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Van Crashworthiness and Aggressivity Study

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A SERIES OF EIGHT van crash tests was conducted by Dynamic Science under Contract No. DOT-HS-8-01942 (Task Order No. 4), "Van Crashworthiness and Aggressivity Study," sponsored by the National Highway Traffic Safety Administration (NHTSA). This paper presents the results of six symmetric, head-on van-to-NHTSA Fixed Test Device crash tests and two van-to-car collisions (1, 2, 3).*

These tests were conducted to 1) study the crashworthiness and aggressivity of vans, 2) provide baseline van collision data to support extension of FMVSS 208, Occupant Crash Protection, to vans, and 3) support current vehicle standards and provide initial information for the future FMVSS 400 series standards.

TEST SCOPE

The test matrix and summary of test conditions for the eight van crash tests are presented in Table 1. Two representative van models (a 1979 Ford Econoline 150 and a 1979 Dodge B-200) were used in the series. These vans are shown in Figures 1 and 2. The first six van tests were conducted against a unique load-measuring barrier, the NHTSA Fixed Test Device. Impact speeds were selected as 15, 25, and 30 mph. The last two tests were van-to-car front-to-front collisions using a typical full-size passenger car (1979 Chevrolet Impala). This vehicle is illustrated in Figures 3 and 4 in relation to the two van models. Closing velocities of 64.0 mph for the Ford Van-to-Chevrolet test and 61.7 mph for the Dodge Van-to-Chevrolet were chosen so that a velocity change of 30 mph would occur on the van (see Appendix A).

The NHTSA Fixed Test Device (4) is a unique segmented load-measuring barrier which was supported by a 36-inch extension attached to the Dynamic Science fixed barrier. The front face of each of the 40 load-measuring modules used a 7 x 8 x 1-1/2-inch plywood face as the impact surface (Figure 5). The frontal height was set to simulate the front of a Chevrolet Impala (Figure 6).

In each test, the van contained two instrumented Alderson Part 572, 50th percentile male

*Numbers in parentheses designate References at end of paper.

ABSTRACT

This paper presents the results of a series of van crash tests which were conducted by Dynamic Science, Inc. under contract to the National Highway Traffic Safety Administration (NHTSA). Six van tests were conducted against a unique load-measuring barrier to study the crashworthiness and aggressivity of two typical van models at speeds of 15, 25, and 30 mph. Two additional tests were conducted between each of the two van models and a typical full-size passenger car. The results of these tests are being used by NHTSA to support extension of Federal Motor Vehicle Safety Standard (FMVSS) No. 208 to vans, and to provide initial information for the future FMVSS 400 series standards.

The views and opinions presented in this paper are those of the authors and do not necessarily reflect the official view of the U.S. Department of Transportation, National Highway Traffic Safety Administration.

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anthropomorphic dummies located in the two front outboard seating positions. Each occupant was restrained with the vehicle's production restraint system; however, the Dodge Van's standard, two-point restraint system was replaced by the optional production, three-point restraint system. The seats were put at midposition, but not welded in place. Vehicles which contained tilt steering wheels (see Table 1) were tested with the wheel placed in the lowermost driving position, in order to evaluate a more vertical position, typical of passenger cars. Fuel was removed from the vans and replaced with water.

Table 1 - Van Crash Test Matrix

Test No.	Test Date	Test Configuration	Vehicle Model	Vehicle Weight (lb)	Closing Speed (mph)
1	4/10/79	Van-to-Load Cell Barrier Head-on	1979 Ford Econoline 150 Van	4,990	15.25
			NHTSA Fixed Test Device	>100,000	
2	4/11/79	Van-to-Load Cell Barrier Head-on	1979 Ford Econoline 150 Van	4,997	25.10
			NHTSA Fixed Test Device	>100,000	
3	4/12/79	Van-to-Load Cell Barrier Head-on	1979 Ford Econoline 150 Van*†	4,998	30.02
			NHTSA Fixed Test Device	>100,000	
4	4/17/79	Van-to-Load Cell Barrier Head-on	1979 Dodge B-200 Van†	4,647	25.17
			NHTSA Fixed Test Device	>100,000	
5	4/18/79	Van-to-Load Cell Barrier Head-on	1979 Dodge B-200 Van*†	4,654	30.22
			NHTSA Fixed Test Device	>100,000	
6	4/19/79	Van-to-Load Cell	1979 Dodge B-200 Van†	4,651	15.28
			NHTSA Fixed Test Device †	>100,000	
7	5/09/79	Van-to-Car Symmetric Head-on	1979 Ford Econoline 150 Van	4,994	63.58
			1979 Chevrolet Impala*	4,400	
8	5/11/79	Van-to-Car Symmetric Head-on	1979 Dodge B-200 Van	4,649	62.28
			1979 Chevrolet Impala*	4,403	

*Used for Mobile Parametric Measuring Device Test.
†Contained tilt steering wheel.

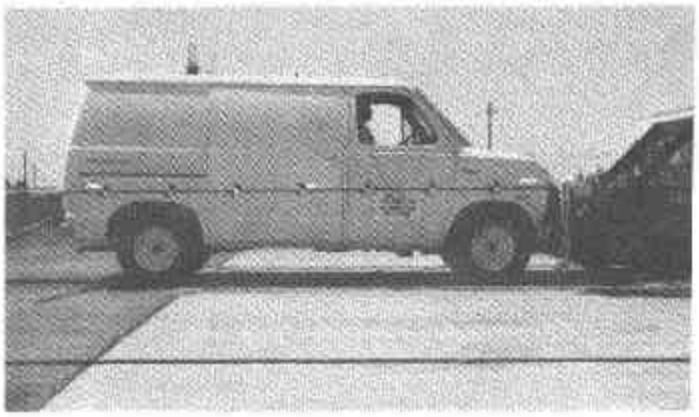


Fig. 1 - 1979 Ford Econoline 150 van, pre-test

Fig. 2 - 1979 Dodge B-200 van, pre-test

Fig. 3 - Chevrolet Impala interface with Ford van

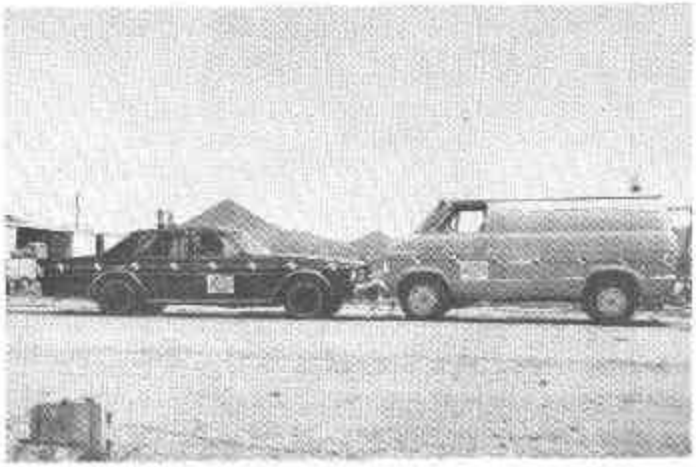


Fig. 4 - Chevrolet Impala interface with Dodge van

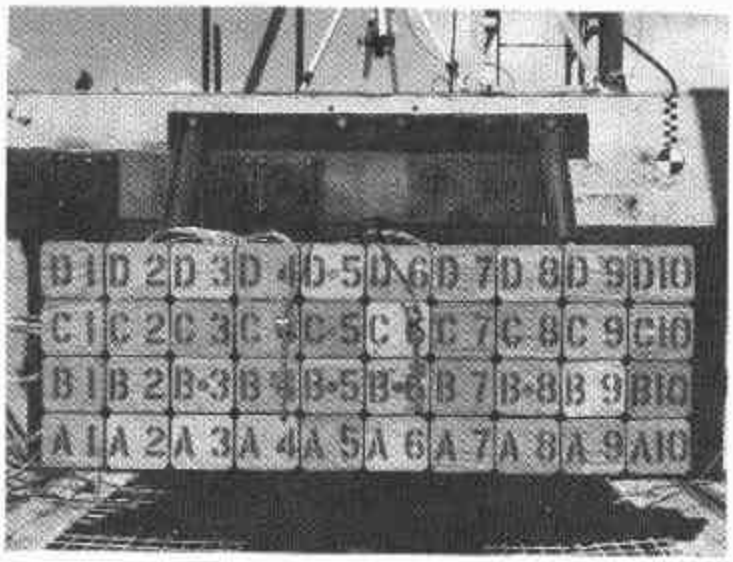


Fig. 5 - Frontal view of NHTSA Fixed Test Device with 36-inch extension

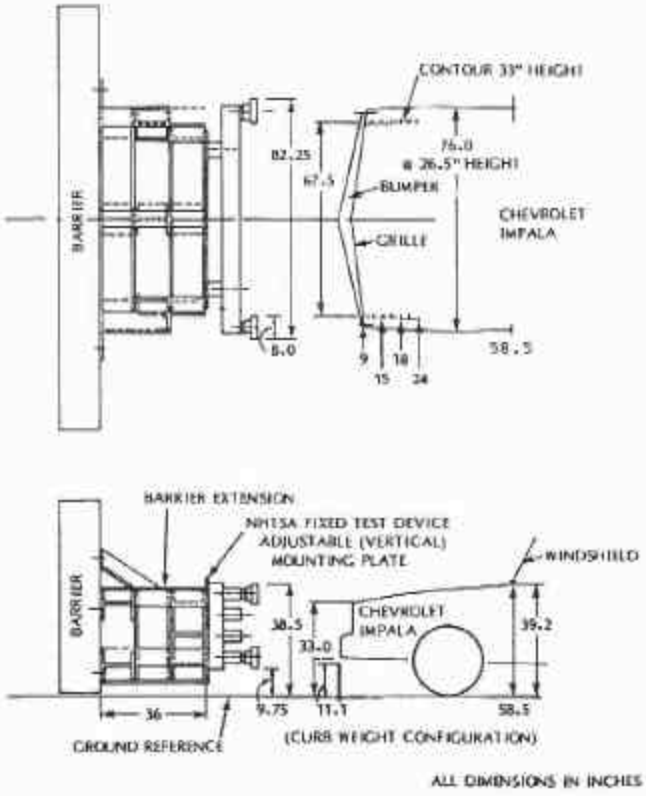


Fig. 6 - 1979 Chevrolet Impala interface with NHTSA Fixed Test Device

ELECTRONIC INSTRUMENTATION

Table 2 presents a summary of vehicle and Fixed Test Device instrumentation. A total of 87 data channels was used in conducting the van-to-Test Device tests. Van instrumentation consisted of 41 data channels requiring the use of three Remote Signal Conditioning Modules (RSCM's). The NHTSA Fixed Test Device contained a total of 46 data channels requiring the use of 4 RSCM's.

Table 2 - Vehicle and Fixed Test Device Instrumentation Summary

	Locations	Data Channels
Van Instrumentation		
Vehicle Accelerometers	9	19
Dummy Instrumentation:		
Head (3), Chest (3), Femur (2)	2	16
Seat Belt Load Cells:		
Lap (2), Shoulder (1)	2	6
Total		41
NHTSA Fixed Test Device Instrumentation		
Load Cells	40	40
String Potentiometers	6	6
Total		46

Table 3 presents a summary of vehicle instrumentation used in the van-to-Chevrolet collisions. A total of 71 data channels were used in conducting these tests. Van instrumentation consisted of the same 41 data channels as in the barrier tests. The Chevrolet Impala instrumentation consisted of 30 channels requiring the use of 3 RSCM's.

PHOTOGRAPHIC INSTRUMENTATION

In all tests, seven high-speed cameras (five 1000 fps and two 500 fps) and one panning camera (24 fps) were used to cover the crash event. Two of the cameras were mounted on board the van to observe occupant kinematics. In addition to high-speed cameras, black-and-white photographs and color slides were taken to record pre-test and post-test vehicle and dummy positions.

Table 3 - Vehicle Instrumentation Summary for Van-to-Car Tests

	Locations	Data Channels
Van Instrumentation		
Vehicle Accelerometers	9	19
Dummy Instrumentation:		
Head (3), Chest (3), Femur (2)	2	16
Seat Belt Load Cells:		
Lap (2), Shoulder (1)	2	6
Total		41
Chevrolet Impala Instrumentation		
Vehicle Accelerometers	4	8
Dummy Instrumentation:		
Head (3), Chest (3), Femur (2)	2	16
Seat Belt Load Cells:		
Lap (2), Shoulder (1)	2	6
Total		30

TEST RESULTS FOR VAN-TO-BARRIER COLLISIONS

Since three test speeds (15, 25, and 30 mph) were used, a reasonably good data base for examining the effects of impact velocity for van-to-Fixed Barrier impact tests was established. The methodology used to study these effects was to plot various vehicle and occupant response parameters against the actual test speeds. Occupant response parameters were also plotted against selected vehicle response parameters.

OCCUPANT RESPONSE PARAMETERS VERSUS IMPACT VELOCITY - The pertinent occupant response data are presented in Table 4 for critical response parameters as defined in FMVSS 208. The peak chest acceleration, excluding intervals whose cumulative duration is not more than 3 milliseconds, is the current FMVSS 208 chest criteria, the chest Severity Index (SI) data are also presented since these criteria were used previously in FMVSS 208.

Head Injury Criteria (HIC) is as defined in FMVSS 208, with an allowable limit of 1000. Figures 7 and 8 indicate that this parameter was well within the 1000 limit value at 25 mph, but slightly exceeded 1000 at 30 mph for the Dodge driver and the Ford passenger.

Chest SI and Peak Chest Resultant deceleration data are shown in Figures 9 through 12. At 25 mph, these chest parameters were well within the established limit of 1000 for the SI and 60 g for the Chest Resultant deceleration. Although the SI values at 30 mph were well below 1000 in both vans, the chest g for the Ford driver slightly exceeded the allowable 60 g limit.

Femur load criteria are as defined in FMVSS 208, with an allowable compression limit of 2,250 pounds. Figures 13 through 16 indicate that this parameter tends to increase with impact speed, but several values at 30 mph are less than 25 mph. The maximum femur load occurred at 25 mph for the Dodge driver left femur and the Ford driver right femur. These values, as well as the value for the Dodge driver right femur at 30 mph, exceeded the 2,250-pound limit specified in FMVSS 208.

In summary, several dummy response parameters exceeded FMVSS 208 limits at 30 mph, and femur load limits were exceeded even at 25 mph. Improved restraint systems might help to reduce excessive occupant femur and head response values and thereby improve the crashworthiness of the vehicles.

VEHICLE RESPONSE PARAMETERS VERSUS IMPACT VELOCITY - The pertinent vehicle response data are presented in Table 5. These include structural parameters that have been used in previous

Table 4 - Comparison of Occupant Response Data - Barrier Tests

Parameter	Ford Test 1		Ford Test 2		Ford Test 3		Dodge Test 4		Dodge Test 5		Dodge Test 6	
	LF	RF	LF	RF	LF	RF	LF	RF	LF	RF	LF	RF
Velocity (mph)	15.3		25.1		30.0		25.2		30.2		15.3	
HIC	78	70	557	393	929	1072	660	468	1006	724	74	97
Chest SI	81	62	289	171	561	290	277	206	391	305	77	58
Peak Resultant Chest Acceleration (g)*	26.2	21.4	41.4	29.8	60.6	39.3	39.1	36.7	46.0	41.0	25.7	22.9
Left Femur Load (lb)	-98	-64	-137	-141	-927	-1632	-2346	-193	-789	-81	-261	-148
Right Femur Load (lb)	-1030	-231	-2851	-184	-2617	-953	-980	-81	-2557	-232	-469	-66

*3 msec clip, per FMVSS 208.

research programs to quantify vehicle crashworthiness and aggressivity.

Dynamic crush from accelerometer integration and film analysis are shown in Figures 17 and 18. Post-test static crush data are shown in Figure 19. As expected, the crush increases with impact speed, and both vans indicate similar crush versus speed curves. It should be noted, however, that the maximum dynamic crush at 30 mph is about 20 inches, compared to dynamic crushes of 30 inches for typical full-size passenger cars. Since increased crush (within acceptable compartment intrusion limits) tends to reduce the occupant injury severity of a crash in both the struck and striking vehicles, structural modifications to increase the 30-mph crush value to 25 inches is suggested as one approach to improve van crashworthiness and reduce potential crash aggressivity.

Van velocity change versus impact speed is shown in Figure 20. For a perfectly plastic collision (coefficient of restitution = 0), there would be no rebound velocity, and the vehicle velocity change (ΔV) would equal the initial impact speed. This is illustrated by the dashed line. In actuality, return of some crush energy is inevitable, but this should be kept small to minimize the velocity change of the vehicle's occupants. As shown in Figure 20, the data for the Ford and Dodge vans are comparable and close to the perfectly plastic collision line.

