REAR IMPACT TEST METHODOLOGIES: QUASISTATIC AND DYNAMIC

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ABSTRACT

The performance of a vehicle's seat back in rear impact accidents can significantly affect occupant kinematics and resulting injury potential. The only current United States (U.S.) government regulation addressing seat back strength is outlined in Federal Motor Vehicle Safety Standard (FMVSS) 207, Seating Systems [1]. The test method outlined in this regulation is only partially predictive of seat performance in dynamic and/or real world impacts. Many seats continue to demonstrate gross deformations or catastrophic failures with potentially injurious occupant kinematics under the impact conditions of the FMVSS 301 Fuel System Integrity testing [2]. The Quasistatic Seat Test (QST) methodology, which utilizes an Anthropometric Test Dummy (ATD) and applies the load to the seat back through the ATD's lumbar spine, has been shown to be a predictor of seat deformation under dynamic loading [3]. Different seat designs tested utilizing the QST methodologies are presented.

Additionally, sled tests conducted at impact levels consistent with FMVSS 301 severities are presented and analyzed regarding occupant containment and the degree of encroachment of the deforming seat back or front seat occupant into the rear occupant's seating compartment. Crash test data, including ATD injury measures, from tests performed for the development of the recently upgraded FMVSS 301 rear impact standard were reviewed. Furthermore, an additional FMVSS 301 test is presented wherein a QST compliant seat was utilized to evaluate changes in ATD kinematics and injury measures.

INTRODUCTION

While seat back strength and deformation characteristics are safety considerations for various impact modes, it is particularly important in a rear impact. The FMVSS 207 compliance test, which calls for application of a point load at the uppermost cross member of a detrimmed seat back, requires a moment resistance of only 3,300 in-lbf (373 Nm). This test has long been the subject of criticism in the automotive safety community for its low criteria and its failure to consider occupant kinematics or their influences on failure modes seen in dynamic or real-world testing. It has been noted that because of the way the point load is applied, seats tested via the FMVSS 207 methodology typically deform symmetrical, whereas in a purely rearward dynamic rear impact, seats will often twist or fail asymmetrically [4]. As such, there are a number of other test methods, whether quasi-static or dynamic, for quantifying the seat back performance of a given automobile seat in the rear impact mode.

A debate exists over what seat back energy absorbing characteristics, generally stiff versus yielding, are most applicable for optimized occupant protection considerations. Although not the subject of this work, data is presented from the analysis of a variety of test methods that depict seat back rearward deformation and the associated injury potential and/or measurements. From an automotive safety perspective, a real-world predictive test methodology is critical as serious and fatal injuries do occur when the front seat occupants experience excessive seat back deformations. Such deformations also put the occupants seated behind them at risk.

Quasi-Static Test (QST)

The Quasi-Static Test, or QST, seat back test methodology is premised around using the occupant itself to load the given seat. In this test, an uninstrumented test dummy (ATD) is forcibly pressed against the fully trimmed seat back in a manner consistent with the way that an occupant might load the seat in a real world collision [3]. This test yields data that includes not only the seat's resistance to rearward bending, but also provides insight into the point and manner in which an occupant will begin to ramp up the seat back as the seat back begins to yield or deform rearward. This is allowed by virtue of the load application following the ATD as it ramps up and out of the seat. This is accomplished by mounting the load applying hydraulic ram to a set of linear bearings that is free to move both horizontally and vertically during the application of load (See Figure 1).

