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SOURCES AND REMEDIES FOR RESTRAINT SYSTEM DISCOMFORT AND INCONVENIENCES

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16. Abstract

This study examines possible causes of failure of automobile occupants to wear restraint systems provided by the manufacturers. Attention is directed primarily to confusion, inconvenience and discomfort factors in seat belt usage. Study phases consisted of: (a) literature survey to determine state-of-the-art in restraint system design and reasons why people avoid using seat belts; (b) preliminary user survey aimed at identifying in greater detail why people find seat belt systems inconvenient and uncomfortable; (c) new car survey to learn more about how current seat belt systems are designed and installed and if there are new developments that can improve the state-of-the-art; and (d) a series of laboratory studies designed to determine if it is possible to create a more suitable seat belt system. Based on laboratory results an optimized system was designed and tested in two vehicles. These optimized seat belt systems were then compared to four other 1974 vehicles systems to determine their acceptability by users from the standpoints of convenience and comfort. Results showed that the optimized system was significantly favored by test subjects.

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what there is about a seat belt configuration that will cause most people to object to wearing it.

b. Mockup studies proved that it is possible to design a practical restraint system configuration that not only will fit 90 percent of the user population properly but that this can be done within the present hardware-vehicle state-of-the-art.

c. System comparison tests demonstrated that the proposed optimized restraint system design created during the mockup studies was significantly favored by test subjects over other vehicle-restraint system typical of 1974 automobiles.

d. Although the experimental, semi-passive restraint systems have certain good points relative to user acceptance, these still do not out-rank the proposed optimized system using a standard three-point system.

However, the specific passive systems tested did not include several other proposed systems, i.e., the systems used in the current evaluation were two versions of passive belt systems available at the time of the test. MFI's literature review identified numerous other passive systems (not air bag) that have never been implemented and evaluated. Due to current interest in the possible favorable reaction of the public to system that do not require overt effort in donning it may be unwise to rule out such systems altogether just because two specific samples did not turn out to compare favorably with the present, optimized three-point belt system.

e. A more general conclusion regarding the total study findings is that it can be observed almost without exception that auto body style is established with little regard to its impact or constraint on effective restraint system design and installation. Because of this restraint systems are viewed by designers as "add ons", and they are therefore attached and arranged <u>to fit the car, not the occupants</u>. The errors are so common that MFI's researchers could tell whether a belt system was going to fit badly almost immediately by visual inspection even before trying on the belts. When mistakes

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EXECUTIVE SUMMARY

A study was undertaken to examine the possible causes of lack of auto seat belt use because of belt-use confusion, inconvenience and/or discomfort. Previous user surveys had indicated that many people give as the reason for not using seat belts the fact that they are too uncomfortable and that they are difficult to put on and take off.

The study consisted of several phases including the following:

a. Literature survey to determine the state-of-the-art in seat belt design and why people seem to avoid using seat belts.

b. A preliminary user survey to try to identify in more detail why people find seat belt systems inconvenient and uncomfortable.

c. A new car survey to learn more about how current seat belt systems are designed and installed and to discover if there are new developments that might be better than the current state-of-the-art.

d. A series of laboratory studies to see if it was possible to create a more suitable seat belt system.

e. Based on the laboratory results, a proposed optimized system was designed and installed in two vehicles, one with bucket seats, the other with bench seats.

f. The two optimized seat-belted vehicles were tested, comparing them to four other 1974 cars and their own restraint systems, to see if the optimized system was judged by typical users to be more acceptable from the standpoint of convenience and comfort.

Conclusions indicate that:

a. Design-related reasons were evident from the initial analyses, i.e., it was possible to state fairly clearly

are this apparent one can only conclude that some design control must be required in order to gain the attention of designers.

As a result of the foregoing it is recommended that:

a. Specific operational requirements dealing with belt-type seat restraint system "fit should be made to FMVSS 208 in order that future seat belts will be more acceptable and therefore remove excuses for lack of use based on confusion, inconvenience and discomfort. The recommended amendments provided in this report should be used as the basis for revising FMVSS 208. The geometric and dimensional criteria should be applied to any future belt-type systems also, since the factors that annoy the user relate directly to "fit".

b. It is recommended that other passive (non air bag) systems be investigated in more detail to determine if an alternate passive system concept might be acceptable to the majority of consumers -- in addition to the obvious advantages MFI found for handicapped people. Such a study should include the fabrication and evaluation of potentially acceptable system or systems using the general methodology developed for the current study.

c. It is recommended that additional study be made of restraint system requirements for the other occupant positions where currently there are no upper torso restraint capabilities. Other occupants have the same right to protection regardless of the apathy of some people regarding use of seat belts. Although the current fit criteria would obviously apply to other occupant positions and systems, little sincere effort has been given to this problem, especially in terms of feasibility, practicality and cost.

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1.0 INTRODUCTION

Seat belts are installed in automobiles to save lives and reduce injuries. Indeed there is ample evidence that firmly establishes the fact that in the event of an accident vehicle occupants who are wearing seat belts have a much lower probability of being killed or injured than occupants who are not wearing seat belts. Yet only a small proportion of automobile passengers and drivers wear their seat belts. Why?

Ignorance of the benefits of seat belts certainly is not a major factor. Most people believe that wearing belts lessens the chance of their being a casualty in an automobile accident. There is, of course, a minority of people who feel that any actual or implied requirement to wear a seat belt is an intolerable infringement of their personal freedom.

However the major reason for not wearing a belt is that it involves too much trouble. Regardless of whether they blame themselves as being "too lazy" or put the blame on the belt system design as too inconvenient, uncomfortable, or confusing, it is the bother of donning, wearing, and doffing a belt system that dissuades most people.

Various approaches have been taken in attempting to increase seat belt usage among automobile occupants. Attempts to make people use belts despite their reluctance to do so have taken the form of legislated enforcement of belt wearing (particularly in Australia) and the installation of a starter interlock system (that prevents the car from being started until occupants have donned their belts).

A less severe approach involves the use of a buzzer and light that come on to remind the forgetful occupant to don the seat belt before the automobile gets underway. This system also has been used in conjunction with the starter interlock system.

One way to reduce the low usage rate is, of course, to design a system that requires no effort on the part of the occupant to use it. The air bag system is one such system since it remains in its stowed condition until activated by vehicle impact, at which time the bags inflate to absorb the impact of the occupants.

Systems that involve no active role on the part of the occupant are termed "passive systems." In addition to the air bag other passive systems are available or under development. There are several types of passive system in which the lap belt and shoulder harness wrap around the occupant automatically. Some systems require the occupant to perform a minimum of action for donning and doffing; these are referred to as "semi-passive systems."

There is still another approach to inducing automobile occupants to use their seat belts. This approach involves improving the design of the standard or "non-passive" seat belt systems in such a say as to virtually eliminate any objections to wearing them. Such improvements are directed specifically toward the factors that previously have deterred occupants from using seat belts. This approach attempts to eliminate or minimize elements in the system that cause inconvenience, discomfort, or confusion. The 1974 system with its integral lap belt and shoulder harness and with the introduction of the emergency retractor represents this design improvement approach.

Of the various approaches just cited this study is primarily concerned with the last. That is, the major effort of this research program has been to determine the sources of discomfort and inconvenience in standard seat belt systems, especially the 1974 system, and to develop improvements that will remove or alleviate them.

The present study also seeks to evaluate some representative configurations of the semi-passive belt system. However, other passive systems such as the air bag are not considered.

Nor have those aspects of the 1974 system that involve other approaches to increase belt usage, such as the starter interlock or buzzer-light reminders, been included in this research.

1.1 Objective of the Study

As indicated by the title, the objective of this study is to determine the "sources and remedies for restraint system discomfort and inconvenience." Such a broad statement of objective requires qualification. As indicated in the previous section the types of restraint systems to be considered are limited primarily to standard seat belt systems with some attention paid to several types of passive (or semi-passive) seat belt systems.

Further qualification of the overall objective requires some elaboration of sub-objectives. In order to determine the sources and remedies of discomfort and inconvenience in restraint systems the following sub-objectives were adopted:

1. Identify specific user complaints about seat belt systems.
2. Determine relative importance of complaints in affecting non-usage of seat belts as interpreted by respondents.
3. Determine relative importance of complaints by the relative frequency of their occurrance.
4. Identify design features in seat belt systems that are primarily responsible for the most prominent complaints.
5. Obtain usage rates for various types of seat belt systems.
6. Identify the distinctive features of seat belt systems associated with especially high or especially low usage rates.

7. Develop corrections for the design features determined to have a negative effect on belt usage rates.

8. Fabricate a recommended seat belt configuration for preliminary evaluation.

9. Carry out preliminary evaluation and report resulting data and conclusions.

And finally, in order to apply the information derived from the accomplishment of these sub-objectives: Prepare recommended standards and/or practices formulated for possible incorporation into Federal Motor Vehicle Safety Standards 208 and 209.

1.2 Approach

The approach adopted for accomplishing the overall study objective involved the following five different methodologies:

1. Literature Research

2. User Survey

3. Automobile Survey

4. Laboratory Mockup Studies

5. Comparative Evaluative Tests

1.2.1 Literature Research

At the outset a search was made through a wide variety of documents for information relevant to the study. The three primary areas of interest were:

1. State of the art, including an interest not only in the currently available variations in seat belt design, but also the evolutionary developments of the past and the proposed concepts of the future;

2. Usage rates, that is, indicators of the proportion of various segments of the automobile-using public who use the various types of seat belt configurations under various conditions; and

3. User attitudes, that is, the attitudes of automobile users, both drivers and passengers, toward various seat belt systems.

1.2.2 User Survey

This survey was carried out among 168 respondents who were administered a special questionnaire designed to elicit specific data, some of which was not available in the literature. In-depth probing as to why seat belts were not used by drivers and passengers was a special feature of the automobile user survey.

1.2.3 Laboratory Mockup

In the laboratory-mockup phase of the study MFI researchers had the first opportunity to introduce design modifications based on data obtained in the previous phases. The mockup included a representative car seat and provisions for setting up innumerable anchor point positions for retractors. Using test subjects having a wide range of anthropometric characteristics plus other differences (e.g., physical handicaps, mentally retarded, wearing police weapons and other equipment, etc.), various types of retractors, buckles, and general system configurations as well as belt geometries were evaluated.

1.2.4 Automobile Survey

In order to acquire first-hand experience with the current state of the art, seat belt systems in more than thirty 1974 vehicles were inspected in detail and a number of pre-1974 models also checked. In addition to providing familiarization with the design of various types of seat belt systems the automobile survey also allowed a comparative evaluation of the "fit" of the different systems on test subjects representative of segments of the population more apt to experience difficulties, such as the fifth percentile female.

1.2.5 Comparative System Evaluation Tests

Based on results from previous phases of the research a seat-belt system incorporating the design features necessary to minimize inconvenience and discomfort was developed. This special system was tested along with five other systems, some experimental, others standard, but all mounted in actual automobiles. The test consisted of evaluations made by 24 selected subjects on each of the six systems plus a complete series of pair comparisons and rank orderings.

The results of these five methodological approaches provided the recommended practices and/or standards proposed for consideration and incorporation into the FMVSS 208 and 209.

2.0 STATE OF THE ART

The state of the art referred to is not that related to the strength or restraining capabilities of seat belt systems but, rather, to methods of getting people to <u>use</u> their seat belts. We will refer to such methods as "use-inducement techniques."

2.1 Development of Use-Inducement Techniques

Lap belts for automobiles first became available in 1955 as optional or self-installed equipment. In 1964 they became standard equipment. In 1968 lap belt and shoulder harness for the outboard front seat occupants became standard equipment in all automobiles sold in the U.S. (Barnes, 1972, p. 2). By 1972 two of every three cars registered in the United States had lap belts and one of every two had lap belts and shoulder harnesses in the front outboard positions (Johannessen and Yates, 1972, p. 3).

The purpose of seat belts is, of course, to reduce injuries and fatalities of occupants of vehicles involved in accidents. As stated earlier it has been irrefutably demonstrated that seat belt systems, particularly those with shoulder harnesses in the front outboard positions (where 85% of the fatalities in car crashes occur), are very effective in protecting the wearer in a crash (Bohlin, 1967; Nelson, 1972; Johannessen and Yates, 1972, p. 3). Moreover people believe that seat belts are effective, with about 90 percent of the respondents in several studies indicating that they believed seat belts saved lives or reduced the seriousness of injury (e.g., Raeder and Kuziomko, 1968, pp. 3-4; Hinkle and Dillon, 1974, p. 28).

Nevertheless, despite the fact that seat belts contribute significantly to safety, and in spite of the fact that most people know this, a number of studies carried out prior to 1974 indicate that a majority of drivers and passengers do not use seat belts. Research shows that lap belt usage usually has been between 10 and 20 percent and lap belt and shoulder harness usage often less than 3 percent (Marzoni, 1971; Greenberg and Mayer, 1963; Raeder and Kuziomko, 1968; Nelson, 1971; Fleischer, 1972).

The most frequent reasons given for non-use of seat belts include inconvenience, discomfort, laziness, forgetfulness, and fear of entrapment (Greenberg and Mayer, 1963; Colborne, et al, 1968; Raeder and Kuziomko, 1968; and Waller and Barry, 1969). According to one study, "almost 70% of the respondents gave bother and annoyance as their reason for non-use or only partial use of their seat belts" (Greenberg and Mayer, 1963, p. 3). This same study indicated that approximately 30% gave entrapment, confinement, or constraint as reasons for non-use of seat belts.

Another study found that 25.2% of the respondents indicated forgetfulness or carelessness and 21.5% indicated discomfort or inconvenience as reasons for not using seat belts (Raeder and Kuziomko, 1968, p. 7). Reasons given by drivers for not wearing the shoulder harness in cars so equipped are shown in Table 1 (from Marzoni, 1971, p. 56). It will be noted that "never formed habit" occurs with the greatest frequency. This is to a considerable extent probably due to the effects of the other major reasons given, viz., confinement, discomfort, inconvenience, and laziness. One study has shown that once the habit of wearing seat belts is acquired through response to special incentives, it often is retained even when those incentives are removed (Perel and Ziegler, 1971).

Since seat belts continue to be installed in cars and since they do reduce death and injury when used, what techniques can be employed to induce reluctant car occupants to wear belts? At least six major methods have been employed during the last decade with varying success. These are:

1. Advertising
2. Legal requirements
3. Reminders
4. Passive restraints
5. Starter interlock
6. Improved design

Table 1

Reasons Why Drivers in Equipped Cars Never Wear Shoulder Harness

Never formed habit	26
Too confining	24
Not comfortable; improper fit	17
Inconvenient, nuisance	11
Too lazy; don take time/trouble	10
Doubt value as safety measure	9
Not necessary for short/local trips	7
Belt and harness duplicate one another	6
Poor design, engineering, construction features	5
Exposure to accident where harness was detrimental	1
Not necessary for travel at lower speeds	

(Percentages add to more than 100% due to multiple responses)

From Marzoni, 1971, p. 56

2.1.1 Advertising

Even before lap belts were made standard equipment in 1964 numerous advertising campaigns were mounted to persuade people to purchase, install, and use lap belts. However some five years after lap belts first came on the market less than 5% of private vehicles were equipped with them, and less than 30% of the occupants of such vehicles used the belts (Tourin and Garrett, 1960). At that time one study found that an appeal to the masculinity of the potential purchaser (i.e., showing that professional racing drivers used seat belts) was found to be more successful than scare tactics (Blomgran and Scheuneman, 1961).

There was a belief among 73% of driving respondents in one study that public service announcements on radio and TV have helped others to wear their seat belts. But over half of these claim that such advertising has had no effect on them (Marzoni, 1971).

Other research has shown that in California an intensive campaign of radio and TV public service announcements professionally designed to increase seat belt usage had no significant effect (Fleischer, 1973). On the other hand, in Britain, a multi-media approach (i.e., broadcast, press, seminars, meetings, posters, etc.) increased usage of seat belts among drivers from 16% to 29% (Morris, 1972).

Nevertheless advertising probably will remain a relatively ineffective technique in the United States. As one authority has commented: "Although intensive multi-media campaigns may result in a doubling or trebling of safety belt use over current levels (10-15%), it is unlikely that voluntary use of safety belts will increase substantially, say beyond 50%, without major changes in vehicle configuration or legal requirements." (Fleischer, 1973, p. 11).

2.1.2 Legal Requirements

In Australia seat belt usage became compulsory in the State of Victoria in December 1970 and throughout the rest of the country by January 1972. In New South Wales seat belt usage increased from 25% before legislation to 75% shortly after the law was passed (Henderson, 1972). A similar change in usage rate occurred in Victoria (Andreassend, 1972).

So far as we know at present the only community in the United States that has enacted legislation making the use of seat belts mandatory is the town of Brooklyn, Ohio. One report indicates that the result has been a 50 to 70% increase in the use of seat belts (Pulley, 1972).

A law requiring the use of seat belts in automobiles has been passed in Puerto Rico, and at least ten State legislatures currently are considering such a law. Proposed revisions to the Highway Safety Standards include a requirement that each State enact legislation enforcing the use of seat belts (Federal Register, 1972). It is unlikely, however, that the U.S. Congress will pass such a law in the near future since apparently Americans are not in favor of being legally obliged to wear seat belts. In Australia a public opinion poll showed that over 75% agreed with the compulsory belt-use legislation (Vulcan, 1972), whereas one survey in the U.S. found that only about 35% of the respondents believed that a federal law should require seat belt use, while 43% were opposed to such a legal requirement (Raeder and Kuziomko, 1968). In another study, 7% of the 1576 respondents indicated that they did not feel that legislation requiring the use of seat belts should be passed (Barnes, 1972).

2.1.3 Reminders

As of January 1, 1972 all automobiles manufactured for sale in the United States were obliged by Federal Motor Vehicle Safety Standard 208 to have a warning system consisting of a buzzer and light to remind front seat occupants to fasten their lap belts. As noted above, forgetfulness was cited as a major reason for not using seat belts. Results of a preliminary study on fleet cars of a service organization tend to indicate that reminders do have an appreciable effect on seat belt usage, which increased from 25.5% to 68.4% (Bintz, et al, 1974).

Before the advent of reminder systems as standard equipment a Ford-sponsored study first selected test subjects who reported that they seldom used belts. They then had them drive test cars with reminders installed for thirty days. Subsequent to this exposure to the reminders, in one test 56%, and in another 76% of the subjects reported that they used the belts "almost always" or "more than half the time" (Shaw, 1971a).

A General Motors study reported that visual inspection of drivers showed that 43% of drivers in cars with reminder systems were wearing seat belts compared to 19% in cars without the system (Referenced in Cohen and Brown, 1973, p. 5). Another study indicated that there was a 54% usage rate in cars having the buzzer-light warning, compared with a 29% rate in similar cars not having it (Ford Motor Company, 1972a).

However a study in which automobile drivers were observed while operating their vehicles found virtually no difference between seat belt usage in 1972 model vehicles that had the reminder system (manufactured after January 1, 1972) and those that did not (manufactured in the latter part of 1971), the rates being 23% and 22% respectively (Robertson, 1974). An Insurance Institute for Highway Safety study found seat belt usage rate to be 18% in vehicles equipped with the buzzer-light reminder system and 16% in non-equipped vehicles under the same conditions (Referenced in Cohen and Brown, 1973, p. 6).

The discrepancies between the results of these studies probably are due to various differences in the methodologies employed. For example studies in which self-reporting of belt usage is employed can be expected to show higher usage rates than studies in which data were gathered by observation or recording devices, as had been shown in research that used both self-reporting and the more objective techniques on the same subjects (Cohen and Brown, 1973; Waller and Barry, 1969). On the other hand the nature of the test-subject sample may have an effect. Thus new car owners apparently are more prone to wearing belts in response to the reminder system than are owners who have had their cars for several months. One study found that observed belt-usage rates in vehicles with reminders tends to drop about 17% from the period when the car has been owned for one month to the period when it has been owned for three months (Ford Motor Company, 1972b).

Most studies, however, show an increase in usage rate with the reminder system. One of the more conclusive demonstrations of this comes from the study conducted by National Analysts using automobiles of rental car agencies in Fayetteville, North Carolina. Without the drivers' knowledge, counters recorded seat belt usage, and subsequent to the return of the car the drivers were interviewed. A three-point belt system with detachable shoulder harness and without an inertia reel retractor was the configuration tested with and without a reminder system. According to the recording counters, without the reminder belts were worn on 23% of the trips; with the reminder they were worn on 51% of the trips, which represents a statistically significant increase. Table 2 summarizes the self-reported use of the seat belts, and it can be seen that there is an increase in three of the four conditions when reminders were involved (Cohen and Brown, 1973).

The question arises as to how comparable seat belt usage behavior in rental cars is to seat belt usage behavior in personal cars. When the test subjects who used rental vehicles with the reminder system were asked what sort of action they would take if the system were installed on their personal car, 59.6% said they would use it, 11.2% said they would modify it, and 29.8% said they would disconnect it (Cohen and Brown, 1973, p. 26).

2.1.4 Passive Restraint Systems

According to the Federal Motor Vehicle Safety Standard 208 a passive restraint system is one that meets crash protection requirements "by means that require no action by vehicle occupants." If the occupants had to do nothing to deploy or remove a passive system this should satisfy such reasons for not using belt systems as forgetfulness, laziness, and inconvenience.

Passive protection installed in cars was to become mandatory for cars manufactured during the 1976 model year, but this requirement has been postponed until the 1977 model year.

Table 2

Summary of Reported Use of Seat Belt In Rental Cars With and Without Reminder System

	Without Reminder System		With Reminder System	
	#	%	#	%
Use lap belts on more than half the trips less than 25 miles	50	51.0	126	67.88
Use lap belts on more than half the trips more than 25 miles	61	63.6	148	76.3
Use shoulder belts on more than half the trips less than 25 miles	3	3.1	13	7.0
Use shoulder belts on more than half the trips more than 25 miles	10	10.4	15	7.7

Based on data in Cohen and Brown, 1973, p. 22.

This report will deal with passive systems in greater detail in Section 3.6. At this point, however, we will be concerned with passive systems only from the perspective of their use as a method (one of the six we are considering) to induce increased usage rates. But first it is necessary to indicate that their are a number of different types of passive systems. One comprehensive study has categorized passive systems into seven classes with over 40 subclasses and types (Phillips, 1973). However there are only two major types of passive restraint system that have been in use outside of strictly experimental installations, namely, the air bag, and the passive seat belt systems.

In the air bag system the compact bag located in front of occupants is inflated during vehicle impact, absorbing the force of the rapidly decelerating occupant. Effective January 1, 1972 air bags became a legally acceptable substitute for seat belts and the buzzer-light reminder system and, subsequently, for the ignition interlock system. However the number of vehicles sold with this system amounts to only a few thousand, and many of those were sold to corporate fleets for field testing.

One study found that 59% of its respondents knew so little about the air bag system that they could not express an opinion about it. Of the rest, 69% had generally favorable comments on the system (Marzoni, 1971).

In the preceding study, no basis of comparison was made with any other system and the respondents were expressing general attitudes toward air bags without reference to, say, seat belts. In another study, however, respondents were required to make a choice between the air bag system and other systems. Conducted in 1971, this study involving over 500 test subjects who were owners of 1968 model or newer cars found that in initial preferences, 40% of the respondents indicated a preference for seat belts (i.e., of the standard non-passive type), 19% indicated a preference for air bags and the rest made other choices. After the test subjects had witnessed filmed demonstrations of the various systems the indicated preferences shifted to 82% for seat belts and 5% for air bags (Baxter, 1972).

In a study carried out in Michigan 84% of the 1576 respondents to a questionnaire indicated that they preferred seat belts to air bags while only 5% indicated that they preferred air bags (Barnes, 1972).

The results of these studies suggest that air bags generally would not be acceptable to the American driving public.

The passive system that has received most attention in the United States has been the air bag. In Europe most attention has been given to the passive seat belt system. A distinction is made between passive and semi-passive seat belt systems. "A passive system <u>must</u> deploy about the occupant <u>upon ingress</u> with no action on his part...... A semi-passive system must be stowed on the retaining hook....by the occupant upon egress and removed from the hook upon ingress" (Johannessen and Yates, 1972, p. 6).

One study showed that among 325 Swedish drivers and front seat passengers there was general satisfaction with a passive seat belt system. In comparison with their own car 74% of the respondents indicated that the passive system was "very much better" and 16% indicated that it was "somewhat better." It should be noted that people who gave favorable responses were to a significant degree users of cars without retractor-belts (Bohlin and Pilhall, 1972).

In one phase of the current study it was found that 15 out of 18 (83%) of a group of test subjects indicated their preference for a semi-passive system over a standard 1974 (Vega) seat belt system after having tried both.

