U.S. Department
of Transportation

**National Highway
Traffic Safety
Administration** 85672

Memorandum

Subject: Submittal of NHTSA Memorandum, "Response to DaimlerChrysler Review of 'Test Procedures' Paper," to Docket No. NHTSA-00-7013-21

Date: JUN 22 2000

From: Raymond P. Owings, Ph.D.
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Research and Development

Reply to
Attn. of:

To: The Docket

Thru: Frank Seales, Jr.
Chief Counsel

Attached is a memorandum titled "Response to DaimlerChrysler Review of 'Test Procedures' Paper," which was prepared by the agency's Office of Vehicle Safety Research. The memorandum responds to the comments received on the NHTSA report, "Updated Review of Potential Test Procedures for FMVSS No. 208," that was submitted to Docket No. 99-6407. The original study was released as a part of the actions associated with the Notice of Proposed Rulemaking (NPRM) for advanced air bags. Research and Development was requested to provide this memorandum as part of the agency research activities to prepare for any rulemaking that is to be published as a followup to last year's NPRM. Research and Development requests that this memorandum be placed in Docket No. NHTSA-00-7013.

Attachment

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Response to DaimlerChrysler Review of "Test Procedures" Paper

As part of its issuance of its November 5, 1999, Supplementary Notice of Proposed Rulemaking (SNPRM) for advanced air bags, the agency published two supporting technical papers-- "Updated Review of Potential Test Procedures for FMVSS No. 208" and "Development of Improved Injury Criteria for the Assessment of Advanced Automotive Restraint Systems - II." This response is written as an addendum to the first of the supporting technical papers in order to address a critique submitted by DaimlerChrysler as part of its comments to the SNPRM.

In the DaimlerChrysler critique of the "Test Procedures" paper, their conclusions are stated as follows:

> *"This was a limited study based on NHTSA's analysis procedure using average crash pulse acceleration and correlation in terms of magnitude, shape and phase of the crash pulses. It ignores other aspects of crash phenomena, such as complex 3D response, intrusion, etc.*
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> 1. *NHTSA's definition of vehicle stiffness, MV^2/X^2, is too simplistic to address aggressivity, which is controlled by pulse shape characteristics. It does not address locally high accelerations, in the initial phase of crush, driven by the full frontal rigid barrier impacts. It does however address the tendency to increase the available crush space.*
>
> 2. *The severity of the acceleration pulse, studied in terms of average acceleration and the time-to-zero velocity, indicates that rigid-barrier impacts are more severe than full frontal vehicle-to-vehicle impacts at higher velocities. NHTSA's conviction that the full frontal barrier test is representative of real-world crashes at equivalent velocities is unfounded.*
>
> 3. *In terms of average acceleration, a full frontal rigid barrier test at 22 mph represents the average crash severity of 50%-100% overlap vehicle-to-vehicle crashes.*
>
> 4. *The excessive severity of rigid-barrier impacts at 30 mph drives air bags that are more aggressive than are needed in vehicle-to-vehicle crashes at equivalent velocities.*
>
> 5. *The moving deformable barrier test is more severe than the full frontal rigid barrier impact and the vehicle-to-vehicle crashes at corresponding speeds."*

To address the statements preceding the specific points found in DaimlerChrysler's conclusions, it is helpful to understand precisely how crash conditions were grouped in the "Test Procedures" paper for mapping the crash conditions into the appropriate test configurations. As found in the analysis of the National Automotive Sampling System (NASS) data presented in Chapter 3 of the paper, the frontal crashes contained in NASS were segregated by impact mode (full barrier--full engagement or distributed damage, left offset, and right offset), crash pulse (soft or stiff), and by three levels of intrusion (none, up to 15 centimeters (6 inches), and over 15 centimeters (6 inches)). The precise definition of how the crashes in NASS were mapped can be found in Table 3.8. While characterizing crash pulses by average acceleration and crash pulse duration was presented in the paper to show the trends and similarities of crash types, this was not the only consideration presented or used to map the crashes into the various test configurations. In analyzing DaimlerChrysler's characterization of crash pulses, the effect of using their characterization would be to increase the target population of those crashes that are mapped into the rigid barrier test (full frontal and frontal oblique). Their characterization would expand the count for left and right offset "soft" crashes, as they have claimed that soft type pulses occur for larger degree of overlap than that which was chosen for the agency analysis.

The following addresses each of the specific findings found in the conclusions:

1. *NHTSA's definition of vehicle stiffness, MV^2/X^2, is too simplistic to address aggressivity, which is controlled by pulse shape characteristics. It does not address locally high accelerations, in the initial phase of crush, driven by the full frontal rigid barrier impacts. It does however address the tendency to increase the available crush space.*

The agency has an extensive research program in place to address vehicle compatibility and aggressivity. The agency agrees that the linear stiffness parameter, MV^2/X^2, used to address vehicle aggressivity in the paper is simplistic. However, while simplistic, it provides an insightful measure of vehicle aggressivity. Also, while we also agree that initial stiffness possibly may contribute to a vehicle's aggressivity, our studies to date have not been able to demonstrate this effect.

At the Fifteenth Enhanced Safety of Vehicles Conference held in Melbourne, Australia, during May 1996, a program of coordinated research was agreed upon that would be undertaken under the worldwide banner of International Harmonized Research Activities (IHRA). The research is comprised of six high priority areas in which nations would collaborate over a 5-year period. These priority areas included research into vehicle compatibility. The agency has been a full participant and leading researcher in the area of vehicle compatibility. During the six Vehicle Compatibility working group meetings that have been held to date, the group has identified three factors that affect compatibility--mass, geometry, and stiffness. With respect to stiffness, the subject of this critique, the group has explored but has not identified one all-encompassing definition that can be used as a predictor of a vehicle's aggressivity. In the DaimlerChrysler comments, the initial stiffness is deemed a significant factor. Even before DaimlerChrysler provided its viewpoint, initial stiffness has been discussed at length during the working group meetings. In particular, for some time, the initial stiffness was viewed as a major contributor to a vehicle's aggressivity in side crashes. However, a view has evolved within the group that geometry is the key factor in this crash mode. Furthermore, initial stiffness, though seemingly important, is now viewed as a marginal factor since the relative strength of a vehicle's side structure is substantially less than that of the striking vehicle's front structure during the crash. That is, the side structure undergoes substantial intrusion before significant crushing of the striking vehicle's front structure takes place. With respect to frontal crashes, research is underway to explore the role of stiffness in vehicle compatibility. The agency has calculated initial stiffness parameters at the first 125 and 250 millimeters (5 and 10 inches) of crush. Part of our interest in looking at the initial stiffness is to explore the structural interactions that take place at the beginning of a crash that lead to an adverse over-ride/under-ride structural interaction or conversely to good structural interaction between vehicles during the collision. To date, the statistical studies that have been conducted by the University of Michigan Transportation Research Institute have not shown any correlation between these calculated parameters and the probability of serious injury/fatality in the vehicle's collision partner in real world crashes. With respect to the linear stiffness parameter, MV^2/X^2, that was selected for use in the report, the agency agrees with DaimlerChrysler that it is simplistic, but also believes that this parameter helps explain some important aspects of vehicle compatibility in frontal crashes. For example, in all of the statistical studies published by the agency to date, the light trucks and vans as a group have been shown to have more than twice the fatality rates in their collision partners compared to passenger cars. In examining the linear stiffness parameter plotted in Figure 4-1 of the report, it is seen that the linear stiffness levels display the dichotomy between automobiles and LTVs. Furthermore, in evaluating the frontal vehicle-to-vehicle crashes conducted by the agency as part of its compatibility research, the impacting vehicles with the higher levels of linear stiffness also imparted substantially greater crush and intrusion to their collision partners. This observation is relevant, as our analysis of NASS shows that the probability of serious injury is substantially increased when vehicle intrusion is greater than 15 centimeters (6 inches). (See Figure 3-3 of the report.) Intuitively, the linear stiffness parameter makes sense from the point of view that, when two vehicles collide, the vehicle with the larger stiffness value experiences lesser crush overall.

In summary, the agency has an extensive research program in place to address vehicle compatibility and aggressivity. The agency agrees that the linear stiffness parameter, MV^2/X^2, used to address vehicle aggressivity in the paper is simplistic. However, we feel strongly that it provides an insightful look at vehicle aggressivity. Also, while we agree that initial stiffness possibly may contribute to a vehicle's aggressivity, our studies to date have not been able to demonstrate this effect.

