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Memorandum

U.S. Department of Transportation

National Highway Traffic Safety Administration

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Subject: ACTION: Preliminary Regulatory Evaluation, HEADS, Amendments to FMVSS No. 201, Upper Interior Head Protection, April 1997

Date: AUG 20 1997

From: William H. Walsh
Associate Administrator for Plans and Policy

Reply to Attn. of:

To: DOCKET

Thru: John G. Womack
Acting Chief Counsel

179 pp

Please submit the attached 10 copies of the "Preliminary Regulatory Evaluation, Head-Impact Energy Absorbing Dynamic Systems (HEADS), Amendments to FMVSS No. 201, Upper Interior Head Protection, April 1997," to the appropriate docket.

Attachments

Distribution:
Associate Administrator for Safety Performance Standards
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Associate Administrator for Safety Assurance
Associate Administrator for Traffic Safety Programs

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People Saving People

Preliminary Regulatory Evaluation

NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION

Head-Impact Energy Absorbing Dynamic Systems (HEADS), Amendments to FMVSS No. 201, Upper Interior Head Protection

Office of Regulatory Analysis
Plans and Policy
April, 1997

SUMMARY

This Preliminary Regulatory Evaluation accompanies a Notice of Proposed Rulemaking to amend FMVSS No. 201, Upper Interior Head Protection, issued August 18, 1995, (60 FR 43031) to allow advanced head-impact energy absorbing dynamic systems (HEADS) devices such as inflatable air bags and/or inflatable trim (dynamic trim) to be installed at the manufacturer's option. Some HEADS devices can not deploy past padding thick enough to meet the 15 mph test required by the August 1995 FMVSS No. 201 final rule. To allow these HEADS devices, optional test procedures are proposed: Option #1 - All target points are tested at 15 mph using the free-motion headform (FMH) as required by the FMVSS No. 201 final rule published August 1995; Option #2 - Target points covered by the HEADS device are tested at 12 mph using the FMH with the device undeployed and covered target points are tested at 18 mph with the FMH with the device deployed and Option #3 - Target points covered by the HEADS device are tested at 12 mph using the FMH with the device undeployed and an 18 mph lateral pole test is conducted with the device deployed.

Benefits:

With HEADS devices meeting Option #2 or Option #3, static padding benefits would be lost in the 12-15 mph range. However, benefits would be gained in the 15-18 mph range with the HEADS device deployed. Compared to the 201 static padding benefits assessment, the net gained benefits would be 119 fatalities and 125 MAIS 4-5 injuries (Mertz-Prasad Method) and 311 fatalities and 512 MAIS 2-5 injuries (Lognormal Method) per year. The lost benefits would be 1,075 MAIS 1-3 injuries (Mertz-Prasad Method) and 1,273 MAIS-1 injuries (Lognormal Method) per year. The net impact of these test procedures would thus be fewer serious injuries, but more minor injuries.

The analysis indicates that an optional test procedure of 12 mph undeployed and 18 mph deployed for HEADS devices or systems would yield positive net safety benefits equivalent to 199-501 fatalities prevented annually, if 100 percent of the passenger car and light truck fleet were so equipped.

Although not quantified, other potential fatal and nonfatal injury benefits for HEADS devices may accrue for; (1) injuries caused by lateral pole intrusion into the occupant compartment (target population = 73 fatalities and 61 nonfatal injuries) and (2) injuries from window ejection from lateral impacts (target population = 398 fatalities and 693 nonfatal injuries). Both target populations were measured at greater than or equal to 15 mph, the lateral ITS deployment speed.

Cost:

There is no FMVSS cost, as HEADS systems would be optional safety equipment installed at the manufacturer's option.

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I. BACKGROUND

The NHTSA Authorization Act of 1991 (Sections 2500-2509 of the Intermodal Surface Transportation Efficiency Act, P.L. 102-240) directed the agency to issue a rule on improving interior head impact protection. An NPRM was published February 8, 1993 (58 FR 7506). The proposed test procedure defined upper interior head impact zones which had to meet performance criteria when contacted with a free motion head form (FMH) at 15 mph. The FMH is the modified head of a Hybrid III dummy (Part 572 E).

On August 18, 1995, the National Highway Traffic Safety Administration (NHTSA) issued a final rule (60 FR 43031) amending Federal Motor Vehicle Safety Standard (FMVSS) No. 201 "Occupant Protection in Interior Impact" to require passenger cars, trucks, buses and multipurpose vehicles with a gross vehicle weight rating (GVWR) of 10,000 lbs or less, to provide improved protection when an occupant's head strikes upper interior components, including A and B-pillars, side rails, roof headers and the roof, during a crash. The amendments add test procedures and a performance criterion for a new in-vehicle component test. The test procedures specify a 15 mph FMH impact test that simulates a typical head impact against a vehicle upper interior component. The performance criterion or injury criterion is the HIC - 1000 limit. Target points are specified; 16 for a typical 4-door passenger car and 20 for a typical passenger minivan. The new requirements will be phased-in within a four year period (10%, 25%, 40%, 70% and 100%) beginning September 1, 1998.

The agency received a total of 11 petitions for reconsideration from seven automobile manufacturers (Ford, Mercedes-Benz, Volvo, Toyota, Volkswagen (VW), BMW, and Honda), two manufacturer's associations (American Automobile Manufacturers Association (AAMA) and the Coalition of Small Volume Automobile Manufacturers, Inc. (COSVAM)), one safety organization (Center for Auto Safety (CAS)), and one multi-stage manufacturer (ASC incorporated). The manufacturers requested additional lead time and carry forward/back credits, test procedure clarification and/or revisions. A 2-day Workshop was conducted for industry representatives/test engineers December 13-14, 1995, at the Vehicle Research and Test Center (VRTC), East Liberty, OH in order to answer their questions about the test procedure contained in the final rule. The lead time, carry forward/back credits, and FMH test procedure issues raised in the petitions for reconsideration are addressed in a separate rulemaking. (See 62 FR 17618, April 8, 1997)

Four manufacturers (BMW, Ford, Mercedes-Benz and Volvo) petitioned the agency for new procedures for testing new dynamic head protection systems. As these petitions were out-of-scope in the context of the final 201 rule, the agency treated these as petitions for rulemaking. Dynamic or advanced technology head protection systems will be referred to generically in this document as head-impact energy absorption dynamic systems or HEADS.

The agency issued an ANPRM in order to gather comments pertinent to HEADS (61 FR 9136, March 7, 1996). The agency received a total of ten comments from five automobile manufacturers (Ford, Volvo, BMW, VW and Mercedes-Benz), one automotive supplier (Autoliv GmbH), one manufacturer's association (AAMA), and three consumer advocate groups (Advocates for Highway and Auto Safety (Advocates), the Automotive Occupant Restraints Council (AORC) and the Insurance Institute for Highway Safety (IIHS)). Their general comments to the ANPRM and their specific responses to the 17 questions/issues raised are summarized in the next section of the report.

The purpose of this preliminary regulatory evaluation is to support a Notice of Proposed Rulemaking and to address the benefits, costs and related technical issues pertinent to HEADS. If a final rule were issued, it would amend FMVSS No. 201 to accommodate the new HEADS systems.

II. OVERVIEW OF COMMENTS TO THE ANPRM

NHTSA's Proposal

Through their petitions and news articles, the agency became aware of several prototype and conceptual HEADS systems; (1) Ford's "head-and-chest" air bag (see 12/17/95 Press Release), (2) BMW's Inflatable Tubular Structure (ITS) (See "ITS, A New Restraint System for Side Impact Protection," SAE paper No. 961018), (3) an Inflatable Trim or Dynamic Padding concept, (4) Volvo's Side Curtain air bags and (5) Autoliv's Inflatable Curtain (IC) which uses vertical air bag columns to protect the face, neck and chest from injury in a side collision or rollover. The dominant common element among the HEADS designs was lateral impact with rollover protection capability. Some of this information was presented orally to NHTSA staff by the manufacturers. The petitioners requested a variety of changes to the rule to accommodate HEADS; (1) a complete exclusion of any vehicle equipped with HEADS, (2) an exclusion of targets protected by HEADS, (3) for targets protected by HEADS allow a 12 mph FMH test speed with HEADS not deployed, (4) inclusion of a full scale vehicle dynamic test in the standard and (5) test with the dynamic system deployed. In the ANPRM, NHTSA proposed three possible approaches for testing HEADS systems:

Proposed Approaches

A. - For dynamically deployed padding: For the targets protected by dynamically deployed padding (or trim), impact the targets with the FMH at 12 mph, prior to deployment of the padding. Impact these same points again at 20 mph after the deployment of the padding.

Conduct crash tests at 15-20 mph to ensure that sensors activate the deployment of the padding.

B. - For dynamically deployed air bags or other inflatable devices (Option #1): For the upper interior targets protected by an air bag or other inflatable device, impact the targets with the FMH at 12 mph, prior to the deployment of HEADS. All other targets are tested at 15 mph with the FMH. Conduct an 18 mph side impact crash test into a fixed, rigid pole of 10 inches in diameter. This test would be representative of the real-world lateral impact where the head makes contact with a fixed object such as a pole or tree.

C. - For dynamically deployed air bags or other inflatable devices (Option #2): For the targets protected by an air bag or other inflatable device, impact the targets with the FMH at 12 mph, prior to deployment of HEADS. All other targets are tested at 15 mph using the FMH. Conduct a 30 mph side impact test using the ISO #10997 moving deformable barrier (MDB) fitted with a rigid face. This test would be representative of a real-world lateral impact from a high hooded vehicle (e.g., a pickup truck) in which the head makes contact with the front end of the striking vehicle.

Approaches B and C were presented by the U.S. delegation to the ISO/TC22/SC 10/WG3 in its draft technical report, Document N100, "Road Vehicles - Test Procedures for Evaluating Various Occupant Interactions with Deploying Side Impact Air Bags, February 9, 1995."

A. General Comments

AAMA - While more effective technologies are continually being explored and developed by member companies, any additional mandated test procedures would be unwarranted. AAMA member companies do not consider head protection enhancement through utilization of new technology to be incompatible with final rule compliance.

Ford - The present substantial requirements of FMVSS No. 201 and 214 already provide a means of evaluating the performance of dynamic systems. Ford has participated in the preparation of the AAMA comments, and fully endorses them.

Advocates - They strongly oppose the manufacturer requests such as; (1) a complete exclusion of vehicles equipped with dynamic systems and (2) an exclusion of targets arguably protected by dynamic systems. Commends NHTSA to use dynamic systems as a basis for considering even greater safety benefits from further amendments of FMVSS No. 201.

Volvo - They have been working with Autoliv AB to develop electronically actuated "Side Curtain" air bags which deploy downward from the roof of the vehicle in 25 msec in a side crash and work in conjunction with side thorax air bags. Each curtain would consist of eight segments that inflate simultaneously with a single charge. A single curtain would cover both front and rear side windows. Volvo expects to introduce the "Side Curtain" (similar to Autoliv's Inflatable Curtain) in their 960 models in model year 1999. [See Ward's Engine and Vehicle Technology Update, November, 15, 1996] Volvo does not support the inclusion of full scale dynamic tests in an amended FMVSS No. 201 regulation. A dynamic test specifying one specific test configuration will be of limited use in evaluating head impact that may occur over a wide area of the car upper interior.

BMW - They plan to offer the ITS in their 700 Series model by June 1997. [See The Washington Times, April 4, 1997] The ITS stows in an extremely small cross section of the upper interior e.g., under the A-pillar and side rail trim. (See Illustration 1, Appendix) During a side impact crash, the ITS polyamid fabric tube inflates 5-6 inches in diameter (4-5 feet long) to support the occupant's head and neck. (See Illustration 2, Appendix) The ITS works in combination with the side thorax air bag and tends to move the occupant inward laterally to make room for the deployment of the ITS and moves the occupant away from the inner door. This system, designed by Simula, Inc., significantly reduces HIC values, eliminates head rotation outside the vehicle (extravehicular head excursions), contributes toward preventing ejection, and has a delayed deflation time, unlike conventional air bags, to protect during rollovers and secondary impacts. The ITS system crosses the front side window at a diagonal such that the head of a 95th percentile male would make ITS contact with the driver/passenger's seat adjusted fully rearward and a 5th percentile female head would make ITS contact with the seat adjusted fully forward. Romeo Engineering came up with the ITS idea, Simula, Inc. developed it, and Autoliv is manufacturing it for BMW. Eventually, the ITS product will be licensed so that companies other than BMW can use it.

BMW needs at least two years of lead time to design and install the ITS systems. They suggest that NHTSA specify multiple test procedures that would provide manufacturers with the flexibility to offer the most advanced systems suitable to their product lines.

BMW recommended the following test procedures in addition to the FMH impact tests:

1. Full scale crash test - Prefers moving vehicle-into-pole tests rather than FMVSS No. 214 type tests.

2. Test dummy - Prefers the EuroSID rather than the SID with the Hybrid III head/neck.

3. Speed for full scale crash tests - 18 mph for a rigid pole test. 15 mph equivalent MDB speed for a 214 type test.

4. Sensor performance - Activated at the above test conditions and the system would be fully deployed within 30 ms.

5. Special FMH impact tests (undeployed condition): 12 mph for the A-pillars (AP1, AP2 and AP3), B-pillars (BP1, BP2 and BP3), and side rail (SR1, SR2 and SR3). Following deployment SR3 may not be protected by ITS at 15 mph as there is no HEADS overlap or coverage.

Volkswagen (VW) - The entire area covered by a dynamic system would be certified to meet the 15 mph FMH impact requirements when the system is triggered in a static mode. No lower speed tests are necessary at the undeployed condition. Areas not covered by the system would also continue to be tested at the 15 mph impact speed. VW recommended the following test procedures for areas covered by HEADS;

(1) Tests are only to be performed in the deployed condition using a FMH at 15 mph,

(2) Deployment of the system is to be tested using a rollover simulation such as that specified in FMVSS No. 208, (Occupant Crash Protection) and either FMVSS No. 301 (Fuel System Integrity) or FMVSS No. 214 (Side Impact Protection) moving barrier side impact tests,

(3) Once inflated, the system should remain inflated for a period of time which represents foreseeable crash events, and

(4) Lower speed impact tests into areas covered by the system would not be required under the undeployed condition.

One manufacturer presented a conceptual design for a padding system that deploys along the roof rail/pillar components using advanced materials (referred to as Inflatable Trim). The idea is to conserve interior occupant space and maintain driver visibility to the greatest degree possible. The trim would inflate locally, but would provide head protection for impacts, against headers and pillars.

AORC - They support the continuous review and refinement of FMVSS No. 214, the agency's dynamic side impact protection rule, with the use of the SID dummy combined with the Hybrid III head/neck.

They do not consider the vehicle-into-pole crash test an appropriate tool for evaluating compliance with FMVSS No. 201. They are concerned about the proliferation of costly "specialty tests" and believe that the addition of another test is of questionable benefit. Regarding the NHTSA's third proposed approach for testing HEADS (the high hooded vehicle tests with the top of the flat, fixed barrier face 50 inches off the ground), AORC agreed that it would seem reasonable that the height of the FMVSS 214 or ECE impacting surface should be raised as suggested.

IIHS - They suggest that NHTSA act quickly to grant special consideration to dynamic systems (HEADS) that offer benefits outside the scope of the existing standard and to ensure the installation of dynamic interior protection systems in new cars as soon as possible. They stated that NHTSA has to deal with two different compliance issues; (1) with HEADS, compliance with FMVSS No. 201 may be difficult, but the systems may offer greater upper interior head protection when deployed and (2) for some HEADS systems, the benefits may fall outside the scope of the standard. In the latter case, IIHS indicated, the HEADS systems may have problems with the FMVSS No. 201 target points, but may provide greater protection for head impacts outside the vehicle and ejection through side windows.

Autoliv agrees with the idea that FMVSS No. 201 may have to be modified to accommodate advanced systems which may enhance benefits due to the prevention of head ejection, head contact with side window glass and reducing the consequences of intruding external objects. They stated that advanced technologies offer potential in reducing head ejection in side and other impact modes that is probably best assessed in full scale crash tests and that FMVSS Nos. 208 and 214 are natural platforms for this condition. They have developed an Inflatable Curtain (IC) which will meet an 18 mph lateral pole test with HIC reduced from 4,010 to 450 at an inflation pressure 33.4 psi (2.2 bar). (See Illustration 3, Appendix)

The IC deploys from behind the upper side rail trim at both front and rear seating positions and can provide protection from rollover crashes, intruding objects and from intruding car body structure. The design employs a gas generator (cold gas) located in the C-pillar and inflates a 16 liter volume. The curtain weighs approximately 1,000 grams (2.2 lbs.) per side and is used in conjunction with thorax air bags. The IC inflates in less than 25 ms and stays inflated for more than 5 seconds. Autoliv is an occupant restraint/air bag supplier in Europe like TRW is in the United States.

B. Response to ANPRM Q/As

To assist the agency in developing possible ways of evaluating the performance of HEADS, NHTSA requested answers to a series of questions/issues. The questions/issues and the industry response to each are listed below:

1. What test procedures could be used to measure the performance of a dynamic system?

Responses: AAMA members strongly urge NHTSA not to require additional test procedures beyond those currently required in FMVSS No. 201 or 214. In BMW's view, dynamic systems appear to increase head protection under real-world crash conditions, and a single test may not be able to reflect all these increased benefits. They support the use of different procedures to accommodate various systems. BMW supports the more severe pole test, which demonstrates the performance improvements of ITS system, but this may not be appropriate for every dynamic system. One of the criteria which discriminates the performance of the various dynamic systems is the potential to provide protection for side impacts with external objects such as trees and poles, side window glass or the front high hooded area of a colliding vehicle. NHTSA may need to specify more than one type of dynamic test, giving the manufacturers the option of certifying to any one of the procedures. BMW suggests that the side impact pole test should be one of the alternative procedures.

Mercedes-Benz (M-B) recommends testing each target point as outlined in the August 18 final rule, however, any point fitted with a HEADS would be FMH tested in the fully deployed mode at 15 mph. Volvo indicated that they favor; (1) conducting FMH testing at 12 mph with the device inactivated and (2) conducting FMH testing at 15 mph into the activated HEADS device, with the performance criterion of 1000 HIC maximum. VW wants the HEADS deployed with the vehicle in the static mode and impact tested at the appropriate points using the FMH at 15 mph. They recommended that a dynamic test procedure (e.g., 208 rollover, 301 fuel tank integrity or 214 dynamic side impact) be required to deploy the HEADS for some specified period to ensure protection for occupants under rollover and subsequent multiple impacts. [Note: This is different than a conventional frontal air bag which is vented and does not stay inflated throughout the crash sequence.] Autoliv supported the following test procedures: (1) 12 mph FMH impact tests against the undeployed dynamic system and (2) 15 mph FMH impact tests against the target areas with the system deployed.

2. What performance criteria would assure that advanced systems, when deployed, provide protection equivalent to that provided by countermeasures that meet the requirements of the final rule?

Responses: AAMA stated that the FMVSS No. 201 and FMVSS No. 214 performance criteria are all that are needed to assure the effectiveness of HEADS. BMW stated that a HIC measurement of 1,000 or less when measured in frontal 30 mph fixed barrier impact with a Hybrid III dummy has been well established as a tolerance level acceptable to humans. They suggest using the same criteria for a lateral pole impact test. BMW indicated that it would appear reasonable for NHTSA to propose the recording of such HIC measurements using a modified U.S. SID with a Hybrid III head and neck. M-B stated that meeting the dynamic requirements of the improved FMVSS No. 201 for each target point fitted with HEADS (in the deployed mode) would demonstrate the systems's ability to meet or exceed the requirements. Volvo indicated that they favored HIC<= 1000 with the above FMH tests. Autoliv supported HIC <=1000.

3. Are there other test methods appropriate for dynamic systems using full scale crash tests and an anthropomorphic test device?

Responses: AAMA indicated that tests beyond the level of FMVSS No. 214 are not needed. BMW employed several different lateral crash test modes with and without the ITS system to demonstrate test severity (ranked from least to most severe based on HIC and head g's); (1) the FMVSS No. 208 Lateral Moving Barrier Crash Test in S5.2, namely - 90 degree 4,000 lbs. moving barrier (MB) at 20 mph from FMVSS No. 301, Fuel Tank Integrity, and the Hybrid III dummy used laterally. The FMVSS 301 barrier face is flat (60" X 78") and is 5 inches off the ground, (2) 90 degree ECE barrier side impact crash test with the EuroSID presumably at 30 mph, (3) FMVSS No. 214 MDB test procedure with the EuroSID dummy, (4) 90 degree moving pole test (5,400 lbs. MB with a 350 mm pole welded to the barrier face) at 25 mph using the EuroSID, and (5) 90 degree car-into-pole test with a 10 inch diameter stationary pole at 18 mph using the modified SID described above (Hybrid III head and neck mounted on the SID body). As far as the pole tests were concerned, BMW believes that moving the vehicle into the pole (as opposed to the moving the pole into the test vehicle) is a more realistic crash event and, therefore, should be used.

It can be observed from the HIC data recorded that the 18 mph car-into-pole test is the most severe of the 5 test configurations examined by BMW maximizing the effectiveness of the ITS system. M-B indicated that in order to assure low speed deployment, the system can be required to deploy in an FMVSS No. 301 side impact test and that the FMVSS No. 214 dynamic test would assure that the system does not degrade occupant protection. Volvo does not support the inclusion of full scale dynamic tests. Autoliv indicated that the effectiveness of HEADS in reducing head ejection in side or other impact modes, or in a subsequent collision, is probably best assessed in full scale crash tests such as FMVSS No. 214. They indicated that eventually HEADS could be evaluated simultaneously with frontal and side protective systems via FMVSS No. 208 and 214. They suggested, for example, that FMVSS No. 214 could be enhanced to include a higher barrier face to simulate high hood striker vehicles, or alternatively, a relevant pole test could be instituted as proposed in the ANPRM.

4. If the agency were to propose a lower impact speed for targets protected by a dynamic system, are there components of the dynamic system which are not protected by the system, but which could not meet the upper interior requirements at the current impact speed (15 mph)?

Responses: AAMA stated that the possibility of such a condition would be solely dependent upon the design of the system. BMW stated that AP1, AP2, AP3, SR1, SR2, BP1, BP2, and BP3 would not provide protection from 12 to 15 mph. These target points are shown in Illustrations 4 and 5 in the Appendix. In addition, BMW noted that SR3, which could be interpreted to be the upper side rail ITS anchor points, may not provide protection for the rear passenger from 12 to 15 mph when the ITS is deployed.

BMW concluded that a padding thickness of 1 inch can not be accommodated with the ITS system. Volvo believes that all targets not covered by HEADS should meet the requirements at the current speed of 15 mph. Under VW's proposal, the entire area covered by HEADS would be certified to meet the 15 mph head impact requirements using the FMH. Areas not covered by HEADS would continue to be tested at 15 mph using the FMH. Ford does not object to adjusting the interior head impact speed from 15 to 12 mph for vehicles that provide; (1) a lap-shoulder belt and (2) a side impact head or "head-and-chest" combination supplemental air bag for each front outboard occupant. However, Ford has significant concerns about the redundancy and burden of additional full-scale crash test requirements that would be implemented along with the proposed speed adjustment because it would provide no additional side impact safety benefits for its customers.

The FMVSS No. 201 upper interior head protection final rule was intended to provide head impact protection in frontal, side and rollover crashes. The benefits of each potential HEADS needs to be compared to the final rule. Excluding target points or reducing the impact speed of the FMH would reduce benefits for those targets in crashes which do not cause the HEADS to deploy. To help the agency understand the relative benefits of possible proposals and the benefit tradeoffs, NHTSA requested answers to the following questions:

5. What effect would reducing test speeds have on injuries in non-deployment crashes?

Responses: AAMA indicated that this is virtually impossible to estimate due to the many variables involved in real-world crash scenarios. BMW indicated that in non-deployment situations, the system always provides protection for head impact speeds up to 12 mph, thus potential injuries in a non-deployment crash would only concern head impact speeds between 12 and 15 mph. The BMW ITS system is designed to deploy at an FMVSS 214-equivalent moving barrier impact speed or delta-V of 15 mph, which translates into a lateral head velocity of approximately 6 mph. Similarly, ITS will also deploy in a rollover crash if the lateral delta-V is 15 mph. Volvo indicated that most padding materials useful for meeting FMVSS No. 201 have non-linear material characteristics (e.g., force-deflection characteristics). The padding material chosen must be adapted towards an optimum injury reducing performance at the maximum speed in 201, e.g. 15 mph. The material, therefore, may not be ideal for reducing injuries at lower speeds or for a range of speeds. Under the VW proposal, a reduced test speed (e.g., 12 mph) does not represent a concern because testing of the deployed HEADS would be conducted at 15 mph using the FMH and deployment of the "system" would be tested in a crash test environment such as side impact or rollover.

6. What is the effectiveness of each dynamic system in reducing fatalities and injuries? What percentage reduction in the various injury criteria (e.g., HIC) would result if these technologies were installed? Would this reduction vary by delta-V? If so, specify the relationship between delta-V and injury criteria reduction for the specific system.

Responses: AAMA indicated that the effectiveness would be design-specific and would likely be different for each system. BMW stated that given the test protocols discussed above, HIC reductions of up to 86 percent could be achieved with the ITS system. This was calculated for their 18 mph vehicle-into-pole test using the Hybrid III head/neck on the SID body. Although HIC was reduced, TTI(d) and pelvic g's increased by marginal amounts.

BMW's data from their comments (See Docket No. 92-28-N06-005, Attachment 2) demonstrated a range of ITS effectiveness based on HIC depending on the severity of the test procedure. For example, 30.58 percent for the FMVSS 214 crabbed MDB and EuroSID (presumably 30 mph), 71.7 percent for the EEVC MDB, 90 degrees impact with EuroSID (presumably 30 mph), 74.56 percent with a moving pole barrier (14 inch diameter) and EuroSID at 25 mph. A section of pole is mounted on the face of the EEVC barrier. The ITS had the highest effectiveness with the 18 mph vehicle-into-pole test. The FMVSS No. 208 (S5.2) lateral moving barrier crash test at 20 mph conducted by BMW employed a driver-side thoracic air bag and ITS system and no dynamic system protection for the rear passenger. For this test, BMW used the rear passenger response as the baseline (without ITS system) performance measure. The results showed extremely low HICs for both the driver and rear passenger positions and NHTSA questions the comparability of the HIC values for making ITS effectiveness calculations. VW has no test data to respond to this question. Autoliv also provided examples of IC effectiveness based on HIC from 30 km/h lateral pole tests: HIC was reduced from 4,010 to 450 (88.8 percent effective) at 33.4 psi inflation pressure and from 4,010 to 550 (86.3 percent effectiveness) at 36.4 psi inflation pressure.

7. Could the dynamic systems cause increases in neck injuries? If so, what data is available to quantify this impact? What criteria can be used to determine whether lateral neck motion is increasing or causing injury?

Responses: AAMA indicated that the effect of dynamic systems on neck injury is unknown but dynamic systems, that must add energy to the collision before they can help absorb crash energy, present an injury risk in some circumstances. BMW's test results for the ITS system indicate that no increase in neck injury is likely to result. In fact, overall neck injuries were significantly reduced. [

] [Bracketed blank space indicates confidential information removed.] Volvo stated that the problem with neck injuries must be carefully studied and further research on neck injury criteria is recommended. They indicated that a new side impact anthropomorphic dummy is desired for gathering more knowledge on neck injury mechanisms.

VW observed that the pocketing behavior, which is considered to be related to neck injury, should be minimized with an inflated, pressurized system as compared to deformable sheet metal or foam type countermeasures. Autoliv was concerned that neck injuries are difficult to assess as they can occur in frontal as well as side impacts. In addition, they were concerned that the lack of neck injury criteria make it a very difficult task to compare different systems and discuss trade-offs.

8. Some advanced technologies appear to offer potential reductions in the likelihood of ejection. What would the effectiveness of dynamic systems be in reducing ejection in side or other impact modes or in a subsequent collision?

Responses: BMW's ITS system deploys across the side window opening, is self-supporting (e.g., does not depend on the window glazing for structural support), and is non-vented (e.g., remains deployed for the full duration of the crash event rollover and or subsequent events). They claimed that ITS was 100 percent effective in preventing partial head ejection in lateral impacts with barrier equivalent delta-V of at least 15 mph and probably 30 percent effective in rollover ejection with a lateral delta-V of 15 mph. AAMA indicated that safety belts are still the most effective means of reducing the risk of ejection. The effectiveness of dynamic systems in reducing complete or partial ejection would best be determined through analysis of statistically-significant real-world crash databases that include vehicles fitted with dynamic systems. Volvo indicated that it appears as if HEADS may have the potential of reducing ejections in a number of crash modes and situations. This is, however, dependent on a number of factors, e.g., when during the crash event the system is deployed, how long it is in the activated stage, the shape of the system, etc.

VW believes that the probability of ejection from the vehicle could be reduced with the use of dynamically deployed systems which provide protection over a relatively large area of the vehicle interior.

9. The dynamic systems known to NHTSA will deploy and protect the near-side occupant in a side impact. Will the dynamic system for the far-side occupant deploy in a side impact or in rollovers to protect against possible rebound effects or subsequent collisions?

Responses: AAMA indicated that, generally, dynamic systems are designed for near-side occupants. It is not anticipated that a far-side dynamic system would be deployed in a near-side impact due to the minimal potential safety benefits when balanced against the risk of dual deployment. Whether or not a dynamic system deploys in a rollover depends on the sensor and/or the deployment algorithm utilized. BMW indicated that they had not completed their analysis and made a decision on the ITS deployment mode it will use on its first production vehicles (e.g., to deploy only the struck side ITS or both sides simultaneously). VW indicated that systems could certainly be designed and certified such that deployment in all areas of the vehicle could take place under lateral impact conditions and simulated rollover using test procedures specified in the standard. Autoliv believes that an enhancement of protective function will be possible when adequate sensors are available also for far-side occupants. They stated that a future feature can be expected to be protection against the rebound effects in frontal oblique collisions.

10. Do MY 1996 vehicles meet 12 mph test requirements? Do any MY 1996 vehicles meet 15 mph test requirements?

Responses: AAMA stated that their members are not aware of any 1996 models that perform at 12 mph. AAMA members are currently expending what limited resources are available in attempting to support the mandated FMVSS No. 201 phase-in and have not conducted testing at 12 mph. In its Upper Interior Head Protection, FMVSS No. 201, Petition for Reconsideration, IIHS claimed that many cars already meet the 15 mph requirement, but was not able to document their claim. BMW's 1996 vehicles were not designed to comply at 12 mph. They implied in their comments that they were in the process of conducting 12 mph tests. M-B has no experience with 12 mph impact speeds. Current M-B vehicles can not meet 15 mph at all the target points due to the high level of body structural integrity. Current VW models do not, in all cases, comply with the FMVSS No. 201 FMH 15 mph impact requirements.

11. Should an impact speed greater than 15 mph be used in FMH testing of the system in order to compensate for the loss of benefits because the system does not deploy in rollover and frontal crashes? If so, is 20 mph an appropriate speed?

Responses: AAMA members are not aware of any justification for 20 mph. Testing for compliance at 15 mph with advanced countermeasures has confirmed that the challenge to meet or exceed the requirements at 15 mph at all points is formidable. BMW believes the superior overall head protection provided by any system, including dynamically deployed padding systems, that would comply with their suggested pole test injury criteria would more than compensate for any "loss in benefits" because the system does not deploy in rollover and frontal crashes. M-B recommends that vehicles equipped with HEADS be tested to verify compliance according to FMVSS No. 201 with the FMH and test them only when fully deployed. Volvo believes that the HEADS requirements should be similar to other head injury mitigating measures - e.g., 15 mph impact speed should be used.

VW thinks that a higher test speed is not necessary or practical. Autoliv does not agree that a higher impact speed with HEADS deployed is necessary to compensate for a loss of static padding benefits as HEADS deployed will offer equal or greater benefits due to partial head ejection prevention potential, glazing contact prevention, and protection against intruding fixed objects.

12. Are there existing crash data analyses concerning head injuries as a function of crash modes and target components?

Responses: AAMA refers NHTSA to its own data (Table IV-15) of the report entitled "Final Economic Assessment, FMVSS No. 201, Upper Interior Head Protection, June 1995." BMW stated that one of the reasons they developed ITS was that their own crash research (German database) showed that head injuries were over represented in side impact crashes [e.g., side impacts comprise 21 percent of all crashes (single and multiple vehicle), but account for 36 percent of the severe injuries of which 70-85 percent are head injuries.] BMW also submitted data comparing near-side/far-side risk of injury for the head (70/85 percent), chest (55/30 percent) and pelvis (20/30 percent). M-B submitted data generated by NHTSA (e.g., estimates of fatalities caused by head injury, 2,457 (or 83 percent) of the 2,942 fatalities are caused by the occupants head impacting an area other than the front header.) They also submitted data showing that when the occupant is belted, the head injury occurs mostly from both rollover and side impact, instead of frontal impact, whereas with the unbelted occupant, the cause of an AIS 3+ injury will come from a frontal collision. However, a large percentage of these injuries result from a subsequent side impact and or rollover. No such analysis is available with regard to VW or Audi vehicles.

To allow NHTSA to become better acquainted with HEADS under development, the agency requested answers to the following miscellaneous questions:

13. Are dynamic systems compatible with the B-pillar mounted shoulder anchorage points? Are integrated restraint seats (IRS), which have shoulder belts anchorages attached to the upper seat back, more compatible with HEADS?

Responses: BMW stated that the ITS clears the B-pillar mounted shoulder belt anchorage. The ITS system will prevent the head from contacting the belt anchorage and D-ring assembly. AAMA indicated that dynamic systems can be designed to be compatible with belt anchorages attached to either the B-pillar or the seat back. M-B believes the problems of belt anchorages on the structure as well as integrated restraint seats are solvable. Volvo stated that covering D-rings and seat belt attachment hardware is, in general, difficult for these purposes. For HEADS, this conflict may, however, be less as compared to traditional measures such as padding. The Volkswagen contemplated system would be compatible with the current B-pillar mounted anchorages. Autoliv stated that ordinary seat belts with the B-pillar mounted shoulder anchorage point do not reduce the effectiveness of an advanced system , if it deploys from the upper area - e.g., from the roof rail area.

14. How much would the dynamic systems add to the price and weight of the vehicle?

Responses: AAMA stated that vehicle cost and weight are expected to increase and will vary by design. BMW stated that the price of their ITS system would be competitive and indicated that it would add 4 pounds to the vehicle weight. Autoliv indicated that the Inflatable Curtain weighs 2.2 lbs. per side. VW's HEADS, believed to be similar to the Inflatable Curtain. is only in the concept phase and as such cost and weight data are not available.

15. What are the performance criteria for the sensor system designs? What is the time interval necessary for full deployment of the dynamic system?

Responses: BMW stated that the ITS would deploy given a barrier equivalent lateral delta-V of 15 mph. The time interval for full deployment of the ITS is 30 msec. AAMA indicated that its members plan to perform vehicle testing of their dynamic systems to verify deployment in various types of impacts. The methodology used in determining performance conditions will be similar to that currently being used for frontal air bag systems. Although VW is at the concept phase of design, they stated the sensor design would be similar to that used for front impact air bag sensors, but the specific performance parameters, algorithms, and timing inturvals would have to be developed and established specifically for each system. Autoliv stated that the inflation time should have an upper limit to ensure that the advanced system is inflated in time to be effective. This time requirement should be vehicle specific. For the Inflatable Curtain inflation time is less than 25 ms.

16. If changes are made to the August 18, 1995 final rule (60 FR 43031), what is the anticipated time frame for introduction of dynamic systems? Are any dynamic systems being introduced prior to the requirements of the August 18, 1995 final rule?

Responses: BMW plans to offer the ITS system as standard equipment in the 700 Series by June 1997. Ford's might be available in MY 1998. (Based on News Release indicating calender year mid-1997.) Volvo plans to introduce the Side Curtain air bags in their 960 models in MY 1999. AAMA indicated that introduction dates will vary by manufacturer. AAMA members plan to introduce dynamic systems for supplemental head protection in side impacts which are compatible with the August 18, 1995, final rule regardless of NHTSA's action on amending the FMVSS No. 201 head impact test procedures. M-B expects to offer the HEADS system within a few model cars to meet the required phase-in schedule, but the FMVSS 201 test conditions must be modified first. VW anticipates a two year lead time once a decision has been made to proceed, but because of the structural design changes involved, system implementation would probably take place with new or redesigned model introductions. Autoliv has indicated that two years may be needed to market their Inflatable Curtain system. An August 26, 1996, Automotive News article reported that (1) Saab 9000 CD's successor will feature an Inflatable Curtain (without side air bags) developed by Autoliv AB of Sweden at the January 1997 Auto Shows and (2) M-B will feature Autoliv's Inflatable Curtain (with side air bags) in its small, A-class model at the March, 1997 Auto Show in Geneva. Volvo is planning to introduce "Side Curtain" air bags (similar to Autoliv's IC system) which work in conjunction with existing thorax air bags in their 960 models in 1999.