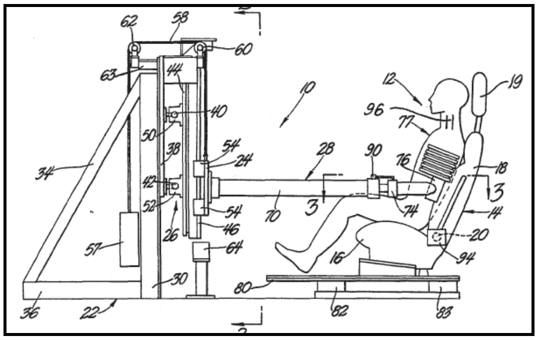

Figure 1. QST Test Setup Diagram [5]

The QST test pass / fail criteria, as designed by Dr. Viano while with General Motors in the early 1990's, specifies:

(1) 15,000 in-lbf (1700 Nm) Moment About H-point
(2) No Separation of Hardware Causing >450 lbf (2,000 N) Drop in Force in 50 milliseconds, and >10º Change in Seat Back Angle
(3) Seat Back Twist Not to Exceed 15º for Seat Back Angles up to 60º
(4) Head Restraint Height to B-Plane and Front Surface Within 0.8 inch (20 mm) of Back-of-Head Ellipse for the 95th Percentile Occupant

Sled Testing

Sled testing offers the freedom to analyze occupant kinematics and restraint system performance for numerous impact modes and speeds depending on the test apparatus set-up. Utilizing a sled allows for dynamic test results more consistent with that seen in real-world accidents while being able to reuse a vehicle buck (partial vehicle) or occupant compartment for multiple tests. Once a sled fixture is set-up with a particular occupant compartment, variations in the occupant safety system can be tested to analyze differences occupant kinematics and/ or restraint performance.

FMVSS 301/301R

Federal Motor Vehicle Safety Standard (FMVSS) 301 details the current U.S. mandated requirements for fuel spillage during and after a motor vehicle crash. The standard currently has frontal, rear and side test procedures. Of interest for this paper is the upgraded rear impact test procedure, which will be referred to as 301R. Vehicles subjected to this testing that were manufactured prior to September 2006 were impacted in the rear by a flat, non-deforming barrier at 30 mph (48 kph) with 50th percentile ATDs positioned in the front outboard seating positions. The FMVSS 301R standard was upgraded in 2003 and incorporated a phase-in such that vehicles manufactured after September 2008 are still required to have ATDs in the front outboard seating positions, however, the rear impact barrier is now deformable and required to be moving at a speed of 50 mph (80 kph) with a 70 percent overlap with the vehicle (See Figure 2). During the test sequence and for various time increments following the test, different fuel spillage requirements must be met.

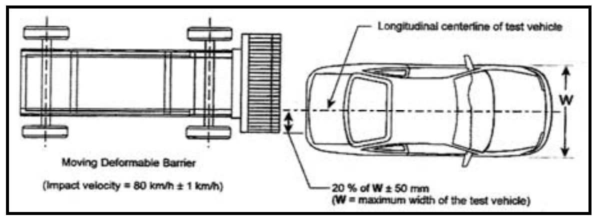

Figure 2. FMVSS 301R Test Setup Diagram

This upgraded test procedure requires the collection of valuable data regarding ATD injury measures, seat back rotation, driver belt load, and driver webbing motion that was not required in the earlier version [6]. Although the data is now collected, FMVSS 301R does not include pass/fail criteria for seat performance or ATD measured injury levels.

During the development of the FMVSS 301R upgrade, a series of rear offset tests were conducted at a speed of 50 mph (80 kph). The publicly available data files for these tests were obtained from the NHTSA Crash Test Database and included instrumented ATDs and their associated injury measures. This data is analyzed below.

TEST RESULTS

Quasi-Static Test (QST)

Numerous QST tests have been performed. As discussed above, this method loads the subject seat via a hydraulic ram by applying force through an uninstrumented ATD's lumbar spine. Prior to testing, each seat was inspected for defects before being mounted in the test fixture via their OEM (original equipment manufacture) seat track mounting brackets. Test instrumentation included angular transducers on both sides of the seat back, tri-axial load cells at the seat/fixture interface, a load cell on the force applicator (ram), as well as displacement transducers on the ram assembly (See Figure 3).

The data collected via this instrumentation provided insight into, not only the strength of the seat, but also how the failure pattern influences the occupant kinematics. Detailed measurements were taken prior to initiation of force to document the initial geometry of the seat relative to the test apparatus and data recording instruments.

Numerous QST tests have been performed on front seating position seats until catastrophic failure was experienced. Results are reported in Table 1.

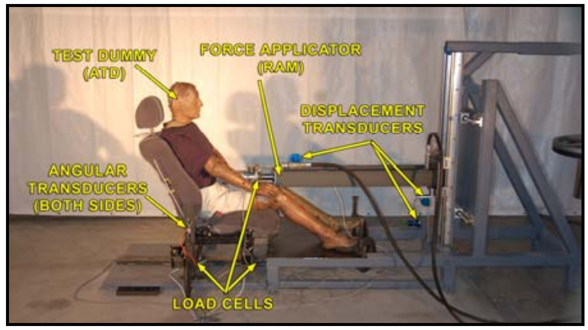

Figure 3. QST Test Set-up

Table 1.
QST Test Results

Seat	**Single or Dual Recliner**	**Peak Force** lbf (N)	**Peak Moment at H-point Up to 60 deg** in-lbf (Nm)	**Twist Angle Up to 60 deg** deg	**Energy Up to 60 deg** in-lbf (J)
Left Front 1993 Nissan Sentra	Dual	1,547 (6,884)	9,454 (1,068)	17	6,364 (719)
Right Front 1994 Chevrolet Lumina	Single	1,441 (6,409)	10,612 (1,199)	16	14,923 (1686)
Left Front 2003 Ford Ranger	Dual	1,862 (8,281)	11,225 (1,268)	6	15,387 (1,739)
Left Front 1993 Nissan 240 SX	Single	1,479 (6,579)	12,241 (1,383)	20	19,495 (2,203)
Left Front 1999 Honda Accord	Single	1,562 (6,948)	13,230 (1,495)	27	21,358 (2,413)
Left Front 1993 Volkswagen Passat	Dual	2,130 (9,478)	13,317 (1,505)	25	19,189 (2,168)
Left Front 2000 Ford Focus	Single	1,894 (8,425)	13,542 (1,530)	4	18,332 (2,071)
Reinforced 1994 Pontiac Trans Sport	Modified to be Dual	2,994 (13,317)	16,092 (1,818)	20	18,781 (2,122)
Right Front 1996 Saab 900	Dual	2,839 (12,629)	17,235 (1,947)	3	33,248 (3,757)
Right Front 1998 Opel Astra	Dual	2,792 (12,421)	19,935 (2,252)	22	24,321 (2,748)
Left Front 2003 Saturn Vue	Dual	3,369 (14,988)	22,322 (2,522)	30	27,716 (3,131)
Left Front 2002 Chevrolet Trailblazer	Single	2,747 (12,219)	34,522 (3,900)	27	38,056 (4,300)
Left Front 1990 Mercedes 300SL	Dual	7,644 (34,002)	49,608 (5,605)	32	62,012 (7,006)

Figure 4 demonstrates characteristic pre- and post- QST test conditions of a single recliner seat. As described, the QST fixture allows for asymmetrical deformation of the deforming seat structure as the ATD loads and ramps up the seat back.

Pre-Test

Post-Test

Post-Test, Rear View

Figure 4. QST Test: Chevy Lumina

Sled Testing

Four rear impact tests were conducted utilizing a deceleration sled. The sled fixture includes a sled carriage that is accelerated by way of a falling mass suspended by a block and tackle arrangement (See Figure 5). The sled is decelerated via an impact into a deformable barrier wherein the shape and depth of the barrier determine the crash pulse. Fixture instrumentation includes high-speed camera documentation and tri-axial accelerometers.