2.1.5 Ignition Interlock

Apart from the few thousand cars furnished with air bags all cars manufactured for sale in the United States after August 15, 1973 have been outfitted with an electrical ignition interlock that prevents the car from being started until the seat belts of all front seat occupants have been engaged. For the two outboard front seat positions the system includes a non-detachable lap/shoulder belt combination with an emergency retractor on the shoulder belt.

It is difficult to measure the effects of the interlock system on seat belt usage since its implementation was accompanied by a radical change in seat belt design which could also be expected to have a modifying influence on the seat belt usage rate. The problem is in the separation of the effects of these two simultaneously introduced design changes.

Table 3 shows the seat belt usage rates observed in 1973 and 1974 vehicles in several east coast cities. The investigator and author of the report states: "This study indicates that belt use was increased in urban areas by the introduction of the interlock system in 1974 vehicles" (Robertson, 1974, p. 15). There is no doubt that the data indicate an increase in the proportion of people using seat belts in 1974 cars, but there is considerable doubt that this is attributable solely to the interlock system.

A number of studies have shown that the installation of an ignition interlock system does indeed increase seat belt usage appreciably. One of the earliest of such research projects was carried out in 1970 by NHTSA using GSA cars that had specially-installed starter interlock systems. This study found that some 80% of the drivers indicated that the interlock system was acceptable (Perel and Ziegler, 1971). Several other studies found belt usage rates in cars having the starter interlock system ranging from about 60 to 90% (Shaw, 1971a; 1971b; Ford study referenced in Pulley, 1972, pp. 3-4; Ford study and General Motors study referenced in Robertson, 1974, pp. 15-16).

The National Analysts study (Cohen and Brown, 1973) using rental cars in Fayetteville, North Carolina provides some data showing the effects of belt usage rates of the interlock system independent of other design changes. In one phase of this study the usage rate was determined for a three-point belt system with an integral shoulder harness on an emergency retractor with a reminder system but without a starter interlock system. In another phase the usage rate was determined for a belt system identical to the first except that it had a starter interlock system. Table 4 presents a summary of results of the reported use of seat belts under these two conditions. It will be noted that the reported use is somewhat higher

Table 3

Comparison of Belt Use in 1973 Automobiles Equipped With Buzzer-Light Systems and 1974 Automobiles Equipped With Interlock Systems

Belt Use	1973 Models Buzzer-Light Equipped		1974 Models Interlock Equipped	
	N	%	N	%
Lap and Shoulder	192	8	267	44
Lap Only	418	19	52	9
None	1,636	73	287	47
	2,246	100	606	100

Based on data in Robertson, 1974, p. 7

Table 4

Summary of Reported Use of Seat Belt In Rental Cars With and Without Starter Interlock System

	Without Interlock System		With Interlock System	
	#	%	#	%
Use lap belts on more than half the trips less than 25 miles	149	72.7	62	83.8
Use lap belts on more than half the trips more than 25 miles	136	75.2	51	85.0
Use shoulder belts on more than half the trips less than 25 miles	128	62.8	58	78.4
Use shoulder belts on more than half the trips more than 25 miles	116	64.1	51	85.0

Based on data in Cohen and Brown, 1973, p. 22

for the interlock configuration, although the differences are not statistically significant (Cohen and Brown, 1973).

The question again arises as to the comparability of seat-belt usage behavior in rental cars with seat-belt usage behavior in personal cars. When the test subjects who used rental vehicles with the starter interlock system were asked what type of action they would take if this same system were installed in their personal car, 47.7% said they would use it, 18.9% said they would modify it, and 33.3% said they would disconnect it (Cohen and Brown, 1973, p. 26).

2.1.6 Improved Design

Logically if seat belt systems were designed specifically to satisfy the complaints of vehicle occupants who indicate they do not wear seat belts because they are inconvenient or uncomfortable, the seat belt usage rate could be expected to increase. The 1974 seat belt system with its integral lap-belt/shoulder harness configuration and with the shoulder harness on an emergency retractor does incorporate significant improvements designed to reduce inconvenience and discomfort. Consequently these design changes should induce more people to use seat belts. And indeed, as we have observed, research indicates that usage rates have increased with seat belt systems in which these design characteristics hav been implemented. However as we have also seen, in 1974 automobiles the introduction of improved seat belt design was accompanied by the introduction of the starter interlock system which makes it difficult to isolate the effects of each on seat belt usage.

Again, data from the National Analysts study (Cohen and Brown, 1973) is pertinent. In one phase rental cars were outfitted with a three-point belt with a detachable shoulder harness that was stowed by folding onto overhead hooks. This system had a warning device but no starter interlock system and was, therefore, similar to the seat belt system in 1972 and 1973 automobiles.

In another phase cars were furnished with a three-point belt with an integral shoulder harness on an emergency retractor. This system had a sequential warning system but no interlock system. The latter system was similar to the system installed in 1974 cars in that it had the major design innovations in the belt and retractor design. But it differed in not having the starter interlock system.

Table 5 shows the usage rates of these two systems. It can be seen that the 1974-type system had little effect on the usage rate of lap belts, but the increase in the usage rate of shoulder harnesses could be said to be spectacular.

2.1.7 Observations On Techniques To Induce Usage

We have considered six techniques for inducing seat belt usage. Of these advertising over radio and TV appears to be completely ineffective in the United States. It is possible that an intensive multi-media campaign might increase seat belt usage somewhat, but it is doubtful if the change would be considerable or long lasting. The effects of a continuous campaign eventually would wane and the expense involved probably would result in this method having a very low cost-effectiveness.

For the present and the near future, federal legislation of mandatory seat belt usage appears unlikely since apparently Americans tend to be against such an approach. Some state legislatures are considering such a law and at least one community (Brooklyn, Ohio) had already enacted a mandatory seat belt usage law. But even if some states and more communities do decide to implement this approach, most Americans for some time to come will not be affected.

Of course a system that involved absolutely no effort or discomfort on the part of the user would be ideal from a convenience point of view, but such a system may not be satisfactory from a protection point of view. The extreme example of such a system is a zero system, or no system at all. Some passive systems may be very attractive in terms of comfort and convenience but fall short of meeting Federal Motor Vehicle Safety Standards. At present this appears to be the case with some of the passive seat belt systems evaluated by the public. However design improvements in the near future may make such systems acceptable in terms of both convenience and protection.

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Table 5

Summary of Reported Use of Seat Belt in Cars With and Without Lap Belt With Integral Shoulder Harness on an Emergency Retractor

	Without Shoulder Harness Retractor, etc.		With Shoulder Harness Retractor, etc.	
	#	%	#	%
Use lap belts on more than half the trips less than 25 miles	126	67.8	149	72.7
Use lap belts on more than half the trips more than 25 miles	148	76.3	136	75.2
Use shoulder belts on more than half the trips less than 25 miles	13	7.0	128	62.8
Use shoulder belts on more than half the trips more than 25 miles	15	7.7	116	64.1

Based on data in Cohen and Brown, 1973, p. 22.

At present the air bag system meets Federal Motor Vehicle Safety Standards for protection and its inconvenience to the car occupant is minimal. Nevertheless drivers appear to prefer the non-passive seat belt system to air bags according to several opinion surveys.

The remaining three techniques for inducing belt usage, i.e., reminders, starter interlock, and improved design all have been incorporated in the 1974 seat belt system. As we have seen, research results relative to the effects of each of these techniques on usage rates have been less than clear-cut. In the case of reminders different studies have produced different results. And in the case of the starter interlock and improved seat belt design it is difficult to segregate the effects of each.

The only research of which we are aware that allows comparative evaluations of the usage rates obtained through the same continued conditions on the major seat belt configurations from the pre-1972 to the 1974 systems was the National Analyst study (Cohen and Brown, 1973). A summary of some of the pertinent results of this study is presented in Table 6. The evidence of this and other studies seems clear on one point: subsequent to the implementation of these three inducement techniques seat belt usage -- especially shoulder harness usage -- has increased considerably.

The present study is, of course, concerned primarily with the matter of improved seat belt design, which addresses itself directly to the reasons most frequently given as to why seat belts are not used. Of the three techniques employed in the 1974 system it is in seat belt design that the most effective inducement improvements still can be made.

The objective of this study is to identify those improvements in current seat belt design that will induce a greater seat belt usage rate.

Table 6 - Summary of Reported Use of Seat Belt in Cars with Four Different Types of Seat Belt System Configurations

	Pre 1972 Type (Detachable Shoulder Harness With No Warning System)		1972-1973 Type (Detachable Shoulder Harness With Warning System)		1974 Type (Integral Shoulder Harness, Emergency Retractor, Warning System, <u>But No</u> Starter Interlock)		1974 Type (Integral Shoulder Harness, Emergency Retractor, Warning System, <u>With</u> Starter Interlock)	
	#	%	#	%	#	%	#	%
Use <u>lap</u> belts on more than half the trips <u>less</u> than 25 miles	50	51.0	126	67.8	149	72.7	62	83.8
Use <u>lap</u> belts on more than half the trips <u>more</u> than 25 miles	61	63.6	148	76.3	136	75.2	51	85.0
Use <u>shoulder</u> belts on more than half the trips <u>less</u> than 25 miles	3	3.1	13	7.0	128	62.8	58	78.4
Use <u>shoulder</u> belts on more than half the trips <u>more</u> than 25 miles	10	10.4	15	7.7	116	64.1	51	85.0

Based on data in Cohen and Brown, 1973, p. 22

3.0 EXECUTION AND RESULTS OF PRESENT STUDY

The present study was designed to determine those factors in seat-belt design that disuade usage because they produce discomfort, inconvenience, and/or confusion. The interest of this study was limited to the belt systems alone, and it did not investigate problems associated with related equipment such as ignition lockouts and reminder buzzers.

The study was primarily concerned with seat belt systems in 1974 model automobiles. It also investigated experimental passive belt systems, however, and considered the nature of the problems encountered in the usage of pre-1974 seat belt systems.

3.1 Methodology

A wide range of investigative and analytic techniques was employed. These can be categorized into five major steps or phases: (1) literature research; (2) a user opinion survey; (3) mockup studies; (4) a new-car evaluation study; and (5) optimized system tests.

3.2 Phase I - Literature Research

The literature research phase continued throughout the entire study. Its function was to inform us of any type of discomfort and inconvenience problems that may have occurred with any type of seat belt system, and to keep us abreast of the latest research concerned with seat belt design and consumer opinions and usage rates.

The many references used in the previous and following sections show the application of this phase of the study; the bibliography lists the sources reviewed.

3.3 Phase II - User Opinion Survey

During the period of August-October 1973 MFI conducted an independent survey among automobile users, both drivers and passengers, to determine their opinions about various aspects of pre-1974 seat belt systems. The purpose of the survey was to elicit detailed, design-related information concerning belt-system annoyances that could be identified with specific restraint system components or geometry since most previous opinion data was too generalized to permit such identification. After several pilot trials the special questionnaire shown in Appendix A was used.

The questionnaire was administered to automobile users in parking lots, at shopping centers and business complexes, to friends, relatives, and neighbors of MFI staff members as well as to other randomly selected test subjects. No special effort was made to see that the subject sample conformed to any prescribed set of characteristics. The means and ranges of age, weight, and stature of the 168 respondents to the questionnaires are given in Table 7.

As shown in Table 8 the male sample tended to be somewhat older and taller than males in the previous studies shown. However all the means for the females queried in this study fall within the ranges of the means for the previous studies. While the sample is reasonably representative of the three characteristics it is unlikely that these characteristics are any more relevant to the nature of the information being sought by the questionnaire than a number of other characteristics such as educational background, occupation, socio-economic status, etc.

As indicated, the purpose of the survey was to obtain special information from automobile users, and so long as a broad spectrum of types of users was contacted the nature of the frequency distribution was unimportant. The intention was not to compile another statistical analysis of complaints but, rather, to provide additional insurance that one or more previously undocumented reasons for not using seat belts -- the knowledge of which could contribute to improved design -- has not been overlooked.

A characteristic of the subject sample that would appear particularly relevant is seat belt usage rate. This information is given in Table 9. A problem in comparing these data with usage rates found in other studies is the multiplicity of conditions and methods under which the material was obtained and the numerous forms in which it was organized and presented.

Table 7 - Means and Ranges of Ages, Weights, and Statures of Respondents to Opinion Survey

		Age (years)		Weight (pounds)		Stature (inches)	
	N	Mean	Range	Mean	Range	Mean	Range
Males	88	44.1	19-87	171.5	130-220	71.0	63-75
Females	80	35.4	17-71	138.2	110-250	63.7	60-67
Total	168	40.0	17-87	155.7	110-250	67.6	60-75

Table 8 - The Means of Ages, Weights, and Statures of Subject Samples in Four Phases of the Present Study and Four Previous Studies

		MALES				FEMALES			
		N	Age (years)	Weight (pounds)	Stature (inches)	N	Age (years)	Weight (Pounds)	Stature (inches)
Present MFI Study	Opinion Survey	88	44.1	171.5	71.0	80	35.4	138.2	63.7
	MFI 1971[1]	40	38.3	161.1	68.2	40	38.4	129.1	63.2
	HEW[2]	3000+	---	168	68.2	3000+	---	142	63.0
	DOT[3]	509	38.0	179.7	68.8	524	32.5	132.6	63.5
	DOT[4]	50	29.1	166	69.2	50	31.7	139	63.7

[1]Woodson, et al., 1971; [2]U.S. Dept. of Health, Education, and Welfare, 1965;
[3&4]Stoudt, 1969 (included two studies and two subject samples).

Table 9 - Lap Belt and Shoulder Harness Usage Rates Among MFI Survey Respondents

Lap Belt			Shoulder Harness		
Usage	N	%	Usage	N	%
Always	36	21	Always	12	7
Sometimes	92	55	Sometimes	12	7
Never	40	24	Never	144	86
Total	168	100	Total	168	100

But the usage rates of these MFI respondents certainly fall well within the ranges of those of other studies of pre-1974 cars, representative lap belt usages ranging between about 25% and 79% and shoulder harness usages ranging between about 2.5% and 33% (Marzoni, 1971; Greenberg and Mayer, 1963; Raeder and Kuziomko, 1968; Fleischer, 1972; 1973; Cohen and Brown, 1973; Robertson, et al, 1972).

Table 10 shows the proportion of yes/no responses to questions concerning specific experiences with problems of discomfort, confusion and inconvenience with pre-1974 seat belt systems. It will be noted that the greatest difficulties occurred with: (1) belts from different seat positions becoming entangled with one another; (2) the shoulder harness crossing the chest area in such a way that it is annoying; (3) methods for adjusting the length of the belts being difficult to understand; (4) arranging belts properly for making the connection taking too much time; (5) confusion as to which belts go together.

It is interesting that the three areas which seemed to present no problem at all were related to the effects the shoulder harness might have as it comes into contact with the user. This tends to emphasize the seriousness of the second most important problem in the series, i.e., the shoulder harness crossing the chest area or neck region in such a way that it is annoying.

As already indicated, only a very small proportion of the respondents had really made use of the shoulder harness. The majority of them solved the various shoulder harness problems by avoiding them, i.e., by not using the shoulder harness.

However the survey results turned out to be useful in many ways. They tended to corroborate objectively several theories that MFI had concerning anti-usage attitudes. For example, we had considered that improper crossing of the chest and neck area by the shoulder harness would be a major source of discomfort. This was clearly corroborated by survey results.

Although the chest-crossing geometry of the shoulder harness continues to be a problem in many 1974 seat belt systems,

Table 10 - Proportion of Yes/No Responses to Questions Concerning Specific Experiences With Problems of Discomfort, Confusion, and Inconvenience With Pre-1974 Seat Belt Systems

	Responses (%) Yes	No
Belts get tangled with other belts.(confusion)	35.9	64.3
Shoulder harness crosses the chest area so it is annoying (discomfort)	33.3	66.7
Do not understand how to lengthen and how to shorten belts (confusion)	31.3	68.7
It takes time getting belts properly arranged for connecting (inconvenience)	31.3	68.7
Cannot tell which belts go together (confusion)	28.6	71.4
Lap belt rides up on my stomach (discomfort)	25.0	75.0
Belts are hard to reach because of where they are installed (inconvenience)	23.5	76.5
Belt adjustment devices are awkward to manipulate (inconvenience)	18.8	81.2
When the shoulder harness is fastened to the lap belt and becomes twisted, I cannot figure how to untangle the belts (confusion)	14.3	85.7

Table 10 (Continued)

	Responses (%) Yes	No
I cannot reach dashboard controls when shoulder harness is secured (inconvenience)	12.5	87.5
The lap belt tends to tighten up too much as I drive along (discomfort)	12.5	87.5
Shoulder harness falls off my shoulder (discomfort)	7.7	92.3
Shoulder harness cuts across my neck (discomfort)	7.1	92.9
The shoulder harness webbing seems to be too stiff (discomfort)	7.7	92.3
Cannot tell where to insert belt into the buckle (confusion)	6.2	93.8
Cannot be sure how to pull lap belt so the retractor will not lock too soon (confusion)	6.7	93.3
The buckle or adjusting hardware seems too heavy (discomfort)	6.7	93.3
Shoulder harness rides across my face (discomfort	0	100
The shoulder harness seems to have a rough surface (discomfort)	0	100
The shoulder harness rests too heavily on my shoulder (discomfort)	0	100

a number of other difficulties identified in pre-1974 systems by the survey have now been partially corrected in the 1974 systems. Thus, seldom do front seat belts become entangled with one another now, nor is there a problem in adjusting the length of the belt (although entanglement continues to exist in rear seats of 1974 cars). On the other hand 1974 belt systems occasionally still ride up on the stomach, and in some bench seat configurations it still is possible to be confused as to which belt attaches to which buckle.

In the sections of the questionnaire that gave respondents an opportunity to elaborate on observations or make suggestions we found that we had anticipated virtually all the useful recommendations. One point however is worth repeating. A very stout and bosomy woman said that it was impossible for her to put on the shoulder harness since it was not long enough to accommodate her dimensions. But because she believed thoroughly in the effectiveness of shoulder harnesses she had a webbing extension specially made and installed which allowed her to use the shoulder harness in her car.

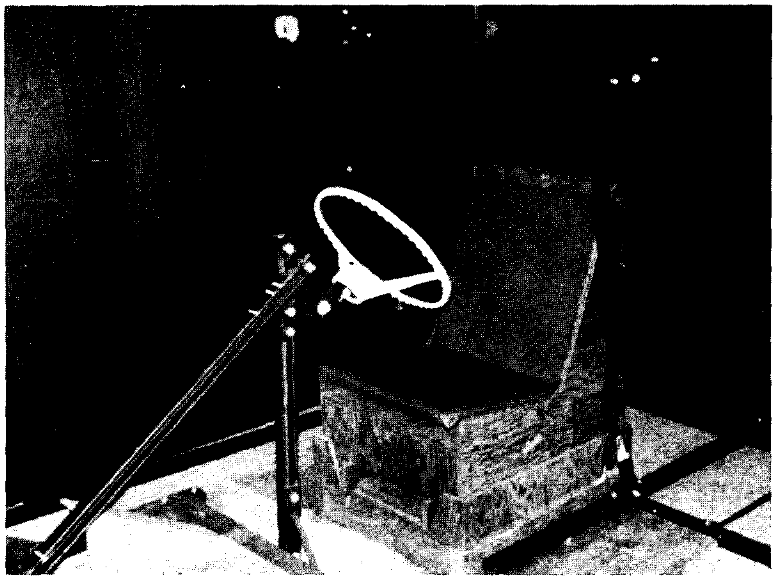
3.4 Phase III - Mockup Studies

In order to be able to experiment with various seat belt configurations, modifying anchor points or exchanging components for test subject evaluations, a mockup offered the ideal evaluation situation. In the latter part of 1973, but before the 1974 model automobiles became generally available, MFI commenced mockup studies that continued for several months, so that the latter stages of Phase III were carried out simultaneously with the Phase IV, New Car Evaluation.

A primary objective of the mockup studies was to develop design criteria for a recommended optimized seat belt system, one that eliminated or minimized the principal causes for confusion or lack of convenience and comfort.

3.4.1 Equipment

The heart of the mockup system was a seat having the dimensions shown in Figure 1. Behind and at both sides of the seat was an adjustable metal framework on which seat belt



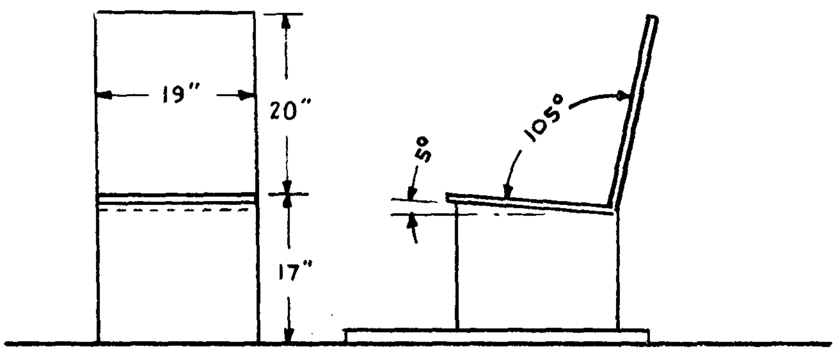


Figure 1 - Mockup Seat With Dimensions

components such as retractors, belt and hardware components could be mounted in virtually any position relative to the seat.

A number of different types of retractors were installed in the mockup, but most tests were carried out with the following systems.

One retractor system was used for two purposes, the first being to check anchor-point positions and belt geometry. For this purpose the positions of the lap-belt retractor, the shoulder-harness retractor, and the buckle strap could be adjusted three-dimensionally. A swivel-mounted webbing guide also allowed refined adjustments of the approach of the shoulder harness to the torso.

The point at which the shoulder harness was attached to the lap belt also was adjustable. This was accomplished by means of Velcro material which offered substantial resistance to shear forces yet allowed easy, rapid changes of the juncture point. A 3-inch strip of male Velcro was sewn on the end of the shoulder harness, and a 10-inch female strip was sewn on the end of the lap belt, thereby allowing for considerable flexibility in positioning the joining point between the shoulder harness and the lap belt.

The second purpose of the retractor system (including use of Velcro on the end of the lap belt) involved checking five different types of buckles mounted in different positions. Each of the buckles as well as each of their associated latch plates was attached to a 5-inch strap onto which was sewn a strip of male Velcro. A strip of female Velcro was sewn to the end of the strap of the non-retractor segment of the belt to which buckles usually are attached. This allowed either a buckle or a latch plate to be attached to either the retractor segment or the non-retractor segment of the belt system. Thus, in this mockup of the driver's position each buckle and latch-plate configuration could be reversed, the buckle being attached alternately to the left or right side.

The five different buckle configurations (see Figure 2) were:

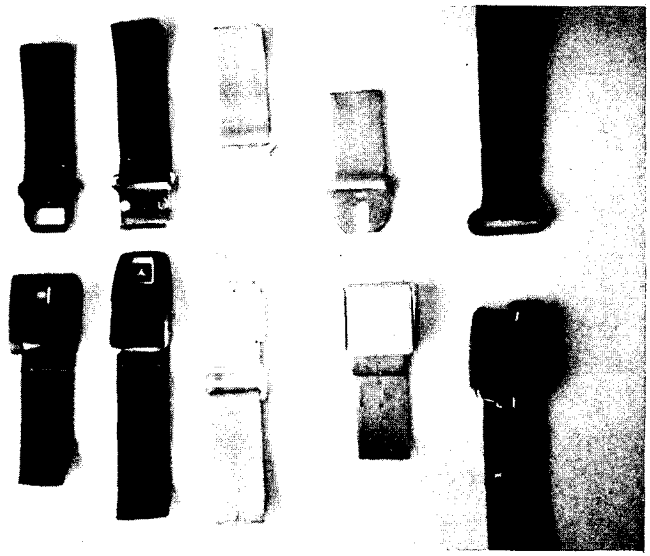


Figure 2 - Five Buckle Designs Compared

a. Push-button - similar to those currently utilized on most 1974 American cars.

b. Lift-latch - similar to those used for aircraft passenger seats.

c. A magnetically locked Lift-Latch, formerly used on Mercedes Benz automobiles.

d. MFI Squeeze-Latch - a buckle designed by MFI. The buckle consisted of two prongs that were squeezed together by means of finger grips on each side of the buckle assembly, thus allowing the buckle to be removed from a latch plate.

e. Push-Pull (Instinctive) Latch - a buckle used by several foreign manufacturers. The buckle casing slides back and forth to operate internal latches. When the buckle is pushed toward the latch plate, the buckle mechanism allows the two pieces to join and lock. When the buckle cover is pulled away from the latch plate, the mechanism releases the latch plate.

A second retractor system was also mounted in the metal framework for use with the seat. It's function was to determine the magnitude of force acceptable to subjects in the pull-out operation of the lap belt and during a "lean-forward" movement of the test subject's torso against the shoulder harness. Two simulated retractors consisted of straps mounted on reels provided with a manually adjustable tension or force regulator.

In conjunction with the mockup study but not actually making use of the seat and retractors was another experiment designed to determine subjects' preferences with respect to buckle button size, shape, and release force. Seven different types of buckles (see Figure 3) were evaluated by subjects individually while seated in a chair, and compared with the entire array of buckles presented on a special holding frame.

3.4.2 Test Subjects

A total of 37 test subjects was used in the mockup studies. For the sake of economy the test subject population

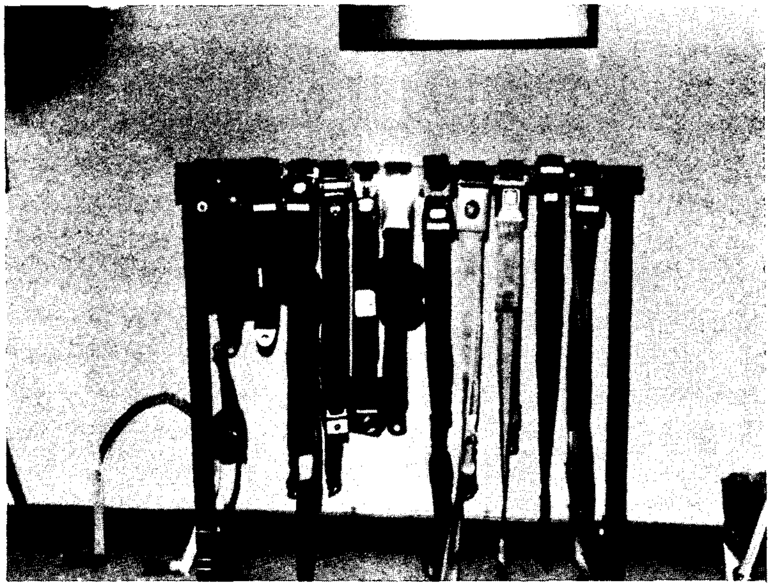


Figure 3 - Buckle Push-button Evaluation

purposely was kept small but selectively unique. That is, a number of "special case" subjects were selected on the basis of suspected correlations between their unique characteristics and key restraint system or component features in addition to a randomly-selected number of subjects. Table 11 provides a breakdown of subject characteristics.

Because all kinds of people with varying infirmities ride in autos and should therefore be accommodated by a restraint system, several subjects were selected to demonstrate possible interactions between typical infirmities and seat-belt fit and use. Among our subject population were the following:

a. Three subjects with low-to-medium mechanical aptitude.

b. Two subjects with low I.Q.

c. Two with mild and two with medium-to-severe arthritic conditions.

d. One with almost complete paralysis of arms and hands.

e. One with a stiff right knee (so that the leg would not bend for entering the back seat).

f. One triple-amputee (including a right prosthetic arm).

g. Two pregnant women ($6\frac{1}{2}$ months and 9 months).

h. One extremely obese female.

Although this subject sample obviously does not represent a statistically valid representation of the total user population with regard to subject responses, it did provide considerable insight into design-related questions and user interaction with key belt-system parameters.

Not all test subjects were used in all the tests carried out in the mockup but rather were selected on the

Man Factors, Inc.
San Diego, California

Table 11 - Some Characteristics Of Test Subjects Participating in Phase III

Subject Number	Sex	Age (Yrs.)	Weight (Lbs.)	Height (Ins.)	Seated Height (Ins.)	Hip Breadth (Ins.)	Pelvic Breadth (Ins.)	Special Characteristics
1	M	55	170	70½	35½	15½	13¼	Mild arthritic
2	M	49	180	69½	36½	15¼	9 7/8	
3	M	59	170	67	34	15½	11	Stiff right knee
4	F	37	135	60	31	15 3/4	9½	
5	F	62	80	58	27 3/4			Severe arthritis
6	M	56	215	76	37 7/8	17½	13 3/4	
7	F	73	140	61	31½	16	11¼	Arthritic, weak right & left thumbs
8	M	59	180	72	36½	15¼	10	
9	M	60	156	70½	36	14½	9 1/8	
10	F	22	133½	60	31 3/4	15¼	10¼	Mild mental retardation
11	F	28	242	60	33	17	12	Extreme obesity
12	M	49	170	72	36 1/8	15 3/4	12	Mild arthritis, hands only
13	M	15	130	70	34	14	10	Equiv. age 12 yr.
14	F	22	150	72	36¼	17¼	11½	Pregnant 6½ mo.
15	F	33	96	62	32 3/4	15¼	10	Polio, could not fasten belts without help
16	M	28	185	68½	37	15½	11¼	Triple amputee; prosthetic right arm to shoulder
17	F	47	100	60	31	12½	9	
18	M	27	225	73	37 3/4	18 3/4	11¼	
19	F	41	120	65	33	14¼	10½	
20	F	22	100	61	33½	15	9¼	
21	M	32	165	73	34¼	15	10	Left hand prosthetic, mid forearm (4 yrs)
22	F	21	109	60	31 7/8	14¼	9½	
23	F	71	134	62	31	15	9	Severe arthritis, hands
24	M	29	160	70	35	14½	9 1/8	
25	M	37	156	72 3/4	36 3/4	15	10½	Police - weapons, etc.
26	M	30	176	70½	35½	16¼	10¼	Police - weapons, etc.
27	F	30	150	66½	33 3/4.	16 5/8	11	
28	M	48	165	71½	33 3/4	14½	11½	
29	F	38	116	64	32 3/4	13 3/4	8½	
30	M	22	160	72	---	---	---	No muscle use below shoulders, wheelchair
31	F	42	210	64½	35 3/4	18	14½	Extreme obesity
32	F	32	215	63	32 3/4	18½	12¼	Extreme obesity
33	F	11	78	58½	28¼	12	7¼	Child
34	F	10	73	56½	28¼	11¼	6 3/8	Child
35	F	22	138	65	33 3/4	14 3/8	10	Pregnant 9+ months
36	M	11	80	57½	28½	11 3/8	7 7/8	Child
37	M	11	80	58½	27 3/4	10½	8½	Child

basis for need for their particular characteristics.

3.4.3 Procedures

a. Buckle Configuration Preference Study

With the subject seated in the mockup, the positions of the retractors, webbing guide and the point at which the shoulder harness joins the lap belt were adjusted until the most satisfactory belt geometry was attained for each subject. Such a geometry resulted when the harness crossed the shoulder midway between the neck and acromium, passing over the sternum midway between the nipples and making the junction with the lap belt at the inboard pelvic crest. The settings of the belt system components were marked and recorded for each subject.

Next, the five different buckles were alternately installed on the system, the buckle positioned on the right and the latch plate on the left for one series of trials, and their positions reversed for another series.

The subject was asked to don and doff the system with each configuration several times. He was then asked to rank-order the five buckles in their two positions on the basis of ease of buckling and unbuckling.

b. Belt Force/Tension Study

The force required to pull the lap belt out obviously is important to the user. However the designer would like to have sufficient force on the retractor to insure that the belt system retracts fully each time it is released. Therefore it is important to know how much force can be allowed before the user begins to object. A similar situation exists with regard to the tension on the shoulder harness. The wearer objects to heavy tension on the shoulder and across the breast area, but the designer needs to provide sufficient retraction force to insure complete retraction of the shoulder harness upon release of the belt system.

It is of course more difficult to establish acceptance limits than it is to determine maximum application limits. Although a person may be able physically to apply more force, he or she usually does not consider maximum force an acceptable imposition, especially for a task that has to be done repeatedly. Thus the tests conducted required repeated trials so that each subject could establish in his own mind what his acceptance criterion was.

Following several criterion trials, each subject then was required to indicate the maximum force acceptable for extending the lap belt and for leaning forward against the shoulder harness. Initial force settings were randomly set on two simulated retractors and subsequent to each trial they were adjusted higher or lower at the subject's request. An unlimited number of trials was allowed until the subject indicated that the force was set at the maximum acceptable. This force was then read and recorded and the procedure repeated. Three readings were taken for both pull-out and tension acceptance forces.

c. Push-button Preference Study

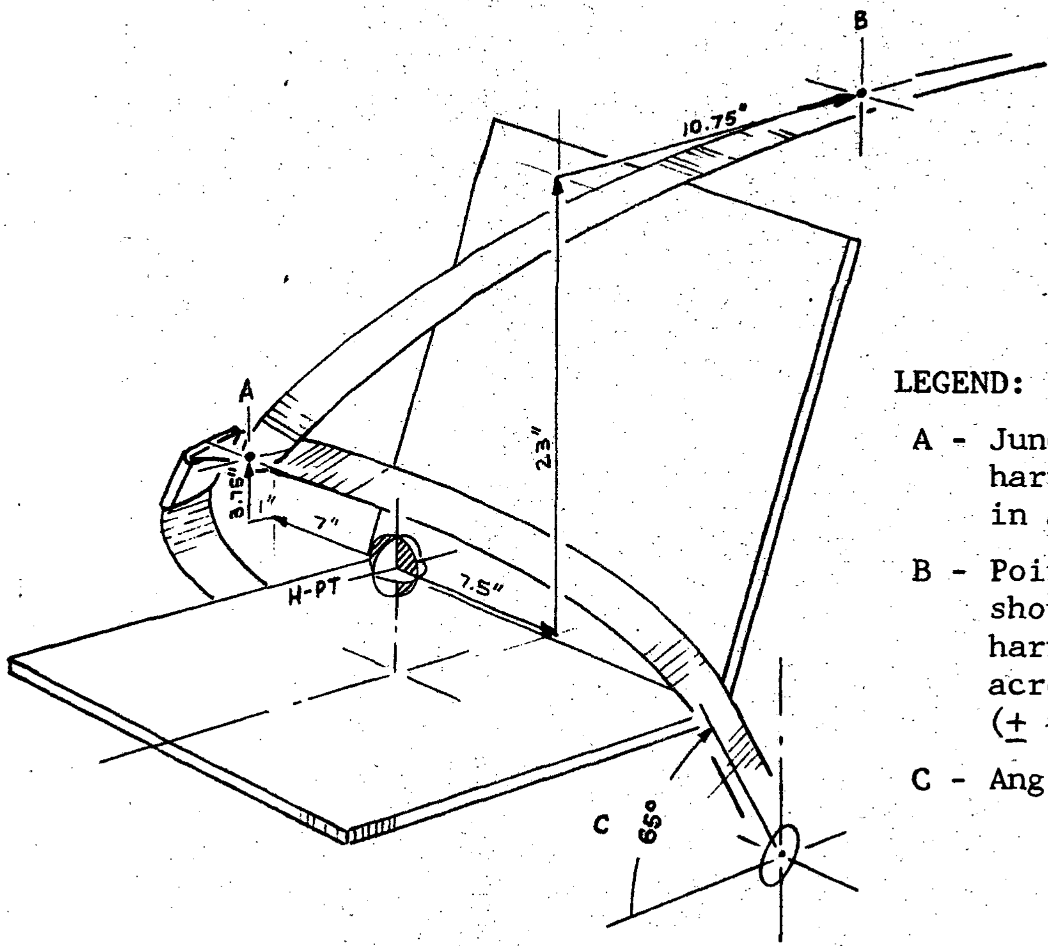
The subject sat in a chair adjacent to 7 different lap belts. These were placed around him one at a time as in an actual automobile. All belts had the standard push-button buckle, and the objective of the test was to have the subject indicate which buckle buttons require more than an acceptable amount of force to actuate the release mechanism. Actuating forces of the buttons ranged from 2.5 pounds to 9.25 pounds. These were actual, off-the-shelf buckles.

Finally, the subject indicated which of the buckles he preferred on the basis of the distinctive shape and size of its push button.

3.4.4 Results

As a result of the data obtained during the belt-geometry aspect of the mockup study a recommended optimized belt-system geometry was derived. The dimensions and angles of this optimized system are indicated in Figure 4.

The mockup study also demonstrated that the range of variability for the recommended dimensions is too small to



LEGEND:

A - Juncture between shoulder harness and lap belt ($\pm$ 1" in all directions)

B - Point above occupant's shoulder from which shoulder harness departs to pass across the shoulder and chest ($\pm$ ½" in all directions)

C - Angle of seat belt ($\pm$ 10°)

Figure 4 - Geometric Requirements for Seat Belt-Shoulder Harness Assembly and Installation to Insure Proper Fit for Passenger Population Ranging From 5th %-tile Female Through 95th %-tile Male (Adults)

accommodate the changes that occur during seat adjustment when the lap belt anchor points and the shoulder harness guide are not mounted directly on the seat. Figure 5 illustrates the changes in belt geometry that occur to a vehicle-anchored system when the seat is adjusted as opposed to a system wherein the belt is attached to and travels with the seat.

Results of the buckle type and position experiment were as follows:

a. 14 subjects preferred the push button type buckle and most preferred that the buckle be on the inboard belt component. This is the configuration presently found in American cars of late vintage (which conforms to current FMVS standards) and probably reflects more experience on the part of the subjects with this configuration than with the others.

b. 9 subjects preferred the Mercedes type of buckling system, and more subjects preferred the buckle on the outboard belt component, which is the position it occupies in Mercedes vehicles prior to the 1973 buckle change.

c. 8 subjects preferred the new MFI squeeze-type buckle which was created specifically for this test. Most preferred having the buckle on the outboard belt component (the position for which it was originally designed).

d. 5 subjects preferred the aircraft type lift-latch, located on the left outboard belt component, the position usually found in passenger airliners.

e. No subject seemed to like the instinctive push-pull type of buckle because it was confusing.

f. Subjects with manual disabilities preferred the Mercedes buckle because it did not require finger dexterity or finger strength.

A summary of these results is presented in Table 12.

SEAT ANCHORED

SEAT ANCHORED

When belts are anchored to seat, optimum fit is retained

VEH ANCHORED

VEH ANCHORED

When belts are anchored to vehicle, optimum geometry is lost as seat is repositioned

Figure 5 - Webbing Geometry Optimization

Table 12 - Buckle Type/Position Preference Study

Type	Outboard belt	Inboard belt	Either
Push Button	5	7	2
Aircraft Lift Latch	4		1
Mercedes Lift Latch	5	4	
MFI Squeeze Latch	4		4
Instinctive Push-Pull			

In the force acceptance study there appeared to be no direct correlation between acceptance values and body build, the females accepting slightly higher forces than the males. In the case of the lap belt the mean pull force for the males was 3.1 pounds and for the females 3.2 pounds. The mean shoulder harness force was 2.9 pounds for the males and 3.3 pounds for the females.

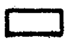
d. Push-button Configuration/Force Study

Since push button forces and the size and shape of push buttons vary considerably on seat belts manufactured prior to 1974, it was important to determine if these factors were important to users. The results of this preference study are shown in Table 13. Because it was desirable to use actual hardware in the study there was no way to have a continuous variation of shape and size of button or an even distribution of forces for all buttons. However it is felt that the variations represented by our varied assortment of actual buckles were sufficient to indicate limits for size of button opening and maximum force that should be designed into button actuation. In addition other design features that subjects did not like were discovered by use of actual hardware.

The forces covered a range of 2½ lbs to 9¼ lbs. Its became obvious that except for one or two subjects the higher force was undesirable to most subjects. The size parameter was less clear although subjects invariably selected larger buttons when there was a choice within a given shape. The lowest force received the largest vote. It seems reasonable to believe, however, that the practical upper force limit is about 4 lbs since the sum of votes for 4 and 4½ lbs was the same as that given the two buckles having the lowest forces.

It should be noted that an oval-shaped push button (non-operating mockup) devised by MFI staff members to illustrate a shape that is considered more compatible with the shape of the human thumb and the size of the larger thumbs that might be used (including a gloved hand) was included in the test. Unfortunately it was not possible to evaluate force in conjunction with this shape and size. The oval shape was preferred by 6 subjects as compared to 7 for the most preferred shape.

Table 13 - Push Button Shape/Force Study Results

Shape	Size	Preference Score*
	1-3/16 in.	7
	1 x 1 1/4	6
	7/8 x 1	5
	1 x 1	4
	1 x 1	2
	10/16 x 1-3/8	2
	7/8 x 1-1/8	1

Force (lbs)	Preference Score*
2-1/2	8
3	2
3-1/2	1
4	6
4-1/2	4
5-1/2	2
9-1/4	4

*Represents the number of test subjects who indicated.

Other important aspects of the button design also were noted. Subjects preferred button configurations that possessed tapered sides to guide the thumb or finger and to prevent them from becoming caught between the edge of the opening and the button itself.

e. Other Observations

Before the 1974 systems became available the mockup study brought to our attention problems that were to occur in these systems. For example in August 1973, with two uniformed policemen as test subjects, it was observed that during doffing the shoulder harness would catch on the officers' badges. Subsequently this problem was encountered by a number of police departments that have purchased 1974 automobiles. It is one of the reasons why the California Highway Patrol is having the shoulder harnesses removed from their 1974 patrol cars (Anonymous, 1974, p. 32).

A major result of the mockup studies was the development of some criteria for the recommended optimized system. These criteria included the dimensions indicated in Figure 4, the requirement for seat-mounted anchor points, and use of the push button buckle with the size, shape, and force magnitude to be specified in the Proposed Amendments to the Federal Motor Vehicle Safety Standard 208 (see Section 4). Recommendations for retractor forces also are based on mockup study results and they too are presented in the Proposed FMVS Amendments.

3.5 Phase IV - New Car Evaluation

As 1974 model automobiles began to become available a new car survey was initiated. One objective of the Phase IV effort was to provide MFI researchers with the opportunity to become familiar with the wide range of seat belt systems that conform to 1974 design requirements. Familiarity with these systems was needed to insure that an extensive variety of problems that can occur with the latest systems designs would be observed. Also, it was expected that some designs might suggest need for additional design criteria to be added to MFI's initial recommendations.

A second objective of the new car survey was to determine if any available automobile had a seat belt system that closely approximated MFIs' recommended design criteria so that it might be used, possibly with modifications, as a basis for comparative evaluations to be made in Phase V, optimized system tests.

3.5.1 Procedures

The new car restraint systems evaluation was done at two levels, i.e., at a gross, preliminary level to help select a reasonable number of vehicle/models for more detailed examination, and at a detailed level wherein specific cars were examined using selected subjects with different characteristics and taking certain critical measurements.

Approximately 60 different cars were examined at the gross level. Two MFI staff members performed this preliminary survey. One of the investigators was fairly large (approximately 80^{th} percentile male) and the other fairly small (approximately 5^{th} percentile female). The purpose of the preliminary survey was to isolate those vehicles that would provide distinct differences in size, interior configuration, variation in restraint system configuration and mounting, variation in seat and headrest, variations in exterior viewing access, etc. Clearly some models within a single manufacturer's line were so nearly the same that detailed evaluation of all similar models would not have been cost-effective.

Uniformed policemen, obese and physically handicapped individuals, and others having characteristics that might result in difficulties in the use of 1974 seat belt systems were used as test subjects in selected vehicles, where mockup studies indicated problems associated with certain vehicle-system configurations. Numerous photographs were taken of various subjects in various vehicles to provide photographic records of special "fit" problems (see Appendix B).

3.5.2 Results

Of the approximately 60 vehicles examined in the initial survey 30 were selected for detailed evaluation. These included 27 standard systems and 3 experimental passive systems. Table 14 identifies these cars and gives some of the information gathered about each one. The first columns provide quantative data regarding retractor and buckle or latching release forces. The remaining columns represent the ratings of experimenters with regard to the various parameters evaluated. These ratings admittedly are subjective and are based on the number and magnitude of the problems associated with a particular aspect of a system. The fewer the difficulties encountered by the experimenter, the lower the score. Scores of 1, 2, and 3 were given as three gradations of "good." Scores of 4, 5, and 6 were given as three gradations of "average." And scores of 7, 8, and 9 were given as three gradations of "poor."

It must be kept in mind that these ratings should not be considered definitive since for the most part they are based on the observations of one or two individuals in one or two vehicles, and differences have been noted between two vehicles of the same make and model. In deference to the evaluations, however, by this time our evaluators were extremely well versed in looking for and evaluating system problems.

Although detailed data obviously are important in evaluating various systems and vehicles, it is perhaps more important to understand the major deficiencies that occur most frequently. It appears that basic hardware components and general system concepts are reasonably satisfactory in most vehicles. However the specific execution of a concept within vehicle models often is very poor. That is, even though a particular model/restraint system has all the basic ingredients necessary to provide a satisfactory restraint system, such factors as the layout of anchor points and webbing guides tend to be poor on most of the vehicles examined.

It is interesting to note that the principal deficiencies usually are the same ones MFI was able to identify during earlier mockup studies. Primary among these were:

a. Poor webbing geometry - belts crossing the shoulder and chest improperly; buckle release position too low and difficult to get hold of for fastening and unfastening; belt/latch plate inaccessible for initial donning; etc.

Table 14 - Some Characteristics Of 27 Standard 1974 Seat Belt Systems and 3 Passive Belt Systems

			Retractors*															
	Make	Model	Lap Belt Type	Lap Belt Force (lbs)	Shoulder Harness Type	Shoulder Harness Force (lbs)	Buckle Button Force (lbs)	Belt System Force	Buckle Button Force	Off Shoulder	On Neck	On Inboard Breast	Chafes	Twists	Stowed Belt Access	Buckle Access	Buckle Mating	Retrac. Lock out	Full Retract
1	AMC	Ambassador	Auto	4	Veh	3.5	3	4	3	1	6	8	2	2	2	8	2	5	2
2	AMC	Gremlin	Auto	3	Veh	3.5	1.5	3	2	1	6	8	2	2	2	8	2	5	2
3	AMC	Matador	Auto	4	Veh	3	4	4	4	1	6	8	2	1	2	8	2	5	2
4	Buick	Apollo	Auto	4	Veh	3.5	5	4	5	1	6	6	1	4	6	6	6	7	8
5	Buick	Electra	Auto	3.5	Veh	3.5	4	4	4	1	5	8	3	8	3	8	6	5	6
6	Buick	La Sabre	Auto	4	Veh	3	4	4	4	1	4	8	4	4	3	6	4	7	6
7	Buick	Opel			Veh	2.5	2	3	2	1	3	6			8	1		1	6
8	Buick	Regal	Auto	5	Veh	2.5	4.5	4	5	1	6	7	3	5	5	6	7	7	8
9	Capri				Veh	3.5	5	4	5	1	2	6	2	2	8	5	7	1	8
10	Chevrolet	Camaro	Auto	4	Veh	3	4	4	4	1	6	6	2	2	2	2	4	2	2
11	Chevrolet	Impala	Auto	4	Veh	2	4.5	3	5	1	3	3	1	2	1	3	3	5	1
12	Chevrolet	Nova	Auto	3.5	Veh	3	4	3	4	1	6	6	1	2	2	6	6	5	8
13	Chevrolet	Vega	Auto	4.5	Veh	1.5	4.5	3	5	1	4	7	2	8	9	5	3	8	6
14	Datsun	210	Web	2	Belt	1	2.5	2	3		6	7	2					3	2
15	Dodge	Coronet	Auto	3.5	Belt	3	4	2	2	1	6	7	1	4	5	6	6	9	7
16	Fiat		Auto	3	Belt	1	6	2	6	8	1	5	2	2					
17	Ford	Mustang II				5	4	8	4	1	9	9	5	2	4	9	7	5	3
18	Ford	T-Bird	Auto	3	Veh	2.5	3.5	3	4	1	5	4	2	2	2	6	8	5	2
19	Honda	Civic	Web	4	Belt	2	4	3	4	1	7	7	2	2	2	5	7	3	2
20	Mazda	RX-4	Veh	3	Veh	8				1	7	7	4	4	6	4	2	1	4

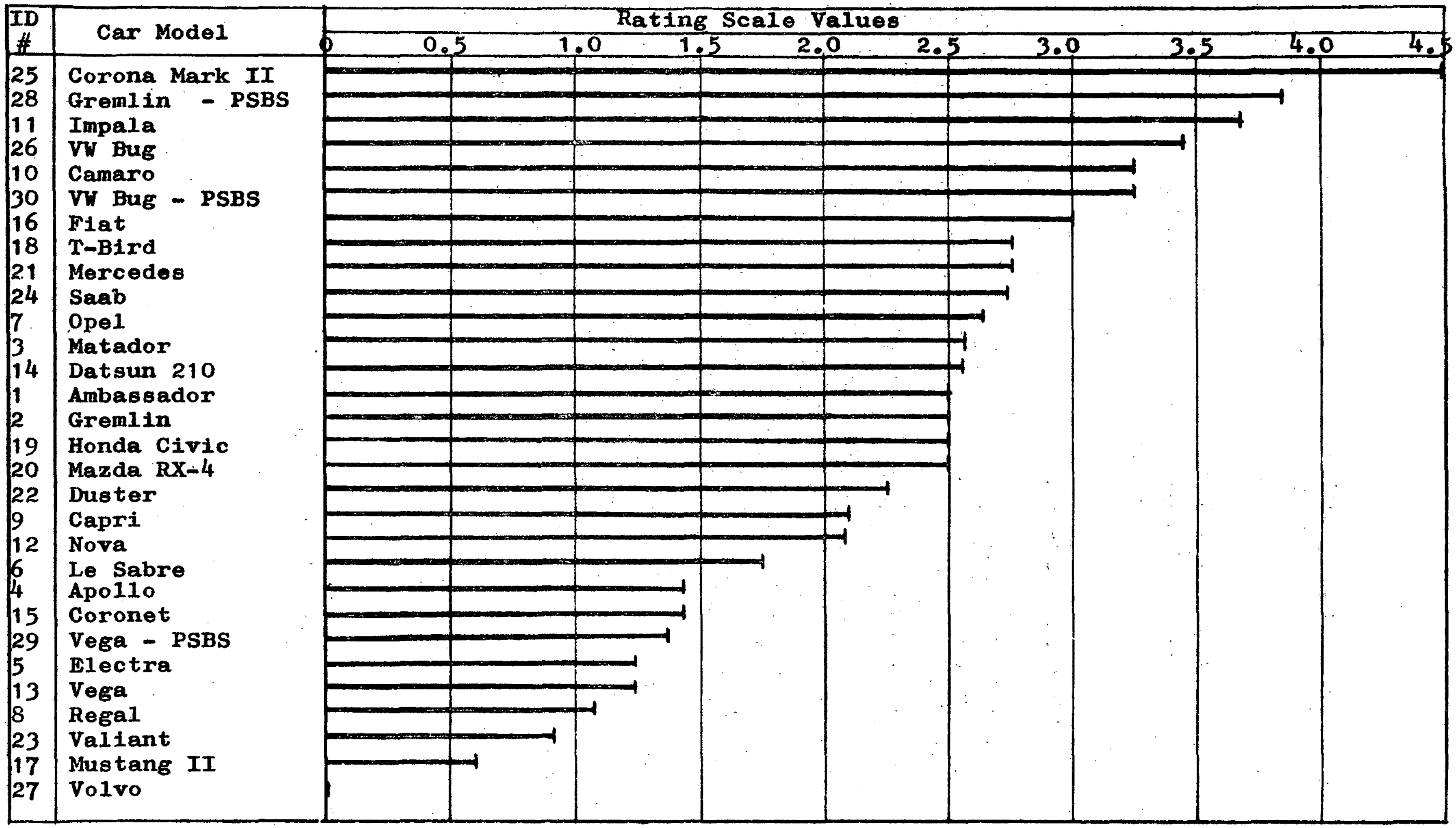
Table 14 (Continued)

21	Mercedes				Belt	2	2	2	2	3	1	6	3	2	2	4	7	3	3
22	Plymouth	Duster	Auto	2.5	Belt	2.5	3.5	3	4	3	3	5	2	2	5	5	4	6	5
23	Plymouth	Valiant	Auto	3	Belt	3.5	6.5	3	7	3	5	5	2	5	8	7	8	5	8
24	Saab				Belt	3	4	3	4	1	8	8	2	2	4	2	2	3	2
25	Toyota	Corona Mark II	Veh	2	Veh	3	3	3	3	1	3	2	1	3	1	2	1	1	1
26	Volkswagen	Bug			Veh					1	1	4	1	2	8	4	4	1	1
27	Volvo											6							
Experimental Passive Seat Belt Systems																			
	System Designer	Test Vehicle																	
28	American Safety	Gremlin			Veh	2-5	None	4	0	4	1	5	6	5	1	0	0	1	1
29	General Motors	Vega			Belt	3-6	None	5	0	1	8	7	9	7				1	
30	Volkswagen	V.W. Bug	None		Veh	4.5	5 (Emerg.)	5		5	1	4	8	1				1	

* Auto = Automatic; Belt = Belt-Sensitive; Veh = Vehicle Sensitive.

** 1 = Best; 9 = Worst; 1, 2, 3, = Good; 4, 5, 6 = Average; 7, 8, 9 = Poor.

Table 14 Supplement: Summary of Seat Belt Systems Evaluations
By Automobile Model



Notes: 1. All vehicles contain manufacturers' standard seat belt system except those marked PSBS (experimental Passive Seat Belt System).

2. The above ratings are based on "expert opinions" of MFI staff during the new car survey, the purpose of which was to identify appropriate vehicles for the main, optimized system comparison test.

b. Poor mounting configuration - causing belts to twist, allowing belts to remain slack and fall out of the door after doffing.

c. Extraneous interferences - center consoles preventing user from getting hold of the buckle; door-mounted arm rest designs that precluded getting hold of the stowed latch plate; etc.

d. Retraction systems that "lock-out" too easily.

Three experimental passive systems also were included in the new car evaluation. An experimental system by Volkswagen had no lap belt, but had a shoulder harness that was attached to the upper rear window frame of the door. A single retractor mounted between the two front seats allowed the belt to extend when the door was opened and to retract around the torso of the user when the door was closed. In the event of an accident, the vehicle-sensitive retractor would lock the shoulder harness, and the occupant's knees were supposed to come into contact with a crushable panel as a substitute for a lap belt (see Figure 6).

Two other experimental passive systems, one by American Safety Equipment Corporation and the other by General Motors, were also investigated. These systems were similar to each other and since they were used in Phase V they are described in Sections 3.6.1.4 and 3.6.1.5 (see Figure 7). A common characteristic among these passive systems was the necessary attachment of the shoulder harness to the upper rear window frame of the door and the use of a single retractor between the seats. This condition caused a major problem common to all three systems, viz., there was considerable chafing between the shoulder harness and the upper torso of the wearer, and the shoulder-crossing geometry is entirely dependent on the position of the door post/ seat position.

Since the upper segment of the belt was not attached to a retractor it remained stationary and did not move with the upper torso when the wearer moved or turned in his seat. The resulting abrasion was immediately noted as being extremely disturbing.

VW EXP BELT

VW EXP BELT

Figure 6 - VW Experimental Passive Restraint System

Figure 7 - American Safety and General Motors Experimental, Semi-Passive Systems

As already indicated the primary objectives of the new car survey were to familiarize MFI researchers with the various systems, to allow them to note special problems, to identify good or poor systems, and to search for a system that approximated the recommended criteria. Each of these objectives was attained.

A number of special problems encountered by people having certain unusual characteristics first noted in the mockup also were found to occur in the majority of the 1974 vehicles. Those of special importance will be described in the sections of this report relating to Phase V, the optimized systems test. However one of these is worthy of a comment here.

The police department of a community in San Diego County acquired 1974 Coronets as patrol cars. The Chief of Police and several of his men had complained to us about problems they were encountering with the use of the seat belt system. Once, on exiting rapidly from a vehicle an officer's gun had caught in the belt and was extracted from the holster unbeknownst to him. Another officer's mace container became caught in the shoulder harness, causing him to be twisted around and to fall during a rapid egress. Another patrolman complained of catching his arm in the retracted belt every time he exited. Still another officer objected to the fact that the belt prevented him from drawing his weapon from its split-front holster while riding in the car. All of the patrolmen had experienced inadvertent retractor lock-out repeatedly during donning.

During a demonstration for MFI researchers an officer failed in his attempts to simulate an emergency start since he could not don the system rapidly. This was due to the fact that the Coronet system employs an automatic retractor for the lap belt and a belt-sensitive retractor for the shoulder harness. Because of their manner of functioning, both retractors can become locked, especially when a hurried attempt is made to don them, and this can result in a situation that requires considerable effort to unlock them. With the ignition interlock system preventing the officer from starting the car the importance of retractor types was emphasized.

Because of this incident and a number of other observations made during the new car survey a special investigation into the operation of retractors used in 1974 systems was carried out. For the front outboard seat positions three basic types of retractors are in use, viz.: (1) the automatic-locking retractor; (2) the belt-sensitive emergency-locking retractor; and (3) the vehicle-sensitive emergency-locking retractor.

As a result of the investigation of these three types of devices we have concluded that on the basis of comfort and convenience the vehicle-sensitive retractor is best, the belt-sensitive retractor next best, and the automatic retractor ranks third. Following is a discussion of the distinctive characteristics of each of these three types, their advantages and disadvantages.

The automatic retractor system (ARS) employs the principle of the ratchet. Once the pulling motion is stopped and the belt allowed to begin retraction, the ratchet operates to prevent any further extension of the belt from the retractor. Thus a steady force is required when pulling the belt out from the retractor until it is extended sufficiently to engage the latch plate with the buckle. When released the spring-loaded reel in the retractor removes any slack in the belt and automatically adjusts its length to fit snugly across the user.

There are two principal disadvantages to the automatic retractor system. First, once the belt has been buckled it is not possible to adjust the seat position in a forward direction without the belt tightening since its length is fixed by the locked ratchet. Therefore the belt must be unbuckled and allowed to be fully retracted, after which the seat may be moved forward; then the belt can be pulled out and buckled again.

The second major disadvantage of this system is the necessity for maintaining constant force on the belt while it is being extended. Any inadvertent slackening in the tension of the belt during extension causes the ratchet to lock. In order to release the ratchet mechanism the belt has to be allowed to go back into the retractor to within an inch or so of full retraction. Only after this is done can extension of the belt be attempted again. Many subjects try to pass the latch plate from one hand to the other. In so doing they inadvertently let the belt slacken and thus lock-out the belt.

The belt-sensitive retractor system (BSS) senses a critical rate of rotation of the reel which it locks. Thus in the event of a rapid deceleration of the vehicle (as during impact in an accident) the occupant is thrust forward, pulling the belt with him. Under such circumstances the belt is being pulled out of the retractor at such a rapid rate that the sensor causes it to become locked, thereby stopping the forward movement of the user.

The disadvantage of this system is that there is a limitation to how rapidly the belt can be pulled out of the retractor during donning. If it is pulled out too fast the system will lock. However to unlock the system it is not necessary to allow the belt to retract almost fully, as in the automatic system, but rather just a release of the tension on the belt and a slight retraction will unlock it and allow it to extend further.

Another advantage of the belt-sensitive system over the automatic system is that it is not necessary to avoid momentary stoppages or reversals of movement when extending the belt to keep it from locking. When used for both lap belt and shoulder harness, and BSS system also allows unlimited forward adjustment of the seat with the belts buckled.

The sensors in the vehicle sensitive system (VSS) respond to the inertial forces of the vehicle itself rather than to any action of the belt system, as is the case with the belt-sensitive system. In the event of a rapid deceleration due to braking or impact, the sensors cause activation of the locking mechanism which prevents any extension of the belt, thereby holding the occupant in place.

This system has the advantage over both other systems that no special precautions are necessary to keep the belt from locking when it is being extended for donning. The belt can be pulled out as fast as necessary and can be stopped intermittently or reversed without causing the locking mechanism to activate.

Like the belt-sensitive system but unlike the automatic system the vehicle-sensitive system allows unlimited forward adjustment of the seat with the belts buckled.

A summary of the advantages and disadvantages of the three types of retractors is given in Table 15.

The three types of retractors can be installed in vehicles in various configurations. Two major configuration categories can be identified, viz., a one-retractor system and a two-retractor system. In the case of the latter it is useful to consider subcategories identifiable according to which of the three systems -- or combination of systems -- is employed.

One-retractor systems always are emergency-locking systems because of the requirement specified in the FMVSS 208 that the torso restraint must employ such a retractor. They may, however, be either belt-sensitive or vehicle-sensitive. In our investigation we observed one-belt systems only in cars of European manufacture, such as the Volkswagen, Saab, and Volvo.

A major disadvantage of a one-retractor system is that the latch plate must slide along the belt to the appropriate positioning for fastening depending on seat position and user girth. This may require two hands, one for pulling the belt out of the retractor and the other for sliding the latch plate along the belt, although with systems in which the latch plate slides easily the operation may be accomplished with one hand. Nevertheless in these systems the latch plate, because of its shape, does not tend to act as an aid in aiming the belt directly at the buckle.

On some installations, a clip device (that looks something like a comfort clip) can be moved along the belt (by overcoming more friction than it takes to move the latch plate) to hold the latch plate at a convenient height, to make the latch plate accessible when the belt is in stowed condition. In such a condition the belt is vertical, and without such a clip the latch plate almost always slides to the bottom of the vertical length of belt, placing it (in most cars) behind the seat near the floor.

Table 15 - Disadvantages And Advantages of Three Different Types of Actuators

Type of Actuator	Disadvantages	Advantages
Automatic Locking	Locks with slight reverse movement of belt. Belt must retract fully to unlock. When actuator does not move with seat, seat cannot be adjusted forward. Tightens on bumpy ride.	Webbing pull-out rate unlimited.
Belt Sensitive	Webbing pull-out rate limited.	Does not lock with slight reverse movement of belt. Does not have to retract fully to unlock. When actuator does not move with seat, seat can be adjusted forward. Does not tighten on bumpy ride.
Vehicle Sensitive		Webbing pull-out rate unlimited. Does not lock with slight reverse movement of belt. Does not have to retract fully to unlock. When actuator does not move with seat, seat can be adjusted forward. Does not tighten on bumpy ride.

Two-retractor systems of the following types were observed:

System	Lap Belt	Shoulder Harness
1	Automatic	Belt-Sensitive
2	Automatic	Vehicle-Sensitive
3	Belt-Sensitive	Belt-Sensitive
4	Vehicle-Sensitive	Vehicle-Sensitive

Systems 1 and 2 tend to be used in American-made vehicles; systems 3 and 4 in foreign-made vehicles.

Systems 1 and 2 have the problems associated with the automatic system. With the automatic/belt sensitive system it is possible for either or both retractors to become locked during the donning process. If the belt-sensitive part of the system becomes locked because the shoulder harness was pulled out too fast -- and the lap belt allowed to retract without first unlocking the shoulder harness by releasing tension in it -- it is possible for both retractors to become locked with virtually no slack in the belt system. This can present a serious problem in getting the system back into operational condition since it is very difficult to unlock either retractor. (This was the situation that occurred in the Coronet police car.)

Although both retractors in system 3 can also become locked during the donning phase, either one will unlock when tension is released, hence theoretically it is not possible for them to remain locked when they are without slack in the retracted condition.

The vehicle-sensitive part of system 2 cannot lock during donning hence inadvertent locking can occur only with the automatic retractor, which can be unlocked in the usual manner.

System 4 is essentially trouble-free as far as inadvertent locking is concerned. On this basis it should be rated highest in convenience and lack of confusion.

As a consequence of this investigation another criterion was added to the recommended system which specifies that such a system should come equipped with vehicle sensitive retractors for both the lap belt and shoulder harness.

We were fortunate in the new car survey in finding a vehicle that had a system whose features approximated those of the MFI recommended criteria. The vehicle was the 1974 Toyota Corona Mark II which has seat-mounted anchor points and two vehicle-sensitive retractors (see Section 3.6.1.1 for further details on this system). This vehicle/restraint system removes at least two major convenience problems; i.e., inadvertent belt system lock-out and misfit because of change in seat position. Its only deficiencies in its production configuration relate to the position of the buckle and shoulder harness webbing guide.

3.6 Phase V - Optimized-System Tests

Findings of the mockup studies of Phase III provided the design and installation criteria for an optimized seat belt system (see Figure 4). The findings of the new car evaluation of Phase IV indicated to what extent the systems in the various 1974 model automobiles approximated these criteria (see Table 14).

The primary objective of Phase V was to develop an optimized system designed in accordance with the criteria, with evaluation of the system being done on the basis of comparison with other seat belt systems. Among these other systems were to be types representative of those currently available to the car-using public as well as types still undergoing experimental development.

3.6.1 Equipment

Seat belt systems installed in six different automobiles represented the essential basis on which the testing was carried out. Each of these systems was assigned an identifying code letter -- A through F (see below). Equipment used in conjunction with the testing included clip boards and stop watches. Motion pictures were taken with a Minolta Autopak - 853 camera and photographs were taken with two Instamatic 40 cameras. Data were recorded on special questionnaire forms (see Section 3.6.3.1).

3.6.1.1 System A

The 1974 Toyota Corona Mark II was found to have a seat-belt system that most nearly approximated the selected criteria. It was the only system found that had both the torso-restraint retractor and the buckle mounted directly on the seat, which of course allowed unimpeded seat adjustment without modification of belt geometry.

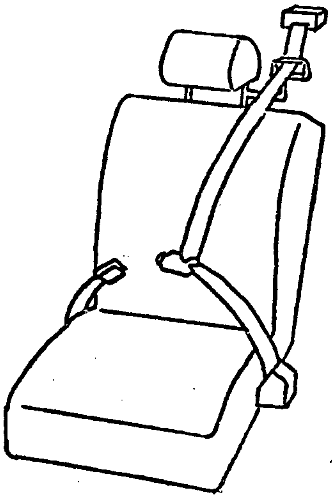
Furthermore both retractors in this system were vehicle-sensitive so that the inconvenience of inadvertent lockout during donning associated with both the automatic and belt sensitive retractor was not a problem. Other advantages of the vehicle sensitive retractor have already been described.

However the production installation did not conform precisely to the MFI criteria and so some installation modifications were made. The buckle strap was extended 3 inches so that it would position the juncture of the shoulder harness and the lap belt to between 6 and 7 inches from the mid-sagital plane. A bracket and new webbing guide was fabricated to cause the shoulder harness to approach the occupant's shoulder, as described in Section 3.4.4, i.e., the shoulder harness was made to approach the shoulder higher and further outboard than in the production version.

The bracket for holding the harness guide was mounted on the outboard headrest support-bar. Although this solution is <u>not</u> part of MFI's design criteria nor is this method of positioning the shoulder harness the only method to accomplish the desired effect this technique was convenient and made no permanent modifications in the vehicle, (allowing it to be restored to its original condition upon completion of the tests). In making an integral design for permanent mounting it is likely that a number of other techniques could be devised to bring the webbing to the proper position relative to the user including an integrated seat/headrest guide.

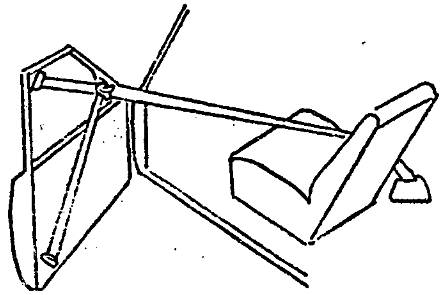
The Toyota lap-belt retractor had a force of 2 lbs. and the shoulder harness retractor a force of 3 lbs. The buckle-button release force was 3 lbs., all of which were compatible with MFI criteria.

For an illustration of System A, see Figure 8.



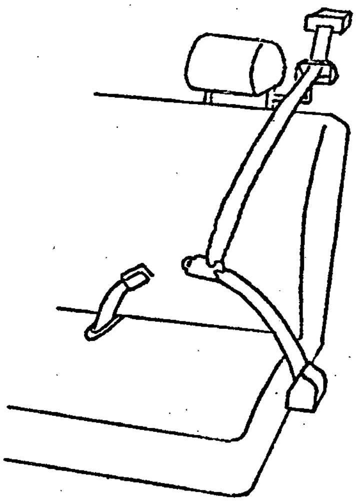
A

MFI/Toyota
Bucket Seat
(In Toyota)



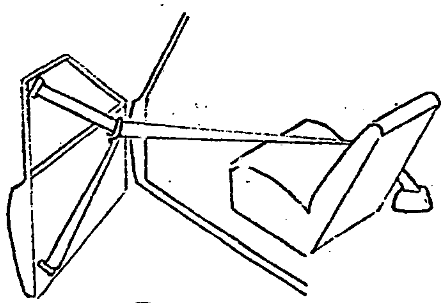
D

Experimental A.S.C.
Semi-Passive
(In Gremlin)



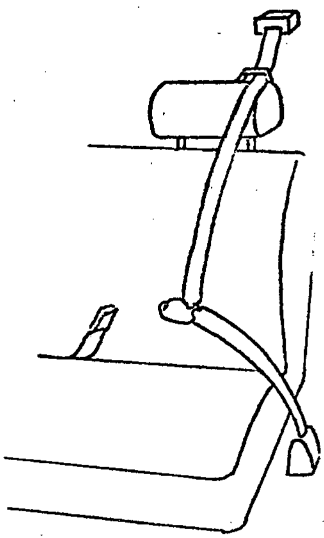
B

MFI/Toyota
Bench Seat
(In Mercury)



E

Experimental GMC
Semi-Passive
(In Vega)



C

Standard GMC
(In Impala)

F

Standard
Single
Retractor
(In Capri)

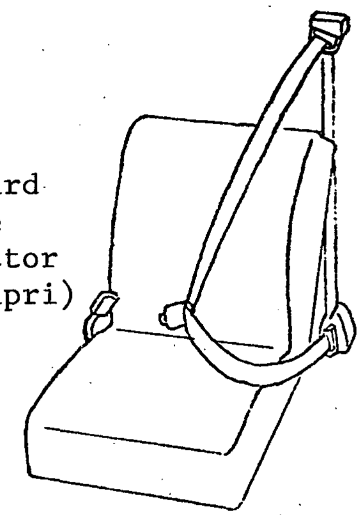


Figure 8 - Seat Belt Systems to be Evaluated in MFI Tests

3.6.1.2 System B

System A had been designed specifically for a bucket-seat installation. The question arose as to whether this system, which came so close to meeting the recommended criteria, could be satisfactorily adapted to the more common bench-seat installation. System B established the fact that such an adaptation could be accomplished successfully.

System B using the same geometric criteria used in System A was mounted in a 1966 Mercury Montclair four-door sedan with bench seats. The framing of the front bench seat was reinforced and special brackets installed for mounting the buckle strap and the lap-belt retractors.

An actual Toyota seat belt system was installed in the Mercury with the buckle-strap and lap-belt retractor mounted on the seat. A special sleeve was installed in the seat for the buckle strap to pass through. The buckle strap was enclosed in a bendable stiffener that projected out of the sleeve and held the buckle in an erect but moveable or non-rigid position at the same relative location as the buckle in System A (see Figure 8).

The shoulder harness retractor was mounted above the rear door as in the Toyota. A bracket and webbing guide identical to that in the Toyota were mounted on the outboard support bar of a specially fabricated headrest. This bracket held the shoulder harness in the same position relative to the user as in the Toyota.

The three system-component forces in System B were the same as in System A, the lap belt retractor exerting 2 lbs., the shoulder harness retractor 3 lbs., and the buckle-button 3 lbs.

System B was essentially identical with System A except for being installed in a bench seat configuration rather than a bucket seat configuration (see Figure 8).

3.6.1.3 System C

System C was the standard seat-belt system that came installed in a 1974 Chevrolet Impala with bench seats. It came equipped with an automatic retractor that exerted 4 lbs. of force on the lap belt, and a vehicle sensitive retractor that exerted 2 lbs. of force on the shoulder harness. The buckle button release force was 4.5 lbs.

During the new car evaluation of Phase IV the Impala system was judged to be one of the better systems available in terms of comfort and convenience. The Impala system was chosen for inclusion in this test to allow comparisons to be made between a relatively good commercially available system and MFIs' optimized systems.

3.6.1.4 System D

System D was an experimental semi-passive belt system designed and fabricated by American Safety Equipment Corporation. The belt was installed in a 1972 Gremlin.

In this system a belt loop is attached to the upper part of the aft vertical frame of the front door windows adjacent to the driver and front passenger seats. (The Gremlin is a two-door car with bucket seats in front. Both front seats are equipped with a semi-passive belt system). The other end of this belt loop was attached to the lower rear edge of the respective doors.

Between the two bucket seats was mounted the single retractor for each seat. The belt extending from the retractor terminated in a slip ring that was free to slide along the door-mounted belt loop. That segment of the belt loop below the slip ring became the lap belt, and the segment above the slip ring became the shoulder harness when donned.

As can be seen in Figure 8 , with the door open the belt extending out of the retractor would cross over the seat, tending to interfere with entry and exit. To prevent this a hook was provided just below the window at the forward edge of the door for stowing the belt out of the way. The sliding ring was equipped with a hoop designed to fit over the stowage hook. Since belt stowage and unstowage had to be accomplished manually, technically the system was not fully passive. It was, therefore, commonly referred to as a semi-passive system.

In System D the single vehicle-sensitive retractor had a retraction force of 2 pounds at the initial point of withdrawing the belt from the retractor. This force steadily increased as belt withdrawal continued until it reached a maximum of 5 pounds at the point where the belt ring could be attached to the stowage hook.

Opening the door from the inside by pushing against the forward end of the armrest required 2 pounds of force when the restraint system was not exerting any force against the door. With the restraint system exerting force against the door in the unhooked mode the force required to open the door increased to 5 pounds. With the belt attached to the hook on the window sill a force of 3.5 pounds was required to open the door.

3.6.1.5 System E

System E (see Figure 8) was a semi-passive belt system similar in design to System D. System E was a preliminary experimental design of General Motors Corp. mounted in a 1973 Vega. Like the Gremlin the Vega was a two-door model with bucket seats. And as with System D, System E consisted of a door-mounted belt loop to which a belt segment from a single retractor was attached by means of a slip ring.

The retractor, which in this case was belt-sensitive, was mounted between the seats. A stowage hook was provided at the front edge of the door just below the window. However there was no hoop on the slip ring for stowing the belt on the hook. Stowage was accomplished merely by placing the webbing of the retractor belt over the hook. This was the only obvious difference between Systems D and E in design concept and, although minor, it did have a noticeable effect on convenience.

In System E the single, belt-sensitive retractor had a retraction force of 3 pounds at the initial point of withdrawing the belt from the retractor. This force steadily increased as belt withdrawal continued until its maximum of 6 pounds occurred at the point where the webbing could be attached to the stowage hook.

Opening the door from the inside by pushing against the forward end of the armrest required 7 pounds of force when the restraint system was not exerting any force against the door. With the restraint system exerting force against the door in the unhooked mode, the force required to open it was 8.5 pounds. With the belt attached to the hook at the front of the door a force of 10 pounds was required to open the door.

Both systems D and E were included in the Phase V test because of current official interest in passive systems.

3.6.1.6 System F

System F was a standard seat-belt system that came installed in a 1974 Capri with bucket seats (see Figure 8). It came equipped with a single vehicle-sensitive retractor which exerted 3.5 lbs of force. The buckle button release force was 5 lbs.

During the new car evaluation portion of Phase IV the Capri system was judged to be one of the poorer systems available in terms of comfort and convenience. The Capri system was chosen for inclusion in this test to allow comparisons to be made between a relatively unsatisfactory commercially available system and the recommended optimized systems.

3.6.2 Test Subjects

The question of "representativeness" was considered in the selection of test subjects. But what characteristics are especially representative of potential seat-belt users? Virtually everyone in the United States either has ridden or can be expected to ride in an automobile.

Some anthropometric traits such as weight, height, functional reach, and strength, that are often used as test-subject selection criteria for studies concerned with driver performance, have no particular relevance for this study which is concerned not with objectively observable behavior but rather with evaluations made on such subjectively interpreted bases as comfort and convenience.

Certain demographic characteristics may, however, be of more relevance since some studies have shown a correlation between them and seat-belt usage. For example most studies show age as positively correlated with belt usage, i.e., with less usage among the young. However other studies show no such correlation, or an inverse one (Fhaner and Hane, 1973, pp. 31-32; Robertson, 1974, p. 10).

Approximately 32.4% of American drivers are 29 years of age or younger (National Safety Council, 1973, p. 54). Of the 24 test subjects that participated in the main test 13, or 54.2%, were 29 years of age or younger. To the extent that the studies showing a positive correlation between age and belt usage are correct, our younger sample might include a greater number of non-belt users than the national driver population. On the other hand our sample is not intended to limit its representation to drivers but rather extends to all potential belt users, including the young pre-drivers of whom there were two in our sample.

Most studies show no significant distinction between the sexes in belt usage (Fhaner and Hane, 1973, p. 32; Robertson, 1974, p. 10). Nevertheless because males drive more than females and because in the American driving population males represent about 56% and females 44% (National Safety Council, 1973, p. 54), we selected our sample to reflect these differences. Instead of a sample size of 20 test subjects, as originally planned, the number of increased to 24, with 14 males representing 58% and 10 females representing 42%. (Actually there were 26 test subjects but two of them did not participate in the main test -- only in the ancillary tests of Phase V, as described in Sections 3.6.3.1 and 3.6.3.2.)

It was not until data resulting from the Phase V tests were analyzed that an important distinction between the sexes emerged. The females were considerably more critical than the males in their evaluations. This suggests, of course, that in research involving evaluations based on comfort and convenience the sex composition of the sample of test subjects is an important factor.

A number of subjects were selected for traits shown during the preceding phases to present special problems of comfort and convenience in the use of seat belts. Human body size is one of the most critical characteristics to be taken into consideration in designing equipment that must fit properly. It was therefore of great importance to determine how the various systems would be evaluated by subjects approaching the extremes in body size. The single dimension used was erect seated-height and the percentile values were those given in Federal Motor Vehicle Safety Standards 208 and 209. The upper extremity was represented by a 95th percentile male, whose seated height was 37.9 inches. The lower adult extremity was represented by a 5th percentile female whose seated height was 31 inches.

Two children, a male and a female, also were used because of their size since both had seated heights several inches less than that of the 5th percentile adult female. But size was not the only reason for including children. Many people of about their age (11 and 12 years old) are actual or potential seat-belt users. It is important to know how they judge the different systems.

Since another size problem is that of obesity, one of the subjects specially selected was a 5'3" female who weighed 215 pounds.

A woman seven months pregnant also was selected because of the special problem of size and because of possible heightened sensitivity to discomfort.

Other subjects were selected because of the mobility limitations imposed on them by physical handicaps, viz., arthritic hands, amputated left arm, and quadraplegia. All these last three subjects were licensed drivers. The quadraplegic had limited use of his arms and hands and drove a vehicle with specifically designed controls.

A uniformed policeman was included because Phases III and IV had brought to light a number of seat-belt usage problems peculiar to the necessity of wearing police equipment.

Table 16 identifies each test subject by number and gives the sex, age, weight, height, seated height, and other characteristics of the 26 test subjects.

Subjects with numbers 1 through 24 participated in all aspects of the main test, data from which were used in some

Table 16 - Some Characteristics Of Test Subjects Participating in Phase V

Subject Number	Sex	Age (Yrs.)	Weight (Lbs.)	Height (Ins.)	Seated Height (Ins.)	Other Characteristics
1	F	37	135	60	31	5th %ile, seated height, erect
2	F	73	140	61	31.5	Arthritic Hands
3	F	19	130	65	34	
4	F	35	140	68	34.5	
5	F	12	70	59	27	Child
6	F	45	215	63	26.5	Obese
7	F	43	190	67	34.25	Pregnant
8	F	24	138	67	34	
9	F	17	110	63	32.25	
10	F	41	135	67	35.25	
11	M	49	180	69	36.5	
12	M	59	170	67	34	
13	M	56	215	76	37.9	95th %ile, seated height, erect
14	M	59	180	72	36.5	
15	M	11	80	58	28.5	Child
16	M	20	165	71	36	
17	M	25	165	72	35.13	
18	M	26	185	70	34	
19	M	23	145	65	33.25	
20	M	22	165	65	34.75	
21	M	17	185	68	35.13	
22	M	17	170	66	33.75	
23	M	41	147	71	35.25	Uniformed Policeman
24	M	22	180	72	36.5	
25	M	44	180	74	36.5	Amputee-left arm
26	M	25	200	72	---	Quadraplegic

ancillary tests. Several of these 24 subjects also participated in some of the special ancillary tests. The participation of the amputee (Number 25) and the quadraplegic (Number 26) was limited to the ancillary tests only.

About a third of the subjects were acquired through the cooperation of the State of California Department of Human Resources Development; another third had been test subjects in previous phases of this study or other MFI studies; and the final one-third were selected from various sources for their unique characteristics.

3.6.3 Procedures

Test subjects were notified in advance when they were scheduled for testing. Upon their arrival all pertinent data concerning them were recorded. Height and weight were taken verbally from the subject but seated height was measured and recorded.

Subjects were read an explanatory background and introduction to the tests (see Appendix D) and were then taken to the vehicles where the test commenced. No explanation of seat belt system functioning was given before the first trial. Instead the subject was allowed to try it on his own so that he could experience the difficulties in learning. If the problem appeared insuperable, the proper procedure was demonstrated.

This phase of the research was divided into two major sets of tests, the main test and ancillary tests.

3.6.3.1 The Main Test

The main test involved 24 test subjects making evaluations on six seat-belt systems. Three forms of evaluations were made, each based on different types of information and derived through different methods at different stages in the testing sequence.

The first form of evaluation was carried out by means of a questionnaire (see Appendix C). After the subject had entered the vehicle and donned the seat belt he was asked the first set of six questions. In this set there is one subset of questions applicable to the standard systems (A, B, C, and F) and another applicable to the passive systems (D and E). The evaluation of this set is concerned with the donning phase, while the two subsets take into account the fact that operations of the standard and passive systems are fundamentally distinct from one another during this phase.

Subjects responded to such questions as, "Did you have any difficulty in finding the buckle?" by indicating whether or not they had a problem and, if so, how severe. No problem was scored as "0". Problems were scored as "1" if minor, "2" if moderate, and "3" if serious. All 25 questions in the questionnaire were scored in a similar manner.

The 11 questions in Set No. 2 were asked after the subject had: (1) adjusted the seat to the rearmost, forward, and preferred position; (2) reached for the glove compartment and left vent handle (or the emergency brake release); (3) turned to look toward the left rear; and (4) turned to the right to look out the rear window. The questions were framed so as to determine whether or not the seat belts caused the subject any interference in carrying out these operations (inconvenience), or whether or not the belts produced any discomfort resulting from subject's attempts to carry out the operations. All questions in Set No. 2 were applicable to both the standard and passive systems.

The questions in Set No. 3 were asked after the subject had doffed the belt system. In the case of the passive system this meant putting the belt in the stowed position on the hook and opening the door.

The Set No. 3 questions were concerned with problems encountered in doffing. The subset for the standard system had 4 questions, and for the passive system 3 questions.

The two questions in each of the subsets for standard and passive systems in Set No. 4 were intended to determine if the seat belt system interfered with egress from the vehicle, and they were asked just after the subject had made a normal exit.

After the Set No. 4 questions were administered the subject reentered the vehicle, this time to make an emergency exit, i.e., to doff the seat belt system and leave the vehicle as quickly as possible. The test began with the subject wearing the seat belt and with both hands on the steering wheel. At the command, "go!" timing by a stop-watch commenced and the subject removed his/her hands from the wheel and began egress. In the case of the standard seat belt systems the subject first doffed the system and then opened the door. In the case of the passive systems the subject opened the door immediately without having stowed the belt (on the hook).

Timing continued until subject was out of the vehicle, clear of the belt-system with both feet on the ground. The watch was then stopped and the timing read and recorded.

Subject then re-entered the vehicle and was instructed to attempt an emergency exit from the opposite door (i.e., the door on the front-seat passenger's side), thereby simulating a condition in which his own door was jammed shut after an accident. In most cases subjects were not required to complete this attempt due to the difficulty of crossing the console in bucket seat models and also because of the strenuous effort that would be required by the elderly and handicapped.

The two questions in Set No. 5, applicable to both the Standard and Passive Systems, were asked after completion of both emergency exit attempts. The first question was concerned with difficulties encountered during exit from the driver's side. The second question asked was "Did you experience or can you imagine any difficulties in making an emergency exit from the opposite door?" The word "imagine" was included to take into account situations in which the emergency exit was not completed but the subject was capable of perceiving the nature of the impediments imposed by his own belt system or that in the right-front passenger's seat.

This completed the questionnaire evaluation of the first system. The entire procedure was repeated for the second system and upon completion a pair comparison was made as follows. The first system evaluated was designated the "Criterion System." The second system was designated the "Comparison System." The subject was then asked to indicate the appropriate response to the following: Compared with the Criterion System (which was identified by the name of the vehicle in which it was mounted as well as by its letter code) the Comparison System (similarly identified) is worse, the same, or better. Subject's answer choice was then recorded.

This process was repeated so that after each pair of systems had been individually evaluated on specific items they were then evaluated on a general and comparative basis. Each subject made fifteen pair comparisons since, with six systems involved, there are 15 distinctive pairing possibilities.

An effort was made to avoid biasing the data by learning and order effects. This was accomplished by insuring that different subjects did not become exposed to the various systems in the same sequence.

Table 17 shows the sequence of belt-system pair comparisons for the first seven of the 24 subjects. It will be noted that each of the 15 pairs is comprised of no system from either the proceding or subsequent pairs so that repetitive experience with any one system is avoided. Also, the sequence of systems for each subject is distinctive, thereby reducing or eliminating any biasing influence of order effects. And so the process went for the 24 subjects.

When each subject had completed the entire series of 15 pair comparisons, he or she was asked to rank-order the six systems, giving the best system the first position and the worst system sixth position, with the rest appropriately ordered in between.

Having become familiar with the operation of all systems through evaluating each on specific points, and also having considered each in a pair comparison five times, the subject made a final impressionistic evaluation based on all previous experience.

3.6.3.2 Ancillary Tests

The ancillary tests were designed to initiate preliminary investigations into such questions as: (1) the effects of various relatively unusual human characteristics (such as

Table 17 - Example of Belt-System Pair-Comparison Sequences For First Seven of 24 Subjects

Subject I.D. Number	1	2	3	4	5	6	7
Belt-System Pair-Comparison Sequences	EF AC BD CE AD BE CF AE BF DE AF BC DF AB CD	DB CA FE DC BA FD CB FA ED FB EA FC EB DA EC	BE AD CE BD AC EF CD AB DF BC AF DE BF AE CF	ED FA CB FD BA DC FE CA DB EC DA EB FC EA FB	DF AB CD EF AC BD CE AD BE CF AE BF DE AF BC	FE DC BA FD CB FA ED FB EA FC EB DA EC DB CA	CE BD AC EF CD AB DF BC AF DE BF AE CF BE AD

Belt-System Letter Code:

A MFI-Modified Toyota System
B MFI-Modified Toyota System - Bench Seat Configuration
C Chevrolet Impala System
D American Safety Equipment Experimental Passive System
E General Motors Experimental Passive System
F Capri System

obesity) on the evaluation of the seat belt systems; (2) the effects of wearing winter clothing (gloves and bulky coat) on system evaluation; (3) the comparative evaluation of a magnetic lift latch; and (4) the mean time required to doff each system and make an emergency exit from the vehicle.

It was not intended that these tests should be definitive, but rather that they identify whether these conditions appeared to have significance to the overall problems of restraint system convenience or comfort. Results could also indicate whether further research might be needed before final standards are defined.

One part of the first ancillary test did not actually involve additional testing but rather was based on analysis of data from main test results (e.g., test subjects having special characteristics were segregated for individual analysis). The characteristics involved were: short seated-height (subjects Nos. 1, 15, and 5); tall seated-height (subject No. 13); obesity (subject No. 6); pregnant condition (subject No. 7); arthritic condition in hands (subject No. 2); and a uniformed policeman (subject No. 23). The short seated-height characteristic was represented by a male child, a female child, and a 5th percentile female. The tall seated-height characteristic was represented by a 95th percentile male. (For anthropometric details see Table 16).

A uniformed policeman was included since research in Phases III and IV demonstrated that the uniform and equipment worn by policemen present special problems.

In addition to the eight test subjects whose data were selected from the results of the main test, two other subjects having special characteristics also made evaluations of the seat-belt systems. Both subjects were males, one with an amputated left arm, the other a quadraplegic.

The questionnaire was not administered to these two subjects. They donned and doffed the belt systems and performed as many simulated driving operations as possible. (Both were licensed drivers.) The amputee tried all six systems. But due to the strenuous effort involved in entry and egress for the quadraplegic he tried only four of the six systems. As in the main test, after each pair of trials both subjects were required to make a pair comparison, and upon completion of all trials they rank-ordered the systems.

The systems were the same as those used in the main test with one exception. In System A the standard push-button buckle was replaced with the magnetic lift-latch buckle used in the Phase III tests. This modified System A is identified as System A-1.

Four test subjects who previously had participated in the main test were called back for a test designed to indicate if there might be some effect on evaluations when the subjects were required to wear winter clothing (in the main test series all test subjects wore summer clothing).

Test subjects were selected so as to take into account differences that might occur due to sex and age (e.g., two males, one young and one old, and two females, one young and one old).

Subjects were not required to respond to the questionnaire, however, they performed all the functions of donning, seat and control operations, doffing, and exiting performed in the main test. They also made pair comparisons and did rank ordering as they had in the main test.

Comparisons by the subjects were made between <u>systems</u> and not between the two conditions of summer and winter clothing. Thus subjects first proceeded through the entire test procedure in summer clothing, then repeated the procedure in winter clothing.

The magnetic lift-latch formerly used on Mercedes Benz automobiles also was evaluated separately on a small scale during the ancillary tests. This was the buckle used in the Phase III mockup studies, described in Section 3.4.1.

The main test established the fact that test subjects considered Systems A and B to be virtually identical by giving these systems similar ratings. Consequently any single change introduced into one of these systems should account for the consistent preference of one system over the other.

The lift-latch buckle was installed as the only modification on System A and in this configuration the system is designated System A-1. It was used in the special Subject-Characteristics Test and the Summer/Winter Clothing Test and the evaluations it received, compared with those received by System B, is therefore indicative of subjects' preference between the lift-latch and the push-button latch.

As described in Section 3.6.3.1, test subjects were required to make three emergency exits from each of the vehicles in which the six seat belt systems were installed. For the purposes of analysis data resulting from this test were considered separate from the main test and were therefore included with the ancillary tests.

3.6.4 Phase V Results

The results of Phase V testing will be discussed under the following categories:

1. The Main Test
   a. Questionnaire
   b. Paired comparisons
   c. Rank ordering
2. Ancillary Tests
   a. Special subject-characteristics
   b. Summer/winter clothing
   c. Egress timing

3.6.4.1 The Main Test

a. The Questionnaire

Scores for the three trials on each question and each seat-belt system were averaged for each subject. An analysis of variance of these mean scores (see Appendix E for summary) showed a highly significant overall difference among the seat-belt systems. The system by question interaction was also highly significant, showing that the differences among the systems were not consistent over all questions. In order to identify the particular differences producing the overall significance the system (by question) means were computed as shown in Table 18. Differences among systems were evaluated for each question using Tukey's H.S.D. criterion for differences between pairs of ordered means.* In view of the large number of comparisons involved a conservative .01 level of significance was used. These mean scores also allow the isolation of specific problems occurring in each system.

In this study a system is considered to have a problem when the mean score is 1.00 or above since in the questionnaire "no problem" was indicated by a score of "0", while a problem was indicated by a score of "1" if minor, "2" if moderate, and "3" if serious. We believe this to be a reasonably conservative interpretation. Certainly scores of less than .50 indicate that whatever difficulties may have been encountered were not considered seriously troublesome except possibly to a small minority. On the other hand it is possible that scores ranging between .50 and 1.00 reflect at least a minor problem among a substantial segment of the sample.

Differences between means of these data become significant at the .01 level when they are .50 or more, so that a mean score of .75 when compared to one of .20 is significantly different and could be interpreted as at least reflecting a problem from a relative standpoint. And that same score of .75 would not be significantly different from a problem (by our definition) which has a score of, say, 1.10.

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*Kirk, Roger E. Experimental Design: Procedures for the Behavioral Sciences. Belmont, Calif., Brooks/Cole Publishing Company, 1968. PP 88-90

Table 18 - Means of All Scores For All Subjects' Responses to Each of 25 Questions

	Set No. 1						Set No. 2											Set No. 3				Set No. 4		Set No. 5	
Questions	1	2	3	4	5	6	1	2	3	4	5	6	7	8	9	10	11	1	2	3	4	1	2	1	2
System A	.07	.03	.03	0	.06	.35	.04	.10	1.04	0	.11	.35	.03	.07	.14	.33	.04	.04	.01	.35	.08	.08	0	.36	.25
System B	.03	.04	0	0	.06	.32	0	.10	1.02	.01	.19	.31	.21	.19	.06	.24	.08	.14	.06	.28	.07	.06	0	.32	.17
System C	.01	.06	.67	.08	.31	.60	1.51	.38	.35	.01	.18	.60	.07	.61	.19	.38	.12	.07	.43	.30	.13	.56	0	.67	.18
System D	.24	.11	.06	.29	.12	.58	.48	.58	.76	.14	.44	.66	.26	.68	.44	1.03	.76	.56	.35	.09	0	.61	.82	.42	2.90
System E	.28	.28	.13	.41	.12	.76	.51	.84	.40	.22	.08	1.20	.29	1.03	.99	1.39	1.10	.69	1.22	.25	0	.10	.13	.69	2.48
System F	1.55	1.34	1.49	.03	.51	1.47	1.66	.63	.69	.15	.24	.49	.31	.81	.88	.97	.25	.15	.67	.84	2.58	.37	2.38	1.03	.44

Nevertheless, by setting the minimal level for the indication of a problem expressed in means at 1.00, we believe that this establishes a magnitude of seriousness high enough to ensure that the same condition would be interpreted as a problem by an extremely wide range of U.S. automobile users.

It should be kept in mind that the scores assigned by the subjects were based solely on their personal interpretations of how various aspects of the system impinged on them in terms of comfort and convenience. Therefore a mean score of, say, 1.05 for one question cannot be said to be more or less important than a score of 1.05 for another question because one question is concerned with a more important factor than another in terms of safety or some other "objective" criterion.

The sole criterion of importance in this study is the admittedly subjective responses of the test subjects.

The aspect of design with which this study is concerned is its effect on comfort and convenience. Only a user of a belt system can make judgments in this area, and such user judgements are the only basis for our quantitative data. Therefore each mean score indicates not only a measurement of a group evaluation of comfort and convenience but it also represents the magnitude of importance of the respective item in the minds of the evaluators.

The problem scores range from 1.02 to 2.90.

Table 19 shows which differences between mean scores for each seat belt system are or are not significant at the .01 level for each question, i.e., have or have not at least a difference of .50, as determined by Tukey's H.S.D. technique. Seat belt systems between which mean scores were not significantly different have their code letters joined by underlining; those not so joined differ significantly. Also shown in the table are those instances in which the mean score indicated that a problem existed within a particular belt system. Systems having problems associated with any particular question are identified by their code letters, enclosed in parentheses for that question.

Table 19 - Systems For Which Differences Between Mean Scores For Each Question Were or Were Not Significant*

1 of 4 pages

Set No. 1 (Asked after subject donned belt system)

(S) = Standard System

(P) = Passive System

1.	(S) Locating latchplate (P) Confusion on getting past belt on entry	<u>A B C D E</u>	(F)
2.	(S) Retrieving latchplate (P) Interference with entry	<u>A B C D E</u>	(F)
3.	(S) Extending webbing (P) Unhooking webbing	<u>A B D E</u>	C (F)
4.	(S) Finding Buckle (P) Harness dragging across chest	<u>A B C D E F</u>	
5.	(S) Securing buckle (P) Harness missing shoulder	<u>A B C D E F</u>	
6.	(S) (P) Straightening webbing	<u>A B C D E</u>	(F)

Table 19 (Continued)

Set No. 2 (Asked after subject has adjusted seat, reached for controls, and turned to look rearward)

For both Standard and Passive Systems

1.	Interference with seat adjustment	B A D E (C) (F)
2.	Interference with reach	A B C D E F
3.	Obstruction of left rear view	C E F D (A) (B)
4.	Limitation in turning for rear window view	A B C D E F
5.	Failure of webbing to fit snugly	A B C D E F
6.	Webbing touching neck or face	A B C D E F (E)
7.	Webbing falling off shoulder	A B C D E F
8.	Harness crossing inboard chest (breast)	A B C D (E) F
9.	Webbing exerting pressure on shoulder	A B C D F E
10.	Webbing chafing across shoulder	A B C (D) (E) F
11.	Lap belt riding up on stomach	A B C F D (E)

Table 19 (Continued)

Set No. 3 (Asked after subject doffed belt system)

1.	(S) Locating buckle (P) Doffing belt system	A C B F D E
2.	(S) Operating buckle release (P) Stowing (hooking) belt system	A B C D F (E)
3.	(S) Webbing hanging up on clothes, etc. (P) Webbing dragging across clothes, etc.	B C D E A F
4.	(S) (P) Retraction and stowage complete	A B C D E (F)

Set No. 4 (Asked after subject had exited from vehicle)

1.	(S) (P) Interference with exit	B A E F C D
2.	(S) Belt system clearance of door (P) Hold door against belt tension	A B C E D (F)

Table 19 (Continued)

Set No. 5 (Asked after subject completed emergency exit from adjacent door and toward opposite door)

For both Standard and Passive Systems

1.	Emergency exit from driver's door	A B D C E (F)
2.	Emergency exit from opposite door	A B C F (D) (E)

*System-identifying letters that are joined by underlining have mean scores that do not differ significantly; those not joined do differ significantly. Letters A through F enclosed in parenthesis indicate systems on which a problem has been noted.

Legend:
- System A - Toyota
- System B - Mercury
- System C - Impala
- System D - Gremlin
- System E - Vega
- System F - Capri

The table shows that for set No. 1, which was concerned with the donning phase, the distinctions are very clear cut. No problems occurred for any systems except System F. And with only one exception (i.e., System C in question Number 3), only System F was significantly different from all others in four out of six questions. Moreover none of the other systems differ significantly from each other (with the exception of C in Question 3).

For the other sets the significance/non-significance distinctions are more complicated with overlappings and independent groupings occurring for some questions. It will also be observed that out of the twenty-five questions, no significant difference between the means for all six systems occur in five questions (Set No. 1, Questions Nos. 2 and 3; Set No. 2, Questions Nos. 4, 5, and 7). With a single exception ("F" in Set No. 1, Question No. 5) all these means for all systems in each of the five questions are below 0.50.

But of greater importance to the objectives of this study were those areas in which problems were identified. All systems had at least one question for which the mean score was 1.00 or above, and the total number of problems was 19.

Table 20 identifies each of these 19 problems according to the set and question with which it is concerned and also indicating in which system it occurred. A brief description of the problem and the mean score, which represents the magnitude of seriousness assigned to it by the 24 test subjects, also are given. In addition to the 19 scores that were 1.00 or above, two other scores are shown, viz., 0.99 and 0.97. These were the only scores occurring in the 0.90's, and though technically not problems by our criteria they were close enough to at least be considered and so are shown in parentheses.

As noted in Section 3.6.3.1 nine of the 25 questions had two queries, one directed exclusively at the 4 standard systems (A, B, C and F) and one directed exclusively at the passive systems (D and E). The two queries of each question dealt with the same general activity, e.g., donning or doffing, but because of fundamental differences between the two types of system they addressed the characteristics specific to each type. The other 16 questions had a single query applicable to both types of system.

Table 20 - Problems Identified According to Set Number and Question Number

Set No.	Question No.	Problem	System	Mean Score
1				
	1	Difficulty in Locating latchplate	F	1.55
	2	Difficulty in retrieving latch plate	F	1.34
	3	Difficulty in extending webbing	F	1.49
	6	Difficulty in straightening webbing	F	1.47
2				
	1	Interference with seat adjustment	C	1.51
	1	" " " "	F	1.66
	3	Obstruction of left rear view	A	1.02
	3	" " " " "	B	1.04
	6	Webbing touching neck or face	E	1.20
	8	Harness crossing inboard chest	E	1.03
	9	Webbing exerting pressure on shoulder	(E)	(0.99)
	10	Webbing chafing across shoulder.	D	1.03

Table 20 (Continued)

Set No.	Question No.	Problem	System	Mean Score
	10	Webbing chafing across shoulder	E	1.39
	10	" " " "	(F)	(0.97)
	11	Lap belt riding up on stomach	E	1.10
3				
	2*	Difficulty in stowing belt system	E	1.22
	4	Incomplete retraction and stowage	F	2.58
4				
	2	System not clear of door	F	2.38
5				
	1	Emergency exit from driver's door	F	1.03
	2	Emergency exit from opposite door	D	2.90
	2	" " " " "	E	2.48

*This question from the sub-set applicable exclusively to passive systems.

Legend:
System A - Toyota
System B - Mercury
System C - Impala
System D - Gremlin
System E - Vega
System F - Capri

In no instance was a problem involving both a standard and a passive system associated with any one of the 9 double query questions (5 questions in Set No. 1; 3 questions in Set No. 3; and 1 question in Set No. 4). And in only one instance was a passive-system problem identified by a double-query question (Question No. 2, Set No. 3, System E).

In Set No. 3 there are four questions in the subset for the standard systems and three questions in the subset for the passive systems. Question No. 4 in the former was, "Was retraction and stowage complete?" Since in the passive system stowage was manual and retraction not a problem in doffing, this question was not asked in reference to the passive systems. However for the purpose of data analysis a score of zero, or no-problem, was assigned to the non-existent question.

It is of practical importance to indicate the known or suspected determinants of each problem, as we will now do while considering the problems as they were identified by question-sets and questions within each set, as shown in Table 20.

Notice that the only problems identified in Set No. 1 occur in System F. The problems encountered in System F during the donning phase (Set No. 1, Questions Nos. 1, 2, 3, and 6) were due to several factors. First, the single retractor system can present problems in location of the latch plate because it is free to slide along the belt. Second, the location of the retractor and the webbing guide placed the belt behind the seat while in its stowed position, making access difficult. Third, the retractor had insufficient force, resulting in incomplete retraction which left the belt and latch plate hanging loose and consequently made them more difficult to locate.

Interference with the seat adjustment (Set No. 2, Question No. 1), which occurred in System C, resulted from the fact that the ratchet in the automatic retractor (mounted separately from the seat) locked the lap belt, keeping it from extending when the seat was moved forward. System F experienced the same problem but for different reasons. Although it had a vehicle-sensitive retractor, the fact that there was but one retractor, mounted separately from the seat, resulted in the belt tightening from the permanently-anchored (non-retractor) end as the seat was moved forward. The latch plate that slides freely along the webbing prior to donning offers considerable resistance to the webbing sliding through it when the system is donned. Consequently the seat cannot be moved forward without the belt tightening uncomfortably on the wearer unless the system is doffed or the latch plate adjusted manually.

Obstruction of the left rear view by the shoulder harness (Set No. 2, Question No. 3) was a problem only in Systems A and B. In both systems interference with visibility resulted from the webbing between the shoulder and retractor that had been repositioned by the MFI webbing guide mounted on a special bracket. This guide placed the webbing further outboard, in the line of sight through the left rear-door window.

System E (one of the passive systems) had a problem with the belt impinging against the neck (Set 2, Question 6) since the location of the upper anchor point (on the door) was too far aft and the lower loop too low and too far aft. These same conditions in System E were responsible for the problem of the harness across the inboard breast (Set No. 2, Question No. 8) and the near-problem of webbing exerting pressure on the shoulder (Set No. 2, Question No. 9).

Webbing chafing the shoulder (Set No. 2, Question No. 10) was a problem with both passive Systems (D and E) because the single retractor is located toward the lower end of the belt, i.e., near the pelvic restraint. At the upper anchor point for the shoulder harness there is no retractor and consequently no provision for length adjustment. Therefore forward movement of the upper torso results in abrasion with the non-moving shoulder harness.

The near-problem of webbing chafing the shoulder occurred in System F because of the nature of its single-retractor arrangement. When the torso moves forward, the length of the lap belt section needs to be extended. And since it is permanently anchored without a retractor at its outboard end it takes the additional length of belt from the shoulder harness through the loop of the latch plate near the pelvis. This causes the shoulder harness to move (i.e., chafe) against the torso.

System E presented a problem with the belt riding up on the stomach (Set No. 2, Question No. 11). This situation tended to occur primarily when the subject leaned forward, creating a need for a longer shoulder harness which, in this single retractor passive system, can only be provided by the lap-belt portion of the single belt segment. Shortening of the lap belt caused it, and the ring through which it passed into the shoulder harness (See Figure 9), to ride up on the stomach.

Though generally similar in design to System E this situation was not registered as a problem for System D (although the difference between their mean values was not significant). One apparent contributor to the better performance of System D was the design feature of a longer shoulder-harness/lap-belt segment which allows the sliding ring connection to the retractor segment to be further away from the stomach.

In System E subjects indicated that they had considerable difficulty in stowing (i.e., hooking) the belt system (Set No. 3, Question No. 2, Passive). It will be noted in Table 18 that no such problem was indicated for the other passive system, i.e., System D. Indeed, the mean score of System E is 3.5 times greater than that of System D. Though these two systems were very similar in design and operation it was in the area of stowage that there was an important, yet very simple, difference.

The sliding ring of System D came equipped with a metal hoop designed to fit over the stowage hook. By grasping the hoop stowage became an easy one-hand operation. Without such a hoop in System E stowage was accomplished by placing the webbing over the hook. This proved confusing because it was not obvious which segment of the belt went over the hook and it was difficult because it usually required the use of both hands to accomplish the hooking act.

The mean scores for these two systems clearly indicate the favorable effect on the user of a simple innovation designed specifically to facilitate use of the equipment.

System F had a very serious problem due to incomplete retraction and stowage (Set No. 3, Question No. 4, Standard).

GREMLIN

Figure 9 - Slip Ring Discomfort

The single retractor had insufficient force to overcome the friction in the system, the consequence of which was virtually no retraction. This condition resulted in another serious problem in that when the door was opened after doffing a considerable length of the belt usually fell out of the doorway (Set No. 4, Question No. 2, Standard; See Figure 10). This incomplete retraction also was a major factor in the difficulties experienced in making an emergency exit from the door on the driver's side in System F (Set No. 5, Question No. 1).

Having to climb through the belt system of the adjacent seat in both passive systems (i.e., D and E) in order to make an emergency exit from the opposite door (one the right-hand or passenger's side) was considered to be of the utmost seriousness (Set No. 5, Question No. 2). In this case the belt system seemed so formidable to the subjects that it received the highest score in the study -- 2.90 out of a possible maximum of 3.00.

Now we will review these data once again. This time, however, the problems will be considered according to system rather than according to set or question.

Table 21 identifies all problems according to the system in which they occurred. Also given in this table is a description of the problem, its magnitude (i.e., the mean score), and the set and question in the questionnaire with which it is associated. From this table it can be seen that there tend to be two major clusters of scores, viz., those 2.38 and above and those 1.66 and below. The sizeable difference (0.72) between these two clusters suggests that the four scores in the group of 2.38 and above reflect opinions held to a much stronger degree than those in the other group.

Of greatest concern to the subjects was the difficulty (and inconvenience) encountered in attempting an emergency exit from the door on the side opposite from where the subject was sitting in the two vehicles in which the passive systems were installed. Thus, the mean score on this point for System D is 2.90, and for System E the mean score is 2.48.

System F had both the other scores in this high cluster, each of which was concerned with problems associated

Figure 10 - Belt Falling Out Door

Table 21 - Problems Identified According to System

System	Set	Question	Problem	Magnitude of Problem (Mean Score)
A	2	3	Obstruction of Left rear view	1.04
B	2	3	Obstruction of left rear view	1.02
C	2	1	Interference with seat adjustment	1.51
D	2	10	Chafing across shoulder	1.03
	5	2	Emergency exit from opposite door	2.90
E	2	6	Rubbing neck or face	1.20
	2	8	Pressure on shoulder	1.03
	2	9	(Pressure on shoulder)	(0.99)
	2	10	Chafing across shoulder	1.39
	2	11	Lap belt riding up on stomach	1.10
	3	2	Difficulty in stowing system	1.22
	5	2	Emergency exit from opposite door	2.48

Table 21 (Continued)

System	Set	Question	Problem	Magnitude of Problem (Mean Score)
F	1	1	Difficulty in locating latchplate	1.55
	1	2	Difficulty in retrieving latchplate	1.34
	1	3	Difficulty in extending webbing	1.49
	1	6	Had to straighten webbing	1.47
	2	1	Interference with seat adjustment	1.66
	2	10	(Chafing across shoulder)	(0.97)
	3	4	Retraction incomplete	2.58
	4	2	System not clear of door	2.38
	5	1	Emergency exit from driver's door	1.03

Legend:
- System A - Toyota
- System B - Mercury
- System C - Impala
- System D - Gremlin
- System E - Vega
- System F - Capri

with the poor retraction of the belt. The question of incomplete retraction and stowage had a mean score of 2.58, while the mean score for the question concerned with parts of the belt system not clearing the door (primarily because of incomplete retraction) was 2.38.

System F is the only system that has problems in each of the five sets of questions representing respectively the donning phase (four problems), the operation phase (one problem and one near-problem), the doffing phase (one problem), the normal exit phase (one problem), and the emergency exit phase (one problem). With a total of eight problems and one near-problem, System F had the most problems of any of the six systems tested.

System E had six problems and one near-problem; System D had two problems; and Systems A, B, and C each had one problem.

Solely on the basis of all the preceding data it probably would be safe to conclude that the system judged to be best by the 24 test subjects was among A, B, and C, and that the worst system was F. But we can determine with confidence the rank order of the six systems as judged by the test subjects on all 25 questions by the mean score for all subjects on all questions for each system.

These overall mean scores for each system are presented in Figure 11 and Table 22, from which it will be observed that virtually equivalent to one another and superior to all the other four systems. Since Systems A and B were essentially identical it was expected that their mean scores would be comparatively close to one another. However it also was expected that because the two systems were installed in vehicles of different size and type -- one having bucket seats and the other a bench seat -- these non-seat-belt-system factors might have an appreciable effect on the evaluations. Actually, however, the effect was minimal.

Although the mean score for both systems turned out to be identical, there were differences between the two systems

Legend: A - MFI/Toy
B - MFI/Merc
C - GM/Imp
D - AS/Pass
E - GM/Pass
F - Cap

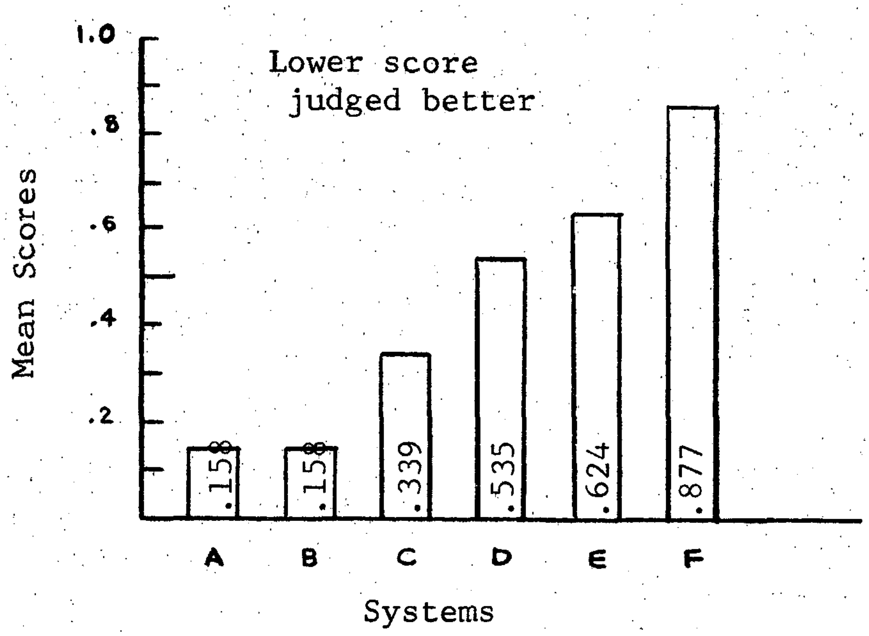


Figure 11 - Mean Scores Of All Questions And All Subjects For Each System

Table 22 - Mean Scores Of All Questions and All Subjects For Each System and Differences Between Systems

System		A	B	C	D	E	F
Mean Score		.158	.158	.339	.535	.624	.877
System Differences	A		0	.181	.377	.466	.719
	B			.181	.377	.466	.719
	C				.196	.285	.538
	D					.084	.342
	E						.253

Note: Significant difference at the .01 level = .181

in their respective mean scores for most of the individual questions, as can be seen in Table 18. There also were differences between subjects, as indicated by differences between Systems A and B in their mean scores for females and males (shown in Table 26).

However all the differences were relatively minor and they obviously balanced out so that the overall mean for each system was the same. In any case these results imply consistency in the testing procedures. They further suggest that the subjects tended to limit their evaluations to the seat-belt systems, regardless of the variations of the vehicles in which they were installed.

Table 22 shows that Systems A and B were considered significantly superior to all others. In the case of System C it should be noted that this "significance" of difference is technical since the difference of .181 between Systems A and B on the one hand and System C on the other happens to be precisely the number indicative of significant difference at the .01 level as derived by Tukey's H.S.D. technique (see Appendix E).

Table 22 also shows that the differences between the mean of Systems A and B on the one hand and Systems D, E, and F on the other are all well beyond the statistically-significant point. Furthermore it shows that all differences between Systems C, D, E, and F are statistically significant except for the difference between the two passive systems, D, and E.

It is clear, then, that on the basis of overall mean scores Systems A and B were judged superior to the others.

b. Pair Comparison

The second measurement of the test subject's evaluation of the seat-belt systems is based on data resulting from the pair-comparison tests described in Section 3.4.3.1. Figure 12 and Table 23 present a summary of the findings of these tests.

A few examples will demonstrate the meaning of the table.

Legend: A - MFI/Toy
B - MFI/Merc
C - GM/Imp
D - AS/Pass
E - GM/Pass
F - Cap

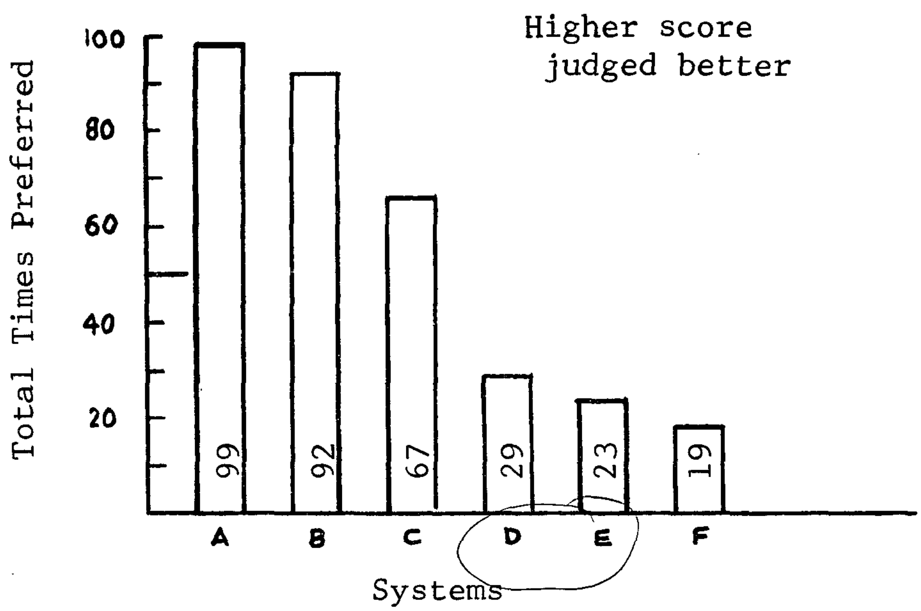


Figure 12 - Total Number Of Times Each System Was Preferred In Pair Comparison Tests

Table 23 - Matrix Showing The Frequency Distribution of Selections Made Among Six Seat-Belt Systems By 24 Test Subjects in Pair Comparison Tests*

		Preferred Systems					
		A	B	C	D	E	F
Non-Preferred Systems	A		8	3			
	B	11(5)		3		1	1
	C	18(3)	16(5)		3	3	1
	D	23(1)	23(1)	20(1)		5	9
	E	23(1)	22(1)	19(2)	12(7)		8
	F	24	23	22(1)	14(1)	14(2)	
Total Times Preferred		99	92	67	29	23	19

*Figures in parenthesis indicate the number of times both systems were considered to be equivalent, and are given in the appropriate cells below the diagonal only.

Legend:
System A - Toyota
System B - Mercury
System C - Impala
System D - Gremlin
System E - Vega
System F - Capri

Each cell shows the number of times the system identified at the head of the column was preferred over the system identified at the head of the row. Since the total number of subjects was 24 and since each one was obliged to make one comparison between each pair of systems, the greatest number of times one system could be preferred over another is 24. This number does occur in the cell that represents the preference for System A over System F. Consequently, in the diagonally opposite cell which represents the preference for or choice of System F over System A, there is no number.

As another example, in the comparisons between Systems A and B, A was preferred 11 times, B eight times, and they were considered equivalent five times. The total number of times, or comparisons is, again, 24.

The figures in "Total Times Preferred" show Systems A and B to be relatively close to one another, both having a considerably greater frequency of preference than any of the other systems. Indeed, in these overall results all the systems tend to have approximately the same relationship with one another as occurred in the overall results (overall mean scores) of the questionnaire, with A and B far in the lead, C in number 3 position, D and E being considerably lower than C, with D slightly higher than E, and F in the lowest positions.

c. Rank Ordering

The third measure of the test subject's evaluation of the seat-belt systems is based on data resulting from the subject-ascribed rank order of the six systems, the procedure for which is described in Section 3.6.3.1.

In Table 24, which gives a frequency distribution of the highest rank-order positions for each of the six seat-belt systems, it will be noted that Systems A and B are the only ones that occur 100 percent of the time among the top three positions. That is, all test subjects considered these two systems good enough to qualify them for placement within the upper half of the rank ordering. And half of the subjects placed System A in the first position.

Table 24 - Frequency Distribution of Highest Rank-Order Positions for Each of the Six Seat Belt Systems

	First Position		Second Position		Top 2 Positions		Top 3 Positions	
	No.	%	No.	%	No.	%	No.	%
System A	12	50.0	5	20.8	17	70.8	24	100
System B	9	37.5	12	50.0	21	87.5	24	100
System C	3	12.5	6	25.0	9	37.5	20	83.3
System D	0	---	1	4.2	1	4.2	2	8.3
System E	0	---	0	---	0	---	0	---
System F	0	---	0	---	0	---	2	8.3

Legend:
System A - Toyota
System B - Mercury
System C - Impala
System D - Gremlin
System E - Vega
System F - Capri

In frequency of selection for the highest rank-order positions the table shows that System C comes third and System E last.

In order to get a perspective on the overall results, with the frequency distribution of the lower half of the rank ordering as well as the upper half allowed to have its effects, the means of the subject-ascribed ranks for each of the six seat belt systems were determined. These are shown in Figure 13 and Table 25. It will be observed that the same pattern that occurred with the questionnaire mean scores and the pair-comparison totals appears again. Systems A and B are in the highest positions and comparatively close to one another. System C comes in third position and at a considerable distance from those that precede and follow it. Systems D and E come next in their familiar relationship, D being somewhat higher (i.e., in value, but of course lower in rank order) than E. And again, in last position, is System F.

d. Observations

The results of Phase III of this study tended to substantiate the results of Phases I and II. On the basis of what was learned in Phase I it was concluded in Phase II that the Impala had one of the best commercially-available seat-belt systems, and that the Capri and the Vega systems were among the worst. The fact that the mean score of System C is close enough to those of Systems A and B to result in statistical significance adds support to our Phase II conclusions about the Impala. And the fact that System F (the Capri) was consistently evaluated as the worst of the six systems also corroborates the findings of the earlier phases.

In an earlier pilot test a standard Vega system was compared with the American Safety experimental passive system in a Gremlin. In this pilot test the standard 1974 Vega system was indicated as being comparatively inferior to the passive system.

Of the total of 18 subjects used in this pilot test, 3, or 17%, preferred the standard Vega system and 15, or 83%,

Legend: A - MFI/Toy
B - MFI/Merc
C - GM/Imp
D - AS/Pass
E - GM/Pass
F - Cap

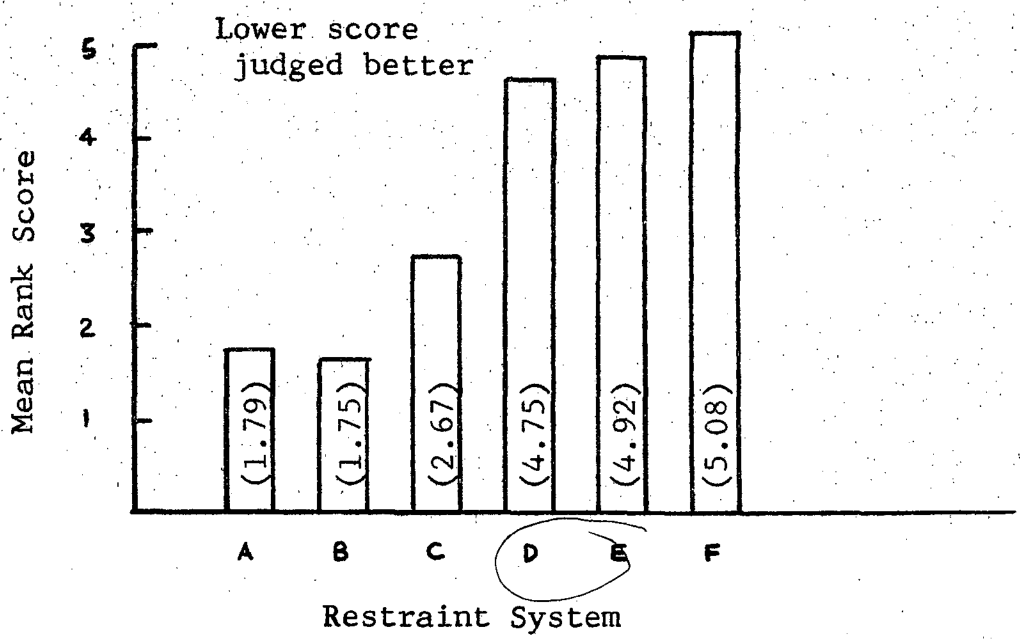


Figure 13 - Means of Subject-Ascribed Ranks For Each Of The Six Seat-Belt Systems

Table 25 - Means of Subject-Ascribed Ranks for Each of the Six Seat-Belt Systems

	System A	System B	System C	System D	System E	System F
Mean Subject-Ascribed Rank	1.79	1.75	2.67	4.75	4.92	5.08

Legend:
- System A - Toyota
- System B - Mercury
- System C - Impala
- System D - Gremlin
- System E - Vega
- System F - Capri

preferred the American Safety experimental passive system.

Subsequently, in the main test we find that subjects clearly preferred a well-designed standard system (A, B, and C) to a passive system (D and E). However it also showed that a passive system in the Vega is preferred to a poorly designed standard system (F). This latter finding is corroborated by the results of the pilot test.

The consistently high ratings for Systems A and B in Phase V also substantiate the findings of Phases III and IV.

The only condition identified as a problem for Systems A and B was the obstruction of the left rear view by the harness. In this connection three points should be considered. First, the presence of the problem was due to our design which was specifically oriented to body geometry and was not, for this prototype model, concerned with rearward visibility. Visibility obstruction was caused primarily by the webbing that passed through the MFI holding bracket and continued up to the retractor. It is probable that our criteria for body geometry can still be met by a design that eliminates or minimizes the obstruction, possibly by a relocation of the retractor.

Second, the use of the side-view mirror normally provides the appropriate visibility in the area obscured by the belt.

And third, by our definition this was just barely a problem, the mean score being 1.04 for System A and 1.02 for System B.

It also should be pointed out that rear viewing from many vehicles probably is poorer because of body/structure design than by webbing interference and that drivers can still see around the webbing by slight head movements more easily than they can see around body structure that currently exists.

In no other instance in Systems A and B was there even any approximation of a mean score to the point of indicating a problem, the highest one being 0.36.

It should be emphasized that the findings of the main test concerning the relative merits of the six systems in terms of comfort and convenience have been derived not from one test only but rather from three tests that can be considered essentially independent. Although the same 24 test subjects were used for all three tests each test was designed to elicit different types of information, by different methods, at different stages of the testing sequence. Thus the questionnaire required responses that were concerned with specific items in each of the systems. The pair comparisons were made after completion of the questionnaires for two systems and the subject was required to make a comparative overall appraisal of these two systems. The rank ordering was done after the subject had completed all questionnaires and pair comparisons, and she or he made an impressionistic evaluation based on all the preceding testing experience.

Given the distinctive conditions under which each of the three tests was administered, the different facets of test experience on which the responses depended and the different extent to which overall impressions formed the basis of the responses, it is likely that subjects tended to respond to each test independently, according to the way they felt at the moment.

The objective of the main test was to determine differences in evaluations by a representative sample of test subjects of comfort and convenience among the six seat-belt systems. Differences in evaluations among individual test subjects or between sub-groups of subjects within the sample were not included as part of the research effort in the main test. Such differences were considered in the ancillary tests, which compared the effects of such factors as the type of clothing, body size, and type of physical handicap.

Nevertheless the data of the main test were studied to see if either sex or age had an influence on evaluations. No appreciable difference in evaluations was observed between younger and older subjects, but a marked difference was exhibited between the sexes. Females were considerably more critical of all systems than were males. For all systems the overall mean score of the females (.536) was over 38 percent higher than the overall mean score of the males (.388).

Figure 14 and Table 26 shows the mean score attained by each sex for each system. It will be noted that in all cases the scores of the females are consistently higher than those of the males by a considerable margin.

This unanticipated result may be interpreted as meaning females are more sensitive to discomfort and/or differences in anatomy than males, with the female breasts especially susceptible to discomfort problems with the shoulder harness. In any case it should be noted here that since males and females in this test sample were in approximately the same proportion as they occur in the national driving population, the differences between the sexes as reflected in their evaluations would not make the overall results unrepresentative of findings to be expected among the general driving population. On the other hand since there were relatively fewer females in this test than in the U.S. population as a whole, their more critical point of view may be under-represented for the potential car-user population.

This sex-correlated difference in evaluation will be considered further in the Conclusions and Recommendations (Section 3.7).

3.6.4.2 Ancillary Tests

As described in Section 3.6.3.2, the ancillary tests were designed to initiate preliminary investigations into such questions as: (1) the effects of various relatively unusual human characteristics (such as obesity) on the evaluation of the different seat belt systems; (2) the effects of wearing winter clothing, i.e., gloves and bulky coat, on system evaluation; (3) the comparative evaluation of a magnetic lift-latch; and (4) the mean time required to doff each system and make an emergency exit from the vehicle.

It was not intended that these tests should be definitive but rather that they should look into the feasibility of future research in the areas investigated. Therefore any

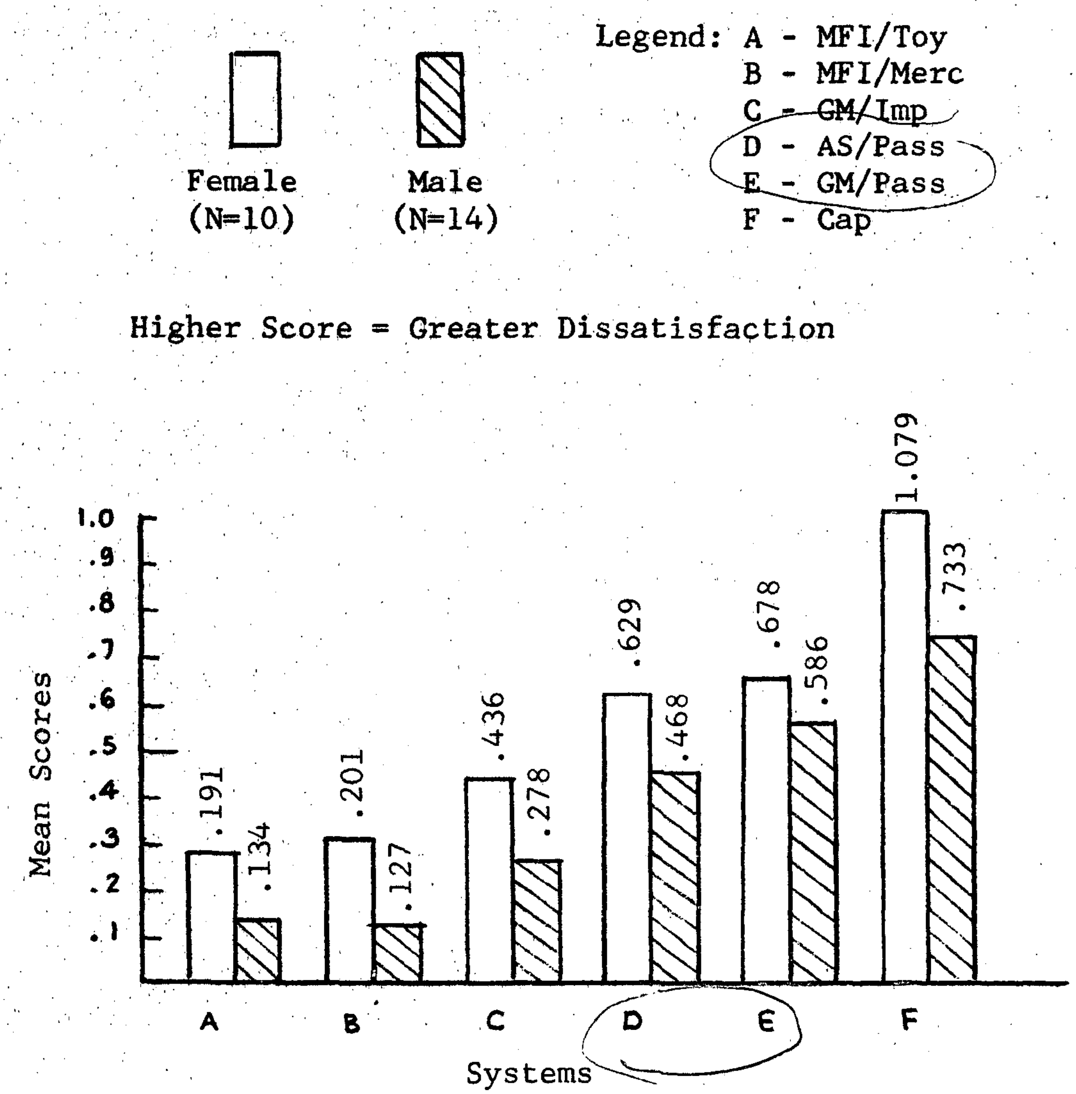


Figure 14 - Mean Scores of Female and Male Subjects For All Questions On Each System

Table 26 - Mean Scores Of Female and Male Subjects For All Questions on Each System

System	Mean Scores Female N = 10	Mean Scores Male N = 14
A	.191	.134
B	.201	.127
C	.436	.278
D	.629	.468
E	.678	.586
F	1.079	.733

Legend:
System A - Toyota
System B - Mercury
System C - Impala
System D - Gremlin
System E - Vega
System F - Capri

conclusions drawn from the ancillary tests must be considered strictly tentative.

a. Special Subject-Characteristics

Data from the main test results concerning the eight test subjects having special characteristics were segregated for individual analysis. Table 27 presents the results of this investigation, and since the findings are concerned with the specific problems identified by each of the eight subjects, the table requires little further comment. However a few general observations seem warranted.

In the donning phase (Set No. 1) the policeman and the obese female experienced the most problems. In the case of the former, police equipment tends to make donning manipulations cumbersome. In the case of the latter the requirement to reach around a large, rotund form with standard-size arms results in inadequate capability to extend the hand readily to the locations of the stowed latch-plate and buckle.

The pregnant female experienced the most problems during the wearing and driver-operations phase (Set No. 2). It will also be noted that webbing touching neck or face (Question No. 6) was identified as a problem in all or most vehicles by all four mature females (including subject No. 2) although the complaint was minimal in systems A, B and C. This is primarily due to the tendency of the shoulder harness to cross over and around the inboard side of a full bosom which pulls the upper part of the harness further inboard until it contacts the neck or face. This condition can become particularly promounced with an obese female (see Figure 15).

In the doffing and exiting phases (Sets Nos. 3, 4, and 5) the policeman experienced the greatest number of problems, due primarily to difficulties imposed by his equipment.

In addition to the eight test subjects whose data were selected from the results of the main test, two other subjects having special characteristics also made evaluations of the seat-belt systems. Both subjects were males, one with an amputated left arm, the other a quadraplegic. The amputee tried all six systems, while the quadraplegic tried only four of the

Table 27 - Problems Identified by Subjects Having Special Characteristics*

Set No. 1

Questions	Systems	Female Child	Male Child	5th %ile Female	95th %ile Male	Obese Female	Pregnant Female	Arthritic Hands	Uniformed Policeman
Subject I.D. Number		5	15	1	13	6	7	2	23
1. (S) ** Locating latch plate	A								
	B								
(P) ** Confusion on getting past belt on entry	C								
	D					X			X
	E	X							X
	F			X	X	X	X	X	X
2. (S) Retrieving latch plate	A								
	B								
(P) Interference with entry	C								
	D								X
	E								
	F	X		X	X	X	X	X	X
3. (S) Extending webbing	A								
	B								
(P) Unhooking webbing	C					X			X
	D								
	E								
	F	X	X	X		X	X		X
4. (S) Finding buckle	A								
	B								
(P) Harness dragging across chest	C					X			
	D	X							
	E			X		X			
	F								
5. (S) Securing buckle	A								
	B								
(P) Harness missing shoulder	C					X	X		
	D								
	E								
	F					X	X		
6. (S) (P) Straightening webbing	A								
	B								
	C								X
	D		X		X		X		X
	E		X	X	X				X
	F	X	X	X	X	X	X		X

Table 27 (Continued)

Subject I.D. Number

Set No. 2 (For both S & P Systems)

Questions	Systems	5	15	1	13	6	7	2	23
1. Interference with seat adjustment	A								X
	B								
	C		X	X	X	X	X	X	X
	D		X			X	X	X	X
	E	X	X			X	X		
	F		X	X	X	X	X	X	X
2. Interference with reach	A								X
	B				X				
	C	X						X	
	D	X	X			X	X		X
	E	X			X	X	X		
	F		X		X	X	X		
3. Obstruction of left rear view	A		X		X		X	X	
	B			X	X		X	X	
	C							X	
	D		X				X	X	
	E								
	F			X			X	X	X
4. Limitation in turning for rear window view	A								
	B								
	C								
	D	X					X		
	E						X		
	F						X		X
5. Failure of webbing to fit snugly	A								
	B								X
	C								
	D	X	X	X					
	E								
	F		X	X	X				
6. Webbing touching neck or face	A		X			X	X	X	
	B			X		X	X	X	
	C			X		X	X	X	
	D		X	X		X	X		
	E			X	X	X	X	X	
	F			X	X	X	X		
7. Webbing falling off shoulder	A	X							
	B								
	C								
	D	X							
	E								
	F		X		X				X
8. Harness crossing inboard chest (breast)	A								
	B					X			
	C			X		X	X	X	
	D	X	X	X			X		
	E	X	X	X		X	X		X
	F			X	X	X	X		X

Table 27 (Continued)

Questions	Systems	5	15	1	13	6	7	2	23
9. Webbing exerting pressure on shoulder	A						X		
	B						X		
	C			X			X		
	D		X				X		
	E				X	X	X		
	F			X	X	X	X		
10. Webbing chafing across shoulder	A					X	X		
	B					X	X		
	C					X	X	X	
	D	X	X	X	X	X	X		X
	E	X	X	X	X	X	X	X	
	F	X	X	X		X	X		
11. Lap belt riding up on stomach	A								
	B								
	C								
	D			X				X	X
	E			X		X		X	
	F		X	X					

Set No. 3

Questions	Systems	5	15	1	13	6	7	2	23
1. (S) Locating buckle release	A								
	B					X			
(P) Doffing belt system	C								
	D		X						X
	E	X	X			X	X		X
	F								
2. (S) Operating buckle release	A								
	B								
(P) Stowing (hooking) belt system	C							X	X
	D	X	X						X
	E	X	X		X				X
	F	X		X				X	
3. (S) Webbing hanging up on clothes, etc.	A		X						X
	B								X
	C								X
(P) Webbing dragging across clothes, etc.	D								
	E						X		
	F	X		X			X		
4. (S) (P) Retraction and stowage complete	A								
	B								
	C								
	D								
	E								
	F	X	X	X	X	X	X	X	X

Table 27 (Continued)

Questions	Systems	5	15	1	13	6	7	2	23
Set No. 4									
1. (S) (P) Interference with exit	A								
	B								
	C					X			
	D			X	X		X	X	X
	E								
	F			X		X			
2. (S) Belt system clearance of door	A								
	B								
	C								
(P) Holding door against belt tension	D			X	X			X	X
	E						X		
	F	X	X	X	X	X	X	X	X
Set No. 5 (For both S & P Systems)									
1. Emergency exit from driver's door	A						X	X	X
	B						X		X
	C		X						
	D		X	X	X				X
	E			X					X
	F	X	X	X		X	X	X	X
2. Emergency exit from opposite door	A		X						
	B								
	C								
	D	X	X	X	X	X	X	X	X
	E		X	X	X	X	X	X	X
	F		X	X					

(Column headings 5–23: Subject I.D. Number)

*X = problem = mean score of 1.00 or above

**(S) = Standard System questions applicable to systems A, B, C, and F
(P) = Passive System questions applicable to systems D and E

Figure 15 - Robust Female Problem Fit

six systems. After each pair of trials both subjects were required to make a pair comparison, and upon completion of all trials they rank-ordered the systems.

The systems were the same as those used in the main test with one exception. In System A the standard push-button buckle was replaced with the magnetic lift latch buckle that was used in the Phase I tests (the modified System A identified as System A-1).

The results of this test are shown in Table 28. The preferences of the amputee appear to conform approximately to those of the subjects in the main test. However the quadraplegic rated the passive system as being best. To a considerable extent this was due to the fact that this system provided him with the additional independence of being able to close the car door by himself by pulling on the belt.

b. Summer/Winter Clothing

As described in Section 3.6.3.2, 4 subjects participated in a test designed to indicate if there might be some effect on evaluations when the subjects were required to wear winter clothing, such as a heavy overcoat and thick gloves.

The seat belt systems were the same as those used in the main test except for the magnetic lift-latch buckle configuration (System A-1).

The subjects did pair comparisons and rank ordering with the comparisons being made between systems and not between the two conditions of summer and winter clothing.

Results of this test are shown in Table 29 where it will be noted that in the case of both males the selections of rank and the number of times preferred are identical for both clothing conditions. In the case of the two females, however, there are important differences. When wearing winter clothing both passive systems (D and E) are given more favorable evaluations.

As the female test subjects explained, the wearing

Table 28 - Pair Comparison Preferences and Rank Order Selections of Seat-Belt Systems by Two Handicapped Subjects

Sex:	Male		Male	
Handicap:	Amputated Left Arm		Quadraplegic	
Subject I.D. Number:	25		26	
System	Rank	Times Preferred	Rank	Times Preferred
A-1	1	5	2	2
B	2	4	3	1
C	3	3	4	0
D	5	2	1	3
E	4	0	Not Tested	
F	6	1	Not Tested	

Legend:
System A-1 - Toyota w/Mercedes Latch
B - Merc
C - Imp
D - Grem
E - Vega
F - Cap

Table 29 - Pair Comparison Preferences and Rank Order Selections of Six Seat Belt Systems By Four Subjects Wearing Summer and Winter Clothing

Sex:		Male				Female			
Age:		17 yrs.		56 yrs.		17 yrs.		73 yrs.	
Weight:		185 lbs.		215 lbs.		110 lbs.		140 lbs.	
Subject I.D. Number		21		13		9		2	
System	Clothing	Rank	Times Preferred	Rank	Times Preferred	Rank	Times Preferred	Rank	Times Preferred
A-1	Summer	2	4	3	3	3	3	5	2
	Winter	2	4	3	3	3	3	5	1
B	Summer	1	5	2	4	1	5	1	4
	Winter	1	5	2	4	4	2	3	3
C	Summer	5	1	1	5	2	3	3	3
	Winter	5	1	1	5	5	1	4	1
D	Summer	3	3	5	1	4	2	2	4
	Winter	3	3	5	1	1	5	1	5
E	Summer	4	2	4	2	5	1	4	1
	Winter	4	2	4	2	2	4	2	4
F	Summer	6	0	6	0	6	0	6	0
	Winter	6	0	6	0	6	0	6	1

Legend:
System A-1 - Toyota w/Mercedes Latch
B - Merc
C - Imp
D - Grem
E - Vega
F - Cap

Table 29 Supplement: Summary of Pair Comparison Preferences in Ancillary Tests

System		Number of Times Preferred: Male Amputee	Quadra-plegic	Male 17 yrs	Male 56 yrs	Female 17 yrs	Female 73 yrs	TOTAL	Rank
A-1	S	5	2	4	3	3	2	30	2
	W			4	3	3	1		
B	S	4	1	5	4	5	4	37	1
	W			5	4	2	3		
C	S	3	0	1	5	3	3	23	4
	W			1	5	1	1		
D	S	2	3	3	1	2	4	29	3
	W			3	1	5	5		
E	S	0	--	2	2	1	1	18	5
	W			2	2	4	4		
F	S	1	--	0	0	0	0	2	6
	W			0	0	0	1		

S = Subject wearing summer clothing.

W = Subject wearing winter clothing.

-- = Not tested

of a bulky coat over a full bosom introduced greater interference to visual access to the buckle and the stowed latch plate. This coupled with the impairment of tactile sensitivity by the gloves apparently made the use of the passive systems, which did not require precise visual inputs, preferable.

c. <u>Magnetic Lift-Latch</u>

The magnetic lift-latch was evaluated on a small scale during the ancillary tests. This buckle was used in the Phase III mockup studies and is described in Section 3.4.1.

The lift-latch buckle (System A-1) was used in the special subject-characteristics and the summer/winter clothing tests (Section 3.6.4.2). The evaluations it received, compared with those received by System B, are an indication of preference between the lift-latch and push-button latch.

Table 29 shows that System B is consistently preferred over System A-1 when summer clothing is worn. Even with winter clothing three of the four test subjects continued to prefer System B.

Table 28 shows that the amputee preferred System B to System A-1 but that the quadraplegic preferred System A-1 to System B.

d. <u>Egress Timing</u>

During the conduct of the main test, test subjects were required to make three emergency exits from each of the vehicles in which the six seat belt systems were installed. As described in Section 3.6.3.1, these emergency exits were timed. Results of this test are of limited value because the various vehicle configurations (e.g., door size, and relative position of seat and steering wheel and door) undoubtedly had an effect on egress timing. However it was not possible to make a comparative test of all six systems without the subject exiting from the vehicle since, with the passive systems, in an emergency condition doffing and exiting are the same.

The three trials in each system did not occur one immediately after another. They were conducted during the first three of the five questionnaire trials in each system.

Results of the timing tests are shown in Table 30. There appears to be no general improvement with experience from Trial 1 to Trial 3.

Males are consistently faster than females except in the case of the passive systems (D and E).

The fact that System F had the longest times is consistent with the many problems identified in this system by test subjects.

Further interpretation of these data would be strictly speculative.

3.7 Conclusions and Recommendations

The study resulted in a number of specific conclusions concerning aspects of seat-belt design and operation that would eliminate or alleviate problems of discomfort and inconvenience. Those design recommendations that come under the purview of the Federal Motor Vehicle Safety Standards will be presented in Section 4.

A number of other conclusions and recommendations resulting from the observations and analysis made throughout the five phases of this study are worthy of separate comment. A summary of these follows.

a. Automatic lockout retractors on lap belts cause confusion and inconvenience because they lock-out inadvertently. A vehicle-sensitive system does not, and therefore should remove a major element of consumer complaints.

b. The buckle position as presently located on most vehicles is too low and far back making it extremely difficult to locate and secure. It should be raised so that the harness/belt junction falls approximately coincident with the forward crest of the wearer's pelvic bone. Current buckle positions are especially difficult for certain people (e.g., those who

Table 30 - Mean Times For Doffing Seat Belt and Exiting From Vehicle

		Females N = 10 (seconds)	Males N = 14 (seconds)	All Subjects N = 24 (seconds)
System A (Toyota)	1st Trial	4.3	3.9	4.1
	2nd Trial	4.0	3.7	3.8
	3rd Trial	4.3	3.7	4.0
	All Trials	4.2	3.8	4.0
System B (Mercury)	1st Trial	4.2	3.7	3.9
	2nd Trial	4.0	3.7	3.8
	3rd Trial	4.0	3.5	3.7
	All Trials	4.1	3.6	3.8
System C (Impala)	1st Trial	4.6	4.5	4.5
	2nd Trial	5.1	4.6	4.8
	3rd Trial	5.0	4.6	4.7
	All Trials	4.8	4.6	4.7
System D (Gremlin)	1st Trial	4.1	4.0	4.1
	2nd Trial	3.7	3.7	3.7
	3rd Trial	3.7	4.0	3.9
	All Trials	3.9	3.9	3.9
System E (Vega)	1st Trial	4.3	5.3	4.9
	2nd Trial	5.4	4.3	4.7
	3rd Trial	4.6	5.3	5.0
	All Trials	4.7	5.0	4.9
System F (Capri)	1st Trial	6.7	4.8	5.6
	2nd Trial	6.0	5.6	5.8
	3rd Trial	5.3	4.3	4.7
	All Trials	6.1	4.9	5.4

are obese or arthritic) to reach and/or manipulate the buckle-latch plate mating or buckle button operation. Lengthening the buckle strap and thus improving the harness/belt juncture position should remove another major complaint.

c. Very few upper-harness anchor-points or webbing-guides position the harness to cross the wearer's shoulder properly (in most cases they cause the webbing to cross high on the shoulder or directly on the neck). This in turn (coupled with the awkward buckle position) causes the harness to cross the chest directly on the inboard breast area, especially annoying to women. A properly controlled harness geometry should remove a third major complaint.

d. When two buckles are fastened to the same anchoring strap (particularly the center and right front positions), there is frequent confusion about which buckle to couple to. Also, with this condition people often sit on the buckles and have to shift around to find their appropriate buckle. Use of independent buckle straps and encoding of buckles should minimize this complaint.

e. Latch plates generally are too small, making it difficult for the user to get hold of them and to pull them out or aim the latch plate tongue at the buckle opening. A latch-plate large enough to hold adequately should reduce this complaint.

f. Because most buckles are not positioned high enough they are hard to reach, particularly for the infirm. When a center console is involved it is even more difficult to get hold of the buckle or to get the hand in a position to press the push-button with the thumb. By raising the buckle position and leaving more hand clearance this complaint should be eliminated almost entirely.

g. Buckle push-button force and webbing pull and tension forces have, for the most part, tended to fall within acceptable limits. However some designs create extra resistance because of stitching that catches on retractor housings or because of the way in which webbing binds as it goes through guides. Fabrication quality control will help to eliminate this problem.

h. There is a wide variation in where designers position belt anchor points (floor and roof) and in many cases this does not appear to have any structural justification -- especially when similar models have anchor points placed in more appropriate positions, thus obtaining better belt crossing angles. Another instance of poor design is the webbing guide positions. A single maker may place a guide properly in one model because of the particular type of seat installed (i.e., the seat back or head rest is sufficiently large to allow the guide to be far enough outboard), but allow the position of the guide in another model to be located very poorly -- just because of the shape of the seat or head rest. More precise positioning will eliminate the fit problems as long as the geometry is constant throughout seat travel.

i. There are several good approaches to clearing the way past seat belts for rear-seat entry in two-door models but most cars are not so designed. The good designs illustrate that it is practical to provide a reasonably clear access route. Some of the better concepts include spring-loaded webbing guides that rotate the webbing out of the way, guide hooks on the sides of folding front-seat backs so that the webbing is pulled forward and partially out of the way for rear-seat entry etc. However it is concluded that this problem has little if any belt-use influence and therefore is of secondary importance.

j. Because most systems are anchored to the floor of the car and use an automatic locking retractor on the lap belt, people frequently find they cannot adjust the seat forward to the desired position because the lap belt has locked up. Although we have long believed that belts should be fastened to seats rather than to vehicle structure, only one car so far has this type of anchoring system (i.e., the Toyota Mark II). When belts are anchored to the seat an optimum geometry can be maintained no matter where the seat is placed. Even the buckle position in this vehicle is somewhat higher, making it easier to manipulate the buckle than in most other vehicles. Another unique feature of this design is a curved, flexible buckle strap stiffener that makes the strap and buckle fit the occupant's hip and thigh more comfortably. This vehicle also uses vehicle-sensitive, emergency-locking retractors so that there is no inadvertent lock-out during donning of the belts. This clearly demonstrates state-of-the-art as well as economic feasibility.

k. Passive belt systems that have the upper segment of the shoulder harness attached directly to structure without a retractor produce unacceptable amounts of abrasion between the harness and the upper torso of the wearer during torso movement. We believe this will always produce consumer complaints regardless of other favorable features of the passive belt type system.

l. The equipment worn by police officers while on duty presents a number of problems in the use of a standard 1974 seat-belt system. Weapons and badges become entangled in the belt during doffing, at times preventing the officer from making a rapid exit. Access to weapons is sometimes restricted while the system is being worn. And difficulties in donning can cause a critical delay in an emergency start. For the time being at least we do not believe law enforcement personnel should be required to wear seat belts, but should be allowed to use them as they see fit for a given situation.

It is strongly recommended that a study be undertaken to determine the extent and nature of the restrictions in seat-belt usage imposed by police equipment with the objective of providing a basis for the development of an alternate system designed to accommodate the special police situation.

m. Serendipitously the present study developed data that indicated that the women subjects were considerably more critical from the standpoint of comfort and convenience of all six belt systems of Phase V than were the male subjects. Quite independently another study carrying out research in a related area at the same time as ours arrived at similar conclusions. This study showed females with a higher "discomfort index" than males, being, respectively, 21.5 and 19.2, which prompted the conclusion that "females seem to find the 1974 belt system much less comfortable" than do males (McDonnell Douglas Automation Company, 1974, p. 25).

In Section 3.6.4.1 of this report we had tentatively suggested that "this unanticipated result might be attributed to the females being more sensitive to discomfort and/or to differences in anatomy, with the female breasts especially susceptible to discomfort problems with the shoulder harness."

The McDonnell report, however, suggests that this may be due in part to the fact that shorter people also find the seat belt system less comfortable (McDonnell Douglas Automation Company, 1974, p. 25), and indeed data in the report indicate some negative correlation between height and discomfort.

In re-analyzing our data we found that this negative correlation between height and discomfort did not occur with our subjects. Indeed, the situation was quite the opposite with a positive correlation existing between mean height and the mean overall score for problems experienced, (see Table 31).

It is recommended that further research be carried out to determine the basis of this difference between the sexes in their reported estimates of discomfort, and to seek further evidence relative to possible correlation between body height and discomfort.

Table 31 - Mean Scores of Shortest and Tallest Female and Male Subjects for all Questions on all Systems

		Mean Height (Ins.)	Mean Score
Females (N = 10)	Shortest 5	61.2	.522
	Tallest 5	66.8	.550
Males (N = 14)	Shortest 7	65.4	.361
	Tallest 7	72.0	.410

4.0 PROPOSED MODIFICATIONS TO FEDERAL MOTOR VEHICLE SAFETY STANDARDS NOS. 208 and 209

4.1 General

One objective of the present study was to develop suggested modifications for FMVSS 208 and 209 to reflect the findings of this study.

FMVSS 208 specifies performance requirements for the protection of vehicle occupants in crashes but it does not address the comfort-convenience problem. FMVSS 209 on the other hand specifies assembly-component requirements mostly in terms of the "job" each element performs, i.e., it does not address the problem of comfort-convenience.

Results of this study provide a number of rather clear-cut performance criteria that relate to how confusing, inconvenient or uncomfortable a belt system will turn out to be if it is improperly configured or installed. These criteria have been interpreted in the following recommended modifications to FMVSS 208. No modifications are recommended to FMVSS 209 at this time since it is believed that our suggestions are more appropriate to the substance and content of 208. However, it is recommended that those who have the final responsibility for standards preparation consider the interactions between the two related standards to determine whether some modification may be required in both standards.

Note: Proposed modifications are <u>underlined</u>.

Ref: FMVSS No. 208

Par. S7 Seat Belt Assembly Requirements -- Passenger Cars

Par. S7.1 Adjustment.

Par. S7.1.2 The intersection of the upper torso belt with the lap belt in any Type 2 seat belt assembly furnished in accordance with S4.1.1 or S4.1.2, with the upper torso manual adjusting device, if provided, adjusted in accordance with manufacturer's instructions, shall be at least 6-inches, and no more than 7-inches from the front vertical centerline of a 50^{th} percentile adult male occupant, measured along the centerline of the lap belt, with the seat back in the manufacturers' nominal design riding position.

Par. S7.1.2.1 The fully-adjusted torso harness/lap belt assembly shall be anchored and/or guided in such a manner that the buckle-release device (e.g., push-button or other operating element) falls within 5-inches of the juncture between the torso and lap belt portions of the assembly along the inboard axis of the lap belt (see Figure S7-1).

Par. S7.1.2.2 The torso harness/lap belt assembly shall, when the buckle-release device is activated, automatically retract the assembly so that the torso webbing lies snugly alongside and approximately parallel with the long axis of the seat back edge, and so that the lap belt webbing and latch plate falls into a position alongside and approximately even with the depressed surface of the seat cushion. If a door-mounted armrest is provided, there shall be a minimum of 4-inches clearance between the aftmost edge of the armrest and the retracted latch plate so that hand access is assured. No part of the assembly shall retract to a position wherein it can become caught by closing the door.

Par. S7.1.2.3 The retractor force(s) for the torso and lap belt webbing retraction shall be sufficient to fully retract both elements to their fully stowed position, but in no case shall the retraction force exceed 4.0 lbs. When upper and lower retractors are employed, they shall provide equal retracting force so as to preclude one retractor from pulling the restraint assembly into other than the optimum, fully-retracted position specified above. No webbing folds, rough edges, or stitching shall cause the webbing to snag or bind, either during pull-out for donning, or during retraction, which might prevent complete retraction as required in S7.1.2.2.

Par. S7.1.2.4 A belt stiffener shall be provided for the inboard buckle strap to cause the buckle to stand erect and be readily accessible for donning. The stiffener shall be so designed that it has sufficient lateral flexibility so that a passenger passing over it can gain access to a center seat

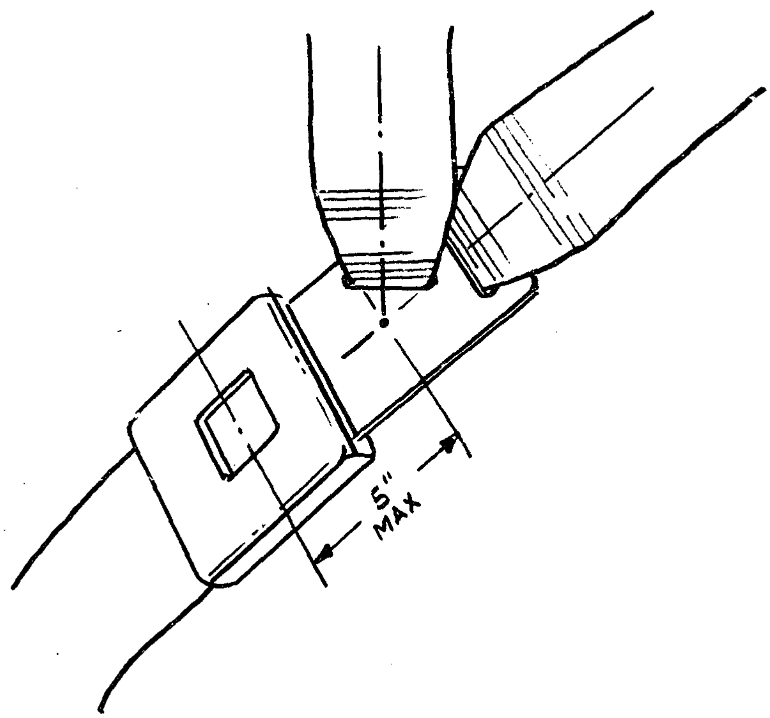


Figure S7-1 - Buckle-Latch Plate Relationship position without undue interference or discomfort. The length of the inboard buckle strap (and stiffener) shall be sufficient to place the buckle and coupled lap and torso harness juncture approximately as shown in Figure S7-2.

Par. S7.1.4 The geometric and dimensional criteria for this standard are shown in Figure S7-2. The seat belt system shall provide sufficient extension capability to allow a 50th percentile adult female to reach the following while wearing the restraint system in the approved manner:

a. From the driver's position -- all driver controls plus glove compartment latch, nearest ash tray, left front window-lift handle, seat-adjust control and locks on both front doors.

b. Right front passenger's position -- to within 6-inches of the floor, 10-inches in front of the leading edge of seat.

Vehicle-sensitive emergency retractors shall be used for both shoulder harness and seat belt retraction. Both ends of the seat belt shall be attached to the seat or passed through seat-mounted guides to prevent change in belt geometry with changes in seat position.

Par. S7.2 Latch Mechanism and Webbing Characteristics

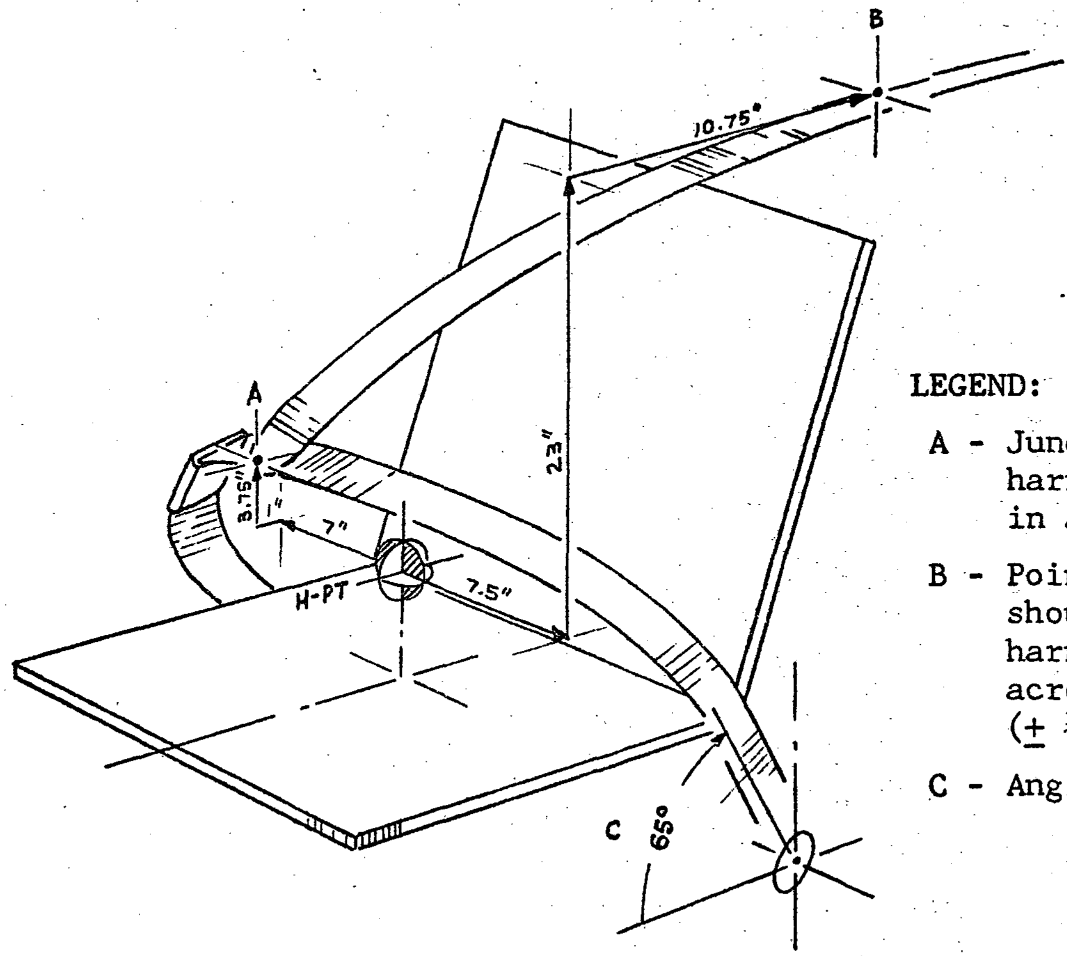
Par. S7.2.1 Latch Mechanism -- A seat belt assembly installed in a passenger car shall have a latch mechanism --

(a) Whose components are accessible to a seated occupant in both the stowed and operation positions;

(b) That releases both the upper torso restraint and the lap belt simultaneously, if the assembly has an upper torso restraint that requires unlatching for release of the occupant;

(c) That releases at a single point by a push button action;

(d) That is operable by one-hand and/or either hand;



LEGEND:

A - Juncture between shoulder harness and lap belt (± 1" in all directions)

B - Point above occupant's shoulder from which shoulder harness departs to pass across the shoulder and chest (± ½" in all directions)

C - Angle of seat belt (± 10°)

Figure S7-2 - Geometric Requirements for Seat Belt-Shoulder Harness Assembly and Installation to Insure Proper Fit for Passenger Population Ranging From 5th %-tile Female Through 95th %-tile Male (Adults)

(e) Whose release operation force shall not exceed 4.0 lbs;

(f) Whose release device (push button) is designed to minimize the probability of inadvertent release.

Par. S7.2.1.1 Latch identification shall be readily apparent between adjacent seat position both visually and by feel (e.g., color and size and/or shape differences).

Par. S7.2.1.2 The size and shape of the latch plate and the buckle shall be compatible with the gripping characteristics of a 5th percentile adult female to a 95th percentile male hand (see Figure S7-3). Push button opening shall be a minimum of 1-inch by 1-inch, and the push button shall be recessed a minimum of 1/32", maximum of 1/8". Sides of the push button opening shall be tapered and enclosed so that the user's thumb or finger is guided easily into the opening, but cannot become caught between the edge of the opening and the push button.

Par. S7.2.1.3 The combined weight of the buckle and latch plate shall not exceed 8 oz. The buckle and/or latch plate shall be free of sharp corners, edges or burrs that could puncture the skin or catch or tear the occupant's clothing. Latch plate dimensions shall approximate those shown in Figure S7-3.

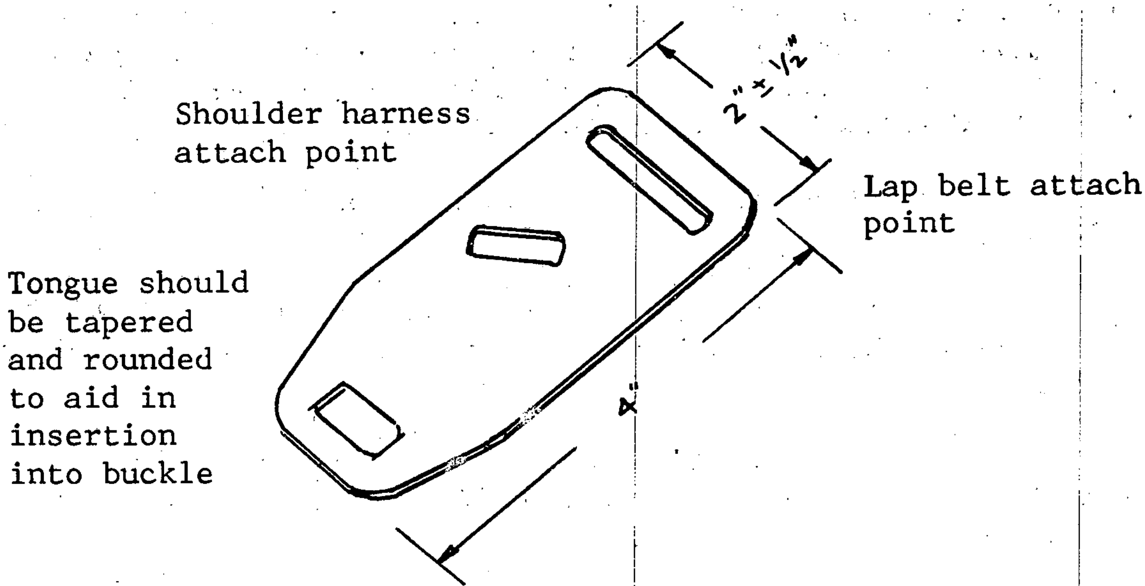
Par. S7.2.2 Webbing Characteristics

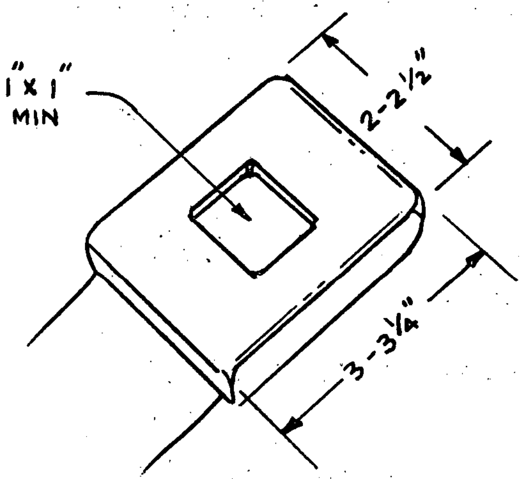
Par. S7.2.2.1 Webbing length shall be in compliance with S7.1.4.

Par. S7.2.2.2 Webbing width shall comply with FMVSS 209, Sf.2.

Par. S7.2.2.3 Webbing color and/or shade shall be visually differentiable from background upholstery. A clearly-discernible contrasting color strip shall be imprinted on the reverse side of the webbing (e.g., side next to user's body) to aid the user in determining if his or her belts are twisted.

Note: The above related to a standard three-point belt system, however, geometric criteria also apply to passive belt systems.





The above dimensions are minimum required to assure capability for maintaining adequate gripping and aiming of latch plate into buckle. The width should not exceed 2½-inches, the length 4½-inches.

Figure S7-3 - Latch Plate/Buckle Configurational and Dimensional Characteristics (front, outboard seats)

5.0 SUMMARY

A study was undertaken to examine the possible causes of lack of auto seat belt use because of belt-use confusion, inconvenience and/or discomfort. Previous user surveys had indicated that many people give as the reason for not using seat belts the fact that they are too uncomfortable and that they are difficult to put on and take off.

The study consisted of several phases including the following:

a. Literature survey to determine the state-of-the-art in seat belt design and why people seem to avoid using seat belts.

b. A preliminary user survey to try to identify in more detail why people find seat belt systems inconvenient and uncomfortable.

c. A new car survey to learn more about how current seat belt systems are designed and installed and to discover if there are new developments that might be better than the current state-of-the-art.

d. A series of laboratory studies to see if it was possible to create a more suitable seat belt system.

e. Based on the laboratory results, a proposed optimized system was designed and installed in two vehicles, one with bucket seats, the other with bench seats.

f. The two optimized seat-belted vehicles were tested, comparing them to four other 1974 cars and their own restraint systems, to see if the optimized system was judged by typical users to be more acceptable from the standpoint of convenience and comfort.

5.1 Conclusions

a. Design-related reasons were evident from the initial analyses, i.e., it was possible to state fairly clearly

what there is about a seat belt configuration that will cause most people to object to wearing it.

b. Mockup studies proved that it is possible to design a practical restraint system configuration that not only will fit 90 percent of the user population properly but that this can be done within the present hardware-vehicle state-of-the-art.

c. System comparison tests demonstrated that the proposed optimized restraint system design created during the mockup studies was significantly favored by test subjects over other vehicle-restraint system typical of 1974 automobiles.

d. Although the experimental, semi-passive restraint systems have certain good points relative to user acceptance, these still do not out-rank the proposed optimized system using a standard three-point system.

5.2 Recommendations

Specific amendments to the FMVSS 208 should be made to aid in insuring that automobile manufacturers design and install restraint systems so that they will fit the user population and operate properly to remove confusion, inconvenience and discomfort.

A further recommendation is that a more comprehensive user opinion sampling be taken to support further the opinions of the subjects used in this study. That is, although the present tests show all subjects decidedly in favor of the optimized system, the number of subjects is relatively few with respect to predicting the opinion across the total user population. Although the authors feel confident that their present results would be verified by the larger sampling, further confidence may be required by the auto industry before they will accept the proposed new clauses in FMVSS 208.

5.0 SUMMARY

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d. Although the experimental, semi-passive restraint systems have certain good points relative to user acceptance, these still do not out-rank the proposed optimized system using a standard three-point system.

However, the specific passive systems tested did not include several other proposed systems, i.e., the systems used in the current evaluation were two versions of passive belt systems available at the time of the test. MFI's literature review identified numerous other passive systems (not air bag) that have never been implemented and evaluated. Due to current interest in the possible favorable reaction of the public to system that do not require overt effort in donning it may be unwise to rule out such systems altogether just because two specific samples did not turn out to compare favorably with the present, optimized three-point belt system.

e. A more general conclusion regarding the total study findings is that it can be observed almost without exception that auto body style is established with little regard to its impact or constraint on effective restraint system design and installation. Because of this restraint systems are viewed by designers as "add ons", and they are therefore attached and arranged <u>to fit the car, not the occupants</u>. The errors are so common that MFI's researchers could tell whether a belt system was going to fit badly almost immediately by visual inspection even before trying on the belts. When mistakes are this apparent one can only conclude that some design control must be required in order to gain the attention of designers.

5.2 Recommendations

a. Specific operational requirements dealing with belt-type seat restraint system "fit should be made to FMVSS 208 in order that future seat belts will be more acceptable and therefore remove excuses for lack of use based on confusion, inconvenience and discomfort. The recommended amendments provided in this report should be used as the basis for revising FMVSS 208. The geometric and dimensional criteria should be applied to any future belt-type systems also, since the factors that annoy the user relate directly to "fit".

b. It is recommended that other passive (non air bag) systems be investigated in more detail to determine if an alternate passive system concept might be acceptable to the majority of consumers -- in addition to the obvious advantages MFI found for handicapped people. Such a study should include the fabrication and evaluation of potentially acceptable system or systems using the general methodology developed for the current study.

c. It is recommended that additional study be made of restraint system requirements for the other occupant positions where currently there are no upper torso restraint capabilities. Other occupants have the same right to protection regardless of the apathy of some people regarding use of seat belts. Although the current fit criteria would obviously apply to other occupant positions and systems, little sincere effort has been given to this problem, especially in terms of feasibility, practicality and cost.

6.0 NAMES, QUALIFICATIONS & PARTICIPATION OF RESEARCHERS

Bernard F. Pierce, Ph.D. - Program Manager/Principal Investigator. Dr. Pierce has had nearly 20 years' experience in the field of physical anthropology and human engineering research and development. He served as Principal Investigator for the DOT/NHTSA Contract No. FH-11-7619, "Driver Eye Position and Control Reach Anthropometrics." As a Senior Scientist with Man Factors, Inc., Dr. Pierce directs experiments and studies related to anthropometrics, performance measurement, bioengineering and vocational training. Prior to joining MFI he held the position of Manager, Research and Evaluation, Economic Development Operations, Thiokol Chemical Company.

Wesley E. Woodson - