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16. Abstract

This research was conducted to identify and investigate aspects of NCHRP Report 230 which require additional technical research. This report deals with five broad areas of concern: (1) the importance and effect of soil conditions on the dynamic performance of barriers, (2) methods for re-evaluating pre-Report 230 test results in light of the current Report 230 criteria, (3) linking the occupant risk factor to "real-world" accident cases, (4) assessing the potential hazards of the redirected vehicle, and (5) replacement of the 4500-lb test car.

This is the fourth of a six-volume report dealing with specific technical topics in NCHRP Report 230. The others in the series are:

Vol. No.	FHWA No.	Title
I	RD-87/096	Executive Summary
II	RD-87/097	The Effect of Soil Strength on Longitudinal Barrier Performance
III	RD-87/098	Evaluating Pre-Report 230 Crash Tests
IV	RD-87/099	The Importance of the Occupant Risk Criteria
V	RD-87/100	Hazards of the Redirected Car
VI	RD-87/101	Replacing the 4500-lb Passenger Sedan in Report 230 Tests

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APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
in	inches	2.54	millimetres	mm
ft	feet	0.3048	metres	m
yd	yards	0.914	metres	m
mi	miles	1.61	kilometres	km

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
in^2	square inches	645.2	millimetres squared	mm^2
ft^2	square feet	0.0929	metres squared	m^2
yd^2	square yards	0.836	metres squared	m^2
mi^2	square miles	2.59	kilometres squared	km^2
ac	acres	0.395	hectares	ha

MASS (weight)

Symbol	When You Know	Multiply By	To Find	Symbol
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

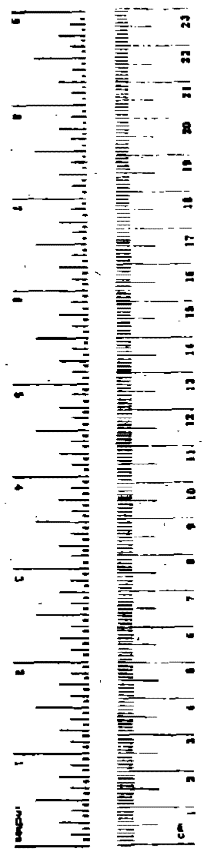
VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
fl oz	fluid ounces	29.57	millilitres	mL
gal	gallons	3.785	litres	L
ft^3	cubic feet	0.0328	metres cubed	m^3
yd^3	cubic yards	0.0765	metres cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



APPROXIMATE CONVERSIONS TO SI UNITS

LENGTH

Symbol	When You Know	Multiply By	To Find	Symbol
mm	millimetres	0.039	inches	in
m	metres	3.28	feet	ft
m	metres	1.09	yards	yd
km	kilometres	0.621	miles	mi

AREA

Symbol	When You Know	Multiply By	To Find	Symbol
mm^2	millimetres squared	0.0016	square inches	in^2
m^2	metres squared	10.764	square feet	ft^2
km^2	kilometres squared	0.39	square miles	mi^2
ha	hectares (10 000 m^2)	2.53	acres	ac

MASS (weight)

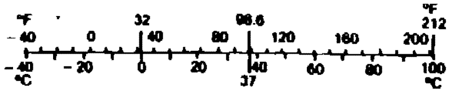
Symbol	When You Know	Multiply By	To Find	Symbol
g	grams	0.0353	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams (1 000 kg)	1.103	short tons	T

VOLUME

Symbol	When You Know	Multiply By	To Find	Symbol
mL	millilitres	0.034	fluid ounces	fl oz
L	litres	0.264	gallons	gal
m^3	metres cubed	35.315	cubic feet	ft^3
m^3	metres cubed	1.308	cubic yards	yd^3

TEMPERATURE (exact)

Symbol	When You Know	Multiply By	To Find	Symbol
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



These factors conform to the requirement of FHWA Order 5190.1A.

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* SI is the symbol for the International System of Measurements

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Introduction

Since the early days of highway safety research, the design of longitudinal barriers such as guardrails, bridgerails and median barriers has been greatly influenced by two basic assumptions about the causes of occupant injuries when vehicles collide with such devices. It has been assumed that occupants are subjected to the highest risk of injury during the vehicle's initial collision with a barrier; subsequent collisions with the same or other roadside features were presumed to be less hazardous because of lower vehicle speeds. Secondly, the probability of severe occupant injury was presumed to be directly and primarily related to the intensity of vehicle collision accelerations. It was thought that by designing roadside hardware to limit high values of vehicle accelerations the frequency and severity of occupant injuries would be diminished.

This research produced findings which imply that these traditional assumptions may not be completely accurate. This study indicated that (a) even when subjected to what has generally been considered severe impact conditions, occupants are not severely injured, and (b) vehicle trajectory and stability after the initial collision are major factors in the causation of occupant injuries. The following sections discuss these findings in detail.

The Flail Space Model

Traditionally the dynamic performance evaluation of longitudinal barrier systems has been accomplished by assessing kinematic and dynamic quantities derived from carefully controlled crash tests. In addition to requiring that the vehicle be smoothly redirected and remain upright, the peak 50-millisecond average lateral and longitudinal accelerations were acquired and evaluated based on the assumption that the severity of occupant injury in a longitudinal barrier collision was primarily a function of the vehicle's collision dynamics. Chi(1) provides an informative historical evaluation of the many pre-NCHRP Report 230 injury evaluation criteria.

NCHRP Report 230(2) advocated the use of the flail space concept and the occupant risk criteria which linked vehicle kinematics to the occupant's risk of sustaining physical injuries. The occupant risk factor is the hypothetical impact velocity of the occupant with the vehicle interior: the greater the occupant impact velocity the more severe the resulting injuries. The occupant is assumed to behave as a free missile that continues to travel with the pre-collision trajectory and velocity while the vehicle responds to the collision forces. In essence, the vehicle compartment moves toward the occupant, striking the occupant at a determinable velocity. This concept allows all of the previous occupant severity indices to be unified in a single value: the occupant risk factor.

At the time Report 230 was written, there was little evidence to establish threshold values for the occupant to passenger compartment impact velocity required to prevent severe injuries. Some data were available for frontal occupant impacts into the windshield from crash cushion studies. No data were available, however, for occupant lateral impacts into the door during redirectional collisions. In addition, there were no comprehensive data available to establish flail space dimensions appropriate for calculating the occupant risk factor.

To better define the flail space envelope, a survey was made of typical 1978 to 1984 vehicle interior dimensions to determine the distribution of flail space distances. The following equation, which can be used to calculate the occupant's impact velocity with the vehicle interior when the vehicle is not yawing, illustrates the importance of the flail dimension, s.

$$v = \sqrt{2As} \qquad (1)$$

$$A = \frac{\int_{t_0}^{t_1} a_t dt}{(t_1 - t_0)} \qquad (2)$$

where

υ = occupant-compartment impact velocity (fps)

A = average vehicle accelerations (ft/s^2)

a_t = actual vehicle accelerations as a function of time (f/s^2)

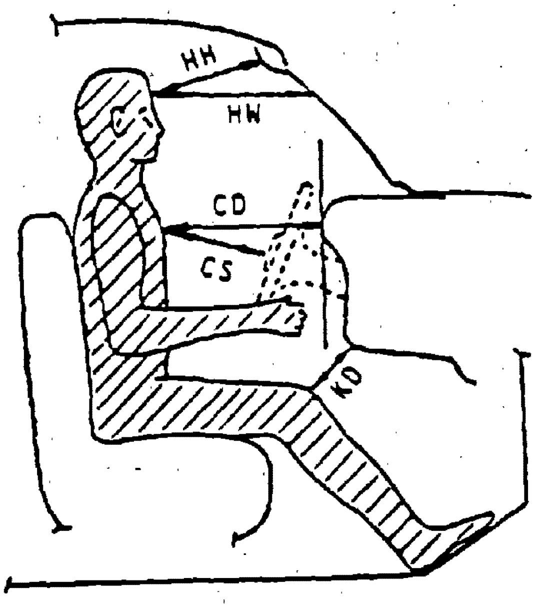
t_1 = time of occupant-compartment impact (s)

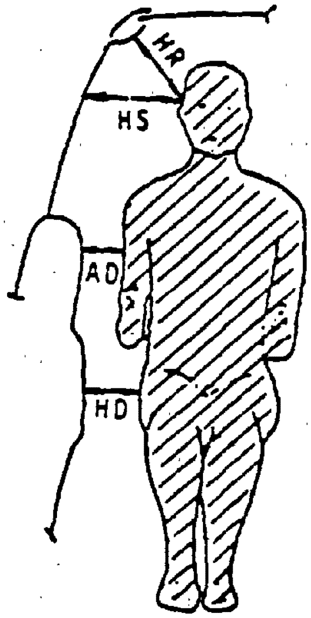
t_0 = time of vehicle impact with longitudinal barrier (s)

For relatively long collision events such as redirectional collisions, the occupant impact velocity increases as the square root of the appropriate flail space distance given the same average acceleration. This implies that occupants in "spacious" compartments where the flail space is maximized are more at risk. Table 1 summarizes the results of a passenger compartment survey which was performed using data from the New Car Assessment Program (NCAP) on 1978-1984 passenger sedans; appendix A provides additional details of the passenger compartment survey. To create a "worst case" scenario the passenger was assumed to be a 5th-percentile female seated in the right front passenger position with the seat in the rearmost position. The Report 230 value of two feet was found to be an appropriately conservative yet realistic value for the longitudinal flail distance compared to 22 inches (55.9 m) shown in table 1 for the 75th percentile value of the dimension HW. For the lateral flail distance, values in table 1 range from 7 to 13 inches (17.8 to 33.0 cm) for the dimension HS and a 12-inch (30.5-cm) lateral flail distance was deemed appropriate as suggested in Report 230. The data of table 1, then, indicate that the Report 230 recommendation of 1 ft (61.0 cm) in the lateral direction and 2 feet in the longitudinal direction are in fact representative of the vehicle population.

Table 1. Typical passenger compartment clearance dimensions.

Dimension+	Range*	Median* Distance	75th Percentile* Distance
HW	15-24	20	22
CD	19-24	21	22.5
CS	10-17	13	15
HS	7-13	9	10
AD	1-7	4.5	5.5
HD	5.5-9.5	6	8
HH	11-20	14	15
HR	4-10	6	7.5
KD	3-10.5	7	8





+Dimensions are for a 5th percentile female seated in the driver position with the seat in its rearmost position.

*The dimensions are, to a small degree, functions of the vehicle weight. The values reported are for 1978 to 1984 passenger cars with core weights greater than 3680.

Anthropometric Dummy Sled Tests

To establish a linkage between the flail space model and occupant protection standards used by the NHTSA, a series of sled tests were conducted in which unrestrained anthropometric dummies were observed during simulated small car frontal and side impacts. The purpose of these tests was to assess the validity of the flail space concept, therefore, actual flail distances were used to calculate the occupant risk factor. Full details of these pendulum tests appear in appendix B. Three frontal tests were performed in which the passenger compartment underwent velocity changes of 25, 35 and 45 fps (7.6, 10.7 and 13.7 m/s) at acceleration rates of 4.7, 9.8 and 16.6 g's, respectively. Four side impact tests were performed in which the passenger compartment experienced velocity changes of 20, 30, 35 and 45 fps (6.1, 9.1, 10.7 and 13.7 m/s) at constant accelerations of 2.6, 9.4, 14.1 and 18.4 g's, respectively.

A 1979 Honda Civic passenger compartment body buck with standard bucket seats was used in these seven tests. A Part 572 5th-percentile female dummy instrumented according to FMVSS 208(3) was positioned in a normal attitude with the seat in the rearmost position for the frontal tests. A 165-lb 50th-percentile male side impact dummy (SID) was used in the side impact tests. Figures 1 and 2 show sequential photographs from the test series and illustrate typical trajectories of the occupant in frontal and side impacts. A summary of the sled test findings is contained in table 2.

The findings shown in table 2 confirm the hypothesis that the simulated occupant behaves like a free missile. The occupant risk factor computed from the sled acceleration pulse using the free missile assumption compares favorably with test signals produced from the dummy accelerometers for both frontal and side impacts. The calculated occupant impact speed was reasonably close to the observed values as shown in table 2, though the calculated values become more accurate as the

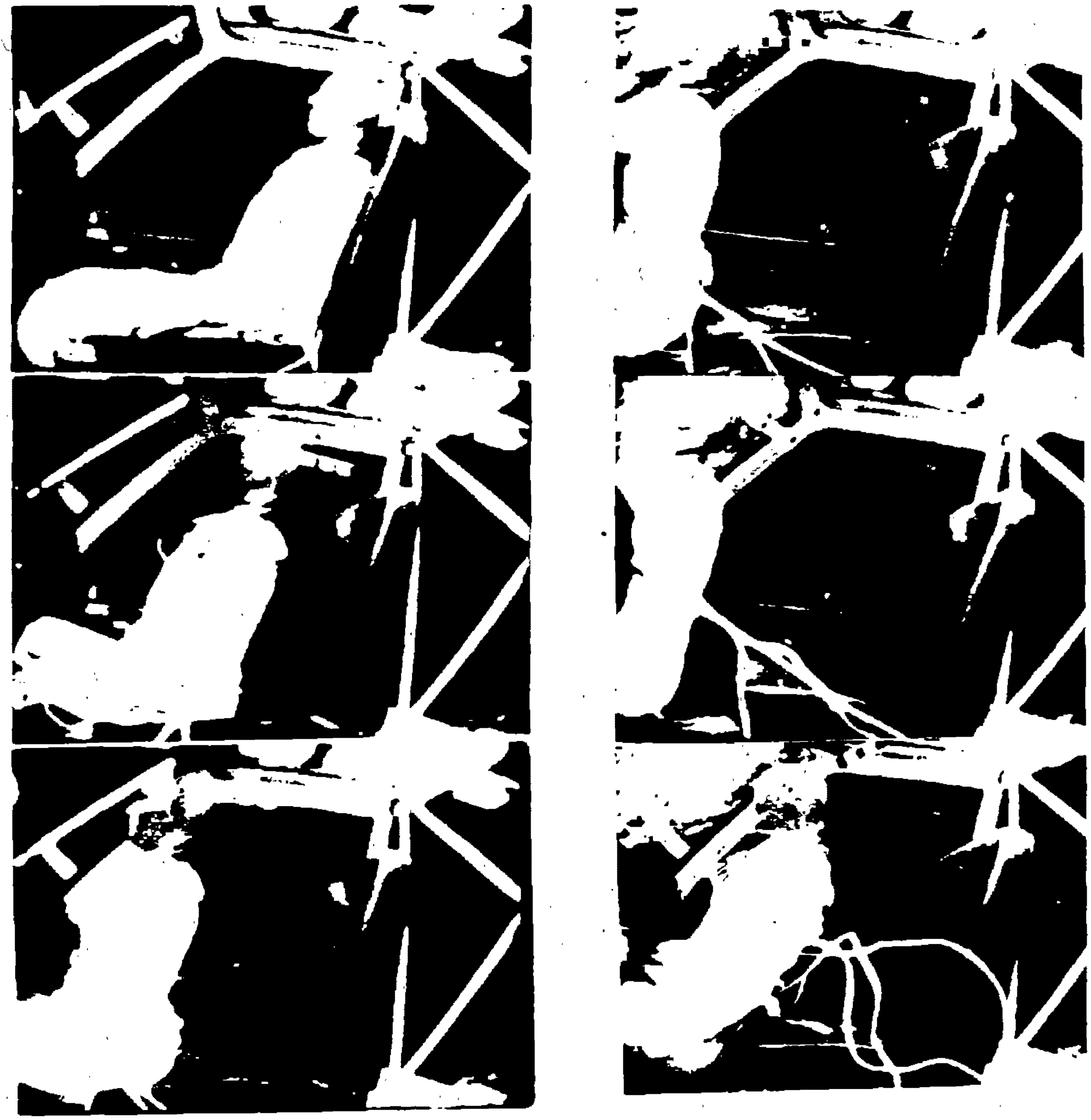


Figure 1. Typical frontal impact.

Figure 2. Typical side impact.

Table 2. Sled test results.

Test No.	2534	2533	2535	2540
Sled Response(a)(c)				
Change in Velocity (fps)	20	30	35	40
Acceleration (g's)	-3.6	-8.0	-15.0	-18.4
Occupant Risk Data				
Time to Head Impact (sec)(b)	0.092	0.049	0.048	0.042
Average Sled Acceleration (g's)	-2.6	-9.4	-14.1	-18.4
Measured Occ. Impact Velocity (fps)	7.7	14.8	21.8	24.9
Calculated Occ. Impact Velocity (fps)	9.5	18.1	22.2	25.3
Head Injury Criteria Data				
HIC	37	121	193	316
HIC Duration (sec)	0.012	0.006	0.010	0.006
Head Severity Index	52	163	221	569
Thoracic Trauma Index Data				
Spine g's - T12y	12.5	36.4	32.1	65.2
Upper Rib g's - LURy	10.7	30.4	47.7	46.7
Assumed Age (yrs)	41	41	41	41
Weight (lbs)	165	165	165	165
TTI	69	91	97	113
Probability of AIS > = 3 (%)	0	3	6	16

(a) Buck was a 1979 Honda Civic passenger compartment.

(b) Flail distances were measured as 22.5 inches longitudinal and 6.5 inches lateral and used in velocity calculations.

(c) Side impact dummy was used in side impacts and Part 572 5th percentile female in frontal collisions.

Table 2. Sled test results (continued).

FRONTAL IMPACTS

Test No.	2538	2537	2539
Sled Response (a)(c)			
Change in Velocity (fps)	25	35	45
Acceleration (g's)	-5.6	-10.9	-16.8
Occupant Risk Data			
Time to Head Impact (b)	0.140	0.105	0.085
Average Sled Accel's (g's)	-4.7	-9.8	-16.6
Measured Occ. Impact Velocity (fps)	21.1	33.2	45.6
Calculated Occ. Impact Velocity (fps)	23.5	34.4	45.8
Head Injury Criteria Data			
HIC	87	468	1345
HIC Duration (sec)	0.061	0.030	0.014
Head Severity Index	30	55	94
Peak Chest Accelerations (g's)	29.7	55.0	94.4

(a) Buck was a 1979 Honda Civic passenger compartment.

(b) Flail distances were measured as 22.5 inches longitudinal and 6.5 inches lateral.

(c) Side impact dummy was used in side impacts and Part 572 5th percentile female in frontal collisions.

accelerations increase, tending to overestimate the occupant risk factor at low accelerations.

For frontal impacts, the dummy responses tend to support the 30 fps (9.1 m/s) occupant risk value suggested in Report 230. A Head Injury Criteria (HIC) score of 1345 occurred when the anthropometric dummy head impacted the windshield at about 46 fps (14.0 m/s). By interpolating the data in table 2 it was estimated that a head impact velocity of 40 fps (12.2 m/s) would result in a HIC of 1000, the critical value established in FMVSS 208. In Report 230 a safety factor of 1.33 was applied to the 40 fps (12.2 m/s) limit to arrive at the 30 fps (9.1 m/s) design limit. Chest accelerations also exceeded the FMVSS 208 60-g criterion for the 46-fps (14.0-m/s) dummy impact condition. In redirectional tests, however, the longitudinal occupant risk is generally not a critical parameter since longitudinal accelerations are rarely sufficient to propel the occupant to the instrument panel. For this reason, the remainder of this volume will be primarily concerned with the <u>lateral</u> occupant risk factor.

For side impact sled tests, the anthropometric dummy responses were surprisingly low. Historically (i.e., NCHRP Report 153)$^{(4)}$, lateral vehicle accelerations of 5 g's were considered high. For test 2540 in table 2, the sled was accelerated laterally at -18.6 g's, and the resulting HIC was a mild 316, well below the FMVSS 208 threshold of 1000. The maximum occupant risk factor was calculated to be about 25 fps (7.6 m/s) which exceeds Report 230 suggested design limit of 20 fps. It should be noted that the actual lateral flail distance of 6.5 inches (16.5 cm) rather than the 12-inch (30.5-cm) value suggested in Report 230 was used in determining the occupant impact velocities shown in table 2.

Another injury measure better suited to side impacts is the Thoracic Trauma Index (TTI). Eppinger, et al$^{(5)}$ developed a family of curves which relate the TTI to the probability of sustaining a given level of injury. This relationship is shown in figure 3 and the TTI is defined by the following equation.

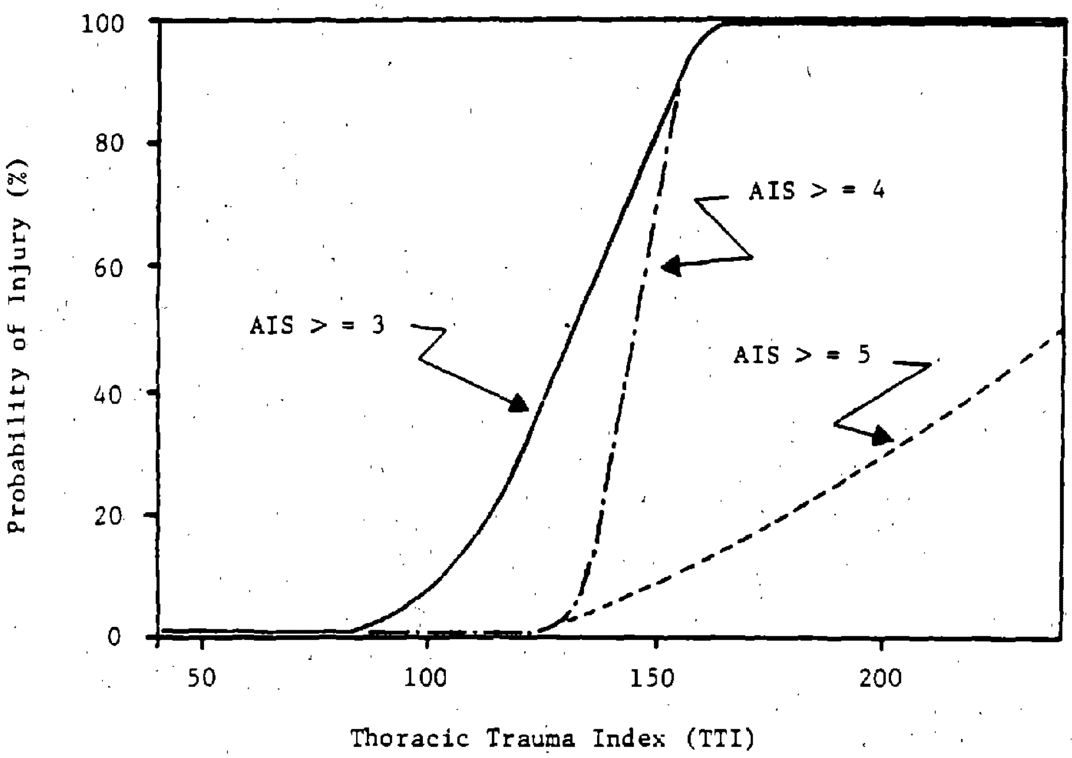


Figure 3. Probability of injury versus TTI.(4)

$$TTI = 1.4\ Age + 0.5\ (LUR_y + T12_y)\ \frac{Weight}{165} \qquad (3)$$

where

AGE = occupant age (years)
LUR_y = left upper rib y acceleration (g's)
$T12_y$ = Spinal y acceleration (g's)

Even at a vehicle lateral acceleration of -18.6 g's and an occupant impact velocity of 24.9 fps (7.6 m/s), the probability of a hypothetical 41-year old 165-lb (74.9-kg) occupant (TTI = 113) sustaining an AIS of 3 or greater is only 0.16, and the probability of sustaining an AIS of 4 or greater is nil as shown in figure 3. The probability of severe injury (AIS >=4) is very remote for this occupant even under impact conditions which are generally considered to be severe.

The sled tests illustrated two important points. First, simulated occupants do behave like free missiles during collisions and their impact velocities can be calculated knowing the compartment geometry and the vehicle accelerations. Second, the lateral occupant risk design limit of 20 fps (6.1 m/s) shown in Report 230 as well as vehicle acceleration values contained in NCHRP Report 153 may be unnecessarily conservative.

Accident Analysis of Occupant Injuries

To further investigate the apparent noncriticality of the lateral occupant risk factor during redirectional crash tests, a number of longitudinal barrier accident cases were examined in detail. Since 5 percent(6) of all fatal accidents, as shown in table 3, can be attributed to an impact with a longitudinal barrier one might reasonably question the conclusions of the last section.

In order to examine the importance of lateral impact velocity in real highway accidents, it was necessary to isolate those accident cases in

Table 3. Distribution of most harmful events where the first object struck is a longitudinal barrier.(3)

Most Harmful Event	Longitudinal Barrier is the First Harmful Event (No.)	(%)
Overturn, Non-collision	453	31
Other Non-collision	116	8
Non-fixed Objects	115	8
Longitudinal Barrier*	442	31
Pier/Abutment/Parapet End	73	5
Other Fixed Objects	242	17
Total Longitudinal Barrier**	1,441	100
Total Fatal Accidents	27,516	

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*Most harmful event may not necessarily be the first harmful event. It may include subsequent impact with same bridge rail or a bridge rail across the highway.

**Longitudinal barrier accidents represent 5.2% of the 27,516 fatal accidents.

which the lateral occupant impact velocity was the principal injury producing mechanism. All cases where some other aspect of vehicle dynamics or barrier performance that could have caused the occupant injuries were screened from the data base leaving only those where the:

- Barrier was the first item struck by a passenger sedan;
- Vehicle was tracking before the first impact (i.e., heading angle and velocity vector were within 10 degrees);
- Vehicle was smoothly redirected after the first impact with no signs of vaulting, penetration or severe post-wheel snagging;
- First impact was not with a bridge pier, barrier terminal, or end treatment;
- Vehicle did not roll over as a result of the first impact.

Using these criteria, 25 accident cases were selected from the Narrow Bridge Study data base of 124 bridge related accidents.(7) Of the 124 narrow bridge cases 43 were eliminated because they involved a first collision with an end treatment or guardrail-bridge rail transition. Table 4 shows characteristics of the remaining 81 narrow bridge accidents which occurred along the midspan of the barrier system. The vehicle was not tracking in 46 percent of the cases and of the cases where the vehicle was tracking, only about half met the "proper" performance criteria listed above. Occupants suffered serious to critical injury in only 3 of the 26 eligible cases.

In order to supplement this small sample size, the Longitudinal Barrier Special Studies data base from the National Accident Sampling System (NASS) for the years 1982 and 1983 were surveyed and 139 cases were deemed eligible out of a total of 555. The total number of eligible cases was therefore 165.

One of the most basic and widely used measures of occupant injury is the Abbreviated Injury Scale (AIS);(10) which is briefly listed below.

Table 4. Characteristics of 81 bridgerail accidents.(6)

		No Second Impact	Result of Second Impact				Totals
			Redirected or Spinout to Rest	Redirected Into Another Roadside Feature	Rollover	Vault/ Override	
Vehicle Tracking at First Impact	Redirected or skid to stop	7	9	8		2	26
	Snagged	4	2	1			7
	Penetrated			1			1
	Vault/Override	2	2	3	1		8
	Rollover	2					2
	Total	14	13	13	1	2	44
Vehicle Not-Tracking at Impact	Redirected or skid to stop	7	13				20
	Snagged	3	5	1	1		10
	Rollover	3					3
	Vault/Override	1	2	1			4
	Total	15	20	2	1		37
Totals		29	33	15	2	2	81

AIS	Injury	
1	minor	non-life threatening
2	moderate	
3	serious	
4	severe	life threatening
5	critical	
6	unsurvivable	

Each individual injury is assigned an AIS score by the accident investigator. For example minor cuts and scratches on the face may be scored as an AIS of 1 and a broken rib may be reported as an AIS of 3. A frequently used measure of the severity of all occupant trauma is the <u>maximum</u> AIS (MAIS). The MAIS is the highest AIS experienced by the occupant. Thus, the MAIS of the occupant with facial cuts (AIS = 1) and broken ribs (AIS = 3) would be 3.

An AIS of 4 or above is defined as life-threatening. The intent of Report 230 was to select an occupant risk design limit such that occupants would not sustain an AIS 4 or greater injury. Report 230(2) on page 30 states that:

> "An attempt has been made to set threshold values at a level equivalent to the American Association of Automotive Medicine Abbreviated Injury Scale (AIS) of 3 or less.(9) AIS-3 classifies the resulting injury as severe but not life threatening."

Report 230 states in the passage quoted above that <u>all</u> injuries of AIS-3 or less are acceptable though hardware developers should always strive to minimize occupant injury. Hence, the intention of Report 230 is primarily to eliminate life-threatening injuries, that is injuries of AIS-4 or <u>greater</u>.

Table 5 shows the distribution of the MAIS in each of the three data sources. Nearly 90 percent of the eligible cases shown in table 5 (134 minor cases and 14 serious cases) exhibit injuries which are below the

Table 5. Distribution of injury in three data bases.