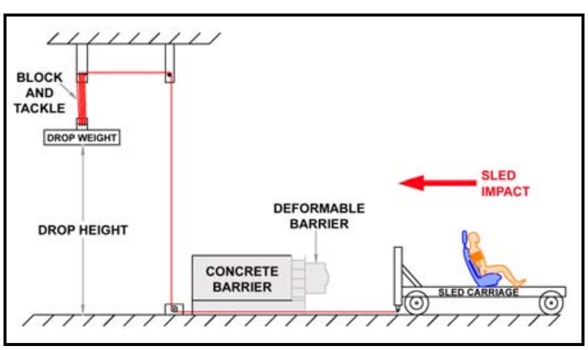

Figure 5. Sled Test Setup Diagram

A total of four impact sled tests were preformed with various combinations of seats and restraint systems. All tests included 50th percentile male ATDs.

Tests 1 and 2 included two seats mounted side-by-side on the sled fixture. Each seat, therefore, experienced the same deceleration pulse and each was loaded by a 50th percentile male ATD. In each of the first two tests, one of the included seats was designed with a single recliner mechanism whereas the second seat incorporated dual recliners. Tests 3 and 4 were run with only one seat at a time but under similar impact conditions in order to consider the effect of alternate restraint designs.

Sled Test 1 – For Sled Test 1, a production right front early 1990's vintage Chevrolet Lumina seat was tested in conjunction with a reinforced right front seat from an equivalent vehicle. The reinforced seat was originally equivalent to the OEM seat, but was reinforced with the addition of a second recliner mechanism. The attachment of the recliners to the lower seat structure was also reinforced. Lastly, the lower seat back cross member, which was originally a straight tubular structure, was replaced with a flat strap that could act as a pelvic catcher strap. Figure 6 shows the dual recliners with reinforcements and the pelvic catcher strap.

Figure 6. Test 1 Reinforced Seat

A 50th percentile Hybrid III male ATD with seated pelvis was placed in each seat and normally belted with the OEM restraint, which included a locking latch plate. The OEM seat was set to its full rear track position. In this position, the upper seat track was found to overhang the lower seat track significantly at the rear. Recognizing this as a potential failure mode contributing to rearward seat back deflection, the lower seat tracks for the reinforced seat were mounted rearward of the OEM mounting position to eliminate the rear offset of the upper versus lower tracks. The restraint anchorage positions relative to the ATDs were kept consistent for both seating positions. The seat backs were set to a recline angle of 24 degrees from vertical and angular rate sensors were positioned on both sides of the upper seat backs in order to document the dynamic seat deflection (See Figure 7). The sled was accelerated to an impact speed of 15.8 mph (25.4 kph).

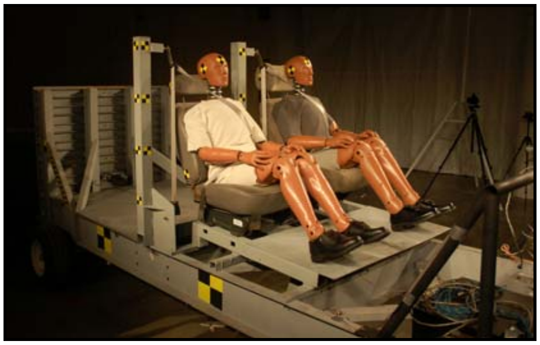

Figure 7. Sled Test 1 – Pre-test Set-up

Dynamically, the sled fixture sustained a maximum longitudinal deceleration of 15 Gs with a delta-V of 19.5 mph (31.4 kph) after impacting the deformable barrier. During the impact sequence, the OEM, single recliner seat back rotated rearward to 74 degrees from vertical on the left, recliner side, and 80 degrees on the right, simple pivot side, of the seat. Post-test static measurements reported a residual seat back angle of 50 and 65 degrees for the left and right sides, respectively.

Data recorded during the test sequence noted that the reinforced, dual recliner, seat dynamically rotated uniformly on both sides of the seat to approximately 53 degrees from vertical. The post-test residual seat back angle was also uniform at 36 degrees from vertical. Figure 8 depicts the post-test seat back rearward deformation.

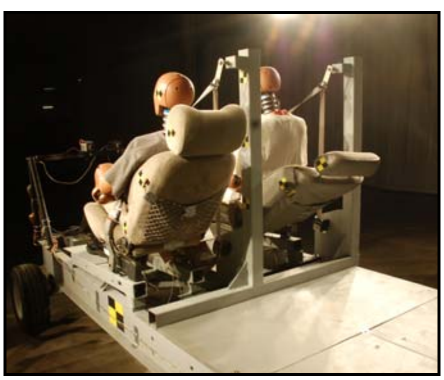

Figure 8. Sled Test 1 – Post-test
(OEM shown on Right)

Sled Test 2 – Sled Test 2 incorporated a full vehicle buck rigidly mounted to the sled fixture. A 1992 OEM, single recliner driver's seat was tested alongside a 1989 OEM, dual recliner right front passenger seat. Both seats were positioned into the buck such that the restraint anchor points had the same relative position for both the ATDs. The seat backs were set to a recline angle of approximately 20 degrees from vertical. A 50th percentile Hybrid III male ATD with seated pelvis was placed in each seat and normally belted with the buck's OEM passive restraint system (See Figure 9). The sled was accelerated to an impact speed of 16.2 mph (26.1 kph).

Figure 9. Sled Test 2 – Pre-test Set-up

The impact resulted in a maximum longitudinal deceleration of 17.7 Gs with a delta-V of 20.1 mph (32.3 kph). The maximum seat back deflections and resulting ATD movement is depicted in Figure 10.

Figure 10. Sled Test 2 – Test Sequence Maximum Deflection (from Video Analysis)

The ATDs' heads were painted in order to identify head impact locations. Figure 11 shows the post-test residual positions of the seat backs and ATDs. The driver's single recliner seat deformed such that the driver's ATD was seen to ramp up the seat back with its head making contact with the left rear seat back and leaving the red paint transfer seen in Figure 11. This contact was of sufficient force level to deform, or bow out, the left rear seat back structure as seen in Figure 12. In comparison, the right front, dual recliner seat prevented ATD contact with the rear seating compartment.

Figure 11. Sled Test 2 – Post-test, Red Transfer on Left Rear Seat from Driver's Seating Position ATD Head Impact

Figure 12. Rear Seat Back Deformed from Driver's Seating Position ATD Contact

Sled Test 3 & 4 – Tests 3 and 4 were conducted following an investigation and analysis of a real-world multiple-impact accident sequence wherein an early impact deformed the driver's seat back fully before a later impact resulted in the belted driver's full ejection. When the vehicle came to rest, the driver's seatbelt was found buckled with the webbing roped in the D-ring such that approximately 62 inches (157.5 cm) of webbing was extended. Load marks were identified on the lap belt components indicating webbing pass through from the shoulder belt into the lap belt during the accident sequence.

Test 3 and 4 utilized the front occupant compartment of a similar 4-door Sport Utility Vehicle (SUV) to that of the real-world accident vehicle. The buck was rigidly mounted to the sled fixture and subjected to rear impacts. In both tests an OEM driver's seat was set to a fully reclined seat position at the start of the test to consider the restraint system's ability to prevent occupant ejection in the rear impact mode from a previously failed seat back. Both tests utilized 50th percentile Hybrid III male ATDs with standing (pedestrian) pelvises.

In Test 3 the ATD was restrained with the standard OEM restraint system which included a single pass-through, sliding latch plate. The seat belt was put on the ATD normally with the belt clamped at the D-ring such that approximately 62 inches (157.5 cm) of webbing was extended, consistent with the above as-found position in the real-world accident vehicle. The driver's seat was then set to the fully reclined position. Any loose webbing was shared between the lap and shoulder portions of the restraint system prior to impact. The full recline angle of the seat was measured to be approximately 58 degrees from vertical (See Figure 13).