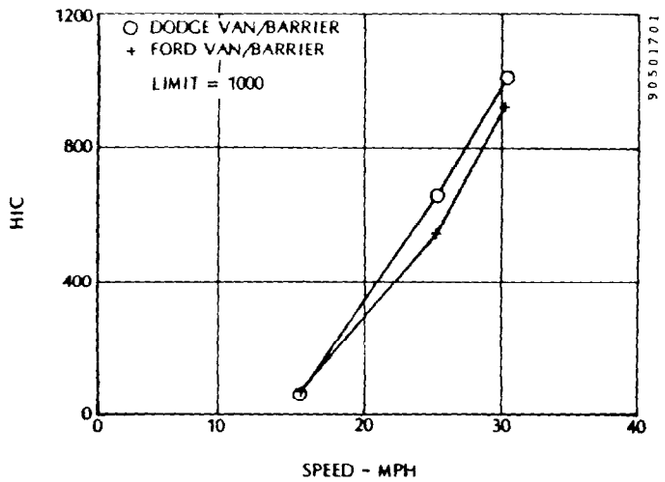


Fig. 7 - Driver head injury criteria (HIC) versus impact speed

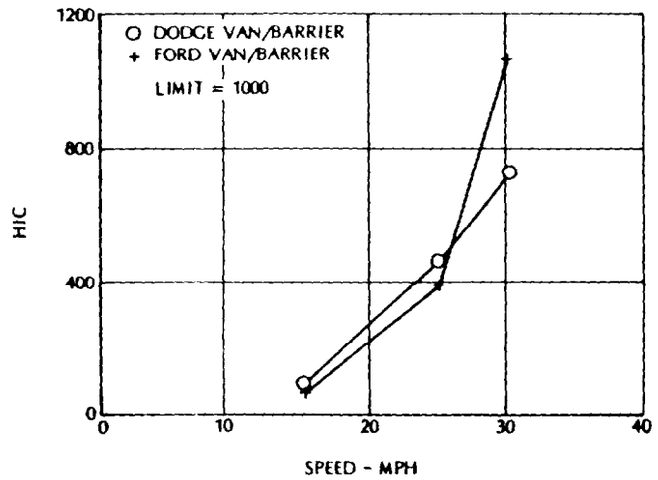


Fig. 8 - Front passenger head injury criteria (HIC) versus impact speed

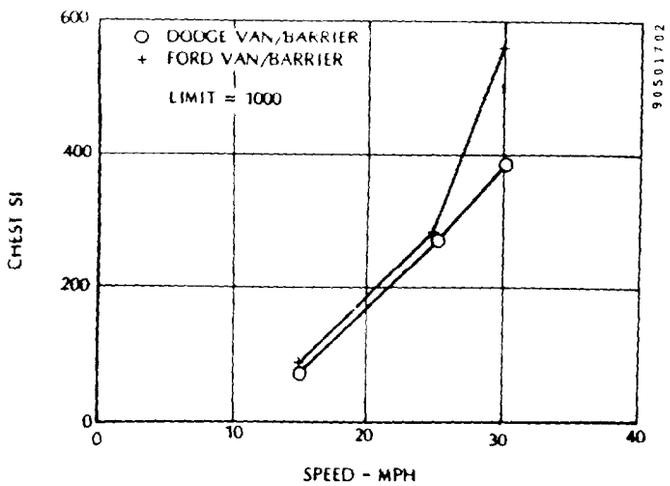


Fig. 9 - Driver chest severity index (SI) versus impact speed

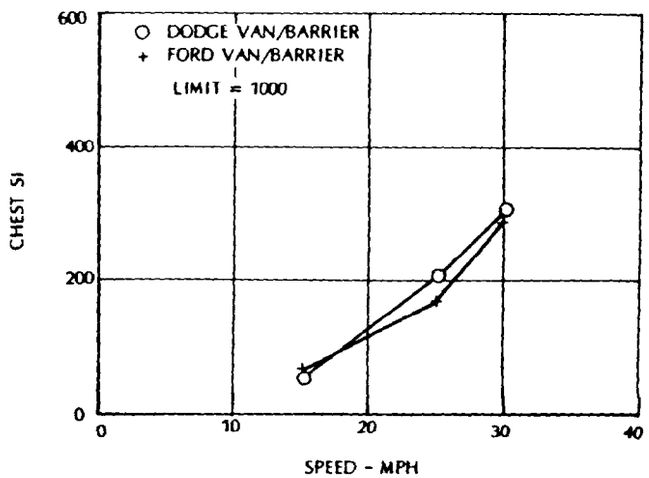


Fig. 10 - Front passenger chest severity index (SI) versus impact speed

The coefficient of restitution is about 0.1, which is representative of data for full-size passenger cars.

Compartment acceleration is a vehicle parameter that can affect van crashworthiness through its effect on occupant response. The peak acceleration data are plotted in Figure 21. The peak compartment accelerations for the Dodge were generally higher than for the Ford. The actual time histories of compartment acceleration for the 30-mph barrier tests are shown in Figures 22 and 23, where it can be noted that the Dodge peak occurs early in the pulse and is of relatively short duration.

The significance of maximum compartment deceleration on vehicle crashworthiness is controversial since the peak value depends on the filter used (in these tests, a class 60 filter, as recommended in SAE J211b). Therefore, another parameter, average compartment acceleration, was considered. This is defined as the area under the acceleration curve (i.e., velocity change) divided by the effective time duration of the pulse (determined using the time when the compartment acceleration drops to 1 g). These data are plotted in Figure 24 and show no significant differences between van models over the test speed range.

Engine inertia forces may possibly increase the aggressivity of a vehicle by generating high interface loads. The van acceleration data are shown in Figure 25, where it can be observed that the Dodge engine experienced higher peak accelerations than the Ford engine. Since the weights of the two engine/transmission masses were similar (768 lb for the Ford and 796 lb for the Dodge), the engine

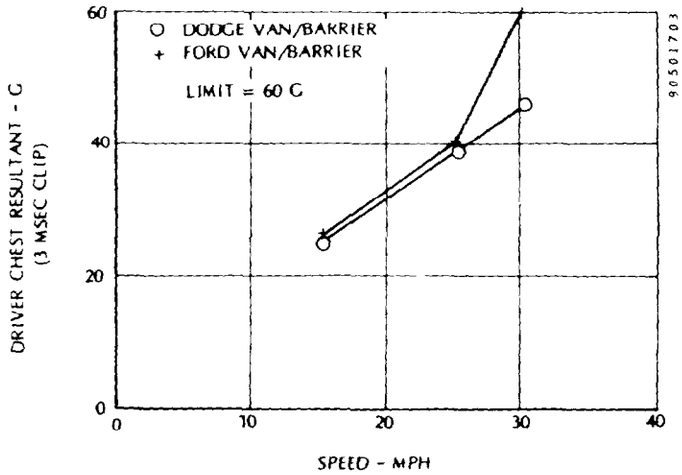


Fig. 11 - Driver peak chest resultant deceleration versus impact speed

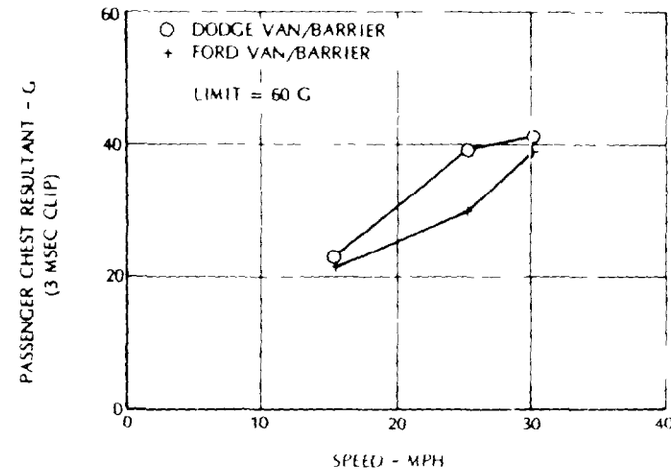


Fig. 12 - Front passenger peak chest resultant deceleration versus impact speed

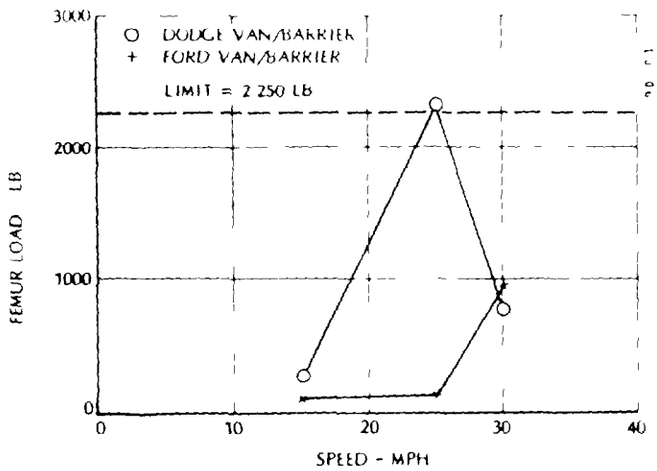


Fig. 13 - Driver left femur load versus impact speed

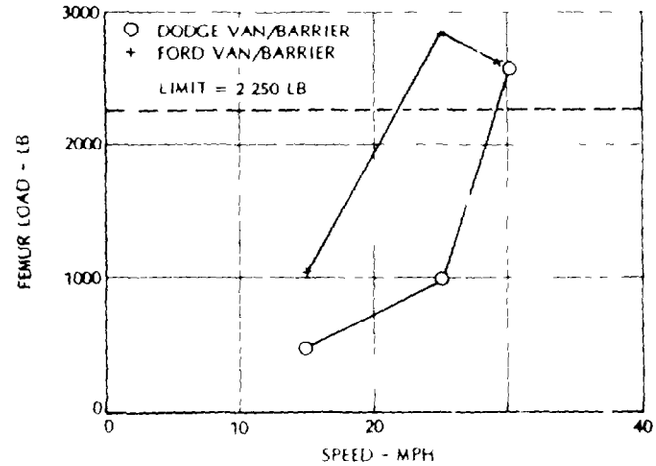


Fig. 14 - Driver right femur load versus impact speed

inertia forces for the Dodge were higher than for the Ford.

The total interface force can be estimated from inertia forces using a two-mass dynamic model, i.e., the mass of the engine and the mass of the rest of the vehicle. This computation is illustrated in Figures 26 and 27 for the 30-mph tests, where (A1 + A2)/2 is the time-averaged compartment acceleration on the right and left sides, and A5 is the engine acceleration. The interface force can also be obtained by summing the load data from the 40 load cell modules on the NHTSA Fixed Test Device. These data are shown in Figures 28 and 29. The maximum forces as a function of speed are presented in Figures 30 and 31.

Cross plots of the total load cell force versus vehicle displacement (from van compartment accelerometer data) are shown in Figures 32 and 33. These figures show little difference between the Ford and Dodge vans in terms of overall structural stiffness. It should be noted, however, that the total interface load cell forces (Figures 28 and 29) have lower peak values than the interface forces derived from inertia loading data (Figures 26 and 27). This discrepancy

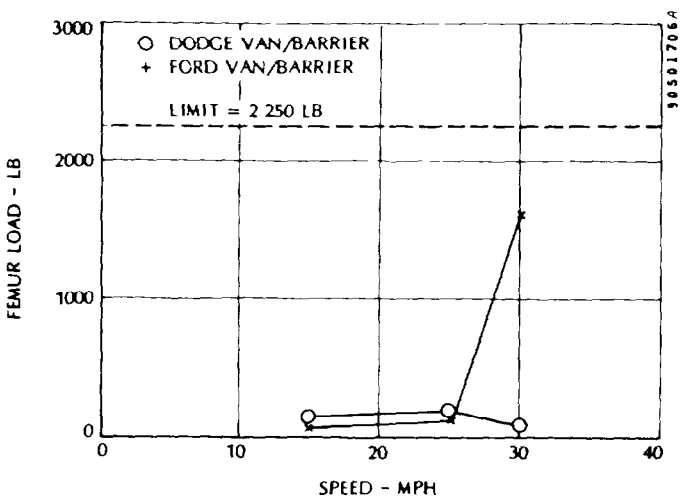


Fig. 15 - Front passenger left femur load versus impact speed

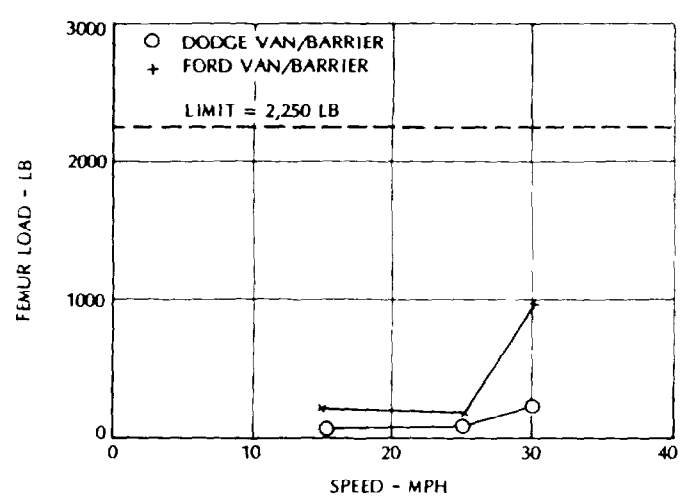


Fig. 16 - Front passenger right femur load versus impact speed

Table 5 - Comparison of Vehicle Response Data - Barrier Tests

	Ford Test 1	Ford Test 2	Ford Test 3	Dodge Test 4	Dodge Test 5	Dodge Test 6
Velocity (mph)	15.3	25.1	30.0	25.2	30.2	15.3
Velocity Change (mph)	17.09	27.87	31.97	27.14	32.79	17.12
Accelerometer Dynamic Crush (in. @ msec)	8.8 @ 50	16.1 @ 65	20.1 @ 69	17.3 @ 71	21.2 @ 71	8.9 @ 61
Film Dynamic Crush (in. @ msec)	8.1 @ 50	15.3 @ 67	19.5 @ 68	16.7 @ 68	19.1 @ 66	7.5 @ 56
Static Crush (in.)	6.9	13.1	16.4	14.5	16.6	6.5
Peak Compartment Acceleration (g @ msec)	-25.1 @ 16	-29.5 @ 26	-34.9 @ 16	-43.4 @ 15	-51.9 @ 14	-27.6 @ 27
Average Acceleration (g, Over msec)	-11.61, 66	-15.15, 82	-18.0, 78	-14.77, 82	-17.6, 82	-10.36, 70
Peak Engine Acceleration (g @ msec)	-45.5 @ 26	-59.0 @ 27	-66.5 @ 25	-85.1 @ 22	-83.5 @ 35	-37.1 @ 32
Fixed Test Device Force (klb @ msec)	82.50 @ 44	97.36 @ 25	129.92 @ 38	93.40 @ 45	114.57 @ 42	81.12 @ 30
Engine/Car Inertia Force (klb @ msec)	112.16 @ 16	138.01 @ 28	193.18 @ 36	176.28 @ 15	208.41 @ 14	115.52 @ 27