17. Will the systems be introduced as optional or standard equipment?

Responses: AAMA stated that availability will vary by manufacturer. BMW has indicated that the ITS system will be standard equipment in the 700 Series for MY 1998 and would be introduced in June 1997. BMW stated that the system may be standard on certain car lines and optional on others, at least during the early model years. For M-B it is not clear at this time whether HEADS will be optional or standard equipment. VW does not believe HEADS would be an optional piece of equipment. It would probably be standard on particular models.

C. NHTSA's Analysis of Comments

The commenters were very supportive of the ANPRM and recognized the potential benefits of HEADS. IIHS urged NHTSA to modify FMVSS No. 201 as they believe that HEADS has the potential of greater benefits when deployed and greater benefits in non-201 head contact modes. Several commenters misunderstood the ANPRM as they were opposed to any more mandatory full scale tests. AAMA, for example, indicated that they were against any new test procedures and that 201 and 214 were sufficient. Ford stated they were concerned about burdensome and redundant tests. The test procedures NHTSA proposed in the ANPRM were to be used at the manufacturer's option if their vehicles were equipped with HEADS. They were not intended to be mandated.

In general, the manufacturers preferred FMH tests at 12 mph with HEADS undeployed and 15 mph with HEADS deployed. No one suggested a FMH test speed greater than 15 mph with HEADS deployed. In the case of ITS, BMW and Autoliv indicated that a higher speed wasn't necessary to compensate for the loss of static padding benefits at 12 mph because this would be offset by the potential benefits in other crashes modes (e.g., partial head ejection and side glazing contact prevention as well as fixed object intrusion protection). Some of the manufacturers (Autoliv, M-B) acknowledged that a FMVSS No. 208 (frontal), FMVSS No. 214 (lateral), FMVSS No. 301 (fuel tank integrity) barrier used laterally as in FMVSS No. 208 or ISO #10997 (simulating a high hooded striker vehicle's front end) barrier tests possessed potential 201 upgrade possibilities. M-B, for example, supported the use of the FMVSS 301 or 214 barrier. AORC suggested further refinement of FMVSS 214 using a modified SID (combined with the Hybrid III head/neck). BMW indicated that they thought some combination of tests might be needed, but that they preferred the vehicle-to-pole test for their ITS system. No manufacturers, other than BMW and Autoliv, embraced the pole test. VW suggested that they would supplement their 15 mph HEADS deployed (only) test with a dynamic sensor test.

The manufacturers (AAMA, BMW, M-B, Volvo, and Autoliv) agreed that the head injury criterion for HEADS should be the same as that used for static padding -- namely HIC <=1000. BMW acknowledged that SR3 (contactable by the rear passenger) would not be protected from 12 to 15 mph with the ITS deployed. The manufacturers were not able to quantify the increase in injuries that would occur if the FMH impact speed for the undeployed HEADS target points was reduced from 15 to 12 mph. Based on the ITS system, BMW was able to quantify HEADS effectiveness in reducing HIC at 86 percent from a 30 km/h (18 mph) pole test using a modified SID (H-3 head/neck assembly). The pole was aligned with the outboard dummy head CG. For a sled pole test using EuroSID-1 at 32 mph and 17 mph, with the ITS between the head and the B-pillar, the effectiveness of ITS in reducing HIC was 70.5 and 61.4 percent, respectively. BMW believes their ITS system will be 100 percent effective in preventing partial head ejections and 30 percent effective in preventing full body ejection in rollovers. NHTSA modeled a NASS rollover ejection case using the MADYMO model of a 50th percentile dummy and an ITS-type system. Ejection was prevented from occurring. Also, NHTSA conducted two full-scale 208-type rollover test for a driver and passenger-side pre-inflated ITS system using a 1995 Ford Explorer. In one test, the test vehicle experienced 11 quarter turns and SID dummy ejection was prevented by the ITS system as the side window openings were partially blocked.

Ford announced its new "head-and-chest" side air bag that protects head and chest November 28, 1995. Based on computer simulations and several actual crash tests, Ford indicated in its press release "... with the combination air bag, the HIC value dropped to 482 from a fatal 4,159 in a vehicle without the head air bag during a 20 mph pole test." This is an 88.4 percent effectiveness based on HIC. The system consists of a large rectangular air bag stored in the seat back that deploys vertically between the occupant and the side interior of the car. It is the agency's understanding that deployment of the "head-and-chest" air bag may not require lowering target point impact speeds below 15 mph as requested by Volvo, Autoliv and BMW and others. Autoliv indicated that effectiveness levels of 86.3 to 88.8 percent may be possible with the Inflatable Curtain system based on 20 mph pole tests.

BMW does not believe that increases in neck injury are likely to occur with their particular systems. NHTSA examined the ITS performance data and agrees, that compared to the baseline case, neck loads and the neck moments decreased, except M(y). M(y) is the neck extension/ flexion moment and, although it increased, the change in magnitude was not of concern. The lateral neck moment (M(x)), which is of interest, decreased. All the ITS neck loads were below the accepted injury threshold of the BioSID. [

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[Brackets with blank space denotes confidential information deleted.] VW noted that pressurized inflatable systems may not have a tendency to "pocket" which is related to neck injury. Volvo stated that neck injury research was needed.

Regarding the overall performance of the ITS system, based on one 18 mph pole test, HIC was reduced from a 56 (86) percent probability of a fatality (HIC = 2,495) to a 0.03 (.002) percent probability of a fatality (HIC = 331), based on the lognormal (Mertz/Prasad) probability curves described in the 201 FEA. Chest g's and TTI(d) increased slightly which is acceptable as the HIC reduction far outweighs the chest g's increase.

Regarding ejection prevention potential of HEADS, the ITS system deploys across the side window opening, is self-supporting, and is non-vented (e.g., post-deployment time of 5 sec.). This implies that if the side window glass breaks, the ITS becomes a semi-rigid member blocking the head, and possibly the body, from extravehicular excursions throughout the crash sequence and subsequent crash events. The Ford system is vented and probably would not have ejection prevention capability. Regarding the simultaneous deployment of near-side and far-side HEADS, AAMA stated their belief that the benefits of such a configuration would be minimal. BMW indicated they were still working on the analysis of such a deployment scenario. Autoliv stated that such a deployment scenario depends on sensor technology. According to AAMA, none of their member's 1996 models comply with FMVSS No. 201 at 15 mph and none of BMW's 1996 models comply at 12 mph. M-B and VW can not meet 15 mph at all target points in their 1996 models. With regard to head injuries by crash mode and interior component, AAMA suggested that NHTSA consult its own Final Economic Assessment (FEA), FMVSS No. 201, Upper Interior Head Protection, June 1995. BMW and M-B provided injury proportions by crash mode and by far-side/near-side based on their German databases.

The manufacturers believe that HEADS can be designed not to interfere with the B-pillar shoulder belt anchorage points (BP2). The ITS system clears the B-pillar shoulder belt anchor. The Ford Head-and-Chest air bag appears to deploy right over top of the B-pillar anchor as does the IC system. Regarding the incremental weight and consumer cost of HEADS systems, BMW and Autoliv (IC) estimated weight at about 4 to 4.5 lbs., whereas consumer costs are unknown at this point for both systems. Full deployment time for the BMW system is estimated to be 30 ms and the Autoliv IC system at less than 25 ms. Volvo will use a system similar to Autoliv's. Autoliv mentioned that deployment time would be vehicle specific. The BMW ITS system is planned as standard equipment for their 700

Series models in MY 98, the Ford Head and Chest System is expected in mid-1997 or MY 1998 and Volvo plans to introduce their "Side Curtain" air bag system in their 960 models in 1999. The Autoliv IC system will be featured in the successor to the Saab 9000 CD at the January, 1997 Auto Shows and M-B will feature the IC system in their small A-class model at the March, 1997 Auto Show in Geneva. The manufacturers were not specific as to whether HEADS would be standard or optional equipment.

III. ISSUES

1. Warning Labels and Child Safety - For a 2-9 year old child seated on the passenger side next to ITS, the agency believes deployment would occur above their head, regardless of the seat track position. The top of a seated 6 year old child's head would be about 2 feet from the seat cushion. For a child standing or kneeling next to the side window (out-of-position), NHTSA is concerned about the potential for injury due to the deployment of ITS specifically, and HEADS in general. BMW indicated in their comments that the ITS deploys with a velocity of 6 mph. Although this deployment velocity may be benign, the relative or combined velocity of a child's head moving toward a deploying ITS in a lateral crash, or deploying HEADS, may be worthy of concern. Further, the agency is concerned about the combined affects of HEADS and thorax air bags on the properly seated and out-of-position child, the need for yellow or red Child Warning Labels in the proximity of HEADS and/or the need for a supplemental Out-of-Position Child Test using a 3 or 6 year old child dummy. The agency is seeking comments on whether Child Warning Labels and/or an Out-of-Position Child Dummy Test need to be regulated.

2. Noise/Ear Drum Pressure - As we understand it, the ITS is inflated from a gas generator, located in the instrument panel, but the deployment noise source of the ITS would be near the side of the head and the human ear drum. NHTSA is concerned about the deployment of HEADS in combination with other deploying air bags (e.g., frontal air bags and thorax bags) and the potential for increased occupant compartment air pressure and noise levels

beyond the safe human tolerance limits. This could occur in a crash with subsequent crash modes prior to window breakage. It is known that in an automobile crash the human sensory system automatically shuts-down as protection against pain. Assuming the auditory nerve shuts-down in a crash, there may not be an ear drum noise/pressure safety problem. On the other hand, the use of compressed gas inflation sources rather than pyrotechnic may diminish this problem. Alternatively, the occupant compartment of today's vehicles may be adequately vented to outside air pressure so that this is not a concern. Although NHTSA does not regulate compartment noise and/or air pressure for frontal air bags, the agency is seeking comments as to whether regulatory action is needed for HEADS equipped vehicles and/or multiple air bag equipped vehicles.

3. Occupant Compartment Space Effluent - Compressed gas may have low particulate matter, whereas pyrotechnic generated inflation gas may have a higher particulate matter. The agency is concerned that some predisposed asthmatic occupants may be at risk with multiple deploying vented air bag units (e.g., trigger or precipitate upper respiratory problems). Although NHTSA does not regulate effluent for frontal air bags, the agency is seeking comments on whether HEADS will be inflated by compressed gas or pyrotechnic gas and whether HEADS will be vented or non-vented systems.

4. Front HEADS vs. Rear HEADS Certification and Compliance Pole Tests - The agency is concerned about the cost of compliance tests and how to pole test a vehicle with HEADS in

all four outboard seating positions. Based on the subject NPRM, for example, to certify BMW's ITS system, two test vehicles would be required to be employed. One test vehicle would be used to test the 15 mph targets unaffected by HEADS and the 12 mph targets affected by HEADS, while a second identical test vehicle would be needed for the 18 mph pole test. This would essentially employ a combination of tests, namely Options #1 and #3 (See Chapter IV). For HEADS in the two front outboard designated seating positions, the agency is proposing one pole test under Option #3. For HEADS in the two front and two rear outboard designated seating positions, it would be ideal to employ a second pole test for the rear seat positions. At this point, unfortunately, certification cost would become an impediment as three identical test vehicles would be needed. In view of the above (multiple test vehicles and multiple test costs), the agency is proposing to require one pole test for HEADS in the high occupancy front outboard seating position. The assumption being that the rear passenger HEADS technology would probably be identical to the front passenger HEADS technology. In the case of ITS, the inflated tubular section would protect only the front occupants, whereas Volvo's Side Curtain air bag would protect both the front and rear passengers similar to Autoliv's Inflatable Curtain. If the vehicle was equipped with a rear HEADS system, such as the Volvo's Side Curtain, a rear dummy would not be required. It is believed the Ford Head-and-Chest air bag protects only the front passengers. Although the severity at the rear outboard seating position would be less than the front seat, a single pole test aligned with the front dummy head CG would test the rear HEADS crash sensors (if independent from the front) and deployment of the rear HEADS. NHTSA believes this responds to the issue of how to compliance test a vehicle with HEADS at all four designated outboard seating positions. For Option #3, under the NPRM, one cost savings idea if the vehicle is HEADS equipped, is for NHTSA to conduct the FMH tests on one side of the test vehicle and conduct the pole test on the other side of the same test vehicle. Safety Assurance staff are concerned that if HEADS failure occurs, enforcement action is compromised due to the removal of seats, etc., to do the FMH tests. Another cost savings idea for Option #2, under the NPRM, would be to conduct FMH tests at 12 mph on one side of the vehicle and 18 mph FMH tests on the opposite side of the vehicle. Commenters are requested to respond to this issue and other cost savings approaches. In addition, comments are requested as to whether an instrumented P572(M) rear dummy should be employed for the pole test for vehicles equipped with front and rear HEADS systems.

5. Inflation Time and Delayed Deflation Time (Vented vs Non-Vented HEADS design) - BMW and M-B suggested that their HEADS inflation times would be about 30 ms. This is the time from crash detection by the electronic sensors to full HEADS deployment. Several commenters (M-B and BMW) suggested that HEADS post-inflation time be regulated. This generally implies use of a non-vented air bag design and a closed gas pressurization system. For frontal air bags, venting is needed to provide energy absorption and occupant ride-down. BMW and Autoliv are planning HEADS with delayed deflation time to protect occupants in case of secondary head contact events. NHTSA believes that regulating post-inflation time for HEADS would be inappropriate as it would be design restrictive and would, essentially,

dictate HEADS design. NHTSA does not regulate front air bag post-inflation time. Commenters are asked to respond to this issue.

6. Pole-to-B-pillar Engagement - NHTSA examined the FMVSS No. 214 dummy seating procedure (e.g., mid-track dummy seating position) to see how close it came to conforming with one particular aspect of the draft ISO pole test procedure, namely - "...seat the dummy so that its head is sufficiently within the front window opening that the pole is unlikely to strike the A or B-pillar." For crash tests conducted between 1994 and 1996, the agency examined a sample (n=53, where 18 were 2 door and 35 were 4 door models) of FMVSS No. 214 pre-crash compliance test photographs to study driver head to B-pillar overlap. Some head to B-pillar overlap was visible for most 4-door models, including compact and large vehicles. For 6 of the 4-door models, there was a slight amount of clearance between the back of the head and the B-pillar. In contrast, for the 2-door passenger vehicles examined, there was visible clearance between the back of the dummy head and the B-pillar. Based on this sample, the agency would expect some overlap to occur for 4-door sport utility vehicles, vans and many pickup trucks. NHTSA has concluded that, based on the proposed 214 seating procedure to locate the head CG or pole target for the lateral pole test, the pole would engage the B-pillar for the vast majority of 4-door test vehicles. This aspect of NHTSA's proposed pole test procedure may not conform exactly with the draft ISO pole test procedure requirement discussed above (e.g., position the dummy so that the pole is unlikely to strike the A or B-pillar). Therefore, lateral pole tests where the dummy's head and the pole clear the B-pillar, may be more severe (based on HIC and intrusion), hence higher

HEADS effectiveness would be achieved, compared to those where the head overlaps the B-pillar and/or the pole engages the B-pillar, hence lower HEADS effectiveness would probably be achieved. Because engagement of the B-pillar changes intrusion levels, some models (2-door models) may experience more intrusion than others (4-door models). It should be noted that although intrusion is not a performance factor it could be a HEADS design factor.

In view of the above, the agency is proposing a modified FMVSS No. 214 dummy seating procedure to locate the head CG (hence pole target point) for the proposed pole test procedure with at least 2" (50 mm) of clearance (when viewed laterally) between the back of the dummy's head and the front edge of the B-pillar at the centerline height of the head CG. If the appropriate head clearance is not achieved, the pole test procedure would allow the seat back to be adjusted a maximum of 5 degrees to achieve at least 2" (50 mm) of head to B-pillar clearance at the centerline of the CG height. And, if the appropriate head clearance is still not achieved, the procedure would allow the seat to slide forward from the mid-track position until at least 2" (50 mm) of clearance exists between the back of the dummy's head and the B-pillar (at the head CG height) without creating significant interaction between the dummy's legs and knees and the interior of the vehicle. In addition, when examining the 53 photographs and viewing the vehicle laterally, the agency noticed some possibility of the vertical head to side rail contact potential and that sliding the seat forward could further exacerbate this situation. The agency seeks comments on the above proposed modified

FMVSS No. 214 seating procedure and any vertical and/or horizontal window opening and lateral head clearance problems.

7. SR3 Compliance for BMW's ITS System - BMW has developed an advanced lateral head protection device called the ITS (Inflatable Tubular Structure), which has great potential for reducing serious head injuries. It is estimated in Chapter V., Benefits, that 572 more fatalities and 880 more non-fatal injuries could be forestalled over and above the requirements of the FMVSS No. 201 final rule, if ITS systems were installed in all passenger car and light truck vehicles. However, BMW interior styling/aesthetics requirements may require the 15 mph performance of the rear ITS anchorage point (defined as SR3 per FMVSS 201's test procedure) to be compromised. SR3 is an upper interior head protection target point regulated by FMVSS No. 201, and for this design, would be located on the side rail near the head of the rear occupant. BMW petitioned NHTSA to allow 12 mph performance undeployed for regulated target points necessary for the HEADS system stowage/packaging (e.g., AP1, AP2, AP3, SR1, SR2, BP1, BP2 and BP3). The three dimensional geometry of the ITS when deployed would appear to protect the occupant's head from contacting these same target points. However, SR3 is not protected when the ITS system is deployed. Under NHTSA's proposal, target point performance such as SR3 which is compromised due to the storage of the undeployed inflatable device (including attachment points and inflation mechanisms), would be exempted from the 15 mph requirements. BP4 is unaffected by the ITS system.

When inflated, ITS consists of a cylindrical air bag (5 to 6 inches in diameter and 4-5 feet in length) and is anchored at two points; one end is low on the A-pillar near the instrument panel (IP) and at the other end is high on the side rail behind the B-pillar. (See Illustrations 1 & 2., may not be to scale) The lower anchorage of the ITS is below AP3 on the A-pillar, near the intersection of the instrument panel, where front head contact would be impossible due to the geometry considerations.

In their docket comments (92-28-N06-005) in response to the March 7, 1996 ANPRM, BMW noted that the rear ITS anchorage, which is the same as SR3 for purpose of FMVSS 201 certification/compliance testing, may not provide protection for the rear outboard passenger from 12 to 15 mph with the ITS deployed. As stated in their comments "...BMW concedes that with respect to the single point SR3 for the rear occupant, the ITS system does not provide protection between 12 and 15 mph, but, in the aggregate, ITS provides superior head protection to that required by the Amendment." For 15 mph head protection at least 1.0 to 1.5 inches of static padding are needed, and unfortunately, the ITS can not deploy through more than 1 inch of padding and still meet packaging and performance requirements. NHTSA is proposing that under test procedure Options #2 and #3 (See Chapter IV. C. NPRM Test Procedure Options), the performance of target points under which the HEADS system is packaged or stowed with HEADS undeployed (including attachment points and inflation mechanisms) would be reduced to 12 mph. Under the proposed test procedures (Option #2 and #3), comments are requested on other objective criteria, in addition to or instead of, those discussed above which could be used to justify reducing target point performance from 15 to 12 mph.

Arguments for Granting an Exemption for SR3

1.) The rear passenger is a very small target population, hence any loss in benefits from reducing the performance of SR3 would be very small. The head injury target population for the head striking the rear side rail for passenger cars and light trucks is shown in Table V-17, Chapter V, Benefits. If it is assumed that one tenth (1/10) of all side rail head impacts occur at the SR3 target point, (an arbitrary, but not unreasonable assumption), the SR3 target population would be about 17 fatal injuries and 230 non-fatal injuries. The number of fatal and non-fatal head injuries would be expected to be higher because head protection is compromised from 12-15 mph at SR3. However, the incremental increase would be very small (about 3 fatalities would be given up), assuming that all (100 %) passenger cars and light trucks/vans had the ITS system. Initially, the ITS system would be offered as an option on a few selected vehicles. Since Simula plans to license the ITS system to others at some point in the future, its popularity as a safety countermeasure may grow and many more vehicles could be affected down-stream at the SR3 target point. It is impossible at this time to know the actual number of vehicles affected. If all passenger cars and light trucks were equipped with the ITS system, the aggregated loss of benefits at SR3 would be more than off-set, by many fold (See Table V-18, Chapter V, Benefits), by the benefits accrued at the higher certification speed (an 18 mph lateral pole impact test) for the other ITS protected target points. ITS intrusion protection benefits and partial/full ejection prevention benefits, not quantified in the subject analysis, would also contribute to the net benefits gained at 18 mph.

2.) To achieve 15 mph static padding protection at SR3 may require BMW to create a lump, bulge, or interior discontinuity, consisting of extra thick padding, along the interior side rail wall. This may render the vehicle unmarketable in their eyes, hence BMW management could decide to withdraw the ITS from production consideration. This results in a lost opportunity, for if ITS is not mass produced, the real-world benefits can not be realized or measured.

Argument for not Granting an Exemption for SR3

Safety innovation in lateral and frontal head protection is to be encouraged, but without dismantling or compromising an existing standard or standards. The granting of an exemption, which could result in lower safety stringency, is a poor precedent to set for the long term. Simula, developer of the ITS system for BMW, plans to license the ITS to other manufacturers in the future. Therefore, other manufacturers will probably be seeking the same, or additional, 201 target point exemptions for their HEADS system. Further, if NHTSA will accommodate a reduction in stringency on this standard, the agency may be called on in the future to reduce the stringency of other standards as well (e.g., FMVSS No. 208).

The NPRM process will help NHTSA gather further information from BMW, and other manufacturers, on target points essential to HEADS system operation, but which may never exceed 12 mph protection level with HEADS undeployed or deployed. Based on this information, the agency can determine if exempting targets will be the exception or the rule, as well as, understand the negative consequences of requiring compliance where exemptions are desired. Should NHTSA exempt target points from the requirements of FMVSS No. 201, Upper Interior Head Protection, in order to accommodate head-impact energy absorbing dynamic systems (HEADS) for BMW, in particular, and other manufacturers, in general, for reasons other than packaging/stowage or essential to mechanical operation or inflation of the HEADS system?

NHTSA has tentatively decided to exempt SR3 (that is, permit 12 mph performance with HEADS undeployed) for BMW's ITS system for purposes of the subject NPRM because the hardware at SR3 is essential to the operation of the HEADS system. However, SR3 will not provide more than 12 mph lateral head protection for a rear passenger with the ITS deployed. The agency believes that the 3 fatalities per year that would be given up (if all vehicles were equipped with the ITS system and SR3 was exempted from 15 mph performance) is acceptable as the loss is more than off-set by the gain of an 18 mph dynamic performance system. Safety innovation would not be inhibited and vehicle marketability would not be impeded due to interior styling or interior aesthetics degradation potentially caused by thicker 15 mph padding.

IV. ALTERNATIVE TEST PROCEDURES

In the ANPRM, the agency proposed three options for testing the performance of HEADS or dynamically deployed air bags and other inflatable devices:

Proposed Approaches

A. - For dynamically deployed padding: For the targets protected by dynamically deployed padding (or trim), impact the targets with the FMH at 12 mph prior to deployment of the padding. Impact these same points again at 20 mph after the deployment of the padding. Conduct crash tests at 15-20 mph to ensure that sensors activate the deployment of the padding.

B. - For dynamically deployed air bags or other inflatable devices: For the upper interior targets protected by an air bag or other inflatable device, impact the targets with the FMH at 12 mph, prior to the deployment of HEADS. All other targets are tested at 15 mph with the FMH. Conduct an 18 mph side impact crash test into a fixed, rigid pole of 10 inches in diameter. This test would be representative of the real-world lateral impact where the head makes contact with a fixed object such as a pole or tree.

C. - For dynamically deployed air bags or other inflatable devices: For the targets protected by an air bag or other inflatable device, impact the targets with the FMH at 12 mph, prior to deployment of HEADS. All other targets are tested at 15 mph using the FMH.

Conduct a 30 mph side impact test using the ISO #10997 MDB fitted with a rigid contact face. This test would be representative of a real-world lateral impact from a high hooded vehicle (e.g., a pickup truck) in which the head makes contact with the front end of the striking vehicle.

Discussion

The test procedure options that NHTSA has developed for the NPRM are based on (1) information provided by the manufacturers on prototype HEADS system designs or design concepts (e.g., Ford's Head-and-Chest Air Bag, BMW's Inflatable Tubular Structure, Autoliv's Inflatable Curtain and the design concept for linear Inflatable Trim), (2) the severity level of the test procedure, and (3) practicability considerations. Illustration 6 in the Appendix shows an artist's sketch of the Inflatable Trim concept.

OPTION #1

Theoretically, it's possible for a HEADS system to deploy vertically from the seat back or side inner door panel in such a way that it would not disturb the 15 mph performance of the static padding minimally required by FMVSS No. 201 at the HEADS protected target points. Therefore, one option the manufacturers would have is meeting the 15 mph FMH requirements with HEADS undeployed.

(NOTE: Options #1, #2 and #3 being discussed in this section should not be confused with Options A, B and C in the ANPRM.)

OPTION #2

This option is designed to accommodate the dynamic padding concept, as well as inflatable devices, in which the static padding performance might be degraded to 12 mph at HEADS protected targets with HEADS undeployed. Testing would be done in the laboratory with the FMH. Based on geometry considerations, it is believed that the head of a seated 50th percentile dummy in a flat/planar, lateral dynamic crash test would probably not strike the inflatable or deployable trim. Thus, the testing would be done with the FMH. For target points "covered" by dynamically deployed trim, manufacturers test the targets with the FMH at 12 mph, prior to deployment of the HEADS system, and test at "any" one of the "covered" target points with the FMH at 18 mph when the HEADS system is fully deployed. "Covered" means when viewed from any of the angles specified in S8.13.4 over the stowed system, including mounting and inflation components, but exclusive of any cover or covers. The 18 mph FMH test speed is consistent with the lateral pole impact speed of 18 mph being proposed and discussed below.

Inflatable HEADS systems similar to Autoliv's ITS or IC system or Ford's Head and Chest Air bag can also be certified under Option #2. Therefore, NHTSA is proposing the same criteria as discussed earlier in Issue 7, SR3 Compliance for BMW's ITS System, for determining if target point performance can be degraded to 12 mph (HEADS undeployed), namely; when viewed from any of the angles specified in S8.13.4 over the stowed system, including mounting and inflation components, but exclusive of any cover or covers. The purpose of excluding any cover or covers is to ensure that the side rail trim cover or door is designed to be as congruent as possible with the stowed inflatable air bag system.

In addition, under Option #2, NHTSA is proposing to require the manufacturer's to conduct a HEADS Crash Sensor Test based on the lateral impact requirements of FMVSS No. 214, Side Impact Protection. The HEADS Crash Sensor Test would be conducted simultaneously with the manufacturer's normal 214 dynamic test and would require the dynamic padding to deploy in at least 30 ms from the time of initial MDB impact. The maximum deployment time proposed is consistent with comments concerning existing HEADS systems such as Autoliv's Inflatable Tubular System (ITS) and the Inflatable Curtain (IC). BMW and Mercedes-Benz (Docket No. 92-28-N06-005 and 007, respectively) indicated their systems deployed in 30 ms. Volvo's "Side Curtain" developed by Autoliv deploys downward in 25 ms in a side impact (Ward's Engine and Vehicle Technology Update, November 15, 1996.) Comments are solicited regarding the proposed HEADS system deployment time for Option #2. NHTSA estimates that the delta V of FMVSS 214 in the range of 12-15 mph.

It should be noted that deployable trim or inflatable trim is a design concept and there may be unforeseen test procedure problems such as horizontal or vertical approach angle limitations, or target location problems, which may require future amendments to the rule. For example, unless the FMH is aligned correctly with the inflated, ballooned material and its supporting substrate, the inflated trim could roll and collapse, resulting in a glancing impact (e.g., low HIC). In theory, the FMH targets points would be established before the

HEADS system (or dynamic padding) is deployed and FMH horizontal and vertical approach angles would be set-up at the "covered" target point prior to HEADS system deployment.

The February, 1993 NPRM, and development of the FMH test procedure, employed speeds of 15 and 20 mph. In addition, the HIC transformation formulas were developed using 15 and 20 mph, short duration impact pulse. Although NHTSA does not anticipate any problems with FMH tests of 18 mph as specified in Option #2, a longer duration head impact pulse (such as might be encountered in FMH impacts with targets points on inflated surfaces) may require a modified HIC transformation formula.

OPTION #3

NHTSA is considering a third test procedure option, namely - the adoption of the draft 18 mph, 90 degree ISO lateral pole crash test procedure referenced above (ISO/TC 22/SC 10/WG 3, February, 9, 1995) in combination with 12 mph FMH impact tests, prior to HEADS deployment. A 10 inch diameter rigid pole would be required. The SID dummy seating procedure and other aspects of the 214 dynamic side impact protection test procedure would also be adopted, as appropriate, for use with the ISO pole test. Modifications to the 214 dummy seating procedure may be necessary. A modified SID called SIDH3 will be employed (e.g., Hybrid III head/neck sub-assembly on the SID body). With the pole centerline targeted at the front outboard passenger head CG, the agency believes this is a very severe test as HIC values are very high (fatal probability levels) and intrusion is very high, but similar to the real-world crashes with fixed pole objects like a telephone pole or a tree.

NHTSA is proposing the 18 mph lateral pole impact speed as this is consistent with the pole test drafted by the ISO working group (the February 9, 1995 document referenced above). Therefore, NHTSA's proposal supports harmonization. In addition, it is known that Autoliv has developed their ITS and IC systems to perform at the 18 mph pole impact speed and a 10 inch diameter pole. Although Ford used a 20 mph lateral pole test, the pole diameter is unknown. The commenters also argued that because HEADS provides protection in other crash modes (e.g., intrusion, window ejection, etc.) raising the impact speed above 15 mph was not necessary. However, no commenters computed what the compensating benefits would be from other crash modes.

NHTSA examined the target populations for ejection and intrusion/pole impacts (See Chapter V, Benefits). The target population for these groups is roughly equal to the benefits lost by reducing test speeds from 15 to 12 mph. Therefore, the effectiveness of Autoliv's ITS system, for example, would have to be nearly 100 percent against fatalities in order to off-set the benefits lost from a 12 mph test requirement. (ITS and IC systems are about 86 percent effective against HIC, not necessarily fatalities.) There is no realistic expectation that the level of 100 percent effectiveness could ever be reached. Therefore, it is appropriate to increase test speed for deployed systems to ensure that the benefits lost by a 12 mph undeployed test will be off-set.

NHTSA is proposing the same criteria as discussed in Option #2 above, for determining if target point performance can be degraded to 12 mph (HEADS undeployed), namely; a 12 mph FMH impact would be permitted in the undeployed mode for points directly over an undeployed dynamic system (including attachment and inflation mechanism), exclusive of any cover or covers. When the HEADS system is deployed, an 18 mph pole impact test is required. Under Option #3, comments are solicited regarding additional methods to objectively define which target points would be "covered" by the HEADS system and which would not.

A. Prior Pole Test Experience

Table IV-1 shows HIC responses of the various moving barrier test procedures considered by the agency compared to the pole tests. Table IV-1 shows that of all the crash tests considered, the highest HIC values were achieved with an 90 degree, 18-20 mph pole tests, where the pole was aimed directly at the head CG. Table IV-2 shows examples of lateral pole intrusion levels measured by NHTSA in various side impact full scale pole crash test programs (e.g., 4 VW Rabbit tests, 2 fuel tank integrity tests for LTVs and 2 Federal Outdoor Impact Laboratory (FOIL) baseline Ford Taurus tests). Table IV-2 also shows that the HIC is most significantly influenced by direct head-to-pole contact, whereas, in the 90 degree fuel tank integrity pole tests (striking behind the cab) and the baseline FOIL Ford Taurus test (striking between the steering wheel and dummy chest) without head-to-pole contact had little, if any, effect on HIC.

Table IV-1
Full Scale Lateral Crash Test Data

Test Vehicle	Type of Test Procedure	HIC
BMW Model X	FMVSS 208 Lateral Barrier Test using the FMVSS 301 4,000 lbs. Barrier @ 20 Mph (Hybrid III used laterally), High Barrier Face (60" X 78").	38 driver (Front) 135 pass. (Rear)
BMW Model X	EEVC Moving Barrier @ 90 Degrees, Assume 30 Mph, 2,095 lbs., EuroSID-1, Low Barrier Face.	378
BMW Model X	FMVSS 214 MDB @ 27 Degrees Crabbed, 33 mph, 3,000 lbs, EuroSID 1, Low Barrier Face.	425
BMW Model X	Moving Pole into Vehicle @ 25 mph, 14 in. diam. Pole mounted to a 5,400 lbs. moving barrier incl. pole section, EuroSID-1, Head CG was pole Target Point.	1,867
BMW Model X	Moving Vehicle into Pole Test @ 18 mph, SID with Hybrid III Head/Neck Asm., Head CG was Pole Target Point. 16 in. of intrusion.	2,495
Ford Unk Model	Ford Pole Test @ 20 mph, probably ISO pole test. Intrusion unknown. Head-to-pole contact.	4,159
Unknown	Autoliv's Inflatable Curtain. 20 mph pole test. 250-350 mm pole diameter. Head-to-pole contact. Intrusion unknown.	4,010

References: BMW of North America, Inc. Docket No. 92-28-NO6-005, a 7/18/96 briefing of NHTSA Staff by BMW, a Ford News Release dated November 27, 1995, and a Washington Post article 11/29/95 about Ford's announcement. Autoliv GmbH correspondence by FAX 9/06/96. BMW's 12/12/96 FAX from Mr. Karl-Heinz Ziwica granted permission to release confidential information for publication pertaining to: (1) MGA pole test vehicle conveyance means (Figure IV-7) and (2) the above data from the 208 lateral impact test.

Table IV-2

Summary of Baseline Full Scale Vehicle-to-Pole Crash Tests Conducted by NHTSA

Test No.	Test Vehicle MMY & Wt.	Impact Speed/ Impact Direct	Impact Point	Restrained	HIC	TTI(d)	Pelvic g's	Lateral Intrusion
#755	81 VW Rabbit 2,580 #	20mph 45 deg.	34.5"	FSID-06 None RSID-U02 None	977 © 151	41.5 20.0	68.9 17.2	18" @ H-pt. 18.5" @ Mid-dr.
#749	81 VW Rabbit 2,595#	20mph 45 deg.	26.5"	FSID-06 None RSID-U02 None	2945 © 235	62.5 29.3	127 38.4	22.7" @ H-pt. 23.2" @ Mid-dr.
#762	81 VW Rabbit 2,594#	25mph 45 deg.	6.5"	FSID-06 None RSID-U02 None	231 (GZ) 553	83 49	68.2 154	18.4" @ H-pt. 19.3" @ Mid-dr.
#768	77 VW Rabbit (Modif) 2,615#	25mph 45 deg.	9.0"	FSID-06 None RSID-U02 None	152.3 (GZ) 513	65 42	55.4 56.7	16.7" @ H-pt. 17.3" @ Mid-dr.
TRC 930322	86 Ford F-150 4,137 #	20mph 90 deg.	-9.5"	SID-903 3 pt.belt	368 (NC)	7.8-10	14.7	22" @ H-pt. 22.3" @ mid-dr.
TRC 930316	86Chev C-10 4,365#	20mph 90 deg.	-6.9"	SID-903 3 pt.belt	120 (NC)	15.5	12.3	16.9" @ H-pt. 16.4" @ Mid-dr.
FOIL 95S008	90 Ford Taurus 3,494#	21mph 90 deg.	46"	SID-904 Driver Belted	387 (GZ)	----	19.5	21.6" @ H-pt. 22.2 @ mid-dr.
FOIL 95S014	90 Ford Taurus 3,606#	21mph 90 deg.	46"	SID-904 Driver Belted	184 (GZ)	49.3	99	22.6" @ H-pt. 22.8" @ mid-dr.

C = head/pole contact occurred, GZ = head grazed pole, NC = No head/pole contact

Another observation is that the 45 degree angled pole tests appears to be about as severe as the 90 degree pole test based on HIC (with head contact) and intrusion. Maximum HIC and intrusion for the two data sets was 2,945 (1981 VW #749) vs. 2,495 (BMW Model X), respectively, and intrusion was 22.7" to 23.2" vs. 16.0", respectively. For the Ford and Autoliv 20 mph pole tests, HIC exceeded 4,000 (intrusion is unknown). The agency believes these tests were conducted in accordance with a pole test procedure similar to the ISO pole test and that head-to-pole contact occurred. NHTSA prefers the 90 degree pole test because it would be more repeatable/reproducible compared to an oblique pole impact test. However, crash data show that oblique pole impacts in the 30-60 degree range are dominant in the real-world. For a HEADS system to protect at this crash severity level significant benefits and safety improvements overall will be derived. With regard to the pole test procedure, there is concern about HIC sensitivity to; (1) pole centerline and head CG mis-alignment and (2) the confounding influences of test vehicle roll, pitch and yaw.

