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Final Report

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Administration**

Ingress Clearance Requirements and Seat Positioning for Automatic Belt Systems

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16. Abstract

The purposes of this study were (1) to determine how much clearance between a seat belt and seat cushion is needed for a driver to enter the front seat of an automobile equipped with automatic seat belts---without his/her having to lift the webbing, and (2) to derive data regarding where driver prefer to--and therefore realistically would--position themselves with relation to the steering wheel and pedal controls. Based on subjects representative of the 5th, 50th and 95th percentile, a clearance envelope for acceptable ingress/egress clearance was determined and a compliance test procedure recommended. Using these same subjects, their preferred seating positions are essentially those for which they were designed, i.e., 5th percentile females position the seat as far forward as it will go; the general 50th percentile group place the seat about midway between fore and aft extremes, and the 95th percentile males almost invariably position the seat as far aft as it will go.

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METRIC CONVERSION FACTORS

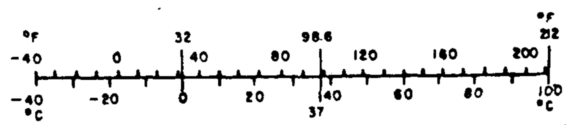
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Ingress Clearance Requirements and Seat Positioning for Automatic Belt Systems

Final Report

1.0 INTRODUCTION

The experiments reported herein represent the results of two studies which, for purposes of convenience and cost effectiveness, were carried out together using the same subjects and test vehicles. The nature and purpose of each of these is discussed below.

1.1 Study Purposes and Objectives

The primary purpose of the Ingress Clearance Requirements study was to determine how much clearance between a seat belt and seat cushion is needed for a driver to enter the front seat of an automobile equipped with automatic seat belts--without his/her having to lift the webbing. The results of this study are intended to provide design criteria and compliance test recommendations for inclusion in revisions to FMVSS 208.

The purpose of the driver Seat Position Preference study was to derive data regarding where drivers prefer to--and therefore realistically would--position themselves with relation to the steering wheel and pedal controls. These data presently are needed in connection with proposed sled-testing of automatic belt systems configured according to recommended comfort criteria.

1.2 Background - Ingress Clearance Requirements Study

A previous comfort/convenience study[(1)] involving automatic seat belt systems showed that a potentially annoying feature of such systems is the difficulty of getting into a car because the webbing often is in the way. This interference is due to the fact that the webbing, being anchored to the aft edge of the door, typically crosses the seat cushion at a point and at a height that positions it directly in the path of the person entering the vehicle.

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(1) Woodson, W.E., et al, Development of Specifications for Passive Belt Systems, Man Factors, Inc., MFI 78-109(R)

Although use of an optional, motorized belt puller system eliminates this problem by pulling the webbing almost entirely out of the entry path, future systems may not include this more expensive option. Therefore, in order to preclude or minimize the high probability of ingress interference and consequent consumer rejection of automatic belt systems in general, consideration is being given to possible rule-making designed to ensure that all future automatic belt systems are developed and installed in such a way as to provide adequate passenger entry clearance.

During the study previously cited, it was observed that if the seat belt webbing is a certain minimum height above the seat cushion, subjects were able to get into the seat without having to left the webbing out of the way. Below that height, entrants found it necessary to reach down and lift the belt high enough to slide under it.

The question therefore arose: What minimum clearance is necessary in order for drivers to get onto the seat without having to lift the belt manually? It was the substance of the ingress study to find an answer to that question.

1.2.1 Ingress Patterns

Two ingress patterns have been noted among test subjects entering the front seat of a car. In one, the individual enters the vehicle foot-first; in the second, he/she first sits in the seat, then swings his/her legs into the vehicle. Men tend to use the foot-first approach, women the buttocks-first approach (although variations do occur). The importance of this matter of ingress approach to the development of an effective test design lies in the fact that it is necessary to measure the belt clearance requirements at the precise point where the webbing crosses the outboard edge of the seat cushion. This can be done fairly easily for the foot-first entry mode. However, it cannot be done with the buttocks-first mode since, in the latter case, the individual entering is sitting sidewise on the seat at the precise moment (or point) at which a clearance measurement should be taken.

1.2.2 Anthropometric Factors

Although it might seem reasonable to assume that tall people would have more difficulty entering a car when the seat belt clearance is small, there appears to be no direct correlation between clearance requirements and occupant size. The problem here is that we are dealing with dynamic, ever-changing mobility-clearance patterns, not just static body dimensions. Also, the fact that ingress configurations vary with placement of the seat, fore or aft. At least on the driver's side the seat more often than not will be positioned forward for smaller drivers and aft for large drivers. With the seat forward the belt typically crosses the seat edge nearer the back rest. When the seat is aft, the belt crosses the seat edge further forward. This variation created different problems for the person trying to enter.

Although one approach to determining clearance requirements might be to place subjects in the seat and then measure their thigh heights above the cushion, this approach would not result in clearance criteria directly related to the dynamic clearance need (i.e., the specific point in space where the individual's leg is passing across the edge of the undepressed cushion during ingress). In fact, at this particular point during ingress a person's leg is in a generally vertical position, as opposed to the horizontal position assumed when sitting in the seat.

1.2.3 Aft vs. Rear Door Anchoring

The specific objective of this study has been to define seat belt clearance when a belt system is anchored at the rear edge of the door, since this is the simplest and least expensive type of mounting (i.e., no special anchor-shifting mechanism is required). Some future systems may, however, utilize a door-mounted track and belt-puller system wherein the anchor and webbing will articulate between the rear and forward edge of the door as the door is opened and closed. And since the outboard anchor would, in this case, be located at the forward edge of the door, it was considered desirable to determine a second webbing-seat clearance requirement for this forward-mounted anchor position.

Although one might assume that belt-seat clearance would be the same regardless of where the belt is anchored, this is not the case. For example, with the belt anchored at the rear of the door the webbing passes across the outboard edge of the seat, somewhere between the midpoint and rear of the seat, depending upon where the seat is positioned. But with the belt anchored at the forward edge of the door the webbing typically crosses the seat cushion, not along the outboard edge, but across the <u>forward</u> edge. In effect then, we are concerned about an outboard edge clearance criterion for rear-edge mounted belts, and a forward edge criterion when the belt is mounted on the forward edge of the door. Such differences are germane both to the design of the experiment and, ultimately, to definition of compliance testing.

1.2.4 Vehicle Differences

Vehicle configurational differences affect not only the patterns of belt mounting and articulation but also the pattern of subject ingress. For example, the fore-aft clearance between the forward edge of the seat and the door frame tends to influence how people approach and enter the vehicle. Actual heights of the seat cushion and door sill above the ground also affect the way in which a person approaches and attempts to enter any particular vehicle. Finally, the relationship between seat cushion, steering wheel, and dash panel also influence entry patterns.

For the purposes of this study, two specific vehicles were selected to provide representative packaging environments. A Ford Escort was chosen to represent a typical contemporary subcompact vehicle configuration, and a Chevrolet Citation as representative of probably future mid-size vehicle configurations. Two-door models were selected in each case in order to avoid introducing another confounding variable (i.e., two-door vs. four-door packages).

We found, however, that although the general interior space in each of the two cars is essentially similar, the doorway of the Escort is considerably narrower than that of the Citation. How much influence this difference might have had on subject mobility patterns we had no way of measuring directly. But based on our general observations during testing, the difference did not appear to modify subject mobility patterns between the two vehicles perceptibly. That is, any differences seemed to relate primarily to specific belt/seat relationships.

1.3 Background: Seat Position Preference Study

Automobile manufacturers typically provide fore-aft seat adjustment flexibility in order that drivers of different sizes can position the seat for comfortable driving. Since this adjustment capability is assumed to be compatible with user size differences (i.e., 5th percentile females can adjust the seat forward, 95th percentile males can adjust it aft, and other drivers adjust it somewhere in between), it would seem logical to assume that current crash-test dummies representing the 5th percentile female, 50th percentile male, and 95th percentile male would fit the designed driver station envelope when the seat was adjusted all the way forward, in mid-position, or all the way aft, respectively. Based on this assumption respective dummy/seat positions could be used for various crash test purposes, such as those presently planned to evaluate seat belt crashworthiness when "comfort belt configurations" are incorporated.

The DOT/NHTSA in planning the upcoming tests needed confirmation, however, that in two specific vehicle models (1981 Escort and Citation) small females, large males, and average size male-female users do in fact position the seat in these particular vehicles as assumed. Such confirmation would provide the necessary rationale for performing the proposed crash tests with the three respective anthropomorphic dummies in the designated seat positions for testing.

2.0 METHODOLOGY

2.1 Ingress Clearance Requirements Study

Before conducting the main test series in this study, a series of preliminary experiments was conducted to evaluate various methods of measuring ingress clearance. This pilot study effort began with a series of observational tests in which a large male and a large female subject performed repeated ingress tasks using both a foot-first and a buttocks-first entry approach. During these trials an experimenter observed subjects to determine how a clearance measurement might be taken. Several measurement methods previously proposed were evaluated with respect to subject activities. One such measurement method was to take motion pictures of the subjects against some type of internally-mounted measuring device (e.g., grid, screen, tape, or scale). A second method was to place a series of vertically-adjustable probes which might be lowered from the upper door frame to outline the subject's entry profile. A third method consisted simply of placing a simulated belt in the vehicle and allowing the subject to practice manipulation of his/her body and limbs past it.

Of the three methods, only the third one proved a truly viable technique. Not only from the standpoint of gaining accurate, repeatable measures of a dynamic mobility envelope, but also in terms of being more representative of a realistic ingress response from test subjects. Thus, the simulated belt system was selected and is described below.

2.1.1 Simulated Belt Approach

A bungee cord was used to simulate automatic lap belt interference patterns. On the inboard side of each car the cord was fastened to its own seat buckle. The outboard end of the cord was left free so that it could be positioned at various heights along the rear (or front) edge of the vehicle door.

Since the clearance measurement desired was the vertical distance between the outboard edge of the seat cushion and the simulated belt, directly above the point where the cord passed across the seat edge, a method had to be devised to overcome cushion differences between the two test vehicles. This was accomplished by placing a 3/4-inch thick plywood board on top of the seat cushion. The size of the board was approximately 17 x 17 inches and proved large enough to account for lateral irregularities of the seat cushion. This made it possible to measure the vertical distance from the edge of the board up to the cord at the precise point at which the cord passed across (above) the seat edge.

Although the measurements to be taken would in each case be 3/4-inch less than the actual clearance, it would be constant with respect to both vehicles and seats. Also, when it was discovered that the cord did not cross the outboard edge of the seats when the belt was anchored along the forward edge of the door, it was equally simple to take a vertical measurement between the leading edge of the board to the cord when it crossed along the forward edge of the seat instead of along the outboard edge.

Prior to beginning the main experiment, marks were placed on the vehicle door edges (both forward and rear) to define actual one-inch increments of vertical clearance as measured between the simulated belt positions above the outboard and forward edges of the reference board in the seat. Thus, during the experiment an experimenter could position the belt anchor level according to the scale on the door and record the actual height of the belt above the seat board edge.

2.1.2 Method-of-Limits Test Procedure

Since the simulated belt technique required subject judgmental responses as opposed to merely measuring some anthropometric variable, a method-of-limits experimental procedure was adopted. That is, clearance-level acceptability judgments were taken by working down from a high position and working up from a low position.

After briefing subjects regarding the purpose and nature of the test and what he/she was expected to do, subjects were asked to enter the car(s) a number of times. Each time a subject entered, the belt anchor was moved, first up, then down until he/she indicated the level was satisfactory for entry without having to lift the cord out of the way by hand. Anchor levels for increasing and decreasing trials were recorded as subject acceptance levels. Subjects were told not to hurry in making a decision and, in some cases, were asked to verbalize their impressions and basis for deciding on an acceptable clearance level.

2.1.3 Subject Sample

In order to remain within previously established time and cost constraints a small, selected sample of test subjects was used. The objective was to provide subjects representative of such critical variables as male vs. female, large vs. small, and young vs. older individuals. Subject characteristics are shown in Table 1. All subjects were drivers, selected on the basis of possessing a valid California driver's license. Included in the sample were caucasians, blacks, orientals, and chicanos. Subjects were picked according to specified stature percentiles (based on U.S. Department of Health Survey statistics of 1960).

Although the basic intent was to select three strategic groups (i.e., 5th percentile females, 50th percentile males and females, and 95th percentile males), a range of plus-or-minus selection criteria was used since the primary response mode would be judgmental (subjective) and thus include more than just anthropometric implications of different subjects.

2.1.4 Procedures

a. Each subject's stature, in stocking feet, was measured and recorded.

b. Each subject was asked to read a prepared description of the impending test.

c. Each subject was taken to the test site and the test procedures reviewed with him/her to make sure they were understood. The belt system was demonstrated to illustrate the problem of entering the car when the belt was mounted too low, as opposed to easier ingress when the belt was mounted higher. Subjects were allowed to try out both conditions. It was emphasized that in order for the clearance condition to be acceptable the subject should be able to get into the car without having to use a hand to lift the belt.

Possible order effects were minimized by having each subject start with alternate vehicles and alternate anchor level starting points (i.e., one subject would experience starting from a higher level first, followed by starting

Table 1 - Subject Characteristics

S No.	%-ile	Male/ Female	Stature
1.	50	F	61½ in.
2.	50	F	61½
3.	50	M	67
4.	50	M	69½
5.	95	M	73
6.	50	M	68½
7.	5	F	60
8.	95	M	71½
9.	50	M	69½
10.*	5	F	59
11.*	50	F	62
12.*	50	F	62
13.	5	F	60½
14.*	95	M	72½
15.	50	M	68½
16.	50	M	68
17.	95	M	70½
18.	5	F	60
19.	5	F	59
20.	5	F	60½
21.	5	F	59½
22.	5	F	59
23.	50	F	61
24.	50	F	62½
25.	95	M	73½
26.	95	M	72
27.	5	F	60
28.	95	M	70½
29.*	5	F	60
30.	95	M	70½
31.	95	M	72½
32.	95	M	71

*Over age 50

with a low level; the next subject would start from the opposite end of the range). Subjects continued entering and judging clearance acceptability as the experimenter raised or lowered the anchor point until the subject indicated an acceptable anchor/clearance level had been reached. If the subject appeared uncertain, the level was shifted up or down to help him/her bracket the area of uncertainty until satisfied as to the level of acceptability.

In a few cases it was apparent that a subject was confusing his/her internal judgment criteria, ie., he might verbalize in a manner that indicated he was concerned with factors other than those directly related to ingress acceptability. In such cases the experimenter reviewed the judgmental factors and cautioned against including others not germane to the test. Generally, all subjects developed a fairly consistent standard of judgment by the time they had performed the first trial and thereafter evidenced confidence with regard to what they felt was the lowest clearance level that would permit them to enter the seat without discomfort or annoyance.

2.2 Seat Position Preference Study

2.2.1 Test Procedure

Each test vehicle was marked in such a way that seat position could be recorded relative to a fixed reference point, i.e., the pivot of the accelerator pedal. The fore-aft distance between this point and the most forward seat adjustment in each vehicle was recorded by placing a mark on the side of the seat cushion. A scale was then affixed to the door sill, alongside the seat, so that as subjects chose a specific seat position the experimenter could record variations between the full-forward reference and adjustments aft of the forward reference. Ultimate subject seat position preferences were recorded as seat distances aft of the accelerator reference.

Upon arrival, subjects were asked to read a copy of the test description. Instructions were also repeated at the test site. Before the subject was asked to enter the test car and adjust the seat to his/her preferred driving position, the seat always was returned to its most aft position. Subjects were not allowed to "settle" for this aft position, even though they might ultimately choose it, i.e., they are instructed to move the seat forward and to "test" alternate positions until they felt they had reached a satisfactory driving position. Each subject was required to perform three trials. Thus, after the first trial the subject was asked to leave the car, then re-enter and re-adjust the seat. An average of the three trials was used as the subject's preferred position. In order to remove possible order effects, subjects alternated between vehicles, i.e., one subject was tested first on one car, the next subject on the other car.

2.2.2 Subject Sample

The subject sample was the same as that used for the Ingress Clearance Requirements Study (see Table 1.).

3.0 RESULTS

3.1 Ingress Clearance Requirements Study

3.1.1 General

Figures 1 through 4 show the distribution of clearance acceptance values for both test vehicles. The first two graphs provide data for the Citation; the latter two for the Escort. Each pair of graphs show separate aft and forward door anchor position data. Clearance heights are shown as ordinate values and subject stature as abscissas. Male datum points are identified by a triangle; female data points by a circle. Open circles and triangles denote values for ascending trials; solid circles and triangles for descending trials. Circles or triangles that are half open, half solid, indicate that the subject selected the same clearance value for both the ascending and descending modes.

As these figures show, except for one or two isolated datum points, the acceptance-value spread is somewhat similar for the entire range of subjects, namely, about one or two inches. It is interesting also to note the randomness among ascending and descending trial values (i.e., acceptance selection), which would tend to indicate that acceptability values do not appear to be biased in any way by the direction in which subjects were exposed to selection modes. However, there is a distinct difference between cars. This and other observations are discussed below.

3.1.2 Between-Vehicle Comparisons

These comparisons are shown in Table 2. It will be noted that when the various clearance means are combined

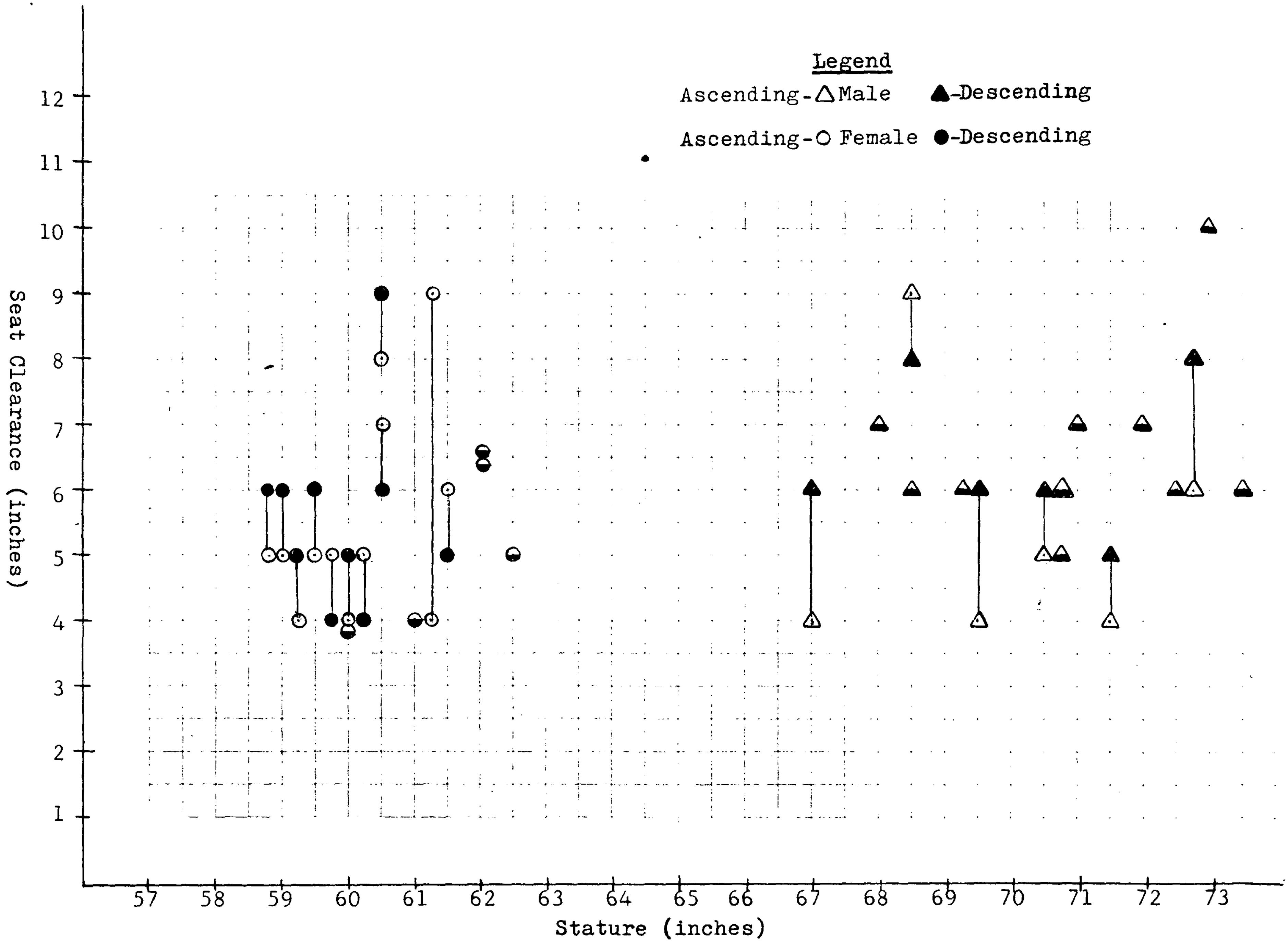


Figure 1 - Seat Clearance: Citation (Aft Anchor)

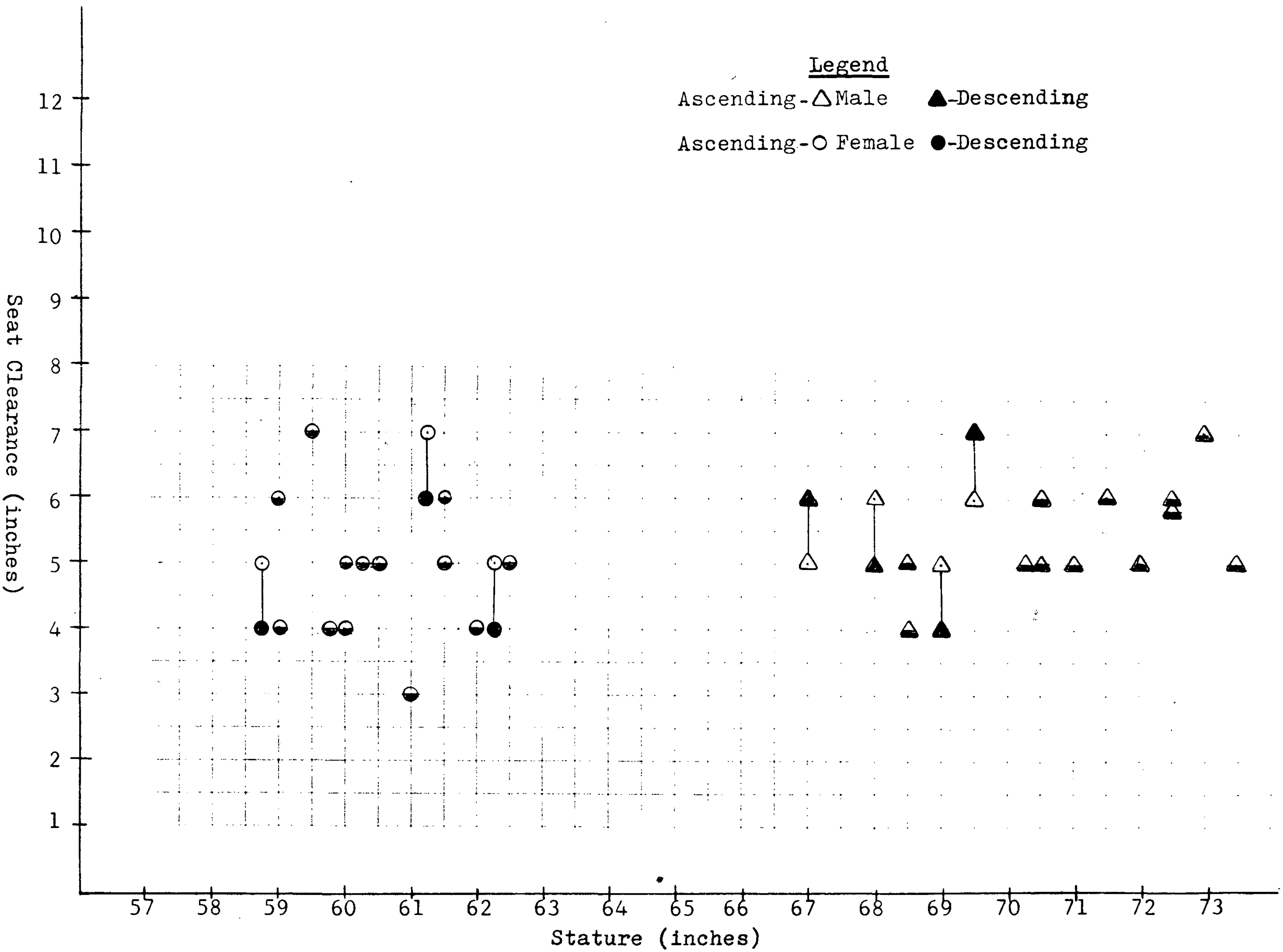


Figure 2 - Seat Clearance: Citation (Forward Anchor)

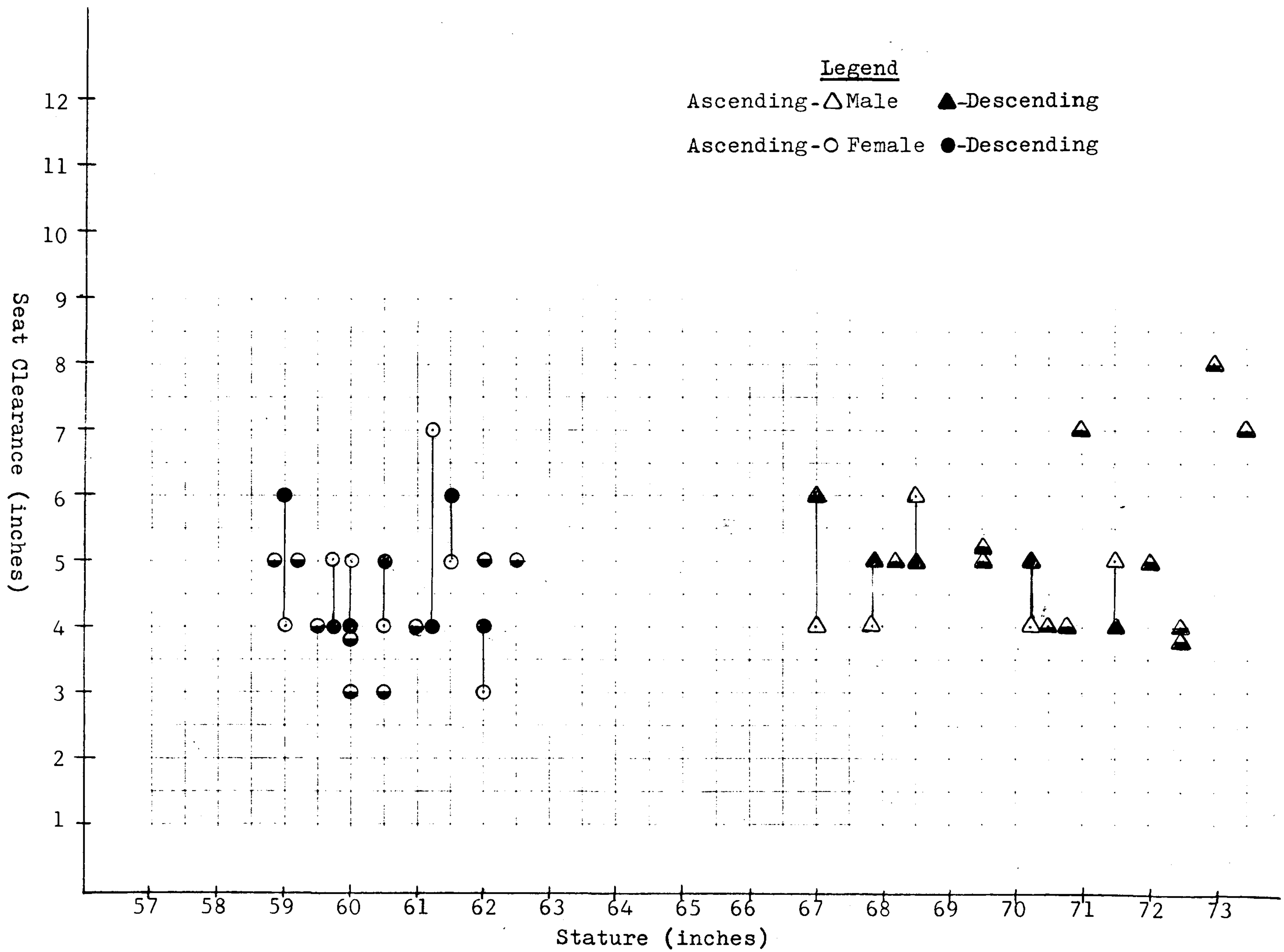


Figure 3 - Seat Clearance: Escort (Aft Anchor)

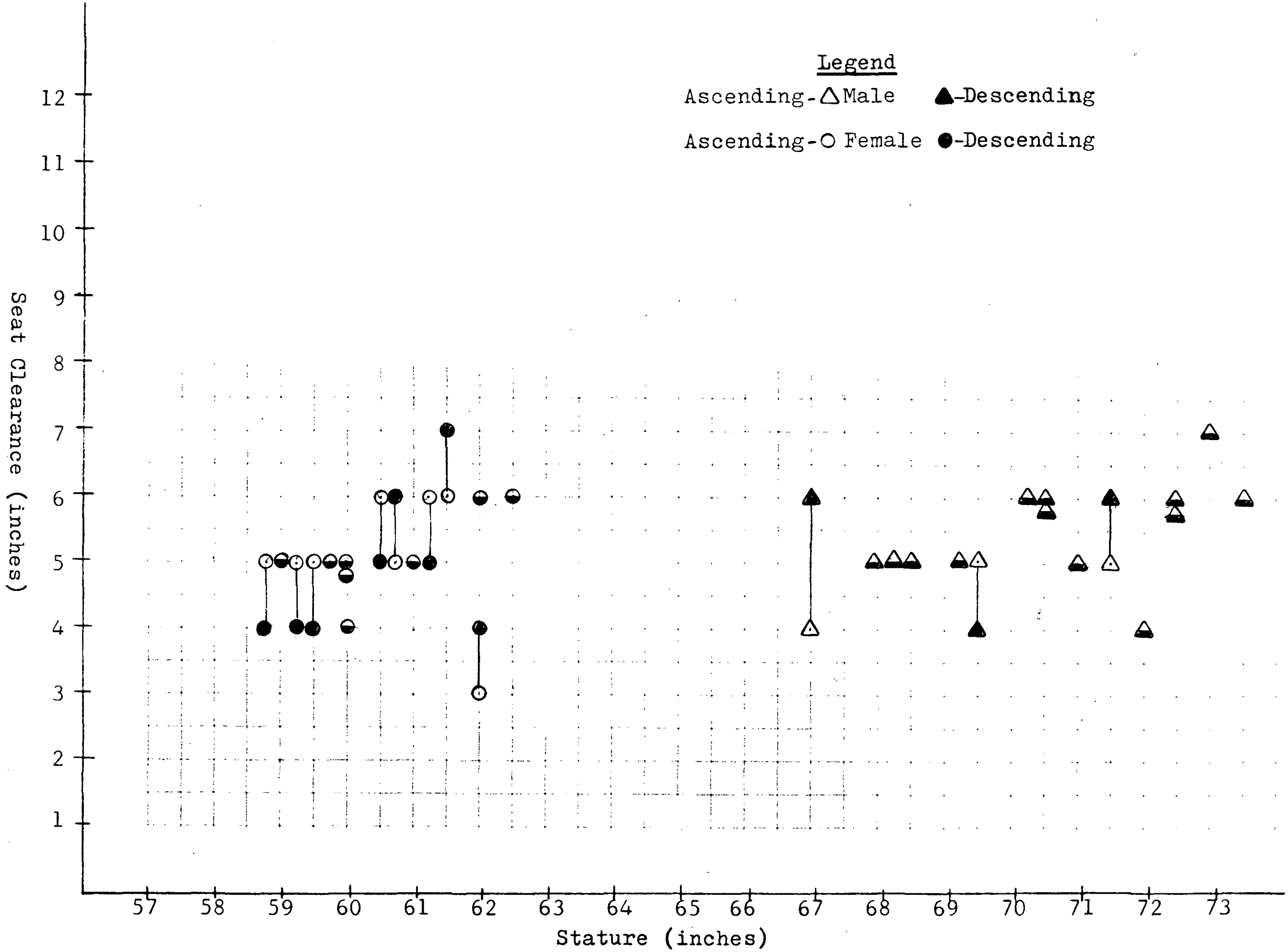


Figure 4 - Seat Clearance: Escort (Forward Anchor)

across trials and anchor positions for all subjects (Column 7), clearance requirements for the Citation appear to be about one-half inch greater than those for the Escort.

3.1.3 Male vs. Female Comparisons

Referring again to Table 2, it is evident that males require slightly greater clearance than do females. Combining the means for the Escort and the Citation this amounts to about 0.6 inches.

3.1.4 Anchor Position Comparisons

Table 2 also shows (Columns 5 and 6) that with the Citation higher clearance values occurred when the belt was anchored to the aft edge of the door than to the front edge. The reverse was true with the Escort. Combining the means from both vehicles, however, reveals only a slight difference between aft and forward mounting, namely, about 0.1 inch (i.e., the mean of the aft anchor clearance values was about 0.1 inch greater than the mean of the forward anchor point values).

3.1.5 Other Observations

Just as in the case of several previous experiments relative to seat belts, a few other conclusions can be derived from observations of the experimenter. Although these are not quantifiable in any strict sense, they are important we feel in developing recommendations for rule-making.

a. <u>Mode of Entry</u> - Initially it was proposed that subjects be required to enter the vehicles by two different modes of ingress (these were discussed briefly in Section 1.3). One would have been a foot-first approach in which the subject would attempt to enter by placing his/her right foot into the car first. The other would be one in which the subject would first sit down on the seat cushion by backing into the car, then swinging his/her legs into the compartment. However, this extra variable was eliminated in favor of allowing subjects to enter as they wish, on the assumption that they would enter in the manner to which they were most accustomed and therefore would not try to enter awkwardly just to please the experimenter.

Fortunately this approach allowed us to make an interesting observation, namely, that women enter a car buttocks first whereas men enter feet first. This

Table 2 - Ingress Clearance Requirements
Summary of Results

	Means of Values						
	Ascending		Descending		Combined		
	Aft	Fwd	Aft	Fwd	Aft	Fwd	Means
CITATION							
All Females	5.62	4.94	5.19	4.88	5.40	4.91	5.15
All Males	6.12	5.44	6.56	5.44	6.34	5.44	5.89
Combined M&F	5.88	5.19	5.88	5.16	5.87	5.17	5.52
5th % (F)	5.40	5.00	5.30	4.90	5.35	4.95	5.15
50th % (F)	6.00	4.83	5.00	4.83	5.50	4.83	5.16
50th % (M)	6.00	5.16	6.50	5.16	6.25	5.16	5.70
95th % (M)	6.20	5.60	6.60	5.60	6.40	5.60	6.00
Older	5.60	4.60	5.40	4.40	5.50	4.50	5.00
ESCORT							
All Females	4.44	5.12	4.44	5.00	4.44	5.06	4.75
All Males	5.06	5.31	5.19	5.44	5.12	5.38	5.25
Combined M&F	4.75	5.21	4.81	5.22	4.78	5.22	5.00
5th % (F)	4.20	5.00	4.30	4.70	4.25	4.85	4.55
50th % (F)	4.83	5.33	4.67	5.50	4.75	5.41	5.08
50th % (M)	4.83	4.83	5.17	5.00	5.00	4.91	4.96
95th % (M)	5.20	5.60	5.20	5.70	5.20	5.65	5.42
Older	4.00	4.80	4.60	5.00	4.30	4.90	4.60
CITATION/ESCORT COMBINED							
All Females	5.03	5.03	4.82	4.94	4.92	4.98	4.95
All Males	5.59	5.38	5.86	5.44	5.73	5.41	5.57
Combined M&F	5.31	5.20	5.34	5.19	5.32	5.20	5.26

(32 subjects: 16 male, 16 female)

difference seems to be related to the instinct of women to keep their knees together--even while wearing slacks. Interestingly, male and female clearance values do not differ greatly, which leads to the tentative conclusion that when people judge the ease with which they can "clear" an automatic seat belt, it matters little how they approach the matter of entering a car.

b. Point at Which Webbing Contacts the Leg - It was generally observed that the belt height with respect to the subject's knee when he/she approached the belt was an important influence on whether the subject would judge the belt clearance adequate or not. Thus, if the webbing height was at or below knee level, it was certain that the subject would object. This appears significant in that it may indicate that the height of the webbing above the ground is more of an influence on judgment regarding clearance than the height of the belt above the seat cushion.

Since the two test cars were nearly similar in terms of road clearance and seat cushion height, the seat-belt clearance values obtained probably are effective criterion measures of adequacy of belt clearance. However, if a very low profile car was to be evaluated, the values herein obtained might not be directly applicable. Likewise, the values may not be applicable to a very high profile vehicle, such as a van or truck.

3.1.6 Conclusions

From the foregoing it is apparent that a seat-to-cushion clearance of 6.0 inches above the seat test board should prove adequate to accommodate at least 95% of the user population.

Although six inches is not necessarily the maximum value selected by one or two tall subjects, it includes most of the taller subjects (who represent the worst case) and all smaller subjects. And though it might be a temptation to select a lesser value--perhaps the mean of all subjects for both cars, namely, 5.26 inches--it would be difficult to defend any such lower value as not causing inconvenience or proving unacceptable to a major segment of the driver/passenger population. And the 3/4-inch difference between meeting the 6.0-inch vs. the 5.26-inch value does not appear to present a difficult or unreasonable problem to the manufacturer.

3.2 Seat Position Preference Study

The results of this study are shown in Table 3. Actually, this illustration consists of three tables; the first two showing subject data separated for each of the test vehicles, and the third showing combined data for the two cars.

Results have been divided into several categories; comparison of males vs. females, combined male-female, by stature percentile groups, and by rough age-group difference. In the last case, since there were not enough subjects involved to provide a smooth distribution of ages, the data are useful only as an indication of whether there were any significant differences evident in the few (5) older subjects.

Some of the more important observations are as follows:

a. Male-Female Differences - In both vehicles females chose seat positions closer to the accelerator pedal than did males when male-female percentiles were combined. This difference amounted to about 5 inches in both test cars.

b. Differences Between Vehicles - When all subject data were combined (i.e., male-female), the average seat-to-pedal distance was about 1½ inches greater for the Escort than for the Citation. Evidently, something about the overall driver station geometries of the two cars caused subjects to prefer the seat closer to the pedals in the Citation than in the Escort.

c. Older Subjects - Since the few older subjects fell primarily in the mid-stature range, no meaningful conclusions can be drawn. However, it is interesting to note that these subjects preferred seat positions within the average range for their expected percentile group (i.e., age evidently did not seem to influence seating preference).

d. Percentile Stature Relationship - It is evident in looking at all three tables that seat position differences fell much as might be expected, i.e., there is a generally increasing pedal-to-seat distance as subject stature increases, and there is the expected difference between the male and female groups in the 50th percentile range.

Table 3 - Seat Position Preference Study
Summary of Results

CITATION

	Means	
All Females	19.16	Inches
All Males	24.00	
Combined M&F	21.58	
5th % (Female)	18.65	
50th % (Female)	20.00	
50th % (Male)	23.25	
95th % (Male)	24.45	
Older Subjects	20.30	

ESCORT

All Females	20.69	Inches
All Males	25.38	
Combined M&F	23.04	
5th % (Female)	20.35	
50th % (Female)	21.25	
50th % (Male)	25.10	
95th % (Male)	25.60	
Older Subjects	21.90	

CITATION/ESCORT COMBINED RESULTS

All Females	19.92	Inches
All Males	24.69	
Combined M&F	22.30	
5th % (Female)	19.50	
50th % (Female)	20.62	
50th % (Male)	24.18	
95th % (Male)	25.02	
Older Subjects	21.10	

Subject Sample

5th %-ile females. . . .	10
50th %-ile females. . . .	6
50th %-ile males.	6
95th %-ile males.	10
Total subjects	32

Based on the above results it is concluded that people within the critical percentile groups do, in fact, wish to position the seat in each of the test vehicles in much the way they were designed to be used (i.e., 5th percentile females position the seat as far forward as it will go; the general 50th percentile group place the seat about midway between fore and aft extremes, and the 95th percentile males almost invariably position the seat as far aft as it will go).

4.0 INGRESS CLEARANCE REQUIREMENTS, STANDARDS RECOMMENDATIONS

4.1 Webbing-Seat Clearance Criterion

For the reasons discussed in Section 3.1.6, a minimum value of 6.0 inches is recommended as the criterion for determining if a particular seat belt system provides adequate ingress clearance. This value represents a vertical measurement taken between the belt and a 3/4-inch board positioned across the top of the seat. Such a clearance should be satisfactory to at least 95% of the user population (i.e., persons of 95th percentile stature or less).

This criterion value is equally applicable to aft-door- or forward-door-mounted systems. However, it can only be considered applicable to vehicles that approximate the configurations tested in this study. Vehicles that have an appreciably lower--or higher--sill and/or seat height above the ground should not be included in the Standard until such time as suitable experimental testing verifies that the recommended clearance requirement is equally applicable.

4.2 Compliance Testing

In order to provide a reliable and repeatable compliance evaluation of new automatic seat belt systems it is recommended that the following general procedures be specified.

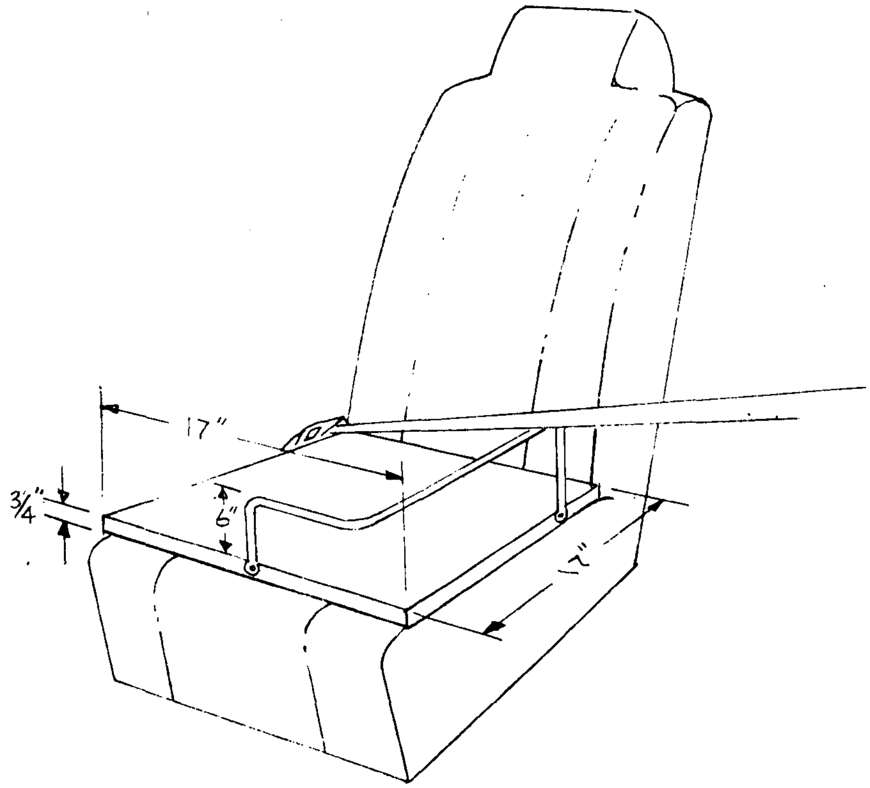
a. Seat-Surface Test Board - As noted earlier, seat cushions vary considerably from vehicle to vehicle, and in many cases it is difficult if not impossible to define the seat edge reference, either along the side or at the front of the cushion. It is therefore recommended that a seat-surface test board be used, perhaps similar to the one used in this study (i.e., a 3/4-inch, 17 x 17-inch piece of plywood, which should be adequate to cover any projected cushion models in the near future). This board should be positioned on the seat in such a way that the outboard edge generally matches the outboard edge of the cushion, and the leading edge is aligned with the leading edge of the cushion.

b. Clearance Test - Two techniques can be used to measure the height of the belt webbing above the edge of the test board. One way would be to simply use a tape measure or small ruler, placing it so that it is vertical to and along the edge of the test board, thus allowing the evaluator to determine how high above the board edge the webbing is at the precise point where it crosses (above) the edge of the board. The webbing should be no lower than six inches above the board at this point.

A second technique that might be used would be to attach a six-inch-high rail to the test board (see Figure 5), thus making it possible to merely place the board in the proper position and inspect the webbing-crossing to see if the webbing is at or above the six-inch reference railing.

In preparing to test for compliance, the test engineer or evaluator should, of course, extend the webbing by opening the door to its full-open position. The webbing should be inspected to make sure it is taut (i.e., if the retractor were not working properly, it might allow the webbing to have slack in it, hence "drape" across the seat cushion). Similarly, the evaluator should also inspect a forward-mounted belt system to make sure the webbing pattern is not distorted due to steering wheel interference.

It is possible also that some belt systems may be designed in such a way that the belt webbing is not "flat" where it crosses the seat edge. If this is the case, the evaluator should try to straighten out any folds that would make it difficult to determine webbing height above the seat test board. If for any reason the webbing cannot be straightened out, two alternatives are suggested. First, one could measure from the test board up to a point that appears to represent the middle of the belt (i.e., so as not to penalize a belt in which the webbing might be twisted, and the lower edge of the webbing lower than the general mid-axis of the belt as it passes across the test board edge).



A six-inch high rail attached to the seat test board could be fabricated to eliminate the need to use a tape measure in determining whether a candidate seat belt crossing was within compliance. Note that the rail provides a limit for belts crossing both the outboard and forward edges of the seat.

Figure 5 - Belt Clearance Test Board

An alternative approach (when a twisted belt cannot be straightened out) might be to substitute a bungee cord (as used in this experiment) in lieu of the installed webbing. This would require hooking one end of the cord to the inboard buckle and the other end to the door anchor. The cord length should be such that it provides a straight line between the two anchor points. The measurements should be taken to the bottom edge of the cord.

4.3 Design Implications of Apparent Clearance Requirements

It became evident before many subjects had been run that their apparent need for considerable clearance between the belt and the seat results in an outboard anchor position high on the door, much higher than would be required for a simple, fixed attachment. That is, in order to make a simple, fixed attach point that would provide a "secure" lap belt configuration when the door is closed, the outboard anchor must be somewhere near the lower, aft corner of the door (on any vehicle model). In neither of the cars tested was such a position acceptable to any subject. In fact, the general anchor point area on the door where subjects began to accept the clearance between webbing and cushion typically occurred at window sill level or higher.

The implication of this fact relative to the "open door" clearance that appears required is simply that manufacturers cannot provide such clearance except by means of some type of outboard anchor point articulation. The anchor will, therefore, have to move from a low, rear corner position on the door to a relatively high position as the door is being opened, then return to the lower position as the door closes. Obviously, a similar anchor articulation will be required if the open-door anchor position is at the forward edge of the door (typical of experimental models that have used a motorized puller and track across the inside of the door).

SEAT BELT CLEARANCE HEIGHT ACCEPTANCE TEST

Subject Instruction

New automatic seat belts will be attached to the door in a manner similar to the simulated system you see on this car. As you can see, the belt tends to cross the pathway to the seat.

The purpose of this experiment is to see how high above the seat cushion such a belt should be to be acceptable to you when you try and get into the seat.

With this simulation, we can adjust the height of the belt above the seat by changing the position of the belt anchor on the edge of the door (demonstrate). We can also anchor the belt either on the back edge of the door or on the front edge.

I am going to ask you to try and get into the driver's seat past the simulated belt at different clearance heights. We may start the belt in a very low position and adjust the belt height upward until you say the height is acceptable, or we may start the belt at a high position and adjust it lower until you say the height is acceptable. Whichever position we start will determine the trial number. That is, once you have finished the first trial, we will repeat the adjustment series from the opposite end of the adjustment for trial two. Once we have completed two trials with the belt attached to the rear edge of the door, we will do a second pair of trials with the belt attached on the forward edge of the door. I will record your height preference for each trial, i.e., two trials for the rear mounting condition, and two trials for the forward mounting condition.

Before we start the first trial, remember that future automatic belts will invariably be attached to the door at some position, thus the belt will always be in the pathway of entry to some extent. That is, you cannot judge all positions unacceptable. What we are looking for is the position you feel you could "live with" considering that there will always be some minor inconvenience.

Now, before we start the first trial, I want you to have a chance to see the difference between a belt anchored fairly low and one mounted fairly high. This way, you will have some idea of the difference it makes to the ease with which you can get into the car. We will also let you see the difference between mounting the belt to the rear and to the front edge of the door.

Do you have any question or comments before we start the first test trial?

1. Trial 1: Belt Anchor Rear-Low

   Trial 2: Belt Anchor Rear-Up one step
   (continue upward until subject accepts)

2. Trial : Belt Anchor Rear-High

   Trial : Belt Anchor Rear-Down one step
   (continue downward until subject accepts)

3. Trial : Belt Anchor Forward-Low

   Trial : Belt Anchor Forward-Up one step
   (continue upward until subject accepts)

   Trial : Belt Anchor Forward-High

   Trial : Belt Anchor Forward-Down one step
   (continue downward until subject accepts)

Note to Experimenter: Start each new subject with the belt anchored opposite to Trial 1 for the previous subject, i.e., so that subject/trial orders are reversed.

Appendix B

SEAT POSITION PREFERENCE TEST

Subject Instruction

The purpose of this experiment is to determine where drivers ordinarily would position the driver's seat in order to drive this car.

I am going to ask you to get into the driver's seat and select the fore-aft seat adjustment position you feel is best for you.

1. After you are seated comfortably, release the seat adjustment lever and slide the seat forward until you think it is in the best position for driving. Try it several times until you believe you have positioned the seat where you would feel comfortable for driving.

Now get out of the car.

2. Now try the adjustment procedure once again, first moving the seat all the way back and then forward once again to the best position.

Now get out of the car.

3. Now try the adjustment procedure one last time, first moving the seat all the way back and then forward once again to the best position.

Note, I will record the positions you select each time to see how consistent you have been.