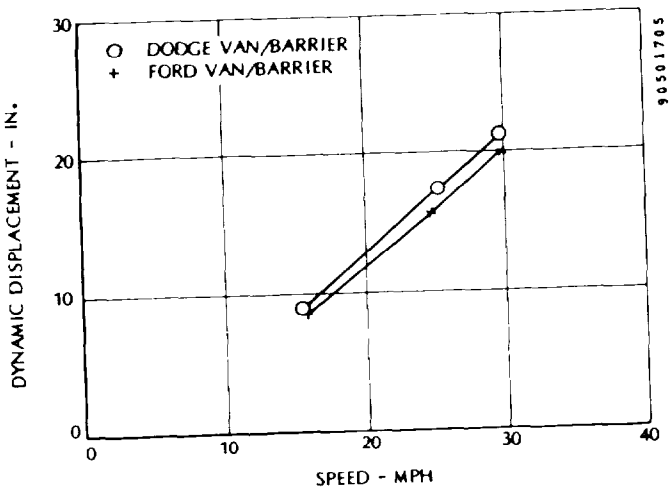


Fig. 17 - Dynamic crush (accelerometer data) versus impact speed

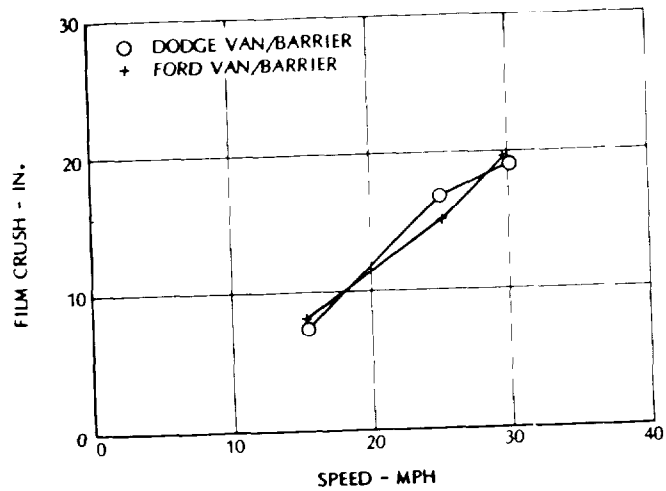


Fig. 18 - Dynamic crush (film data) versus impact speed

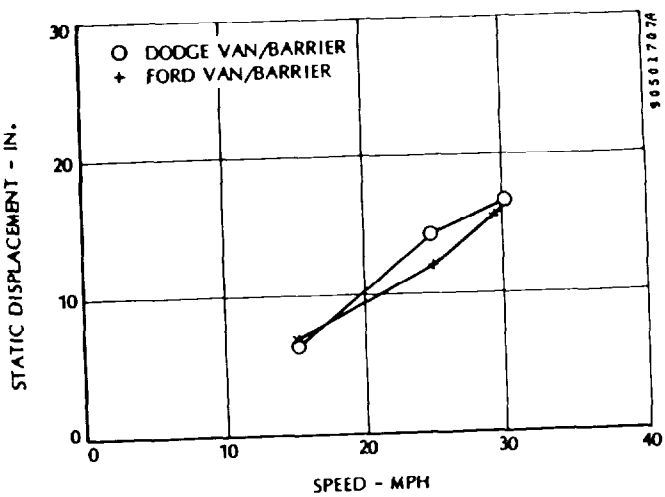


Fig. 19 - Static crush versus impact speed

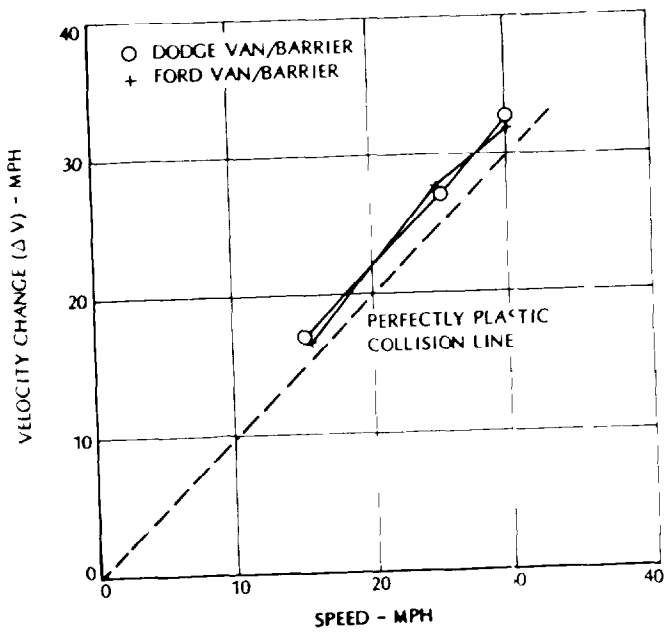


Fig. 20 - Velocity change versus impact speed

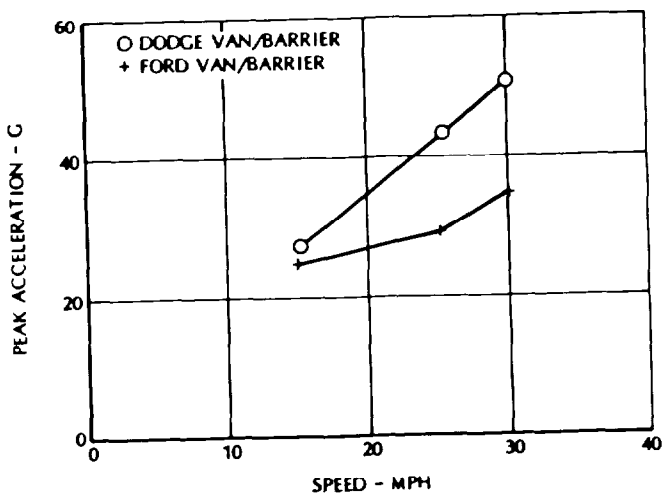


Fig. 21 - Maximum compartment acceleration versus impact speed

is due partly to the approximation of using only two masses in the dynamic model, and partly to loss of load in the load-measuring modules. Bottoming out of some of the load cells can occur under exceptionally severe loading conditions. Several approaches to improve the fidelity of the load-measuring subsystem are currently under consideration at NHTSA. Integration of the barrier force versus time curves in Figures 28 and 29 yield impulse values which are 86 and 85 percent (for the Ford and Dodge tests respectively), of the momentum change values using vehicle mass and velocity change (7323 lb-sec for the Ford, and 6990 lb-sec for the Dodge).

OCCUPANT RESPONSE PARAMETERS VERSUS VEHICLE PARAMETERS - Selected occupant response parameters in Table 4 were cross plotted against vehicle velocity change (Figure 34) and against average compartment acceleration (Figure 35) obtained from Table 5. These figures illustrate a somewhat greater upward trend for velocity change than for average compartment acceleration.

POST-TEST EXAMINATION - Figures 36 and 37 permit a visual comparison of the exterior crush and damage patterns for the Ford and Dodge vans during each of the barrier tests. Additional views of the vans after the 30-mph barrier tests are included as Figures 38 and 39.

Figures 40 and 41 permit visual examination of the interior deformation of the driver and front passenger compartment areas. These figures show considerable steering wheel upward displacement, even at 25 mph, for both vans.

TEST RESULTS FOR CAR-TO-VAN COLLISIONS

Since the vans impacted identical full-size cars (Chevrolet Impalas), the relative crashworthiness of the vans could be assessed by comparing the occupant responses in the two vans. In addition, the relative aggressivity of the vans could be assessed by comparing the structural and occupant responses in the struck cars.

It must be remembered that the closing speed for Ford Test 7 (63.6 mph) was slightly higher than for Dodge Test 8 (62.3 mph), in order to obtain the same velocity change (ΔV) on the van as in a 30-mph barrier test.

OCCUPANT RESPONSE PARAMETERS - The pertinent occupant response data are presented in Table 6 for critical response parameters as defined in FMVSS 208. The van occupant head and chest data plotted against van velocity change (from Table 7) are presented in Figures 42 and 43. The open symbols represent the previous barrier crash data,

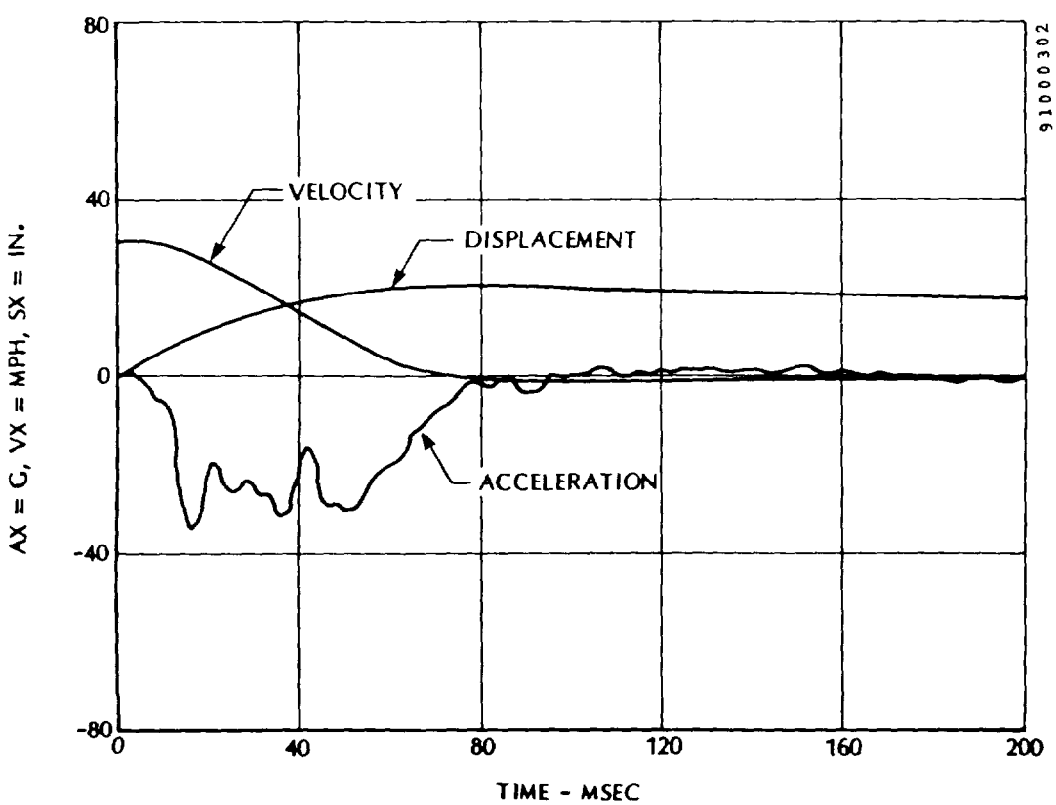


Fig. 22 - Ford compartment acceleration, velocity, and displacement for 30-mph barrier Test 3

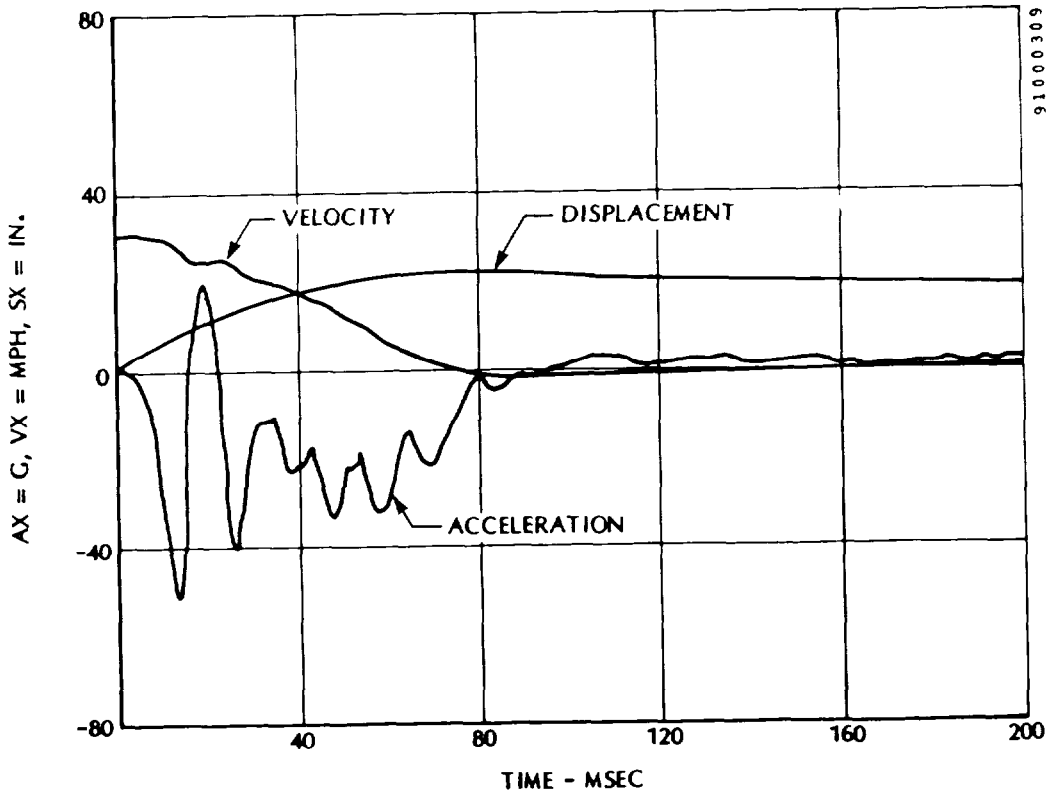


Fig. 23 - Dodge compartment acceleration, velocity, and displacement for 30-mph barrier Test 5

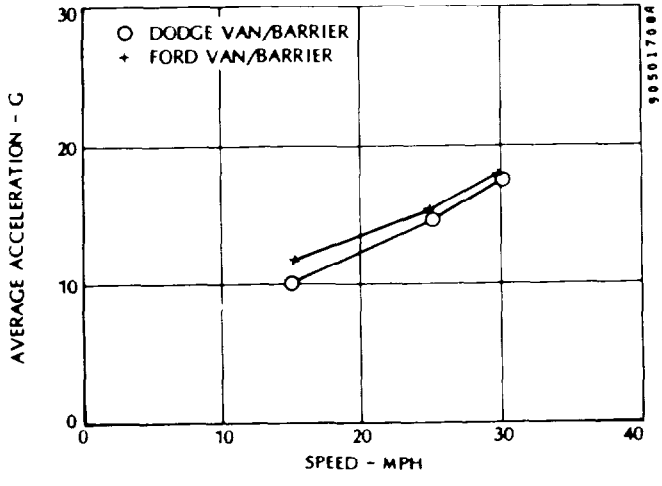


Fig. 24 - Average compartment acceleration versus impact speed

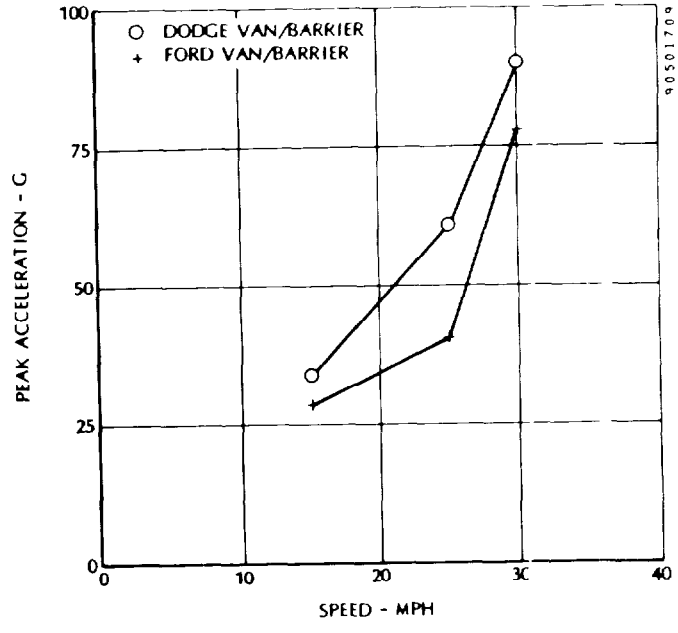


Fig. 25 - Maximum engine acceleration versus speed

the black data points represent the car-to-van test data.

It can be noted that the Ford velocity change for the Ford-to-car test is a little higher than for the "equivalent" barrier test, while the Dodge velocity change for the Dodge-to-car test is a little lower than for the barrier test. This occurred even though the test speed tolerance window (±0.5 mph) resulted in a slightly lower (63.6 mph versus 64.1 mph) closing speed for the Ford-to-car test, and a slightly higher (62.3 mph versus 61.7 mph) closing speed for the Dodge-to-car test. This velocity change data may indicate slightly different coefficients of restitution in the van-to-car tests, or may merely reflect accuracy limits inherent in determining vehicle velocity change from test data.

The data for the van-to-car tests appear to be compatible with the previous barrier test data, however, the HIC data for the Dodge appears somewhat higher, and for the Ford somewhat lower, than would be expected from the barrier tests. In fact, the HIC values obtained in the van-to-car tests have reversed the relative injury levels in the two vehicles found during the barrier tests. Although the data from one test are not conclusive, they do point out that different conclusions regarding the relative crashworthiness of vehicles may be obtained from vehicle-to-barrier or vehicle-to-vehicle tests.

The available dummy data (Tables 4 and 6) were normalized by dividing the data by the appropriate limits in FMVSS 208 (i.e., 1000 for HIC, 1000 for Chest SI, 60 g for Chest g, and 2,250 pounds for femur loads). These normalized data for the Dodge and Ford dummies are cross plotted in Figure 44 to assess van crashworthiness. The normalized data for the Chevrolet dummies in the Dodge and Ford tests are cross plotted in Figure 45 to assess van aggressivity.

The Equal Severity Line (ESL) in Figures 44 and 45 provides a natural boundary for assessing which test produces more severe dummy responses. For example, Figure 44 indicates a scatter of the data about the ESL with one HIC (O) appreciably above the line and one right femur (ΔR) appreciably below the line. Thus, it appears that there is no strong difference in the crashworthiness of the two van models.

On the other hand, Figure 45 indicates almost all of the data is above the ESL, except for one or two femur loads (ΔR, ΔL). Although no statistically valid conclusions can be drawn from only one test per vehicle, these data suggest that the Dodge van may be more aggressive than the Ford.