Figure 13. Sled Test 3 – Pre-test Set-up

In both Tests 3 & 4, the impact speed was measured at approximately 16 mph (25.7 kph). Dynamically, the sled fixture sustained a maximum longitudinal deceleration of approximately 17.5 Gs with a delta-V of approximately 20 mph (32.2 kph) after impacting the deformable barrier.

A review of high-speed film from Test 3 shows the ATD ramping up the seat back and moving fully into the rear compartment. A high-speed camera focused on the pass-through latch plate showed more than 3 inches (76.2 mm) of webbing passing through the latch plate and into the lap belt as the ATD ramped up the seat back (See Figure 14). The ATD moved rearward, effectively unrestrained, until his feet caught the lap portion of the belt webbing (See Figure 15).

Figure 14. Sled Test 3 – ATD Ramping During Test

Figure 15. Sled Test 3 – ATD Post-Test

In Test 4, the configuration was similar to that of Test 3, however, a locking latch plate replaced the OEM single pass-through, falling latch plate. The shoulder belt was again clamped at the approximate 62 inch (157.5 cm) position. The lap belt was adjusted on the ATD in a normally tight configuration with the seat in a normal and upright position. The seat back was then again set to its fully recline position at an angle of approximately 58 degrees from vertical (See Figure 16).

Figure 16. Sled Test 4 – Pre-test Set-up

A film analysis of Test 4 demonstrates the locking latch plate was effective at maintaining the tight lap belt condition. The tight lap belt was seen to limit the amount of ATD excursion and velocity into the rear occupant compartment (See Figure 17). Figure 18 depicts the ATD's post-test position.

Figure 17. Sled Test 4 – ATD Ramping During Test

Figure 18. Sled Test 4 – ATD Post-Test

FMVSS 301R

During research to upgrade FMVSS 301 in the U.S., the government conducted a series of dynamic rear impact tests in order to determine what requirements would provide a reasonable crash simulation of real world rear impacts that resulted in fatal burn cases [7]. One tested crash scenario, which ultimately became the upgraded rear impact standard, was a 50 mph (80 kph) deformable barrier rear impact with 70% overlap. These publicly available tests contained instrumented front seated ATDs. Table 2 below summarizes that data.

Table 2.
FMVSS 301R (50 mph/ 80 kph Deformable Barrier Rear Impact) – Data Summary