The agency does not have sufficient pole crash data at this time to answer the HIC variability question. At this point in time, the agency does not have a pole crash test standard, however, the subject NPRM would ultimately culminate in an FMVSS standard if a final rule were to be promulgated. The agency has had a number of full-scale pole crash tests conducted for research purposes, as described above, at TRC of Ohio and the Federal Outdoor Impact Laboratory (FOIL).

The agency has not conducted any pole tests in which direct head CG contact with the pole occurred. The primary full scale crash data available to NHTSA, showing the magnitude of HIC and feasibility of the head-to-pole impact approach, are the BMW, Ford and Autoliv pole tests contained in Table IV-1.

B. Pole Test Descriptions

NHTSA has had a limited amount of experience with conducting pole tests and has had no experience with the conduct of head-to-pole tests. Referring to Table IV-2, the 1977 VW Rabbit hatchback (Test No. 768) was modified with side impact countermeasures. It was structurally modified to a level designated as "optimized' and included thorax padding. In the VW Rabbit hatchback test series the driver's side, or left side, of the test vehicles were towed into a fixed pole (12 in. diameter) at a crabbed angle of 45 degrees. The front dummy was SID-06 and the rear dummy was SID-U02, and both utilized the Hybrid II head/neck sub-assembly. The front wheels were crabbed or angled at 45 degrees and a specially designed separate rear axle, with 45 degree canted rear wheels, was installed so that the entire vehicle could roll at a crabbed angle of 45 degrees. The agency considers the crabbed pole test to be a very severe test condition. The injury criteria that apply to Table IV-2 are HIC <= 1,000, TTI(d) <= 90 g's and pelvic g's <=130. For the high HIC cases (#755 and #749), the driver dummy's head hit the pole (probably an oblique head impact) and for the low HIC cases (#762 and #768), the driver dummy's head grazed the pole. The pole impact point is given in terms of inches forward from the wheelbase centerline. For Test Nos. 755 and 749, the force on the pole were 21,806 and 23,790 lbs.,

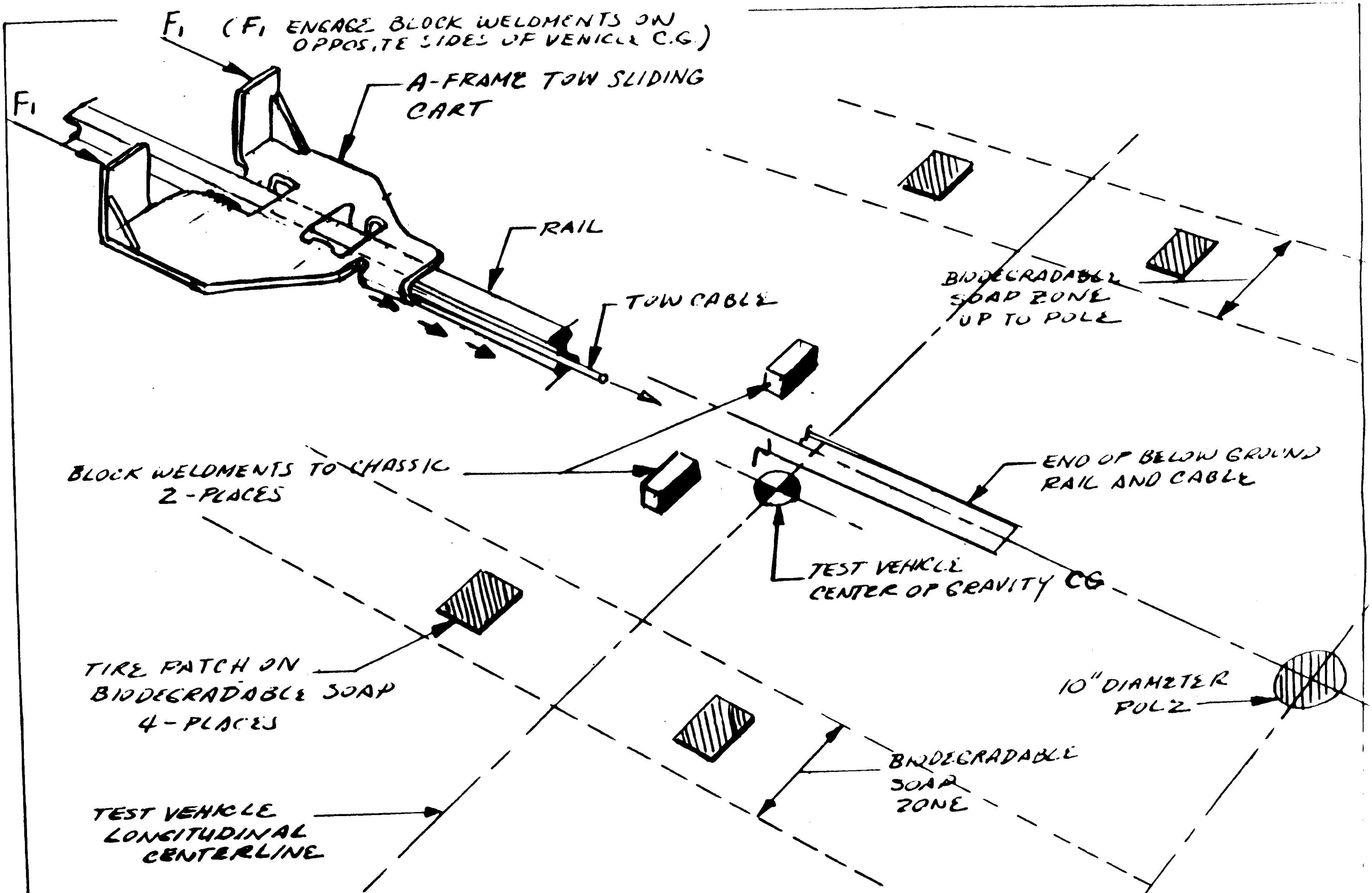

Figure IV-1

TRC FUEL TANK INTEGRITY POLE TEST SET-UP respectively, while for Test Nos. 762 and 768, the crash forces on the pole were 43,379 lbs. and 46,401 lbs., respectively. The VW Rabbit test vehicles were unconstrained at the point of impact. For the fuel tank integrity test series, TRC #930322 and #930316, a 12 inch diameter pole was used and the FMVSS No. 214 seating procedure was employed to position the driver dummy. For these tests, the negative quantity under Impact Point implies that the pole was aligned rearward of the wheelbase centerline. (Note: FMVSS No. 214 requires that the front, upper left-hand corner of the MDB impact the test vehicle at a point 37 inches (nominally) forward of the wheelbase centerline.) For the fuel tank integrity series, the pole impacted right behind the cab of each pickup truck, into the cargo area, and did not intrude into the occupant compartment, hence the very, very low dummy responses. The conveyance means consisted of a cart that slid on that Tow Cable and Rail Guidance System and was connected to the tow cable. The sliding cart pushed the test vehicle down the track. The test vehicle slid laterally on its tires down the track using soap and water as a lubricating medium to reduce friction. The TRC test set-up is shown in Figure IV-1.

Two 1990 Ford Taurus baseline lateral 90 degree pole crash tests were conducted at the Federal Outdoor Impact Laboratory (FOIL) using a Monorail (with Outrigger) System to deliver the test vehicle to the pole. (See Figures IV-2, IV-3 and IV-4) The test vehicle CG was nearest the monorail and the outrigger was used to control test vehicle roll and yaw down the track. The steel track was above the ground. The purpose of the tests was to support development of a finite element model (FEM) of a passenger car-into- pole impact . For both vehicles, the 8.80 in. diameter pole impacted on the driver's side mid-way between

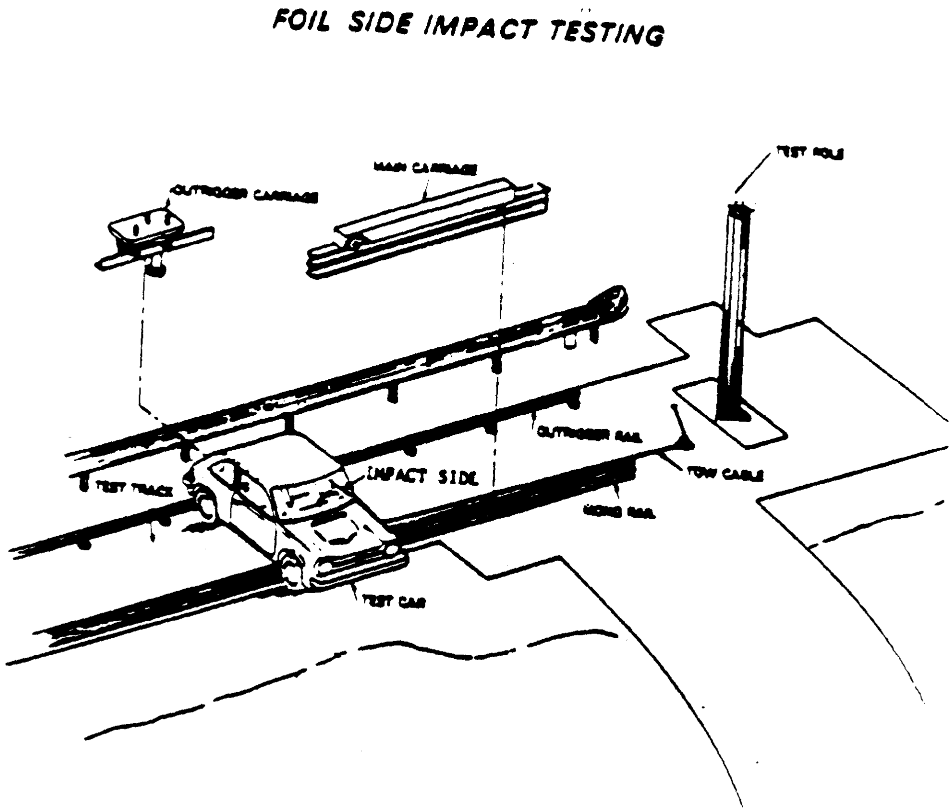

Figure IV-2 FOIL side impact layout.

SOURCE: SIDE IMPACT CRASH TESTING OF ROADSIDE STRUCTURES, FHWA-RD-92-079, MAY 1993, TURNER-FAIRBANK HIGHWAY RESEARCH CENTER, FHWA.

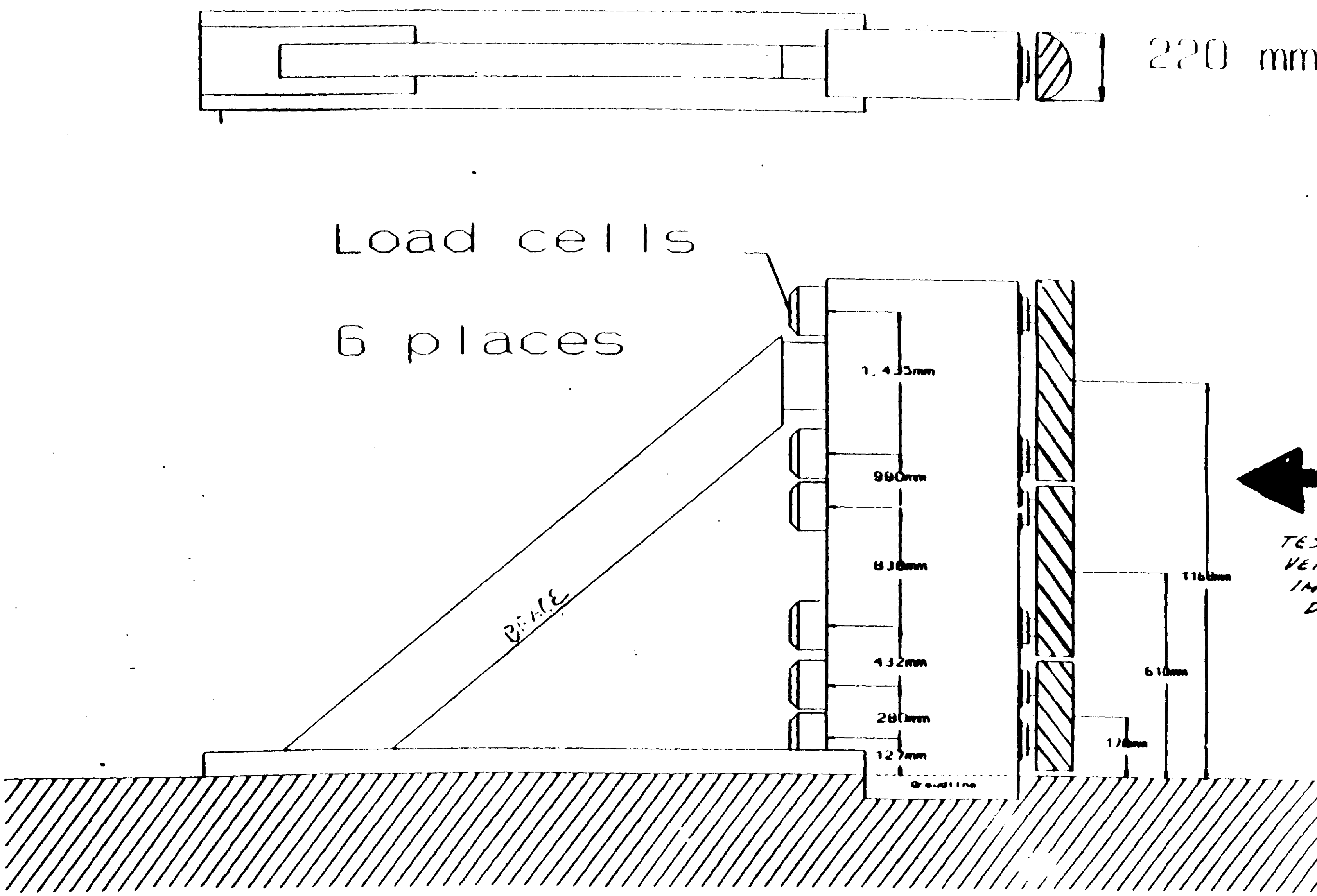

Figure IV-3 **FOIL instrumented rigid pole, side impact configuration.**

SOURCE - FORD TAURUS BROADSIDE COLLISION WITH A NARROW FIXED OBJECT, FOIL TEST No 955008 AUGUST 1996

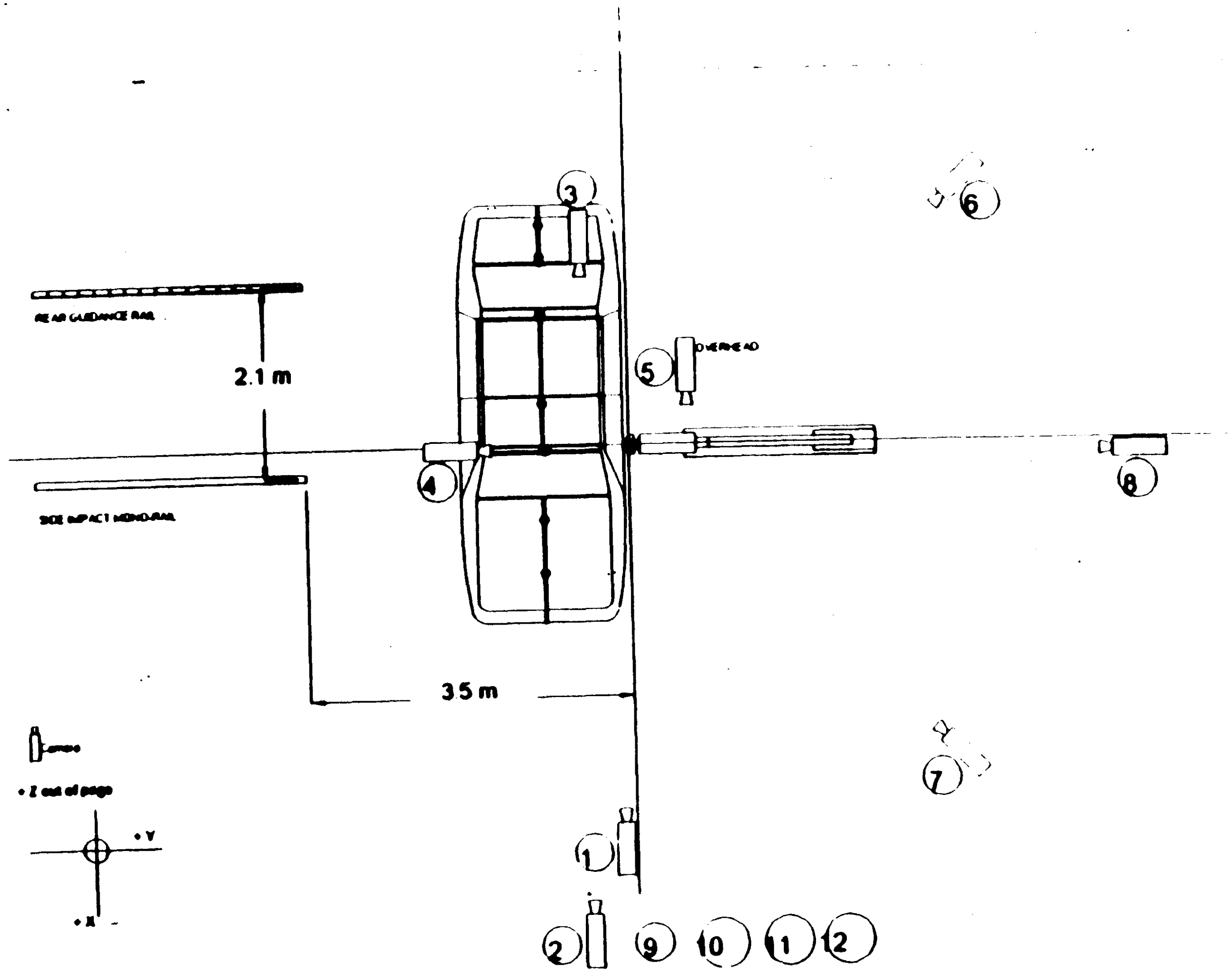

Figure IV-4

TOP VIEW - FOIL LATERAL POLE TEST SET-UP

SOURCE: FORD TAURUS BROADSIDE COLLISION WITH A NARROW FIXED OBJECT, FOIL TEST No. 95S014, SEPTEMBER, 1996.

the steering wheel and the chest of the SID dummy (at approximately 46 inches rearward from the front axle centerline) along the femur, but away from directly contacting the pelvis and thorax. The SIDs were seated in accordance with FMVSS No. 214. The side impact carriage consisted of a 4 in. square aluminum box weldment with two spool shaped wheels on a monorail (single rail) nearest the test vehicle's CG and an outrigger dolly on a second rail for stability. The monorail carriage weighed 19.8 lbs. and remained bolted to the test vehicle's undercarriage throughout the crash event. The rail system terminated 11.48 feet in front of the pole and both test vehicles slid on their tires into the pole. One test vehicle (95S008) rolled and yawed slightly (4 degrees and 1 degree, respectively) when released from the monorail and it appeared as though the front test dummy slightly pre-loaded the driver's side door as the pole was struck. The amount of roll in the second Taurus test is unknown. In FOIL Test No. 95S008, the dummy forehead glanced the pole and the loss of the lumbar spine (T12) response negated the calculation of TTI(d). However, left upper rib (LUR) and left lower rib (LLR) responses were 52.9 g's and 61.9 g's, respectively. In FOIL Test No. 95S014, SID-904 was modified to include the Hybrid III head and neck. The rear third of the dummy's head struck the B-pillar during the crash.

As the pole did not directly contact the dummy head or thorax, in either Taurus test, overall dummy head responses were low, TTI(d) or rib g's were low, but intrusion was high at 22.2-22.6 inches. In both pole tests, all doors remained closed and the frontal air bags did not deploy. Based on 1988-1995 NASS/CDS data shown in Table IV-3 for side impact crashes, fatal and serious head injuries are under represented in vehicle-to-vehicle crashes (as simulated by an MDB-to-car test) but are over represented in vehicle-to-pole crashes (as simulated by a vehicle-to-pole test). The agency is proposing an 18 mph, 90 degree lateral pole test using a 10 inch diameter pole because the severity level as indicated by HIC and intrusion measures exceeds the other 30 mph barrier tests studied. The pole test procedure was developed by the International Standards Organization (ISO) and international harmonization is a near-term goal of the agency. Direct lateral dummy head CG contact with the pole is necessary to maximize HIC. By maximizing HIC, highly effective and efficient HEADS countermeasures would be required and result in significant safety improvements in the real-world.

The third test procedure approach proposed by NHTSA in the ANPRM has been dropped from consideration. A 30 mph lateral impact using the ISO MDB #10997 (2,420 kg.) with a 50 in. high minimum flat barrier face simulating a high hooded LTV-type striking vehicle was proposed. The idea was for head contact with the flat, vertical barrier face to produce high HICs if not protected by HEADS. Based on test data submitted by BMW, the agency has concluded that this would be a low severity, benign test as baseline HICs would be too low for a HEADS countermeasure to make much difference. This, theoretically, would allow the installation of ineffective or low performance HEADS systems. The data supporting this are shown in Table IV-1. The BMW FMVSS No. 208 (S5.2) 90 degree, lateral moving barrier crash test at 20 mph using the FMVSS No. 301 flat faced (60" X 78" @ 5" above the ground) mobile barrier produced a driver HIC of 38 and a passenger HIC of 135 at a lateral kinetic energy level of 53,432 ft-lbs. kinetic energy was calculated using the formula KE $= \frac{1}{2} mv^2$. The ISO MDB #10997 at 30 mph would produce about 72,149 ft-lbs of lateral kinetic energy or 35 percent more energy. HIC is a function of the amount of kinetic energy. Although HICs would increase, it is believed they would not increase significantly from 38 to the range of 40-60 for the driver and from 135 to a range of 150-200 for the rear passenger. Therefore, NHTSA concluded that the severity level or stringency of the third proposed test approach would not be sufficient to significantly improve safety.

The NASS crash data shown in Table IV-3 indicate that the side-to-pole (narrow object) impacts are more critical to occupant injuries and fatalities, while pole-type impacts cause 10.7 percent of vehicles damaged, they are responsible for 20.6 percent of the fatalities. In addition, the BMW, Ford and Autoliv test data show that the rigid pole test represents a more severe impact condition than a moving deformable barrier. There are approximately 80 million timber utility poles in the U.S. roadside environment that measure about 10" (250 mm) diameter adjacent to the doors of passenger vehicles. Based on the NASS/CDS and FARS data 1988-95, about 19 percent of vehicle-to-pole crashes involve poles 4-12 inches in diameter. [Draft Report, Comprehensive Characterization of Light Vehicle Side Impacts, An Investigation Conducted for the FHWA/NHTSA, by the Crash Analysis Center, GWU, August 1996, DeBlois Associates, Washington, DC].

Table IV-3
1988-1995 NASS/CDS Side Impact Crash Data - Pole vs MDB Severity

	Fatalities	Serious Injuries	Vehicles Involved
MDB (Vehicle-to-Vehicle	75%	79.4%	82.7%
Pole (Narrow Object)	20.6%	16.1%	10.7%

C. Other Alternative Test Procedures

NHTSA examined the viability of using the FMVSS No. 214 test procedure to certify HEADS as well as studied the head injury severity associated with lateral extravehicular head excursion (EVHE) (e.g., head contact with the front hood edge of a passenger car at approximately 33" high off the ground). The advantage of this test condition is that manufacturers are already conducting FMVSS No. 214 tests and the HEADS tests could, theoretically, be piggy-backed onto the FMVSS No. 214 testing and would not involve modifying the barrier's face. A SID dummy (with a Hybrid III head/neck) would be allowed as the certification device and assumes the SID and modified SID are shown to be equivalent. [The recent VRTC sled test data (Table IV-10) show they are equivalent test devices, even with the added Hybrid III head/neck complex, as the coefficients of variation across dummies was less than 5 percent.] The lateral kinetic energy level of FMVSS No. 214 procedure is about 1.5 times (109,146 ft-lbs/72,149 ft-lbs.) the ISO MDB #10997 test procedure. This approach would avoid modifying the MDB barrier face. The agency examined several series of crash tests data (primarily FMVSS No. 214 research and development tests: SRL-26, SRL-91, SRL-103 and VRTC-89-0138), where head-to-hood (33" height) contact may have been simulated, for information pertaining to the frequency and associated HIC values (hence severity) of head-to-MDB contact in lateral impact tests. In these cases, the head rotated laterally over the bottom of the window opening and contacted the top of the MDB (a horizontal surface) which was about 33 inches off the ground. The test data shows that it happens infrequently and that the average HIC value was about 1,075. SRL-26 head-to-MDB contact occurred in 3 out of 14 tests with HICs of 953, 2,331 and 309. In SRL-91 head-to-MDB contact occurred 1 out of 11 tests with a HIC of 1,224. SRL-103 head-to-MDB contact occurred in 3 out of 8 tests with HICs of 1,209 and 422 (the third case had an anomalous head acceleration, hence no HIC) and for VRTC-89-0138 no head-to-MDB contact occurred in 5 tests. For 7 out of 38 tests (18.42%), head-to-MDB contact occurred with an average HIC of 1,075. This is about a 8.8 (.17) percent chance of a fatal head injury based on the lognormal (Mertz/Prasad) probability of fatality curves described in the 201 FEA. The agency notes that a lot of the head rotation, and extravehicular head excursion (EVHE), may have been contributed to by body and torso rotation (if unbelted) as well as neck bending motion. NHTSA concluded that piggy-backing the HEADS test on the 214 test (standard barrier height) is probably not worth pursuing because; (1) head-to-MDB contact is a random, unrepeatable phenomenon, (2) outside head contact occurs with low frequency, and when it occurs, very moderate HICs result, (3) the current 214 procedure requires dummies to be belted, thus the possibility of torso rotation away from the vehicle interior (which exacerbates head/neck rotation) is highly diminished and (4) the lateral HIC based on SID is of questionable validity. This test approach probably would not lead to significant benefits and safety improvements as the lower barrier face does not intrude into the greenhouse or upper interior side rail where the HEADS are being installed. [NOTE: Except for the lateral BMW, Ford and Autoliv pole tests with head-to-pole contact, this test approach was still more severe than any of the following test approaches where HIC was estimated from kinetic energy levels.] Although not severe enough to test HEADS system effectiveness, NHTSA is proposing piggy-backing FMVSS 214, Side Impact Protection, certification tests for the HEADS Crash Sensor Test under Option #2.

Alternatively, another approach would be to conduct a lateral impact test with the 214 MDB with a modified rigid face. [This assumes all things being equal - develop a pole test or develop a modified FMVSS 214 barrier test.] The barrier face would be high enough to intrude into the upper interior parts of the greenhouse. Head-to-MDB face contact would be more reliable, but the energy level would probably be too moderate to achieve safety improvements. Inefficient and ineffective HEADS systems could be installed. Compared to ISO #10997, driver and passenger HIC would be expected to increase to 75-100 [(50-100) X 1.5] and 225-300 [(150-200) X 1.5], respectively. Another approach would be to employ the FMVSS No. 301 barrier with the optional 208 lateral impact requirement at 20 mph. The 4,000 pound FMVSS No. 301 moving barrier at 20 or 30 mph would achieve higher lateral kinetic energy levels. The FMVSS No. 301 barrier has a flat face (60" X 78") approximately 5 inches off the ground. Head contact could occur with the rigid face. The lateral kinetic energy levels would be 53,432 ft.-lbs at 20 mph and 120,248 ft.-lbs. at 30 mph. Compared to the 30 mph FMVSS No. 301 MB case, the kinetic energy level would be higher than a 33 mph (109,146 ft-lbs.) dynamic FMVSS 214 by 10 percent. Therefore, the driver and passenger HICs might increase by another 10 percent from a range of 75-150 to 80-160 and from a range of 225-300 to 250-325, respectively. The agency has concluded that the severity level for this approach, as indicated by HIC, is too low and would not force the introduction of highly efficient and effective HEADS countermeasures.

NHTSA is aware that the auto industry is considering two different methods of conducting side pole tests; (1) car-to-pole and (2) pole-to-car. In addition, two pole sizes (10 and 14 in. diameters) are being considered. [See MGA News (Extra), Vol. 10, No. 2, December, 1996] The agency considered the concept of a moving pole test with stationary vehicle, similar to BMWs test using a 5,400 lb. moving barrier with a 350 mm diameter pole welded to the front of the barrier face, as a compliance test procedure. NHTSA has also reviewed the MGA video and test data from 9/06/96 and 9/13/96 comparing a car-to-pole and pole-to-car test for the same test vehicle. The pole-to-car test would appear to solve compliance test problems such as test vehicle pitch, roll and yaw and could possibly provide for a more accurate delivery of the pole to the dummy head CG centerline. NHTSA has tentatively eliminated the pole-to-car test approach from consideration primarily because it would not be equivalent to the real-world pole-to-car crash simulation being proposed. There may be problems matching the kinetic energy and delta-V characteristics of the pole-to-car with the car-to-pole test. In addition, the post-crash dynamics (rotation and translation) of the test vehicle would probably be seriously curtailed and the dummy's head would not be able to interact realistically with the vehicle's interior components. Further, considerable developmental work would be needed to gain a consensus regarding MB mass, intrusion and resulting crash severity. Each pole-to-car test would probably require adjustment of the barrier weight and speed. In the agency's opinion, the car-to-pole test drafted by ISO would have far greater probability of success for the same amount of man power and resources and could be accomplished in a much shorter time frame. The agency seeks comments on the pole-to car test approach.

In conclusion, NHTSA examined several test procedures, including the pole test procedure, for purposes of testing and assessing the effectiveness of HEADS. Based on kinetic energy levels, a moving barrier with a broad fixed face has the potential of producing low HIC values (around 300-325). During the FMVSS No. 214 development process head-to-barrier contact occurred periodically but the dummy was unbelted. Today FMVSS No. 214 is conducted with the dummies belted thus eliminating/minimizing EVHE and head contact potential. Neglecting make/model and year differences, the lateral pole crash tests produced the highest HIC values at 18 and 20 mph of 2,495 and 4,159/4,010, respectively. HEADS effectiveness is directly proportional to HIC and HIC is a function of the amount of kinetic energy and whether direct head contact occurs. Therefore, the lateral pole test will result in the most efficient and effective HEADS countermeasures. In addition, fatal injuries are over represented in pole-type lateral crashes.

D. <u>NPRM Test Procedure Options</u>

The following test procedure options are offered as alternatives in the NPRM:

Option (1) - Employ the current FMH test procedure at 15 mph for all target points as prescribed in the August, 1995 final rule on FMVSS No. 201. This option would accommodate HEADS systems that deploy vertically upward from the arm rest or seat back and do not interfere with static padding performance. One major manufacturer has a HEADS system which deploys from the side of the seat and, theoretically, this would not degrade the performance of static padding at 15 mph.

Option (2) Dynamic Padding or Inflatable Devices - Employ the FMH at 12 mph for "covered" target points (HEADS undeployed) and the FMH at 18 mph for "any" covered target point with HEADS deployed. All other target points are tested at 15 mph using the FMH test procedure. This option is designed specifically to accommodate the dynamic padding approach to HEADS, but can be equally used to certify dynamic inflatable devices as well.

For dynamic padding or inflatable device systems under Option #2, 12 mph performance is permitted for FMH impacts in the undeployed state at target points directly over an undeployed dynamic system and at target points "covered" when viewed from any of the angles specified in S8.13.4 over the stowed system, including mounting and inflation components, but exclusive of any covers or cover. One manufacturer is considering certifying their inflatable HEADS system using Option #2.

In addition, the agency is proposing a HEADS Crash Sensor Test and a maximum allowable deployment time for Option #2, to ensure that the HEADS systems (dynamic padding or inflatable systems) deploy within 30 ms. of MDB impact. The HEADS sensor certification tests would be conducted simultaneously with the FMVSS No. 214, Side Impact Protection. The lateral delta V of FMVSS No. 214 is estimated to be 12-15 mph. The agency requests comments pertinent to the HEADS Crash Sensor Test and whether manufacturers are considering HEADS systems which deploy in frontal or rear end crashes, and if so, what certification test procedures would be most appropriate.

Option (3) Inflatable Devices - Employ a 12 mph FMH test with HEADS targets points undeployed and an 18 mph dynamic lateral pole test for the HEADS system. All other targets are tested at 15 mph using the FMH test procedure. NHTSA is proposing the same criteria as discussed above in Option #2 for determining if target point performance can be degraded to 12 mph (HEADS undeployed). An 18 mph lateral impact at 90 degrees with a 10 in. diameter rigid pole would be required with HEADS deployed. Although the dominant number of pole crashes in the real-world are oblique, in the range of 30-60 degrees, NHTSA is concerned that simulating an oblique striking car-to-pole crash may have repeatability and reproducibility problems. The agency requests comments on the proposed car-to-pole impact angle. In addition, NHTSA requests comments on objective criteria that can be used to determine whether 12 mph performance at a particular target point should be permitted.

Compliance/Certification vs Alternative HEADS - The three optional certification test procedures for HEADS being proposed by NHTSA in the NPRM are based on known HEADS system designs or concepts and tend to provide lateral head protection. One or a combination of options may be needed by the manufacturers to certify HEADS. For example, for HEADS that deploy vertically upward from the outboard seat back or side inner door panel, Option #1 would probably be the most suitable as the FMVSS 201, 15 mph, static padding would not be affected by the HEADS installation. Alternatively, Option #3 could be used to certify compliance. The compliance testing of BMW's ITS system would require some combination of Option #1 and Option #3. The non-HEADS related targets (e.g., FH1, FH2, BP4, RP1, RP2, RH and UR) would employ the 15 mph FMH test per Option #1, the target points exempted per the prescribed criteria under Option #3 would employ the 12 mph FMH impacts (HEADS undeployed) and the 18 mph pole test would be conducted (HEADS deployed). The agency does not believe it is possible to objectively specify which optional test procedure, or combination, a manufacturer must use for which type of HEADS. Obviously, this is a test stringency decision which must be made by the manufacturer depending on the HEADS design. Manufacturers must notify NHTSA as to which option, or combination of options, they employed to certify compliance and which test speed, or combination of test speeds, are relevant to each target point. NHTSA will conduct compliance tests using the same option(s) and speeds.

Do the proposed test procedures cover all the HEADS options? If a manufacturer installs a roof air bag for rollover protection, which of the three test procedure options would be employed? FMVSS 201 specifies an Upper Roof (UR) target point, so the optional test procedures in the NPRM are germane. The laterally projected area of the head of a seated dummy would not make contact, so a dynamic test using a dummy wouldn't make sense (e.g., an Option #3 pole test probably would not be meaningful.) The manufacturer could certify using either Option #1 or #2. Alternatively, what if a manufacturer installs HEADS (dynamic padding or inflatable trim), for the three front seat positions, that deploys only in frontal crashes, but the projected area of the head of a seated 50th percentile seated dummy does not make contact. Which of the three test procedure options do they employ? Probably Option #1 or #2 would be used.

Some HEADS designs may not be accommodated by the subject proposal, specifically, front or rear crash activated HEADS similar to an ITS-type or IC-type systems (not dynamic padding or inflatable padding) which deploy across the windshield or rear DLO to prevent ejection and head contact with glass. The proposed test procedure options do not include a front or rear dynamic crash test procedure that could be used in conjunction with a 50th percentile frontal crash test dummy like Hybrid III. Obviously, new HEADS strategies will be invented in the future which are discriminated against by the current proposal, and NHTSA may need to make amendments, if feasible, to any final rule that is promulgated. The subject proposal is designed to be as flexible as possible so future modifications are not necessary. The commenters are asked to respond to the issue of whether frontal crash actuated and rear crash actuated HEADS systems are being developed by the manufacturers and what test methods and means would be most appropriate.

E. Proposed Pole Test Procedure

The FMH test procedures for Options #1 and #2 (except for the HEADS Crash Sensor Test) are contained in the FMVSS No. 201 final rule. The following section describes the considerations/issues pertinent to the agency proposing Option #3, the pole test procedure. The agency is proposing to adopt the Dynamic Pole Test (9.1.4) described in the draft ISO Technical Report (Road Vehicles -Test Procedures for Evaluating Various Occupant Interactions with Deploying Side Impact Air Bags, ISO/TC 22/SC 100/WG 3 N 100, February 9, 1995.) This will support and promote harmonization which is an agency goal and priority. The draft ISO document states "...seat the dummy so that its head is sufficiently within the front window opening that the striking pole is unlikely to contact the A or B-pillar. Paint or chalk the head just prior to test so an imprint will be left on the deployed air bag. Slide the vehicle sideways or propel the sled buck sideways into the ISO 10 in. diameter rigid pole at 18 mph (perpendicular to the pole) with the vertical centerline of the pole aligned with the head center of gravity." NHTSA is proposing to adopt these general test conditions. A modified SID dummy (with Hybrid III head/neck complex) would be used and the basic test conditions from the FMVSS 214 dynamic side impact test procedure would be employed, as appropriate, with some modifications. The Hybrid III head/neck sub-system can be shown to be biofidelic in the lateral direction and was rated as "fair" from a biofidelic point of view by ISO in 1988. GM adopted the Hybrid III head/neck for their side impact dummy - BioSID.