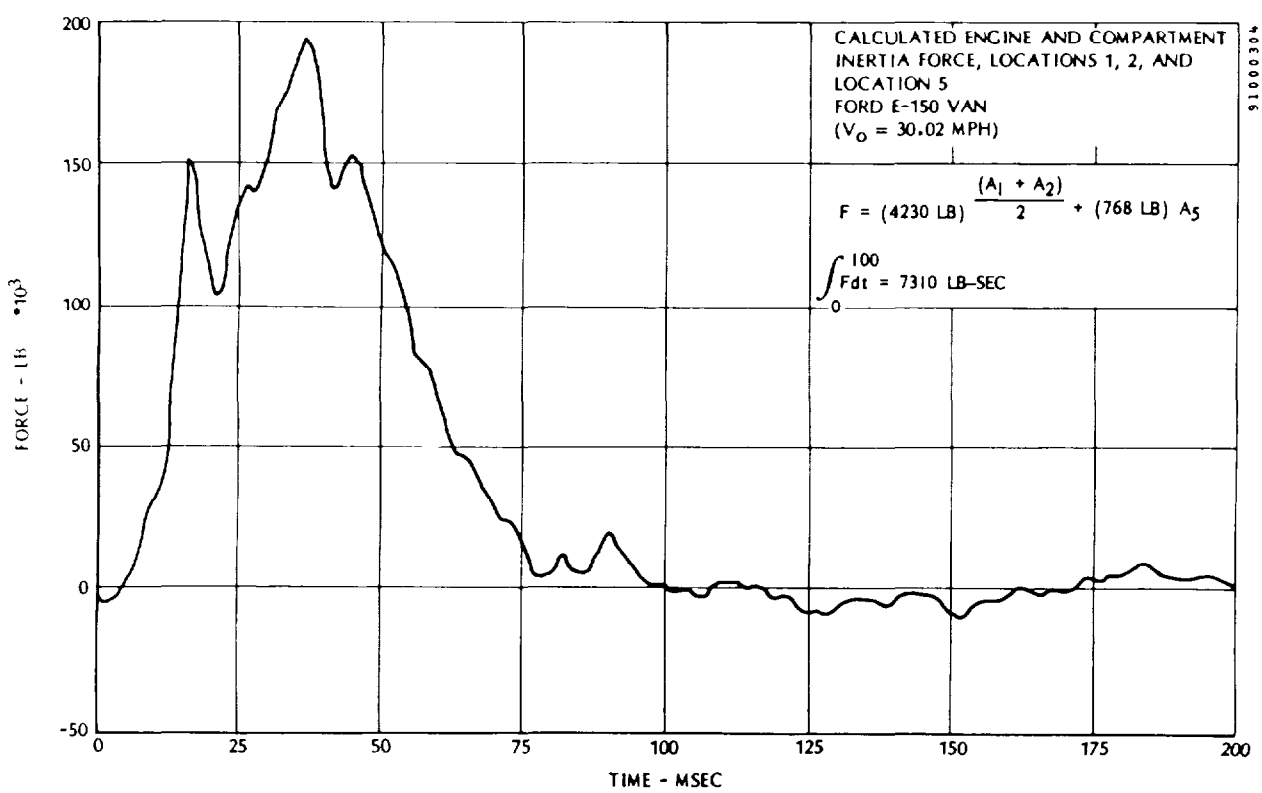


Fig. 26 - Calculated interface inertia force for 30-mph Ford Test 3

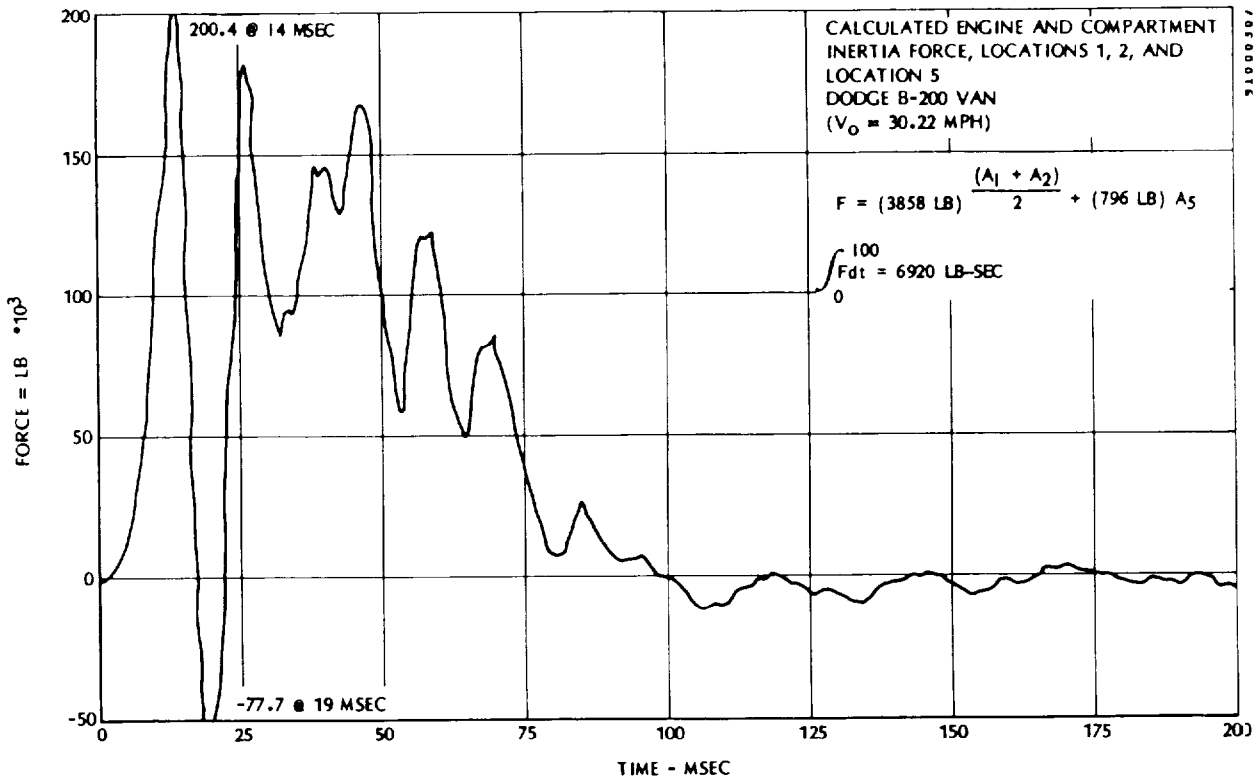


Fig. 27 - Calculated interface inertia force for 30-mph Dodge Test 5

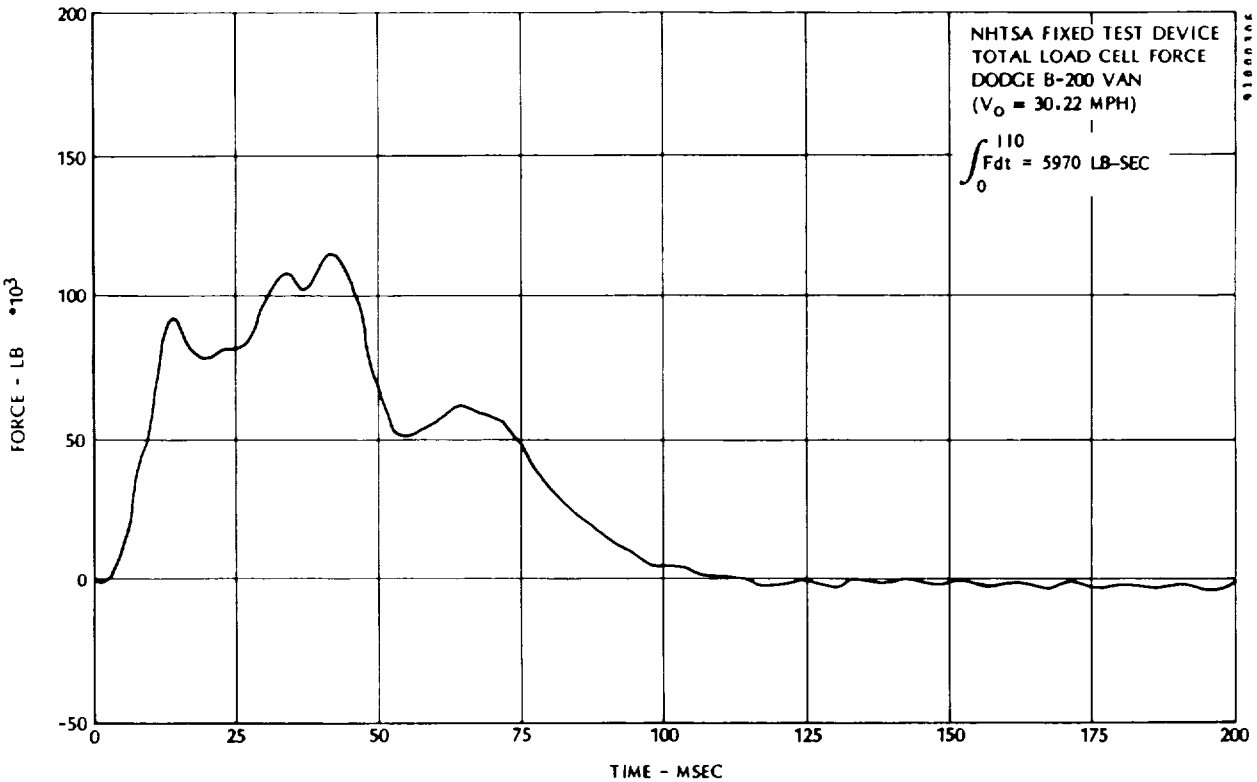


Fig. 28 - Measured interface load cell force for 30-mph Ford Test 3

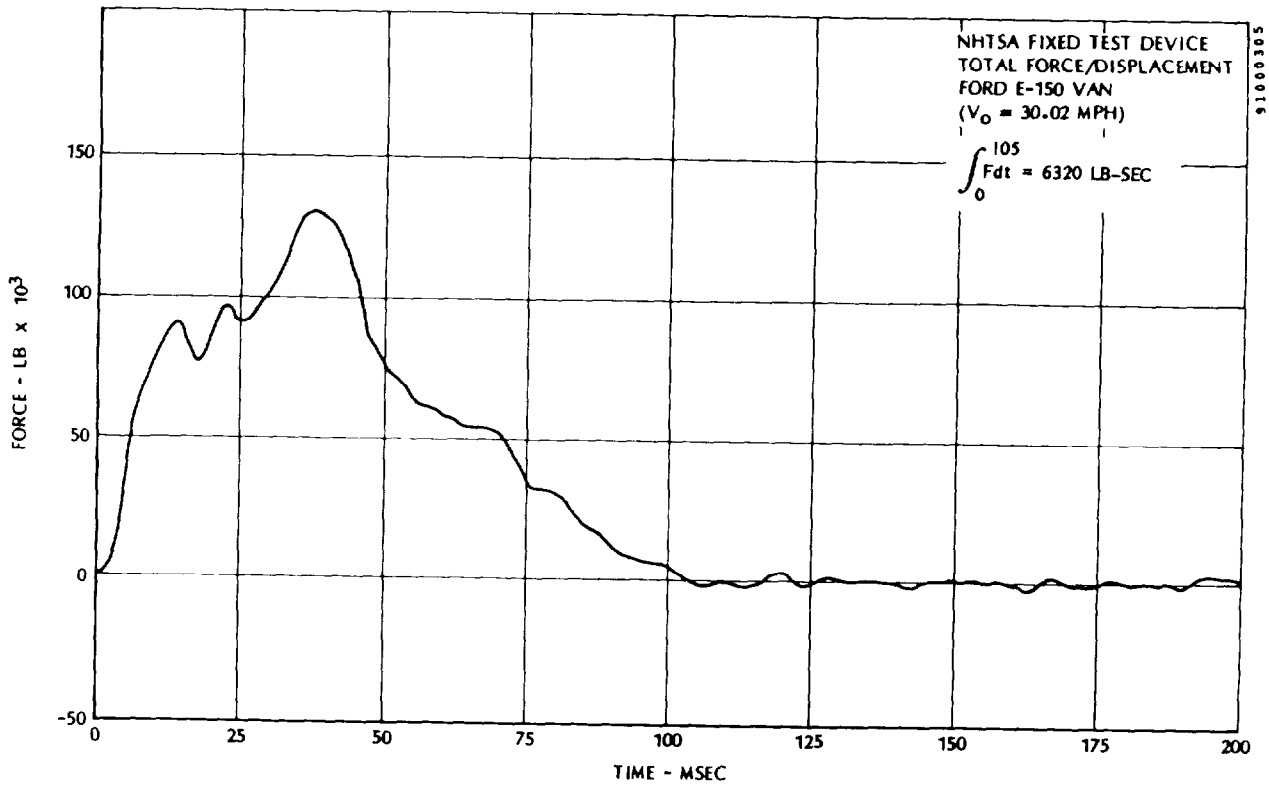


Fig. 29 - Measured interface load cell force for 30-mph Dodge Test 5

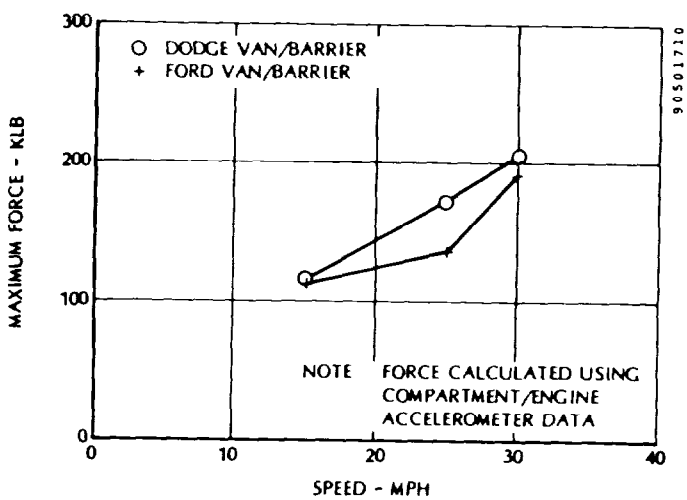


Fig. 30 - Maximum vehicle inertia force versus impact speed

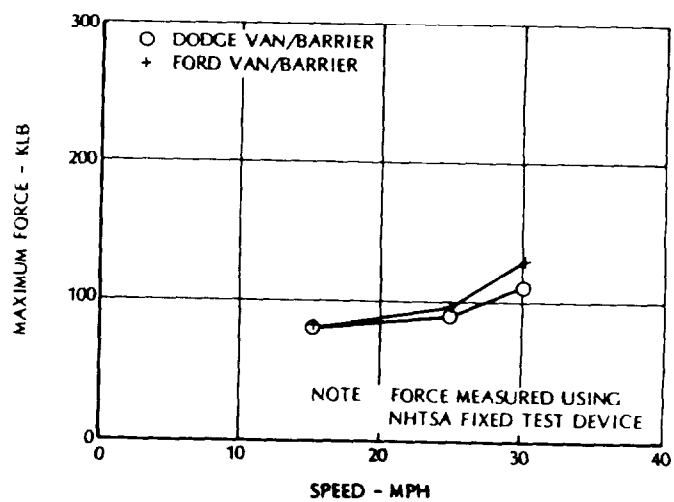


Fig. 31 - Total measured load cell force versus impact speed

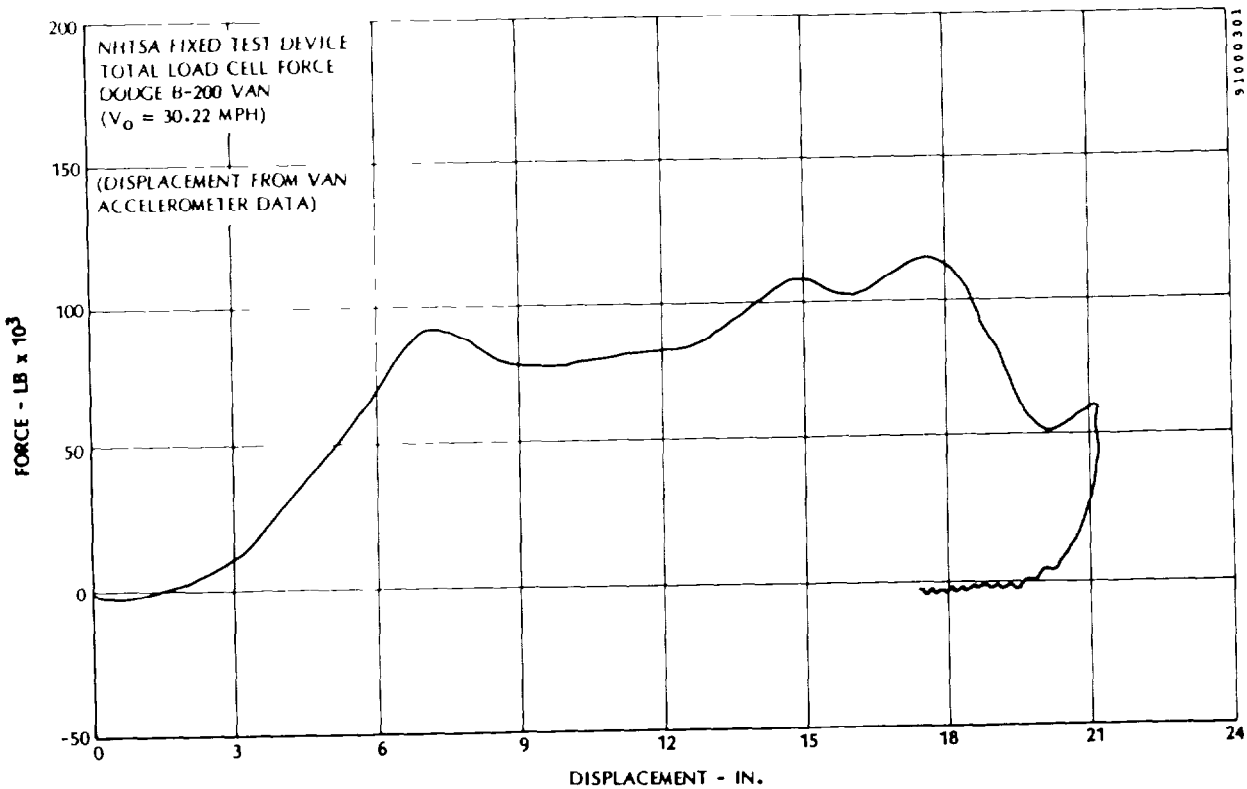


Fig. 32 - Interface load cell force versus vehicle displacement for 30-mph Dodge Test 5

