, and repeatability of the test procedures for the different size occupants.

The tests that failed the injury criteria as well as while those that exceeded 80% of the injury criteria were documented. Similarly, the tests that failed the research values and those that exceeded 80% of the research values were documented in the test matrix considered.

7.0 TEST RESULTS

More than half of the twelve vehicles in the study passed the injury criteria for the configurations tested. Of these, only two vehicles had all injury criteria metrics less than 80% of IARV.

Of the research values, the lower neck twist moment (Mz) was exceeded in NHTSA Seat-03-3 position in one vehicle (with thorax air bag), although all other dummy readings

were in the acceptable range for that bag. The lower neck twist moment was also high in two other vehicles, one with rear seat-mounted bags and the other with front seat-mounted head-thorax combination bags.

Any tests that passed the TWG position tests but failed the NHTSA variation are of special interest, because these may indicate a more severe test condition not addressed by the TWG procedures. Vehicles in which both TWG and NHTSA variations lead to failure likely have aggressive air bags, as indicated by both sets of test procedures. Similarly, vehicles that passed TWG and NHTSA variations are consistent in having less aggressive bags.

The TWG leaning sideways position left the head at a greater distance from the seat back with the air bag. The NHTSA variation moved the dummy pelvis forward, resulting in dummy head contact with the seat back. Since this brought the head closer to the airbag, this position resulted in higher neck loads.

The front door mounted air bags resulted in high loads on the 3 year old chest and head-neck for TWG and NHTSA variation procedures. Rear door mounted air bag test results showed high loads for the head-neck for the 3 year old as well.

8.0 OBSERVATIONS

- For both 3 and 6 year old occupants, high loads (exceeding injury criteria) are sometimes possible in most SAB systems, when tested per TWG positions or NHTSA variations especially from door mounted air bags and seat mounted head-thorax combination bags.
- The TWG 3.3.2.2 procedure provides a good procedure for measuring injuries to the chest of 3 year old occupants.
- TWG 3.3.2.1 (leaning sideways on a booster) is a good procedure for measuring the loads on the head-neck region of the 3 year old. However, in certain vehicles, the TWG position results in the head being away from the seat back (Figure 2). Three additional procedures, the NHTSA-Seat-02-3 (Figure 3), NHTSA-Seat-07-3 (Figure 4) and NHTSA-Seat-08-3 (Figure 5) provide alternative positions that locate the head closer to the air bag. In these alternative positions, the deploying air bag is more likely to only load the head, and not the head and upper thorax, resulting in greater neck loads.

**Table 4.
Injury Criteria and Research Value IARV**

	3 year old	6 year old	12 month
15ms HIC	570	700	390
NIJ	1	1	1
Tension (+ FZ) (N)	1130	1490	780
Compression (- FZ) (N)	1380	1820	960
Chest Deflection (mm)	34	40	N/A
Deflection Rate (m/s)	8	8.5	N/A
RESEARCH VALUES			
Upper Neck - Lateral Moment (MX) (N-m)	30	42	
Upper Neck - Twist Moment (MZ) (N-m)	17	24	
Lower Neck - Flexion Moment (- MY) (N-m)	83	119	
Lower Neck - Extension Moment (+ MY) (N-m)	34	48	
Lower Neck - Lateral Moment (+ MX) (N-m)	60	84	
Lower Neck - Twist Moment (+ MZ) (N-m)	17	24	
Lower Neck - Tension (+ FZ) (N)	1130	1490	
Lower Neck - Compression (- FZ) (N)	1380	1820	
Chest Clip - 3 ms (g's)	55	60	50

- The seat mounted air bags are located at different heights along the seat back. Adding NHTSA-Seat-02-3 (Figure 6), NHTSA-Seat-03-3 (Figure 7), NHTSA-Seat-07-3 (Figure 8) and NHTSA-Seat-08-3 (Figure 5) to the available test positions, in addition to the TWG position (Figure 9), provides the ability to locate the head of the 3 year old leaning sideways at a range of locations along the seat back. This helps in finding a test condition which produces more severe loads.
- Certain TWG positions may not be attainable in some vehicles. For example, the peek-a-boo (TWG 3.3.2.2) requires the chest to be aligned to the top of the air bag module. This is not always possible in vehicles with an air bag that is mounted high in the seat back.
- Certain TWG positions were not considered likely to produce any significant loads on the dummies for the vehicles considered in this study. For example, TWG 3.3.2.4 and 3.3.3.4 (lying on the seat for both seat and door mounted systems) were not tested, based on the study of blank deployments for the selected vehicles.
- A “leaning sideways” type position is not included in TWG procedures for door mounted systems for 3 and 6 year old occupants. NHTSA-Door-04-03 should be included as it produces high loads in certain cases.
- The dummy responses have been low in the five out of the twenty three tests planned with a properly restrained