NHTSA Test No	Test Details	Vehicle	Driver				Right Front Passenger			
			HIC	Chest Gs (3 ms)	Max Neck Nij*	Head Contact with Rear Compartment	HIC	Chest Gs (3 ms)	Max Neck Nij*	Head Contact with Rear Compartment
2315	80% Right Side Overlap	1993 Ford Mustang 2-dr	198	22.8	0.32	Yes	913	53.9	**1.56**	Yes
2318	80% Right Side Overlap	1993 Ford Mustang 2-dr	892	38.0	0.37	Yes	**1191**	**60.4**	0.85	Yes
2397	50% Right Side Overlap	1993 Ford Mustang 2-dr	721	44.9	0.79	Yes	**1332**	**66.4**	**1.00**	Yes
2408	70% Right Side Overlap	1996 Ford Mustang 2-dr	**1586**	41.8	0.68	Yes	583	53.6	**1.09**	Yes
2432	70% Right Side Overlap	1996 Suzuki Sidekick	389	39.5	0.60	Yes	569	39.7	0.51	Yes
2438	70% Left Side Overlap	1996 Chevy Blazer 2-dr	783	22.6	0.51	Yes	**2552**	18.9	0.98	Yes
2439	70% Right Side Overlap	1996 Dodge Neon	739	22.2	0.29	Yes	**1423**	43.0	**1.07**	Yes
2440	70% Left Side Overlap	1996 Geo Prism 4-dr	829	37.2	0.92	Yes	604	19.6	0.23	Yes
2445	70% Left Side Overlap	1996 Plymouth Voyager	690	15.8	**1.08**	**	**1578**	15.5	0.94	**
2925	70% Left Side Overlap	1998 Chevy Metro 3-dr	**1618**	48.6	**2.41**	Yes	760	46.5	**1.54**	Yes
2926	70% Left Side Overlap	1999 Mazda Miata 2-dr Convertible	**1274**	Data Error	**1.98**	Yes	914	Data Error	**1.86**	Yes
2933	70% Right Side Overlap	1998 Chevy Cavalier 4-dr	353	14.8	0.31	**	**1724**	28.7	0.75	**
2960	70% Left Side Overlap	1998 Honda Civic 4-dr	758	32.0	0.75	Yes	**2740**	33.0	**1.03**	Yes
2973	70% Right Side Overlap	1998 Chevy Cavalier 4-dr	**1063**	23.5	0.53	Yes	**2545**	32.6	0.81	Yes
2974	70% Left Side Overlap	1998 Honda Civic 4-dr	926	34.8	0.47	Yes	**1793**	58.3	0.69	Yes
2981	70% Left Side Overlap	1997 Chevy Camaro	930	45	0.23	Not Recorded	480	34	**1.13**	Not Recorded
3427	70% Right Side Overlap	1998 VW Jetta 4-dr	150	14	0.29	Not Recorded	560	15	0.30	Not Recorded
3428	70% Left Side Overlap	1998 Honda Civic 4-dr	790	27	0.37	Not Recorded	310	39	0.51	Not Recorded
3429	70% Left Side Overlap	1998 Ford Escort 4-dr	250	19	0.56	Not Recorded	**1370**	28		Not Recorded
3430	70% Left Side Overlap	1998 Nissan Sentra 4-dr	410	32	0.42	Not Recorded	420	21	0.38	Not Recorded
3431	70% Right Side Overlap	1998 Chevy Cavalier 4-dr	600	24	0.80	Not Recorded	Over loaded	43	**1.40**	Not Recorded

* Calculated utilizing Nij Version 8
** Report is silent on rear compartment head strikes, however photographs indicate contacts likely

Review of the test data indicates that virtually every ATD impacted some portion of the rear occupant compartment. Fourteen (14) instances of Head Injury Criteria (HIC) measures above 1000 were recorded as well as twelve (12) Nij measures above 1.0.

Although all of the above vehicles incorporated FVMSS 207 compliant seats, when loaded dynamically in a rear impact these seats consistently failed to prevent occupant excursion into the rear compartment and potentially injurious impacts with rear structures or rear seated occupants.

Table 3.
Chevrolet Blazer FMVSS 301R Test Data

Test	Vehicle	Driver				Right Front Passenger			
		HIC	Chest Gs (3 ms)	Max Neck Nij*	Head Contact with Rear Compartment	HIC	Chest Gs (3 ms)	Max Neck Nij*	Head Contact with Rear Compartment
Karco Test No. TR-P25021-01-NC 70% Left Side Overlap	1996 Chevy Blazer 4-dr	138	16.5	0.36	No	286	18.8	0.43	No
NHTSA Test No. 2438 70% Left Side Overlap	1996 Chevy Blazer 2-dr	783	22.6	0.51	Yes	**2552**	18.9	0.99	Yes

*Calculated utilizing Nij Version 8

QST Compliant Seat in 301R Test – After reviewing the data summarized in Table 2, the authors conducted an additional 301R compliance test with a vehicle similar to NHTSA Test No. 2438. The 1996 Chevrolet Blazer 2-door tested in NHTSA Test No. 2438 was equipped with FMVSS 207 compliant seats. A review of FMVSS 207 test data for that seat, as compared to a QST compliant designed seat, show that the QST seat is capable of resisting nearly three times the force of the Blazer seat and more than twice the energy. In order to consider the relative performance of the simple FMVSS 207 designed seat versus a QST-type seat, a 1996 Chevrolet Blazer was retrofitted with 1999 Pontiac Grand Am OEM front seats and floor pan. These 1999 Pontiac Grand Am seats were designed and compliant with the above-described QST methodology. The retrofitted Blazer was then tested pursuant to the FMVSS 301R protocol and the results were compared to NHTSA Test No. 2438 (See Table 3).