Also, mechanically, the Hybrid III head/neck show good lateral repeatability based on sled tests. The agency is seeking comments on the proposed pole test procedure. Based on the agency's full scale lateral pole test experience, and as described earlier in the report, there are two methods (single rail vs. dual rail for stability) that have been used successfully to convey a full scale test vehicle laterally up to 20 mph (TRC) and 33.5 mph (FOIL) into a pole. Both methods employ a conventional Cable and Rail Tow System. The first method (FOIL) employs a pair of rails to control the roll, pitch and yaw stability of the test vehicle before being released into the pole and the second method (TRC) employs a single rail and an A-frame cart to control roll, pitch and yaw stability prior to release into the pole.

Although both methods have been used successfully to generate crash test data for both NHTSA and FHWA, neither method has been used in which it was required that the head CG of the outboard dummy strike the pole centerline. However, BMW (per MGA Research Corporation's test facility), Ford and Autoliv have demonstrated that lateral head-to-pole contact is feasible. The MGA pole test procedure details were claimed confidential by BMW and MGA. [

] There are several pole test procedure issues. The overriding design feature of both approaches is that the test vehicle be launched, pushed or propelled, into the pole unconstrained. Under the FOIL approach, as the test vehicle leaves the rail system and the 4 tires engage the test track concrete 11.6 feet in front of the pole, a slight amount (3-6 degrees) of test vehicle roll may occur. This occurs because the tires engage a higher lateral friction surface than the rail system. This may cause the dummy to pre-load the inner door. For example, a 1988 Ford Taurus at 35 mph rolled 2.8 degrees and a 1988 Honda Civic at 30.8 mph rolled 5.6 degrees. In addition, if the tire patch areas under each tire differ and there is a front to rear friction differential, vehicle yaw can occur.

In the FOIL technical reports very little, if any, yaw data were reported. The agency does not believe that the yaw variability of the FOIL method is well defined as this method was used for breakaway luminaire tests in 1985 and 1988 and dummy head CG to pole contact was not a requirement. Little data on pole impact accuracy, roll, pitch or yaw were reported by TRC in their fuel tank integrity test reports as the pole impacted behind the cab of each pickup truck. However, impacting the head CG of the outboard dummy with the pole centerline was not a goal or requirement of the ODI ordered fuel integrity tests. NHTSA talked to the TRC test engineers about test procedure variability. The TRC test engineers estimated a +/- 4 in. pole centerline to head CG alignment variation using their "current" delivery method, but they believe reductions can be achieved with further testing experience. They acknowledged that vehicle yaw can be introduced by discontinuities in the asphalt, the concrete floor or steel grating inside the test facility building. Because they accelerate the test vehicle at a moderate rate and use a long test track, roll stability is not an issue, however, the test track surface discontinuities described above can jostle the test dummy out-of-position which occurred in the fuel tank integrity tests. [

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Videos from MGA demonstrate that the yaw control is "good" using their delivery method for the car-to-pole simulation. The test engineer indicated that with experience the lateral impact variability will improve and is currently about +/- 1½ in. Dummy stability does not appear to be problem. The agency is concerned about the overall impact of test vehicle roll, pitch and yaw variability on pole centerline to head CG alignment variability, and further, the sensitivity of HIC to the mis-alignment variability. Is the HIC variability such that the pole test is inadequate for certifying compliance of HEADS designs? If HIC varies by 25 percent, does that render the pole test useless as a compliance certification tool? What minimum level of HEADS effectiveness based on HIC should be allowed? Does the HIC variability reduce pole test stringency thus deteriorating the ability of the pole test procedure to discriminate between HEADS systems (e.g., low effectiveness HEADS could be certified)? The agency seeks comments on this issue.

One way to reduce or eliminate test vehicle roll, pitch and yaw is to constrain the vehicle, with a pair of FOIL-like rails which extend up to or past the pole. An X-framed, breakaway cart would support the test vehicle chassis, deliver the test vehicle to the pole at 18 mph, and allow some vehicle yaw. Pitch and roll would be reduced or eliminated. In NHTSA's view, an objective of the pole test procedure, is to deliver the vehicle to the pole unconstrained, with the sprung-mass of the test vehicle on all 4 tires, if possible, free to rotate in any direction around the pole, so the dummy can interact with the interior of the vehicle as it would in the real-world. NHTSA does not want to control the interaction of the test vehicle with the pole. On the other hand, if there is too much control (roll, pitch and yaw are eliminated) the result is a sled test and the translational and rotational momentum and energy of the test vehicle would be ignored. Using this method (extending the FOIL rails up to or past the pole), dummy interaction with the test vehicle's interior might be negated. NHTSA is also concerned about altering the vehicle-to-pole dynamics by bolting or welding of delivery carts or dollies to the chassis of test vehicles. Similar to FMVSS No. 214, either side of the test vehicle could be pole tested. The agency seeks comments on the above issues.

NHTSA believes that FMVSS No. 214 is a good indicator of how accurately the MDB (or a towed test vehicle) can be delivered to an impact target point using a conventional Tow Cable and Rail System. For example, the FMVSS No. 214 test procedure and standard prescribes an MDB crabbed angle of 27 +/- 1 degree and an MDB impact angle of 90 +/- 1.5 degrees is described in the OVSC Test Procedure. A horizontal impact point of 37" +/- 2 inches forward of the wheel base centerline is required by the standard. NHTSA examined 214 compliance test MDB impact point data (n=55) for 1994-1996 and examined horizontal as well as vertical impact point accuracy of this test methodology. (See Appendix for detailed data.) The horizontal accuracy achievable with the left, upper corner of the MDB honeycomb face was approximately 37" +0.78"/- 0.56". The maximum horizontal range was +1.84"/-1.12". The vertical accuracy achievable with the left, upper corner of the MDB honeycomb face was about 33" +0.72"/- 0.08". The maximum vertical range was +1.12"/-0.52". Safety Assurance (OVSC) believes these measurements are accurate within +/- 1 mm. These measurements were based on a post-crash hole made by a welding rod mounted to the left forward edge of the MDB barrier face compared to the pre-crash target or bull's-eye. These data demonstrate that the regulated FMVSS No. 214 horizontal impact point tolerance of +/- 2" is practicable. Vertical impact point tolerance is not regulated, but appears to be achievable within a very narrow tolerance. These data represent the accuracy of the Tow Cable and Rail System for delivering a towed MB cart and represent, in general, the accuracy for delivering a test vehicle to a stationary target point in NCAP tests, FMVSS No. 208 and FMVSS No. 301 crash tests. However, the agency cautions that these tolerances may not be applicable to a lateral pole test, specifically to pole centerline to head CG alignment variation.

For the proposed pole test, the assumption is made that the pole is initially aligned with a transverse vertical plane passing though the head CG of the front outboard seated dummy. The intersection of that plane and the exterior of the vehicle body creates a vertical line. This vertical line is aligned with the centerline of the 10 inch diameter pole. Therefore, assuming no test vehicle roll, pitch or yaw variability, and ignoring any head CG horizontal jounce from seat cushion rebound as the vehicle accelerates up to speed, the agency believes the closest the pole centerline can be delivered horizontally to the above described vertical line (representing a projection of the head CG and rounded to the nearest whole number) is about +/- 0.75" to +/- 1.00". Given that roll, pitch and yaw variations may introduce additional horizontal variations, the agency believes a horizontal accuracy of +/- 1.50" (pole centerline to head CG) may be practical for the pole test. This is a tentatively proposed impact point tolerance subject to confirmation from a lateral pole test series. If necessary, the tolerance can be increased based on NHTSA and the manufacturer lateral pole test data. NHTSA seeks public comments on this issue.

Using the Ford Taurus finite element model, developed by EASi Engineering, Inc, VNTSC examined SID dummy head CG longitudinal sensitivity to test vehicle yaw, using the mid-track FMVSS 214 dummy seating position and one adjusted 4 inches forward. The head CG translated +/- 1 inch longitudinally for every +/- 4 degrees of vehicle yaw. The agency cautions that this result is an example of one make/model and may not applicable to the fleet as other vehicles have different vehicle CG and head CG locations. The agency expects that test vehicle pitch and roll would probably be most influenced by test track perturbations and discontinuities within 10-15 feet of the pole.

As a practical matter, it will be difficult, if not impossible, for NHTSA to verify that the head CG of the dummy is properly aligned with the pole centerline within the proposed tolerance bandwidth, when head-to-pole contact occurs, as video or film observation will, in all probability, be obscured by the HEADS system and the intruding interior structure as it is crushed by the pole. Therefore, in practice, one or two horizontal welding rods may need to be attached to the pole perpendicular to the door of the laterally striking vehicle to record the initial contact point of the pole relative to a line made by a transverse vertical plane though the head CG. Overall, based on the lateral width of the dummy head (8") and the projected width of the pole (10"), head-to-pole contact should not be a problem. However, the goal is for the pole to strike as close as possible to the head area aligned with the head CG to maximize lateral HIC and to avoid glancing or grazing-type head-to-pole impacts.

The dummy is positioned following a modified FMVSS No. 214 seating procedure. The dummy head is painted or chalked just prior to the test so an imprint will be left on the deployed HEADS. The test vehicle is conveyed or propelled sideways using several optional methods (e.g., tire cradles with casters, cart-on-rails, tires-to-low coefficient of friction surface, dollies mounted to wheel hubs, etc.) at 90 degrees into a 10 inch diameter pole at 18 mph, with the vertical centerline of the pole aligned with the front seat dummy head center of gravity (CG). Figures IV-1 to IV-4 show the two basic pole crash tests set-ups under consideration by the agency (e.g., one stability rail vs. two stability rails). In general, all other aspects of the proposed pole test procedure will be the similar as FMVSS No. 214 or as described below:

E.1 Test Conditions

1. Vehicle Test Weight - The vehicle is loaded to its unloaded vehicle weight plus its rated

cargo and luggage capacity of 300 lbs., which ever is less, secured in the luggage area, plus the weight of the necessary anthropomorphic test dummies.

2. Vehicle Attitude and Delivery - The test vehicle is delivered to the pole laterally at 18 mph with its sprung mass unconstrained, or unencumbered, at the same horizontal/ vertical attitude as established above based on vehicle test weight and as established based the OEM recommended tire inflation pressure. Because of the need to minimize friction, OEM tires are optional as long as the attitude of the vehicle, with properly inflated OEM tires, is preserved. Any conveyance means that reduces/eliminates test vehicle tire/test track friction may be employed as long as the test vehicle attitude and test weight are maintained and the vehicle strikes the pole unconstrained.

3. Steering Wheel - If adjustable, the steering wheel is placed in the middle adjustment position.

4. Head Restraint Position - Fully up.

5. Seat Position (Horizontal) - A modified FMVSS No. 214 seating procedure is proposed. Based on the FMVSS No. 214 mid-track seating procedure, if 2" (50 mm) of head clearance (when viewed laterally) between the back of the dummy's head and the front edge of the B-pillar is not obtained at the centerline CG height, the seat back may be adjusted a maximum of 5 degrees. If the appropriate head clearance is still not achieved, slide the seat forward without the dummy's knees contacting the instrument panel.

6. Seat Position (Vertical) - Fully down position.

7. Seat Back or Torso Angle - The manufacturer's nominal design position.

8. Lumber Spine - Released.

9. Front HEADS vs Rear HEADS: For the pole test under Option #3, if frontal HEADS equipped, a front outboard SIDH3 dummy (Part 572, Subpart M) is required. If front and rear HEADS, only a frontal outboard SIDH3 dummy is required on the struck side of the vehicle. Comments are requested as to whether a rear dummy should be employed if the test vehicle is equipped with front and rear HEADS systems.

10. Windows - All windows are opened. The sun roof is closed.

11. Doors/hatches - Doors and hatches are latched, but not necessarily locked.

[NOTE: #3, #4, #6, #7 and #11 are the same as FMVSS No. 214.]

E.2 Pole Test Conditions

1. Test Vehicle Speed = 18 mph (29 km/h) laterally, left or right side of the test vehicle.
2. Pole diameter = 10 inches (250mm)
3. Impact Point = The pole centerline is aligned with the head CG. As stated in FMVSS No. 214, the outboard seat is adjusted to the mid-track position, or one adjustment position rearward, if a mid-track position is not available. The SIDH3 dummy seated posture is initially set-up in accordance with the dummy seating procedure in FMVSS No. 214. (See E.1.5, Test Conditions, for further proposed head clearance adjustments.) A transverse vertical plane passing through the dummy's head CG intersects the test vehicle body (with the door closed) along a Line M. The forward circumference of the pole along the pole centerline strikes the test vehicle along Line M.

4. Impact Angle = 90 degrees

5. Pole centerline to head CG tolerance = +/- 1.50 inches (+/- 37.5 mm).

6. Minimum Pole Height = 80+ inches (2,000+mm).

E.3 Test Dummy

1. The SID (Part 572(F)) will be combined with the Hybrid III head and neck (Part 572 (E)) to form a new dummy called the SIDH3. The new dummy will be proposed in an NPRM as Part 572, Subpart M, S752.110 to S572.116, Side Impact Hybrid Dummy, 50th Percentile Male. The head and neck assembly of the SID would be replaced with that of the Hybrid III (Part 572E) dummy. The new SIDH3 dummy weighs about 1.3 lbs. more (170.3 lbs.), compared to the nominal SID weight (169 lbs. +/-3 lbs.), due to the incremental weight increase of the Hybrid-III neck and the new bracket. However, SIDH3 is about 2.0 lbs. lighter than the Hybrid III dummy. Therefore, the weight of the SIDH3 dummy is not a problem. A new neck bracket is required as shown in Illustration 7, Appendix. If the test vehicle HEADS system is mounted to influence the front outboard seating positions, a front SIDH3 dummy is required during the pole test, whereas if HEADS systems is mounted to influence the front and rear outboard seating positions, a front SIDH3 dummy would be used in the pole test and NHTSA is seeking comments on the need for a rear dummy. However, the pole would be aligned only with the transverse vertical plane through the front dummy head CG. HIC is the only required computation as a result of the pole test. However,

SIDH3 (Part 572(M)) lateral head and head/neck calibration tests are required as well as SID (Part 572(F)) lateral rib, lumbar spine and pelvis calibrations.

2. 3-Point Belts (same as FMVSS 214 test procedure).

3. New lateral head and lateral head/neck calibration requirements are based on the BioSID procedures (See Figure IV-13). See User's Manual for the BioSID Side Impact Dummy, Society of Automotive Engineers, Dummy Testing Equipment Subcommittee, March 1991.

4. The calibration temperatures prescribed in Part 572(E) for the frontal Hybrid III dummy apply. Therefore, the Hybrid III head is calibrated laterally at 66-78 degrees F and the Hybrid III neck is calibrated laterally at 69-72 degrees F. Both are calibrated at 10-70 percent humidity.

5. The SID thorax (LUR, LLR), lumber spine (T12) and pelvis are calibrated based on Part 572(F) requirements. The prescribed calibration temperatures apply (66-78 degrees F, 10-70 percent humidity.)

6. Full Scale Lateral Pole Crash Test Temperature - The ambient temperature surrounding the modified SID dummy at the time of the full scale lateral pole crash test is maintained in the range of 69-72 degrees F or the same as FMVSS No. 208 with the Hybrid III dummy. NHTSA seeks comments as to whether the full scale pole crash test temperature range can be expanded to 66-78 degrees as this would be more practical.

7. Assuming HEADS systems are installed symmetrically, the pole test can be conducted on either side of the test vehicle, at the front, outboard seating position.

E.4 Performance Criteria

1. HIC(d) < = 1000.

2. HEADS Crash Sensor Test - Under Option #2, the dynamic system must fully deploy or be fully pressurized within 30 ms based on a FMVSS No. 214 dynamic side impact crash test.

Other than the pole impact speed, and other vehicle attitude properties (e.g., roll, pitch, yaw, horizontal pole centerline to head CG tolerance), the agency does not propose specifying the lateral delivery or conveyance method. Most test facilities NHTSA is aware of employ a Tow Cable and Rail System to pull or push the test vehicle into the fixed load cell barrier, fixed load cell pole or another instrumented test vehicle. NHTSA is aware of several methods which may be used to reduce the friction between the test vehicle tires and the concrete or asphalt pavement when delivering a test vehicle laterally:

1. Employ biodegradable soap on the test facility floor so the test vehicle tires slide laterally on the soap.
2. Plastic pads, or rectangular plates, placed under each tire, anchored with cables, and a soap/water solution on the test track floor. The vehicle brakes are applied to keep the wheels from rolling. The pads or plates hydroplane on the liquid soap, thus reducing friction.
3. Tire cradles with casters under each tire (See Figures IV-5 and IV-6).

Figure IV-5

Illustration of Lateral Conveyance Means
(3/4 VIEW)

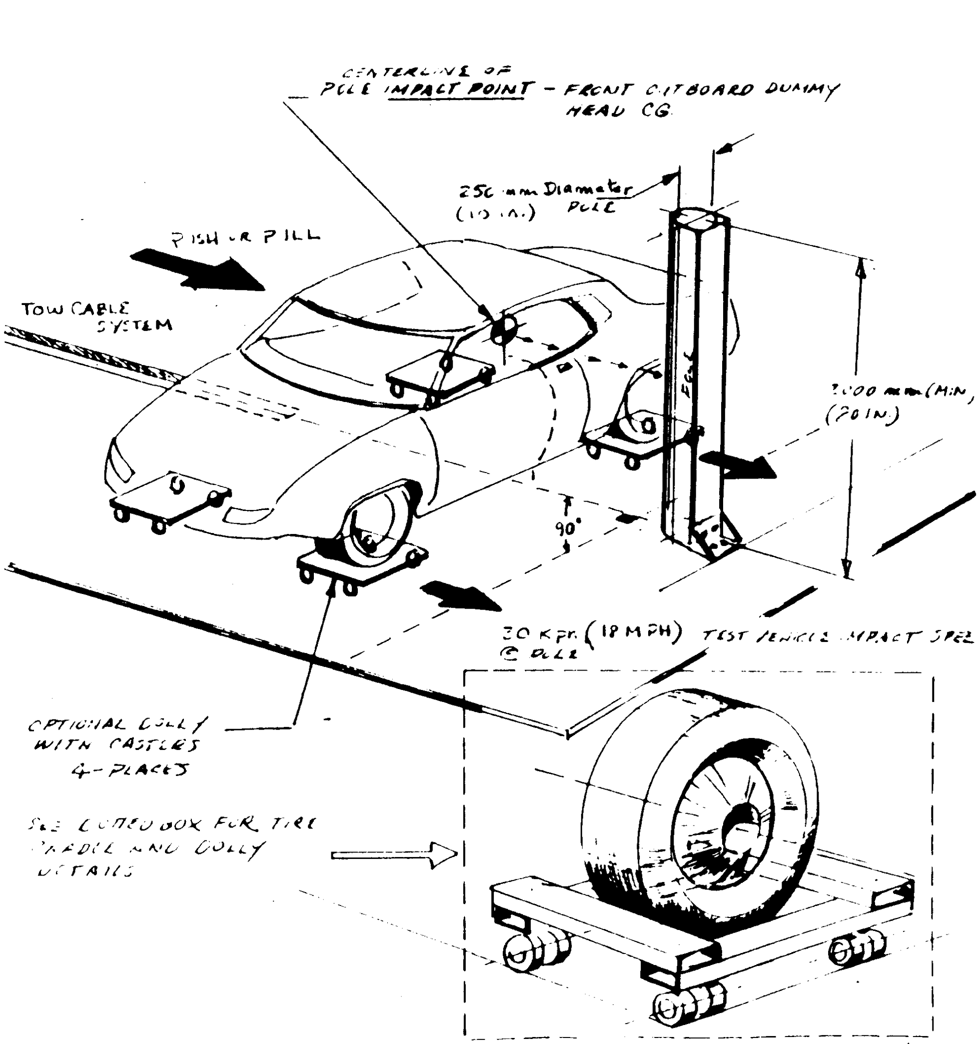
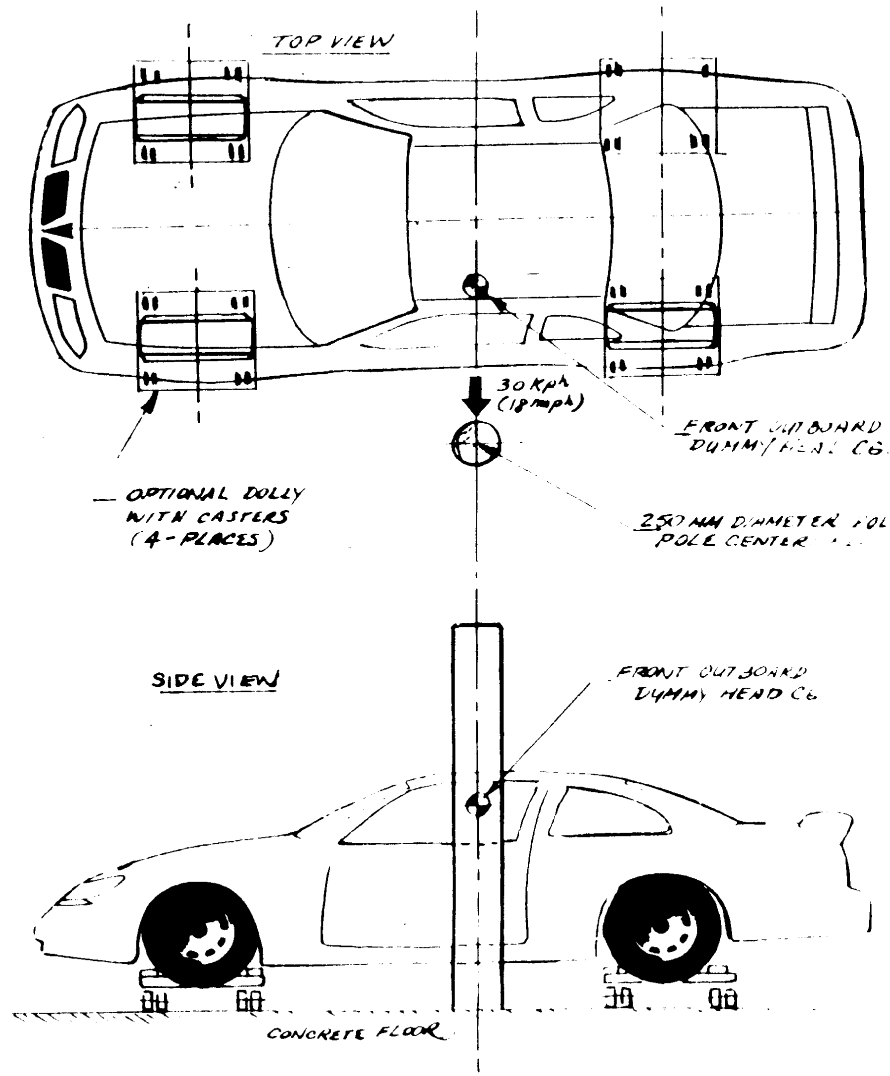


Figure IV-6

Illustration of Lateral Conveyance Means
(Top and Side Views)



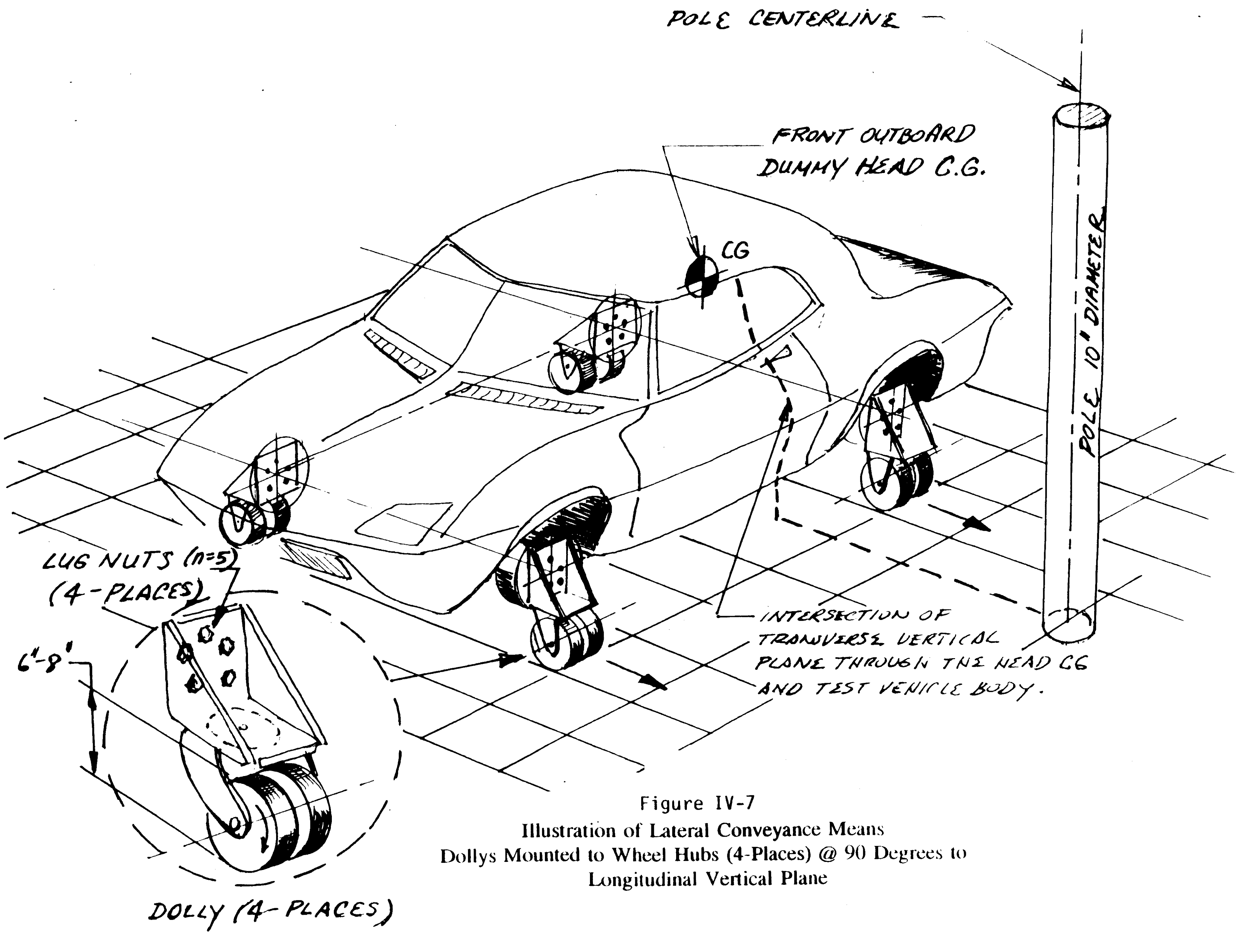


Figure IV-7
Illustration of Lateral Conveyance Means
Dollys Mounted to Wheel Hubs (4-Places) @ 90 Degrees to
Longitudinal Vertical Plane

4. Dollies (small diameter, hard rubber tires) mounted directly to the test vehicle wheel hubs at 90 degrees to the longitudinal centerline plane of the test vehicle (See Figure IV-7).

F. Hybrid III Lateral Head/Neck Biofidelity, Repeatability and Durability

BioSID is the Biofidelic Side Impact Dummy of the fiftieth percentile adult male that was developed in 1989 under direction of the SAE Side Impact Dummy Task Force. The BioSID employs the Hybrid III head and neck. In 1990 the International Standards Organization (ISO) Working Group 5 of ISO/TC22/SC12 developed a biofidelity rating scheme for evaluating the biofidelity of dummies and dummy components, where >8.6 to 10 was considered "excellent," >6.5 to 8.6 was considered "good" and >4.4 to 6.5 was considered "fair" biofidelity. For a dummy to be acceptable, according to ISO, its biofidelity rating would have to be greater than 4. [See Docket No. 88-07-GR-003, ISO Committee ISO/TC22/SC12/WG5 Correspondence, April 18, 1991, A Method to Calculate a Single, Weighted Biofidelity Value for a Side Impact Dummy, Document N253, March 1990, Proposed Weighting Factors for Rating the Impact Response Biofidelity of Various Side Impact Dummies, Document N278, June 1990 and Summary of Opinions of Delegations on Biofidelity Acceptance Levels, Document N287, October 4, 1990.]

Using 4 sets of laboratory component tests, two GM researchers (Mertz and Irwin, 1990) rated the Hybrid III head and neck. The highest rating received for the Hybrid III head and neck was 6.7 (good) and 6.1 (fair), respectively, in the fourth test series. [See the Appendix for Overall Average Biofidelity Ratings for the BioSID, SID and EuroSID Dummies and Dummy Components by Mertz and Irwin (1990).] Using this ISO biofidelity rating system, NHTSA estimated the biofidelity rating of the proposed SIDH3. The overall average biofidelity rating of the SIDH3, based on 4 test series, was estimated to range from 4.1 to 4.9 with an average of approximately 4.6. The overall classification for this estimated 4.6 (avg.) biofidelity rating is "fair." (For further biofidelity details see BioSID Update and Calibration Requirements, Michael S. Beebe, First Technology Safety Systems, Inc., SAE paper No. 910319) Therefore, the biofidelity of the SIDH3 is considered "fair," but, for all practical purposes, acceptable for lateral impact protection evaluation.

Repeatability and reproducibility of the Hybrid III head and neck are considered "good" to "excellent" as shown in the following sections, where "good" implies less than +/-10 percent variability and "excellent" implies less than +/-5 percent variability. NHTSA uses Percent Variance (n=2 tests) and Percent Coefficient of Variation (%CV) (n>=3 tests) to measure repeatability and reproducibility among and between Hybrid III head/neck components as well as the ribs, lumbar spine and pelvic response of the modified and unmodified SID dummies.

Figure IV-8 shows that, compared to lateral cadaver head impact accelerations measured at 2 m/s and 4.5 m/s, the Hybrid III head lies marginally outside the ISO performance corridors. Figure IV-9 shows that the lateral head impact responses of the Hybrid III head are very representative of human cadavers at the 2,500 HIC level. In view of this, the Hybrid III head is a good tool for assessing vehicle component impact performance in side crashes. Nahum's lateral cadaver head impacts were whole cadaver pendulum impacts, but located at a point on the side of the skull similar to the Hybrid III head drop tests. Therefore, the results are believed to be comparable. [See Experimental Studies of Side Impact to the Human head, 24th Stapp Car Crash Conference, October, 1980.] The Hybrid III head drop data (n=4), for the 48" head drops, fits within the variability of the lateral cadaver head impact data. (See Table IV-4) These 4 data points are plotted as one on Figure IV-9 because the acceleration response data was so close together in the 4 cases. Table IV-4 shows that, for the 48" head drop tests, %CV for HIC was 5.16 percent and %CV for max. G's was 3.06 percent. Because of the low percentage of variability (<5%), lateral response repeatability of the Hybrid III head is considered "excellent."

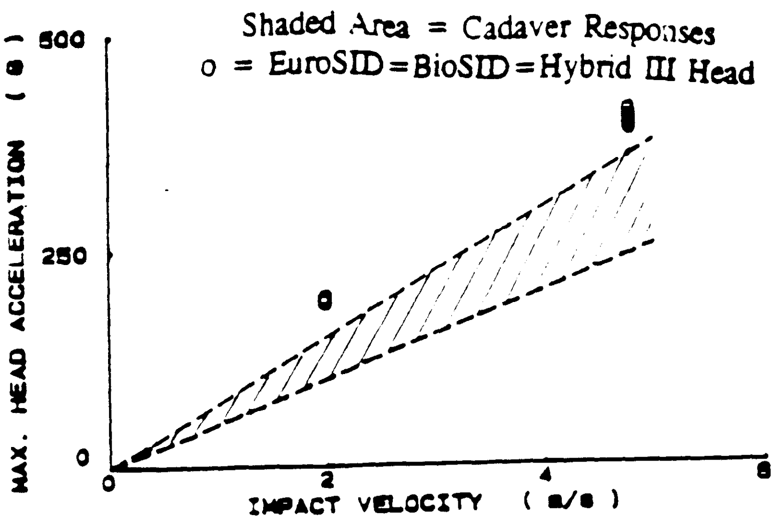


Figure IV-8 A Comparsion of EuroSid (Hybrid III) Response in Lateral Head Drop Tests and the ISO Performance Corridor.

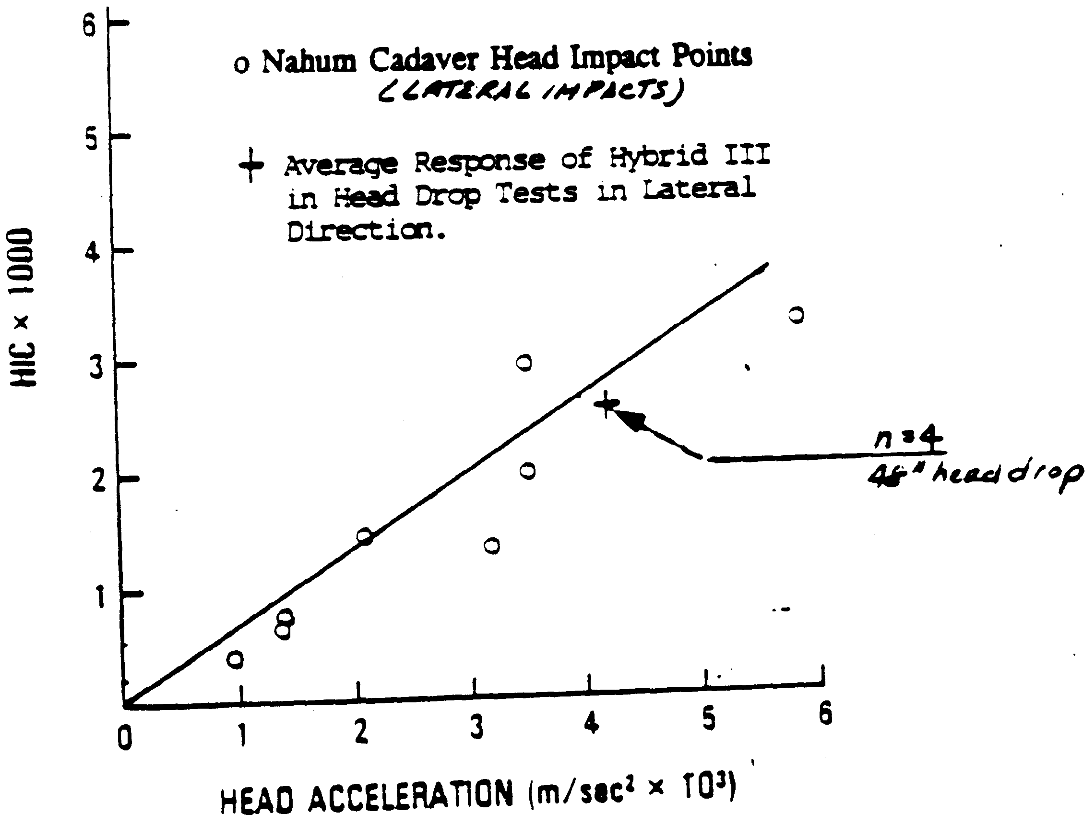


Figure IV-9 - Head acceleration versus HIC

Table IV-4
Hybrid III 1200 mm (48") Lateral Head Drop Tests Padded Plate

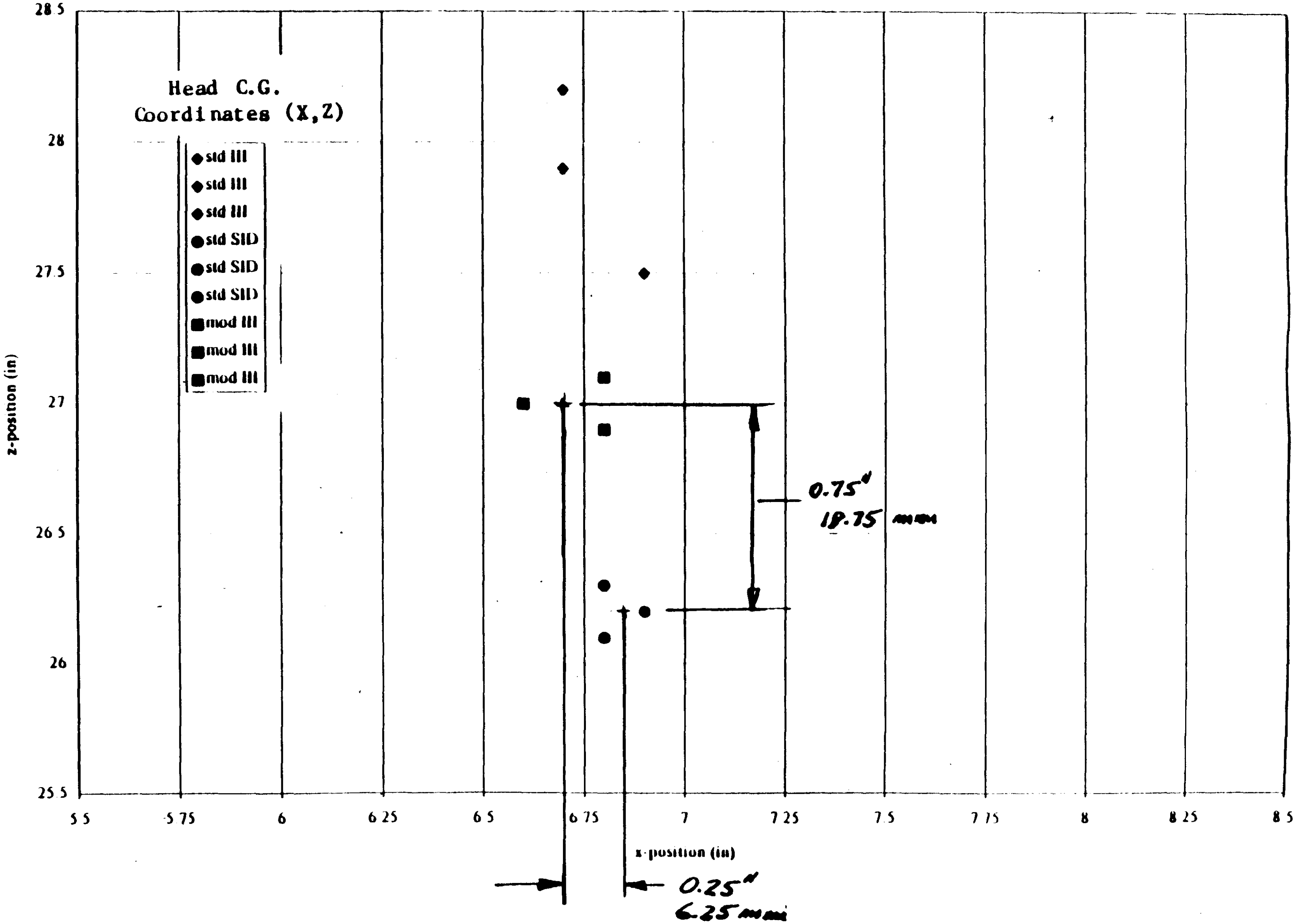
	Max. G's	HIC
#1	413.6	2,502
#2	424.1	2,605
#3	423.0	2,518
#4	396.7	2,302
Average	414.4	2,482
Standard Deviation (SD) n-1	12.675	128.09
% Coeff. of Variation (+/-)	3.06	5.16

%CV = SD divided by mean times 100%

The Hybrid III head/neck with the standard bracket presented dummy seated height and neck alignment problems, compared to the SID (Part 572(F)), so a new neck bracket was designed. NHTSA redesigned the Hybrid III head/neck complex support bracket based on two criteria: (1) the neck alignment matched the SID, or the Part 572(F) dummy, and (2) the head profiles of the two dummies were aligned. Given these criteria, the head CGs are not perfectly aligned. Without the new bracket the Hybrid III head CG (with the H-3 neck) is 1.5 inches higher than the original SID's head CG, whereas with the new bracket the Hybrid III head CG, when mounted on the SID, will be only 0.75 inches higher. The x-axis location of the Hybrid III head, with the new bracket, will be within 1/4" of the original SID. Figure IV-10 compares the X and Z location of the head CG for the Hybrid III dummy, the SID dummy and the modified SID dummy. Alternatively, aligning the head CGs would have

Figure IV-10

Position of Head C.G. Relative to H-Point
with New Neck Bracket (H-Point Coord. (0,0))



8/96 Measurements from SID sled tests.

required giving up overall dummy seated height and general positioning of the head/neck complex.