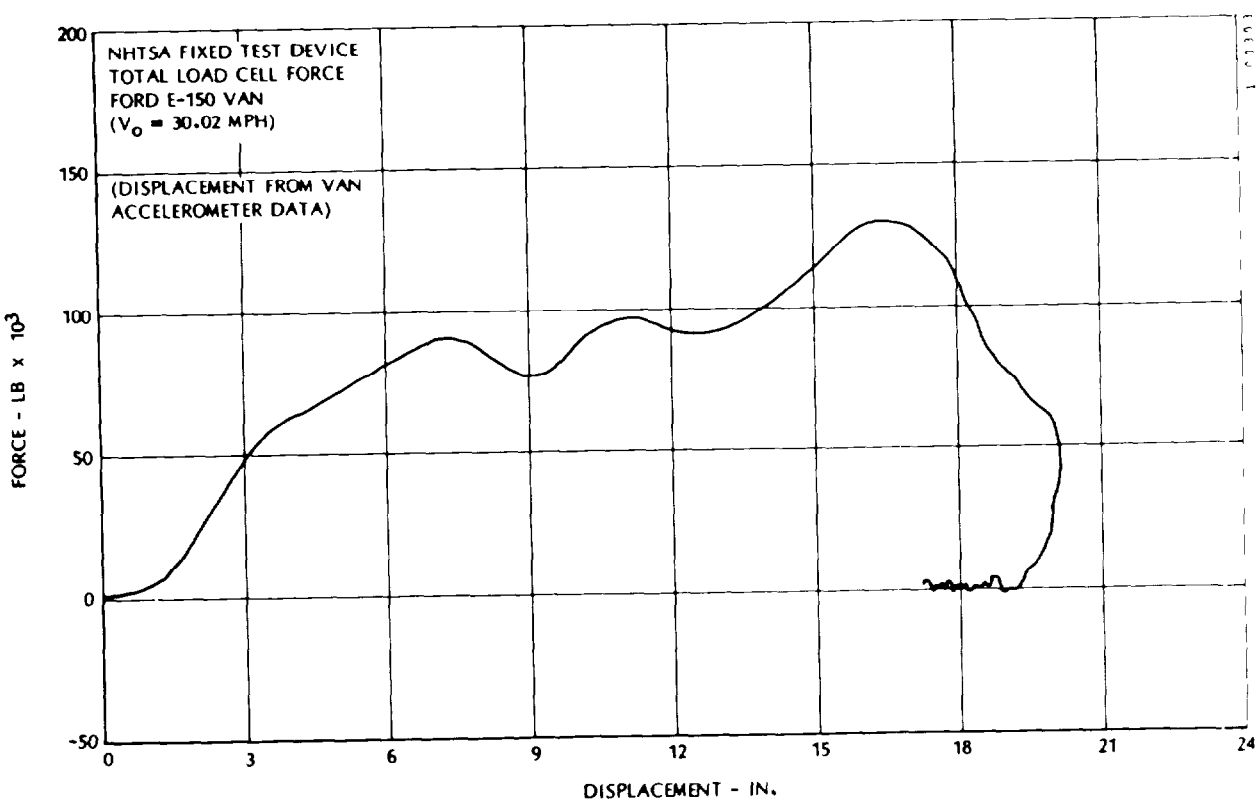


Fig. 33 - Interface load cell force versus vehicle displacement for 30-mph Ford Test 3

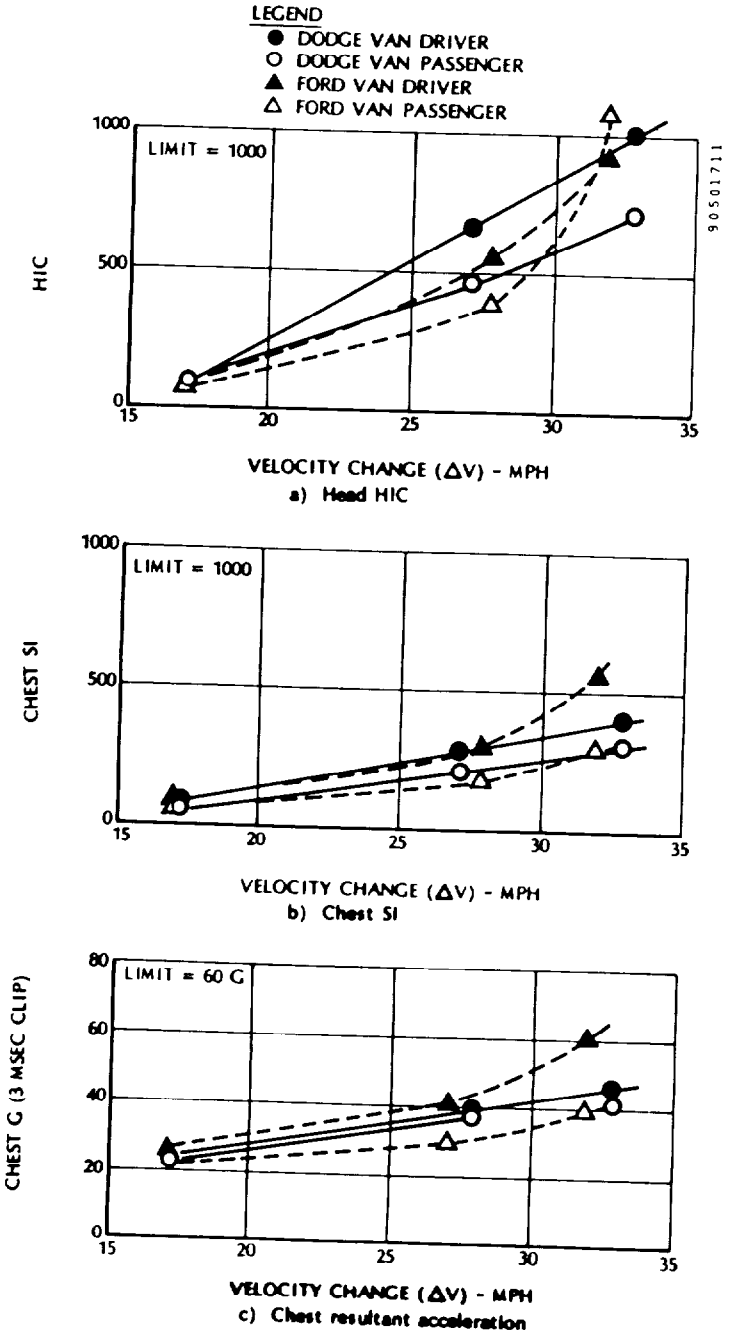


Fig. 34 - Head and chest parameters versus vehicle velocity change (van-to-barrier tests)

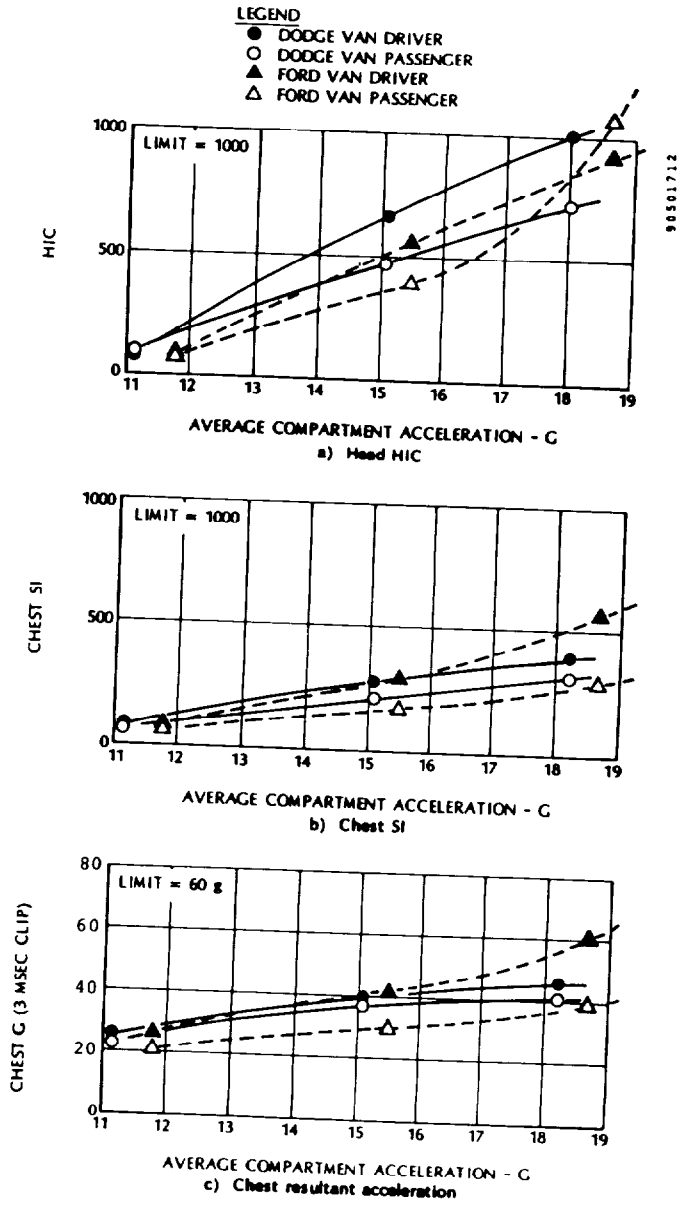
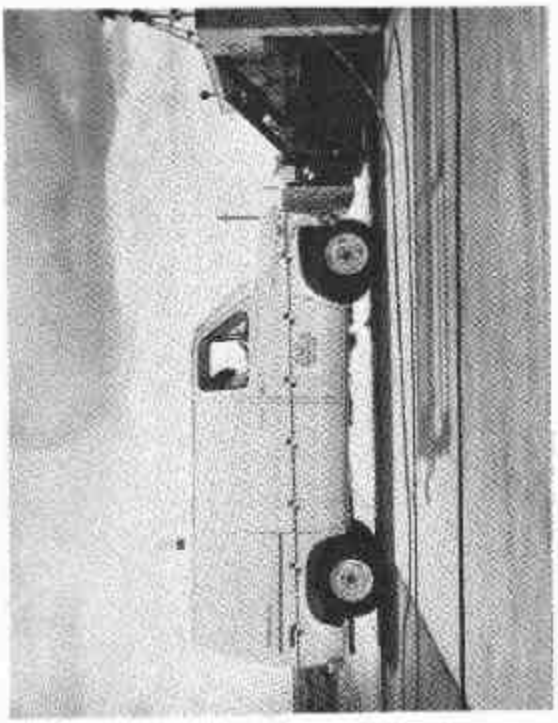
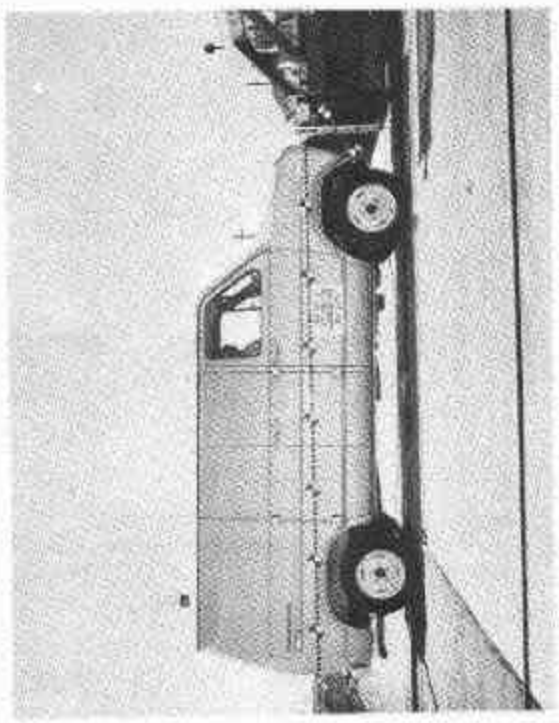


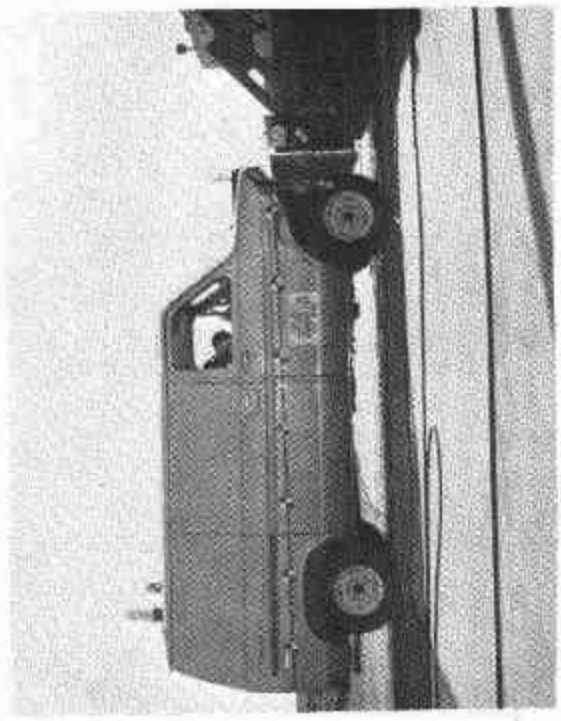
Fig. 35 - Head and chest parameters versus average compartment acceleration (van-to-barrier tests)