2. *The severity of the acceleration pulse, studied in terms of average acceleration and the time-to-zero velocity, indicates that rigid-barrier impacts are more severe than full frontal vehicle-to-vehicle impacts at higher velocities. NHTSA's conviction that the full frontal barrier test is representative of real-world crashes at equivalent velocities is unfounded.*

The agency agrees with DaimlerChrysler that the average acceleration and time duration of rigid barrier impacts can be more severe than vehicle-to-vehicle impacts. In general, a rigid barrier impact is equivalent to a vehicle crashing into another vehicle like itself. For the condition in which the subject vehicle runs into another vehicle of lesser mass, the crash severity of the subject vehicle is less severe than that experienced in a rigid barrier test. Conversely, if the subject vehicle crashes into another vehicle of heavier mass, the crash severity of the subject vehicle is more severe than that experienced in a rigid barrier test. Shown in Figure 2.12 of the paper is the approximate region of the average accelerations and pulse durations for the vehicle-to-vehicle tests conducted by the agency. The data plotted are for the vehicle-to-vehicle tests in which the change in velocity (i.e., the ΔV) ranged from 48 to 60 kmph (30 to 35 mph). This range of ΔVs was selected to correspond to that observed in the 48 and 56 kmph (30 and 35 mph) rigid barrier tests. Here, it is seen that the approximated region bounds the data observed for the 48 and 56 kmph (30 and 35 mph) rigid barrier tests. The agency thus feels that this supports its view that the rigid barrier crash is representative of vehicle-to-vehicle crashes at equivalent velocities. This finding is especially bolstered by the facts that the occupants of the lighter vehicle in vehicle-to-vehicle crashes experience a greater probability of injury than those occupants in the heavier vehicle and that the agency is looking for a test procedure that is representative of the injury-producing crashes. Also, the conclusion that a rigid barrier test is representative of real world injury-producing crashes is further supported when one considers that a large number of the injuries in the real world are incurred in single vehicle crashes in which there is distributed damage across the front of the vehicle (i.e., crashes that are similar to the rigid barrier test).

3. *In terms of average acceleration, a full frontal rigid barrier test at 22 mph represents the average crash severity of 50%-100% overlap vehicle-to-vehicle crashes.*

This issue can be addressed from two perspectives. The first is with respect to vehicle-to-vehicle crashes in which the vehicles engage at a closing velocity in the neighborhood of 96 kmph (60 mph), e.g., both vehicles moving at 48 kmph (30 mph) toward the other. The agency does not disagree that a 22 mph rigid barrier crash represents the average crash severity of some vehicles involved in such crashes, particularly when there is a 50-to-100 percent overlap. For this scenario, the crash severity depends primarily of the mass of the partner vehicle in the collision. For crashes in which the partner vehicle is substantially lighter in weight, the crash pulse will be substantially less severe than when the subject vehicle has a 48 kmph (30 mph) impact into a rigid barrier (which is equivalent to a vehicle crash into a vehicle like itself). For such a vehicle-to-vehicle crash, the outcome very well could be similar to that of a 22 mph full frontal rigid barrier test. On the other hand, the lighter vehicle in this hypothetical crash will suffer a crash pulse that is similar to, if not more severe than, the 48 kmph (30 mph) rigid barrier crash. Furthermore, the likelihood is that the occupants of the lighter vehicle in this scenario will experience higher probability of serious injury. Hence, it is from this viewpoint that the agency has looked closely at the 48 kmph (30 mph) rigid barrier test in this rulemaking.

The second perspective in addressing this issue is from the level of injury severity that is being considered for the representativeness of the crashes. The published paper examined test procedures with respect to how they addressed severe injuries, i.e., injuries in which MAIS $\geq$ 3. If the injury level of interest were to include less severe injuries, e.g., MAIS $\geq$ 2, the representative rigid barrier speed would be lower. If the test procedure were designed to address all crashes independent of injury level, the representative rigid barrier speed would be even lower.

4. *The excessive severity of rigid-barrier impacts at 30 mph drives air bags that are more aggressive than are needed in vehicle-to-vehicle crashes at equivalent velocities.*

The agency has conducted a series of crash tests using 17 model year (MY) 1998-99 vehicles that have redesigned air bag systems. The agency does not agree with the statement that the 48 kmph (30 mph) barrier test will require larger, more powerful (i.e., aggressive) air bags than are needed to adequately protect individuals in severe frontal crashes. Nor does the agency believe that the

48 kmph (30 mph) barrier test would lead to higher injury risk for out-of-position (OOP) occupants compared to current air bags. NHTSA's 48 kmph (30 mph) rigid barrier test data of the 17 vehicles demonstrate that vehicles with "depowered" air bags are able to meet the 50th male injury criteria in most of the tests without the need to "repower" or enlarge the air bag systems. On the driver's side, 14 of the 17 vehicles were able to able to meet all the dummy injury criteria; and 16 of the 17 vehicles were able to meet all the criteria on the passenger side.