Analysis of the retrofitted 301R test data shows that the QST compliant seat provided effective ATD retention under the dynamic 301R test conditions. The ATD was not allowed to move into the rear occupant compartment and strike any rear structure. As such, the potential for significant injury was avoided as demonstrated by the several fold reduction in injury measures when compared specifically to the other Blazer test, and more generally, to most of the tests reported in Table 2.

DISCUSSION/CONCLUSIONS

Currently, and for the past several decades, the vast majority of vehicles being manufactured and sold in the U.S. use seats designed only to comply with the static seat strength requirements outlined in FMVSS 207. This static strength test has consistently been shown to be a poor predictor of dynamically loaded, and therefore real-world, seat performance. Beyond the simple static test of FMVSS 207, several better and more real-world predictive test methodologies are available. These include the QST methodology, dynamic sled tests, as well as full-scale crash tests.

The QST test results, presented in Table 1, demonstrate a wide range of seat back strengths and deformation patterns. H-point moments recorded up to 60 degrees of seat back deflection range from approximately 9,500 in-lbf (1,073 Nm) to above 49,000 in-lbf (5,536 Nm). The QST test results further indicate that a seat designed with only a single recliner on one side and a simple pivot hinge on the other, will consistently result in asymmetrical deformation from occupant loading on the seat back. In turn, this results in less-controlled occupant excursions.

In contrast, dual recliner equipped seats provide an increase in seat back structural strength as compared to their single recliner counterparts. This not only allows for increased occupant retention, but also for more uniform seat back deflection. When these features are combined with occupant retention devices, such as the pelvic catcher strap, rearward excursion of the occupant towards, and into, the rear occupant space is much more effectively controlled.

Consistent with previous work [3, 4], good correlation was seen between the seat back deflection recorded in the QST tested Chevrolet Lumina seat and its sled tested equivalent (Sled Test 2) (See Figure 19).

QST Sled Test

Figure 19: Chevrolet Lumina QST and Sled Tested Seat Comparison

As the various dynamic sled and crash tests demonstrate, when the seat back fails, the restraint system can be compromised to the extent that dramatic occupant excursion into the rear seating compartment, or beyond, is allowed. Occupant restraint in rear impacts relies, therefore, first upon maintaining the integrity of the seat, and secondly, upon maintaining the effectiveness of the seat belt. The locking latch plate has been shown to be effective at maintaining a tight lap belt, and thereby, inhibiting ATD ramping in the event of catastrophic seat back failure.

The upgraded FMVSS 301R test methodology provides valuable data regarding seat back performance, occupant kinematics and injury potential in the rear impact mode. The recent addition of instrumented ATDs provides a new level of insight into occupant motion and injury potential. The vast majority of the 301R data reviewed demonstrated that the seats' rearward deformations allowed the ATDs to ramp up the seat backs exposing them to potentially injurious impacts with the rear compartment. An alarming number of HIC and Nij values above the accepted injury thresholds were recorded.

FMVSS 301R testing has demonstrated that dynamic loading of production seat structures designed to provide effective occupant retention also provide improved injury measures and decreased potential for injurious contacts. These stronger seats limit ATD excursion into the rear seating compartment thereby also reducing injury potential to rear seated occupants. Well designed, current production seats are capable of managing the energy levels seen in the upgraded FMVSS 301R 50 mph (80 kph) offset rear impact test.

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