12-month-CRABI dummy (using a forward facing child restraint system with flip over tray and a rearward facing child safety seat) performed to date. Inspection of the child seats indicated no structural damage in these tests. In similar tests performed by Transport Canada [3], there was one instance of structural failure of the child seat albeit the dummy responses did not approach the proposed injury criteria limits. The potential structural damage of the child seat in testing with the 12-month-CRABI dummy is of concern. Completion of the planned tests with this dummy and analysis of the results should provide an indication if this is an issue with side air bags systems.

- Considerable efforts were spent in locating the correct replacement parts for the side air bag systems (module, mounting hardware, etc.). It is of some concern that often the dealerships were unable to identify or supply the correct parts for these late model vehicles. It is our hope that such confusion will not result in incorrect parts getting used to repair vehicles on the road.

9.0 SUMMARY AND CONCLUSIONS

NHTSA has initiated a program for evaluation of side air bag systems for OOP occupants. This paper presents the status of the evaluation of the recent TWG recommended test procedures for 3 year old and 6 year old occupants to assess the injury to OOP children. The paper also reports on the status of ongoing research on developing test procedures for and initial testing of properly restrained children in child restraints and booster seats, which is not currently addressed by the TWG.

The TWG recommended procedures include proposed test devices, performance criteria, and test procedures to assess SAB deployment injury risks for various size occupants. This paper addresses the evaluation of only test positions selected for this study. It does not address evaluation of the test devices or the performance criteria, i.e. the injury criteria and research values included in the TWG procedures. A thorough assessment of the proposed performance criteria is planned by NHTSA.

Research by NHTSA is ongoing into the evaluation of additional child OOP seated positions, adult OOP dummies, roof mounted air bag systems, and repeatability of the test procedures for the different size occupants. Assessment of the realism of the TWG test procedures and corresponding NHTSA variations is also planned.

The main observations from the research performed to date are included in the previous section. The following is highlighted:

- For the 3 and 6 year old occupants, high loads are possible in some of the current SAB systems, when tested per TWG positions or NHTSA variations.
- For the 3 and 6 year old occupants, the TWG procedures are generally capable of discriminating air bag systems over a wide variety of systems. However, in certain airbag/seating configurations, the TWG positions do not produce the highest loads on the dummies. Additional test procedures are described to augment the TWG procedures for these occupants.
- Additional test procedures are described to augment the TWG procedures for 12 month infants.
- This paper is a status report on an ongoing research program. Complete results from the research will be reported in a future agency report.

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REFERENCES

- [1] "Air Bag Crash Investigations", Chidester, Augustus B; Roston, Thomas A; 2001 17th ESV Conference, Paper #246
- [2] "Three-Year-Old Child Out-of-Position Side Airbag Studies", Pintar, Frank A.; Yoganandan, Narayan; Maltese, Matthew R.; Samaha, Randa R.; Eppinger, Rolf H., Paper 99SC03, Proceedings of the 43rd Stapp Car Crash Conference, 1999.
- [3] "Side Mounted Air Bag Injury Risk to Children", Tylko, Suzanne; Dalmotas, Danius; Stapp Paper # 2000-01-ST-02, Proceedings of the 44th Stapp Car Crash Conference, 2000.
- [4] NHTSA Docket # NHTSA-1999-5098-13, NHTSA-1999-5098-24
- [5] NHTSA Docket # NHTSA-1999-5098-22
- [6] "Recommended Procedures for Evaluating Occupant Injury Risk From Deploying Side Air Bags", The Side Air Bag Out-of-position Injury Technical Working Group (TWG), Adrian K. Lund (IIHS) Chairman, Aug 2000.
- [7] ISO Technical Report 14933, ISO/TC 22/SC10/WG3 N 188, Feb 1999, Draft.



Figure 2. TWG 3.3.2.1 Position



Figure 3. NHTSA SEAT-02-3 Position



Figure 4. NHTSA SEAT-07-3 Position



Figure 5. NHTSA SEAT-08-3 Position



Figure 6. NHTSA SEAT-02-3 Position



Figure 7. NHTSA SEAT-03-3 Position



Figure 8. NHTSA SEAT-07-3 Position



Figure 9. TWG 3.3.2.1 Position