As shown later in this section, the change in head CG height does not affect HIC, TTI(d), pelvic g's or neck resultant forces, but neck moments are slightly influenced. Tables IV-5 and IV-6 show the lateral head drop and lateral neck calibration corridors. Biomechanically, a negative moment refers to lateral rotation toward the left shoulder and positive moment implies lateral rotation toward the right shoulder. Figures IV-11, IV-12 and IV-13 show the calibration equipment and test set-up. The equipment is the same as used for frontal dummy calibration tests. The lateral head drop calibration test is performed with the Hybrid III head alone, whereas the neck calibration test is performed with the head/neck complex together mounted on a pendulum. NHTSA plans to add a Part 572, Subpart M (S572.110 to S572.116) of the CFR, relating to the modified SID dummy, so that when HEADS compliance tests are performed per Option #3 of FMVSS 201 as amended, the laterally calibrated Hybrid III head and neck are used on the SID (Part 572(F)).

Table IV-5
Lateral Head Drop Calibration Corridors (Hybrid III Head)

Test Parameter	Specification
Temperature	18.9 - 25.6 degrees C (66 - 78 degrees F)
Relative Humidity	10 - 70 percent
Peak Resultant Acceleration G's	135 +/- 15 G's
Peak Longitudinal Acceleration (X axis)	15 G's Max.
Acceleration curve must be unimodal	Yes

Table IV-6
Lateral Neck Pendulum Test Calibration Corridors

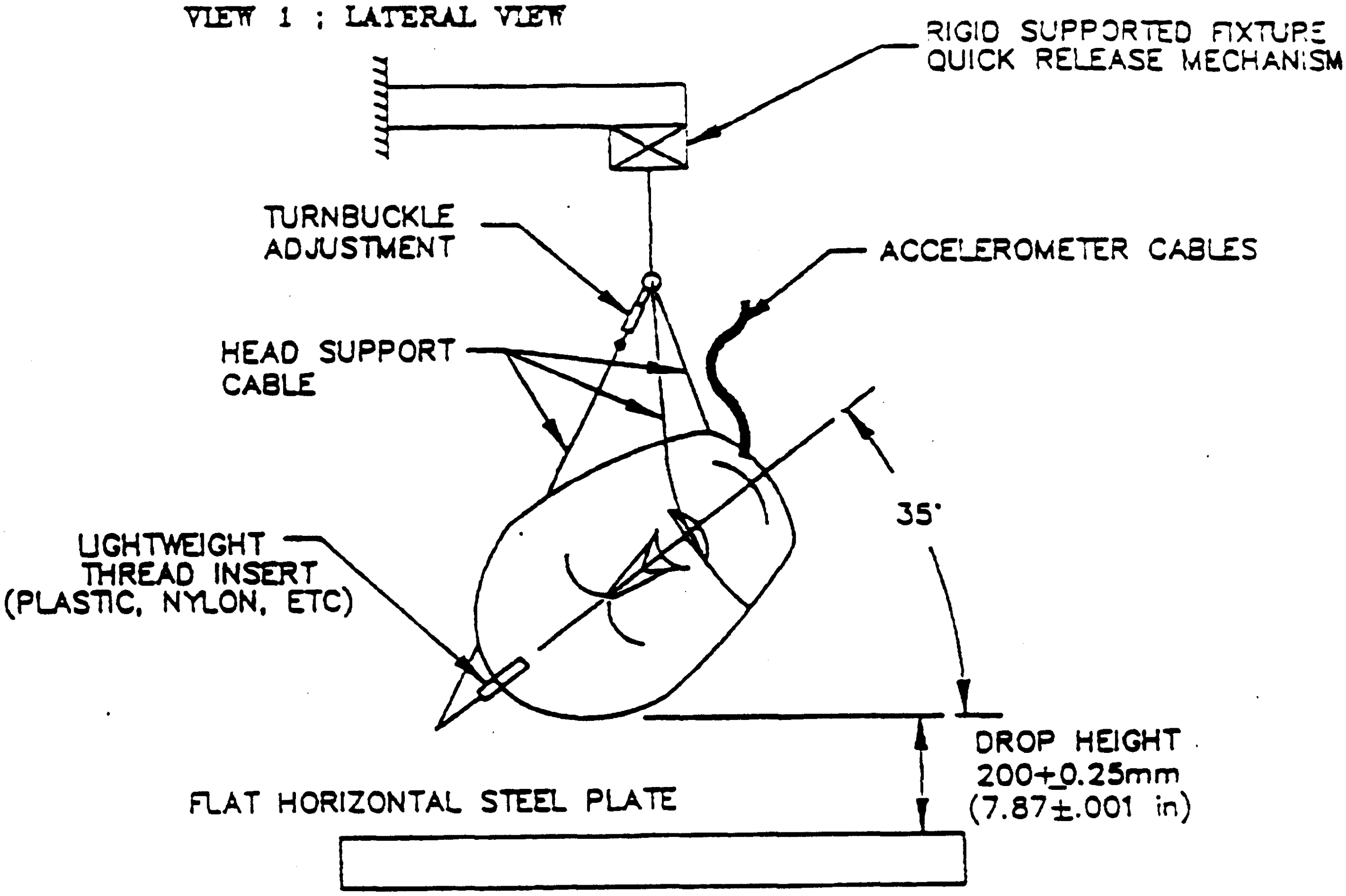
Test Parameter		Specification
Temperature		20.6 - 22.2 degrees C (69 - 72 degrees F)
Relative Humidity		10 - 70 percent
Pendulum Impact Velocity		6.89 - 7.13 m/s
Integrated Velocity	10 ms	1.96 - 2.55 m/s
	20 ms	4.12 - 5.10 m/s
	30 ms	5.73 - 7.01 m/s
	40 - 70 ms	6.27 - 7.64 m/s
Max. Mid-sagittal Plane Rotation (degrees)		64 - 78 degrees
Rotation Angular Decay Time (ms)		50 - 70 ms
Max. Occipital Condyle Moment (N-m)		-108.5 to -88.2 N-m
Posit. Moment Decay Time from Peak to 0		40 - 60 ms
Time of Max. Rotation after Max. Moment		0 - 20 ms

Figure IV-11

HUMANETICS

BIOSID HEAD DROP TEST SET-UP SPECIFICATION

VIEW 1 ; LATERAL VIEW



2 in. X 24 in. X 24 in.
WITH SURFACE FINISH 8 TO 80 MICROINCHES.
IMPACT SURFACE TO BE CLEAN AND DRY

VIEW 2 ; BOTTOM VIEW

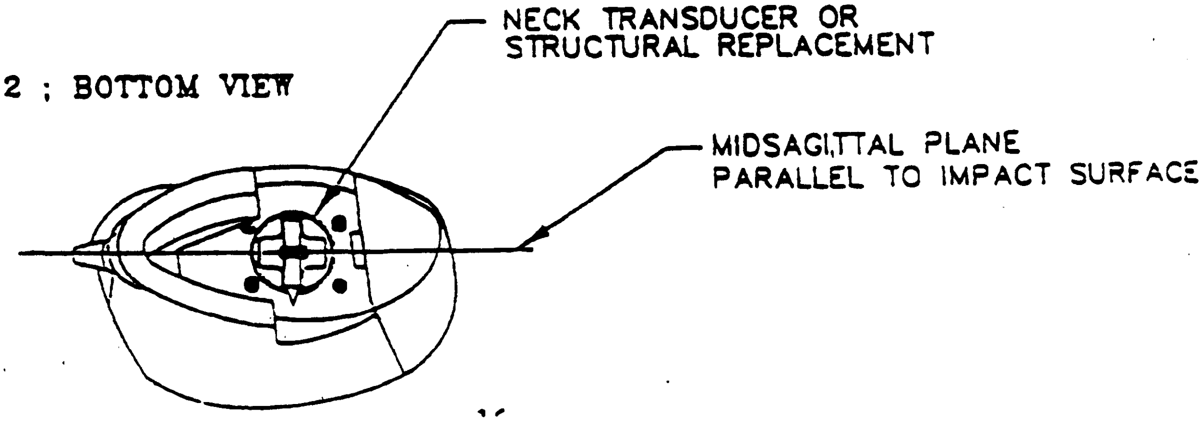
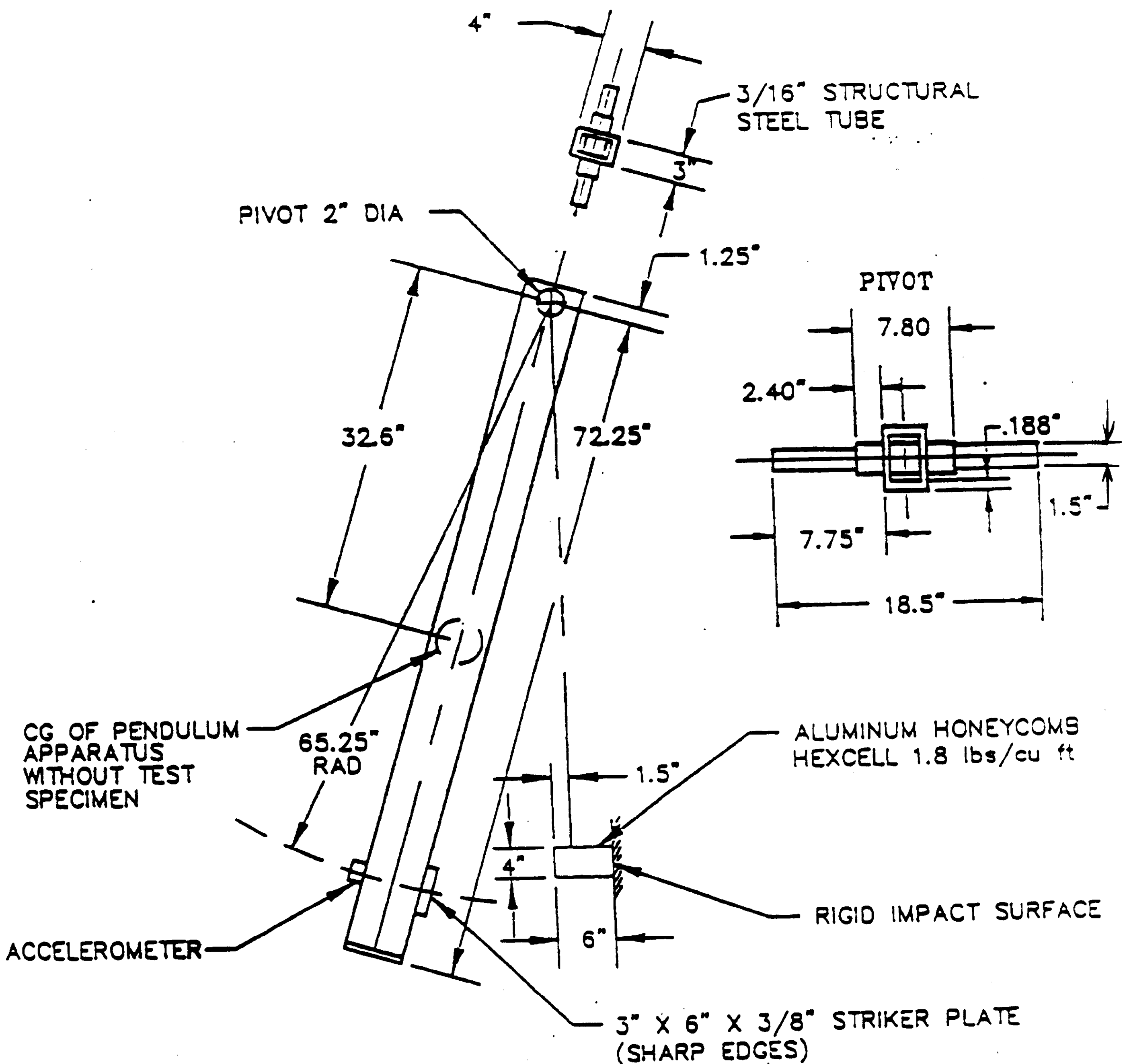


Figure IV-12

HUMANETICS

BIOSID NECK PENDULUM



INERTIAL PROPERTIES OF PENDULUM MOUNTING PLATE AND MOUNTING HARDWARE WITHOUT TEST SPECIMEN

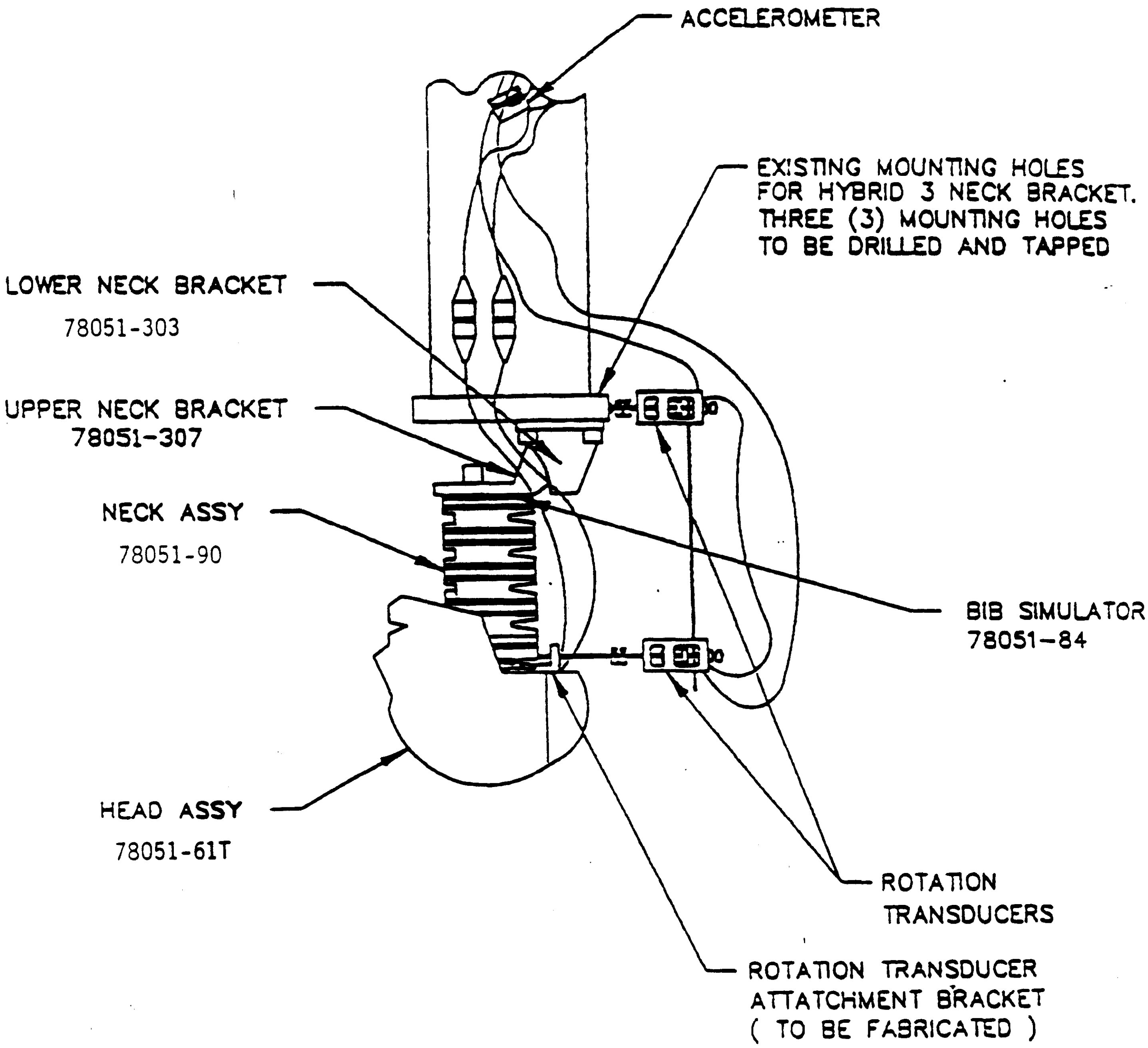
WEIGHT 65.2 lbs

MOMENT OF INERTIA
24.5 lb-ft sec^2
ABOUT PIVOT AXIS

Figure IV-13

HUMANETICS

BIOSID NECK PENDULUM TEST



The SID thorax, lumber spine and pelvis are to be calibrated per Part 572(F) as these calibration corridors define the SID dummy. The Hybrid III lateral head/neck calibration corridors in Tables IV-5 and IV-6 as well as the calibration apparatus Figures IV-11, IV-12 and IV-13 will be incorporated into the CFR.

Although TTI(d) is not a required performance criterion during HEADS tests, NHTSA is tentatively proposing that the SID thorax, lumbar spine and pelvis be simultaneously calibrated, as these calibration corridors define the SID dummy. NHTSA has shown in Table IV-7 that with the new head/neck, rib and lumber spine calibration was maintained within range. The percent coefficients of variation for the left upper rib (LUR), left lower rib (LLR) and lumber spine (T12) were less than 5 percent. A comparable calibration series was not conducted for the pelvis and the agency does not expect much change for pelvic g's. Comments are requested on these SID torso calibration issues. The dummy's head is instrumented with a tri-axial accelerometer package located at the CG of the head and accelerations are to be filtered using SAE Channel Class 1000. The head is calibrated at 66-78 degrees F range and the head/neck complex is calibrated at 69-72 degree F range. The SID thorax, lumber spine and pelvis are calibrated at 66-78 degrees F.

Table IV-7
SID Thorax Calibration Test Series with
New Hybrid III Head/Neck Complex

Dummy	Left Upper Rib (LUR) g's	Left Lower Rib (LLR) g's	Lumbar Spine T12 g's	Pendulum Speed (m/s)
SID SN 137 (8/14/96)	40.2	42.0	16.6	4.29
SID SN 137 (8/20/96)	39.3	39.3	16.4	4.29
SID SN 137 (8/21/96)	39.8	40.7	16.9	4.28
Mean	39.77	40.67	16.63	4.287
SD (n-1)	0.451	1.35	0.252	0.0058
%CV	1.13%	3.32%	1.51%	0.135%

SID Thorax Calibration Corridors are:

Left Upper Rib (LUR)	37 - 46 g's
Left Lower Rib (LLR)	37 - 46 g's
Lumbar Spine (T12)	15 - 22 g's
Pendulum Speed	4.21 - 4.32 m/s
Pelvic g's	40 - 60 g's (Not measured)

<u>Repeatability and Reproducibility Based on Calibration Tests</u>

In 1990, NHTSA issued a final rule amending FMVSS No. 214 to require full scale side crash tests to evaluate side impact protection of passenger cars. The rule instituted the use of the SID dummy (Part 572(F)) as a human surrogate to assess the risk of injury. Two alternative dummy development efforts, the EuroSID-1 and the BioSID, were in progress at that time. The BioSID uses the Hybrid III head/neck system. NHTSA began in 1989 to evaluate the BioSID compared to the SID. A series of BioSID lateral impact calibration tests were performed in 1990 using two BioSID dummies. It was concluded that the calibration responses of the BioSID are both repeatable and reproducible to within the tolerance generally accepted for the anthropomorphic test dummy performance. The results of those lateral head drop tests and lateral neck pendulum tests are shown in Table IV-8. VRTC recently conducted two additional lateral head drop tests and five additional neck pendulum tests using the head/neck components of a third dummy (03). The recent VRTC test results are listed in the Table IV-8 under the dummy 03.

Based on the above data, the repeatability of the dummy head/neck certification response is "excellent" because the percent coefficient of variation (%CV) for each dummy component is extremely small (< +/-5%). Two dummies (Dummy #1 and #2) that were manufactured by one manufacturer, at the same period of time, each had "excellent" repeatability because the percent coefficient of variation was < +/- 5%. When the test data of the third dummy is added for the reproducibility evaluation (Dummy #1, #2 &#3), the coefficient of variation of the neck rotational response increases to approximately 5.5% which is slightly beyond the norm of the "excellent" reproducibility rating. It is within the "good" reproducibility rating that is generally defined by a percent coefficient of variation ranging between 5% and 10%. [For further information, the overall repeatability and reproducibility (R&R) of the Hybrid III dummy is discussed in the Final Regulatory Evaluation, Amendments to FMVSS No. 208, Automatic Occupant Protection and to Part 572, Anthropomorphic Test Dummies, Regarding Use of the Hybrid III Dummy as a Compliance Test Device, April, 1986. Overall R&R of the SID dummy is discussed in the Final Regulatory Impact Analysis, New

Table IV-8
Summary of Hybrid III Head and Neck Calibration Data
Repeatability and Reproducibility Test Series

Dummy #	Head Drop Test Resultant Head G	Neck Pendulum Test Occipital Moment (N-m)	Neck Rotation (Deg.)
01	142.9	84.3	73.3
01	145.4	86.2	75.7
01	136.6	87.8	71.4
01	139.5	87.0	71.9
01	137.7	87.7	71.6
Average #1	140.4	86.6	72.8
S.D. (n-1)	3.7	1.4	1.8
%CV	2.6	1.6	2.5
02	138.5	88.8	69.9
02	141.6	87.7	67.4
02	140.3	90.2	68.9
Average #2	140.1	88.9	68.7
S.D. (n-1)	1.6	1.3	1.3
%CV	1.1	1.5	1.9
03	148.5	93.97	64.2
03	145.0	91.77	65.2
03		89.11	64.0
03		91.24	64.9
03		91.25	66.0
Average #3	146.8	91.47	64.9
S.D. (n-1)	2.5	1.73	0.63
%CV	1.7	1.89	0.97
Dummy #1&#2			
Average	140.3	87.4	71.2
S.D. (n-1)	2.9	1.7	2.6
%CV	2.1	2.0	3.6
Dummy #1,#2,&#3			
Average	141.6	89.0	68.8
S.D. (n-1)	3.8	2.6	3.8
%CV	2.7	2.9	5.5

S.D. = Standard Deviation. %CV = Percent Coefficient of Variation

Requirements for Passenger Cars to Meet a Dynamic Side Impact Test, FMVSS No. 214, August, 1990.]

Although the deviations of the head acceleration and the neck moment responses also increase slightly, when all the dummy tests are combined, they are still within the "excellent" reproducibility rating range.

18 Mph Lateral Sled Test Series

NHTSA conducted a lateral sled test series (n=3) for 3 different dummies at 30 kph (18 mph). Table IV-9 shows the peak values analyzed by the agency. The dummies compared were; (1) SID with Hybrid III head/neck/standard bracket, (2) SID with standard Hybrid II head/neck/bracket, and (3) SID with Hybrid III head/neck/new bracket. The purpose of the test series was to assess the durability of the new neck bracket and to assess the influence of the new bracket and higher head CG position on SID dummy responses, primarily HIC, TTI(d) and pelvic g's. The 18 mph sled test series involved impacts against a rigid plate and the average HIC ranged from 4,912 to 6,684, a very severe test.

Table IV-9
New Neck Bracket 18 Mph Lateral Sled Test Series
Peak Responses (n=3 tests per Dummy Configuration)

	SID w H-3 Head/Neck and Standard Bracket	SID (Part 572(F)) H-2 Head/Neck and Bracket	SID w H-3 Head/Neck and Modified Bracket
HIC	4.696.9	5.812.2	5,334.4
	5.129.5	6.541.2	4,710.4
	5.388.8	7.699.3	4.692.1
Mean	5,072	6.684	4.912
S.D.(n-1)	349.5	951.7	365.5
% CV	6.89%	14.24%	7.44% (< 10%)
Neck F (N) (NEKRF)	2,712.6		3,536.7
	2,918.5		3,295.3
	2,784.5		3,101.7
Mean	2,805.3		3,311.2
S.D. (n-1)	104.5		217.93
%CV	3.725%		6.58% (< 10%)
Neck Moment (N-m) (NEKXM)	94.5		78.8
	92.2		75.4
	97.4		78.3
Mean	94.7		77.5
SD	2.606		1.836
%CV	2.75%		2.37 (<5%)
Upper Rib G's	39.4	40.5	40.8
	41.3	43.0	39.7
	40.6	42.8	42.7
Mean	40.43	42.1	41.07
SD (n-1)	0.9609	1.389	1.518
%CV	2.377%	3.299%	3.695% (<5%)

Percent Coef. of Variation = (+/-) SD divided by the mean X 100 percent.

Table IV-9 Cont'd.
New Neck Bracket 18 Mph Lateral Sled Test Series
Peak Responses (n=3 per Dummy Configuration)

	SID w H-3 Head/Neck and Std. Bracket	SID (Part 572(F) H-2 Head/Neck and bracket	SID w H-3 Head/neck and Modif. Bracket
Lower Rib G's	43.3	42.7	48.5
	45.1	45.9	41.1
	44.1	46.0	48.0
Mean	44.17	44.87	45.87
S.D.(n-1)	0.9018	1.877	4.136
% CV	2.04%	4.18%	9.02 % (<10%)
Upper Spine (T1) T01YG1	62.6	50.0	65.2
	62.1	50.3	63.6
	65.0	52.6	65.7
Mean	63.23	50.96	64.89
S.D. (n-1)	1.55	1.42	1.097
%CV	2.45%	2.79%	1.96% (<5%)
Lower Spine (T12) T12YG	53.5	50.8	50.6
	53.0	50.5	53.0
	54.4	49.2	54.0
Mean	53.63	50.17	52.53
SD	0.7095	0.851	1.747
%CV	1.323%	1.695%	3.33 (<5%)
TTI(d)	48.4	46.7	49.5
	49.1	48.2	47.1
	49.3	47.6	51.0
Mean	48.93	47.5	49.2
SD (n-1)	0.473	0.755	1.967
%CV	0.966%	1.589%	3.998% (<5%)
Pelvic G's PEVYG	53.0	50.7	50.6
	53.1	48.6	50.4
	52.7	49.0	51.4
Mean	52.93	49.43	50.8
SD (n-1)	0.2080	1.115	0.529
%CV	0.3933%	2.256%	1.041% (<5%)

[See the Appendix for the SID Dummy Upgrade - Sled Tests Results - Maximum Values, Minimum Values, and Absolute Values used in Table IV-9. NHTSA used Peak Values regardless of sign.]

Table IV-10
New Neck Bracket and SID Reproducibility
(All Peak Values shown are an average of n=3)

	SID H-3 Head/Neck, Std. Bracket	SID H-2 Head/Neck, Std. Bracket	SID H-3 head/Neck, New Bracket	Percent Variation or %CV
HIC	5,071.7	(1)	4,912.3	1.6% Variance (2)
Resultant Neck Force NEKRF	2,805.3 N	(3)	3,311.2 N	8.3% Variance (2)
Lateral Neck Moment NEKXM	94.7 N-m	(3)	77.5 N-m	20% Variance (2)
Upper Rib	40.4	42.1	41.1	3.3 %CV (4)
Lower Rib	44.2	44.9	45.9	5.4 %CV
Lower Spine T12YG	53.6	50.2	52.5	3.6 %CV
TTI(d)	48.9	47.5	49.2	2.8 %CV
Pelvic g's PEVYG	52.93	49.43	50.8	3.23 %CV

In Table IV-10 (1) indicates that the Part 572(F) or SID dummy lateral HIC is not valid for comparison purposes, (2) Percent Variance = [½ (X1-X2)/ ½ (X1+X2)] X 100%, (3) Part 572(F) SID dummy neck has no instrumentation and (4) %CV = Percent Coefficient of Variation = [S.D./Mean] X 100%.

Sled Test Series Conclusions

MODIFIED SID - The 18 mph sled test series examined the durability of the new neck bracket. This was determined to be satisfactory as HICs were extreme (5,000) and no problems were reported by VRTC. Since the SID torso (Part 572(F)) and the Hybrid III head/neck (Part 572(E)) are existing regulated dummy components that are accepted for lateral crash tests, a durability study of these components was not needed. The overall durability of the SID dummy, based on recent FMVSS No. 214 compliance test experience, appears to be satisfactory, but the long term durability of the bracket and the dummy in the more severe pole test crash environment is unknown. As shown in Table IV-9, the repeatability of the SIDH3 dummy (SID dummy with Hybrid III head/neck and new bracket) remained "good" to "excellent," very similar to the baseline unmodified SID, with percent variance/percent CVs for all measures in the 5-10 percent range.

ACROSS SID DUMMIES - Using 2 way (head/neck responses) and 3 way (torso responses) analysis across the dummy configurations as shown in Table IV-10, the new neck bracket has a minimal influence on HIC, upper rib g's, lower rib g's, lower spine, TTI(d) and pelvic g's with a percent variation/percent CV of less than 5 percent between the SID with H-3 head/neck "old" bracket vs. baseline SID vs. SID with H-3 head/neck "new" bracket. Since the modified SID variance remained within the variance of the baseline SID, or Part 572(F) dummy, the two dummies remained "equivalent, for all practical purposes. However, the head CG height did influence the neck resultant force (NEKRF) and the lateral neck moment (NEKXM) of the modified SID with a variance of 8.29 percent and 20 percent, respectively. Relative to the standard neck bracket, neck loads increased with the new neck bracket, while neck moments decreased. With the new bracket, lowering the head CG increased the resultant neck load, but decreased the neck moment. This is not of concern to the agency as neck injury criteria based on neck loads or moments are not being proposed.

V. Overview of Benefit Methodology

The relative impact of alternative safety devices such as ITS was determined by recalculating the safety benefit analysis that was done for the June 1995 FEA using test data that is specific to the ITS. These data produced an estimate of the effectiveness of the ITS in reducing the level of HIC experienced in sled tests.

Application of these estimates requires a profile of the HIC distribution of injuries for each severity level in "real world" crashes. Such a profile does not exist in accident data because HIC cannot be measured from the information collected on police reports. This analysis was based on a model of HIC distribution in crashes which was derived from a number of available data sources. An example of this model is shown in Table IV-30 of the 6/95 FEA.

To develop a model of HIC distribution, a number of factors were considered. These include:

- o The ranges of HIC over which injuries of each severity level (MAIS) occur.
- o The shapes of the HIC distribution within each injury severity category, i.e., - the relative frequency of successive HIC levels within the range of HIC over which injuries of each severity level occur.

Curves have previously been derived to predict the probability of injury given a specific level of HIC. A curve of HIC/MAIS relationships was originally derived by Langwieder in 1979. This curve was modified by NHTSA staff based on crash test results in 1982 (Hackney and Quarles, 1982). In 1985, Prasad and Mertz generated a specific HIC/MAIS relationship for AIS 4 level injuries using cadaver data. This work was extended to various injury severity levels in unpublished work by NHTSA staff. These MAIS specific curves were used to derive probabilities of injury at varying severity levels for a given HIC level (see, for example, Table IV-27 in the 6/95 FEA). This provided a list of injury probabilities for each HIC level, but it did not reveal the frequency of injury at each HIC level.

The frequency of injury by severity level (as opposed to the frequency of injury by HIC) was derived from NHTSA data bases. A major concern was that the combination of HIC ranges and HIC distribution reflected in the model be reasonably consistent with the actual injury data that were available from the NASS and FARS data bases. Although these data bases do not contain direct information on HIC levels, there are limitations on HIC distributions implied in the relative frequency of injuries of different severities. For example, if 85 percent of all head/face injuries are minor (MAIS 1), this implies that most impacts involve relatively low level HIC's that would produce minor injuries. However, even higher level HIC's have some probability of producing only a minor injury. The probability of receiving a minor injury must be reflected in the overall probability of injury that is derived across all HIC levels.

The real "shape" (or relative incidence) of HIC distributions in actual crashes is not known. However, free motion headform (FMH) test data suggests that this distribution takes the not unexpected form of a bell-shaped curve. Tests conducted at lower speeds produce a narrower peak (i.e., a tighter bunching of results around the most common HIC levels) than do tests conducted at higher speeds. By combining HIC distributions from these groups of tests, weighted according to the relative frequency of lower and higher impact speeds within each injury severity level, a rough estimate of the relative incidence of HIC distribution within each injury severity category was made. The "shape" of the resulting curves is accepted because it primarily represents variation in vehicle performance. The HIC range over which these distributions occur, however, is not an acceptable proxy for the range over which each MAIS level occurs because tests were only conducted at a few specific speeds, while crashes occur over a wide range of speeds. The outlying segments of the HIC range for each MAIS level are essentially missing from the HIC ranges that result from tests conducted over a limited range of impact speeds.

The range of HIC's over which each MAIS level occurs was estimated by combining the three factors noted above and selecting the set of ranges which minimized the disagreements between the matrix predicted by the HIC probability curves and the matrix that results from distributing the known incidence of each injury severity level according to the relative distribution curves derived from the FMH tests. In this manner, the three independently derived inputs (the shape of the distributions, the relative incidence of injury severity, and the predicted probability of injury for the given HIC) were forced to converge into a result that represents a feasible (but not precise) model of actual HIC distributions by injury severity in crashes.

As previously noted, the average effectiveness of the ITS to various impact sites was derived from sled tests. For A-pillars, average effectiveness was derived from a formula which is based on HIC levels. Once the model of HIC distributions was derived, the weighted average resulting HIC/injury severity matrix (see Table IV-32 in the 6/95 FEA). These factors were then applied to the HIC level of each cell and the revised totals for each HIC level re-distributed according to the probability of injury that was derived for that HIC level in the model (the final row distribution for each HIC level). Net benefits were then calculated as the difference between base case and revised totals for each severity level.

A detailed description of the method summarized in the above paragraphs is provided in the June 1995 FEA for FMVSS 201, Upper Interior Head Protection. Readers wishing further details regarding the basic modeling procedures, or their application to benefit estimates of standard padding are referred to that document.

Effectiveness

An estimate of ITS effectiveness in reducing HIC was obtained from test data provided by BMW in their comments to Docket No. 92-28-NO4, September 15, 1995. BMW conducted a series of 5 sled tests into fixed pole structures with and without the ITS. The results of these tests are summarized in Table V-1. The tests were conducted at 2 speeds, 27km/hr and 51km/hr, the equivalent of 16.8 and 31.7 mph. In the 6/95 FEA, a factor was derived to convert vehicle delta-V to occupant delta-V (see Table IV-25 in 6/95 FEA). This factor, .765, was applied to the BMW test speeds to estimate their equivalent occupant delta-V at 12.8 mph and 24.2 mph.