A 48 kmph (30 mph) barrier test will certainly not require a return to the very aggressive air bags from the early 1990's that had limited air bag injury countermeasures associated with them (like lack of tethers, primitive fold patterns, large bag sizes, heavy bag materials, non-recessed modules, massive cover flaps, etc.).

Four out of six of the MY 99 vehicles (tested at 30 mph) were able to meet driver low risk deployment tests with the small female dummy using the "full power" of the redesigned air bags. Therefore, these systems demonstrate the amount of latitude that manufacturers will have in designing the first stage of a multistage inflators so as to not be aggressive to out-of-position occupants.

5. *The moving deformable barrier test is more severe than the full frontal rigid barrier impact and the vehicle-to-vehicle crashes at corresponding speeds.*

The agency agrees with DaimlerChrysler that the offset moving deformable barrier tests conducted by NHTSA are more severe than the full frontal rigid barrier impact, and agrees that the moving deformable barrier test may be more severe than vehicle-to-vehicle crashes at corresponding speeds.

In general, a rigid barrier impact is equivalent to a vehicle crashing into another vehicle like itself traveling at the same speed, with full engagement of the front end of each vehicle. In the rigid barrier crash testing conducted by the agency, the observed occupant compartment intrusion of the tested vehicles has been less than 15 centimeters (6 inches). The moving deformable barrier (MDB) tests conducted by the agency utilized a crash configuration in which there is partial engagement of the front of the target vehicle (i.e., an offset crash). Also, these tests were conducted using a level of overlap of the front of the subject vehicle that tended to make the target vehicle's crash pulse similar to that which it would experience in a rigid barrier test. In these MDB offset tests, the observed occupant compartment intrusion of the target vehicle has been greater than 15 centimeters (6 inches). The combination of generating a crash pulse similar to that of a rigid barrier crash and increasing the occupant compartment intrusion leads to a greater probability of occupant injury in the MDB offset test.

With respect to vehicle-to-vehicle crashes, an MDB-to-vehicle test could be either less severe or more severe than a vehicle-to-vehicle test. Two primary factors are involved in determining the outcome of such a test. The first of these is the mass. The MDB used by the agency weighs 1,364 kilograms (3,000 pounds). An MDB-to-vehicle test generally will be more severe than a vehicle-to-vehicle test in which the bullet vehicle in the vehicle-to-vehicle test weighs less than the MDB. An MDB-to-vehicle test generally will be less severe than a vehicle-to-vehicle test in which the bullet vehicle in the vehicle-to-vehicle test weighs more than the MDB. (It should be noted that, when the weight of the MDB was selected, the agency judged that it would be representative of the average weight of the vehicles in the fleet. Since that time, however, the sales of light trucks and vans have increased unexpectedly from about 18 percent to about 50 percent of new vehicle sales, thus raising the average weight of the fleet.)

The second factor that is involved in the outcome of an MDB test is the stiffness of the MDB. The agency testing with the MDB has shown that high forces are generated during the initial crushing of its aluminum honeycomb face that level off at approximately 356,000 Newtons (80,000 pounds force). At 33 to 88 centimeters (13 to 15 inches) of crush the face becomes very rigid, as the honeycomb material is almost fully crushed. In crashes of sufficient severity (i.e., in tests in which the honeycomb face is fully crushed), the MDB deformable face generates crash forces that are similar to that generated by the front structure of a small pickup truck. This generated level of force is higher than would be created by most passenger cars. In comparing MDB-to-vehicle and vehicle-to-vehicle crashes in which the bullet vehicle in the vehicle-to-vehicle crash weighs nearly the same as the MDB and in which the bullet vehicle is a passenger car, it is expected that the outcome of the MDB test will be more severe on the target vehicle. For this comparison, the higher level of the MDB stiffness will result in greater intrusion in the target vehicle than that induced by a crash with most passenger cars. Furthermore, the higher level of stiffness of the MDB increases the severity of the crash pulse of the target vehicle in an MDB-to-vehicle test. These combined effects can make the MDB-to-vehicle test more severe.