Source	Total Cases in Data Base	Eligible Cases[a]										
		Known Injury Severity						Unknown Severity				
		Minor 0≤MAIS<2		Serious 2≤MAIS<4		Severe 4≤MAIS<7		MAIS = 7		MAIS = 9		
		No.	%	No.	%	No.	%	No.	%	No.	%	
1982 NASS LBSS	292	61	20.9	6	2.1	1	0.3	4	1.4	1	0.3	
1983 NASS LBSS	263	50	19.0	7	2.7	0	0.0	4	1.5	5	1.9	
Narrow bridge	124	23	18.5	1	0.8	2	1.6	0	0.0	0	0.0	
Total	679	134	19.9	14	2.1	3		8	1.2	6	2.3	165

[a] Eligible cases are those where (1) Longitudinal barrier struck by a passenger car
(2) Vehicle tracking before impact (i.e., heading angle and velocity vector are within 10°)
(3) Vehicle was smoothly redirected after first impact; no vaulting, rollover, severe snagging or penetration
(4) First impact was not with an end treatment or transition

design injury limit of 4. Only two percent of the eligible cases exhibit severe injury. It appears that the majority of vehicle occupants escape severe injury when the vehicle is smoothly redirected and remains upright after a longitudinal barrier collision. Unfortunately the severity of occupant injury is unknown in almost 9 percent of the eligible cases (8 AIS 7 and 6 AIS 9 cases). There are two ways in which a NASS investigation can code an unknown injury. An AIS of 9 is used when the occupant cannot be located or departed the accident scene before any officials arrived. Generally an AIS of 9 indicates no injury or only minor injury since the occupant was capable of leaving the scene.

An AIS of 7 indicates there was an injury but of unknown severity. Unlike the AIS of 9, an AIS of 7 is often used by NASS investigators when severe injury occurs but supporting documentation such as autopsy or hospital records cannot be obtained.

The NASS Continuous Sampling System (CSS) data for 1984 was used to calculate the probability of an AIS of 7 being coded when severe injury occurred. As shown in table 6, the probability that any of the eight cases coded as AIS 7 included injuries greater than or equal to an AIS of 4 is very low. All 8 AIS 7 cases and all 6 AIS 9 cases can therefore be grouped with those below the AIS of 4 guideline. Thus, the 8 AIS 7 cases and the 6 AIS 9 cases can be grouped with the 134 minor cases and the 14 serious injury cases to show that 98 percent of the eligible cases indicate an acceptable level of occupant injury. Severe injuries were noted in only two percent of the eligible cases.

The 17 serious and severe injury cases in table 5 were reconstructed in detail to determine exactly what feature of the accident caused these injuries. Each of the 17 cases studied with serious to unsurvivable injuries would have passed the two provisions of the Report 230 criteria requiring the vehicle (a) to be smoothly redirected and (b) to remain upright. With only three exceptions, all of the cases in table 7 involved a subsequent collision with the same or another roadside feature. The

Table 6. Relationship between AIS of 7 and police reported accident severity.

Police Reported Injury Severity	Probability of[a]		No. of Eligible[b] AIS 7 Cases	Probable No. Above AIS 2	Probable No. Above AIS 4
	AIS≥2	AIS≥4			
O - none	0.0050	0.0001	0	0.0	0.0
C - possible	0.0927	0.0016	1	0.0927	0.0016
B - nonincapacitating	0.1592	0.0057	3	0.4776	0.0171
A - incapacitating	0.4181	0.0438	3	1.2543	0.1314
K - fatality	0.6104	0.4416	0	0.0	0.0
U - unknown	0.2210	0.0166	1	0.2210	0.0166
		TOTAL	8	2.0456	0.1667
		USE	-	2	0

[a] From 1984 NASS CSS data

[b] These are the 8 cases with AIS 7 from Table 5

Table 7. Summary of cases with serious to unsurvivable injuries.

Data Base	Case No.	Role	Vehicle Weight	Number of Impacts	First Impact Speed (mph)	First Impact Angle (deg)	First Impact MAIS First Impact	First Impact Occupant Risk (fps)	Second Impact Speed (mph)	Second Impact Angle (deg)	Second Impact MAIS 2nd Impact	Object Struck
NASS	83-53-010T	PUI	3365	2	90	26	2	37	66	38	2	Bridge rail
NASS	82-81-078V	DUI	3397	3	70	2	1	6	67	16	2	Guardrail
NASS	82-75-507V	DUI	1813	2	46	15	0	15	?	90	4	Bridge pillar
NASS	83-32-532V	DUN	2546	2	56	3	0	7	37	90	2	Utility pole
NASS	83-53-010T	DUN	3365	2	90	26	1	37	66	38	2	Bridge rail
NASS	83-39-131V	DUN	3161	2	69	5	0	12	37	45	3	Median barrier
NASS	82-52-083T	DRI	3444	1	31	34	3	46				None
NASS	82-35-125V	DRI	3541	2	?	2	0	?	?	9	2	Guardrail
NASS	82-78-511T	DRI	4535	1	57	35	2	48				None
NASS	83-02-071T	DRI	2338	2	49	17	0	16	28	90	3	Tree
NASS	82-55-293V	DRN	3041	2	46	7	0	8	38	72	2	Ditch
NASS	82-06-511Z	DRN	3981	1	34	10	3	8				None
NASS	83-30-516T	DRN	3062	2	71	3	0	10	49	17	3	Median barrier
NASS	83-77-517T	DRN	2811	2	23	2	1	2	9	45	2	Median barrier
NASS	83-02-523W	DRN	4208	2	64	10	0	12	59	29	2	Median barrier
NBS	80-03-04-068	DUN	3977	2	61	8	1	5	52	19	3	Bridgerail
NBS	80-03-22-071	DUN	3980	4	48	10	0	12	33	90	5	Bridge pillar
NBS	79-12-03-049	DRN	4318	3	52	8	0	4	20	90	4	Wingwall

reconstruction process therefore involved determining the speed and angle for 2 or 3 collisions. The vehicle deformation energy was calculated using the damage analysis portion of CRASH3(8), barrier deformation energy was estimated using BARRIER VII,(9) and energy dissipated by tire-ground friction during the trajectory was estimated by hand analysis methods. By proceeding from the last event to the first and summing all the energies of vehicle and barrier deformation with the energies lost through tire-ground friction and braking a reliable estimate of the impact speed can be produced.

Occupant injuries were assigned to particular impact events with, in most cases, a high degree of certainty. Where there was uncertainty the injury was assigned to all phases equally. Figure 4 shows a typical diagram of the vehicle trajectory, occupant injuries and vehicle interior. Using these pieces of information, it is possible to match injuries with the events which caused them. For example, the dislocation of the occupant's left shoulder shown in figure 4 can be assigned to the first collision. This is confirmed by the damage to the driver's side door shown in the interior sketch and the vehicle's position shown in the trajectory sketch. The lacerations on the right side of the head can be assigned, based on the occupant contact points in the interior sketch, to the second collision. Since it is difficult to determine which phase of the accident caused the concussion it was attributed equally to both impacts. The occupant risk factor can be calculated from the impact conditions using the method presented in volume III and then compared to the actual level of injury experienced in each phase of the accident.

A summary of the 17 cases studied in detail is shown in table 7. When the MAIS for each of the multiple impacts is examined, it becomes apparent that none of the occupants suffered severe injury in the first impact. Recalling that these 17 cases are those 2 percent of eligible cases where severe or serious injury occurred, it appears that the first impact in <u>all</u> 165 eligible cases in table 5 resulted in injuries less than the design limit of 4. In fact, 96 percent of all eligible cases resulted

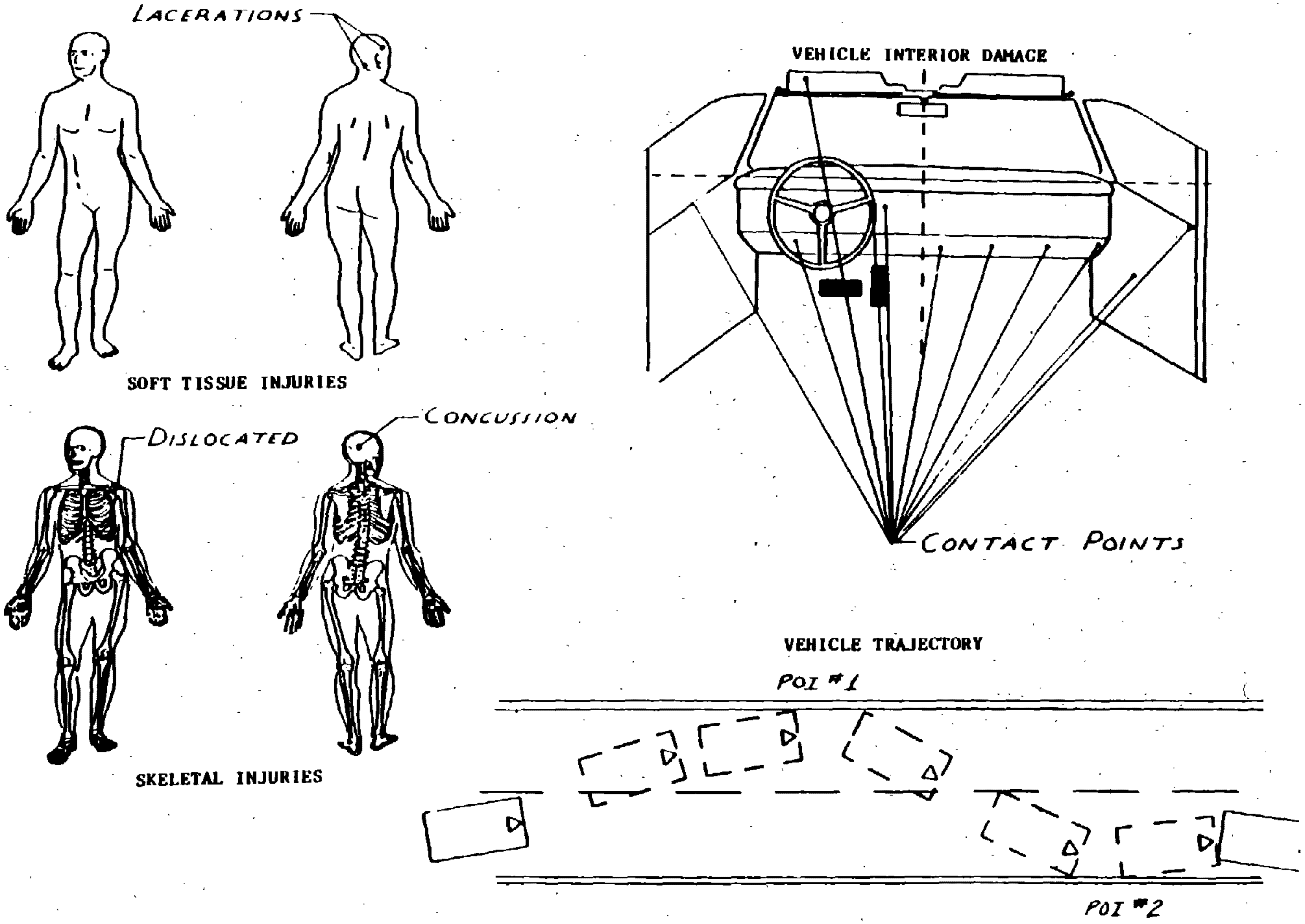


Figure 4. Typical accident reconstruction summary sheet, Case NASS 82-02-078V.

in only minor injuries: 134 minor injury cases from table 5, 13 of the 17 cases summarized in table 7, 6 of the 8 AIS 7 accident cases, and all AIS 9 cases.

The original intent of this research was to discover some relationship between the occupant risk factor and the actual level of injury sustained in real highway accidents. Figure 5 shows a plot of the occupant risk factor versus the MAIS for the first impact of each of the serious and severe injury cases shown in table 7. None of the 17 accident cases resulted in a life-threatening injury after the first impact. Figure 5 illustrates the apparent relationship between the occupant risk factor and the MAIS. Injuries greater than or equal to an AIS of 4 do not appear likely until the occupant risk factor is in excess of 40 fps (12.2 m/s), twice the Report 230 suggested design limit.

Typical Values in Full-Scale Crash Tests

The sled test data indicated that serious injuries were not likely to occur for what has generally been considered to be severe impact conditions. How useful, then, is the occupant risk factor for evaluating longitudinal barriers?

Since Report 230 was published in 1981 nearly 300 full scale crash tests have been performed at Southwest Research Institute alone. Rarely has a test device been disqualified due to the occupant risk criteria alone. Table 8 shows a brief summary of the impact conditions, occupant risk measurements and 50-msec average accelerations from a research project (11) which involves a number of crash tests of operational bridge rails. Bridge rails are generally rigid barrier systems, and therefore provide minimal energy dissipation during collisions; the highest values of the occupant risk factor should be observed during bridge rail tests. Table 8 shows that even in rigid barrier collisions the occupant risk factors are generally in the same range that was shown to be non-critical for the sled tests in table 2. The probability of an occupant sustaining

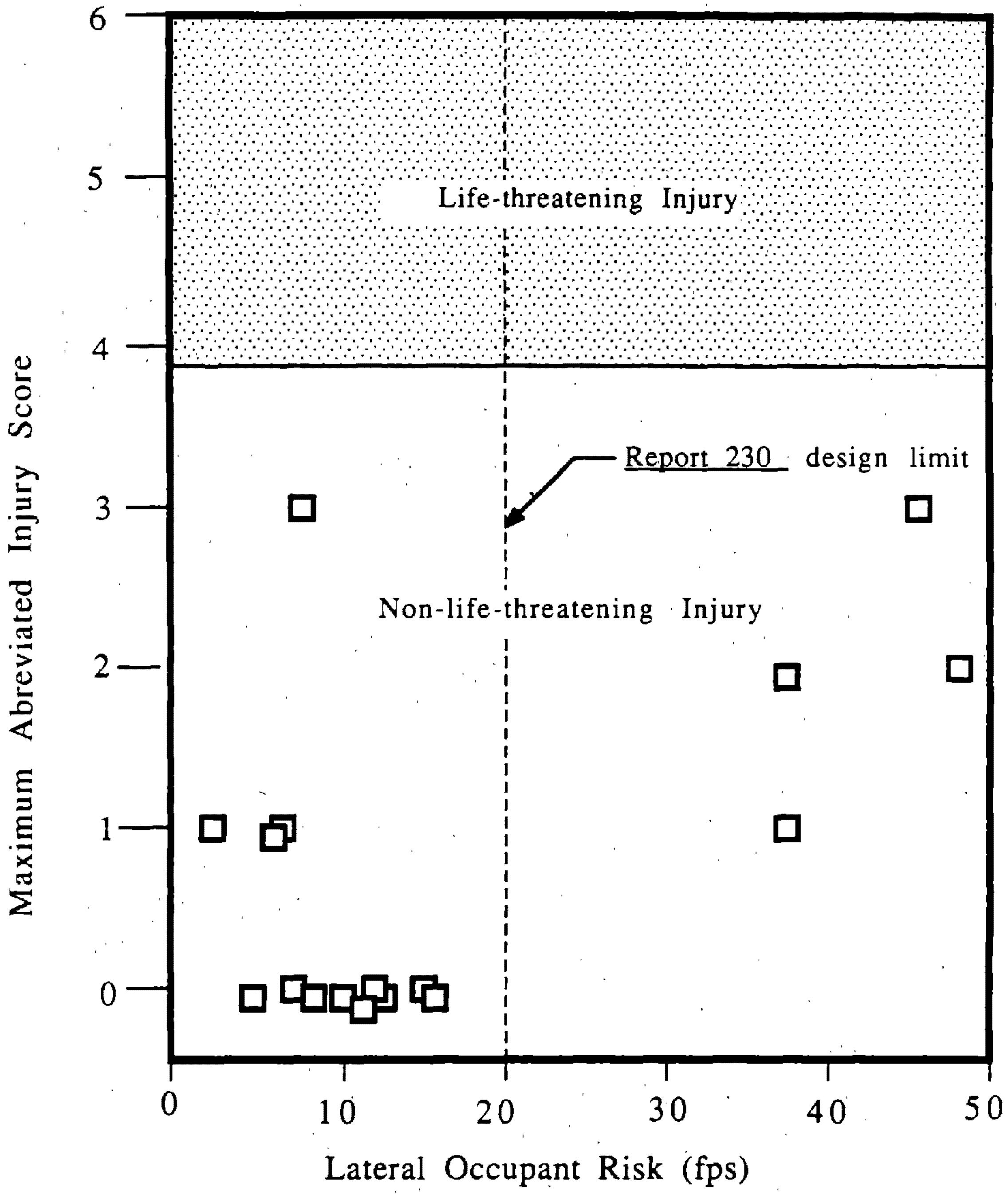


Figure 5. Occupant injury vs the lateral occupant risk factor.

Table 8. Occupant risk values for 15 bridge rail crash tests.(10)

Test No.	Impact Conditions[a] Speed (mph)	Impact Conditions[a] Angle (deg)	Occupant Risk[b] Frontal (fps)	Occupant Risk[b] Side (fps)	50 m-sec Avg[b] Vehicle Accel Front (g's)	50 m-sec Avg[b] Vehicle Accel Side (g's)	Comments
NBR-1	60.7	19.3	7.2	21.8	-5.8	12.6	Smooth Redirection
NBR-2	61.4	24.9	3.0	21.6	-6.3	8.4	Smooth Redirection
NBBR-1	61.4	20.0	5.3	20.7	-4.9	13.5	Smooth Redirection
NBBR-2	58.4	24.3	--	9.9	-5.9	8.2	Smooth Redirection
NCBR-1	59.7	18.8	14.0	22.7	-8.1	12.9	Smooth Redirection
NCBR-2	60.0	25.0	16.6	31.2	-6.9	17.9	Smooth Redirection
OBR-1	58.6	18.8	0.8	19.9	-3.3	10.2	Smooth Redirection
OBR-2	60.8	24.3	20.9	26.0	-5.2	13.7	Snagged Hood
OBR-3	60.0	25.0	0.9	28.2	-5.2	15.9	Smooth Redirection
KBR-1	61.9	20.3	11.5	20.4	-7.5	11.2	Smooth Redirection
KBR-2	60.5	24.0	30.0	23.3	-8.3	13.4	Severe Snagging
OHBR-1	60.6	19.6	7.3	20.6	-5.6	11.4	Smooth Redirection
OHBR-2	60.0	25.0	7.0	25.1	-6.1	12.1	Smooth Redirection
LABR-1	60.4	18.8	--	23.6	-4.4	12.8	Smooth Redirection
LABR-2	59.7	19.1	14.0	22.8	-5.3	10.8	Smooth Redirection

---

[a] 20-degree tests utilized Honda Civics and 25-degree tests utilized Plymouth Furys.

[b] From transducer data.

-- Hypothetical occupant did not displace the required 24 inches.

an AIS of 4 or greater injuries would be remote even for these 15 typical rigid barrier installations.

Clearly there are two problems with using the lateral occupant risk criteria for evaluating longitudinal barrier crash tests. First, as the sled test and accident data imply, serious injury does not appear likely at the current Report 230 design limit for lateral occupant risk of 20 fps (6.1 m/s) or even at a more liberal value of 30 fps (9.1 m/s). The accident data imply that severe occupant injury is not likely until lateral occupant impact velocities of at least 40 fps (12.2 m/s) occur. Secondly, the occupant risk is nearly always below 30 fps (9.1 m/s) even in rigid barrier tests. Hence, although the flail space concept is both accurate and simple to use, it does not provide a measure that is meaningful in assessing longitudinal barrier crash tests.

Discussion

How then are occupants being injured and killed in the nearly 1500 fatal longitudinal barrier accidents which occur each year?(6) Some clues may have been suggested earlier in this paper.

In more than 80 percent of the cases summarized in table 7, the vehicle struck another roadside object after being successfully redirected from the first collision. For all of the vehicle occupants that experienced secondary impacts, the MAIS was greater in the second impact than the first, sometimes by a large margin. For example figure 6 summarizes NASS case 83-02-071T. After the first barrier impact the occupant had sustained no injuries. After the vehicle was redirected, however, it collided with a tree; the MAIS for the second collision was 3. Often, in the cases summarized in table 6, the occupant sustained no injuries during the first redirection only to become involved with another, much more serious subsequent collision. Clearly, redirection into other roadside features poses a serious hazard to vehicle

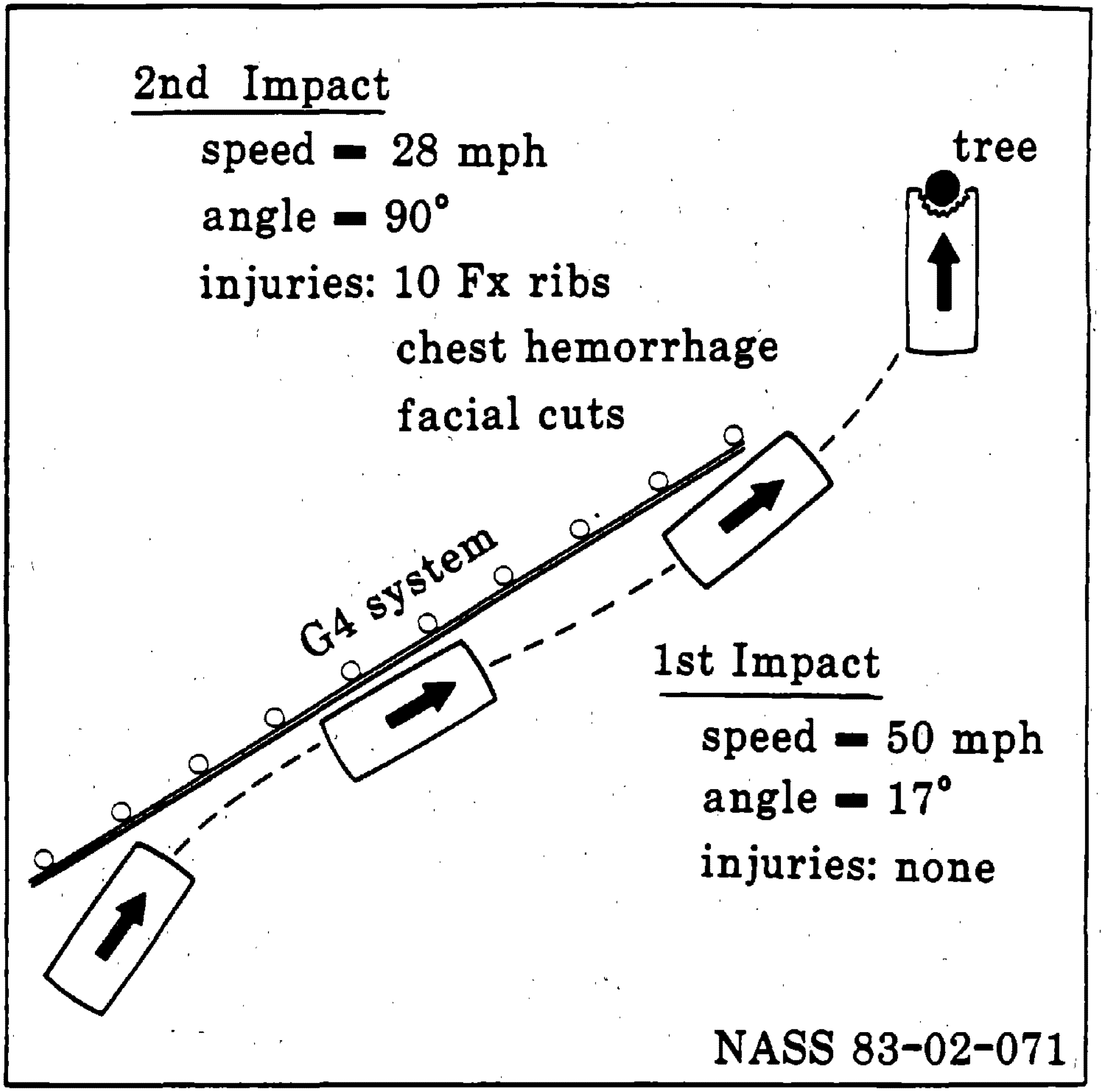


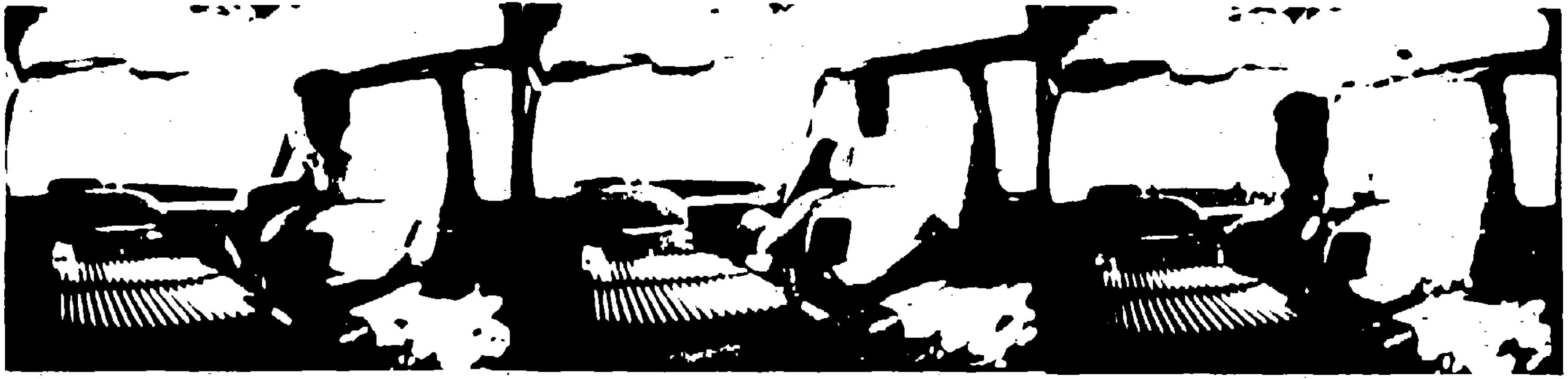
Figure 6. Example of a multiple impact accident case.

occupants. The hazardous aspects of the post impact trajectory will be discussed at length in volume V.

There are several possible reasons for this increase in injury rate for occupants of vehicles redirected from a longitudinal barrier which subsequently impact other roadside features. Although the impact speed is nearly always less in second collisions the angle frequently increases. In table 7, the second impact angle was larger than the first in all the multiple impact cases. Frontal impacts may be more injurious than side impacts because of the greater amount of flail space in which the occupant may accelerate as discussed earlier in this volume. Therefore, as the impact angle becomes larger the impact will become more frontal and because occupants have larger flail distances available in frontal collisions they may be at greater risk of sustaining injury.

Another important feature of the secondary collision is the occupant's position in the passenger compartment. At the time of the initial collision the occupant is usually positioned correctly in the seat. During the first redirectional collision the occupant will strike the door surface and rebound beyond his pre-impact position. Thus, if a second collision occurs, a larger flail space would be available in which to accelerate to a higher velocity. Figure 7 shows a set of sequential photographs of an anthropometric dummy taken during a longitudinal crash test in which the vehicle unintentionally struck two barriers. The dummy struck the door in the first collision, rebounded beyond its original seating position, and then struck the door again at a higher velocity during the second collision. The dummy's flail distance was more than two times greater in the second collision.

The ultimate objective of longitudinal barrier designers is to protect occupants by shielding vehicles from more hazardous roadside objects and to shield pedestrians from traffic. It is often a difficult task to determine what specific aspects of a design will work best toward these goals. For many years longitudinal barrier designers have attempted



First impact - occupant is properly positioned in SCAT

Occupant strikes door assembly at 16 fps

Occupant rebounds after impact with door

Second impact - occupant out of position at second impact

Occupant accelerates toward door

Occupant strikes door assembly at 35 fps

Figure 7. Effect of occupant position on the occupant risk factor.

to find a balance between the often conflicting goals of barrier flexibility for vehicle occupant protection and barrier strength for vehicle containment.

The previous sections have suggested that these goals need not conflict. A longitudinal barrier system which performs correctly, smoothly redirecting the vehicle without serious snagging, vaulting, penetration or rollover, will not subject the occupant to lateral collision forces of a magnitude great enough to cause severe injury. Thus, if designers ensure that longitudinal barriers perform "correctly", vehicle occupants will generally be well protected in redirectional collisions.

Although the foregoing discussion indicates that the occupant risk factor may not be a critical evaluation factor in longitudinal barrier tests, the authors recommend that these measurements continue to be taken especially since they are easily calculated from vehicle dynamics. Moreover, the vehicle kinematics and occupant risk determinations are critical for other roadside hardware evaluation tests such as crash cushions and breakaway supports.

Conclusions and Recommendations

Conclusions

When a tracking vehicle impacts a longitudinal barrier and is smoothly redirected and remains upright, the risk of severe occupant injury in that collision is very small. Although the flail space model and the occupant risk criteria are useful and simple tools for estimating the behavior of occupants in a collision environment, they do not appear to be a discerning assessment factor for <u>redirectional</u> tests. In the absence of snagging, barrier penetration or rollover, it is <u>not</u> likely that high values of occupant-interior impact velocity will be observed.