Table V-1
ITS Sled (Pole) Test

Speed km/hr	Speed mph	Occupant Delta-V**	Head Contact	Base HIC	ITS HIC	Eff.
27	16.78	12.84	B-pillar	700	270	61.43%
51	31.69	24.24	B-pillar	1900	560	70.53%
27	16.78	12.84	window closed	80	250	-212.50%
51	31.69	24.24	window open	190	230	-21.05%
30	18.64	14.26	Pole*	2495	331	86.73%

* Proposed test procedure.
** From Table IV-25 in 6/95 FEA

The BMW base tests fall into 3 groups: those in which the dummy's head hit the B-pillar, those in which the head hit the pole, and those in which the head went through the glass area of the side window. In these later tests, the head essentially hit nothing because in one case the window was open, and in the other the glass shattered. This resulted in an exceptionally low HIC for the base case and a negative effectiveness (i.e., a higher HIC) for the inflated ITS tests, which actually provided more resistance to the dummies head than the shattered window or the unoccupied space in the open window. Since these tests do not represent the cases addressed by the requirements of FMVSS No. 201, they will be excluded from the analysis.

An inflatable ITS device would reduce the HIC levels of injuries that occur at the A-pillar, B-pillar and side header contact points. In addition it would reduce injuries from ejection and intrusion. Since no tests were run at the A-pillar or side header, the B-pillar results will have to be used as a proxy for those contact points. For the more serious intrusion and ejection injuries, the pole impact test is more appropriate.

Effectiveness was calculated using the following algorithm.

$$e = 1-\left(\frac{I}{b}\right)$$

Where: e = effectiveness of the countermeasures in reducing HIC levels
I = HIC results of sled test with deployed ITS
b = HIC results of base case (unaltered vehicle) sled test

For B-pillar impacts the results summarized in Table V-1 indicate a 61.4 percent HIC reduction at 12.8 mph occupant delta-V and 70.5 percent at 24.2 mph. The pole impact test, which was conducted at 14.3 mph, produced an 86.7 percent reduction.

While the three usable sled tests represent a very limited range, they are at least consistent in their results. The proposed system would deploy at a 12 mph vehicle delta-V, which is the equivalent of a 9.2 mph occupant delta-V. The closest test to this impact speed is the 12.8 mph B-pillar impact which produced an effectiveness estimate of 61.4 percent. This represents the most conservative of the three test results and it will be used to estimate benefits from ITS type systems. Consistent with the 6/95 FEA, it will be applied directly for B-pillar and side headers.

No ITS test data are available for the A-pillar. The analysis, therefore, assumed that the added protection to the A-pillar from an ITS is proportional to that which the ITS provides at the B-pillar. A-Pillar benefits were based on a formula which expressed effectiveness as a function of HIC. To reflect the increased effectiveness of the ITS, the effectiveness estimates produced by the A-pillar formula were increased by the ratio of the B-pillar ITS effectiveness to the effectiveness of 1" of padding at the B-pillar calculated in the 6/95 FEA. One inch was chosen because, of the padding widths with a substantial requirement at the B-pillar, it produces the most conservative ratio for estimating benefits. A-Pillar effectiveness was also constrained to not exceed 70.5 percent, the highest result of the two available B-pillar tests. This was done to produce a conservative result.

As noted previously, the ITS would inflate at a vehicle delta-V of 12 mph (9.2 mph occupant delta-V). Crashes that occur below this speed would, therefore, not experience the benefits of an inflated ITS. To reflect this, the portion of injuries that occur at occupant delta-V's below 12 mph were excluded from the calculation. While it is possible that the ITS would provide some padding benefit in its undeployed state, this analysis assumed that its benefit in this state was zero. The portion of injuries below 9.2 mph is derived from data developed in the 6/95 FEA. These data and the resulting portions are summarized in Table V-2.

Use in the Vehicle Fleet (Padding Requirements)

The analysis in the FEA was based on an estimate of the standard padding requirements that would be needed for the existing vehicle fleet to conform to FMVSS No. 201. While much of the fleet could meet the standard without any changes, portions of the fleet required from ½ to 1 3/4" of padding. For this analysis of alternative padding devices, it will be assumed that the portion of the fleet that did not require any changes to meet FMVSS No. 201, will not voluntarily adopt an ITS device, but that the portion that do not meet the standard would use the ITS rather than added padding. The same portion of the fleet will therefore be examined under both the current and the previous 6/95 analysis.

Table V-3 summarizes the padding requirements and effectiveness rates for MAIS 1 level injuries.

Calculation of Net Impact of ITS

The HIC specific A-pillar effectiveness was combined with the average effectiveness estimates for the other 3 impact sites (from Table V-3) according to the relative incidence of injury at each impact site to produce an average effectiveness estimate for each HIC level and injury severity category. For all impact sites, it was assumed that padding will not be effective at HICs above 3500, the level at which A-pillar effectiveness drops to zero. Note that the effectiveness at rear header and other pillars, for which no test data was available, was assumed to be equal to the average effectiveness at all other sites. The weight for these two locations is minor, as they represent only 1.4 percent of all head/face impacts. The results are summarized in Table V-4

Table V-2
Calculation of Occupant Delta-V Distribution, 1982-86
All Contact Points Restrained and Unrestrained
Percent of Total

Delta-V	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal	Total
1	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	0.010	0.004	0.000	0.000	0.000	0.000	0.008
4	0.014	0.000	0.000	0.000	0.000	0.000	0.011
5	0.049	0.000	0.000	0.000	0.000	0.000	0.037
5	0.032	0.021	0.000	0.000	0.000	0.000	0.028
6	0.046	0.000	0.000	0.000	0.000	0.000	0.035
7	0.106	0.065	0.000	0.000	0.000	0.055	0.091
8	0.111	0.040	0.000	0.000	0.000	0.000	0.090
8	0.141	0.068	0.014	0.000	0.039	0.000	0.118
9	0.063	0.095	0.049	0.000	0.000	0.000	0.063
10	0.057	0.026	0.000	0.000	0.106	0.000	0.049
11	0.074	0.115	0.022	0.060	0.000	0.000	0.076
11	0.042	0.025	0.112	0.065	0.058	0.000	0.041
12	0.067	0.055	0.137	0.035	0.000	0.000	0.063
13	0.030	0.053	0.166	0.060	0.111	0.036	0.039
14	0.017	0.078	0.000	0.000	0.000	0.000	0.025
15	0.036	0.040	0.079	0.025	0.000	0.251	0.042
15	0.014	0.063	0.029	0.050	0.000	0.000	0.022
16	0.028	0.047	0.000	0.079	0.000	0.025	0.031
17	0.023	0.037	0.000	0.000	0.000	0.000	0.023
18	0.011	0.012	0.000	0.000	0.000	0.000	0.010
18	0.005	0.043	0.020	0.000	0.000	0.000	0.011
19	0.008	0.009	0.000	0.000	0.182	0.077	0.012
20	0.000	0.010	0.018	0.040	0.077	0.000	0.004
21	0.002	0.034	0.034	0.023	0.000	0.038	0.009
21	0.000	0.005	0.063	0.000	0.000	0.000	0.002
22	0.002	0.012	0.033	0.379	0.000	0.019	0.014
23	0.000	0.000	0.000	0.026	0.042	0.076	0.003
24	0.006	0.000	0.000	0.000	0.000	0.000	0.004
24	0.000	0.008	0.027	0.073	0.000	0.088	0.006
25	0.002	0.000	0.042	0.000	0.000	0.027	0.003

Continued on next page

Table V-2 (Cont.)
Calculation of Occupant Delta-V Distribution, 1982-86
All Contact Points Restrained and Unrestrained
Percent of Total

Delta-V	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal	Total
26	0.000	0.004	0.000	0.014	0.000	0.016	0.001
27	0.002	0.010	0.059	0.028	0.224	0.038	0.009
28	0.000	0.000	0.029	0.000	0.000	0.032	0.002
28	0.000	0.005	0.000	0.042	0.099	0.000	0.003
29	0.000	0.000	0.040	0.000	0.000	0.000	0.001
30	0.001	0.000	0.000	0.000	0.000	0.000	0.001
31	0.000	0.009	0.000	0.000	0.000	0.000	0.001
31	0.000	0.000	0.000	0.000	0.000	0.000	0.000
32	0.000	0.000	0.000	0.000	0.000	0.037	0.001
33	0.000	0.000	0.000	0.000	0.000	0.017	0.000
34	0.000	0.000	0.000	0.000	0.000	0.000	0.000
34	0.001	0.000	0.026	0.000	0.062	0.000	0.002
35	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37	0.000	0.007	0.000	0.000	0.000	0.000	0.001
38	0.000	0.000	0.000	0.000	0.000	0.019	0.000
39	0.000	0.000	0.000	0.000	0.000	0.000	0.000
40	0.000	0.000	0.000	0.000	0.000	0.000	0.000
41	0.000	0.000	0.000	0.000	0.000	0.000	0.000
41	0.000	0.000	0.000	0.000	0.000	0.000	0.000
42	0.000	0.000	0.000	0.000	0.000	0.000	0.000
43	0.000	0.002	0.000	0.000	0.000	0.000	0.000
44	0.000	0.000	0.000	0.000	0.000	0.000	0.000
44	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	0.000	0.000	0.000	0.000	0.000	0.000	0.000
46	0.000	0.000	0.000	0.000	0.000	0.148	0.004
Unk							
TOTAL	1.000	1.000	1.000	1.000	1.000	1.000	1.000
<=9.18mph	52.08%	21.45%	2.26%	0.00%	3.93%	5.48%	42.95%
> 9.18 mph	47.92%	78.55%	97.74%	100.00%	96.07%	94.52%	57.05%

Table V-3
MAIS 1 Injuries, Passenger Cars

	%Reqr. Pdg.	Avg. Eff.	Wtd. Avg. Eff.		%Reqr. Pdg.	Avg. Eff.	
A-Pillars:				**Front Header:**			
None	34.8%	0.0%	0.00%	None	85.0%	0.0%	0.00%
½"	0.0%	NA	0.00%	½"	5.0%	22.6%	1.13%
1"	0.0%	NA	0.00%	1"	5.0%	34.7%	1.74%
1 3/4"	0.0%	NA	0.00%	1 3/4"	5.0%	34.7%	1.74%
ITS	65.2%	11.2%	7.32%				
Total			7.32%	Total			4.60%
B-Pillars:				**Side Rails:**			
None	33.3%	0.0%	0.00%	None	58.8%	0.0%	0.00%
½"	0.0%	NA	0.00%	½"	0.0%	NA	0.00%
1"	0.0%	NA	0.00%	1"	0.0%	NA	0.00%
1 3/4"	0.0%	NA	0.00%	1 3/4"	0.0%	NA	0.00%
ITS	66.7%	29.44%	19.63%	ITS	41.2%	29.44%	12.13%
Total			19.63%	Total			12.13%

The effectiveness estimates in Table V-4 represent the percent reduction in HIC that would result from increased padding at each impact site. These estimates were applied to each HIC level in the baseline HIC distribution derived in Table IV-30 of the 6/95 FEA to produce a revised injury profile. This resulted in a downward shift of the average HIC level for each cell in the table. This downward shift produced new injuries at specific HIC levels. From Table IV-27 of the 6/95 FEA, as HIC severity decreases there is an increasing chance that the result will be

Table V-4
Average Effectiveness for all Impact Points By HIC Level and Injury Severity, Passenger Cars

	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal
50	7.5%	13.3%	25.5%	11.7%	13.6%	15.8%
150	7.5%	14.5%	26.6%	14.9%	13.6%	15.8%
250	7.5%	16.6%	27.6%	18.0%	13.6%	15.8%
350	11.9%	17.8%	28.6%	21.2%	13.6%	15.8%
450	13.4%	19.0%	29.6%	24.3%	13.6%	15.8%
550	14.9%	20.1%	30.6%	27.4%	13.6%	15.8%
650	16.5%	21.3%	31.6%	30.6%	13.6%	15.8%
750	18.0%	22.5%	32.6%	33.7%	26.3%	15.8%
850	19.5%	23.7%	33.6%	36.8%	36.8%	15.8%
950	21.0%	24.8%	34.6%	40.0%	39.4%	15.8%
1050	22.6%	26.0%	35.6%	43.1%	42.0%	15.8%
1150	24.1%	27.2%	36.6%	46.2%	44.7%	15.8%
1250	25.6%	28.3%	37.6%	49.4%	47.3%	15.8%
1350	27.2%	29.5%	38.5%	52.5%	49.9%	15.8%
1450	28.7%	30.4%	39.3%	54.9%	51.9%	15.8%
1550	28.9%	30.4%	39.3%	54.9%	51.9%	15.8%
1650	28.9%	30.4%	39.3%	54.9%	51.9%	15.8%
1750	28.9%	30.4%	39.3%	54.9%	51.9%	15.8%
1850	28.9%	30.4%	39.3%	54.9%	51.9%	18.3%
1950	28.9%	30.4%	39.3%	54.9%	51.9%	37.8%
2050	28.9%	30.4%	39.3%	54.9%	51.9%	37.8%
2150	28.9%	30.4%	39.3%	54.9%	51.9%	37.8%
2250	28.9%	30.4%	39.3%	54.9%	51.9%	37.8%
2350	28.9%	30.4%	39.3%	54.9%	51.9%	37.8%
2450	28.9%	30.4%	39.3%	54.9%	51.9%	37.8%
2550	28.9%	30.4%	39.3%	54.9%	51.9%	37.8%
2650	28.9%	30.4%	39.3%	54.9%	51.9%	37.8%
2750	28.9%	30.4%	39.3%	54.9%	51.9%	37.8%
2850	28.0%	29.7%	38.7%	53.0%	50.3%	36.9%
2950	24.9%	27.2%	36.6%	46.4%	44.8%	33.7%
3050	21.8%	24.8%	34.5%	39.8%	39.3%	30.6%
3150	18.8%	22.3%	32.4%	33.2%	33.8%	27.4%
3250	15.7%	19.9%	30.3%	26.7%	28.3%	24.3%
3350	12.6%	17.4%	28.3%	20.1%	22.8%	21.1%
3450	9.6%	15.0%	26.2%	13.5%	17.4%	18.0%
3550	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3650	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3750	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3850	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3950	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4050	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4150	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4250	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4350	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4450	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table V-5

Final Revised Injury Profile, Passenger Cars (Adjusted for Shift in HIC Injury Probabilities)

HIC	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal	Total
50	5360	1583	183	59	0	0	7185
150	5006	1620	161	71	0	0	6858
250	4916	1492	167	80	0	0	6654
350	6014	1477	221	102	3	0	7816
450	3718	871	140	62	3	0	4793
550	1584	353	55	26	2	0	2020
650	278	941	131	71	10	0	1430
750	120	393	51	31	9	0	605
850	125	397	48	33	16	0	619
950	147	117	52	41	29	0	386
1050	110	94	39	33	30	0	306
1150	87	90	35	29	32	0	272
1250	128	132	26	37	50	0	373
1350	107	104	22	28	42	0	303
1450	144	120	31	34	56	8	394
1550	114	97	25	24	45	11	317
1650	50	44	11	10	21	8	143
1750	37	34	7	7	18	14	117
1850	25	24	5	4	13	20	91
1950	18	18	4	3	10	28	81
2050	13	15	3	3	8	36	78
2150	0	0	0	0	0	1	2
2250	6	9	2	2	5	40	64
2350	0	1	0	0	0	3	4
2450	0	6	2	1	4	39	52
2550	0	0	0	0	0	2	2
2650	0	0	2	1	3	38	44
2750	0	0	0	0	0	0	0
2850	0	0	1	1	2	34	37
2950	0	0	0	0	0	1	1
3050	0	0	0	0	0	0	0
3150	0	0	0	0	0	0	0
3250	0	0	0	0	0	0	0
3350	0	0	0	0	0	0	0
3450	0	0	0	0	0	0	0
3550	0	0	0	0	2	29	31
3650	0	0	0	0	2	24	26
3750	0	0	0	0	2	21	22
3850	0	0	0	0	1	14	15
3950	0	0	0	0	1	13	14
4050	0	0	0	0	1	12	13
4150	0	0	0	0	1	11	12
4250	0	0	0	0	1	10	10
4350	0	0	0	0	0	7	7
4450	0	0	0	0	0	7	7
Total	28108	10030	1425	796	420	428	41206
Base Total	28825	10580	1548	892	571	1591	44007
Net Benefits	717	550	123	96	151	1163	2801

either no injury or a less severe level of injury. The revised injury distribution was totalled across all MAIS levels and the total was then re-distributed to reflect the probability of injury at each MAIS level that was derived in Table IV-31 of the FEA. (The probability of no injury was derived from Table IV-27 of the FEA). The revised distribution is shown in Table V-5. At the bottom of the table, each revised MAIS level total is compared to the original total to produce the net benefits resulting from this proposal.

This same analysis was performed separately for passenger cars and light trucks under each of the proposed front/rear HIC requirements. The resulting benefit distributions are summarized in Table V-6. ITS technology could save 572 additional fatalities and prevent 880 additional nonfatal injuries in the on-road vehicle fleet.

This analysis was based on the HIC distribution predicted by the expanded Prasad/Mertz curves. The Prasad/Mertz head injury risk curve has been generally accepted by the automotive industry and by the SAE biomechanics subcommittee. However, these curves have been subject to the criticism that the method from which they were derived systematically understates the variance because none of the HIC values that were measured correspond to the level of stimulus required to just produce, or not produce, injury. (The authors acknowledge this limitation in their original paper). The Prasad/Mertz curves indicate a very steep rise in injury severity as HIC increases. When combined with actual injuries in the previous analysis, a significant number of HIC/MAIS cells had very large differences between predicted and actual injury proportions (see Table IV-32 in the 6/95 FEA).

Table V-6
Net Impact of ITS vs. Conventional Padding
Prasad/Mertz Curves

	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal
ITS						
Passenger Cars	717	550	123	96	151	1163
Light Trucks	556	393	35	19	41	454
Total	1273	943	158	115	192	1617
Existing Std.						
Passenger Cars	361	358	42	29	36	711
Light Trucks	671	259	19	9	16	334
Total	1032	617	61	38	52	1045
Net Impact						
Passenger Cars	356	192	81	67	115	452
Light Trucks	-115	134	16	10	25	120
Total	241	326	97	77	140	572

Table V-6A
Net Impact of ITS vs. Conventional Padding
Lognormal Curves

	MAIS 1	MAIS 2	MAIS 3	MAIS 4	MAIS 5	Fatal
ITS						
Passenger Cars	202	663	146	153	225	1089
Light Trucks	195	345	37	29	65	439
Total	397	1008	183	182	290	1528
Existing Std.						
Passenger Cars	454	84	46	39	82	575
Light Trucks	389	361	19	14	30	298
Total	843	445	65	53	112	873
Net Impact						
Passenger Cars	-252	579	100	114	143	514
Light Trucks	-194	-16	18	15	35	141
Total	-446	563	118	129	178	655

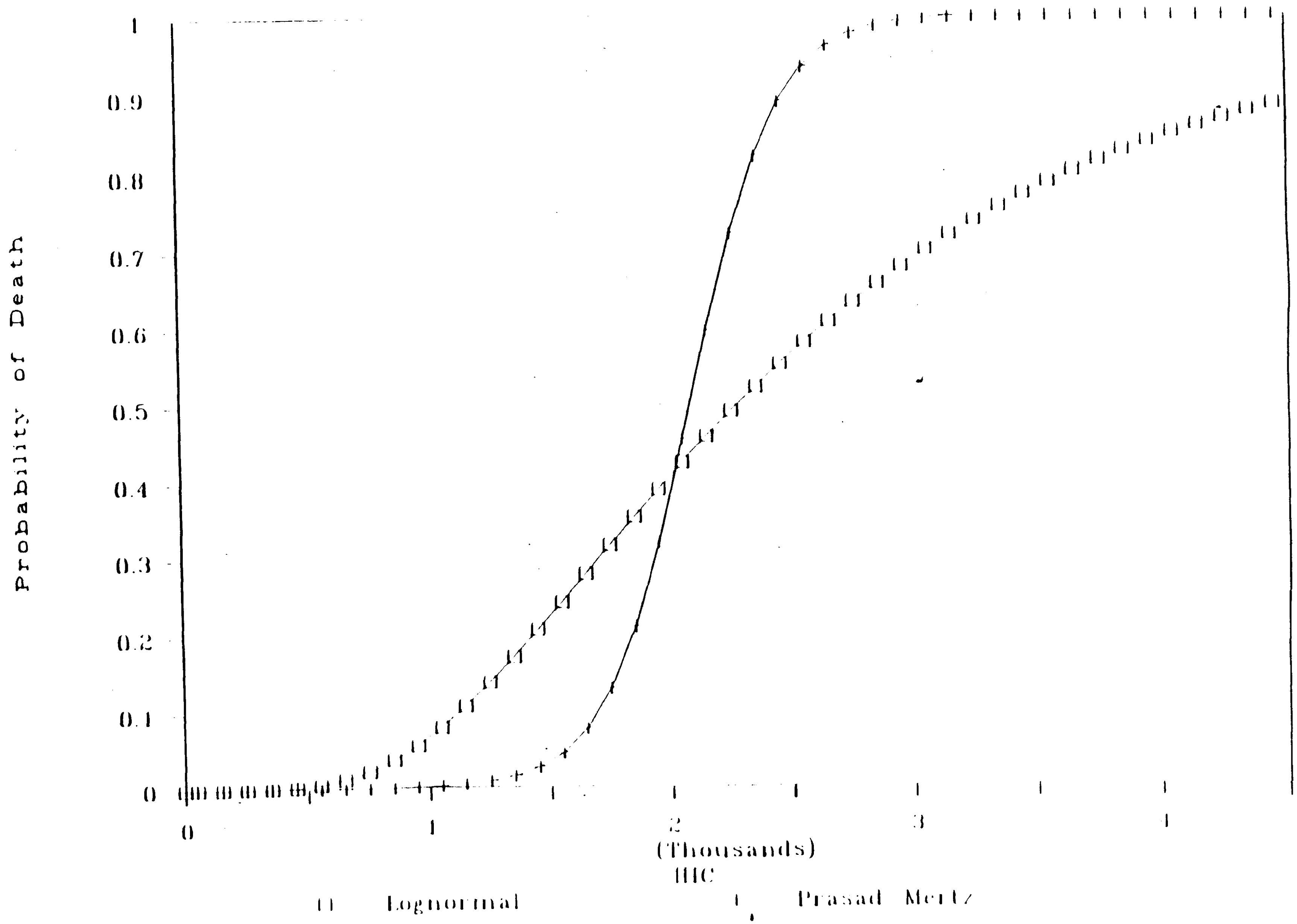
In response to concerns that the expanded Prasad/Mertz curves may predict too steep a climb in injury severity, NHTSA's National Center for Statistics and Analysis (NCSA) developed an alternate set of curves based on the concept of "censored data", which acknowledges the fact that all registered HICs are within, but not equal to, the injury threshold level, and which utilized a Lognormal distribution. The methodology used to create these curves was developed by Ellen Hertz of NCSA and is described in detail in Appendix A of the 6/95 FEA. The resulting curves are illustrated in Figure IV-13 of the FEA.

In Figure V-1 of this current analysis, the fatal curve for both the Prasad/Mertz and the lognormal procedure are shown for comparison. The Prasad/Mertz based curve shows a rapidly increasing probability of death between a HIC of 1,500 and 2,500 with a virtual certainty of death for HICs above 2,500. The lognormal curve predicts a more gradual increase in the likelihood of death, with a probability of roughly 80 percent at a HIC of 4,000. The lognormal curve would thus predict a higher proportion of minor injuries and a corresponding lower proportion of serious and fatal injuries, compared to the Prasad/Mertz based curve.

Intuitively, the rate of increase in the probability of death seen in the Prasad/Mertz curves seems too steep, while the probability of death predicted for high HIC levels by the lognormal curve seems too low. Unfortunately, there is no real-world data to corroborate this judgment. A range of results based on both curves will, therefore, be examined.

Figure V-1

Head Injury Risk Curves



The analysis described in the previous sections was repeated using the lognormal distribution developed by NCSA. The results of this analysis are shown in Table V-6a. Generally, the expanded Prasad/Mertz distribution predicts more fatalities saved than the corresponding lognormal distribution. The impact on injuries is far less predictable, due to the "trickle-down" effect discussed previously. Although the lognormal curves predict lower benefits generally, they actually predict a higher savings from the ITS system, due to disproportionate impact at the higher effectiveness rate.

Test Speeds

Under the proposals outlined in the NPRM, manufacturers who install improved side impact technology would be required to conduct uninflated tests at 12 mph and inflated tests at 18 mph. Since the current standard requires testing at 15 mph, this would imply an improvement in safety at high speed impacts (when the device is inflated) but a lessening of benefits at low speed impacts (when the device is uninflated). To estimate the net impacts of this trade-off, an analysis was conducted of both the 12 mph and 18 mph testing scenarios.

12 MPH Uninflated Tests

To estimate the impact of 12 mph test speeds a series of unpadded free-motion headform tests was conducted by NHTSA at 12 mph. The results of these tests was compared to previous tests conducted at 15 mph to determine the percent change in HIC that results from the lower test speed. These results are summarized in Table V-7.

With tests conducted at different speeds and angles, a different set of results was judged to be appropriate for different impact points. An average of all 4 tests was assumed for the A-pillar while only the 65 degree tests were assumed for the B-pillar (65 degrees being closest to the installed B-pillar) and only the 2,000 lb. tests were used for the side header (2,000 lb. stiffness is closest to the side header stiffness). The percent changes indicated in Table V-7 were applied to unpadded 15 mph tests results previously documented in the 6/95 FEA. This resulted in a lower implied HIC, allowing more models to pass the minimum criteria of 1,000 HIC or less. These results are shown in Table V-8 through V-10.

Table V-7
HIC(d) Unpadded Test

Stiffness	**Angle**	**Average 15 mph***	**12 mph**	**% Change**
2000	40	706.5	659	6.72%
	65	1046.5	843	19.45%
5000	40	1003	870	13.26%
	65	1810	1063	41.27%
A-pillar, (average of all 4)				20.17%
B-pillar, (average of 65 degrees)				30.36%
Side Header, (average of 2000 lbs.)				13.08%

* from Table III-8 in 6/95 FRIA

The results of Table V-8 to V-10 were combined to produce estimates of the portion of the vehicle fleet that would require padding to meet a 12 mph testing requirement. Table V-11 summarizes these results.

The padding requirements calculated in Table V-11 were substituted for 15 mph requirements used in the 6/95 FEA (see Table IV-35 in that report) and the analysis was recomputed under the new assumptions. The impact on safety benefits is shown in the 12 mph row in Table V-16.

18 MPH Inflated Tests

To estimate the impact of 18 mph inflated tests, a similar method was used with some additional adjustments to reflect the minimum effectiveness needed to meet this criteria. In order to estimate the impact of an 18 mph test requirement on HIC, the following relationship was used:

$$HIC = \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a\,dt \right]^{2.5} (t_2 - t_1)$$

Where: HIC = head injury criterion

t_1 and t_2 = any two points in time during the crash of a vehicle which are separated by not more than a 36 millisecond time interval.

a = acceleration

This is the definition of HIC as given in 49CFR571.208.

The integral of acceleration as a function of time ($\int_{t1}^{t2} adt$) is the change in velocity ($v_2 - v_1$) or Δv.

Table V-8
Projected Change to Existing Fleet w/ 12 MPH Requirement

Worst Case Estimates

Passenger Cars	Dummy HIC A-pillar 15 mph	A-Pillar 12 mph	Models Passing <1000 HIC*	Dummy HIC B-pillar 15 mph	B-Pillar 12 mph	Models Passing <1000 HIC*	Dummy HIC Side Rail 15 mph	Side Rail 12 mph	Models Passing <1000 HIC-
Ford Escort	787	628	1	943	657	1	612	532	1
Honda Civic	1010	807		883	615	1	928	806	
VW GOLF	796	635	1	1266	882	1	718	624	1
Ford Tempo	1088	869	1	1317	917	1	1050	913	1
Toyota Camry	1091	871		972	677		1248	1085	
Ford Taurus	851	679	1	1405	978	1	716	622	1
M. Grand Marquis	981	783	1	1057	736	1	1813	1576	
Buick Electra	1567	1251		914	637	1	1091	948	1
Oldsmobile Ciera	937	748	1	1209	842	1	805	700	1
Honda Civic	1331	1062		738	514		993	863	1
Chevrolet Caprice	1711	1366		1465	1020		1329	1155	
CONFIDENTIAL DATA:							0	0	
						1			1
						1			1
CONFIDENTIAL DATA:			1			1			1
			1			1			1
CONFIDENTIAL DATA:			1						
			1			1			
						1			
CONFIDENTIAL DATA:			1			1			1
			1						
						1			
CONFIDENTIAL DATA:						1			
									1
						1			1
Total Passes			11			17			13
LTV's									
S-10	1486	1186		1575	1097		925	804	1
Astro	2096	1673		927	646	1	1186	1031	
Caravan	2132	1702		1306	910	1	1905	1656	
B-150	2335	1864		1074	748	1	901	783	1
Bronco II	1957	1562		849	591	1	943	820	1
F-150	1025	818	1	1013	705	1	1694	1472	
Ford Ranger	977	780	1	1046	728	1	1240	1078	
Astro Van	2140	1708		750	522		0	0	
Econoline	1500	1197		1050	731	1	1000	869	1
Total Passes			2			7			4

* Excludes lowest HIC in duplicate tests of same model, e.g. Honda Civic, Toyota Camry, Astro

Table V-9
(Only 1" Location Needed is A-Pillar for LTVs)
Portion of Vehicle Fleet Requiring Padding to Meet 12 mph Testing

1 inch Padded HICs	Dummy HIC A-Pillar 12 mph	Models Passing <1000 HIC*	Dommy HIC B-Pillar 12 mph	Models Passing <1000 HIC*	Dummy HIC Side Rail 12 mph	Models Passing <1000 HIC*
Ford Escort	525	1	300	1	278	1
Honda Civic	632		281	1	421	
VW GOLF	529	1	402	1	326	1
Ford Tempo	665	1	418	1	477	1
Toyota Camry	666		309		567	1
Ford Taurus	557	1	446	1	325	1
M. Grand Marquis	619	1	336	1	823	1
Buick Electra	819	1	290	1	495	1
Ciera	599	1	384	1	366	1
Honda Civic	754	1	235		451	1
Chevrolet Caprice	849	1	466	1	604	1
CONFIDENTIAL DATA:		1		1		1
		1		1		1
		1		1		1
CONFIDENTIAL DATA:		1		1		1
		1				
		1				
CONFIDENTIAL DATA:				1		
		1		1		
		1		1		1
		1		1		
CONFIDENTIAL DATA:		1		1		
		1		1		1
		1		1		
CONFIDENTIAL DATA:		1		1		1
		1				
Total Passes		23		21		17
LTV's						
S-10	799	1	500	1	420	1
Astro	891		295	1	539	1
Caravan	892	1	415	1	865	1
B-150	889	1	341	1	409	1
Bronco II	882	1	270	1	428	1
F-150	638	1	322	1	769	1
CONFIDENTIAL DATA:	0		0		0	
		1		1		1
CONFIDENTIAL DATA:		1				
		1		1		1
Total Passes		8		8		8

Table V-10

2 inch Padded HICs	Dummy HIC A-Pillar 12 mph	Models Passing <1000 HIC*	Dummy HIC B-Pillar 12 mph	Models Passing <1000 HIC*	Dummy HIC Side Rail 12 mph	Models Passing <1000 HIC*
Ford Escort	536	1	347	1	298	1
Honda Civic	652		325	1	452	
VW GOLF	541	1	466	1	350	1
Ford Tempo	688	1	485	1	511	1
Toyota Camry	689		358		608	1
Ford Taurus	571	1	517	1	349	1
M. Grand Marquis	637	1	389	1	883	1
Buick Electra	867	1	337	1	531	1
Ciera	616	1	445	1	392	1
Honda Civic	788	1	272		483	1
Chevrolet Caprice	907	1	540	1	647	1
CONFIDENTIAL DATA:						
		1		1		1
		1		1		1
CONFIDENTIAL DATA:		1		1		1
		1		1		1
		1				
		1				
CONFIDENTIAL DATA:				1		
		1		1		
		1		1		1
		1		1		
CONFIDENTIAL DATA:		1		1		
		1		1		1
		1		1		
CONFIDENTIAL DATA:		1		1		1
		1				
Total Passes		23		21		17
LTV's						
S-10	842	1	580	1	450	1
Astro	978		341	1	577	1
Caravan	983	1	481	1	927	1
B-150	998	1	396	1	439	1
Bronco II	958	1	313	1	459	1
F-150	658	1	373	1	825	1
CONFIDENTIAL DATA:					0	
		1		1		1
		1				
CONFIDENTIAL DATA:		1		1		1
Total Passes		8		8		8

Table V-11
Portion of Vehicle Fleet Requiring Padding to Meet
12 mph Testing

	Padding Needed	Models Passing	Net Models Needing Padding	Weight
A-Pillars				
Cars	None	11	11	47.83%
	1/2"	23	12	52.17%
	1"	23	0	0.00%
	Total		23	100.00%
LTVs	None	2	2	25.00%
	1/2"	8	6	75.00%
	1"	8	0	0.00%
	Total		8	100.00%
B-Pillars				
Cars	None	17	17	80.95%
	1/2"	21	4	19.05%
	1"	21	0	0.00%
	Total		21	100.00%
LTVs	None	7	7	87.50%
	1/2"	8	1	12.50%
	1"	8	0	0.00%
	Total		8	100.00%
Side Rail				
Cars	None	13	13	76.47%
	1/2"	17	4	23.53%
	1"	17	0	0.00%
	Total		17	100.00%
LTVs	None	4	4	50.00%
	1/2"	8	4	50.00%
	1"	8	0	0.00%
	Total		8	100.00%

According to structural vibration theory, the acceleration response of a simple, linear elastic system is a function of its initial velocity if the system's initial displacement equals zero. This system model simulates the headform-to-pillar (or side rail) impacts very well. Therefore, it is assumed that the HIC responses of the FMH is proportional to its impact velocity to the power of 2.5.

To compute a factor that estimates the 18 mph Δv equivalent of the existing 15 mph Δv test:

$$HIC = \frac{[(1/(t_2 - t_1))^{2.5} (\Delta v_1)^{2.5} (t_2 - t_1)]}{[(1/(t_2 - t_1))^{2.5} (\Delta v_2)^{2.5} (t_2 - t_1)]}$$

$$HIC = \frac{(\Delta v_1)^{2.5}}{(\Delta v_2)^{2.5}}$$

$$HIC = \frac{(18)^{2.5}}{(15)^{2.5}}$$

$$HIC = \frac{1375}{871}$$

$$HIC = 1.577$$

This factor was applied to each 15 mph test HIC result to produce estimates of the 18 mph test HIC. These estimate are shown in Table V-12 through V-14, and their resulting padding requirements are shown in Table V-15.

Aside from the specific ITS device test data, there are currently no other test data for other possible inflation devices. The analysis is, therefore, based on the minimum effectiveness required to meet an 18 mph inflated test. This was calculated as follows:

$$e = 1 - p/h$$

Where: e = effectiveness needed to pass an 18 mph test
p = maximum HIC score needed to pass (1,000)
h = average HIC at 18 mph

The factor "h" was computed from Table V-12. It represents a simple average of the estimated 18 mph HIC's for each injury location. The averages are listed on Table V-12. The results of the minimum effectiveness calculation is shown in the far right column of Table V-15.

The new padding requirements and effectiveness rates summarized in Table V-15 were substituted for the 15 mph requirements and padding effectiveness rates used in the 6/95 FEA (see Table IV-34 and IV-35 in that report) and the analysis was recomputed under these new assumptions. A-Pillar benefits were based on a formula which expressed effectiveness as a function of HIC. To reflect the increased effectiveness of the inflatable device the effectiveness estimates produced by the A-pillar formula were increased by the ratio of the B-pillar minimum effectiveness requirement to the effectiveness of 1" of padding at the B-pillar calculated in the 6/95 FEA. One inch was chosen because, of the padding widths with a substantial requirement at the B-pillar, it produces the most conservative ratio for estimating benefits.

Table V-16 lists the benefits under the current test requirement of 15 mph as well as the 12 mph and 18 mph requirements based on the Prasad/Mertz approach. The fourth and fifth groupings on Table V-16 show the net impact of each standard separately and the last grouping shows the net result of requiring both tests together. As might be expected, the higher effectiveness of the inflatible devices reduces the more serious impacts resulting in 119 fewer fatalities and 125 fewer

MAIS 4 and 5 injuries than the current requirement of 15 mph. The reduced requirements at lower speeds together with the "trickle down" impact from reducing higher speed HICs results in 1075 more MAIS 1-3 injuries.

Table V-16b lists the results of this same analysis using the lognormal curves discussed previously. Under this assumption, the added effectiveness of the inflated devices reduce 311 fatalities and 512 MAIS 2-5 injuries. The reduced requirements at lower speeds results in 1273 more MAIS-1 inujuries. Both models thus predict a positive safety benefit against fatalities and serious injuries, at a cost of more minor injuries.