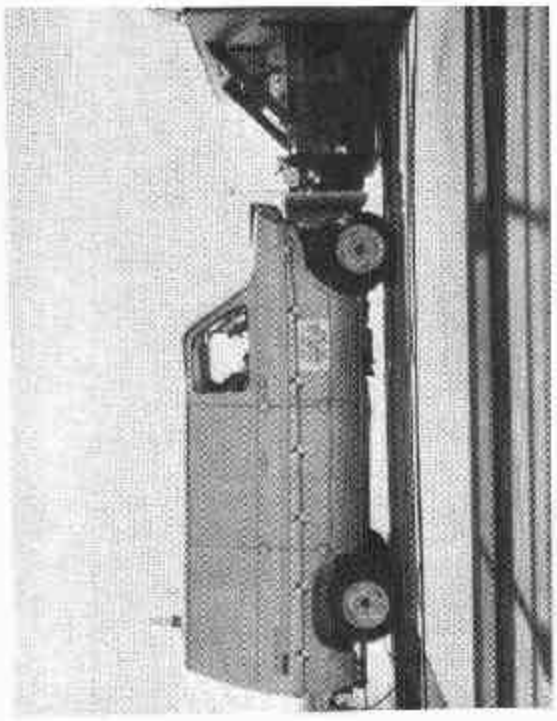
a) Ford pre-test



b) Ford Test 1 - 15 mph

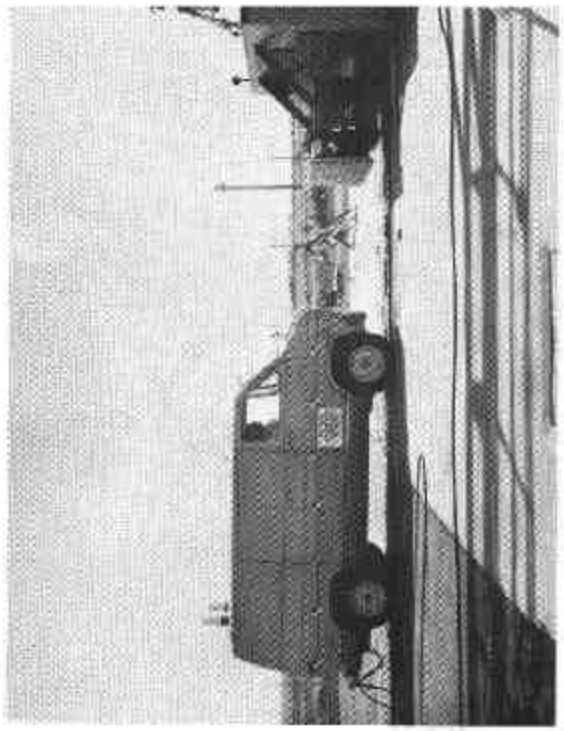


c) Ford Test 2 - 25 mph

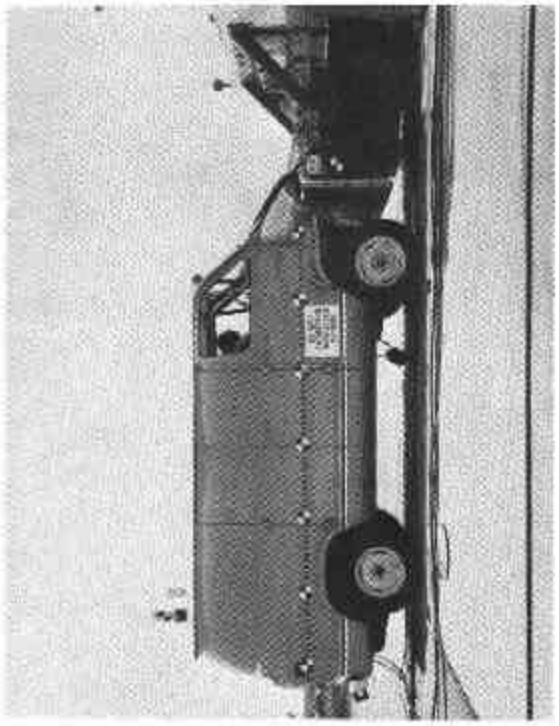


d) Ford Test 3 - 30 mph

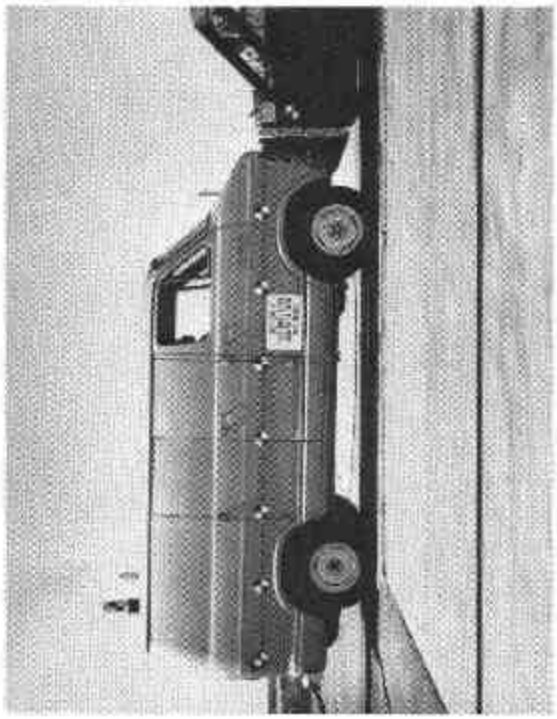
Fig. 36 - Ford van post-test configurations



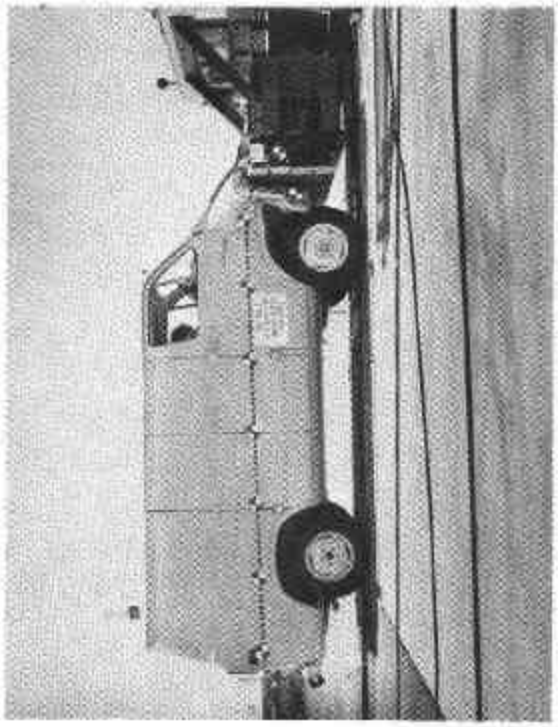
b) Dodge Test 6 - 15 mph



d) Dodge Test 5 - 30 mph



a) Dodge pre-test



c) Dodge Test 4 - 25 mph

Fig. 37 - Dodge van post-test configurations

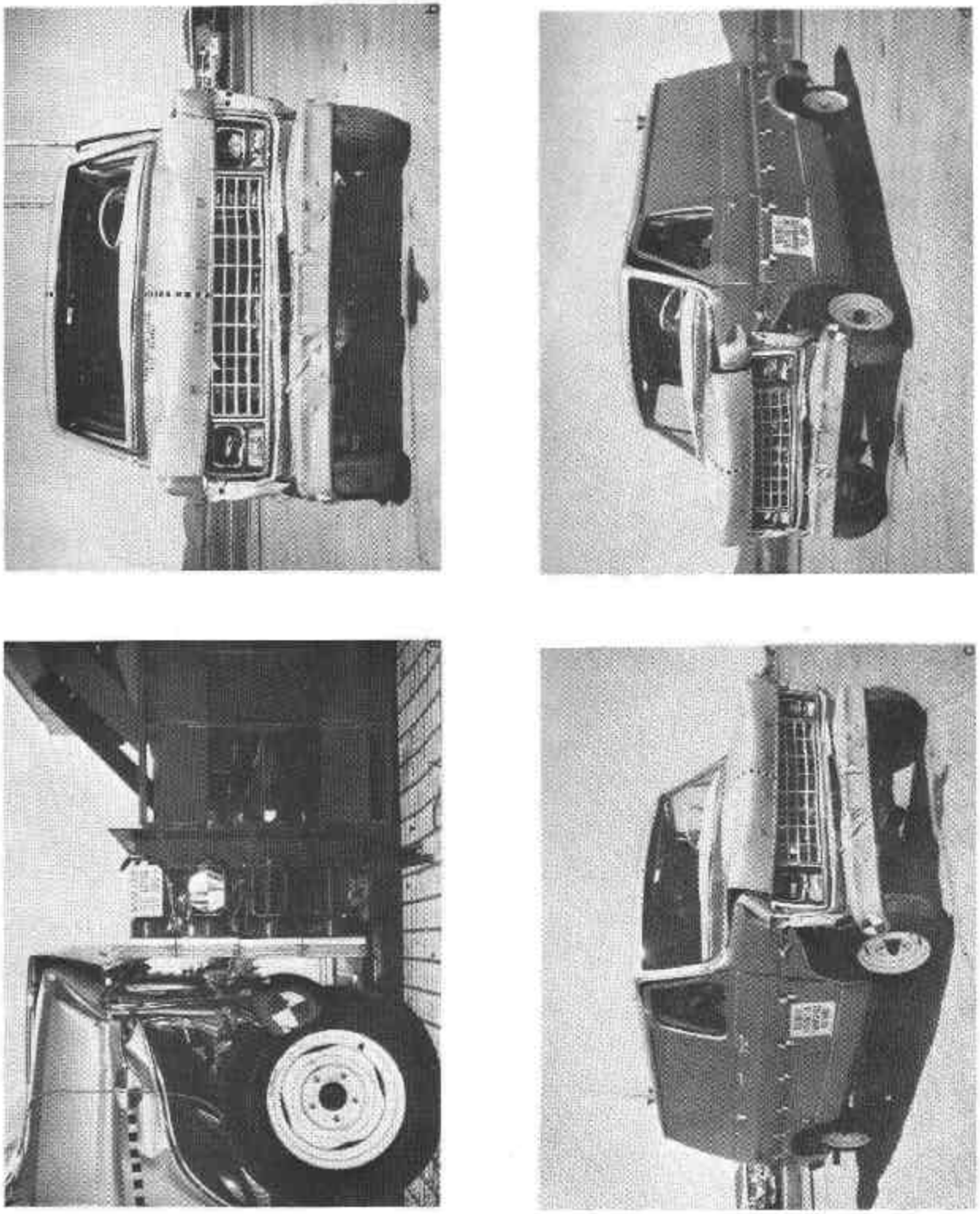


Fig. 38 - Post-test views of Ford vehicle configuration after Test 3 (30 mph)

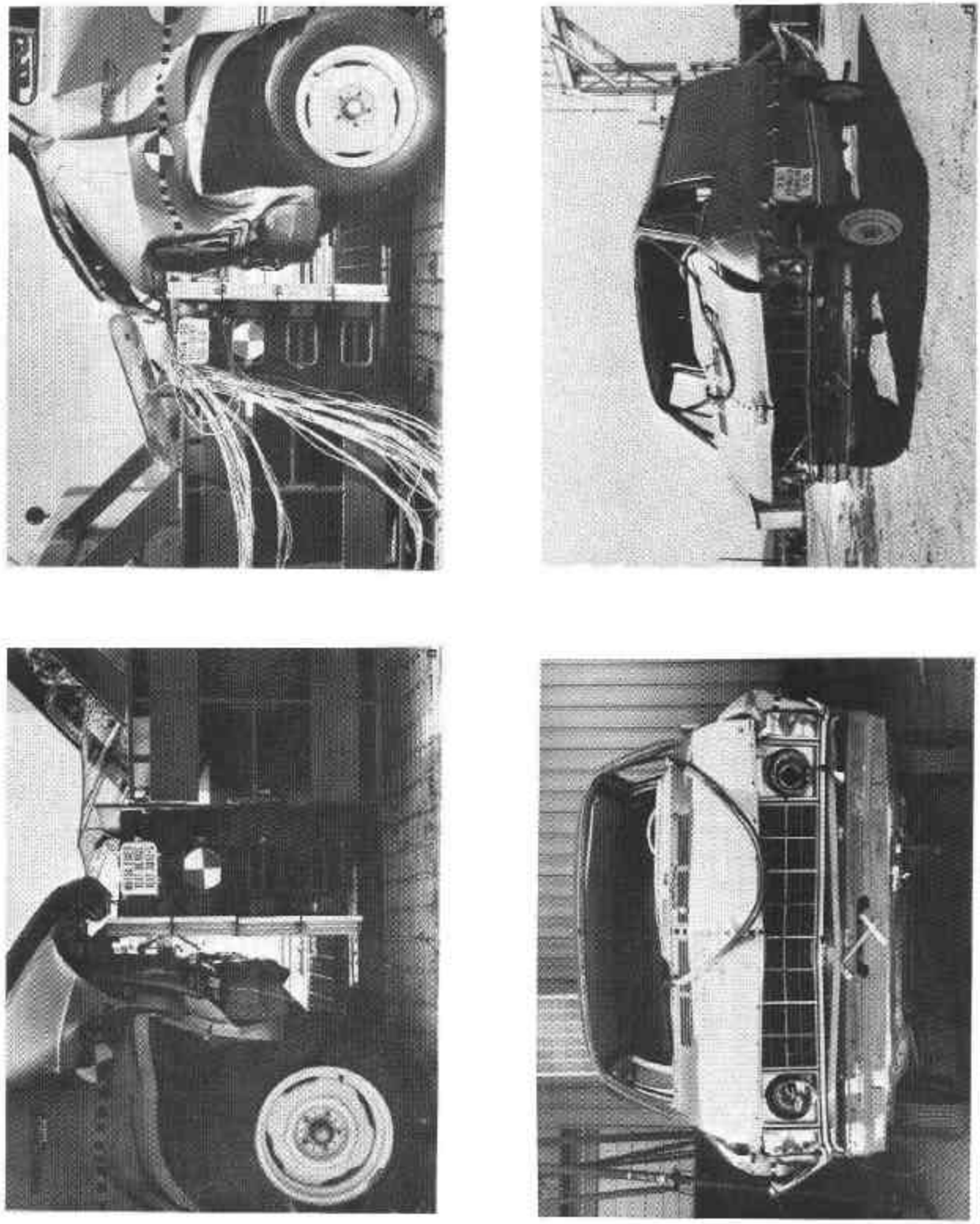


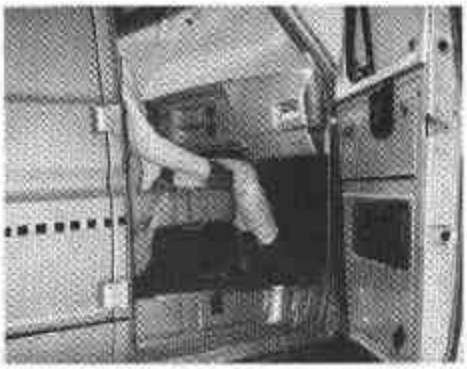
Fig. 39 - Post-test views of Dodge vehicle configuration after Test 5 (30 mph)

a) Ford pre-test driver

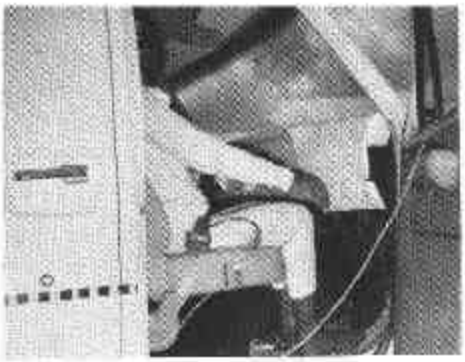
b) Ford Test 1 driver - 15 mph

c) Ford Test 2 driver - 25 mph

d) Ford Test 3 driver - 30 mph



e) Ford pre-test passenger



f) Ford Test 1 passenger - 15 mph

g) Ford Test 2 passenger - 25 mph

h) Ford Test 3 passenger - 30 mph

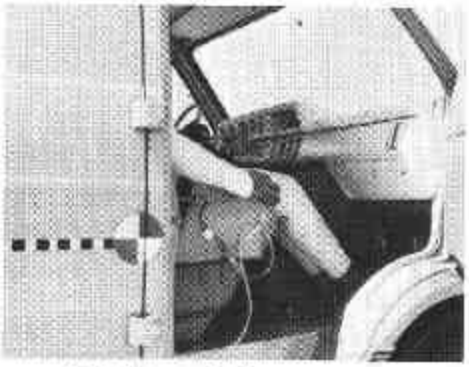
Fig. 40 - Ford van occupant compartment configurations

a) Dodge pre-test driver

b) Dodge Test 6 driver - 15 mph

c) Dodge Test 4 driver - 25 mph

d) Dodge Test 5 driver - 30 mph



e) Dodge pre-test passenger

f) Dodge Test 6 passenger - 15 mph

g) Dodge Test 4 passenger - 25 mph

h) Dodge Test 5 passenger - 30 mph

Fig. 41 - Dodge van occupant compartment configurations

Table 6 - Comparison of Occupant Response Parameters Van-to-Car Tests

	Ford Test 7				Dodge Test 8			
	Van		Car		Van		Car	
	LF	RF	LF	RF	LF	RF	LF	RF
HIC	973	728	1099	1114	1266	864	1448	1319
Chest SI	408	252	504	394	328	307	788	467
Peak Resultant Chest Acceleration (g)*	45.8	33.5	47.2	39.1	42.7	35.9	71.9	52.8
Left Femur Load (lb)	-980	-166	-	-952	-666	-70	-172	-1208
Right Femur Load (lb)	-3111	-540	2287	760	1044	-53	-197	1063

*3 msec clip per FMVSS 208.