Since Report 230 already requires smooth redirection and an upright vehicle, the occupant risk factor is a redundant evaluation criteria. The longitudinal occupant impact velocity of 30 fps (9.1 m/s), however, does appear to correlate with other frontal measures of occupant trauma such as the HIC. The longitudinal occupant risk, unlike the lateral occupant risk, is a discerning evaluation criteria. The investigation of actual flail space dimensions indicated that the current Report 230 recommendations of 1 foot (0.3 m) and 2 foot (0.6 m) for lateral and longitudinal flail distances appeared to represent a reasonable worst-case scenario.

Recommendations

In view of the discussion presented in earlier sections the following specific changes to the Report 230 specifications are recommended:

Occupant Risk Criteria

The occupant risk criteria should be eliminated as a required evaluation factor in the redirectional tests, tests 11, 12 and 30. Since the occupant risk factor is a calculated number, it may be useful to continue calculating and reporting its value though the occupant risk factor should not be used as an evaluation criteria. The occupant risk factor is, however, still a very important evaluation criteria in terminal, crash cushion and breakaway support tests.

An alternative to eliminating the occupant risk criteria altogether is to increase the allowable occupant impact velocity for the lateral direction from 20 fps (6.1 m/s) to a higher value such as 30 fps (9.1 m/s). The authors believe eliminating the criteria in tests 11, 12 and 30 is preferable.

Anthropometric Dummies

As the previous sections have indicated, occupant responses in redirectional collisions are far below the critical responses specified by FMVSS 208.(3) Very little useful information is gained from the use of fully instrumented dummies in the redirectional tests. In addition the cost of including instrumented dummies in the tests and reducing the resultant data adds significant costs to each test. It is recommended that <u>un</u>instrumented dummies be used to provide a record of the occupant's trajectory in the cine coverage but that the practice of using instrumented dummies in tests 11, 12 and 30, the redirectional tests, be curtailed.

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(4) Bronstad, M.E. and Michie, J.D., "Recommended Procedures for Vehicle Crash Testing of Highway Appurtenances," NCHRP Report 153, Transportation Research Board, Washington, DC, 1974.

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(6) Fatal Accident Reporting System 1982, U.S. DOT, National Highway Traffic Safety Adm, Washington, DC 20590.

(7) "Accident Analysis of Narrow Bridge Sites," Federal Highway Adm., Contract No. DOT-FH-11-9285.

(8) Crash3 User's Guide and Technical Manual," U.S. Department of Transportation Technical Report, DOT-HS-805-732, February 1981.

(9) Powell, G.H., "Computer Evaluations of Automobile Barrier Systems," FHWA-RD-73-73, Federal Highway Adm., Washington, DC, August 1970.

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(11) "Bridge Rail Design and Performance Standards," Federal Highway Administration, Contract No. DTFH61-84-C-00002.

(12) Bryden, J.E. and Fortuniwicz, J.S., "Traffic Barrier Performance Related to Vehicle Size and Type," 2nd Interim Report on Research Project 180-1, New York State Dept. of Transportation (1985).

Appendix A. A Survey of Passenger Compartment Geometry

Objective

In the flail space concept, an unrestrained missile (occupant) placed in the front passenger seat moves toward interior compartment surfaces upon collision. After contact with the interior, the occupant rides down with the vehicle and experiences similar velocities and accelerations. Thus, a key determinant of occupant deceleration forces and Δv's is the distance the occupant travels before striking the interior surface at a time the vehicle is being decelerated. The present Report 230 arrangement positions the occupant two feet away from the instrument panel and one foot away from the door, based on a limited survey of passenger sedan interiors.

A detailed survey of passenger sedan compartment geometry was initiated to determine if the specific flail dimensions of two feet from the instrument panel and one foot from the side door are accurate and representative of the actual vehicle population. Figure 8 shows a sample of the MVMA specifications form for categorizing vehicle dimensions.

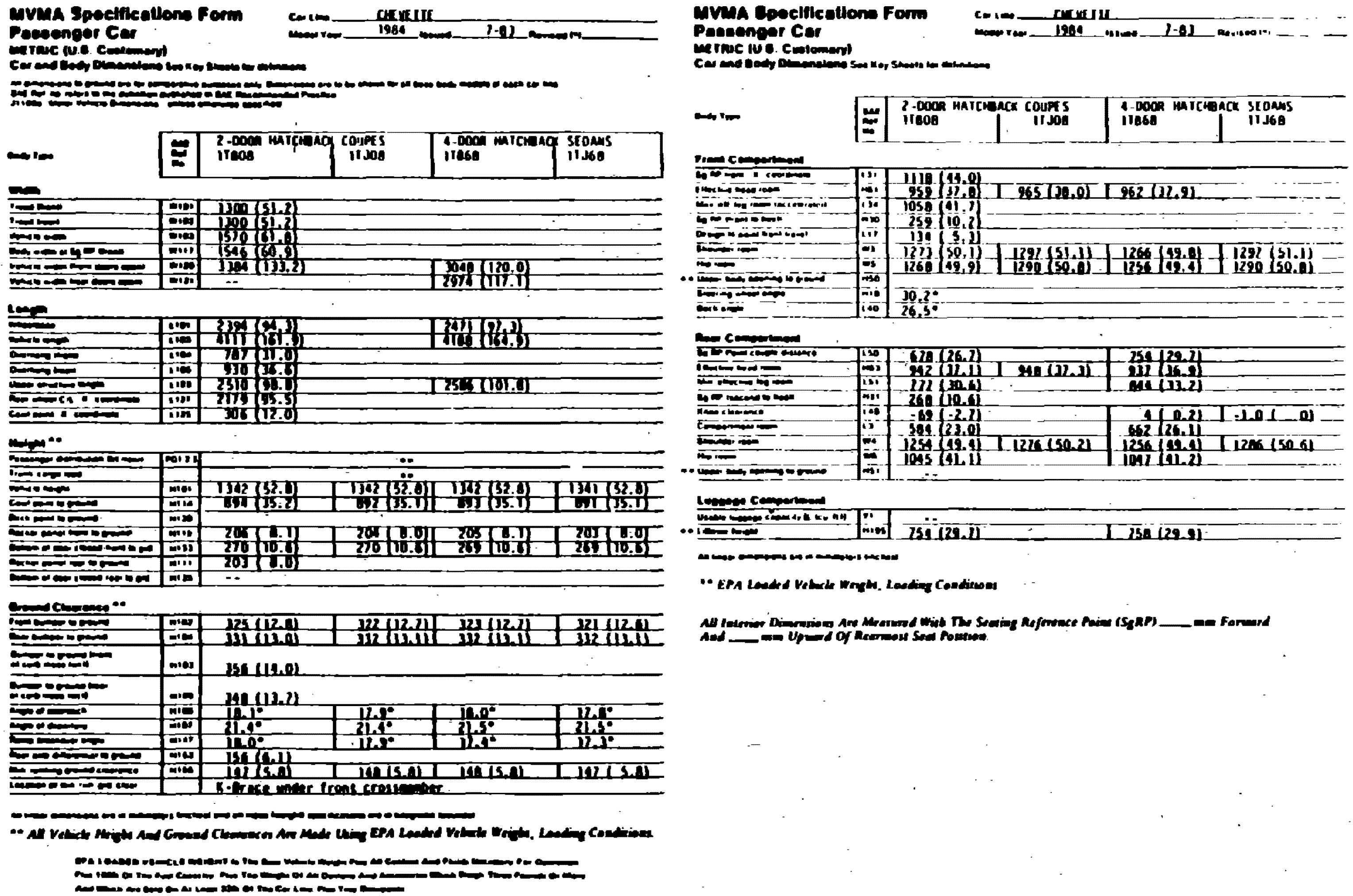
Analyses and Results

Within NHTSA, the Office of Vehicle Research utilizes the NCAP crash test data base. Fiftieth percentile male dummies are placed in the driver and front passenger positions with the seat in the mid-track position. Clearance dimensions are measured prior to a crash test to the nearest one-half inch. Figure 9 shows a pictorial representation of the nine dimensions measured. Definitions are the following:

HH - HEAD TO WINDSHIELD HEADER - Distance from center of forehead to metal trim above windshield immediately in front of subject.

HW - HEAD TO WINDSHIELD - Horizontal distance from center of forehead to point on windshield immediately at front of subject.

HR - HEAD TO SIDE HEADER - Distance from side of head (just above ear) to point on trim (top of window) or pillar immediately to the side of the subject.



MVMA Specifications Form
Passenger Car
METRIC (U.S. Customary)
Car and Body Dimensions See Key Sheets for definitions

Car Line CHEVETTE
Model Year 1984 Issued 7-83 Revised

Body Type	SAE Ref No.	2-DOOR HATCHBACK COUPES 1T808	1TJ08	4-DOOR HATCHBACK SEDANS 1T868	1TJ68
Width					
Tread front	W101	1300 (51.2)			
Tread rear	W102	1300 (51.2)			
Vehicle width	W103	1570 (61.8)			
Body width at SgRP front	W117	1546 (60.9)			
Vehicle width front doors open	W120	3384 (133.2)		3048 (120.0)	
Vehicle width rear doors open	W121	--		2974 (117.1)	
Length					
Wheelbase	L101	2394 (94.3)		2471 (97.3)	
Vehicle length	L103	4111 (161.9)		4188 (164.9)	
Overhang front	L104	787 (31.0)			
Overhang rear	L105	930 (36.6)			
Upper structure length	L123	2510 (98.8)		2586 (101.8)	
Rear wheel C/L X coordinate	L127	2179 (95.5)			
Cowl point X coordinate	L125	306 (12.0)			
Height **					
Passenger distribution [illegible]	PD1 2 &	--			
Trunk cargo load		--			
Vehicle height	H101	1342 (52.8)	1342 (52.8)	1342 (52.8)	1341 (52.8)
Cowl point to ground	H114	894 (35.2)	892 (35.1)	893 (35.1)	891 (35.1)
Deck point to ground	H138				
Rocker panel front to ground	H112	206 (8.1)	204 (8.0)	205 (8.1)	203 (8.0)
Bottom of door closed front to grd	H133	270 (10.6)	270 (10.6)	269 (10.6)	269 (10.6)
Rocker panel rear to ground	H111	203 (8.0)			
Bottom of door closed rear to grd	H135	--			
Ground Clearance **					
Front bumper to ground	H102	325 (12.8)	322 (12.7)	323 (12.7)	321 (12.6)
Rear bumper to ground	H104	331 (13.0)	332 (13.1)	332 (13.1)	332 (13.1)
Bumper to ground front at curb mass	H103	356 (14.0)			
Bumper to ground rear at curb mass	H105	348 (13.7)			
Angle of approach	H106	18.1°	17.9°	18.0°	17.8°
Angle of departure	H107	21.4°	21.4°	21.5°	21.5°
Ramp breakover angle	H147	18.0°	17.9°	17.4°	17.3°
Rear axle differential to ground	H153	156 (6.1)			
Min. running ground clearance	H156	147 (5.8)	148 (5.8)	148 (5.8)	147 (5.8)
Location of min. run grd clear		K-Brace under front crossmember			

[illegible]

** *All Vehicle Height And Ground Clearances Are Made Using EPA Loaded Vehicle Weight, Loading Conditions*

[illegible]

MVMA Specifications Form
Passenger Car
METRIC (U.S. Customary)
Car and Body Dimensions See Key Sheets for definitions

Car Line CHEVETTE
Model Year 1984 Issued 7-83 Revised

Body Type	SAE Ref No.	2-DOOR HATCHBACK COUPES 1T808	1TJ08	4-DOOR HATCHBACK SEDANS 1T868	1TJ68
Front Compartment					
SgRP front X coordinate	L31	1118 (44.0)			
Effective head room	H61	959 (37.8)	965 (38.0)	962 (37.9)	
Max. eff. leg room (accelerator)	L34	1058 (41.7)			
SgRP front to heel	H30	259 (10.2)			
[illegible]	L17	134 (5.3)			
Shoulder room	W3	1273 (50.1)	1297 (51.1)	1266 (49.8)	1297 (51.1)
Hip room	W5	1268 (49.9)	1290 (50.8)	1256 (49.4)	1290 (50.8)
** Upper body opening to ground	H50				
Steering wheel angle	H18	30.2°			
Back angle	L40	26.5°			
Rear Compartment					
SgRP front couple distance	L50	678 (26.7)		754 (29.7)	
Effective head room	H63	942 (37.1)	948 (37.3)	937 (36.9)	
Min. effective leg room	L51	777 (30.6)		844 (33.2)	
SgRP second to heel	H31	268 (10.6)			
Knee clearance	L48	-69 (-2.7)		4 (0.2)	-1.0 (0)
Compartment room	L3	584 (23.0)		662 (26.1)	
Shoulder room	W4	1254 (49.4)	1276 (50.2)	1256 (49.4)	1286 (50.6)
Hip room	W6	1045 (41.1)		1047 (41.2)	
** Upper body opening to ground	H51	--			
Luggage Compartment					
Usable luggage capacity	V1	--			
** Liftover height	H195	754 (29.7)		758 (29.9)	

[illegible]

** *EPA Loaded Vehicle Weight, Loading Conditions*

All Interior Dimensions Are Measured With The Seating Reference Point (SgRP) ____ mm Forward And ____ mm Upward Of Rearmost Seat Position.

Figure 8. MVMA specification form.

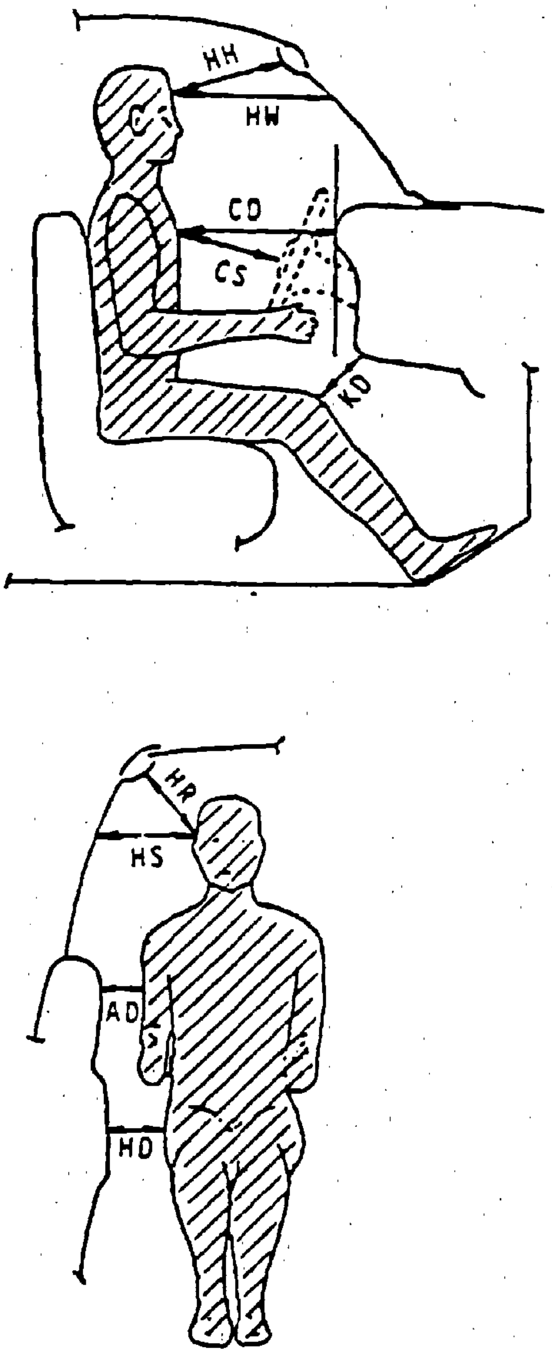


Figure 9. Occupant clearance dimensions.
(Taken from memo prepared by NHTSA Office of Vehicle Research.)

HS - HEAD TO SIDE WINDOW - Horizontal distance from side of head (just above ear) to point on window (or pillar) immediately to the side of subject.

CD - CHEST TO DASH - Horizontal distance from chest (near sternum) to vertical line tangent to dashpanel immediately in front of subject.

CS - CHEST TO STEERING WHEEL - Distance from chest (near sternum) to hub of steering wheel for a subject seated in driver's position.

AD - ARM TO DOOR - Horizontal distance from midpoint of upper arm to door (or other) surface immediately to side of subject.

HD - HIP TO DOOR - Horizontal distance from hip (H-point) to door (or other) surface immediately to the side of subject.

KD - KNEES TO DASH - Shortest distance from knees to lower dashpanel immediately in front of subject.

Data from about 160 crash tests were analyzed.

The data from printouts of clearance dimensions by make, model year and weight of vehicle received from NHTSA were stored on microcomputer, proofed and then transferred to a SAS data set on a main frame computer. A summary of the data analysis is shown in table 9 and the complete data set is included in table 10.

A couple of editing steps were then performed. First, non-passenger cars were deleted from the main data set, as well as a few vehicles where the seat location was not mid-track. Next, the clearance dimensions and weights of vehicles of the same make, model and model year were averaged to yield a single entry. Scatterplots of each dimension for both driver and right front passenger were then produced. These are shown in figures 10 through 26. Variation was large and the outliers were checked for errors.

A few values were found to be completely out of range, possibly due to coding or keypunch errors. Further examination showed that several of the questionable dimensions involved the same crash tests. For example, a

Table 9. Synopsis of the trends shown in the clearance dimension plots.

Clearance Dimension	Seat Position	Range (inches)	Other Comments
HW	RF	12.0-26.0	Modest variation with weight
HW	DR	12.0-27.0	Modest variation with weight
CD	RF	18.0-27.0	Little variation with weight
CD	DR	15.0-25.0	Little variation except for MIN, which varies between 15-20.0 inches
CS	RF	xx	No such dimension (chest to steering column) for passenger
CS	DR	9.0-19.0	Modest variation and values appear to decrease with weight
HS	RF	5.0-13.0	Little variation except with MAX, and all descriptors appear to increase slightly with weight
HS	DR	5.0-13.0	Little variation except with MAX, and all descriptors appear to increase with weight
AD	RF	2.0- 8.0	Modest variation, and all descriptors appear to increase with weight except MIN
AD	DR	1.5- 7.0	Modest variation, and all descriptors except MIN increase with weight
HD	RF	4.0-12.0	Little variation except with MAX, which appears to increase with weight
HD	DR	3.5- 9.5	Modest variation except with MIN, and all descriptors appear to increase with weight
HH	RF	6.0-19.0	Little variation except with MIN
HH	DR	6.0-22.0	Modest variation with weight
HR	RF	3.5-11.5	Little variation except with MAX, which varies between 7-11 inches
HR	DR	3.5-10.0	Little variation except with MAX, which appears to increase with weight
KD	RF	3.0-10.0	Little variation with weight
KD	DR	1.5-11.0	Little variation, and all descriptors appear to increase with weight

Table 10. Complete new car assessment program data set.

OBS	ID	MAKE	MODEL	YEAR	WEIGHT	SEAT	PLACE	HH	HW	HR	HS	CD	CS	AD	HD	RD
1	077	AMC	CONCORD	80	3700	DR	C	13.7	20.0	6.6	9.5	24.0	15.7	4.2	7.8	10.6
2	077	AMC	CONCORD	80	3700	RF	C	13.2	20.0	6.2	8.1	24.2	0.0	4.-	8.2	10.7
3	272	AMC	CONCORD	80	3700	DR	C	13.7	20.0	6.6	9.5	24.0	15.7	4.2	7.8	10.6
4	272	AMC	CONCORD	80	3700	RF	C	13.2	20.0	6.2	8.1	24.2	0.0	4.9	8.2	10.7
5	385	AMC	CONCORD	81	3930	DR	R	14.0	21.0	6.6	9.2	24.5	15.7	4.7	6.7	7.7
6	385	AMC	CONCORD	81	3930	RF	R	14.0	20.5	6.3	9.5	24.0	99.9	5.0	7.0	11.5
7	221	AMC	EAGLE RTV	80	4118	DR	C	16.4	19.5	9.5	12.0	23.3	15.1	5.4	7.6	9.5
8	221	AMC	EAGLE RTV	80	4118	RF	C	15.8	21.0	9.0	11.0	23.0	99.9	4.8	8.3	9.0
9	568	AMC	MATADOR	74	4049	DR	C	16.5	24.3	10.4	10.2	23.8	11.8	6.7	9.5	5.9
10	568	AMC	MATADOR	74	4049	RF	C	16.4	23.8	11.0	10.9	21.9	0.0	8.2	11.4	6.3
11	364	AMC	SPIRIT	81	3180	DR	C	13.3	18.0	5.5	8.2	23.1	15.0	4.0	6.2	11.0
12	364	AMC	SPIRIT	81	3180	RF	C	13.0	17.7	5.0	8.0	23.0	0.0	4.0	6.2	10.7
13	102	AUDI	4000	80	2836	DR	C	99.9	19.4	99.9	99.9	18.7	12.4	99.9	99.9	4.9
14	102	AUDI	4000	80	2836	RF	C	99.9	17.0	99.9	99.9	20.8	99.9	99.9	99.9	6.0
15	357	AUDI	5000	81	3361	DR	R	15.5	20.0	6.5	9.0	21.8	14.3	4.6	7.9	4.1
16	357	AUDI	5000	81	3361	RF	C	16.0	21.0	6.0	9.5	22.0	99.9	5.0	8.0	5.5
17	585	BUICK	CENTURY	82	3527	DR	C	12.9	19.2	6.2	11.0	21.5	13.4	4.4	7.2	6.4
18	586	BUICK	CENTURY	82	3527	RF	C	12.2	18.1	6.8	13.0	21.4	99.9	4.9	7.2	9.3
19	052	BUICK	RIVIERA	79	4440	DR	C	99.9	21.8	99.9	99.9	99.9	99.9	99.9	99.9	7.9
20	052	BUICK	RIVIERA	79	4440	RF	C	99.9	22.0	99.9	99.9	99.9	99.9	99.9	99.9	6.0
21	425	CADILLAC	SEVILLE	80	4615	DR	C	15.1	23.3	99.9	99.9	21.3	13.3	99.9	99.9	5.1
22	425	CADILLAC	SEVILLE	80	4615	RF	C	13.2	21.0	99.9	99.9	20.9	99.9	99.9	99.9	7.2
23	576	CHEVROLET	BLAZER RPV	81	4016	DR	C	12.1	18.6	9.3	10.8	19.6	9.0	4.8	5.0	5.3
24	576	CHEVROLET	BLAZER RPV	81	4016	RF	C	12.5	17.1	8.5	8.8	99.9	20.8	3.8	7.4	6.6
25	450	CHEVROLET	CAMARO	82	3428	DR	C	15.5	23.0	5.0	11.3	21.0	15.0	6.0	8.2	6.0
26	450	CHEVROLET	CAMARO	82	3428	RF	C	15.0	23.0	5.0	11.6	20.5	99.9	6.0	8.2	7.5
27	515	CHEVROLET	CAPRICE	81	4120	DR	C	14.7	20.2	6.5	10.5	21.0	15.0	5.5	6.2	9.2
28	515	CHEVROLET	CAPRICE	81	4120	RF	C	15.0	19.3	6.3	10.4	21.2	99.9	6.6	6.5	9.0
29	523	CHEVROLET	CAVALIER	82	2830	DR	C	12.0	15.7	4.2	8.2	18.1	12.6	4.6	4.7	3.5
30	523	CHEVROLET	CAVALIER	82	2830	RF	C	12.9	16.0	4.6	9.1	22.7	99.9	5.1	6.2	6.7
31	661	CHEVROLET	CAVALIER	84	3110	DR	C	9.1	15.5	4.5	8.0	19.0	15.2	4.5	6.2	5.0
32	661	CHEVROLET	CAVALIER	84	3110	RF	U	9.2	15.5	4.4	6.0	24.5	99.9	4.7	6.5	8.0
33	605	CHEVROLET	CAVALIER	83	3020	DR	C	13.0	17.2	5.2	7.8	19.0	13.2	4.0	6.2	6.0
34	605	CHEVROLET	CAVALIER	83	3020	RF	C	13.0	17.0	5.2	8.0	25.0	99.9	4.2	6.1	7.7
35	451	CHEVROLET	CELEBRITY	82	2713	DR	C	12.8	19.0	5.7	9.4	21.5	13.5	5.2	6.8	6.7
36	451	CHEVROLET	CELEBRITY	82	2713	RF	C	12.5	19.0	5.5	9.8	24.5	99.9	4.5	6.5	6.0
37	688	CHEVROLET	CELEBRITY	84	3590	DR	C	13.7	20.5	5.7	9.3	22.0	15.5	5.0	7.5	5.6
38	688	CHEVROLET	CELEBRITY	84	3590	RF	C	13.6	20.5	5.7	9.2	25.2	99.9	6.0	8.1	6.4
39	073	CHEVROLET	CHEVETTE	79	2716	DR	C	9.7	13.1	4.6	5.5	23.0	13.7	2.5	6.4	4.2
40	073	CHEVROLET	CHEVETTE	79	2716	RF	C	9.5	13.2	4.7	5.8	21.7	0.0	2.7	5.5	5.5
41	426	CHEVROLET	CHEVETTE	80	2641	DR	C	10.6	14.5	99.9	99.9	19.6	12.9	99.9	99.9	4.7
42	426	CHEVROLET	CHEVETTE	80	2641	RF	C	10.3	15.8	99.9	99.9	19.8	99.9	99.9	99.9	5.7
43	525	CHEVROLET	CHEVETTE	82	2827	DR	R	11.1	15.3	5.4	7.1	19.8	13.6	2.1	6.2	6.2
44	525	CHEVROLET	CHEVETTE	82	2827	RF	R	10.1	15.3	5.2	6.4	20.4	99.9	2.2	6.4	7.9
45	005	CHEVROLET	CITATION	80	3230	DR	C	14.0	16.9	6.5	8.2	23.7	15.4	4.7	7.2	7.5
46	005	CHEVROLET	CITATION	80	3230	RF	C	14.5	18.7	6.5	8.5	26.7	0.0	6.2	8.4	8.4
47	474	CHEVROLET	CITATION	82	3000	DR	C	13.4	19.9	7.3	10.0	25.1	15.9	5.3	7.4	6.7
48	474	CHEVROLET	CITATION	82	3000	RF	C	12.1	17.3	7.1	9.7	27.3	99.9	5.9	7.3	9.4
49	475	CHEVROLET	CITATION	82	3000	DR	C	13.8	19.1	6.0	8.6	24.8	16.8	5.8	7.2	7.4
50	475	CHEVROLET	CITATION	82	3000	RF	C	14.7	19.4	5.8	7.9	28.2	0.0	5.7	7.3	10.3
51	477	CHEVROLET	CITATION	82	3000	DR	N	15.0	21.0	7.0	10.0	24.5	16.0	5.3	6.9	7.7
52	477	CHEVROLET	CITATION	82	3000	RF	N	14.0	20.2	7.0	10.0	28.0	99.9	5.4	7.5	9.2
53	479	CHEVROLET	CITATION	82	3000	DR	N	14.7	21.0	6.9	10.0	24.5	15.7	5.2	7.1	7.7
54	479	CHEVROLET	CITATION	82	3000	RF	N	14.7	21.0	6.7	10.0	25.0	99.9	5.5	7.2	10.0
55	480	CHEVROLET	CITATION	82	3010	DR	N	14.2	20.5	6.8	10.0	24.5	15.6	5.3	7.0	7.8
56	480	CHEVROLET	CITATION	82	3010	RF	N	14.5	20.2	7.0	10.0	25.5	99.9	5.7	7.2	9.0
57	481	CHEVROLET	CITATION	82	3000	DR	C	13.8	19.7	6.3	9.0	24.6	16.0	5.0	6.6	7.1
58	481	CHEVROLET	CITATION	82	3000	RF	C	14.9	21.2	6.7	9.6	27.2	0.0	5.3	7.3	8.8
59	482	CHEVROLET	CITATION	82	3002	DR	C	12.2	21.3	6.7	10.2	24.1	15.0	5.4	7.7	7.6
60	482	CHEVROLET	CITATION	82	3002	RF	C	12.0	21.4	6.6	9.7	26.5	99.9	5.4	7.6	9.6
61	483	CHEVROLET	CITATION	82	2993	DR	C	13.8	22.3	6.6	9.1	24.6	14.9	5.5	6.7	7.6
62	483	CHEVROLET	CITATION	82	2993	RF	C	13.6	22.6	7.0	9.1	26.7	99.9	5.5	6.6	8.7
63	486	CHEVROLET	CITATION	82	3000	DR	C	13.3	18.9	6.3	9.6	24.5	15.8	5.3	7.1	7.4
64	486	CHEVROLET	CITATION	82	3000	RF	C	14.0	20.3	6.4	9.3	27.2	0.0	5.4	7.1	10.3
65	492	CHEVROLET	CITATION	82	3010	DR	N	14.0	20.5	6.9	9.8	24.0	15.4	5.4	7.5	7.2
66	492	CHEVROLET	CITATION	82	3010	RF	N	14.5	20.5	6.8	9.9	27.5	99.9	5.5	7.2	9.3
67	494	CHEVROLET	CITATION	82	2948	DR	C	15.2	22.3	7.3	9.0	24.5	15.5	5.5	7.7	7.4
68	494	CHEVROLET	CITATION	82	2948	RF	C	15.4	22.5	6.7	8.1	27.0	99.9	5.8	7.7	9.3
69	495	CHEVROLET	CITATION	82	2992	DR	C	15.2	22.0	6.3	9.0	24.4	15.0	5.0	6.5	7.3
70	495	CHEVROLET	CITATION	82	2992	RF	C	15.1	22.0	6.7	9.0	26.0	99.9	5.8	7.7	9.6
71	545	CHEVROLET	CITATION	82	3000	DR	C	13.0	18.8	5.8	8.6	24.2	15.3	4.9	7.1	6.6
72	545	CHEVROLET	CITATION	82	3000	RF	C	13.8	19.1	6.3	8.9	27.1	0.0	5.4	6.8	9.1
73	551	CHEVROLET	CITATION	82	3000	DR	N	14.5	20.5	6.7	9.5	24.9	16.0	5.1	6.7	7.6
74	551	CHEVROLET	CITATION	82	3000	RF	N	14.5	20.7	6.7	10.0	27.7	99.9	5.7	7.0	9.4
75	552	CHEVROLET	CITATION	82	3000	DR	C	13.7	18.9	7.3	10.6	24.0	15.6	6.5	8.4	7.0
76	552	CHEVROLET	CITATION	82	3000	RF	C	14.1	18.5	6.5	9.4	27.6	99.9	6.6	8.9	8.9
77	613	CHEVROLET	CORVETTE	84	3680	DR	C	11.8	18.6	4.0	8.8	22.2	14.0	2.7	7.5	5.5

Table 10. Complete new car assessment program data set (continued).

78	613	CHEVROLET	CORVETTE	84	3660	RF	C	10.5	18.5	4.0	9.0	18.0	99.9	3.8	7.0	6.1
79	161A	CHEVROLET	IMPALA	78	3575	DR	C	99.9	20.4	99.9	99.9	99.9	12.3	99.9	99.9	7.5
80	161A	CHEVROLET	IMPALA	78	3575	RF	C	99.9	20.9	99.9	99.9	21.5	99.9	99.9	99.9	7.6
81	423	CHEVROLET	IMPALA	79	4179	DR	C	99.9	19.7	99.9	99.9	99.9	16.0	99.9	99.9	8.3
82	423	CHEVROLET	IMPALA	79	4179	RF	C	99.9	20.6	99.9	99.9	99.9	21.6	99.9	99.9	7.3
83	465	CHEVROLET	IMPALA	81	4110	DR	C	13.5	21.0	7.7	11.5	20.5	14.0	5.7	7.4	8.6
84	465	CHEVROLET	IMPALA	81	4110	RF	C	13.5	21.0	8.0	11.7	20.5	99.9	6.5	7.7	8.5
85	064	CHEVROLET	MONZA	79	3240	DR	C	11.0	16.5	5.2	7.7	20.2	16.1	4.0	5.4	5.5
86	064	CHEVROLET	MONZA	79	3240	RF	C	10.5	15.0	4.8	7.5	21.5	0.0	4.0	5.3	6.6
87	132A	CHEVROLET	TRAILDUS MPV	80	3000	DR	C	16.0	20.5	6.2	7.5	25.2	17.0	5.7	7.7	8.8
88	132A	CHEVROLET	TRAILDUS MPV	80	3000	RF	C	15.5	20.2	6.5	7.6	29.0	99.9	6.0	7.5	11.0
89	335	CHRYSLER	IMPERIAL	81	4562	DR	C	14.0	20.0	7.0	9.0	19.5	12.8	5.2	6.8	7.3
90	335	CHRYSLER	IMPERIAL	81	4562	RF	C	13.5	19.5	6.3	9.0	19.9	99.9	5.0	6.3	5.8
91	376	CHRYSLER	LE BARON	79	4160	DR	C	14.0	19.2	4.5	7.2	20.2	14.0	3.5	7.0	6.2
92	376	CHRYSLER	LE BARON	79	4160	RF	C	14.0	18.0	4.4	7.2	20.0	0.0	3.5	6.5	6.8
93	427	CHRYSLER	LE BARON	80	3880	DR	C	15.6	21.5	99.9	99.9	20.5	13.2	99.9	99.9	6.3
94	427	CHRYSLER	LE BARON	80	3880	RF	C	13.0	17.5	99.9	99.9	18.8	99.9	99.9	99.9	7.5
95	527	CHRYSLER	LE BARON	82	3068	DR	H	13.5	19.1	5.5	10.8	21.0	11.6	4.6	6.1	6.4
96	527	CHRYSLER	LE BARON	82	3068	RF	H	12.1	19.2	7.8	9.1	20.3	99.9	4.2	6.2	7.5
97	550	CHRYSLER	LE BARON	82	3000	DR	C	13.3	18.4	5.5	9.0	21.0	15.5	3.8	7.0	8.0
98	550	CHRYSLER	LE BARON	82	3000	RF	C	13.0	18.0	4.5	8.0	20.6	99.9	4.1	6.5	8.0
99	067	CHRYSLER	LEBARON	79	4160	DR	C	14.0	18.2	4.5	7.2	20.2	14.0	3.5	7.0	6.2
100	067	CHRYSLER	LEBARON	79	4160	RF	C	14.0	18.0	4.4	7.2	20.0	0.0	3.5	6.5	6.8
101	462	DATSUN	STANZA	82	2686	DR	C	15.1	21.5	7.5	7.6	23.0	13.0	4.9	6.9	4.6
102	462	DATSUN	STANZA	82	2686	RF	C	15.1	21.0	5.8	6.4	23.1	99.9	5.0	7.0	6.0
103	186	DATSUN	200 SX	80	3038	DR	C	99.9	22.0	99.9	99.9	23.7	16.5	99.9	99.9	6.3
104	186	DATSUN	200 SX	80	3038	RF	C	99.9	18.4	99.9	99.9	22.1	99.9	99.9	99.9	8.2
105	035	DATSUN	210	79	2425	DR	C	99.9	19.0	14.2	14.2	99.9	99.9	99.9	99.9	7.0
106	035	DATSUN	210	79	2425	RF	C	99.9	19.5	99.9	99.9	99.9	99.9	99.9	99.9	6.5
107	119	DATSUN	310	80	2404	DR	C	12.6	17.8	99.9	99.9	19.3	12.8	99.9	99.9	3.1
108	119	DATSUN	310	80	2404	RF	C	12.3	15.3	99.9	99.9	19.4	99.9	99.9	99.9	4.9
109	381	DODGE	CHALLENGER	81	3204	DR	C	12.5	16.1	5.1	4.2	23.4	16.3	2.8	4.9	5.4
110	381	DODGE	CHALLENGER	81	3204	RF	C	12.1	15.9	5.1	8.5	21.0	0.0	3.3	5.0	5.9
111	526	DODGE	COLT	82	2408	DR	R	11.6	15.7	5.8	7.4	19.3	12.8	3.9	7.7	7.4
112	526	DODGE	COLT	82	2408	RF	R	14.2	18.5	6.3	9.1	20.1	99.9	4.5	6.1	5.7
113	674	DODGE	DAYTONA	84	3000	DR	C	12.9	17.5	4.9	9.2	21.0	15.2	4.5	6.2	6.0
114	674	DODGE	DAYTONA	84	3000	RF	C	12.7	17.4	4.9	9.1	23.0	99.9	5.7	6.7	6.7
115	071	DODGE	MAGNUM	79	4440	DR	C	13.2	17.5	6.4	8.5	21.5	15.0	4.2	6.2	7.7
116	071	DODGE	MAGNUM	79	4440	RF	C	15.3	17.3	6.7	9.2	22.3	0.0	5.0	6.4	8.3
117	220	DODGE	MIRADA	80	4136	DR	C	14.0	19.0	7.0	10.8	20.3	13.0	5.0	8.0	8.0
118	220	DODGE	MIRADA	80	4136	RF	C	13.0	19.5	5.0	8.8	20.5	99.9	4.8	9.0	5.5
119	444	DODGE	OMNI	82	2670	DR	C	12.5	18.5	6.5	9.5	20.7	17.2	4.0	7.0	7.5
120	444	DODGE	OMNI	82	2670	RF	C	12.2	18.2	6.5	9.5	25.5	0.0	4.2	6.5	7.0
121	182	DODGE	ST.REGIS	79	4457	DR	C	99.9	18.4	99.9	99.9	99.9	10.7	99.9	99.9	9.0
122	182	DODGE	ST.REGIS	79	4457	RF	C	99.9	15.6	99.9	99.9	99.9	99.9	99.9	99.9	8.5
123	453	DODGE	400	82	3044	DR	C	15.5	19.2	6.5	9.0	21.5	15.0	4.2	6.4	7.0
124	453	DODGE	400	82	3044	RF	C	13.5	19.7	7.2	9.8	21.3	99.9	4.4	6.3	7.3
125	514	DODGE	600	83	3110	DR	C	13.5	19.0	5.6	8.5	21.5	15.5	5.0	5.5	7.1
126	514	DODGE	600	83	3110	RF	C	13.3	18.6	5.7	8.5	21.3	99.9	5.2	5.7	6.5
127	194	FIAT	STRADA	80	2707	DR	C	16.3	19.8	99.9	99.9	21.3	16.6	99.9	99.9	4.3
128	194	FIAT	STRADA	80	2707	RF	C	13.3	16.8	99.9	99.9	20.3	99.9	99.9	99.9	6.3
129	580	FORD	BRONCO	83	3845	DR	C	12.8	17.4	5.6	11.0	21.5	10.0	4.6	6.1	5.0
130	580	FORD	BRONCO	83	3845	RF	C	14.1	19.5	7.9	9.5	23.8	99.9	4.4	6.2	8.1
131	206	FORD	ESCORT	81	2530	DR	C	11.2	16.2	5.5	6.7	20.2	13.7	3.5	5.5	3.4
132	206	FORD	ESCORT	81	2590	RF	C	11.0	16.5	5.2	6.7	19.6	0.0	3.7	5.0	4.5
133	407	FORD	ESCORT	82	2576	DR	C	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
134	407	FORD	ESCORT	82	2576	RF	C	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
135	452	FORD	ESCORT	82	2584	DR	C	15.0	21.1	6.5	7.2	22.3	14.6	3.3	4.0	4.6
136	452	FORD	ESCORT	82	2584	RF	C	16.0	22.1	6.5	7.2	21.6	99.9	3.5	5.8	5.0
137	360	FORD	EXP	82	2545	DR	C	13.0	17.5	7.1	8.0	20.2	11.1	2.6	6.3	4.5
138	360	FORD	EXP	82	2545	RF	C	9.9	15.0	7.0	9.3	18.6	99.9	3.5	5.4	5.3
139	569	FORD	EXP	83	2590	DR	C	12.6	18.5	5.6	6.2	22.0	13.6	3.2	5.7	6.4
140	569	FORD	EXP	83	2590	RF	C	12.5	18.0	5.5	8.2	21.0	99.9	3.7	5.5	7.0
141	092	FORD	FAIRMONT	79	3300	DR	C	13.0	18.5	6.0	8.0	20.7	16.3	5.1	8.1	6.2
142	092	FORD	FAIRMONT	79	3300	RF	C	13.1	16.5	5.9	8.2	23.0	0.0	5.2	7.5	7.2
143	263	FORD	FIESTA	79	2185	DR	C	15.4	19.0	6.3	7.6	22.9	15.0	4.1	5.4	5.8
144	263	FORD	FIESTA	79	2185	RF	C	15.2	18.6	6.2	7.9	23.2	0.0	3.8	5.5	6.1
145	066	FORD	GRANADA	79	3950	DR	C	15.3	20.2	5.7	8.0	22.7	17.0	4.5	7.2	6.7
146	066	FORD	GRANADA	79	3950	RF	C	15.3	20.0	5.5	7.5	22.9	0.0	5.0	7.6	7.7
147	471	FORD	GRANADA	82	3430	DR	C	12.4	18.7	6.0	9.2	21.2	13.7	4.5	7.0	6.5
148	471	FORD	GRANADA	82	3430	RF	C	12.7	19.0	6.3	9.3	23.0	99.9	4.7	6.5	7.0
149	065	FORD	LTD	79	4170	DR	C	14.5	19.5	6.2	8.5	21.0	13.5	6.5	9.0	7.7
150	065	FORD	LTD	79	4170	RF	C	14.5	19.7	6.2	8.6	20.7	0.0	6.5	9.1	7.5
151	203	FORD	LTD	79	4815	DR	C	99.9	18.0	99.9	99.9	99.9	99.9	99.9	99.9	4.4
152	203	FORD	LTD	79	4815	RF	C	99.9	15.6	99.9	99.9	99.9	99.9	99.9	99.9	7.3
153	468	FORD	LTD	82	4130	DR	C	14.0	20.2	5.0	9.2	21.0	13.2	5.2	7.3	6.7
154	468	FORD	LTD	82	4130	RF	C	13.5	20.2	5.5	9.3	21.0	99.9	6.2	8.0	7.0
155	600	FORD	LTD	83	3563	DR	C	8.9	14.7	6.6	6.6	18.0	10.4	3.8	4.4	6.9
156	600	FORD	LTD	83	3563	RF	C	10.1	14.8	8.9	10.8	18.2	99.9	5.1	4.4	6.6
157	644	FORD	LTD	84	3680	DR	C	12.5	19.3	5.6	8.0	20.7	13.4	4.2	4.0	7.1

Table 10. Complete new car assessment program data set (continued).

158	644	FORD	LTD	84	3680	RF	C	12.3	19.0	5.5	7.7	20.6	99.9	4.2	4.2	7.3
159	255	FORD	MUSTANG	79	2951	DR	C	99.9	22.6	99.9	99.9	99.9	99.9	99.9	99.9	5.8
160	255	FORD	MUSTANG	79	2951	RF	C	99.9	17.3	99.9	99.9	99.9	99.9	99.9	99.9	4.5
161	481	FORD	TEMPO	84	3080	DR	C	9.2	16.7	5.0	8.4	20.5	13.5	3.5	5.9	3.5
162	481	FORD	TEMPO	84	3080	RF	C	9.0	16.5	5.3	9.5	21.0	99.9	5.0	5.8	5.0
163	271	FORD	THUNDERBIRD	80	3783	DR	C	14.5	19.0	10.0	13.0	21.0	13.0	7.0	8.3	6.0
164	271	FORD	THUNDERBIRD	80	3783	RF	C	12.5	17.0	10.0	11.5	19.0	99.9	6.0	7.0	5.3
165	575	FORD	THUNDERBIRD	83	3580	DR	C	10.2	16.0	5.5	8.7	19.8	12.7	4.0	6.3	5.2
166	575	FORD	THUNDERBIRD	83	3590	RF	C	10.7	16.2	5.5	8.5	21.0	99.9	4.0	6.1	5.0
167	605	FORD	THUNDERBIRD	83	3570	DR	C	10.5	16.2	5.3	8.7	20.2	13.1	3.9	6.0	5.4
168	605	FORD	THUNDERBIRD	83	3570	RF	C	10.4	18.2	5.2	8.5	20.5	99.9	4.6	6.0	5.2
169	372A	FORD	XXXF	80	3150	DR	C	11.5	17.0	5.5	6.5	21.5	16.0	4.1	6.0	5.9
170	372A	FORD	XXXX	80	3150	RF	C	11.0	16.5	5.0	6.5	22.3	0.0	5.0	6.0	7.5
171	455	HONDA	ACCORD	82	2635	DR	C	22.0	17.3	6.2	7.1	23.4	16.2	4.0	7.2	4.7
172	455	HONDA	ACCORD	82	2635	RF	C	17.2	22.5	6.2	7.0	22.2	99.9	4.5	7.6	4.9
173	094	HONDA	CIVIC	79	2180	DR	C	17.0	20.5	5.4	6.6	25.0	15.7	2.7	5.7	7.0
174	094	HONDA	CIVIC	79	2180	RF	C	16.7	19.5	5.4	6.5	24.5	0.0	2.8	6.2	8.2
175	217	HONDA	CIVIC	80	2296	DR	C	17.1	22.3	6.0	8.4	22.5	16.0	3.5	6.3	6.0
176	217	HONDA	CIVIC	80	2298	PF	[illegible]	18.3	22.6	6.0	8.9	26.3	99.9	3.5	6.0	6.1
177	271	HONDA	CIVIC	81	2456	DR	C	14.5	18.5	6.5	9.0	19.2	14.5	3.5	5.5	9.0
178	271	HONDA	CIVIC	81	2456	PF	C	13.7	17.7	6.5	9.0	20.6	99.9	3.5	9.5	9.0
179	354	HONDA	CIVIC	81	2160	DR	C	13.5	18.0	4.5	6.0	21.7	15.5	3.0	5.7	6.7
180	354	HONDA	CIVIC	81	2160	RF	C	13.5	19.0	4.5	6.3	25.5	0.0	4.0	6.0	9.1
181	669	HONDA	CIVIC	84	2310	DR	C	16.0	21.5	4.5	7.5	23.2	16.5	4.0	6.7	7.4
182	669	HONDA	CIVIC	84	2310	RF	C	16.0	21.5	4.3	7.2	25.6	99.9	4.2	6.7	9.0
183	216	HONDA	PRELUDE	80	2545	DR	C	19.0	25.5	6.0	10.0	24.5	18.5	5.0	6.0	5.5
184	216	HONDA	PRELUDE	80	2545	RF	R	16.0	23.0	5.3	9.1	24.0	99.9	4.3	5.8	6.5
185	633	JEEP	CJ MPV	84	3180	DR	C	20.5	23.2	99.9	99.9	21.2	15.0	99.9	99.9	8.0
186	633	JEEP	CJ MPV	84	3180	PF	C	18.5	21.2	99.9	99.9	20.0	99.9	99.9	99.9	6.4
187	204	LINCOLN	CONTINENTAL	79	5362	DR	C	99.9	19.2	99.9	99.9	99.9	99.9	99.9	99.9	6.0
188	204	LINCOLN	CONTINENTAL	79	5362	PF	C	99.9	19.8	99.9	99.9	99.9	99.9	99.9	99.9	8.8
189	528	LINCOLN	CONTINENTAL	82	4158	DR	C	15.5	19.6	9.5	11.5	22.1	13.8	6.1	6.5	4.9
190	528	LINCOLN	CONTINENTAL	82	4158	RF	C	14.1	19.6	7.5	9.5	20.3	99.9	5.3	5.4	5.2
191	522	MAZDA	GLC	81	2432	DR	C	14.2	18.5	5.6	8.6	20.5	13.7	4.1	6.0	6.0
192	522	MAZDA	GLC	81	2432	RF	C	13.7	17.4	5.2	8.5	20.0	99.9	3.5	5.0	7.0
193	118	MAZDA	626	80	3066	DR	C	12.0	17.0	99.9	99.9	20.5	12.0	99.9	99.9	3.0
194	118	MAZDA	626	80	3066	RF	C	13.0	18.0	99.9	99.9	20.8	99.9	99.9	99.9	5.0
195	470	MAZDA	626	82	2900	DR	C	13.5	16.5	5.0	6.9	20.7	14.5	2.0	6.0	6.5
196	470	MAZDA	626	82	2900	RF	C	13.0	17.9	5.2	7.0	22.0	99.9	3.5	6.0	7.0
197	599	MAZDA	626	83	2900	DR	C	12.7	17.7	5.8	8.6	21.2	13.5	4.2	7.2	5.0
198	599	MAZDA	626	83	2900	RF	C	12.4	17.7	5.7	8.5	22.5	99.9	5.0	7.1	4.7
199	137	MERCEDES	240	80	3714	DR	C	17.6	22.6	99.9	99.9	24.0	14.2	99.9	99.9	4.5
200	137	MERCEDES	240	80	3714	RF	C	15.3	21.3	99.9	99.9	20.9	99.9	99.9	99.9	5.2
201	156	MERCURY	BOBCAT	79	2998	DR	C	99.9	22.0	13.0	13.0	99.9	99.9	99.9	99.9	7.9
202	156	MERCURY	BOBCAT	79	2998	RF	C	99.9	21.5	15.0	15.0	99.9	99.9	99.9	99.9	7.1
203	157	MERCURY	CAPRI	79	3067	DR	C	99.9	17.2	16.0	16.0	99.9	99.9	99.9	99.9	5.5
204	157	MERCURY	CAPRI	79	3067	RF	C	99.9	20.0	13.8	13.8	99.9	99.9	99.9	99.9	4.9
205	587	MERCURY	CAPRI	83	3350	DR	C	9.0	13.4	6.9	6.5	18.2	10.1	4.0	7.0	5.3
206	587	MERCURY	CAPRI	83	3350	RF	C	6.9	12.5	5.0	5.1	19.2	99.9	3.6	5.4	6.2
207	612	MERCURY	COUGAR	84	3560	DR	C	10.6	16.8	5.5	8.7	20.2	13.6	4.0	6.0	5.0
208	612	MERCURY	COUGAR	84	3560	RF	C	10.9	17.2	5.5	8.6	20.5	99.9	4.2	6.2	5.3
209	051	MERCURY	MARQUIS	79	4224	DR	C	99.9	22.5	99.9	99.9	99.9	99.9	99.9	99.9	7.8
210	051	MERCURY	MARQUIS	79	4224	RF	C	99.9	22.4	99.9	99.9	99.9	99.9	99.9	99.9	6.0
211	380	MERCURY	MARQUIS	81	3965	DR	R	15.2	21.0	5.7	7.5	23.5	15.5	5.7	8.2	10.3
212	380	MERCURY	MARQUIS	81	3965	RF	R	15.0	21.5	5.6	7.5	23.0	99.9	6.2	8.0	10.3
213	589	MITSUBISHI	CORDIA	83	2719	DR	C	6.8	12.2	4.6	7.5	19.5	11.9	3.6	6.5	5.8
214	589	MITSUBISHI	CORDIA	83	2719	RF	C	7.9	12.2	4.4	6.0	20.0	99.9	4.1	6.6	6.8
215	583	MITSUBISHI	MONTERO	83	3873	DR	C	20.0	21.1	10.1	6.1	22.4	15.8	2.5	6.1	2.9
216	583	MITSUBISHI	MONTERO	83	3873	PF	C	19.4	20.9	9.1	7.0	21.5	99.9	2.2	5.1	6.5
217	579	MITSUBISHI	PICK-UP	83	3074	DR	C	16.9	21.5	8.3	10.0	22.3	15.3	3.0	4.4	5.3
218	579	MITSUBISHI	PICK-UP	83	3094	RF	C	16.4	20.3	9.5	11.0	20.8	99.9	5.1	5.8	6.8
219	598	NISSAN	PULSAR	83	2460	DR	C	13.2	21.0	4.7	6.5	23.7	16.2	3.7	6.4	6.4
220	598	NISSAN	PULSAR	83	2460	RF	C	13.3	21.0	4.7	6.6	24.0	99.9	3.8	6.6	7.2
221	464	NISSAN	SENTRA	82	2455	DR	C	16.0	24.0	7.0	8.4	23.2	14.7	4.0	6.0	4.6
222	464	NISSAN	SENTRA	82	2455	RF	C	17.4	24.5	6.1	5.5	23.3	99.9	4.0	6.0	6.4
223	666	NISSAN	300	84	3370	DR	C	14.5	21.3	4.1	7.2	21.5	15.0	2.2	6.1	5.0
224	666	NISSAN	300	84	3370	RF	C	18.2	21.0	4.2	7.2	23.0	99.9	3.5	6.5	6.5
225	025	OLDSMOBILE	CUTLASS	79	3820	DR	C	13.0	19.0	5.5	9.2	22.7	13.5	5.7	6.0	6.2
226	025	OLDSMOBILE	CUTLASS	79	3820	PF	C	12.9	19.7	5.2	8.7	27.2	0.0	5.2	5.5	4.7
227	199	OLDSMOBILE	CUTLASS	79	3799	DR	C	13.0	19.0	5.5	9.2	22.7	13.5	5.7	6.0	8.2
228	199	OLDSMOBILE	CUTLASS	79	3799	RF	C	12.8	16.7	5.2	8.7	27.2	99.9	5.0	5.5	4.7
229	136	OLDSMOBILE	CUTLASS	80	3815	DR	C	99.9	22.6	99.9	99.9	22.0	12.5	9.9	99.9	7.2
230	136	OLDSMOBILE	CUTLASS	80	3815	RF	C	99.9	24.2	99.9	99.9	26.0	99.9	9.9	99.9	7.3
231	624	OLDSMOBILE	CUTLASS	84	3700	DR	C	12.0	19.0	5.5	9.3	22.0	13.0	3.7	5.4	4.3
232	624	OLDSMOBILE	CUTLASS	84	3700	RF	C	11.5	18.7	5.4	9.2	26.5	99.9	4.5	5.0	9.0
233	219	PEUGEOT	504	79	3526	DR	C	16.5	20.5	9.0	8.5	23.0	14.5	3.5	6.0	10.0
234	219	PEUGEOT	504	79	3526	PF	C	14.0	19.5	7.0	9.5	20.0	99.9	3.5	5.0	7.0
235	588	PEUGEOT	505	83	3617	DR	C	8.0	12.2	6.0	6.5	15.2	9.5	3.2	6.9	6.5
236	588	PEUGEOT	505	83	3617	RF	C	9.2	14.1	6.9	6.8	18.2	99.9	3.4	6.0	7.2
237	665	PLYMOUTH	COLT VISTA	84	2980	DR	C	13.5	20.0	5.6	7.2	23.5	14.2	2.7	6.0	4.7
238	665	PLYMOUTH	COLT VISTA	84	2980	RF	C	13.8	20.1	5.5	7.3	24.0	99.9	3.5	5.7	9.0
239	668	PLYMOUTH	CONQUEST	84	3170	DR	C	13.2	19.0	3.	.5	22.2	16.0	2.8	5.6	5.7
240	668	PLYMOUTH	CONQUEST	84	3170	RF	C	13.5	19.0	3.	.5	22.0	99.9	3.1	5.5	5.0

Table 10. Complete new car assessment program data set (continued).

241	053	PLYMOUTH	HORIZON	79	2661	DR	C	99.9	13.9	99.9	99.9	99.9	99.9	99.9	99.9	7.0
242	053	PLYMOUTH	HORIZON	79	2661	RF	C	99.9	16.4	99.9	99.9	99.9	99.9	99.9	99.9	6.1
243	1328	PLYMOUTH	HORIZON	80	2840	DR	C	11.3	16.3	4.8	5.6	20.5	18.1	3.8	6.3	9.1
244	1328	PLYMOUTH	HORIZON	80	2840	RF	C	10.3	15.0	4.8	5.8	23.5	99.9	3.8	6.0	8.8
245	1728	PLYMOUTH	HORIZON	80	2760	DR	C	11.3	15.0	5.3	6.3	20.5	16.0	[illegible]	6.9	8.5
246	1728	PLYMOUTH	HORIZON	80	2760	RF	C	11.3	15.5	5.0	6.3	24.3	0.0	4.3	5.5	8.8
247	207	PLYMOUTH	RELIANT	81	2990	DR	C	13.0	17.0	5.5	6.5	20.0	15.5	4.7	6.7	4.9
248	207	PLYMOUTH	RELIANT	81	2990	RF	C	11.5	15.5	6.0	7.5	20.5	0.0	5.0	6.2	4.0
249	405	PLYMOUTH	RELIANT	81	2910	DR	C	13.5	18.0	5.5	7.0	22.5	15.7	4.5	8.2	6.2
250	405	PLYMOUTH	RELIANT	81	2910	RF	C	13.5	17.7	5.3	7.0	22.3	0.0	4.5	7.5	6.3
251	448	PLYMOUTH	RELIANT	82	2807	DR	C	11.5	16.5	5.0	9.4	21.0	14.3	5.3	7.5	5.3
252	448	PLYMOUTH	RELIANT	82	2807	RF	C	11.5	15.0	8.5	11.8	21.0	99.9	7.0	8.5	5.5
253	567	PLYMOUTH	RELIANT	83	2930	DR	C	16.5	22.5	6.2	9.5	23.2	17.0	5.5	8.0	8.6
254	567	PLYMOUTH	RELIANT	83	2930	RF	C	15.9	21.9	6.2	9.5	23.0	99.9	6.0	7.8	8.0
255	593	PLYMOUTH	RELIANT	83	2910	DR	C	14.5	20.4	6.3	9.4	21.9	15.5	5.3	8.0	6.7
256	593	PLYMOUTH	RELIANT	83	2910	RF	C	14.7	20.5	6.5	9.5	22.0	99.9	6.2	8.0	6.5
257	063	PLYMOUTH	VOLARE	79	3820	DR	C	11.6	15.2	4.5	7.5	20.2	13.2	4.1	7.5	7.5
258	063	PLYMOUTH	VOLARE	79	3820	RF	C	11.6	15.0	5.2	7.5	19.5	0.0	4.2	7.0	8.5
259	033	PLYMO	CHAMP	79	2318	DR	C	12.3	17.2	99.9	99.9	19.3	11.3	99.9	99.9	99.9
260	033	PLYMO	CHAMP	79	2318	RF	C	12.5	17.6	99.9	99.9	19.7	99.9	99.9	99.9	99.9
261	202	PONTIAC	FIREBIRD	79	3908	DR	C	99.9	22.0	16.3	16.3	99.9	99.9	99.9	99.9	8.5
262	202	PONTIAC	FIREBIRD	79	3908	RF	C	99.9	22.0	99.9	99.9	99.9	99.9	99.9	99.9	6.5
263	574	PONTIAC	FIREBIRD	83	3330	DR	C	10.0	14.7	5.0	9.7	19.0	12.7	5.8	7.2	5.6
264	574	PONTIAC	FIREBIRD	83	3330	RF	C	10.0	14.5	5.0	9.5	19.2	99.9	5.5	7.2	5.7
265	667	PONTIAC	FIREBIRD	84	3000	DR	C	11.5	16.6	3.7	8.0	18.5	13.7	2.8	5.2	6.0
266	667	PONTIAC	FIREBIRD	84	3000	RF	C	11.0	18.5	3.7	8.0	26.7	99.9	3.9	5.7	10.2
267	625	PONTIAC	PARISIENNE	84	4140	DR	C	15.2	22.5	6.8	10.6	22.0	15.2	1.5	5.5	8.5
268	625	PONTIAC	PARISIENNE	84	4140	RF	C	13.5	22.0	6.7	10.7	21.2	99.9	2.0	5.7	9.7
269	632	RENAULT	ENCORE	84	2600	DR	C	13.0	18.5	5.5	8.2	20.5	15.2	3.5	6.0	8.0
270	632	RENAULT	ENCORE	84	2600	RF	C	13.2	18.3	5.5	8.2	23.2	99.9	4.1	6.0	8.1
271	483	RENAULT	FUEGO	82	2902	DR	C	8.7	22.0	6.5	10.8	22.6	18.5	6.0	7.8	4.7
272	483	RENAULT	FUEGO	82	2902	RF	C	6.1	18.0	5.0	9.8	25.6	99.9	6.0	7.0	7.9
273	218	RENAULT	LECAR	80	2196	DR	C	14.6	18.0	6.8	8.2	21.7	15.2	3.0	3.7	1.5
274	218	RENAULT	LECAR	80	2196	RF	C	15.3	19.0	6.5	8.3	21.0	99.9	3.3	4.5	3.8
275	363	RENAULT	18	81	2750	DR	C	13.5	18.0	6.0	7.3	21.0	16.2	5.0	7.0	10.5
276	363	RENAULT	18	81	2750	RF	C	13.5	18.0	6.0	7.0	26.0	0.0	5.0	7.0	9.0
277	446	SAAB	900	82	3220	DR	C	19.5	23.5	6.5	9.5	21.5	14.5	4.0	7.0	3.6
278	446	SAAB	900	82	3220	RF	C	18.7	23.0	6.3	9.5	18.7	0.0	4.1	7.0	4.0
279	133	SUBARU	GF	80	2594	DR	C	16.8	22.3	99.9	99.9	21.0	13.0	9.9	99.9	4.3
280	133	SUBARU	GF	80	2594	RF	C	14.0	19.3	99.9	99.9	19.8	99.9	9.9	99.9	3.3
281	289	SUBARU	WAGON	80	2947	DR	C	13.2	18.7	5.3	7.8	20.0	12.0	3.0	6.0	3.8
282	289	SUBARU	WAGON	80	2947	RF	C	12.2	17.0	4.0	6.5	18.5	99.9	3.0	7.4	5.5
283	594	TOYOTA	CAMRY	83	2980	DR	C	12.7	18.5	5.2	8.2	21.5	13.8	3.3	6.2	5.1
284	594	TOYOTA	CAMRY	83	2980	RF	C	12.5	18.5	5.2	8.2	23.0	99.9	4.0	6.7	8.0
285	027	TOYOTA	CELICA	79	3025	DR	C	11.0	16.5	6.7	6.2	20.7	15.8	3.2	6.0	5.3
286	027	TOYOTA	CELICA	79	3025	RF	C	11.7	15.9	4.5	7.2	19.0	0.0	4.0	5.7	5.6
287	454	TOYOTA	CELICA	82	3060	DR	C	17.5	23.6	5.5	8.2	21.0	18.1	4.0	5.5	5.6
288	454	TOYOTA	CELICA	82	3060	RF	C	16.3	25.0	5.3	9.2	22.6	99.9	4.3	5.8	6.8
289	099	TOYOTA	COROLLA	79	2651	DR	C	18.5	23.4	7.1	9.0	22.8	15.3	2.8	5.8	7.2
290	099	TOYOTA	COROLLA	79	2651	RF	C	17.9	21.9	6.4	7.8	21.9	0.0	3.0	6.0	6.5
291	563	TOYOTA	COROLLA	83	2760	DR	C	13.7	17.5	5.5	7.2	21.0	14.5	3.5	6.1	3.9
292	563	TOYOTA	COROLLA	83	2760	RF	C	13.5	17.5	5.4	7.2	21.0	99.9	3.6	6.2	5.0
293	682	TOYOTA	COROLLA	84	2680	DR	C	7.5	16.4	4.5	7.2	21.0	15.2	3.5	6.0	8.0
294	682	TOYOTA	COROLLA	84	2680	RF	C	7.5	16.2	4.1	7.3	22.7	99.9	4.1	6.0	9.2
295	685	TOYOTA	COROLLA	84	2610	DR	C	11.2	17.5	5.5	8.0	19.7	18.6	4.0	6.4	5.0
296	685	TOYOTA	COROLLA	84	2610	RF	C	11.7	17.5	5.3	7.8	22.2	99.9	4.2	6.3	6.7
297	496	TOYOTA	CORONA	82	3040	DR	C	12.5	17.0	5.0	7.5	20.0	12.0	3.0	6.0	5.7
298	496	TOYOTA	CORONA	82	3040	RF	C	12.2	16.7	5.0	7.5	20.7	99.9	3.0	5.7	6.5
299	334	TOYOTA	CRESSIDA	81	3417	DR	C	14.5	18.0	5.0	7.7	22.0	14.0	4.0	6.0	2.5
300	334	TOYOTA	CRESSIDA	81	3417	RF	C	15.5	20.0	5.0	7.5	21.8	99.9	3.0	6.3	3.5
301	333	TOYOTA	STARLET	81	2214	DR	C	18.2	22.2	6.9	8.5	24.5	15.7	3.0	5.5	6.0
302	333	TOYOTA	STARLET	81	2214	RF	C	17.0	20.0	5.3	7.5	22.0	99.9	2.5	4.8	4.3
303	122	TOYOTA	TERCEL	80	2314	DR	C	2.3	4.4	10.0	9.9	0.0	1.6	9.9	99.9	4.7
304	122	TOYOTA	TERCEL	80	2314	RF	C	13.8	17.5	99.9	99.9	20.8	99.9	99.9	99.9	6.0
305	590	TOYOTA	TERCEL	83	2426	DR	C	11.6	17.5	4.9	7.1	18.9	12.5	3.1	5.1	6.2
306	590	TOYOTA	TERCEL	83	2426	RF	C	9.4	14.2	6.1	8.5	19.2	99.9	3.6	5.1	6.6
307	365	VOLKSWAGEN	JETTA	81	2650	DR	C	19.6	26.2	7.0	8.8	23.1	14.9	3.9	6.0	5.7
308	365	VOLKSWAGEN	JETTA	81	2650	RF	C	18.9	25.7	6.7	8.3	22.8	99.9	3.6	5.8	4.3
309	465	VOLKSWAGEN	QUANTUM	82	2954	DR	C	17.2	25.0	8.0	8.0	22.0	17.5	4.5	6.0	5.7
310	465	VOLKSWAGEN	QUANTUM	82	2954	RF	C	17.1	25.0	7.0	8.0	22.7	99.9	4.5	5.7	6.3
311	007	VOLKSWAGEN	RABBIT	79	2600	DR	C	19.0	23.5	7.0	8.5	22.7	15.0	4.5	7.0	3.8
312	007	VOLKSWAGEN	RABBIT	79	2600	RF	C	18.5	23.0	6.5	8.1	24.0	0.0	4.0	5.2	3.5
313	428	VOLKSWAGEN	RABBIT	80	2747	DR	C	19.2	29.4	99.9	99.9	21.0	14.3	99.9	99.9	3.6
314	428	VOLKSWAGEN	RABBIT	80	2767	RF	C	14.0	20.1	99.9	99.9	23.0	99.9	99.9	99.9	6.0
315	484	VOLKSWAGEN	RABBIT	81	9999	DR	U	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
316	484	VOLKSWAGEN	RABBIT	81	9999	RF	U	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
317	445	VOLKSWAGEN	SCIROCCO	82	2680	DR	C	14.0	19.5	5.0	8.5	22.0	15.7	4.0	4.5	7.6
318	445	VOLKSWAGEN	SCIROCCO	82	2680	RF	C	13.0	19.2	4.5	9.2	23.5	0.0	4.0	4.5	8.0
319	418	VOLVO	DL	82	3354	DR	C	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
320	418	VOLVO	DL	82	3354	RF	C	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9
321	467	VOLVO	DL	82	3417	DR	C	19.0	23.3	7.3	9.3	20.6	14.0	4.3	6.8	6.6
322	467	VOLVO	DL	82	3417	RF	C	16.8	20.8	7.3	9.4	21.3	99.9	4.3	7.6	6.5
323	573	VOLVO	GLE	83	3560	DR	C	14.2	21.2	6.0	8.0	21.5	12.2	3.7	5.2	5.0
324	573	VOLVO	GLE	83	3560	RF	C	14.5	21.2	6.0	8.0	23.5	99.9	4.4	5.2	4.2
325	030	VOLVO	244	79	3374	DR	C	17.9	22.8	7.5	9.6	22.3	15.1	4.3	7.5	5.3
326	030	VOLVO	244	79	3374	RF	C	18.5	23.1	6.8	8.8	23.5	0.0	4.1	7.3	5.0
327	183	OLDSM	98	79	4709	DR	C	99.9	19.6	99.9	99.9	99.9	99.9	99.9	99.9	5.6
328	183	OLDSM	98	79	4709	RF	C	99.9	19.5	99.9	99.9	99.9	99.9	99.9	99.9	6.5

Toyota Tercel (Crash Test Identification Number 122) had six questionable dimensions. All such dimensions were physically measured by staff, using volunteer subjects of approximate 50th and 95th percentile male sizes, in vehicles of the same or equivalent makes and models as those in question. Measurements were made from the mid-track and rearward-most seating positions. The physical measurements left no doubt that the questionable values were in error. These erroneous measurements were then converted to missing values. This left about 150 data points for each clearance dimension.

The distribution of data was then plotted by weight categories. This would allow, for example, examination of parameters like the median, maximum and minimum values for each clearance dimension by weight of vehicle. The quartiles of the vehicle weight distributions were examined to produce groups containing roughly equal numbers of observations. The resulting weight categories were:

< 2701 lb (1226 kg)
2701-3050 lb (1226-1385 kg)
3051-3680 lb (1385-1671 kg)
> 3680 lb (1670 kg)

Figure 10 is a plot of the head to windshield (HW) dimension by the vehicle weight categories for the right front passenger and is typical of the remaining figures. For each weight category, the distribution of the HW dimension is reflected by the following points:

- MAX -- maximum value of HW
- 75 PCT -- 75th percentile value of HW
- MEDIAN -- median, or 50th percentile value of HW
- 25 PCT -- 25th percentile value of HW
- MIN -- minimum value of HW

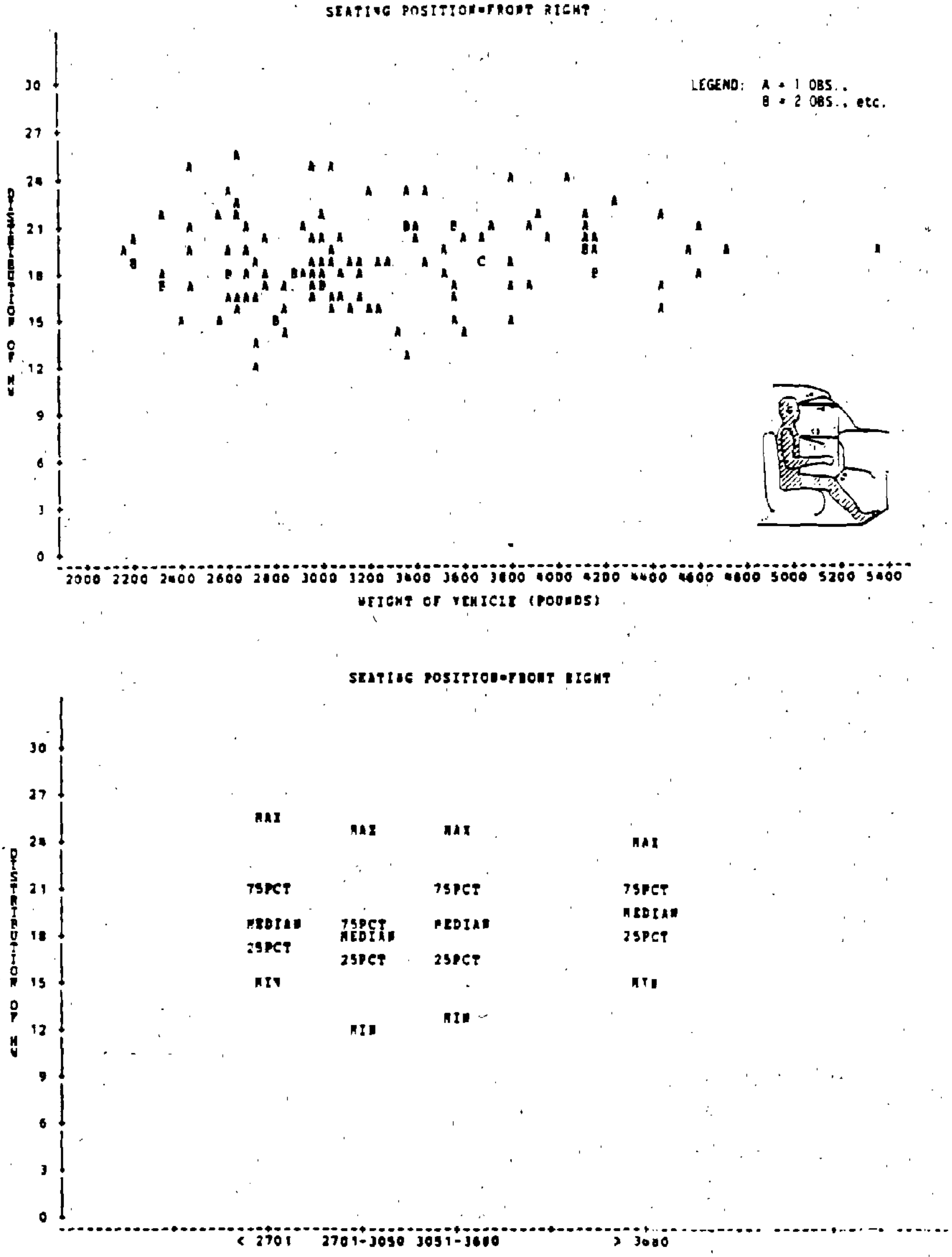
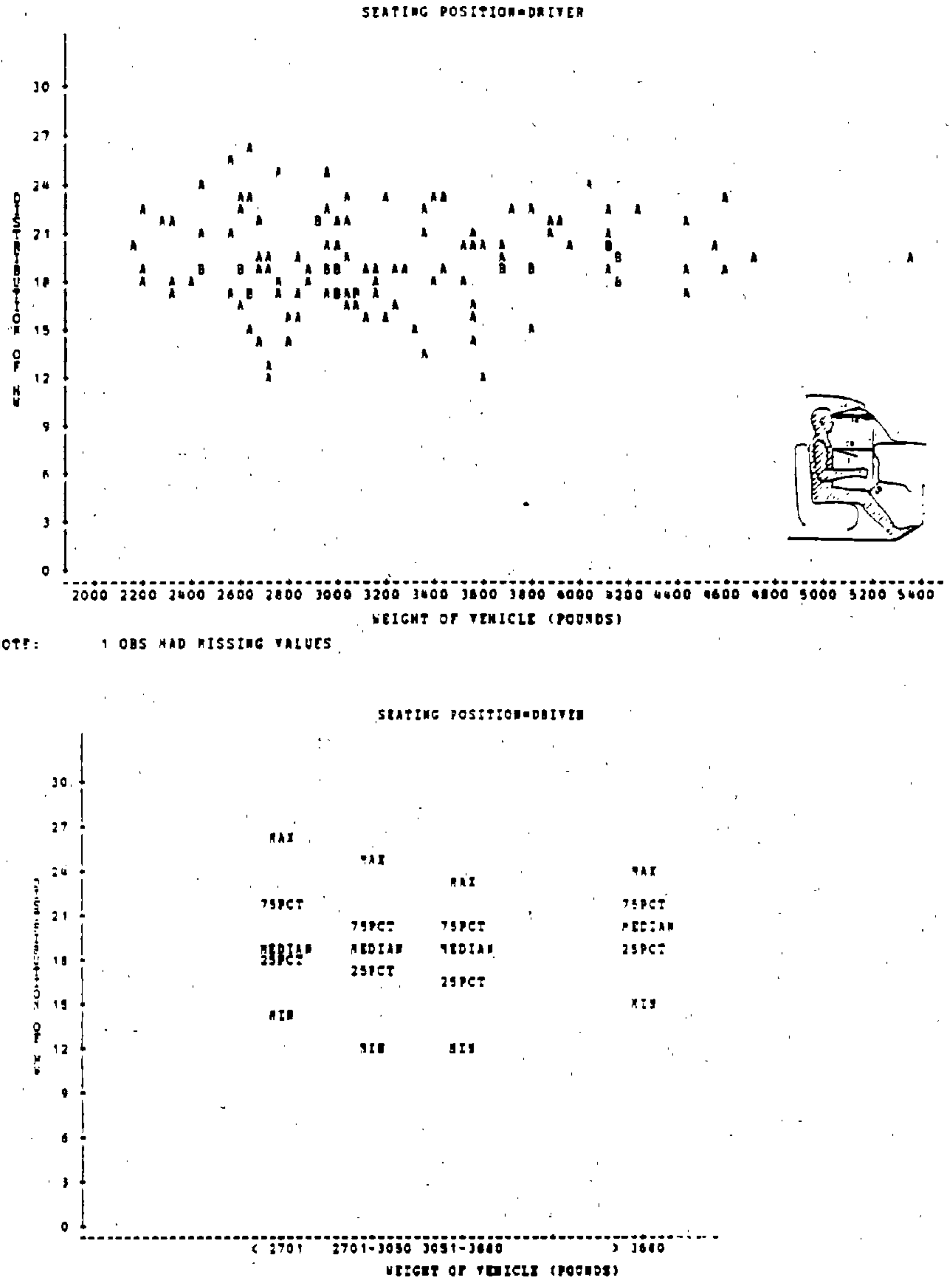
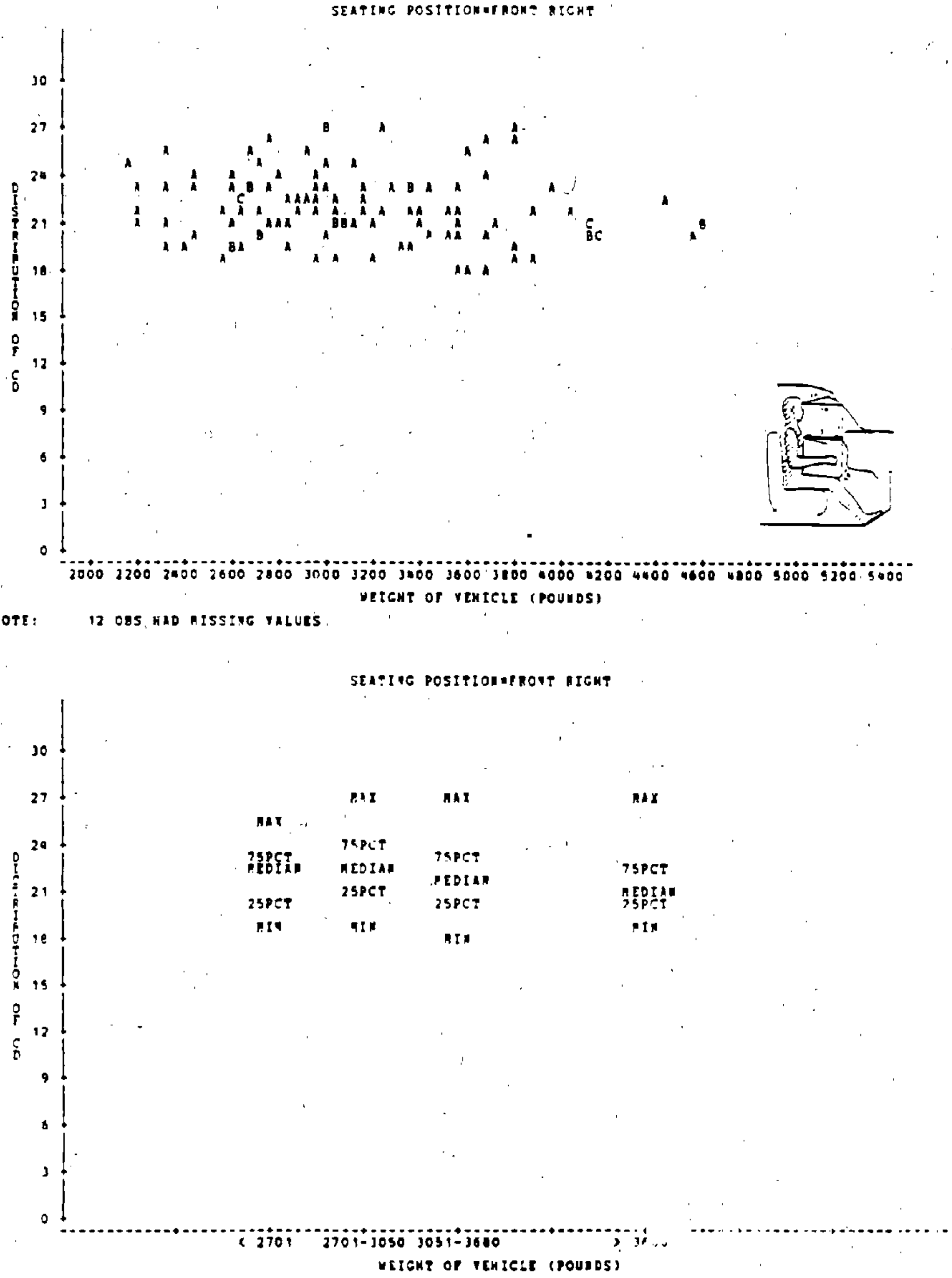


Figure 10. Head to windshield (HW) for right front passenger.



NOTE: 1 OBS HAD MISSING VALUES

Figure 11. Head to windshield (HW) dimension for the driver by weight.



NOTE: 12 OBS HAD MISSING VALUES

Figure 12. Chest to dash (CD) for right front passenger.

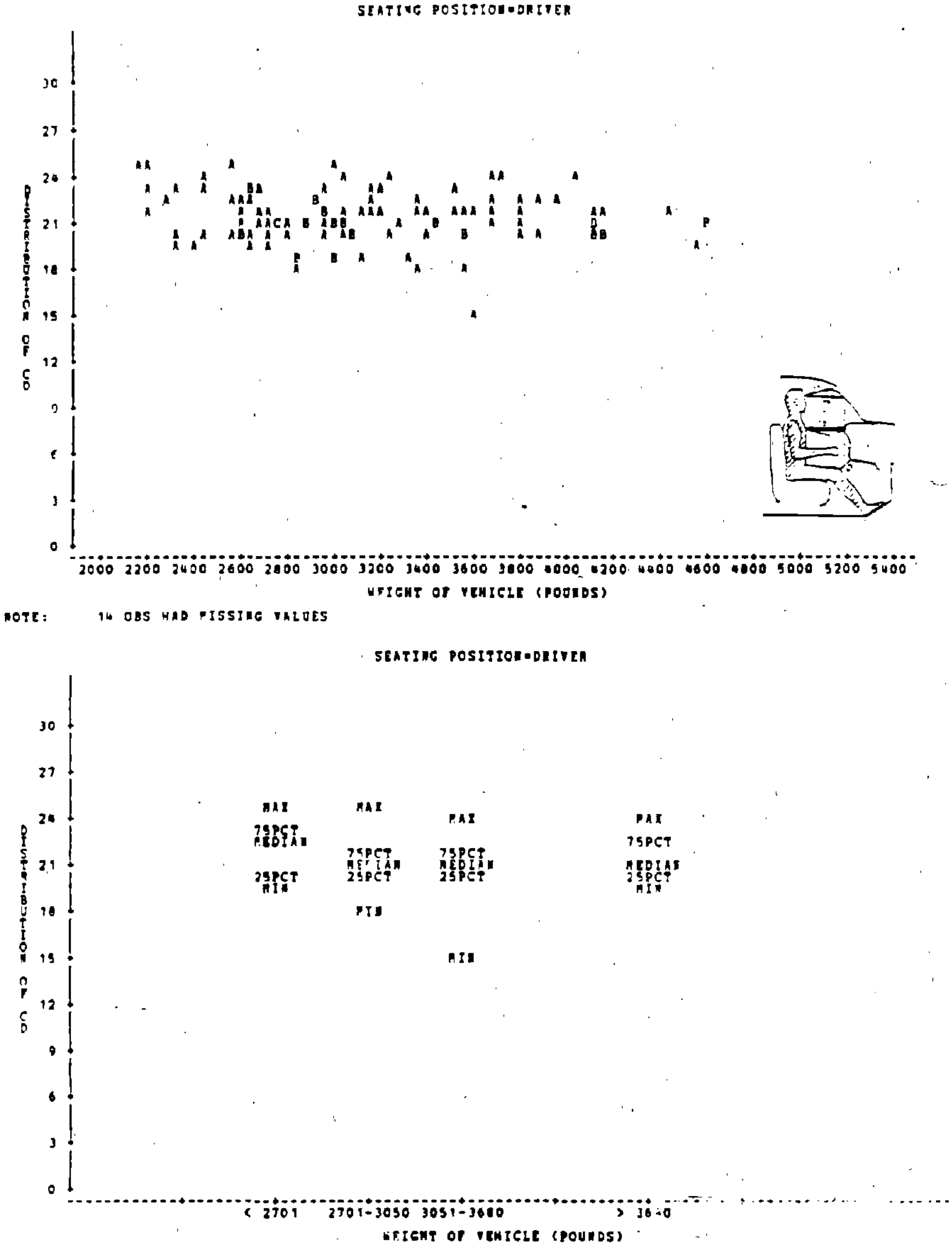


Figure 13. Chest to dash (CD) for driver.

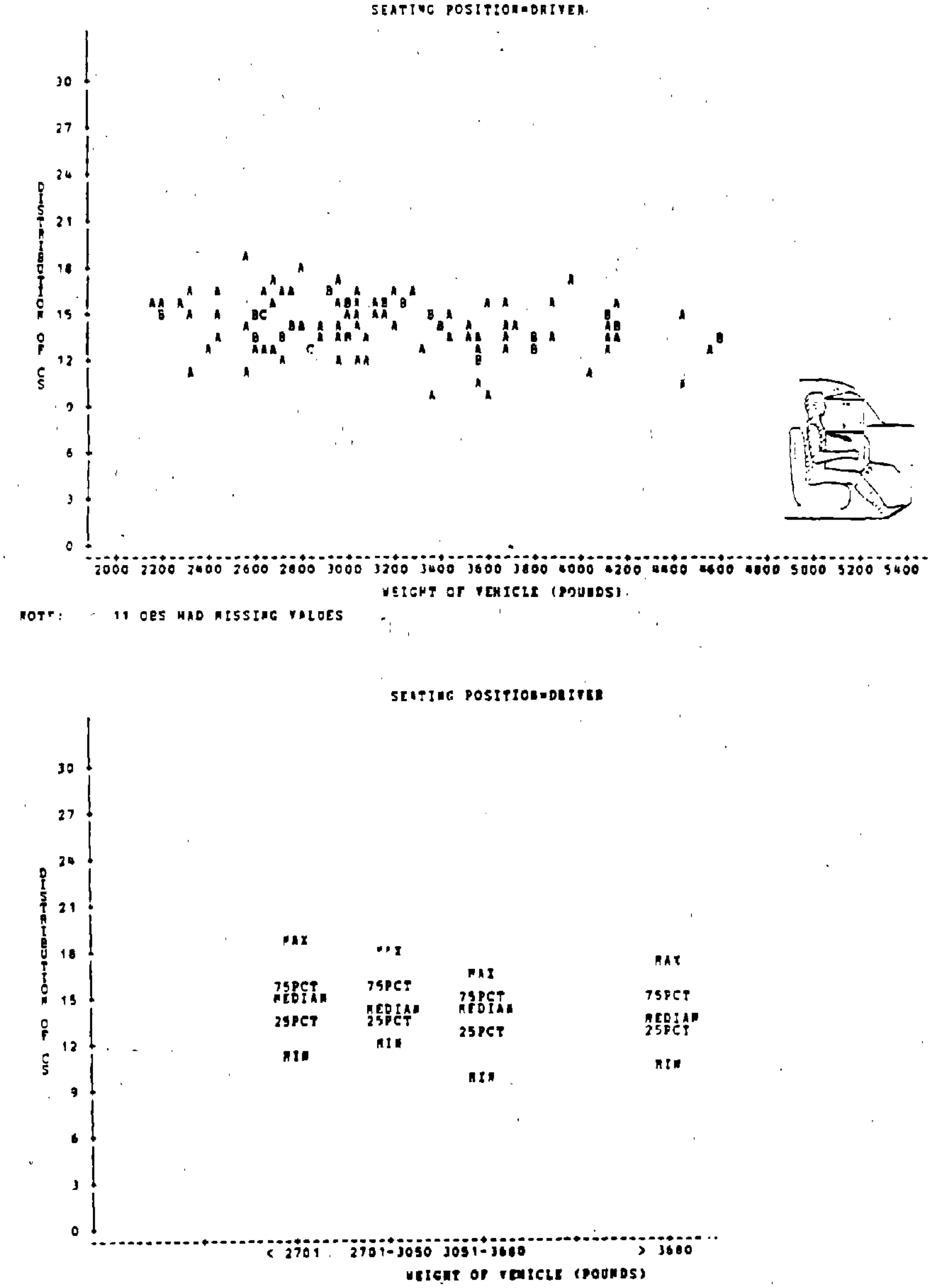
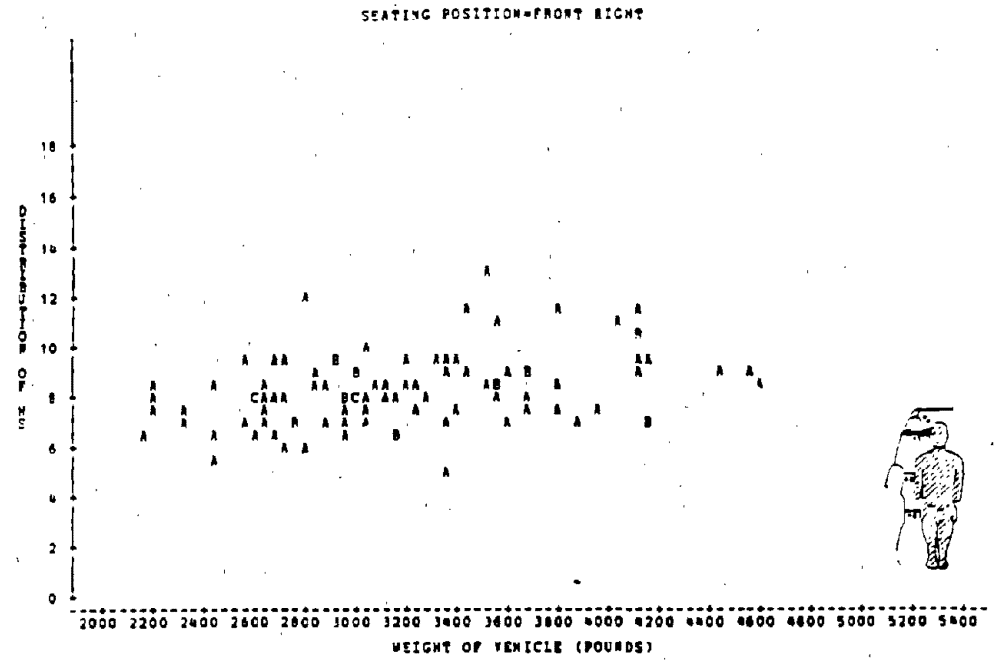


Figure 14. Chest to steering wheel (CS) for driver.



NOTE: 27 OBS HAD MISSING VALUES

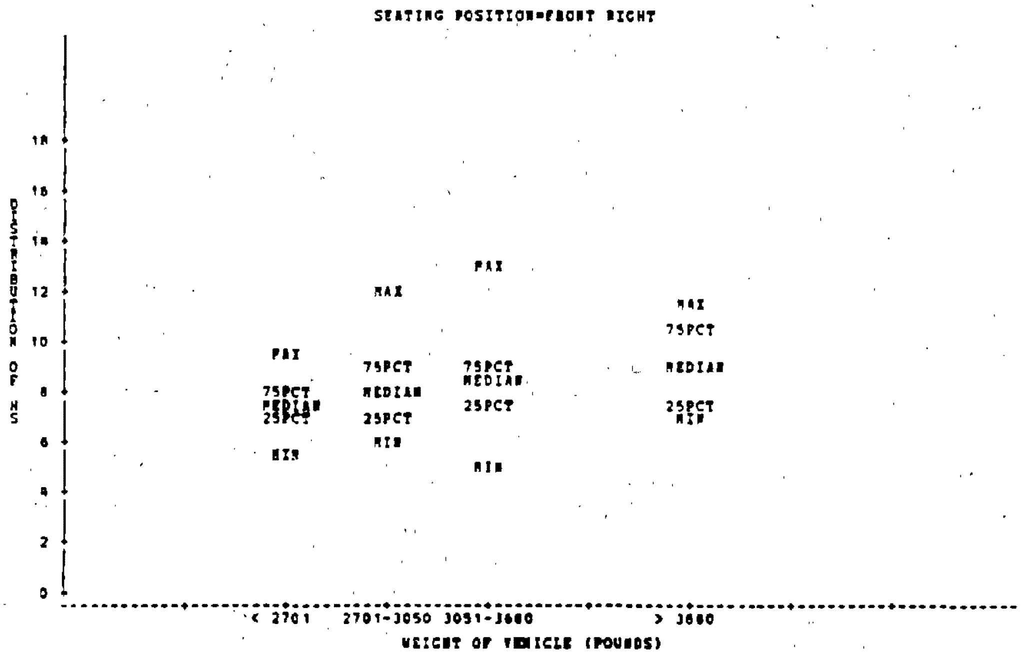


Figure 15. Head to side window (HS) for right front passenger.

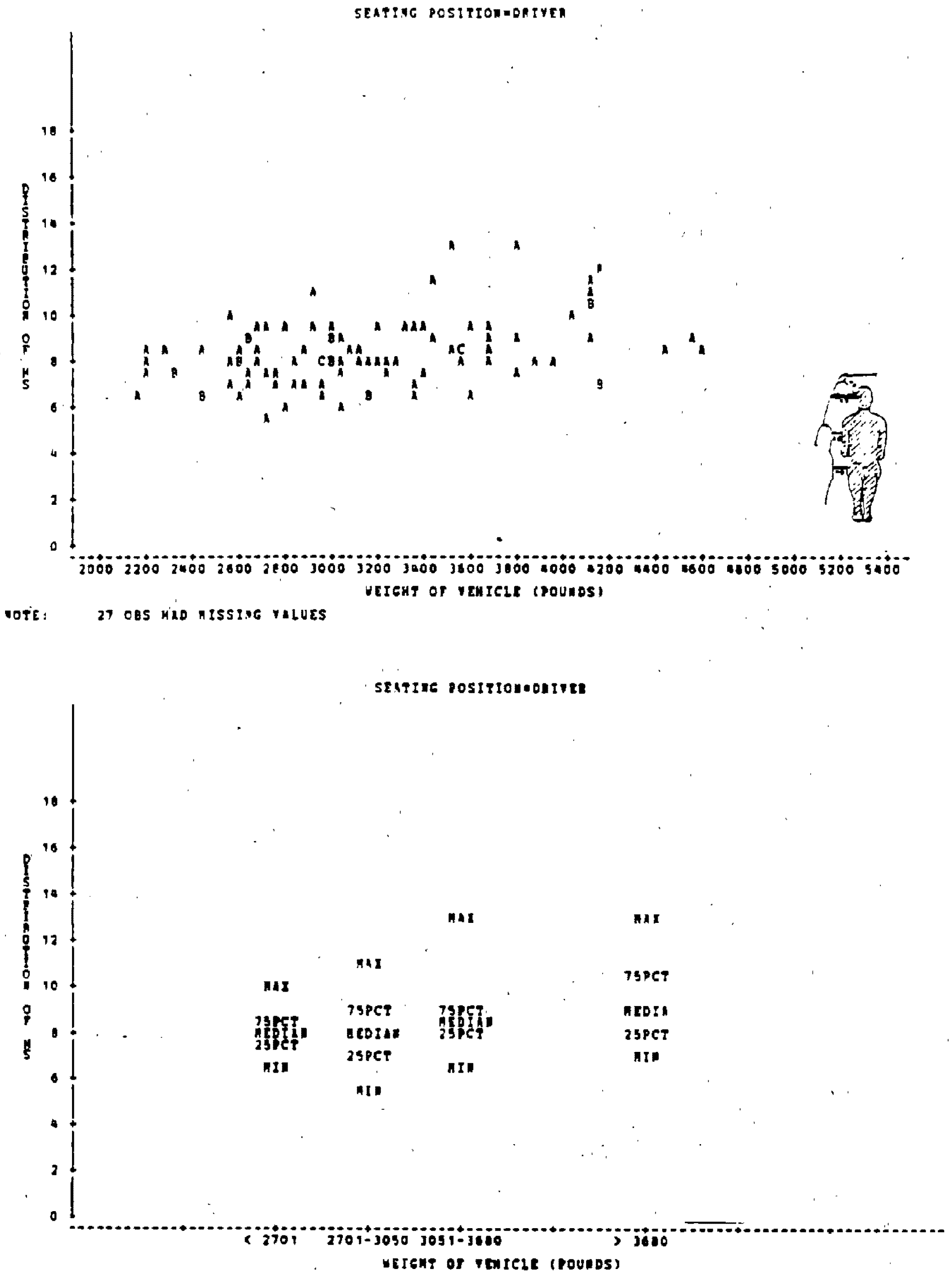
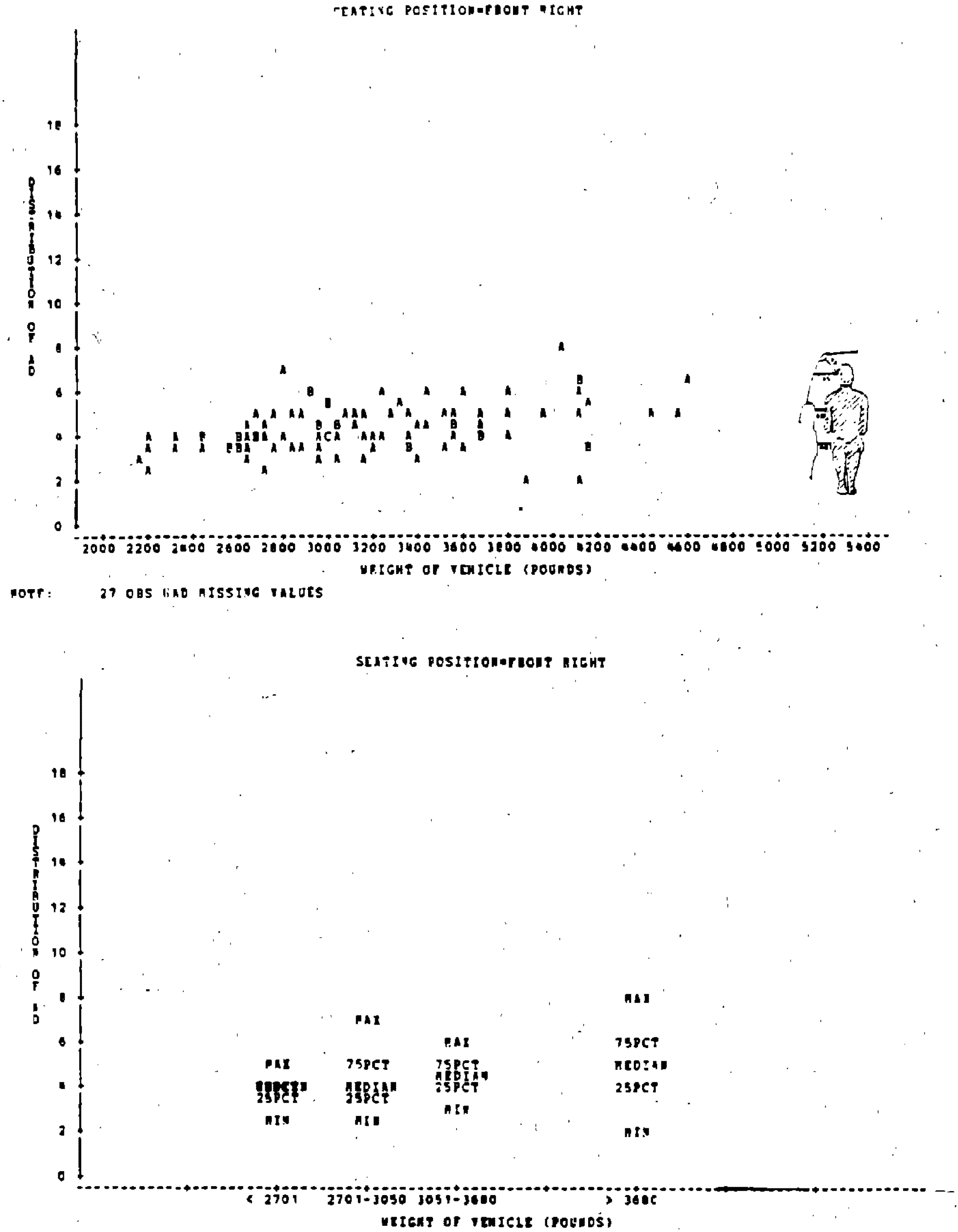


Figure 16. Head to side window (HS) for driver.



NOTE: 27 OBS HAD MISSING VALUES

Figure 17. Arm to door (AD) for right front passenger.

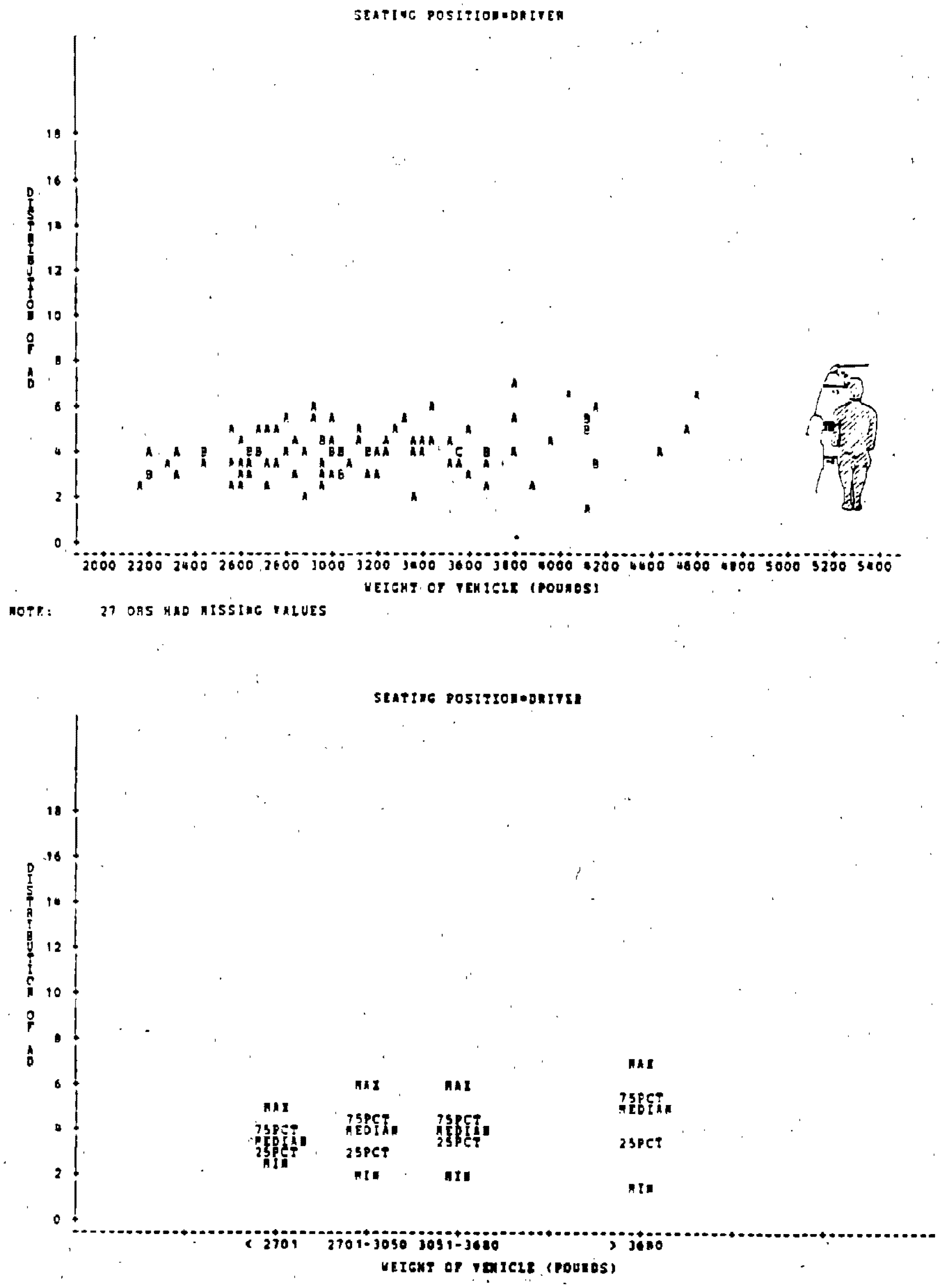
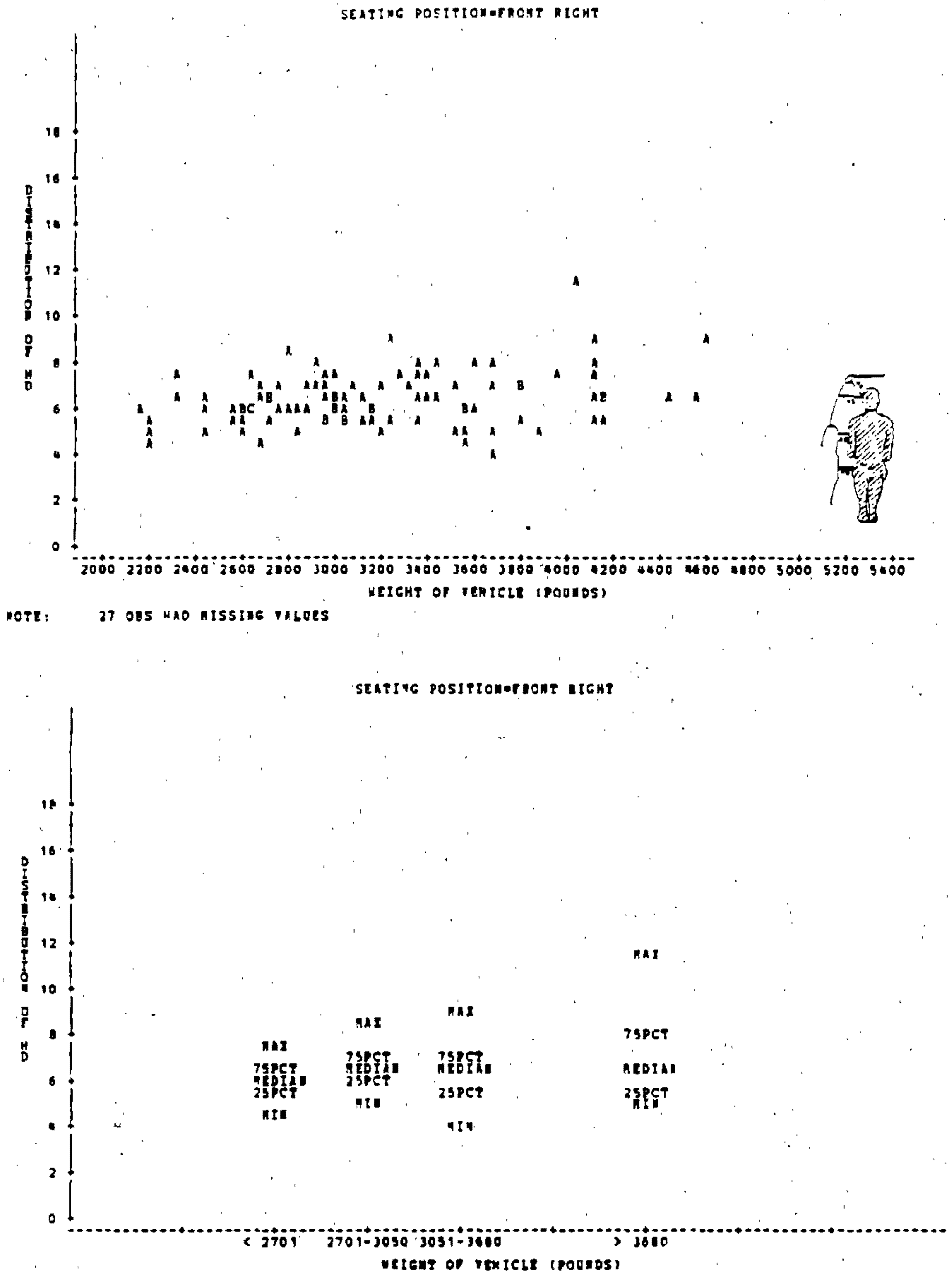
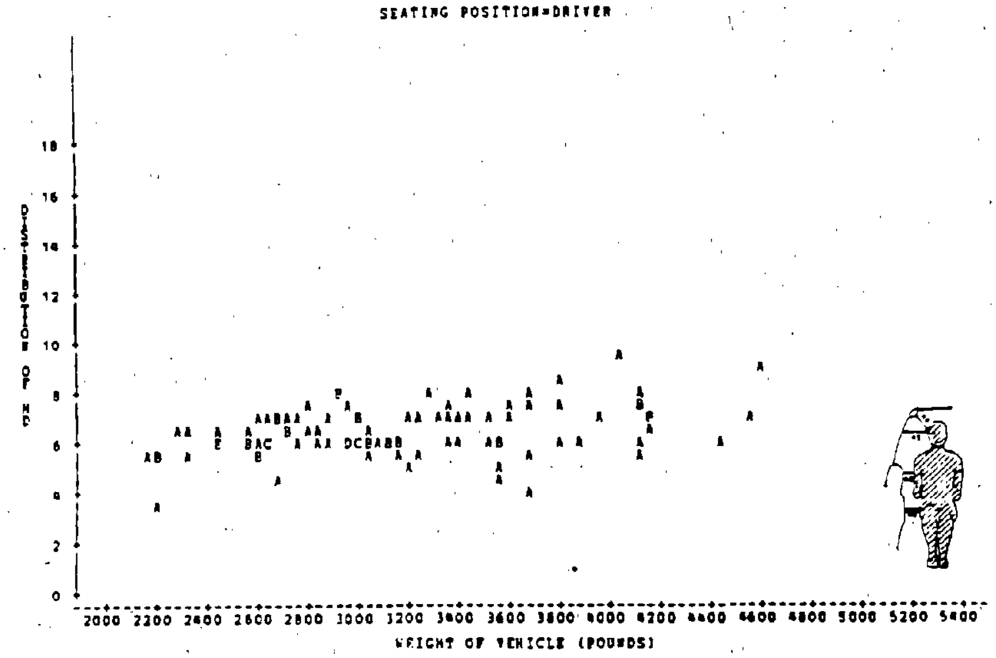


Figure 18. Arm to door (AD) for driver.



NOTE: 27 OBS HAD MISSING VALUES

Figure 19. Hip to door (HD) for right front passenger.



NOTE: 27 OBS HAD MISSING VALUES

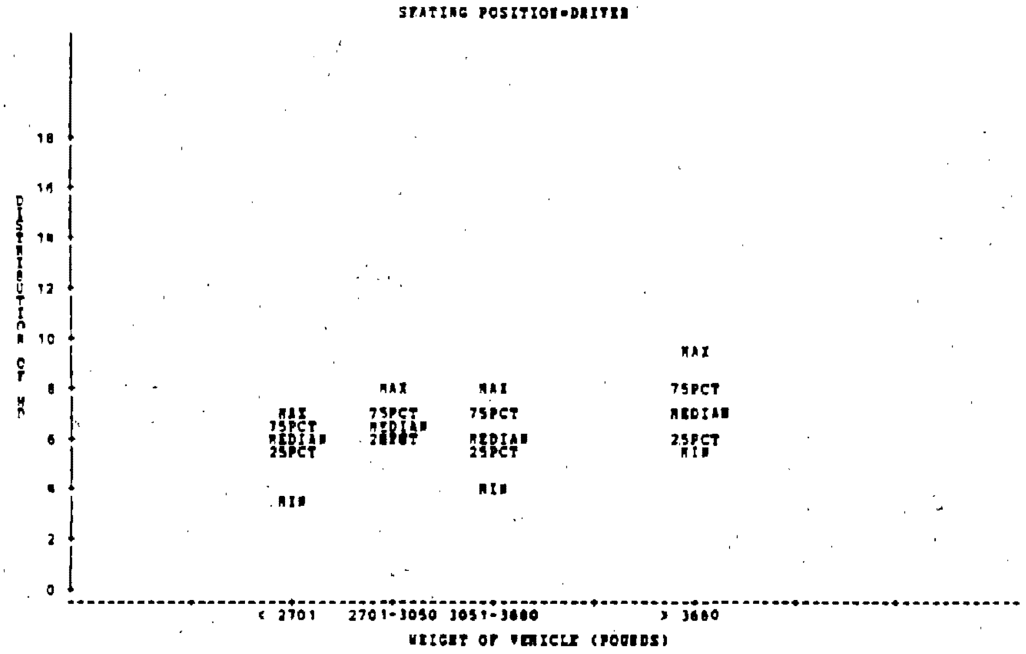
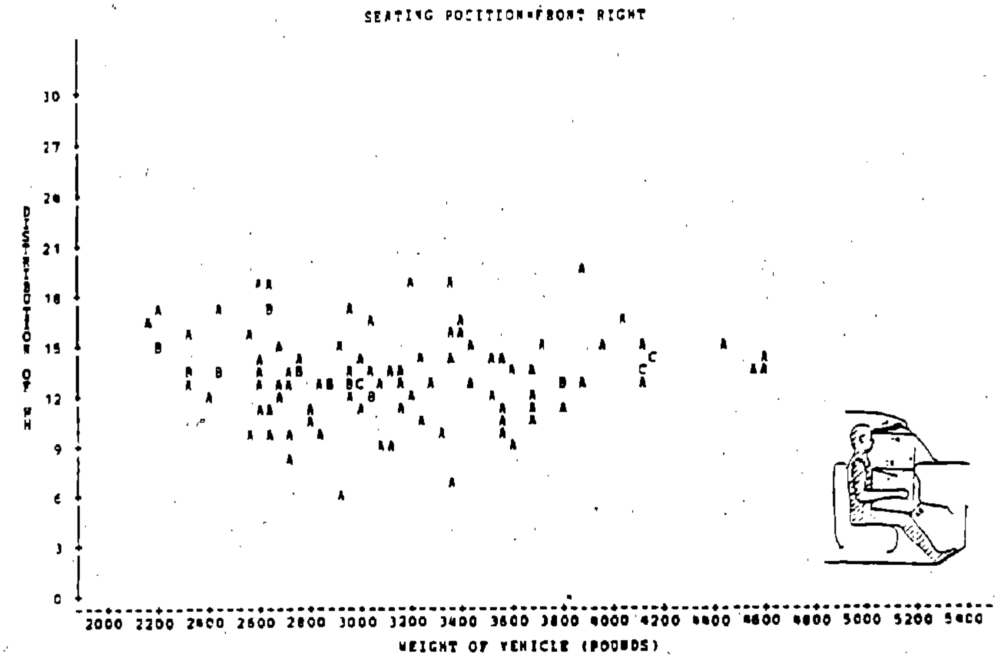


Figure 20. Hip to door (HD) for driver.



NOTE: 16 OBS HAD MISSING VALUES

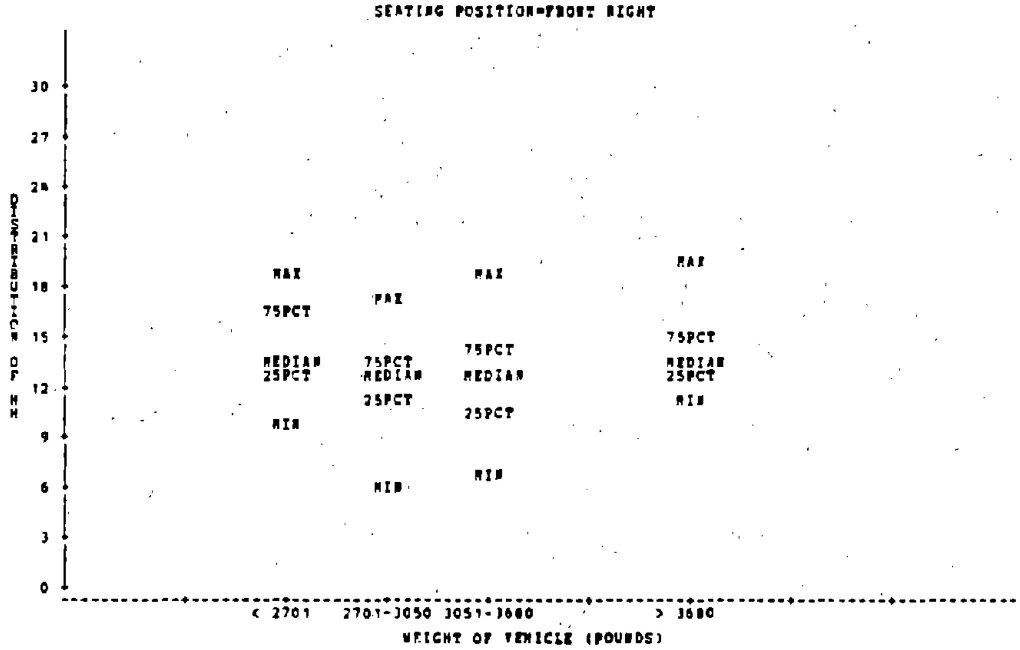
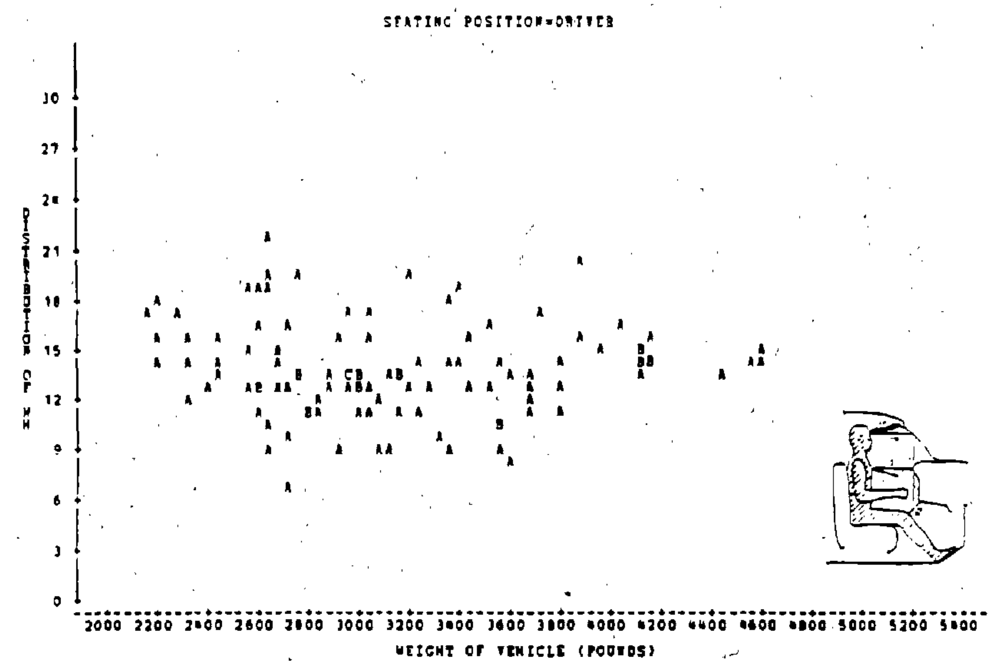


Figure 21. Head to windshield header (HH) for right front passenger.



NOTE: 17 OBS HAD MISSING VALUES

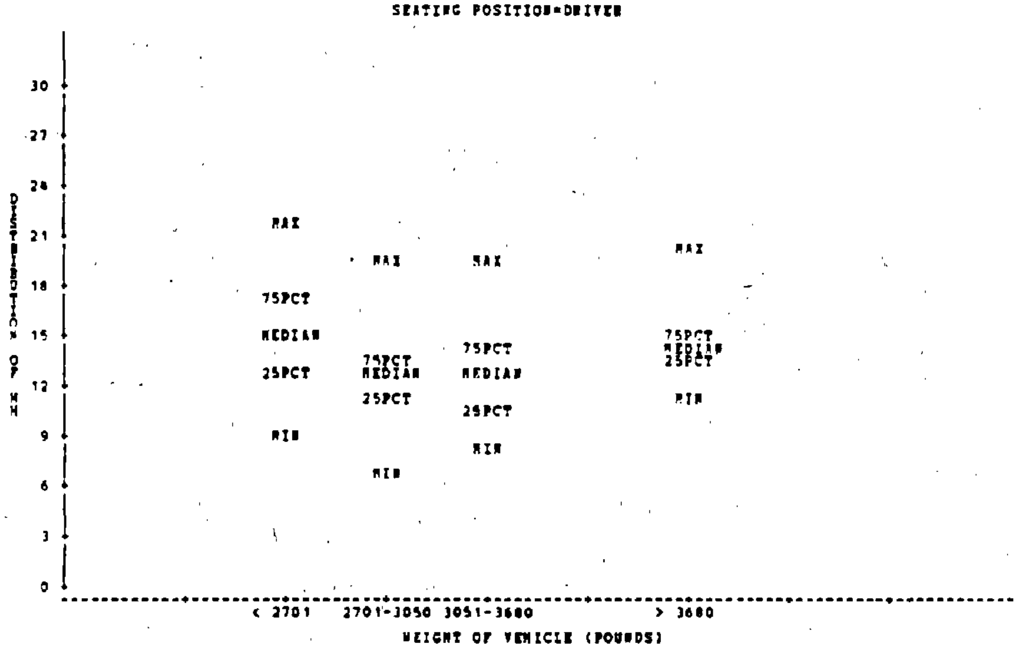
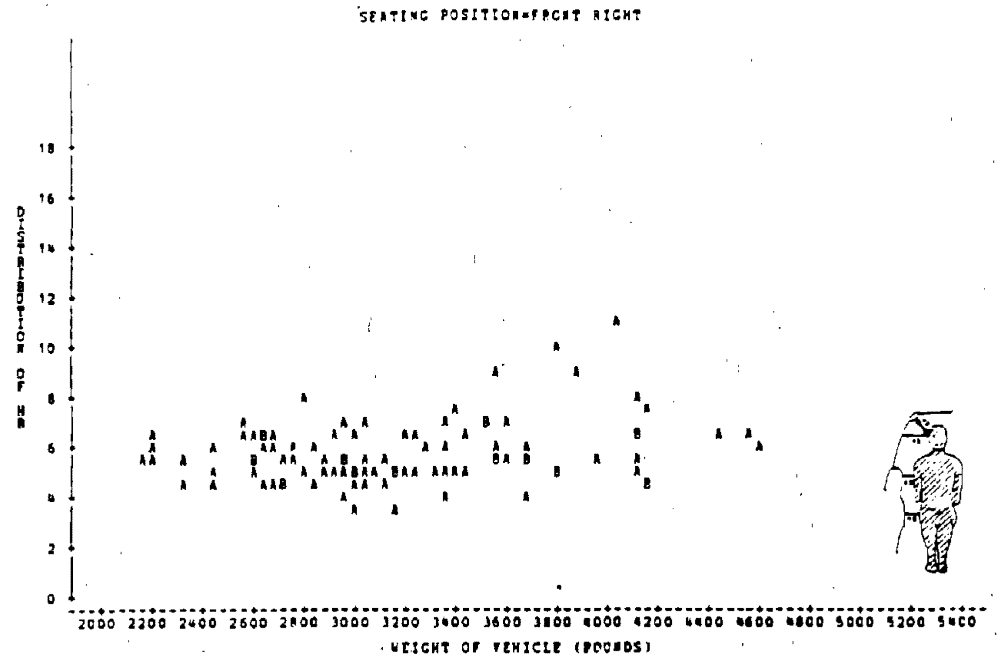


Figure 22. Head to windshield header (HH) for driver.



NOTE: 27 OBS HAD MISSING VALUES

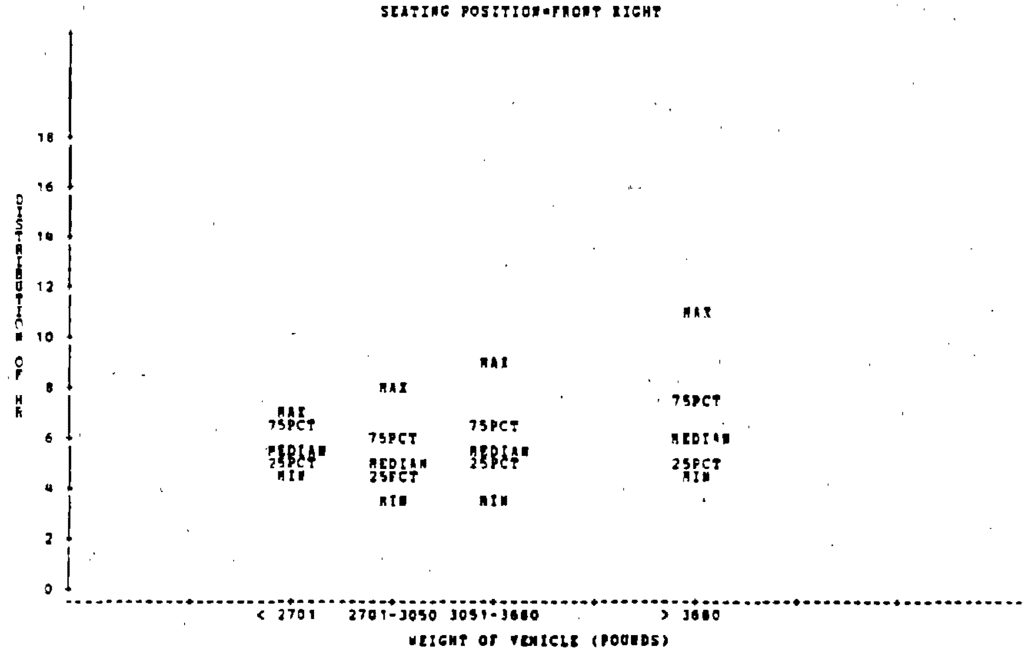


Figure 23. Head to side header (HR), for right front passenger.

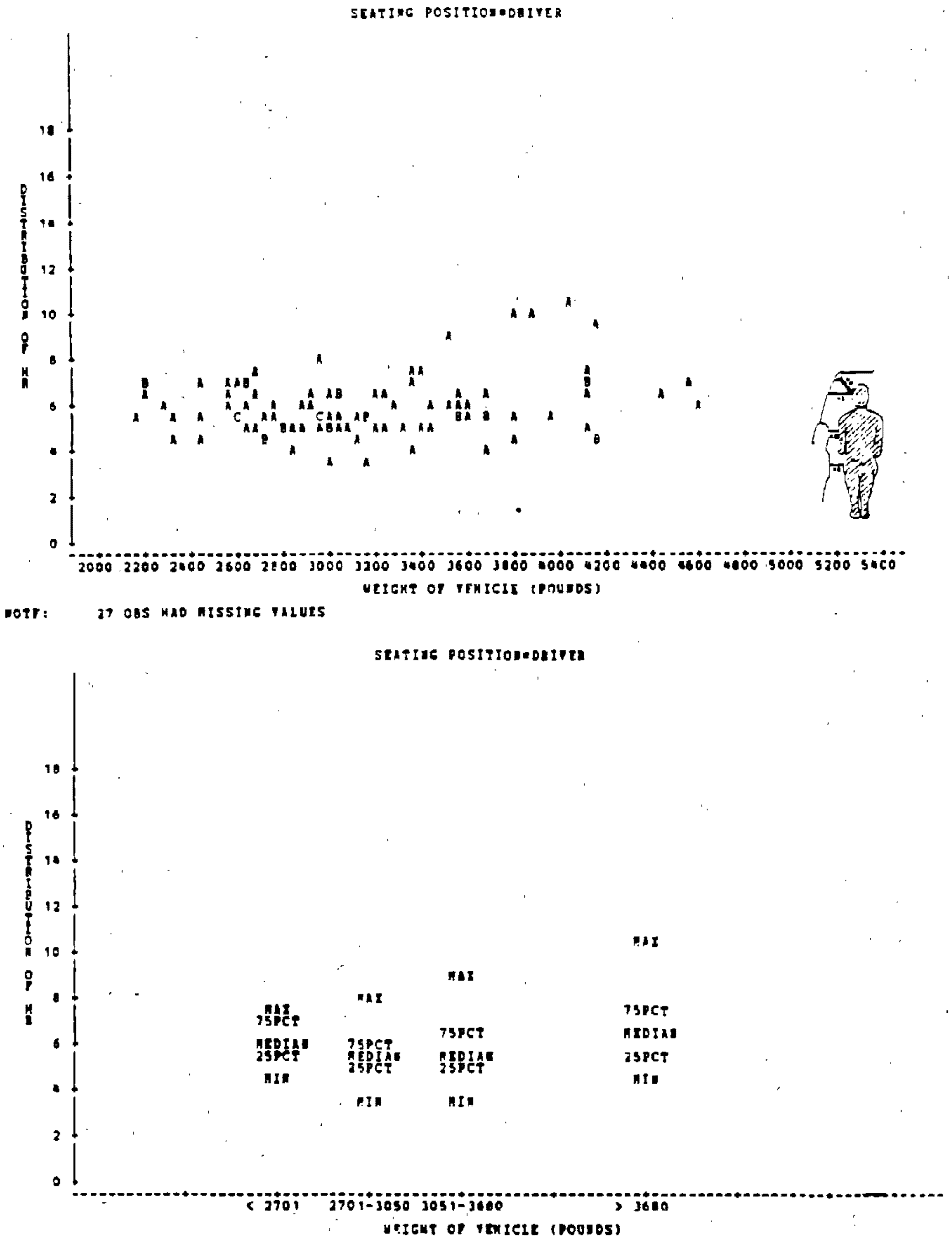
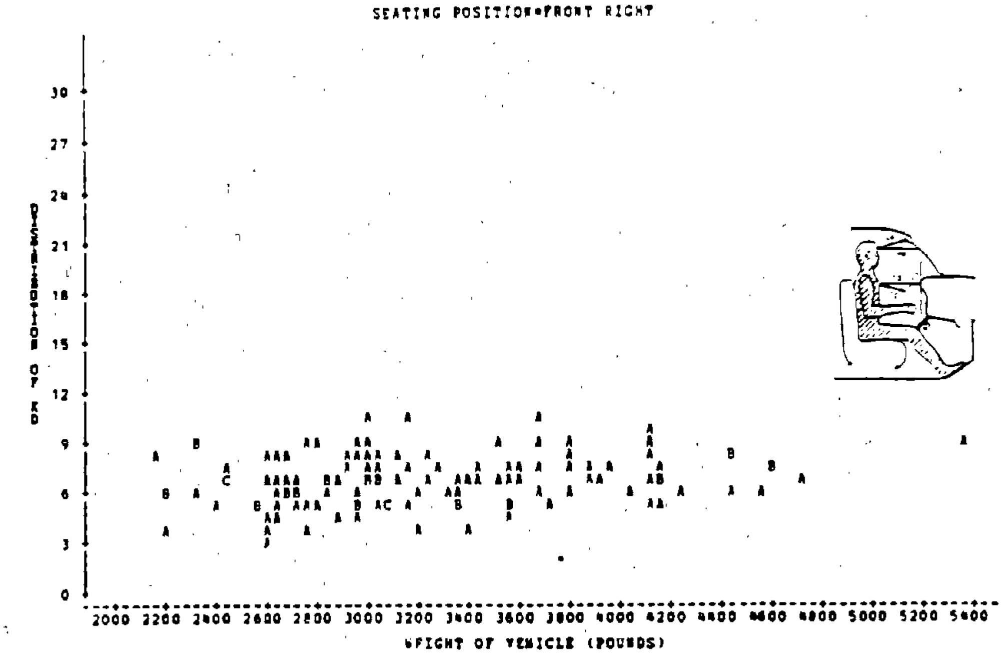


Figure 24. Head to side header (HR) for driver.



NOTE: 1 OBS HAD MISSING VALUES

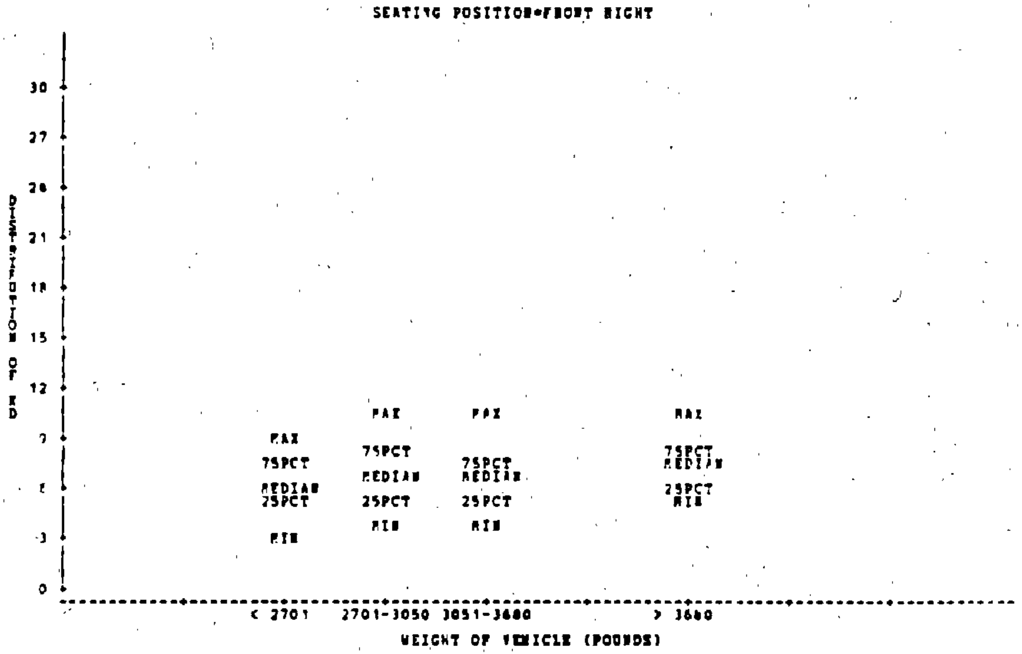
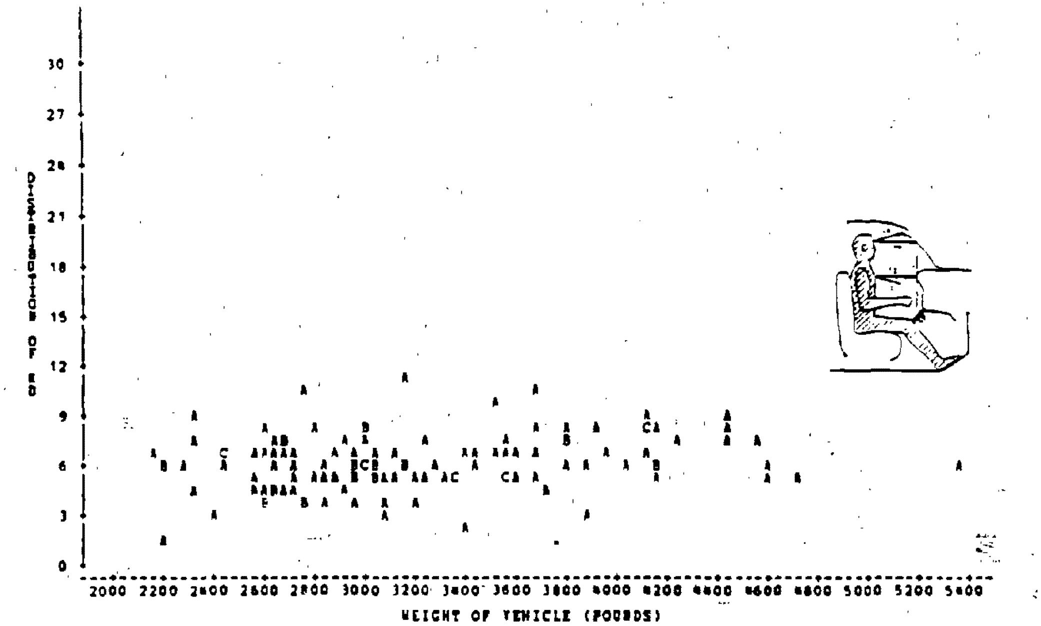


Figure 25. Knees to dash (KD) for right front passenger.

SEATING POSITION=DRIVER



NOTE: 1 OBS HAD MISSING VALUES

SEATING POSITION=DRIVER

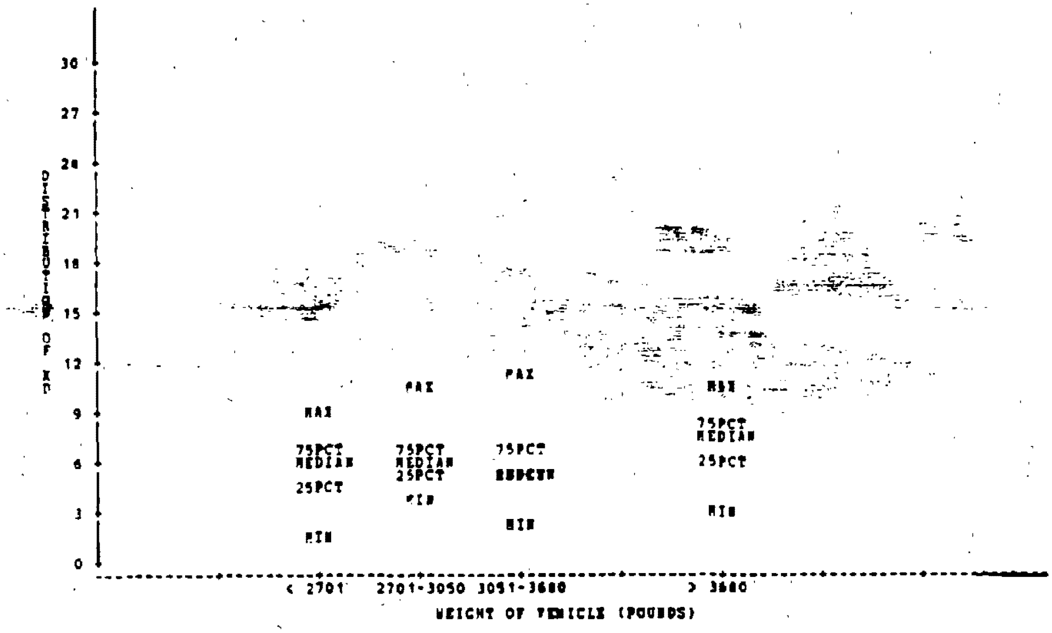


Figure 26. Knees to dash (KD) for driver.

An examination of figure 10 shows only modest variation of HW within the various descriptors noted above. For example, the median values for all weight groups range between approximately 17.5-19.5 inches (44.5-49.5 cm). The largest value of HW is about 26 inches (66.0 cm) and occurs in the < 2701 lb (1226-kg) weight group. The smallest value of HW is about 12 inches (30.5 cm) and occurs in the 2701-3050 lb (1226-1385 kg) weight group.

Figure 11 is the plot of HW for the driver. The plot is quite similar to that for the right front passenger, with modest variation in the descriptors except for the minimum value. The minimum-maximum range is 12-26 inches (30.5-66.0 cm) across all weight categories.

The remaining plots of the clearance dimensions are reasonably similar to the pair discussed above. The entire set of graphs are shown in figures 10 through 26. For convenience, each plot is shown with the corresponding scatterplot. In a few instances, two descriptors (e.g., MEDIAN and 75 PCT) are approximately the same and thus plot on top of one another. Table 9 presents a synopsis of the plots.

What about the representativeness of this NCAP data? Does the data "predict" the real world variation in passenger compartment clearances? Limited examination of the makes and models tested in the NCAP (see table 1059) certainly shows a good distribution by manufacturer. There is a mix of foreign and domestic brands. Vehicle sizes are well distributed from small to large.

Conclusions and Recommendations

The NCAP data base used to develop plots of passenger compartment clearance dimensions appears to offer an objective basis for examining and perhaps modifying the clearance dimensions presently used in the flail space approach. As long as NCAP continues in its present form, these plots can be updated in the future to check for changes. The evidence from within the U.S. auto industry indicates little changes in passenger car compartments in the next decade, and thus the dimensions gleaned from the NCAP data should be useful for representing vehicle interior dimensions for the next decade.

Appendix B. Sled Tests

Introduction

Purpose.

Purpose of this portion of the work effort was to provide validation of the mathematical model of the flail space concept and correlate current recommendations based upon flail space models for occupant risk. This was accomplished by a series of sled impact tests with the Honda Civic buck oriented in both longitudinal and lateral impact directions.

Scope.

Eleven sled tests were performed at impact speeds ranging from 20 to 45 ft/sec (6.1-13.7 m/s). Seven of the tests were head-on impacts with the remaining four impacts occurring on the vehicle right side. Instrumented anthropomorphic dummies were used in all tests and their transducer data were processed to provide the needed occupant risk assessment. A complete description of test procedures and equipment, findings, and conclusions is contained in the following sections.

Experimental Procedures

Test Facility.

Tests were conducted in the SwRI Crash Simulator facility which is centered around a Monterrey Testing Service Model 858.05 rebound sled. Rubber bungee cords were utilized to accelerate the rail-mounted sled and payload, which included the body buck, dummy and instrumentation. An air-pressurized cylinder or programmer at the end of the rails was impacted by the sled/payload combination and provided the desired impact pulse. For this series of tests the impact pulse shape chosen was a square wave typified by a very fast rise time to a constant g level, then followed by a very fast return to zero. As is typical of rebound sleds one-half of the pulse was applied as the sled was decelerated to zero velocity with the remaining half applied as it was accelerated in the reverse direction. Verification of the desired deceleration level was provided by sled-mounted accelerometer signals which were continuously recorded along with data from dummy transducers. Photographs of the sled test and equipment are shown in figure 27.

Body Buck.

The body buck used in these tests was fabricated from a 1977 Honda Civic hatchback. Since the forward portion of the passenger compartment was the only area of interest the Civic body forward of firewall and aft of the "B" pillar was removed with the remaining structure reinforced and adapted to the sled top plate. For the early frontal tests the windshield was replaced with Lexan™ Polycarbonate to reduce shattering and resultant cleanup, but when it was realized that the Lexan™ stiffness was influencing the results, the standard Civic glass windshields were used. The glass in the right door was also replaced with Lexan™ but the material difference did not seem to be a factor in that most dummy impact was concentrated on the door structure at the chest level. Dash panels, seats and right door assemblies damaged during frontal or side impact tests were replaced as necessary with undamaged units.

Dummies.

Either of two dummies was used in the right front passenger seating position for all tests: (1) for frontal impacts a Part 572, 5th percentile female dummy weighing 105 lb (48 kg) or (2) for side impacts a 50th percentile, side-impact, male dummy weighing 165 lb (75 kg). Seat position was full forward for the female dummy and full aft for the side impact male dummy.

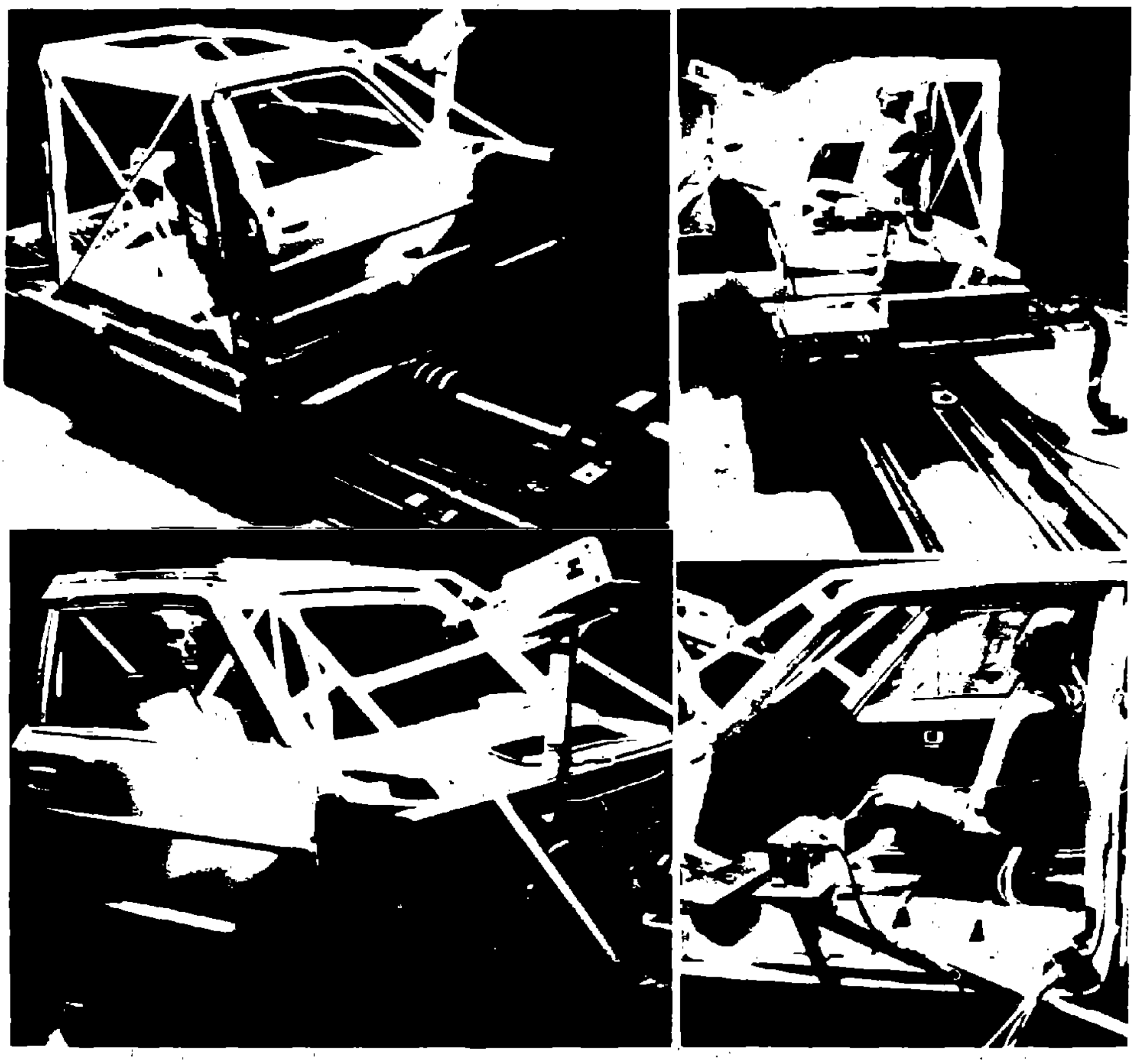
The dummies were fully instrumented for data gathering during each sled test. Transducers were located as follows:

5th Percentile Female Dummy

- Three head accelerometers - one each in the x, y and z directions

(a) Frontal impact setup

Figure 27. Sled test setup.



(b) Side impact setup

Figure 27. Sled test setup (continued).

- Three chest accelerometers - one each in the x, y and z directions
- Two load cells - one in each femur

50th Percentile Side Impact Male Dummy

- Three head accelerometers - one each in the x, y and z directions
- Three upper spine accelerometers - one each in the x, y and z directions
- Three lower spine accelerometers - one each in the x, y and z directions
- One upper rib accelerometer in the y direction
- One lower rib accelerometer in the y direction
- Three pelvis accelerometers - one each in the x, y and z directions

Documentation.

Film coverage included pretest and post-test real-time movies of test details and high-speed (1000 frames/second) movies during each event. The high-speed camera, mounted on-board the sled, was located orthogonal to dummy travel direction so that the entire sequence from sled impact to dummy impact and rebound was documented. In addition, still photographs were taken before and after each event.

Transducer signals were continuously recorded on magnetic tape throughout the impact sequence by high-speed recorder. Signals were played back through appropriate filters to an oscillograph immediately after test for a quick visual output, and later, they were converted from analog to digital data for processing using Institute-developed computer programs. A summary of data recording and processing equipment is contained in table 11.

An impact event marker was included on the magnetic tape in order to synchronize the start of the impact sequence for all data channels.

Findings

Tests which were performed can be categorized into three groups as follows:

- Longitudinal impact using Lexan™ windshield
- Longitudinal impact using glass windshield
- Lateral (side) impact

Table 12, which contains a summary of test results, has these categories grouped together.

Longitudinal Impact Tests Using Lexan™ Windshields

In this group of tests the 5th percentile female dummy's head was initially 21.0 inches (53.3 cm) from the windshield. Although the dummy chest was closer to the dash the upper torso rotated slightly such that the head impacted first in all tests (see sequential photos of figure 28). Data calculated from the four tests indicated that only the higher speed 35 and 40 ft/sec (10.7 and 12.1 m/s) tests had HIC values in excess of 1000 which is considered the critical threshold value. Typical post-test photographs are shown in figure 29.

Dummy chest transducers indicated that peak resultant chest accelerations over 60 g were reached in those tests in which the impact velocity was 30 ft/sec (9.1 m/s) or above. Maximum value obtained was 87.8 g's (test 2529) and duration above 60 g's was 10 milliseconds.

Table 11. Data recording and processing equipment.

Recording:

1. Accelerometers

   Endevco Model 2264-2000
   ±2000 g, 0.24 MV/g
   sensitivity

2. Femur Load Cells

   GSE Inc. Model 2430,
   ±5000 lb

3. Signal Conditioning Unit

   SwRI design

4. Attenuator

   SwRI design

5. Tape Recorder

   Sangamo Electric Co.
   Sabre VII, Model 8246 FM
   Recorder, DC to 20khz
   bandwidth

Processing:

1. Electronic Filters

   SwRI design per SAE J211, Class 180

2. Oscillograph

   Honeywell Model 906C

3. Analog to Digital Converter

   Sangamo Sabre III 3600 Magnetic
   Tape Reducer
   Memodyne 3783 Digital Cassette
   Shugart SA 851R Diskette
   Televideo 920C Console
   GANDALF LDS-120 Model
   SwRI Design Micro-Processor

4. Computer

   CYBER 172

5. Plotter

   Houston Instrument CPS20/3A

6. Printer

   Texas Instruments OMNI 800-810RO
   Terminal

Table 12. Results from sled tests.

SLED TEST NO.	2528	2525	2536	2529	2538	2537	2539
Buck							
Type	Honda Civic	Honda Civic	Honda Civic	Honda Civic	Honda Civic	Honda Civic	Honda Civic
Orientation	0°	0°	0°	0°	0°	0°	0°
Windshield	Lexan	Lexan	Lexan	Lexan	Glass	Glass	Glass
Dummy							
Type	Part 572	Part 572	Part 572	Part 572	Part 572	Part 572	Part 572
Size	5th Female	5th Female	5th Female	5th Female	5th Female	5th Female	5th Female
Seating							
Location	Front Right	Front Right	Front Right	Front Right	Front Right	Front Right	Front Right
Position	Forward	Forward	Forward	Forward	Forward	Forward	Forward
Flail Distance (in.)							
Head to Windshield	21.0	21.0	21.0	21.0	22.5	22.5	22.5
Head to Side Window	--	--	--	--	--	--	--
Chest to Dash	17.0	17.0	17.0	17.0	17.0	17.0	17.0
Body to Door	--	--	--	--	--	--	--
Sled							
Test Condition (Nominal)							
Delta Velocity (fps)	20	30	35	40	25	35	45
Acceleration (g)	-3.6	-8.7	-10.9	-14.2	-5.6	-10.9	-16.8
Test Data							
t_{imp} (time to head impact(s))	0.180	0.100	0.110	0.085	0.140	0.105	0.085
t_{imp} (computed) (s)	0.177	0.110	0.105	0.090	0.158	0.109	0.084
Delta V_{SLED} at t_{imp} (fps)	19.99	28.84	35.10	36.97	21.08	33.23	45.55
A_{SLED} (avg) g's	-3.45	-8.96	-9.91	-13.51	-4.68	9.83	16.64
Dummy							
HIC	176	646	1225	2088	87	468	1345
HIC (time duration - sec)	0.182-0.196	0.111-0.121	0.112-0.121	0.090-0.098	0.149-0.210	0.110-0.140	0.093-0.107
Head Severity Index	--	--	--	--	--	--	--
Chest							
Peak R Accel (g's)	25.2	65.2	69.2	87.8	29.7	55.0	94.4
Time of Accel Above 60 g's	0	0.008	0.010	0.010	0	0.007	0.014
Femur Loads (lbs)							
Right	1840	1461	493	1317	202	587	1113
Left	244	2228	1370	2071	261	1845	3323

Table 12. Results from sled tests (continued).

SLED TEST NO.	2534	2533	2535	2540
Buck				
Type	Honda Civic	Honda Civic	Honda Civic	Honda Civic
Orientation	90°	90°	90°	90°
Windshield	--	--	--	--
Dummy				
Type	Side Impact	Side Impact	Side Impact	Side Impact
Size	Dummy	Dummy	Dummy	Dummy
Seating				
Location	Front Right	Front Right	Front Right	Front Right
Position	Back	Back	Back	Back
Flail Distance (in.)				
Head to Windshield	--	--	--	--
Head to Side Window	6.5	6.5	6.5	6.5
Chest to Dash	--	--	--	--
Body to Door	3.0	3.0	3.0	3.0
Sled				
Test Condition (Nominal)				
Delta Velocity (fps)	20	30	35	40
Acceleration (g)	-3.6	-8.0	-15.0	-18.4
Test Data				
t_{imp} (time to head impact(s))	0.092	0.049	0.048	0.042
t_{imp} (computed) (s)	--	--	--	--
Delta V_{SLED} at t_{imp} (fps)	7.59	13.59	20.43	24.8
A_{SLED} (avg) g's	-2.62	-9.38	-14.10	-18.4
Dummy				
HIC	37	121	193	316
HIC (time duration - sec)	0.092-0.104	0.049-0.055	0.048-0.058	0.042-0.048
Head Severity Index	52	163	221	569.1
Chest				
Peak R Accel (g's)	--	--	--	--
Time of Accel Above 60 g's	--	--	--	0.005
Femur Loads (lbs)				
Right	--	--	--	--
Left	--	--	--	--
Pelvis g's (max)	5.3	31.4	29.8	53.0
Upper Spine g's	12.5	36.4	32.1	65.2
Lower Spine g's	7.4	30.1	27.5	55.0
Ribs X/UP g's	10.7	30.4	47.7	46.7

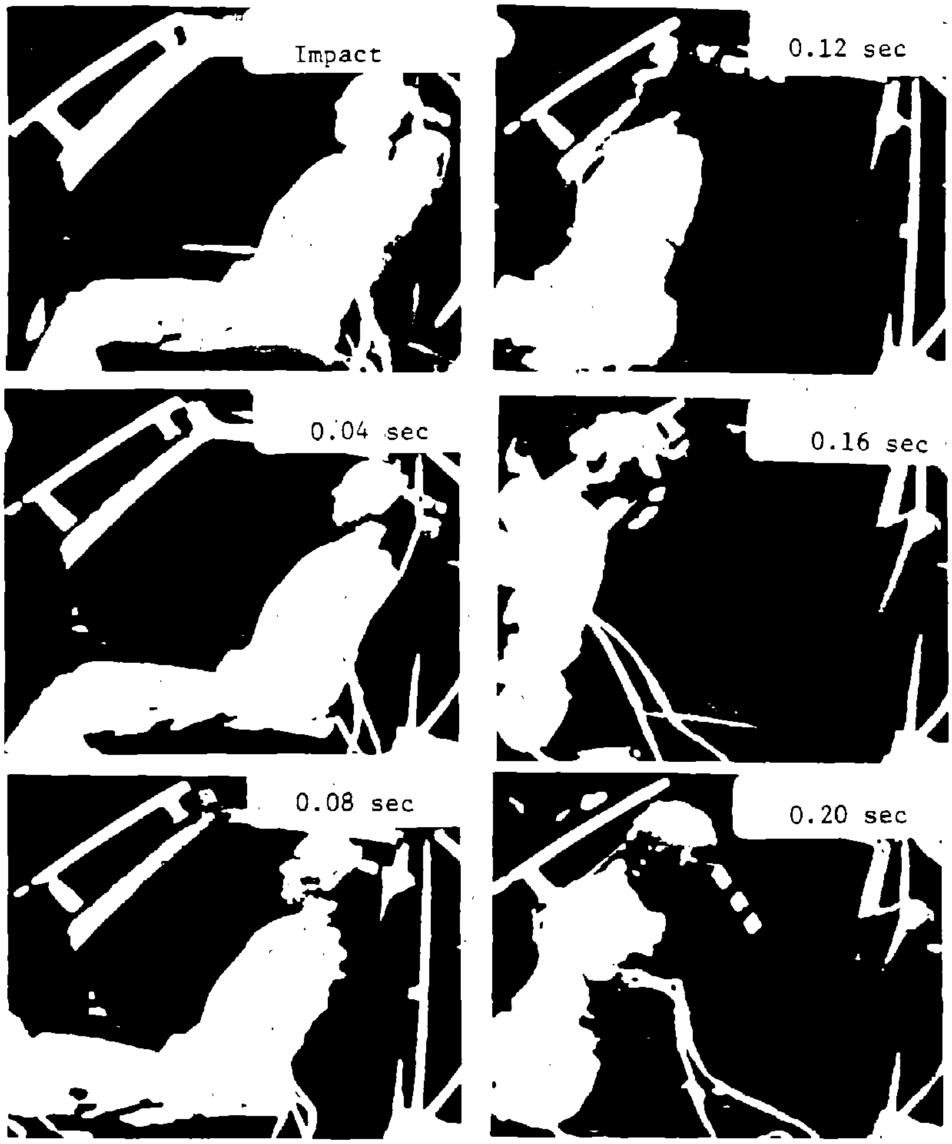


Figure 28. Typical frontal impact using lexan windshield.

Figure 29. Typical results - frontal impact u

At the completion of test 2529 consideration was given to the possible influence on the resulting HIC by the stiffness of the Lexan™ windshield (test 2536) and the other using the standard safety glass windshield (test 2537). Results showed a considerable drop in HIC. Therefore, additional tests were performed using glass windshields.

Longitudinal Impact Tests Using Glass Windshields

Three tests were conducted using the standard Honda glass windshield and rubber channel mounting. Again, these utilized the 5th percentile female dummy, but a slight increase in head to windshield distance, 22.5 inches (57.2 cm), was measured. Again as shown in figure 30, the dummy torso rotated and head impact occurred prior to chest impact. Unlike the previous tests in which no deflection of the windshield (Lexan™) was observed, the glass windshield deformed (see figure 30) on impact and a considerable reduction in HIC value was noted, e.g., an HIC of 468 was obtained in test 2537 (glass windshield) whereas a value of 1225 had been calculated for test 2536 (Lexan™ windshield). Resultant chest accelerations also showed a slight reduction but again the 60-g threshold was exceeded in test 2539 in which a peak of 94.4 g's was measured and the duration above 60 g's was 14 milliseconds. Typical post-test photographs are shown in figure 31.

Lateral Impact Tests

For lateral impacts the sled body buck was rotated 90° such that the dummy impacted the right door. Again, the glass door window was replaced with Lexan™ and was in the up position. In this test series the major portion of the impact energy seemed to be expended by the dummy chest into the door at the sill level and below, and although contact by the dummy head with the window did occur, HIC values were relatively low (maximum 316 in test 2540). Therefore, the material difference was considered insignificant.

In the static position the torso and head of the side impact dummy were only 3 inches (7.6 cm) from the door sill and 6.5 inches (16.5 cm)

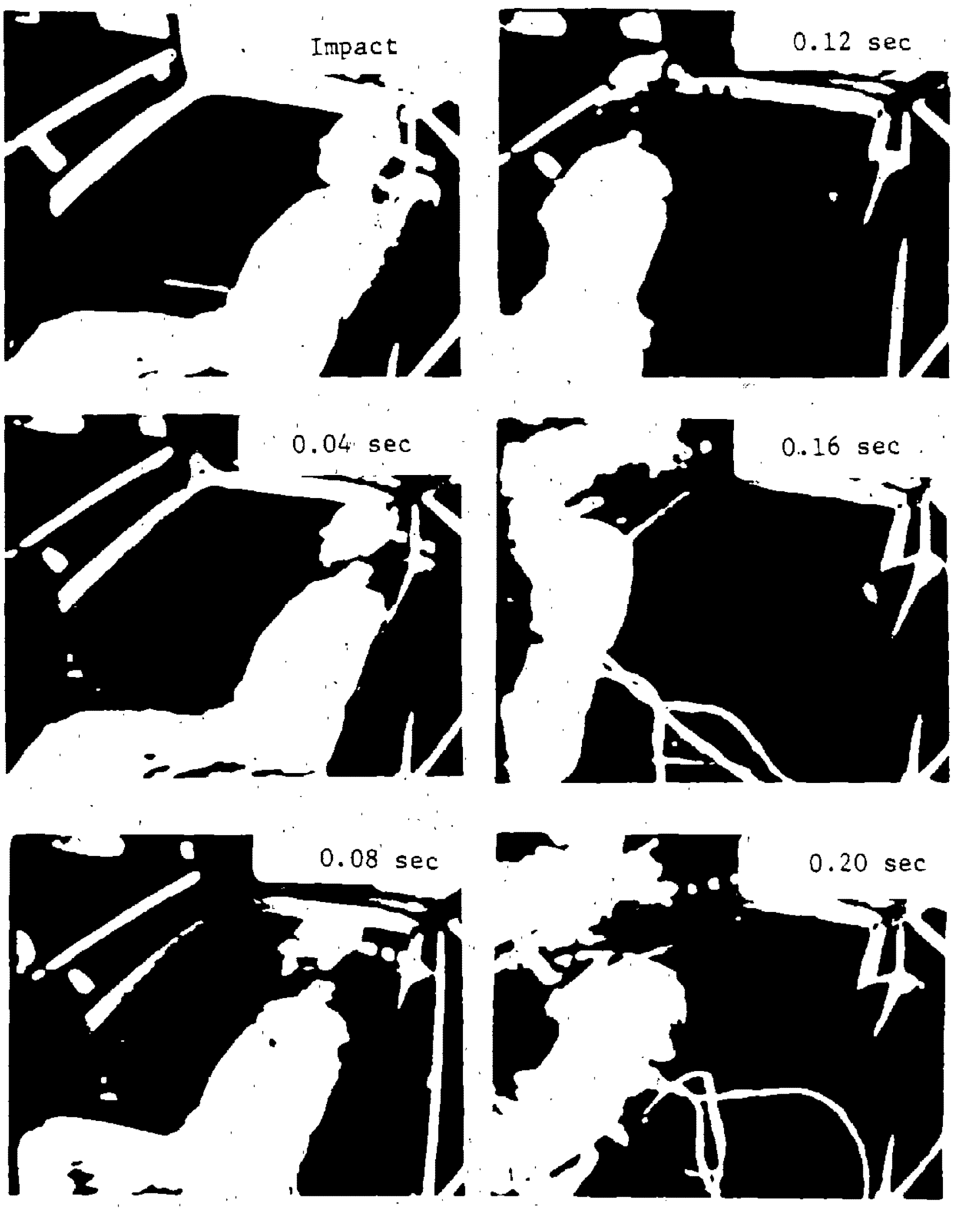


Figure 30. Typical frontal impact using glass windshield.

Figure 31. Typical results - frontal impact using glass windshield.

from the window, respectively, but temporary restraints had to be placed to the left of each to prevent movement as the sled accelerated. These restraints had no effect after impact except they did tend to limit rebound, but this was long after data gathering had occurred. See figure 32.

As was described previously, most of the dummy impact energy was expended at the chest level into the door. However, only at the highest speed test (2540) was the 60-g level exceeded and then only for a 5-millisecond duration. Typical post-test photographs are shown in figure 33.

Conclusions and Discussion

Several conclusions have been drawn from the results of these tests, and will be presented and discussed in the following paragraphs. To provide better clarity frontal and side impacts will be covered separately.

Frontal Impacts

Conclusions are as follow:

- The relationship between occupant risk and HIC is a smooth curve. This is shown in figure 33 which contains plots of both Lexan™ and glass windshields. The influence of the Lexan™ stiffness is shown in that the HIC not only has a higher initial value, but also has a much steeper rise and exceeds 1000 much quicker.

- Occupant risk at 40 ft/sec (12.2 m/s) approximates HIC = 1000. Again, this may be seen in figure 34 in which the glass windshield curve falls just below the intersection of these two points.

Figure 32. Typical side impact.

Figure 33. Typical results - side impact tests.

- The occupant moves as a free body allowing the head to impact the windshield first. This is evidenced by the sequential photographs of figures 28 and 30 and by the plot shown in figure 35 of calculated impact times vs experimental times. Apparently there is a small amount of friction between the passenger seat and dummy, allowing the dummy to rotate slightly and initial contact by the head to occur first, even though the chest-to-dash distance was less than head-to-windshield distance.

- Occupant chest resultant accelerations exceed FMVSS 208 60-g limit for occupant impact velocity of 35 fps (10.7 m/s) and greater. A curve is extended through the points connecting the glass windshield tests in figure 36.

Side Impacts

Conclusions are as follow:

- All dummy risk indicators seem to be subcritical at the deceleration levels tested. Again, this is shown in table 12 in which the HIC values were well below 1000 and only a 5-millisecond duration, 60-g chest acceleration was measured in the maximum impact test.

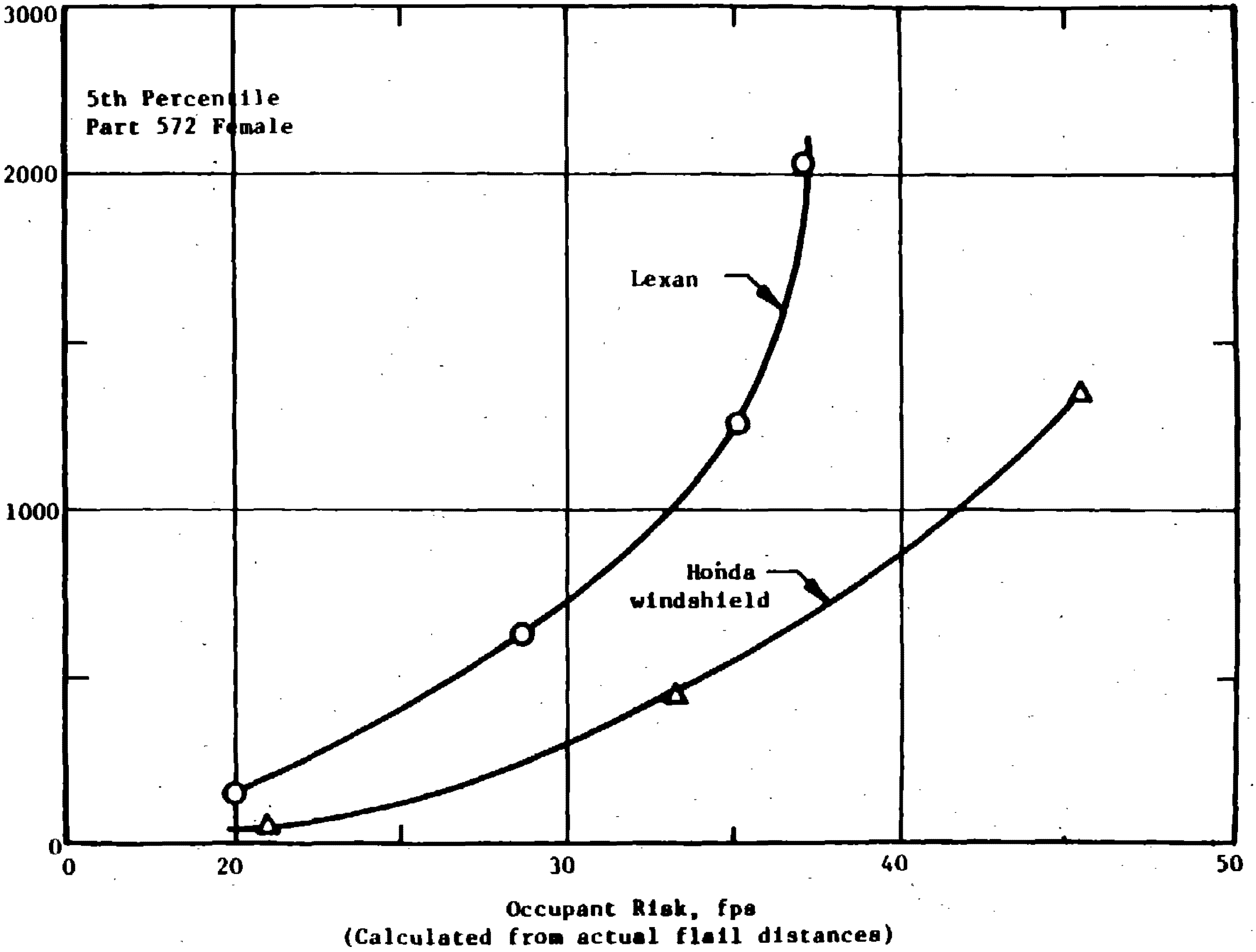


Figure 34. Plot of HIC vs occupant.

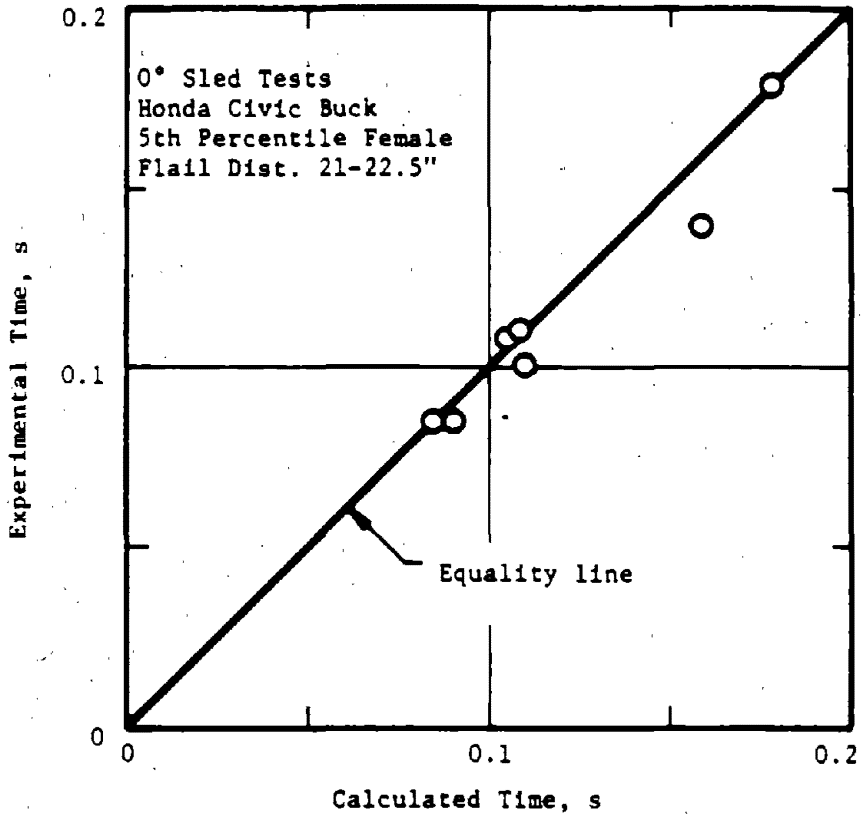


Figure 35. Comparison of experimental to computed time of head/windshield impact.

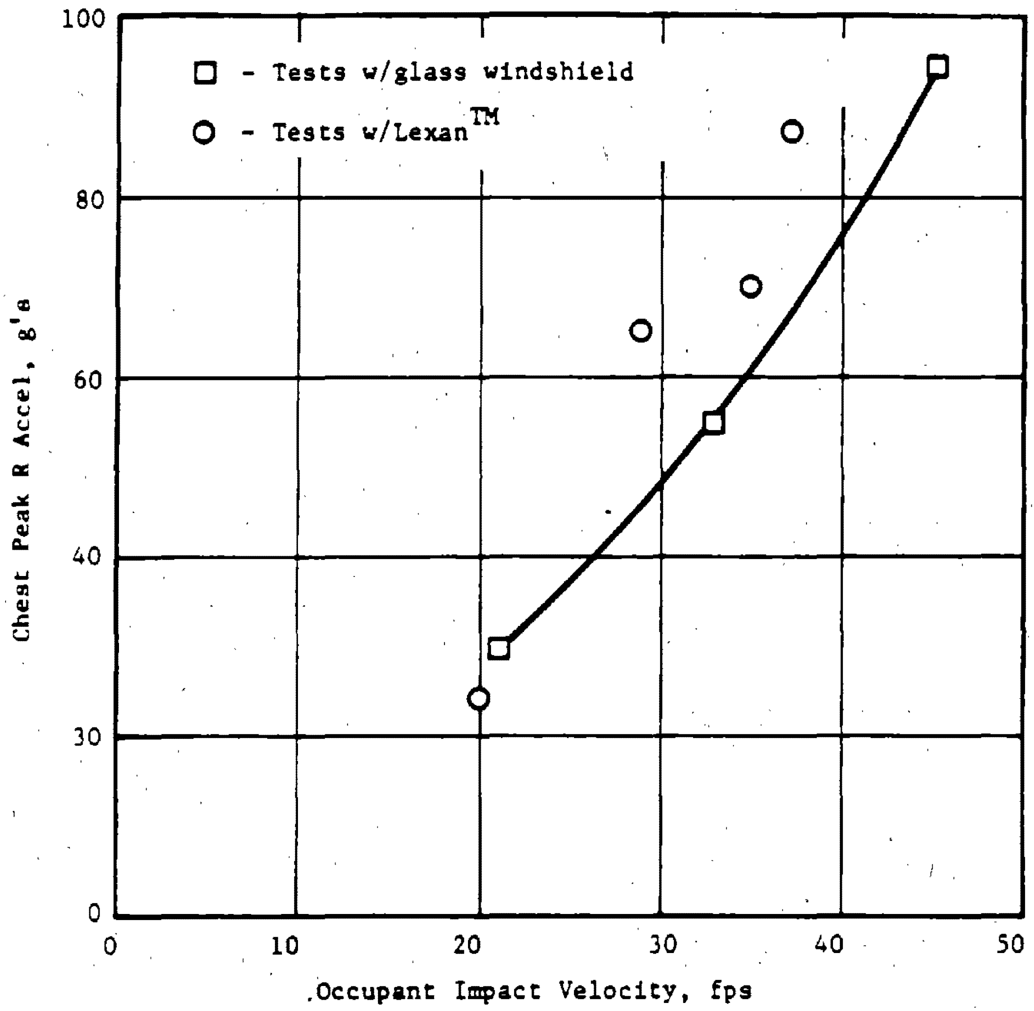


Figure 36. Dummy chest accelerations as a function of occupant to dash impact velocity.