Net Impacts of Conflicting Injury Results

In order to examine the relative value of these offsetting impacts, a fatal-equivalency analysis was performed. In this analysis, the relative value of injuries of different severities in defined using comprehensive costs that reflect willingness-to-pay based studies of how people value their lives and safety. These values were obtained from NHTSA's most recent report on the costs of traffic crashes,[1] and are based on work originally published by Miller.[2] The injury specific value for each severity category was divided by the value of a fatality to produce the relative value of each injury to a fatality. These values were then multiplied by the number of injuries to produce the number of fatal equivalents. For example, the 631 additional MAIS 1 injuries that would result based on

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[1] Blincoe, LJ. The Economic Cost of Motor Vehicle Crashes, 1994. Washington, DC: U.S. Department of Transportation, NHTSA, DOT HS 808 425; July 1996.

[2] Miller, TR. The Plausible Range for the Value of Life -- Red Herrings Among the Mackerel. Journel of Forensic Economics; August, 1990.

the Prasad-Mertz curves are estimated to be the equivalent of 1.6 fatalities. This analysis is illustrated in Table 16c for both the Prasad-Mertz and Lognormal curves.

The analysis indicates that an optional test procedure of 12 mph undeployed and 18 mph deployed for inflatable systems would yield positive net safety benefits equivalent to 199 - 501 fatalities prevented annually in a full vehicle fleet.

Ejections and Pole Impacts

In addition to the interior head impacts discussed previously, ITS or HEAD systems could protect against ejection through side windows. Ejection data were gathered from 1988-1993 CDS files stratified by Delta-V. Since ITS systems deploy at 15 mph, only those ejections that occur at 15 mph or greater would be impacted. These injuries were isolated and adjusted for undercounting in CDS relative to total injuries as defined in the GES, as well as for CDS relative to FARS. A complete description of the methods used for these adjustments was included on page IV-4 of the 6/95 FEA. The results indicate a total of 398 near-side fatalities and 693 near-side nonfatal injuries from ejections that occur with a delta-V of 15 mph or greater. Data is not available to estimate the portion of these ejection cases that would be prevented or the impact that preventing these ejections would have on the injury profile. Clearly, however, there is a significant potential for additional safety benefits from this injury mode.

Table V-12
Projected Change to Existing Fleet w 18 MPH Requirement

Model	Dummy HIC A-Pillar 15 mph	A-Pillar 18 mph	Models Passing < 1000 HIC*	Dummy HIC B-Pillar 15 mph	B-Pillar 18 mph	Models Passing < 1000 HIC*	Dummy HIC Side Rail 15 mph	Side Rail 18 mph	Impacted Models
Ford Escort	787	1241		943	1488		612	965	
Honda Civic	1010	1594		883	1392		928	1464	
VW GOLF	796	1256		1266	1997		718	1133	
Ford Tempo	1088	1717		1317	2077		1050	1656	
Toyota Camry	1091	1721		972	1533		1248	1969	
Ford Taurus	851	1342		1405	2216		716	1129	
M Grand Marquis	981	1547		1057	1667		1813	2860	
Buick Electra	1567	2472		914	1442		1091	1720	
Oldsmobile Ciera	937	1478		1209	1907		805	1271	
Honda Civic	1331	2100		738	1164		[illegible]93	1566	
Chevrolet Caprice	1711	2699		1465	2311		1329	2096	
CONFIDENTIAL DATA:							0	0	
CONFIDENTIAL DATA:									
CONFIDENTIAL DATA:									
CONFIDENTIAL DATA:									
CONFIDENTIAL DATA:									
Total Passes			0			0			1
LTV's									
S-10	1486	2344		1575	2484		925	1459	
Astro	2096	3306		927	1462		1186	1871	
Caravan	2132	3363		1306	2060		1905	3005	
B-150	2335	3683		1074	1694		901	1421	
Bronco II	1957	3087		849	1339		943	1488	
F-150	1025	1616		1013	1597		1694	2672	
CONFIDENTIAL DATA:	0	0		0	0		0	0	
CONFIDENTIAL DATA:									
Total Passes			0			0			0

*Excludes lowest HIC if duplicate tests of same model, e.g., Honda Civic, Toyota Camry, Astro.

Table V-13

1 inch Padded HICs	Dummy HIC A-Pillar 18 mph	Models Passing <1000 HIC*	Dummy HIC B-Pillar 18 mph	Models Passing <1000 HIC*	Dummy HIC Side Rail 18 mph	Models Passing <1000 HIC*
Ford Escort	816	1	679	1	504	1
Honda Civic	885		635	1	765	1
VW GOLF	821	1	911	1	592	1
Ford Tempo	892	1	948	1	865	1
Toyota Camry	892		700		1029	
Ford Taurus	843	1	1011		590	1
M. Grand Marquis	880	1	761	1	1494	
Buick Electra	743	1	658	1	899	1
Ciera	871	1	870	1	664	1
Honda Civic	858	1	531		819	1
Chevrolet Caprice	634	1	1054		1096	1
CONFIDENTIAL DATA		1		1		1
		1		1		1
		1		1		1
CONFIDENTIAL DATA		1		1		1
		1				
		1				
CONFIDENTIAL DATA				1		
		1		1		
		1		1		1
CONFIDENTIAL DATA		1				
		1		1		
		1				
CONFIDENTIAL DATA		1		1		
		1				1
		1				
Total Passes		23		16		15
LTV's						
S-10	792	1	1134		762	1
Astro	194		667	1	978	1
Caravan	142	1	940	1	1570	
B-150	-186	1	773	1	743	1
Bronco II	378	1	611	1	777	1
F-150	887	1	729	1	1396	
CONFIDENTIAL DATA:	0		0		0	
		1		1	1022	
CONFIDENTIAL DATA:		1				
		1		1		1
Total Passes		8		7		5

Table V-14

½ inch Padded HICs	Dummy HIC A-Pillar 18 MPH	Models Passing <1000 HIC*	Dummy HIC B-Pillar 18 MPH	Models Passing <1000 HIC*	Dummy HIC Side Rail 18 MPH	Models Passing <1000 HIC*
Ford Escort	864	1	787	1	541	1
Honda Civic	965		736	1	820	
VW GOLF	869	1	1056		634	1
Ford Tempo	985	1	1098		928	1
Toyota Camry	985		811		1103	
Ford Taurus	899	1	1172		633	1
M. Grand Marquis	955	1	882	1	1602	
Buick Electra	937	1	763	1	964	1
Ciera	939	1	1009		712	1
Honda Civic	997	1	616		877	1
Chevrolet Caprice	865	1	1222		1174	
CONFIDENTIAL DATA:		1				
				1		
		1		1		1
CONFIDENTIAL DATA:		1		1		1
		1				
		1				
CONFIDENTIAL DATA:				1		
		1		1		
		1		1		1
Total Passes		1				
CONFIDENTIAL DATA:		1		1		
		1				
		1				
		1				1
		1				
Total Passes		22		11		11
LTV's						
S-10	966	1	1314		817	1
Astro	543		773	1	1048	
Caravan	503	1	1089		1683	
B-150	247	1	896	1	796	1
Bronco II	681	1	708	1	833	1
F-150	969	1	845	1	1497	
CONFIDENTIAL DATA:					0	
		1		1		
		1				
		1		1		1
		8		6		4

Table V-15

	Padding Needed	Models Passing	Net Models Needing Padding	Weight	Avg. Eff. 18 MPH	Hypothetical Eff. Need to Pass
A-Pillar						
Cars	None	0	0	0.00%	52.97%	52.97%
	1/2"	22	22	95.65%		
	1"	23	1	4.35%		
	Total		23	100.00%		
LTVs	None	0	0	0.00%	62.58%	62.58%
	1/2"	8	8	100.00%		
	1"	8	0	0.00%		
	Total		8	100.00%		
B-Pillars						
Cars	None	0	0	0.00%	45.91%	45.91%
	1/2"	11	11	68.75%		
	1"	16	5	31.25%		
	Total		16	100.00%		
LTVs	None	0	0	0.00%	41.45%	41.45%
	1/2"	6	6	85.71%		
	1"	7	1	14.29%		
	Total		7	100.00%		
Side Rail						
Cars	None	1	1	6.67%	32.33%	34.64%
	1/2"	11	10	66.67%		
	1"	15	4	26.67%		
	Total		15	100.00%		
LTVs	None	0	0	0.00%	48.45%	48.45%
	1/2"	4	4	80.00%		
	1"	5	1	20.00%		
	Total		5	100.00%		

Table V-16
Net Impact of 12 mph Uninflated and 18 mph
Inflated Requirements

NET BENEFITS	MAIS1	MAIS2	MAIS3	MAIS4	MAIS5	Fatal
Current Std (15mph)						
PC	361	358	42	29	36	711
LTV	671	259	19	9	16	334
Total	1032	617	61	38	52	1045
12 mph:						
PC	-79	-243	-20	-2	19	367
LTV	52	168	8	5	5	211
Total	-27	-75	-12	3	24	578
18 mph						
PC	740	530	96	73	150	1177
LTV	622	344	29	15	40	454
Total	1362	874	125	88	190	1631
Net 12 mph						
PC	-440	-601	-62	-31	-17	-344
LTV	-619	-91	-11	-4	-11	-123
Total	-1059	-692	-73	-35	-28	-467
Net 18 mph						
PC	379	172	54	44	114	466
LTV	-49	85	10	6	24	120
Total	330	257	64	50	138	586
Net Offset						
PC	-61	-429	-8	13	97	122
LTV	-570	-6	-1	2	13	-3
Total	-631	-435	-9	15	110	119

Table V-16b
Net Impact of 12 mph Uninflated and 18 mph Inflated
Requirements Lognormal Curves

NET BENEFITS	MAIS1	MAIS2	MAIS3	MAIS4	MAIS5	Fatal
Current Std (15mph)						
PC	454	84	46	39	82	575
LTV	389	361	19	14	30	298
Total	843	445	65	53	112	873
12 mph						
PC	-492	160	24	28	44	274
LTV	93	63	11	7	19	166
Total	-399	223	35	35	63	440
18 mph						
PC	165	553	144	158	236	1159
LTV	131	286	34	29	66	458
Total	296	839	178	187	302	1617
Net 12 mph						
PC	-946	76	-22	-11	-38	-301
LTV	-296	-298	-8	-7	-11	-132
Total	-1242	-222	-30	-18	-49	-433
Net 18 mph						
PC	-289	469	98	119	154	584
LTV	-258	-75	15	15	36	160
Total	-547	394	113	134	190	744
Net Offset						
PC	-1235	545	76	108	116	283
LTV	-38	-373	7	8	25	28
Total	-1273	172	83	116	141	311

Table 16c
Analysis of Net Fatal Equivalents of 12 mph Uninflated and 18 mph Inflated Requirements, Prasad-Mertz Curves

	Injuries Prevented	Comp. Cost	Non-Injury Cost	Injury Comp. Cost	Injury/Fatal Value	Fatal Equivalents
MAIS1	-631	$10,840	$3,466	$7,374	0.002591	-1.64
MAIS2	-435	$133,700	$3,559	$130,141	0.045745	-19.90
MAIS3	-9	$472,290	$5,974	$466,316	0.163912	-1.48
MAIS4	15	$1,193,860	$8,548	$1,185,312	0.416643	6.25
MAIS5	110	$2,509,310	$8,221	$2,501,089	0.879145	96.71
Fatal	119	$2,854,500	$9,591	$2,844,909	1	119.00
Net Impact, Fatal Equivalents						198.95
Lognormal Curves						
	Injuries Prevented	Comp. Cost	Non-Injury Costs	Injury Comp. Cost	Injury/Fatal Value	Fatal Equivalents
MAIS1	-1273	$10,840	$3,466	$7,374	0.002591	-3.30
MAIS2	172	$133,700	$3,559	$130,141	0.045745	7.87
MAIS3	83	$472,290	$5,974	$466,316	0.163912	13.60
MAIS4	116	$1,193,860	$8,548	$1,185,312	0.416643	48.33
MAIS5	141	$2,509,310	$8,221	$2,501,089	0.879145	123.96
Fatal	311	$2,854,500	$9,591	$2,844,909	1	311.00
Net Impact, Fatal Equivalents						501.46

Another category of injuries that would be impacted by ITS or HEAD devices is pole impacts. Data from Table IV-3 indicate that impacts into trees or telephone poles account for 20.6 percent of all side impact fatalities. However, not all of these cases would benefit from ITS or HEAD systems. In order to isolate those cases that would benefit, CDS data from 1988-93 were analyzed using the following selection constraints.

1. front outboard occupants
2. not ejected
3. passenger vehicle hit tree or pole as most severe impact
4. MAIS is head, face or neck exclusively
5. either intruding component or injury source is "other exterior object"

The resulting data were then adjusted for undercounting using the same procedures as for ejections. The results indicate that an estimated 73 fatalities and 61 nonfatal injuries occur in intrusive pole impacts to the side of the vehicle.

The ITS tests previously discussed resulted in an 87 percent reduction in HIC levels at roughly 19 mph. The base HIC at that level was roughly 2,500. Of the 56 unadjusted CDS fatal cases, 22 occurred at delta-V's in excess of 18 mph and the remainder occurred at unknown delta-V's. By way of illustration, the chance of a fatality at a HIC of 2,450 is 82 percent (see Table IV-28 in the 6/95 FEA). An 87 percent reduction in HIC from that level virtually eliminates the chance of a fatality. While many of these cases may have occurred at much higher HICs, the potential savings from these devices in pole impacts should be significant.

In their docket comments (92-28-N06-005) in response to the March 7, 1996, ANPRM, BMW noted that the rear ITS anchorage, which is the same as SR3 for purpose of FMVSS 201 certification/compliance testing, may not provide protection for the rear outboard passenger from 12 to 15 mph with the ITS deployed. As stated in their comments "...BMW concedes that with respect to the single point SR3 for the rear occupant, the ITS system does not provide protection between 12 to 15 mph, but, in the aggregate, ITS provides superior head protection to that required by the Amendment." For 15 mph head protection at least 1.0 to 1.5 inches of static padding are needed, and unfortunately, the ITS cannot deploy through more than 1 inch of padding and still meet packaging and performance requirements. The implication is that BMW will need an exemption of SR3 from the FMVSS No. 201 upper interior head protection requirements.

The rear passenger is a very small target population, hence any loss in benefits from exempting SR3 would be very small. The head injury target population for the head striking the rear side rail for passenger cars and light trucks was derived from CDS data for the years 1988-1993. This data was adjusted to reflect the undercounting of fatals in the CDS using the ratio of fatalities in FARS to those in CDS. The results are shown in Table 17.

Table 17
Side Rail Target Populations

Head to Rear Side Rail Injuries	Passenger Cars	Light Trucks	Total
MAIS 1-5	1,796	515	2,311
Fatal	172	1	173

If it is assumed that one tenth (1/10) of all rear side rail head impacts occur at the SR3 target point, (an arbitrary, but not unreasonable assumption), the SR3 target population would be about 17 fatal injuries and 230 non-fatal injuries. The number of fatal and non-fatal head injuries would be expected to be higher because head protection is compromised at SR3 due to a lower test speed. A rough estimate of the fatalities that would result was calculated as follows:

$f_n = f * e * r$

Where: f_n = added fatals at SR3 point from 12 mph test
e = implied effectiveness rate of 15 mph standard in reducing head injury
r = percent reduction in safety benefits due to reduction in test speed to 12 mph
f = base case target population fatalities at SR3 point (17)

e is calculated from data in Table 16 of this analysis and from data in Table IV-13 and Table IV-14 in the 6/95 FEA. These data show a reduction of 1045 fatalities from the base target population of 2166 fatalities in passenger cars and LTVs, a 48.2 percent reduction.

r is calculated as k/f_s where f_s is the fatalities saved by 15 mph standards (f*e) and k is the loss in f_s due to 12 mph standards. From Table V-16, r = 467/1045 = .4469

f = 17 * .482 * .447
f = 3.7

The incremental increase in fatals would thus be very small (about 4 fatalities would be given up), assuming that all (100 %) passenger cars and light trucks had the ITS system.

Initially, the ITS system will be offered as an option on a few selected BMW vehicles (700 series by March, 1997). Since Autoliv plans to license the ITS system to others at some point in the future; its popularity as a safety countermeasure may grow and many more vehicles could be affected down-stream at the SR3 target point. It is impossible at this time to know the actual number of vehicles affected. Assuming all passenger cars and light trucks would be equipped with the ITS system, the aggregated loss of benefits at SR3 will be more than off-set. (See Table 18), by the benefits accrued from the higher certification test speed (an 18 mph lateral pole impact test) for the other ITS protected target points. Intrusion benefits and ejection benefits, not quantified in NPP's analysis, would also contribute to the net benefits gained at 18 mph.

Table 18

Gained and Lost Benefits from the ITS System

	Mertz-Prasad Method	Lognormal Method
Lost Benefits from ITS @ 12-15 mph	1,075 MAIS 1-3	1,273 MAIS-1
Gained Benefit from ITS @ 18 mph	119 Fatalities 125 MAIS 4-5	311 Fatalities 512 MAIS 2-5
Lost Benefits @ SR3 if Exempted from FMVSS 201	4 Fatalities	4 Fatalities

VI. COST AND LEAD TIME

Since HEADS is optional, no FMVSS costs are incurred for the associated design, engineering, hardware or compliance testing of HEADS countermeasures. However, the manufacturers will incur compliance costs and expenses. This section outlines those costs.

Option #1 compliance costs are the same as the FMVSS No. 201 final rule and Option #2 compliance costs are nearly the same as the 201 final rule. The HEADS Crash Sensor Test, under Option #2, can be piggy-backed on an existing FMVSS No. 214 side impact certification test at minimal or no cost. This assumes proper vehicle selection and advanced planning to reduce or minimize compliance costs. Otherwise, an FMVSS No. 214 compliance crash test costs about $13K, excluding the test vehicle cost. There may be some unknowns with regard to the FMH test procedure for certifying dynamic padding or inflatable trim which may add cost. Since hardware for dynamic padding systems does not exist, NHTSA was not able to try out the existing 201 static padding test procedure.

Option #3 (the 18 mph pole test) is where the additional compliance test costs will be incurred; (1) it is estimated that the pole test will cost in the range of $10-13K (excluding the cost of the test vehicle), (2) the added calibration tests for the head, neck, thorax, lumber spine and pelvis (n=5) are estimated by VRTC to cost about $350 each or $1,750 (5 X $350) total per HEADS test and (3) the tight 69-72 degree F full-scale test temperature range will add to the cost of a standard FMVSS 214 test. The cost of the new bracket is estimated to be about $200-$300. A mechanical drawing of the new bracket is shown in Illustration 7 and consists of three fabricated pieces of 6061 aluminum. The new bracket will be available to support manufacturer's pole testing. Existing SID dummies, Hybrid III head/neck hardware and standard laboratory calibration equipment will be used and no additional cameras or extra data processing is expected for the pole test. There may be some strategies for efficiently utilizing both sides of a test vehicle to reduce the test vehicle costs associated with HEADS certification.

It is assumed that the severity of the pole test will not create more rib replacements than currently experienced in side crash testing. It is believed that most, if not all, crash test facilities have a fixed frontal barrier with a pole crash test hardware that can be installed as an option. Pole tests have been conducted by the manufacturers for research and development purposes for 30 years. Some of the roll, pitch and yaw controls needed to reduce/eliminate pole centerline to head CG variability, may add cost to the existing Tow Cable and Rail Systems. For example, a pair of the above ground stabilization rails and trollies, like the FOIL facility, may cost an added $15-20K per facility to build, fabricate and install. If the rails are not extended past the pole in a FOIL-type set-up, a controlled coefficient of friction surface 10-12 feet in front of the pole may add cost. Roll, pitch and yaw instrumentation may be needed to measure compliance with the Test Procedure boundaries. This rule would be effective 30 days after issuance of the final rule. Optional HEADS hardware consumer cost is unknown.

Carry-Forward Credits Applicable to Phase-in Schedule

In the 201 final rule published August 18, 1995 (60 FR 430312), NHTSA allowed manufacturers to earn carry-forward credits during the phase-in period for producing complying vehicles in excess of the percentage of production required in the early years of the phase-in.

In its petition for reconsideration, Honda asked that manufacturers be allowed to carry-forward credits for vehicles which are produced prior to the beginning of the phase-in and which comply with the new requirements. In the April 8, 1997 final rule (62 FR 16718) addressing the petitions for consideration, NHTSA allowed carry-forward credits for vehicles certified to the new requirements (identified as Option 1 in this NPRM) prior to the beginning of the phase-in.

NHTSA is aware that in June 1997, the 1998 BMW 700 Series was marketed in the U.S. with a dynamic head protection system namely, the Integrated Tubular System (ITS). Other manufacturers may follow this lead. In view of this, NHTSA is proposing that the production of vehicles with dynamic head protection systems certified using Option 2 or 3, which may begin prior to the phase-in, be allowed to be carried-forward and included in the calculation of compliance with the phase-in schedule. For this purpose, Options 2 (18 mph FMH HEADS deployed) and Option 3 (18 mph lateral pole test) would be defined in the 201 HEADS final rule, which would be issued later.

VII. SMALL BUSINESS IMPACTS

The Regulatory Flexibility Act of 1980 (Public Law 96-354) requires agencies to evaluate the potential effects of their proposed and final rules on small business, small organizations, and small governmental jurisdictions. Business entities are defined as small by standard industry classification for the purpose of receiving Small Business Administration assistance. One of the criteria for determining size as stated in 13 CFR 121.601 (as of January 1, 1992) is the number of employees in the firm. None of the suppliers of HEADS or manufacturers utilizing HEADS are believed to be Small Businesses. In addition, this would be an optional compliance methodology, not a requirement. NHTSA is not aware of any second stage manufacturer or alterer issues with regard to HEADS. HEADS will be manufactured by suppliers and installed by the OEMs.

VIII. CUMULATIVE IMPACTS OF RECENT RULEMAKINGS

Section 1(b)11 of Executive order 12866 Regulatory Planning and Review requires the agencies to take into account to the extent practicable "the costs of cumulative regulation." To adhere to this requirement, the agency has decided to examine both the costs and benefits by vehicle type of all substantial final rules with a cost or benefit impact in MY 1990 or later. In addition, proposed rules will also be identified and preliminary cost and benefit estimates provided. Costs include primary cost, secondary weight costs, and the lifetime discounted fuel costs for both primary and secondary weight. Costs will be presented in two ways, the cost per affected vehicle and the average cost over all vehicles. The cost per affected vehicle includes the range of costs that any vehicle might incur. For example, if two different vehicles need different countermeasures to meet the standard, a range will show the cost for both vehicles. The average cost over all vehicles takes in to account voluntary compliance before the rule was promulgated or planned voluntary compliance before the rule was effective and the percent of the fleet for which the rule is applicable. Costs are provided in 1993 dollars, using the implicit GDP deflator to inflate previous estimates to 1993 dollars. Benefits are provided on an annual basis for the fleet once all the vehicles in the fleet meet the rule. Benefit and cost per average vehicle estimates take into account voluntary compliance.

Table VIII-1
Costs of Recent Passenger Car Rulemakings
(Includes Secondary Weight and Fuel Impacts)
(1993 Dollars)

Description	Effective Model Year	Cost Per Affected Vehicles $	Cost Per Average Vehicle $
FMVSS 208, Automatic Restraints	1990 100% of phase-in	$432 - 522 dual air bag $241 motorized auto belt $29 - 65 non-motor auto belt.	Depends on model year. Eventually all air bags. See below.
FMVSS 114, Key Locking System Prevent Child-Caused Rollaway	1993	$8.10 - 16.80	$0.45 - 0.93
FMVSS 214, Dynamic Side Impact Test	1994 - 10% 1995 - 25% 1996 - 40% 1997 - 100	$59.25 - 577.08	$53.64
FMVSS 208, Locking Latch Plate for Child Restraints	1996	$0.77 - 15.38	$2.06
FMVSS 208, Belt Fit	1998	$2.93 - 14.67	$1.08 - 1.56
FMVSS 208 Air Bags Req'ed	1997 - 95% 1998 - 100	$432 - 522	$432 - 522
FMVSS 201	1999 - 10% 2000 - 25% 2001 - 40% 2002 - 70% 2003 -100%	$32.40	$32.40

Table VIII-2
Benefits of Recent Passenger Car Rulemakings
(Annual benefits when all vehicles meet the standards)

Description	Fatalities Prevented	Injuries Reduced	Property Damage Savings $
FMVSS 208, Automatic Restraints	See air bags below	See air bags below	None
FMVSS 114, Key Locking System Prevent Child Caused Rollaway	None	50 - 99 Injuries	Not Estimated
FMVSS 214, Dynamic Side Impact Test	512	2,626 AIS 2-5	None
FMVSS 208, Locking Latch Plate for Child Restraints	Not estimated	Not estimated	None
FMVSS 208, Belt Fit	7	244 AIS 2-5	None
FMVSS 208 Air Bags Required * Compared to 12.5% Usage in 1983	4,570 - 9,110	AIS 85,930 - 155,090	None
Compared to 46.1% Usage in 1991	2,842 - 4,505	63,000 - 105,000	
FMVSS 201	575 - 711	251 - 465 AIS 2-5	None

* Using recent analyses by NHTSA, compared to 1994 fatalities, if all passenger cars had air bags, an estimated 2,000 fatalities would be prevented annually.

Table VIII-3
Costs of Recent Light Truck Rulemakings
(Includes Secondary Weight and Fuel Impacts)
(1993 Dollars)

Description	Effective Model Year	Cost Per Affected Vehicle $	Cost Per Average Vehicle $
FMVSS 208, Head Restraints	1992	$40.22 - 97.56	$4.76
FMVSS 204, Steering Wheel Rearward Displacement for 4,000 to 5,500 lbs. Unloaded	1992	$5.19 - 25.69	$0.92 - 1.74
FMVSS 208, Rear Seat Lap/Shoulder Belts	1992	$59.41	$0.35
FMVSS 114, Locking System to Prevent Child-Caused Rollaway	1993	$8.10 - 16.80	$0.01 - 0.03
FMVSS 208, Locking Latch Plate for Child Restraints	1996	$0.77 - 15.38	$2.06
FMVSS 108, Center High-Mounted Stop Lamps	1994	$12.92 - 19.53	$13.32
FMVSS 214, Quasi-Static Test (side door beams)	1994 - 90% 1995 - 100	$57.81 - 72.50	$53.59 - 67.31
FMVSS 216, Roof Crush for 6,000 lbs. GVWR or less	1995	$21.29 - 191.04	$0.77 - 7.57
FMVSS 208, Automatic Restraints	1995 - 20% 1996 - 50% 1997 - 90% 1998 - 100	See below	See below
FMVSS 208, Belt Fit	1998	$3.23 - 15.30	$5.52 - 7.45
FMVSS 208, Air Bags Required	1998 - 90% 1999 - 100	$432 - 522 dual air bags	$432 - 522 dual air bags
FMVSS 201	1999 - 10% 2000 - 25% 2001 - 40% 2002 - 70% 2003 - 100	$32.09 - 70.27	$49.52

Table VIII-4
Benefits of Recent Light Truck Rulemakings
(Annual benefits when all vehicles meet the standard)

Description	Fatalities Prevented	Injuries Reduced	Property Damage Savings $
FMVSS 208, Head Restraints	None	470 - 835 AIS 1 20 - 35 AIS 2	None
FMVSS 204, Steering Wheel Rearward Displacement for 4,000 to 5,500 lbs. Unloaded	12 -23	146 - 275 AIS 2-5	None
FMVSS 208, Rear Seat Lap/Shoulder Belts	None	2 AIS 2-5	None
FMVSS 114, Locking System to Prevent Child-Caused Rollaway	None	1 Injury	Not Estimated
FMVSS 208, Locking Latch Plate for Child Restraints	Not estimated	Not estimated	None
FMVSS 108, Center High-Mounted Stop Lamps	None	19,200 to 27,400 Any AIS Level	$119 to 164 Million
FMVSS 214, Quasi-Static Test (side door beams)	58 -82	1,569 to 1,889 hospitalization	None
FMVSS 216, Roof Crush for 6,000 lbs. GVWR or less	2 - 5	25-54 AIS 2-5	None
FMVSS 208, Automatic Restraints	See below	See below	None
FMVSS 208, Belt Fit	9	102 AIS 2-5	None
FMVSS 208, Air Bags Required * Compared to 27.3% Usage in 1991	1,082 - 2,000	21,000 - 29,000 AIS 2-5	None
FMVSS 201	298 -334	303 - 424	None

* Using recent analyses by NHTSA, compare to 1994 fatalities, if all light trucks had air bags, an estimated 900 fatalities would be prevented annually.

Table VIII-5
Cost of Proposed Passenger Car Rules
(Includes Secondary Weight and Fuel Impacts)

Description	Effective Model Year	Cost Per Affected Vehicle $	Cost Per Average Vehicle $
Rollover	1997	$0.06 - 0.11 plus testing costs	$0.06 - 0.11 plus testing costs

Table VIII-6
Benefits of Proposed Passenger Car Rules
(Annual benefits when all vehicles meet the standard)

Description	Fatalities Prevented	Injuries Reduced	Property Damage Savings $
Rollover	TBD	TBD	TBD

Table VIII-7
Costs of Proposed Light Truck Rules
(Includes Secondary Weight and Fuel Impacts)
(1993 Dollars)

Description	Effective Model Year	Cost Per Affected Vehicle $	Cost Per Average Vehicle $
Rollover	1997	$0.06 - 0.11 plus testing costs	$0.06 - 0.11 plus testing costs

Table VIII-8
Benefit of Proposed Light Truck Rules
(Annual benefits when all vehicles meet the standard)

Description	Fatalities Prevented	Injuries Reduced	Property Damage Savings $
Rollover	TBD	TBD	TBD

APPENDIX

CROSS SECTION OF ROOF RAIL AT CENTER OF DRIVER'S HEAD
I.T.S. STOWED

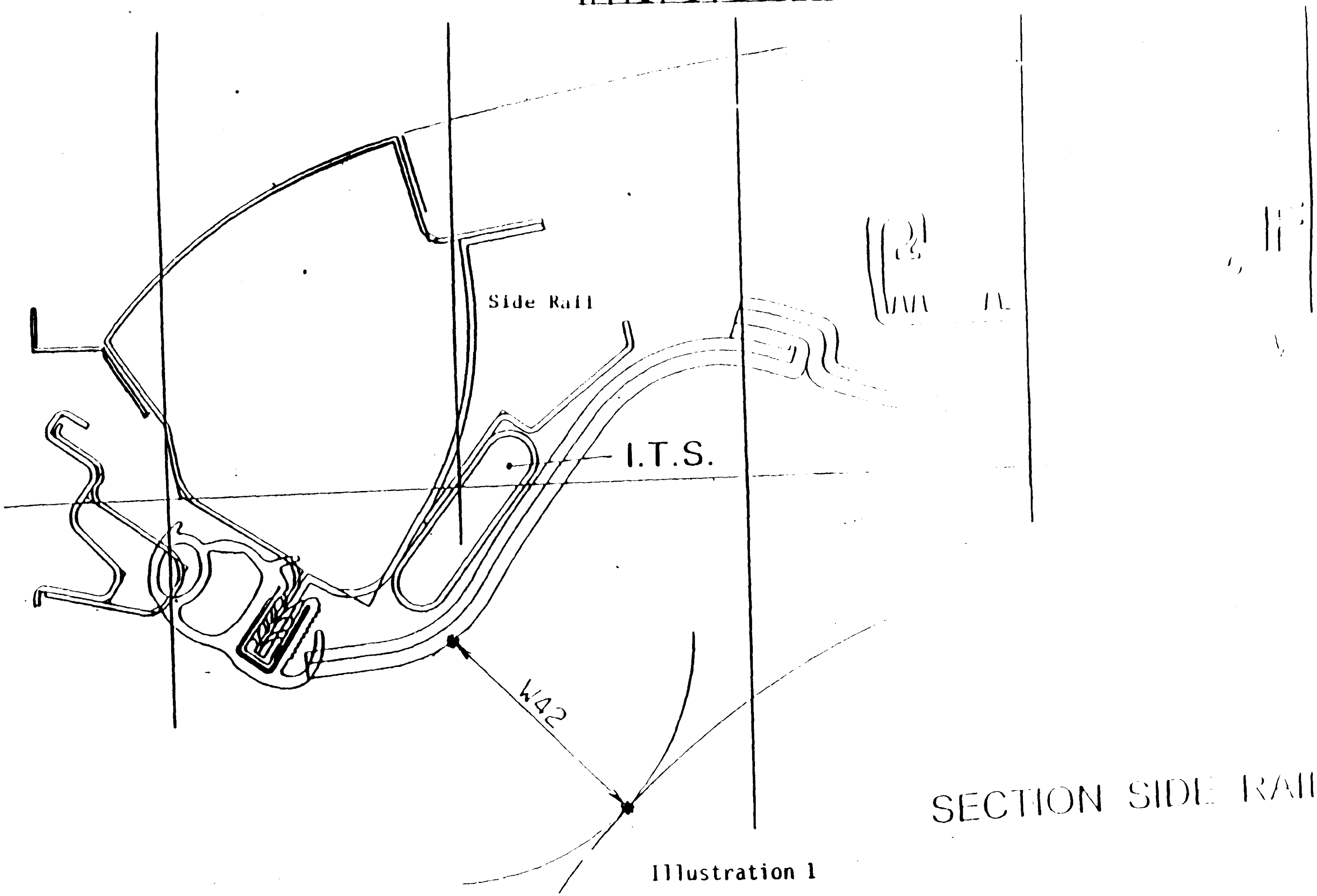


Illustration 1

I.T.S. MOUNTING LOCATIONS ON "A" PILLAR AND ROOF RAIL
I.T.S. DEPLOYED

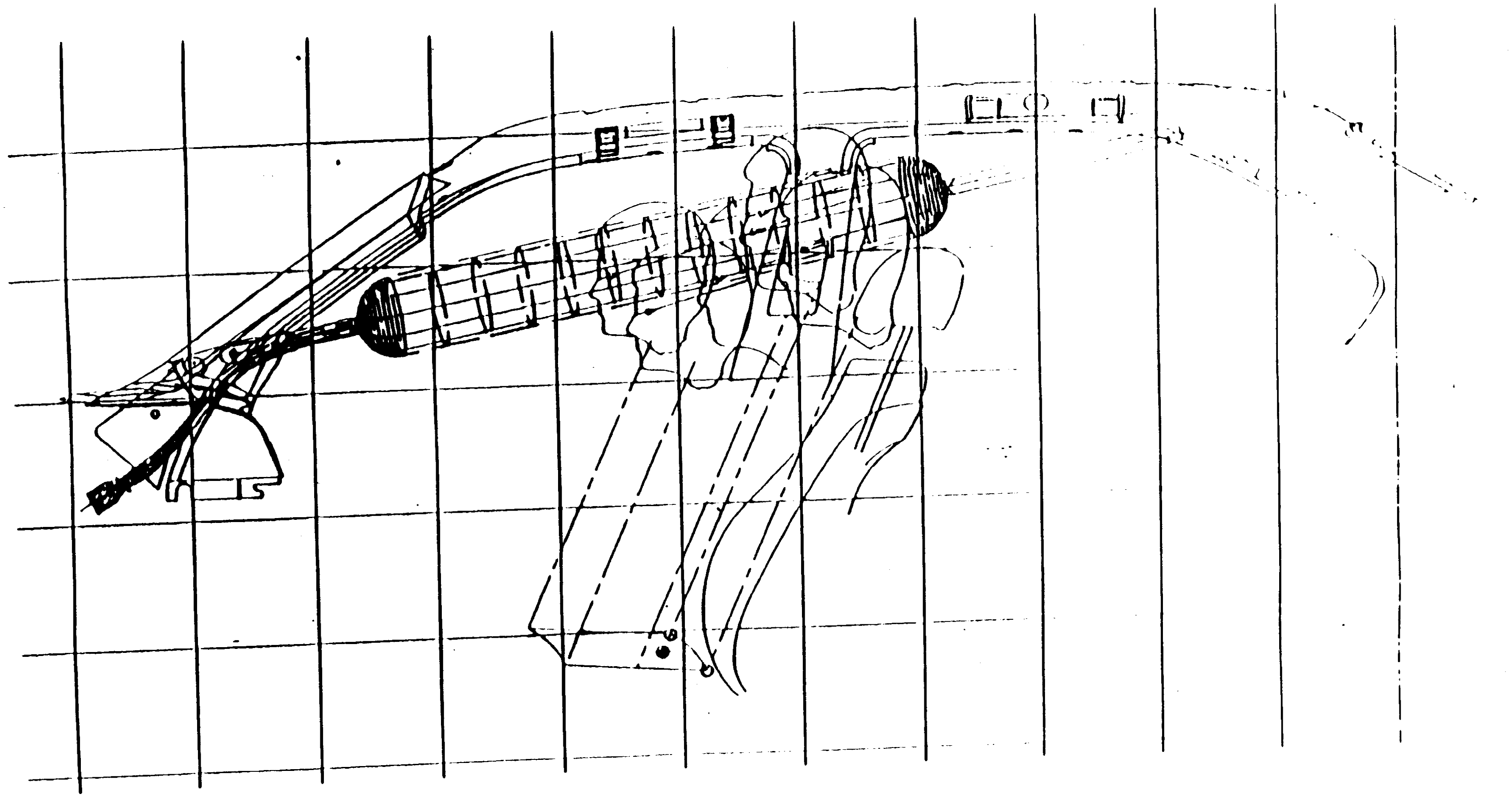
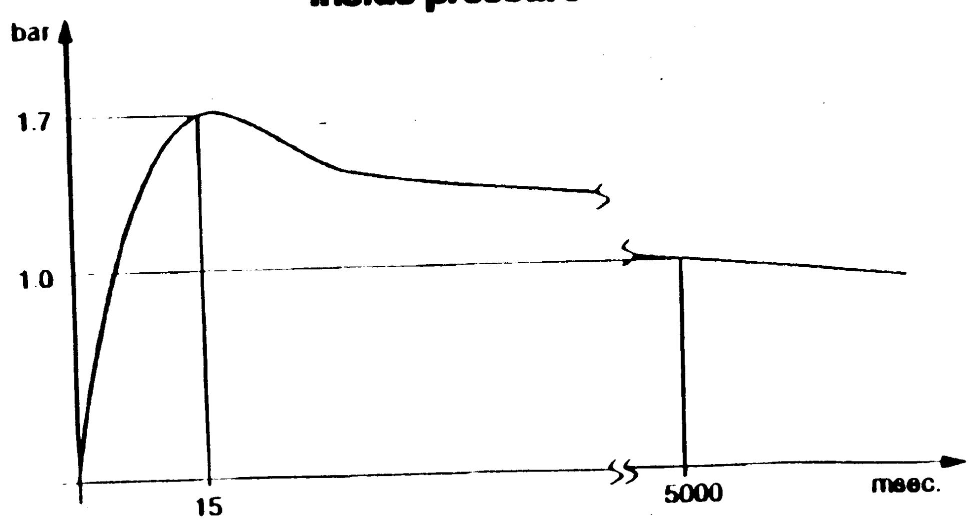


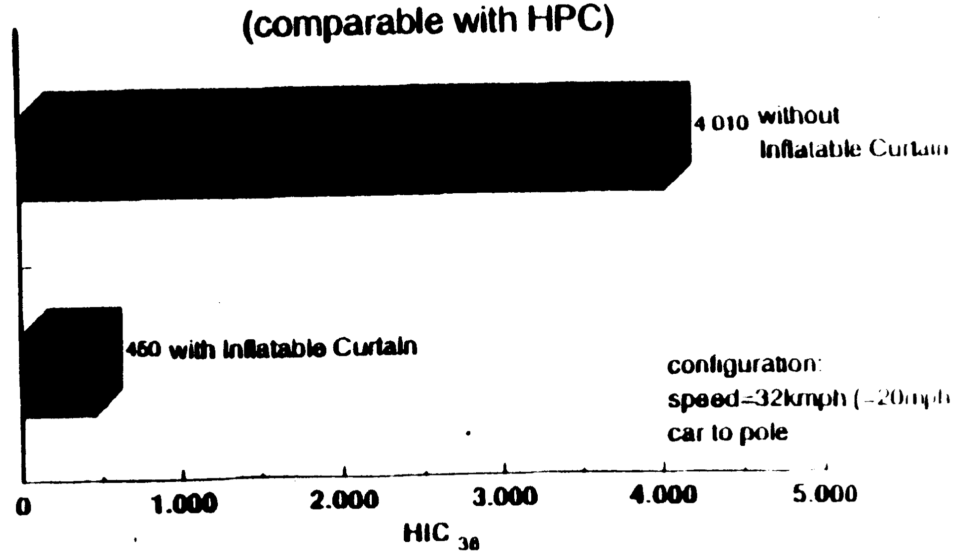
Illustration 2

Illustration 3

Inflatable Curtain

protection of front <u>and</u> rear passengers against:
- roll-over
- cut injuries
- intruding objects
- intruding car body structures





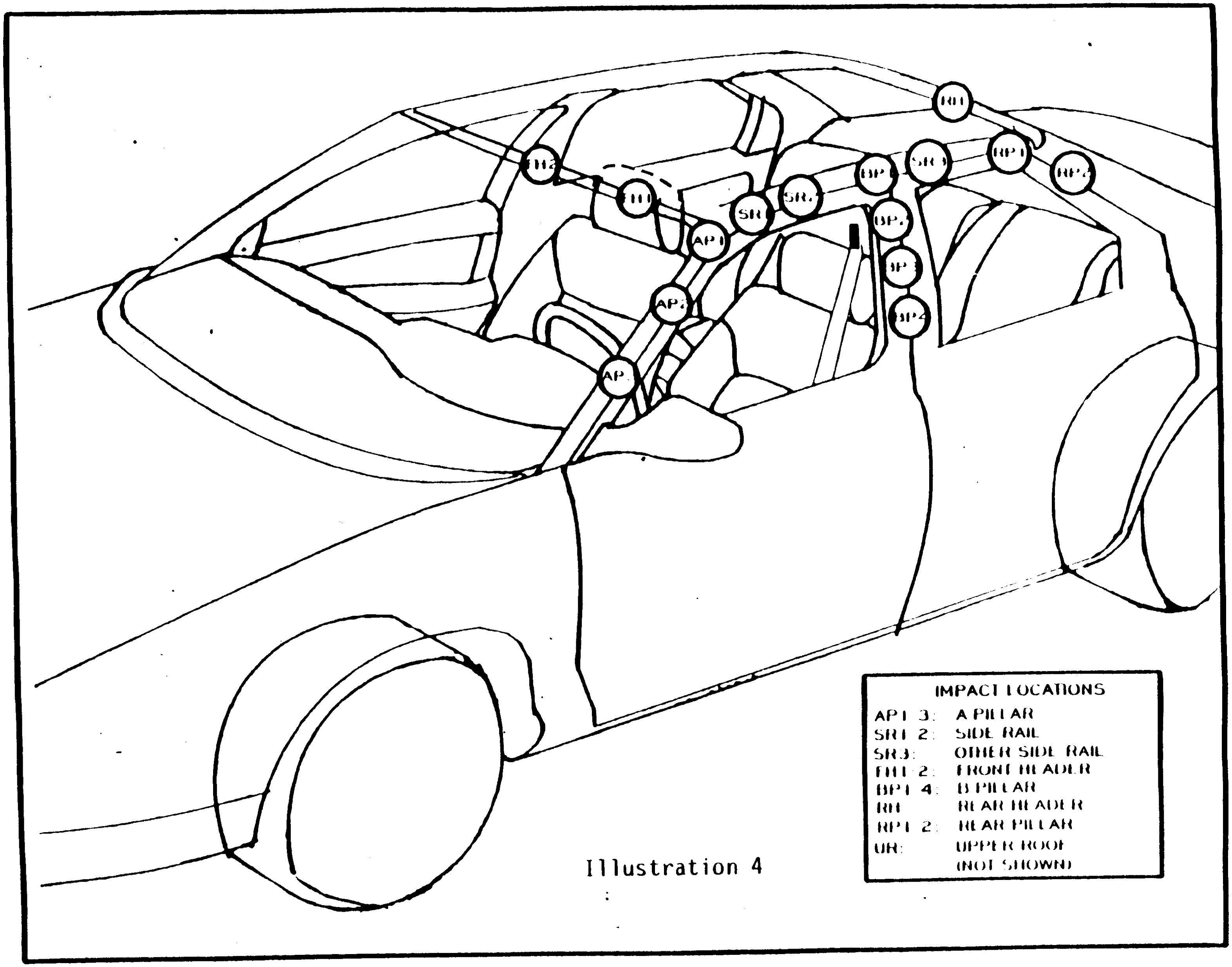
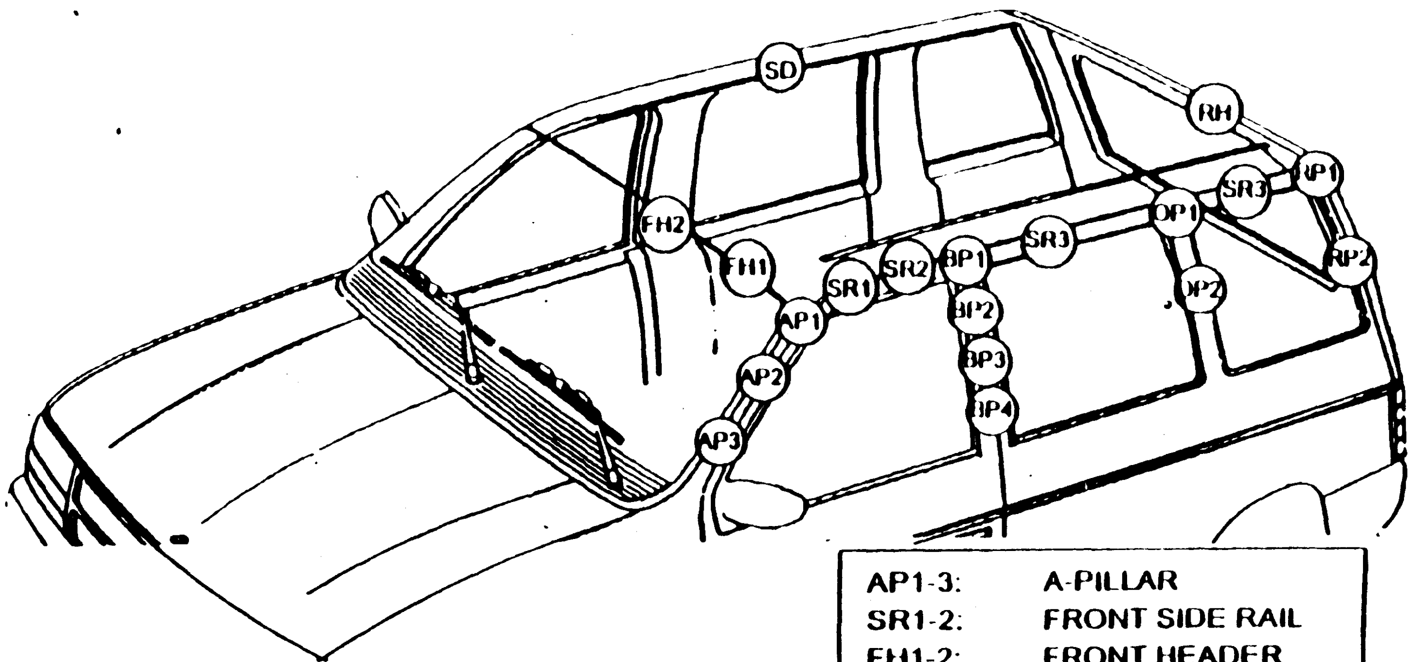


Illustration 4

Illustration 5



AP1-3:	A-PILLAR
SR1-2:	FRONT SIDE RAIL
FH1-2:	FRONT HEADER
BP1-4:	B-PILLAR
SR3:	OTHER SIDE RAIL
RH:	REAR HEADER
OP1-2:	OTHER PILLAR
RP1-2:	REARMOST PILLAR
SD:	SLIDING DOOR TRACK
UR:	UPPER ROOF (NOT SHOWN)

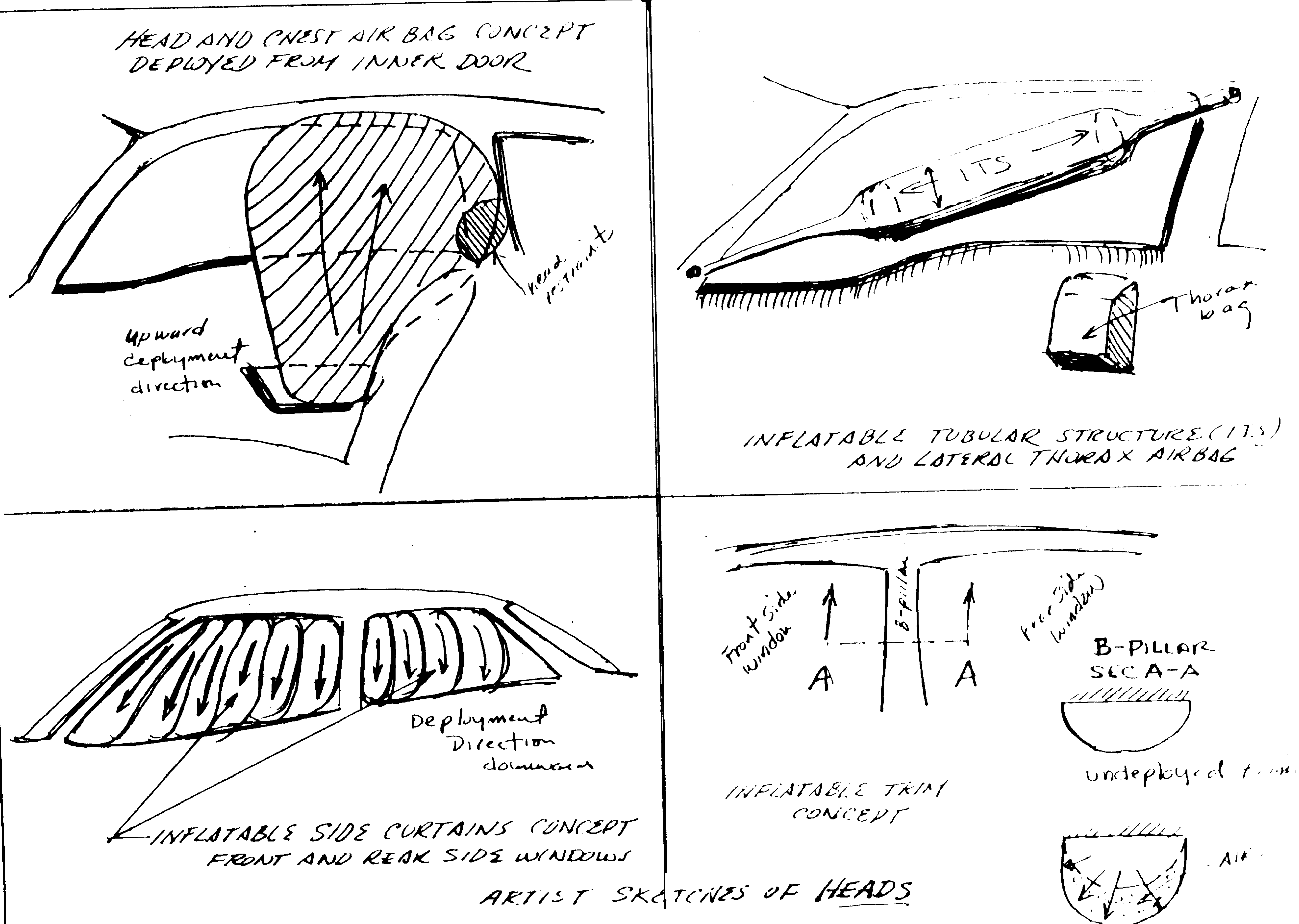
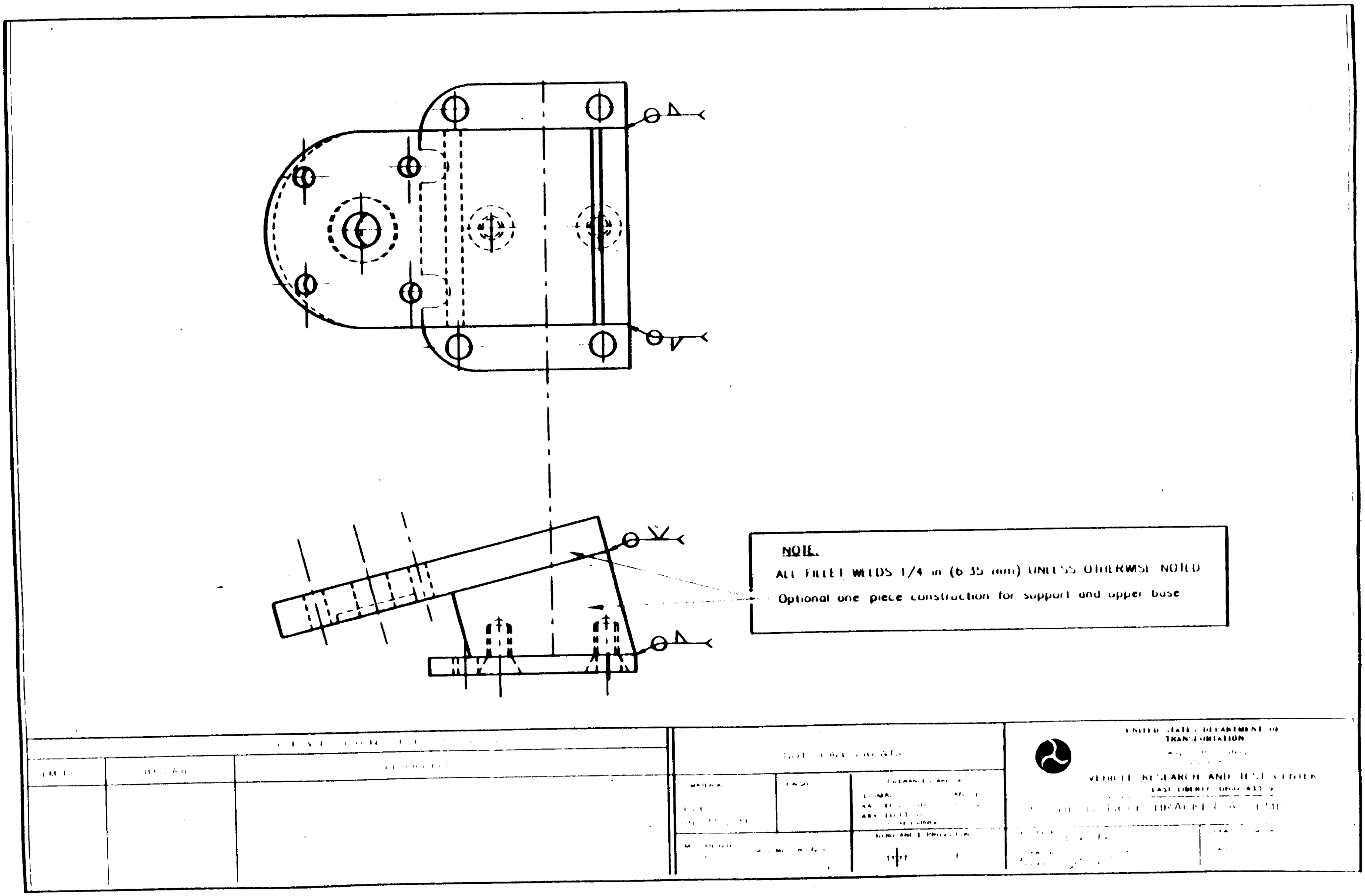


Illustration 6

Illustration 7



FMVSS No. 214: Horizontal and Vertical MDB Impact Point Variation (in.)
Upper LH MDB Face Corner vs. Target 37 Inches Forward of Wheelbase Centerline
MY 94-96 (n=55)

	Vertical (in.)	Horizontal (in.)
Average	0.32	0.11
Median	0.24	0.04
Standard Deviation	0.40	0.67

FMVSS No. 214: Horizontal and Vertical MDB Impact Point Variation (in.)
Upper LH MDB Face Corner vs. Target 37 Inches Forward of Wheelbase Centerline
MY 95-96 (n=42)

	Vertical (in.)	Horizontal (in.)
Average	0.19	-0.03
Median	0.14	0.00
Standard Deviation	0.33	0.54

* A vertical negative value implies that impact was below the nominal reference line of 33 inches above the ground. A horizontal positive value implies that impact was rearward of the nominal reference line of 37 inches forward of the wheelbase centerline.

Based on MY 1994-96 data:

Actual horizontal accuracy was 37" +.78"/-.56"
Actual horizontal range was +1.84" to -1.12"

Actual vertical accuracy was 33" +.72"/-.08"
Actual vertical range was +1.12" to -.52"

FMVSS No. 214 MDB Horizontal and Vertical Impact Point Variability

	A	B	C	D
1				
2				
3				
4		Impact Points for FMVSS 214D Compliance Testing 1994-96		
5				
6		DIVISION	MODEL	DOORS
7		CADILLAC	DEVILLE	4
8		VOLVO	850	4
9		HONDA	ACCORD	4
10		BUICK	REGAL	4
11		DODGE	INTREPID	4
12		TOYOTA	CAMRY	4
13		BUICK	ROADMASTER	4
14		LINCOLN	TOWNCAR	4
15		MITSUBISHI	GALANT	4
16		HYUNDAI	SONATA	4
17		LEXUS	SC300	2
18		SAAB	900	4
19		NISSAN	240SX	2
20		MAZDA	MILLENIA	4
21		VOLKSWAGEN	AUDI 90	4
22		SUBARU	IMPREZA	4
23		NISSAN	MAXIMA	4
24		HYUNDAI	SONATA	4
25		MAZDA	PROTEGE	4
26		SUBARU	LEGACY	4
27		SUBARU	IMPREZA	4
28		CHEVROLET	CAMARO	2
29		CHEVROLET	MONTE CARLO	2
30		MERCURY	MYSTIQUE	4
31		FORD	THUNDERBIRD	2
32		MITSUBISHI	GALANT	4
33		VOLKSWAGEN	CABRIO - conv	2
34		TOYOTA	TERCEL	2
35		TOYOTA	AVALON	4
36		VOLVO	850	4
37		MERCEDES BENZ	C220	4
38		VOLKSWAGEN	GOLF III H/B	4
39		GEO	METRO	4
40		CHRYSLER	CIRRUS	4
41		SUBARU	IMPREZA	4
42		BMW	318ic - conv	2
43		SAAB	900 SE -conv	2
44		GEO	METRO 3DR HB	2
45		SATURN	SL1	4
46		FORD	TAURUS	4
47		FORD	MUSTANG	2
48		Acura	2.5TL	4

FMVSS No. 214 MDB Horizontal and Vertical Impact Point Variability

	A	B	C	D
49		Mazda	626	4
50		Nissan	Sentra	4
51		Nissan	200SX	2
52		Mitsubishi	Eclipse*	2
53		Buick	Riviera	2
54		Subaru	Impreza	2
55		Saab	900S	2
56		Honda	Accord Coupe	2
57		Hyundai	Accent	4
58		Hyundai+	Sonata	4
59		Dodge	Avenger	2
60		Chrysler	Sebring JX Conv.	2
61		Kia	Sephia	4
62				
63				
64				
65				
66				
67		Vertical	Negative - below impact reference line	
68		Horizontal	Positive is towards rear of car	

FMVSS No. 214 MDB Horizontal and Vertical Impact Point Variability

	E	F	G	H
1				
2				
3				
4				
5				
6	MY	NHTSA#	Vertical (mm)	Horizontal (mm)
7	94	CR0110	13	-25
8	94	CR5901	25	46
9	94	CR5308	25	38
10	94	CR0108	23	25
11	94	CR0312	23	0
12	94	CR5104	25	-13
13	94	CR0109	25	13
14	94	CR0205	23	-19
15	94	CR5602	25	38
16	95	CS0500	28	15
17	95	CS5100	25	25
18	94	CS0504	19	13
19	95	CS5200	20	18
20	95	CS5401	23	8
21	94	CR0503	13	33
22	94	CR0505	13	15
23	95	CS5201	13	3
24	95	CS0503	-5	9
25	95	CS5400	-2	9
26	95	CS5502	-4	-28
27	94	CR5502	-5	10
28	95	CS0111	-6	-12
29	95	CS0110	6	0
30	95	CS0207	0	12
31	95	CS0208	-13	6
32	95	CS5601	0	6
33	95	CS5800	6	-3
34	95	CS5103	-2	9
35	95	CS5104	0	-13
36	95	CS5900	3	-25
37	95	CS0504	-5	20
38	95	CS5801	0	-25
39	95	CS0119	0	0
40	95	CS0309	3	-4
41	95	CS5503	8	-6
42	95	CS0505	-2	9
43	95	CS0506	2	-10
44	96	CT0104	8	11
45	96	CT0100	14	14
46	96	CT0203	0	5
47	96	CT0204	0	-25
48	96	CT5300	2	-5

FMVSS No. 214 MDB Horizontal and Vertical Impact Point Variability

	E	F	G	H
49	96	CT5400	2	-8
50	96	CT5201	7	-7
51	96	CT5202	7	-5
52	96	CT5602	10	-18
53	96	CT0106	6	-16
54	96	CT5501	6	16
55	96	CT0501	2	-5
56	96	CT5306	5	-11
57	96	CT0507	7	1
58	96	CT0506	5	-15
59	96	CT0308	7	1
60	96	CT0309	4	-9
61	96	CT0505	16	26
62				
63			Vert	Horiz
64		AVG.	8.2	2.7
65		MEDIAN	6	1
66		S.D.	10	17
67				
68				

Overall Average Biofidelity Ratings for the BioSID, SID and EuroSID Dummies and Dummy Components by Mertz and Irwin (1990)

In 1988, the ISO concluded that neither the EuroSid nor the SID had sufficient impact biofidelity to be used to assess side impact protection. In response to this conclusion, a Side Impact Dummy Task Force was created under the sponsorship of the SAE Human Biomechanics and Simulation Standards Committee to develop a BioSid. In 1990, the basic development of the BioSid dummy was complete. BioSid uses the Hybrid III head/neck system. Therefore, the test procedures used to verify the lateral impact response characteristics of the BioSid head/neck system may be appropriate for the SIDH3 dummy.

In 1990, the biofidelity of the BioSid, EuroSid, and SID dummies was evaluated by two GM researchers (Mertz and Irwin) using the latest biofidelity test conditions and requirements agreed by WG5 of ISO/T22/SC12 at that time. A total of 4 sets of tests were performed. The results of the 4th set of tests and the overall ratings for each test set are given below:

TEST SET #4

	BioSid Dummy		SID Dummy		EuroSid Dummy	
	Rating	Classification	Rating	Classification	Rating	Classification
Head	6.7	Good	0.0	Unacceptable	3.3	Marginal
Neck	6.1	Fair	2.3	Unacceptable	3.0	Marginal
Shoulder	7.6	Fair	None	N/A	3.4	Marginal
Thorax	6.5	Good	4.8	Fair	4.8	Fair
Abdomen	5.6	Fair	4.4	Fair	3.3	Marginal
Pelvis	5.1	Fair	2.8	Marginal	2.1	Unacceptable
Overall	**6.2**	**Fair**	**2.7**	**Marginal**	**3.4**	**Marginal**
	Overall Ratings/Classifications for Each Test Set					
Test Set # 1	5.1	Fair	2.0	Unacceptable	2.9	Marginal
Test Set # 2	5.9	Fair	2.3	Unacceptable	3.2	Marginal
Test Set # 3	6.1	Fair	2.6	Marginal	3.3	Marginal
→ Test Set # 4	6.2	Fair	2.7	Marginal	3.4	Marginal

* Revised Oct. 15, 1996

SID Dummy Upgrade

Sled Test Results - Maximum Values

		Hybrid III Head, Neck, Std. Bracket			SID Head, Neck, and Bracket			Hybrid III Head, Neck, Mod. Bracket		
	Mnemonic	V417SID001	V417SID002	V417SID003	V417SID004	V417SID005	V417SID006	V417SID007	V417SID008	V417SID009
Head Acceleration	HEDXG	21.1	27.7	28.8	9.7	15.7	20.4	32.5	36.8	96.4
	HEDYG	20.8	13.4	20.2	65.1	69.6	72.6	21.3	22.0	22.7
	HEDZG	26.1	25.8	21.9	44.7	49.5	45.8	47.6	90.6	77.4
	HEDRG	584.3	583.3	593.5	648.1*	736.7	740.1	600.3	595.0	592.4
	HIC	4696.9	5129.5	5388.8	5812.2*	6541.2	7699.3	5334.4	4710.4	4692.1
Neck Loads	NEKXF	243.0	347.1	337.5				179.3	225.4	217.3
	NEKYF	228.5	183.3	191.7				133.0	47.3	145.9
	NEKZF	647.6	520.5	590.4				478.4	477.8	481.3
	NEKRF	2712.6	2918.5	2784.5				3536.7	3295.3	3101.7
Neck Moments	NEKXM	94.5	92.2	97.4				78.8	75.4	78.3
	NEKYM	17.7	14.0	17.0				13.9	13.1	14.3
	NEKZM	10.5	12.7	13.0				8.8	10.0	11.7
	NEKOM	20.4	15.8	20.4				16.3	14.7	16.7
Upper Rib Accel.	LURYGI	4.6	3.3	3.6	3.3	2.9	2.9	4.6	4.2	3.9
Lower Rib Accel.	LLRYGI	1.4	4.4	3.6	4.5	4.4	4.5	1.5	3.4	3.5
T_1 Accelerations	T01XG	1.4	1.6	1.1	2.9	2.2	2.0	1.4	1.6	1.5
	T01YGI	6.4	7.8	7.6	4.0	6.6	7.6	8.3	6.8	7.8
	T01ZG	2.3	5.9	6.1	4.0	4.1	4.5	3.5	3.1	3.7
	T01RG	65.7	64.8	68.6	55.1	55.6	57.3	69.6	69.0	69.9
T_{12} Accelerations	T12XG	2.2	3.3	4.1	5.9	5.1	4.5	4.1	2.7	3.8
	T12YGI	1.8	9.9	8.3	9.5	10.0	10.1	6.9	4.5	6.4
	T12ZG	1.5	7.2	7.2	5.4	5.6	6.0	4.4	3.7	4.4
	T12RG	55.2	54.3	56.3	51.8	51.1	50.1	54.1	56.0	57.2
TTI	TTI	48.4	49.1	49.3	46.7	48.2	47.6	49.5	47.1	51.0
Pelvic Accel.	PEVXG	2.6	7.9	6.8	8.4	8.0	7.9	5.6	5.3	5.6
	PEVYG	11.3	14.8	13.8	14.4	14.8	15.4	13.0	10.6	12.4
	PEVZG	3.8	7.1	6.7	6.5	6.5	7.4	5.1	4.7	5.3
	PEVRG	54.2	53.8	53.5	50.9	52.0	50.2	51.4	51.0	52.1

* indicates data may have exceeded channel full scale range

side impact sled buck

simulated 30 kph impact with rigid plate (pole)

SID Dummy Upgrade

Sled Test Results - Minimum Values

	Mnemonic	Hyrbid III Head, Neck, Std. Bracket			SID Head, Neck, and Bracket			Hybrid III Head, Neck, Mod. Bracket		
		V417SID001	V417SID002	V417SID003	V417SID004	V417SID005	V417SID006	V417SID007	V417SID008	V417SID009
Head Acceleration	HEDXG	-148.4	-65.4	-91.9	-64.2	-73.2	50.1	-96.8	93.0	-84.7
	HEDYG	-571.8	-574.8	-579.2	-624.6	725.3	-705.6	-579.4	576.9	-579.8
	HEDZG	-155.7	-120.1	-117.6	-188.7	-262.3	233.2	145.4	142.2	-117.9
	HEDRG									
	HIC									
Neck Loads	NEKXF	-308.0	-164.5	-323.1				-292.6	287.4	-211.9
	NEKYF	-2363.9	-2694.5	-2523.6				-2431.2	-2764.1	2658.0
	NEKZF	-1953.0	-1514.0	-1668.5				2974.5	2743.6	-2748.8
	NEKRF									
Neck Moments	NEKXM	-19.5	-18.1	-19.6				-18.5	-18.7	23.6
	NEKYM	-12.3	-9.8	-8.9				-18.0	-14.8	-17.2
	NEKZM	-16.2	-16.2	-17.3				-17.5	-17.1	16.1
	NEKOM	-13.7	-9.9	-10.0				-16.7	-13.8	15.2
Upper Rib Accel.	LURYGI	-39.4	-41.3	-40.6	-40.5	-43.0	-42.8	-40.8	-39.7	-42.7
Lower Rib Accel.	LLRYGI	-43.3	-45.1	-44.1	-42.7	-45.9	-46.0	-48.5	-41.1	-48.0
T_1 Accelerations	T01XG	-15.8	-13.6	-16.9	-18.2	-17.7	-18.5	-19.8	-21.5	-18.9
	T01YGI	-62.6	-62.1	-65.0	-50.0	-50.3	-52.6	-65.2	63.6	-65.7
	T01ZG	-17.2	-16.8	-17.1	-16.7	-17.3	-18.5	-17.0	-19.5	-19.2
	T01RG									
T_{12} Accelerations	T12XG	-14.9	-12.7	-14.3	-15.2	-15.1	-14.7	-17.1	-17.1	16.1
	T12YGI	-53.5	-53.0	-54.4	-50.8	-50.5	-49.2	-50.6	53.0	-54.0
	T12ZG	-11.5	-11.3	-11.9	-10.7	-11.6	-12.8	-13.5	-12.1	-14.8
	T12RG									
TTI	TTI									
Pelvic Accel.	PEVXG	-11.6	-10.3	-12.4	-11.2	-18.4	-12.9	-10.8	-13.2	-9.8
	PEVYG	-53.0	-53.1	-52.7	-50.7	-48.6	-49.0	-50.6	-50.4	51.4
	PEVZG	-3.5	-3.7	-5.5	-2.4	6.2	5.2	8.6	-9.0	8.3
	PEVRG									

side impact sled buck
simulated 30 kph impact with rigid plate (pole)

SID Dummy Upgrade

Sled Test Results - Max. Absolute Values

		Hyrbid III Head, Neck, Std. Bracket			SID Head, Neck, and Bracket			Hybrid III Head, Neck, Mod Bracket		
	Mnemonic	V417SID001	V417SID002	V417SID003	V417SID004	V417SID005	V417SID006	V417SID007	V417SID008	V417SID009
Head Acceleration	HEDXG	-148.4	-65.4	-91.9	-64.2	-73.2	-50.1	-96.8	-93.0	96.4
	HEDYG	-571.8	-574.8	-579.2	-624.6	-725.3	-705.6	-579.4	-576.9	579.8
	HEDZG	-155.7	-120.1	-117.6	-188.7	-262.3	-233.2	145.4	-142.2	117.9
	HEDRG	584.3	583.3	593.5	648.1	736.7	740.1	600.3	595.0	592.1
	HIC	4696.9	5129.5	5388.8	5812.2	6541.2	7699.3	5334.4	4710.4	4692.1
Neck Loads	NEKXF	-308.0	347.1	337.5				-292.6	-287.4	217.3
	NEKYF	-2363.9	-2694.5	-2523.6				-2431.2	-2764.1	-2658.0
	NEKZF	-1953.0	-1514.0	-1668.5				-2974.5	-2743.6	-2748.8
	NEKRF	2712.6	2918.5	2784.5				3536.7	3295.3	[illegible]
Neck Moments	NEKXM	94.5	92.2	97.4				78.8	75.4	78.3
	NEKYM	17.7	14.0	17.0				-18.0	14.8	-17.2
	NEKZM	-16.2	-16.2	-17.3				-17.5	17.1	16.1
	NEKOM	20.4	15.8	20.4				-16.7	14.7	16.7
Upper Rib Accel.	• LURYG1	-39.4	-41.3	-40.6	-40.5	-43.0	-42.8	-40.8	-39.7	-42.7
Lower Rib Accel.	• LLRYG1	-43.3	-45.1	-44.1	-42.7	-45.9	-46.0	-48.5	-41.1	-48.0
T_1 Accelerations	T01XG	-15.8	-13.6	-16.9	-18.2	-17.7	-18.5	-19.8	-21.5	18.9
	T01YG1	-62.6	-62.1	-65.0	-50.0	-50.3	-52.6	-65.2	-63.6	-65.7
	T01ZG	-17.2	-16.8	-17.1	-16.7	-17.3	-18.5	-17.0	19.5	19.2
	T01RG	65.7	64.8	68.6	55.1	55.6	57.3	69.6	69.0	69.9
T_{12} Accelerations	T12XG	-14.9	-12.7	-14.3	-15.2	-15.1	-14.7	-17.1	-17.1	-16.1
	• T12YG1	-53.5	-53.0	-54.4	-50.8	-50.5	-49.2	-50.6	-53.0	54.0
	T12ZG	-11.5	-11.3	-11.9	-10.7	-11.6	-12.8	-13.5	-12.1	14.8
	T12RG	55.2	54.3	56.3	51.8	51.1	50.1	54.1	56.0	[illegible]
TTI	TTI	48.4	49.1	49.3	46.7	48.2	47.6	49.5	47.1	51.0
Pelvic Accel.	PEVXG	-11.6	-10.3	-12.4	-11.2	-18.4	-12.9	-10.8	-13.2	9.8
	PEVYG	-53	-53.1	-52.7	-50.7	-48.6	-49	-50.6	-50.4	51.1
	PEVZG	3.8	7.1	6.7	6.5	6.5	7.4	-8.6	-9	8.3
	PEVRG	54.2	53.8	53.5	50.9	52	50.2	51.4	51	52.1

side impact sled buck
simulated 30 kph impact with rigid plate (pole)

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