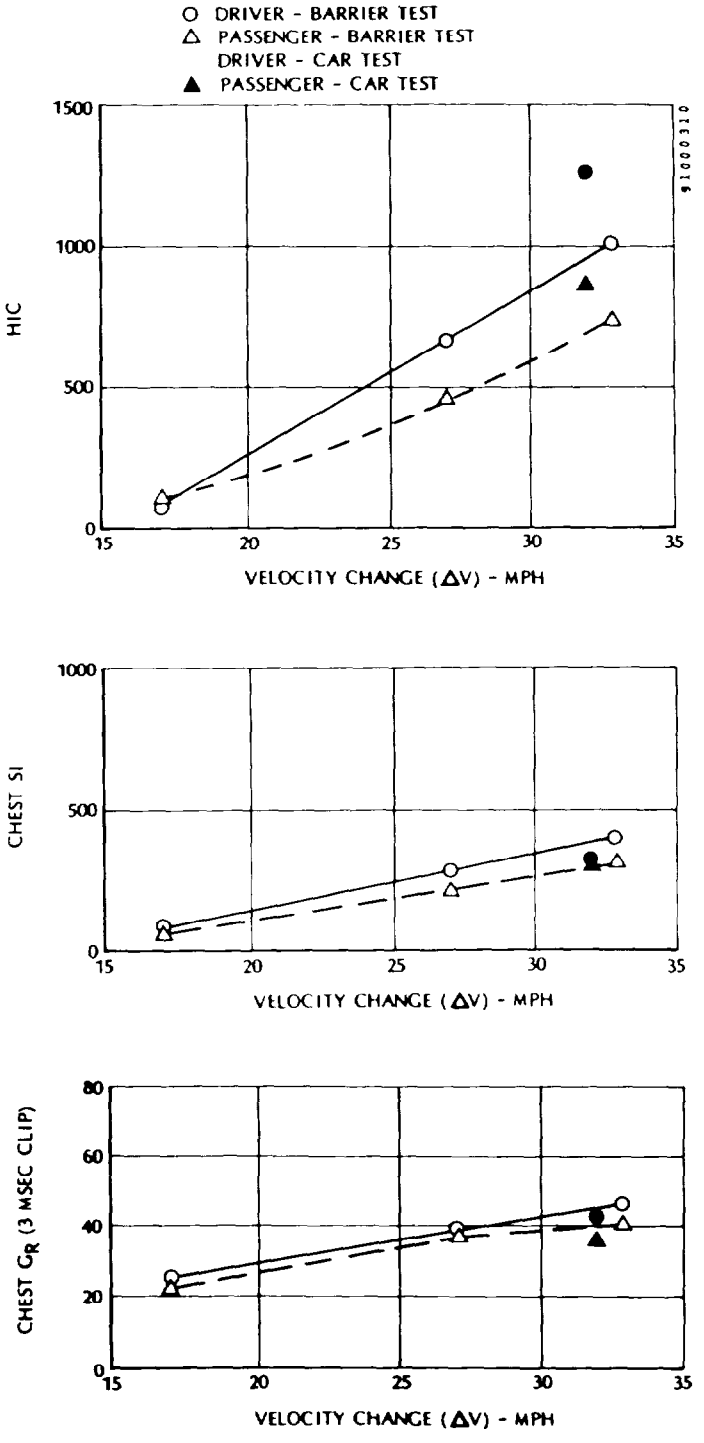


Fig. 42 - Van dummy head and chest parameters versus vehicle velocity change - Dodge van tests

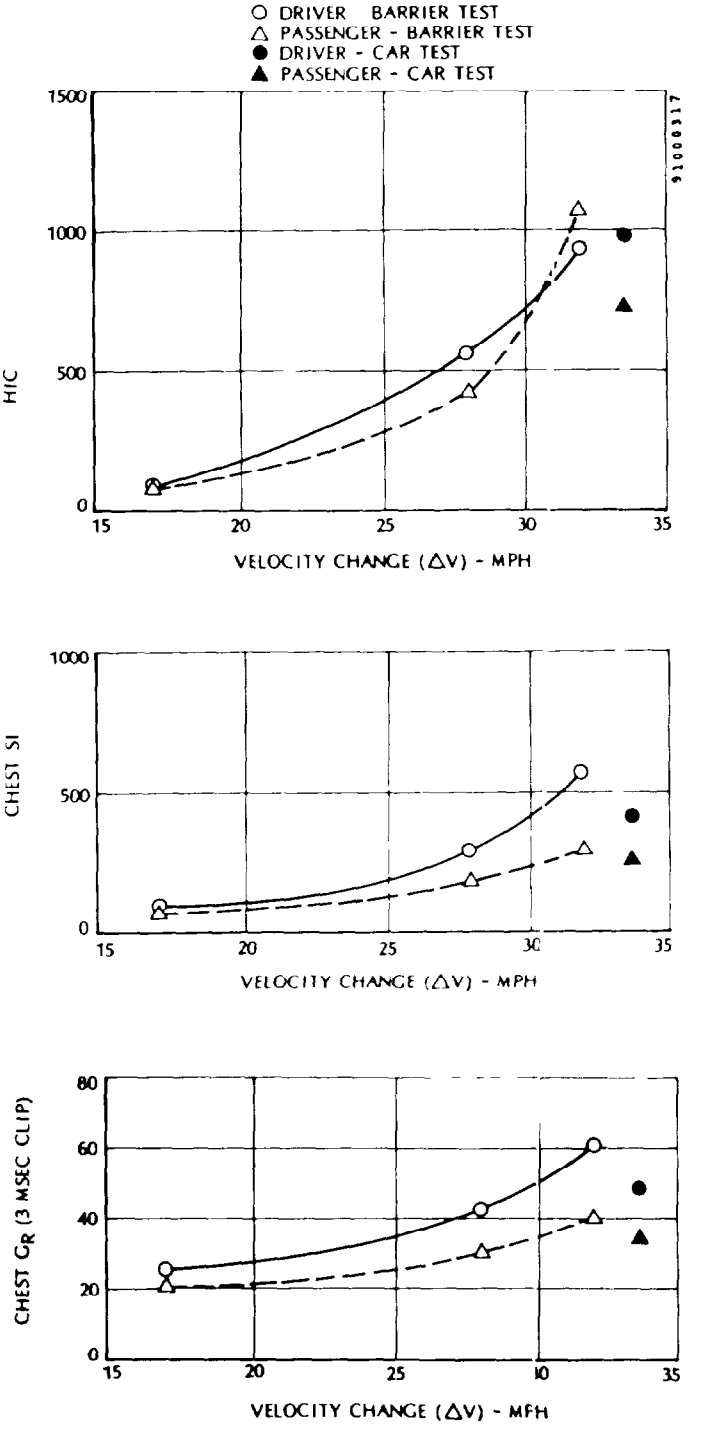


Fig. 43 - Van dummy head and chest parameters versus vehicle velocity change - Ford van tests

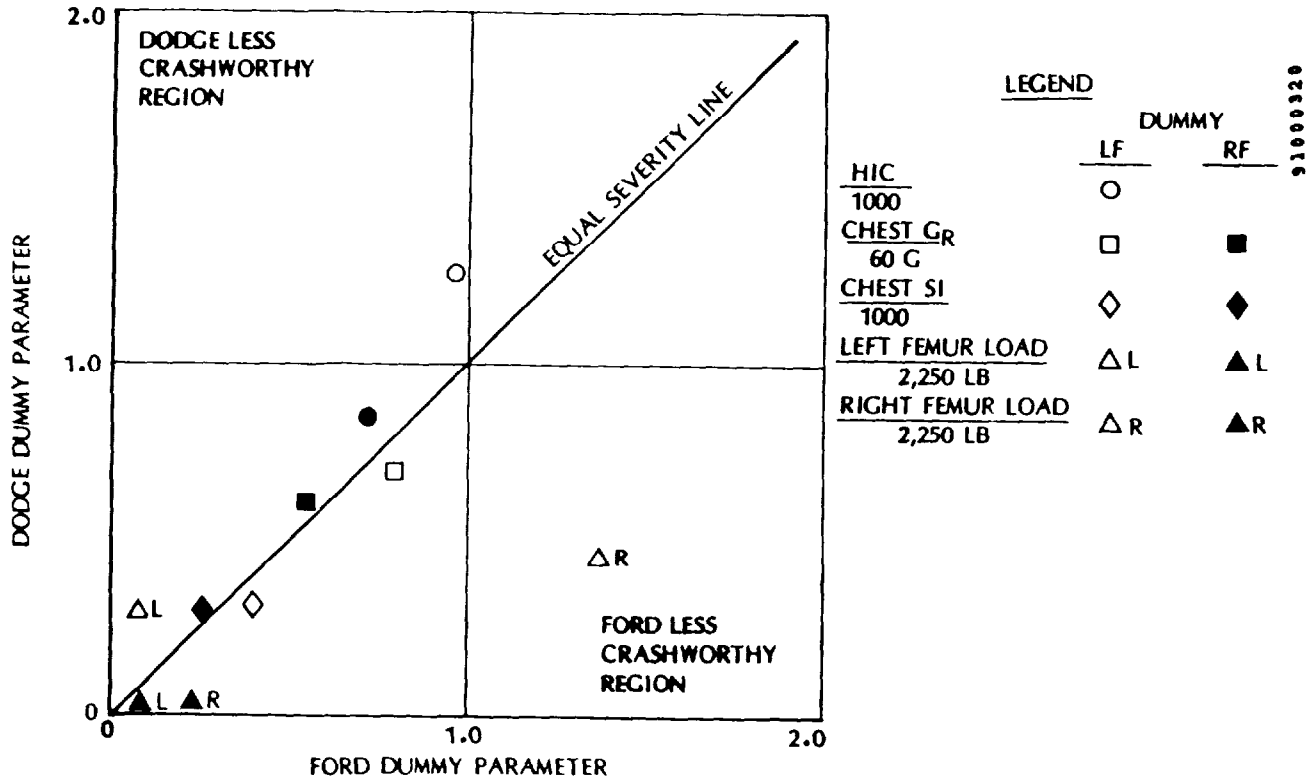


Fig. 44 - Comparison of normalized van dummy parameters - van-to-car tests

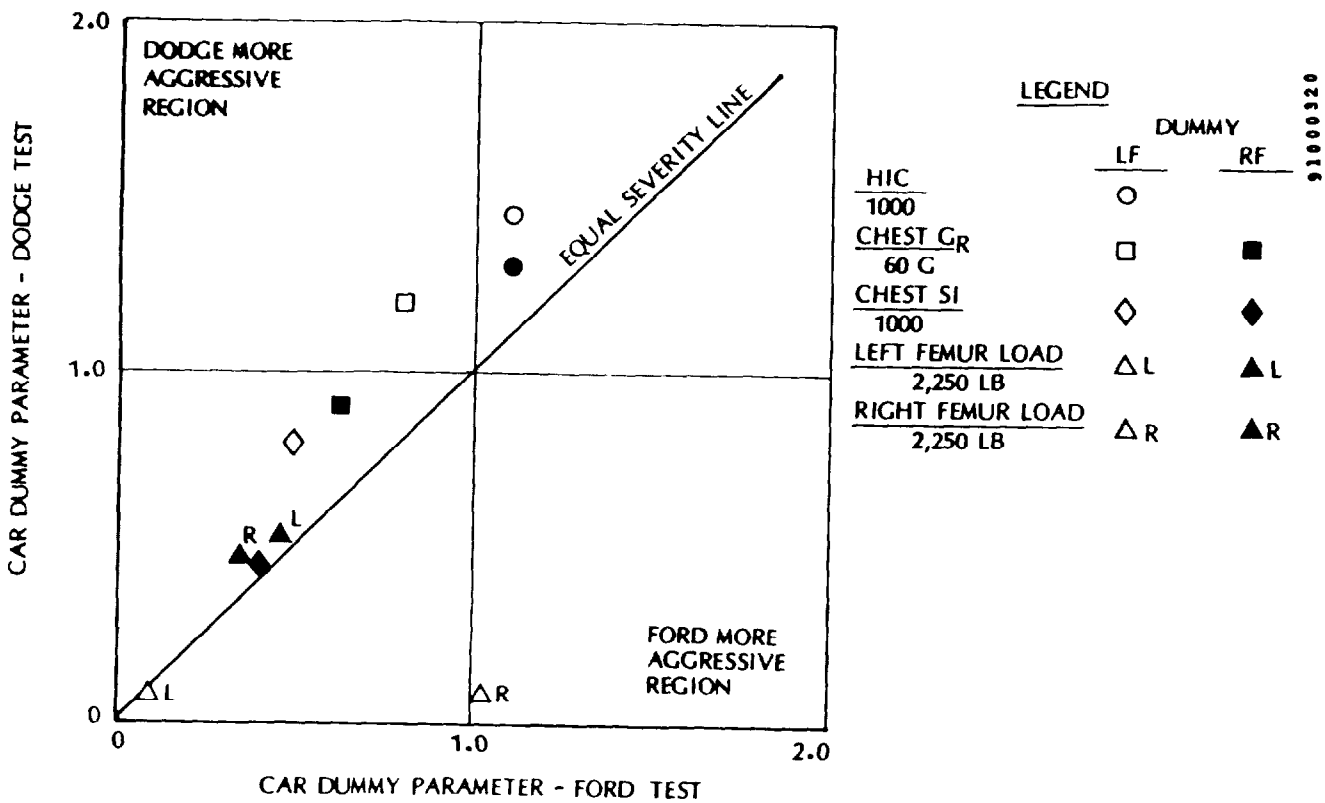


Fig. 45 - Comparison of normalized car dummy parameters - van-to-car tests

VEHICLE RESPONSE PARAMETERS - The pertinent vehicle response parameters are presented in Table 7. These include similar structural parameters as used in the barrier test analysis (Table 5). However, the vehicle-to-vehicle tests required some differences in presentation. For example, the closing velocity is the important test condition rather than the velocity of the van (i.e., a closing speed of 63.6 mph could have been attained with the van stationary and the car traveling at 63.6 mph, or with both vehicles moving at equal and opposite speeds of 31.8 mph as in Test 7). Some parameters, such as vehicle dynamic crush from film or accelerometer data, are difficult to obtain in vehicle-to-vehicle tests, because the interface between the two vehicles is poorly defined during the crash. Thus, Table 7 presents maximum mutual dynamic crush rather than van and car data separately. This data indicates about the same crush distance for Tests 7 and 8.

The individual maximum static (post-test) crush is determinable and is included in Table 7. These data indicate that the Dodge van crushed more and the corresponding Chevrolet car crushed less than for the Ford collision. These data suggest that the Dodge van is less crashworthy, and the Ford van is more aggressive, these conclusions are not consistent with the dummy response data (Figures 44 and 45) which indicated no significant difference in van crashworthiness, and that the Dodge was more aggressive than the Ford. Thus, the dummy and vehicle crush responses in these tests lead to opposite conclusions regarding the relative crashworthiness and aggressivity of the two vehicles.

Figure 46 shows the bumper match and interface for the vans with the Chevrolet, we can see that the Ford bumper does not overlap the Chevrolet as much, and would tend to override more easily. Thus, differences could be expected in crush patterns during Tests 7 and 8. Figure 47 presents the post-test crush profiles for the vans and the Chevrolets. Although the van crush profiles are similar, major differences can be seen in the Chevrolet crush profiles. The collision with the Ford resulted in maximum crush between bumper and hood level and at hood level, while the maximum crush for the Dodge test occurred at bumper level. Since vehicle structural aggressivity is composed of two inseparable factors - the geometry and the stiffness of the structure - it is difficult to assess the aggressivity of the vans only from the stiffness data obtained in these two tests. The effect of the frontal geometrical differences may be as significant to the struck vehicle dummy and structural responses as is the effect of differences in structural stiffness of the two vans.

Figure 48 compares the van post-test crush profiles from the 30-mph barrier tests with the car to-van tests. Although the data appear to show good correlation, the vans crushed somewhat more in the barrier test than in the car-to-van tests. Some differences in crush profile are also observable. These data reflect the fact that structural responses in a fixed rigid barrier test differ from responses with real-world, non-rigid vehicles. Occupants in larger vehicles generally fare better than small car occupants in vehicle-to-vehicle collisions than is indicated during 30-mph fixed barrier tests.

Figure 49 compares the car interior intrusion profiles for the Chevrolets in Tests 7 and 8. There is little difference in the maximum intrusion (3 to 7 inches), but the intrusion pattern is obviously different. For example, at bumper level, the maximum car intrusion by the Dodge occurred closer to the center of the car. At knee and dash level, the maximum intrusion occurred on the car's right side for the Dodge test and on the car's left side for the Ford test. Again, the question of repeatability of test results precludes drawing firm conclusions on the significance of these intrusion differences.

Figure 50 shows the vehicle compartment accelerations, velocities, and displacements for the vans and the Chevrolet in Tests 7 and 8. The car acceleration response data, as well as the derived velocity and displacement data, for the two tests are rather similar. Although the van acceleration data show significant differences in peak values, the derived velocity and displacement data are comparable The differences in velocity data are partly due to the difference in initial closing speed, and the mass ratio of the van/car.

Table 7 - Comparison of Vehicle Response Data - Van-to-Car Tests

	Ford Test 7		Dodge Test 8	
	Van	Car	Van	Car
Test Weight (lb)	4 994	4 400	4 649	4 403
Velocity (mph)	31.8	31.8	31.1	31.1
Velocity Change (mph)	33.7	38.2	32.1	37.4
Maximum Mutual Dynamic Crush (Film Data) (in.)	54.1		54.9	
Maximum Static Crush (in.)	13.6	35.9	15.6	30.9
Peak Compartment Acceleration (g @ msec)	-33.3 @ 53	-40.7 @ 61	-28.8 @ 13	-38.9 @ 54
Average Compartment Acceleration (g, Over msec)	12.9 117	-15.0 116	-14.6 102	-13.72 124
Peak Engine Acceleration (g @ msec)	-48.3 @ 48	-100.2 @ 51	-77.7 @ 48	-98.9 @ 39
Engine/Compartment Inertia Force (klb @ msec)	179.0 @ 48	171.2 @ 51	116.2 @ 48	143.4 @ 35
Maximum Post-test Intrusion (in.)	0.5	5.1	1.2	6.7

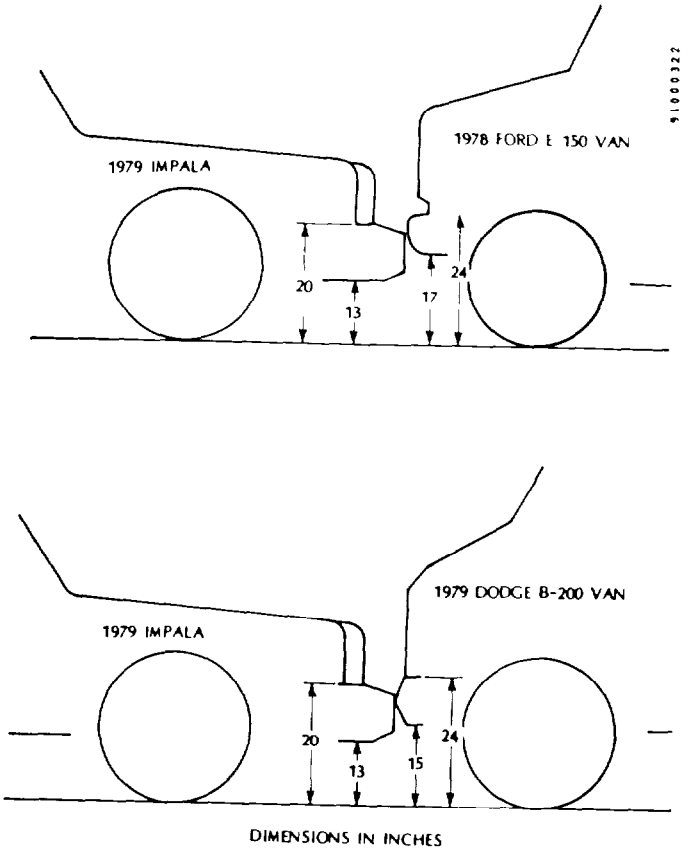


Fig. 46 - Bumper matches and interfaces - van-to-car tests

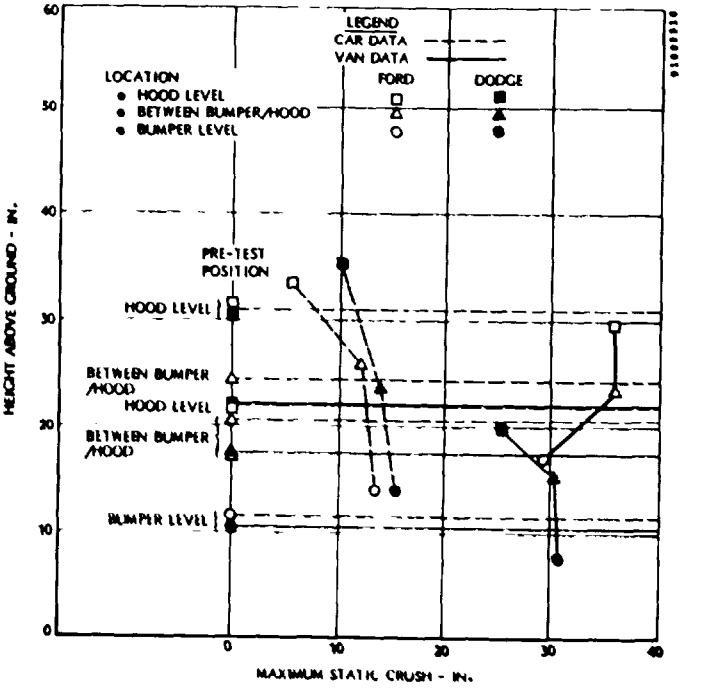


Fig. 47 - Comparison of car and van maximum post-test crush profiles - Ford and Dodge van tests

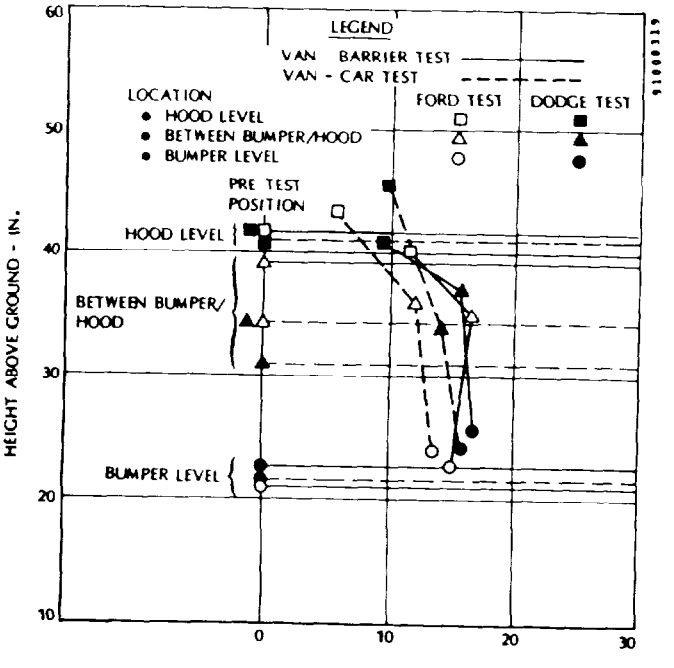


Fig. 48 - Comparison of van maximum post-test crush profiles - 30-mph barrier and van-to-car tests

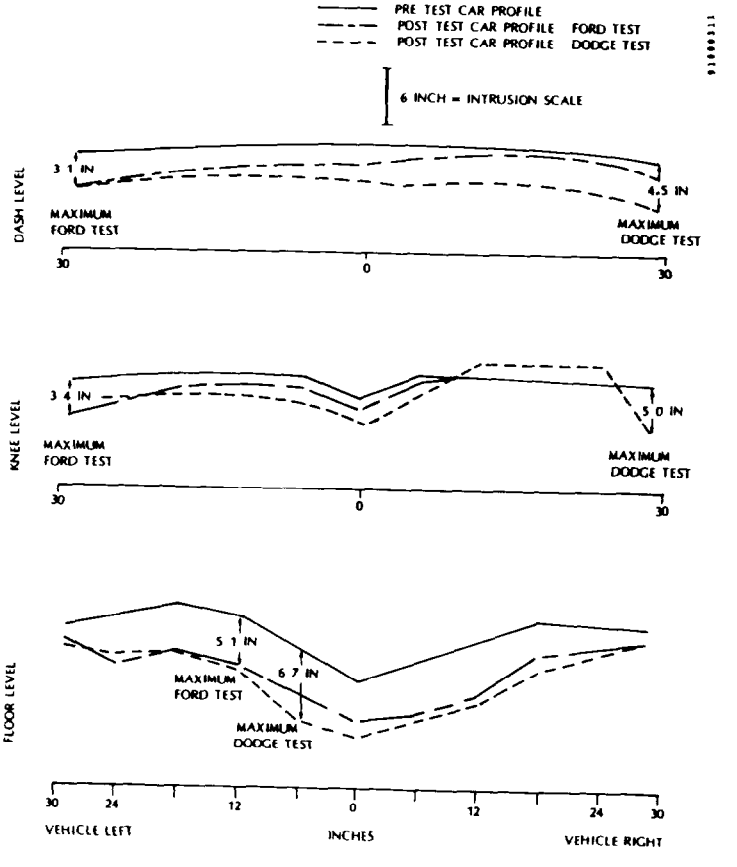
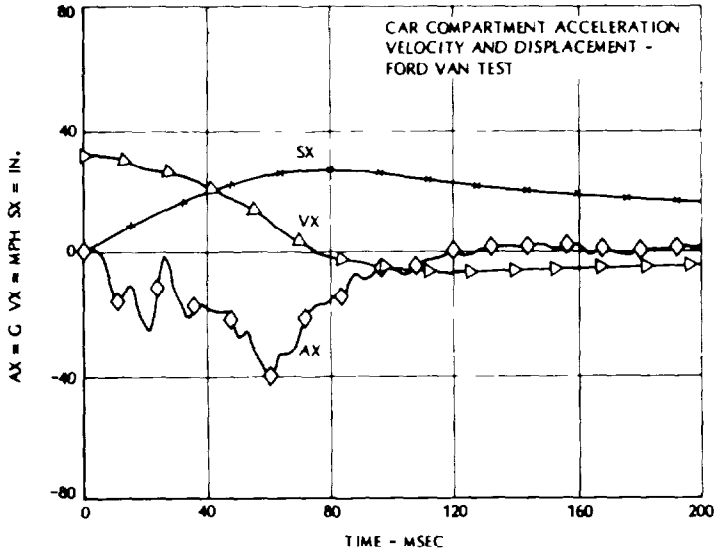
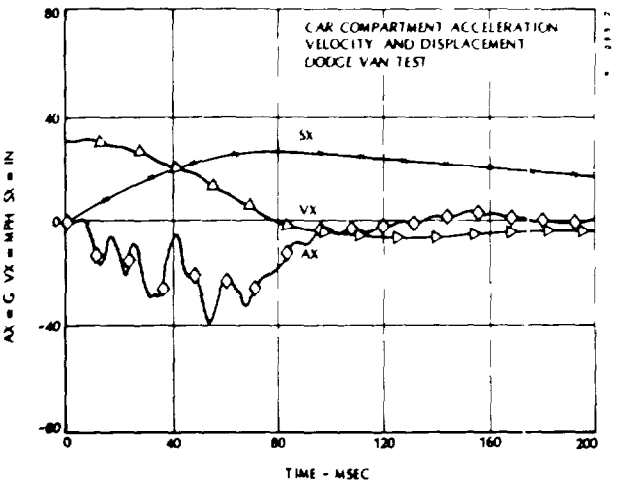
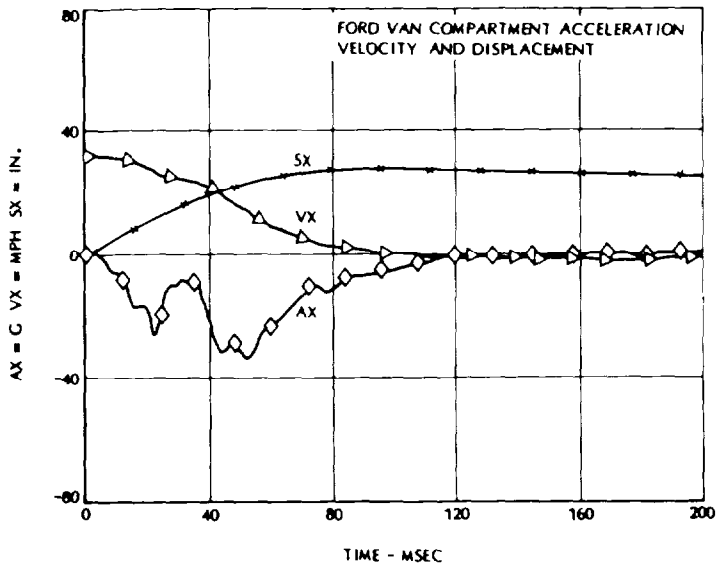


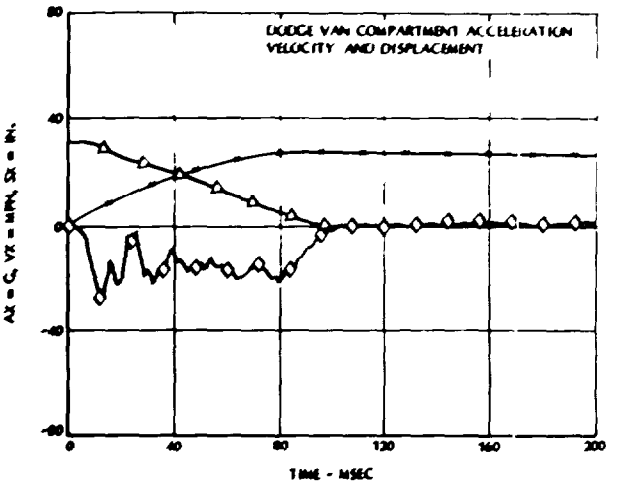
Fig. 49 - Comparison of car interior intrusion - Ford and Dodge van tests







a) Ford van-to-car test



b) Dodge van-to-car test

Fig. 50 - Vehicle accelerations, velocities, and displacements for van-to-car tests

CONCLUSIONS

This research program has generated pertinent crash test data which has been used to assess the crashworthiness and potential aggressivity of typical vans.

The six fixed barrier tests indicate that some FMVSS 208 injury criteria were exceeded, even at 25 mph.

The van dummy data for the eight tests, when normalized and cross plotted, indicated no strong difference in the crashworthiness of the two vans. However, the Chevrolet dummy data from the two van-to-car tests suggested that the Dodge van may be more aggressive than the Ford.

The use of some structural response parameters (such as maximum post-test crush) may suggest aggressivity conclusions contrary to the results obtained from an assessment of the dummy response parameters.

FUTURE RESEARCH EFFORTS

Data from these initial van crashworthiness and aggressivity tests were instrumental in the selection of the Ford Econoline Van in the "Passive Restraints Development of Light Trucks and Vans," Contract No. DOT-HS-9-02076. Early passive restraint tests of the Ford van indicate potential problems in achieving acceptable occupant protection performance levels, especially with an out-of-position child. To provide the Ford van occupants with a safer crash environment, the contract "Van 208 Extension," Contract No. DTNH22-80-C-07179 was awarded to modify the Ford van structure. The new structure will employ controlled energy-absorbing deformation features that will lengthen the crash pulse duration, and lower the maximum vehicle accelerations.

REFERENCES

1. R. Yee, R. Cropper, and S. Davis, "Van Crashworthiness and Aggressivity Study, Test Report 1, Van-to-NHTSA Fixed Test Device Head-on Impact Tests," Report No. 3052-79-95A, Dynamic Science, Inc., June 1979.
2. R. Yee, R. Cropper, and S. Davis, "Van Crashworthiness and Aggressivity Study, Test Report 2, Van-to-Car Head-on Impact Tests," Report No. 3052-79-101, Dynamic Science, Inc., June 1979.
3. R. Yee, R. Pirtle, C. Thatcher, and S. Davis, "Van Crashworthiness and Aggressivity Study, Test Report 3, Accident Investigation Studies," Report No. 3052-79-114, Dynamic Science, Inc., June 1979.
4. S. Davis, and R. Yee, "Development of a Test Methodology for Evaluating Crash Compatibilities and Aggressiveness - Volume I - Summary Report," Report No. 8316-78-171A, Dynamic Science, Inc., March 1979.

APPENDIX A - SELECTION OF CLOSING SPEEDS FOR CAR-TO-VAN TESTS

The equivalent car-to-van closing speed (V_M) computed from a van-to-Fixed Barrier closing speed (V_F) with van weight (W_V) and car weight (W_C) is given by

$$V_M = V_F \cdot \left[\frac{W_C}{W_C + W_V} \right]^{-1} \qquad (1)$$

This formula is derivable from conservation of linear momentum, for a perfectly plastic collision. For the specific parameters associated with the Dodge Van, Ford Van, and Chevrolet Impala, Table A-1 summarizes the pertinent data.

It should be noted that Equation (1) is derived on the basis of equal velocity change for the van. This does not result in equal velocity change to the car in the two car-to-van tests, since the weights of the vans differ. The heavier van (Dodge) results in a higher velocity change for the car.

It should also be noted that the closing speed derived from Equation (1) does not result in equal energy absorption in the van, as in the van barrier test. The vans generally crushed less in the car-to-van collisions than in the 30-mph van-to-Fixed Barrier crash.

Table A-1 - Data for Computing Car-to-Van Test Closing Speeds

Van Model	V_F (mph)	W_V (lb)	W_C (lb)	V_M (mph)
Ford Van	30.0	4,998	4,400	64.1
Dodge Van	30.0	4,654	4,400	61.7

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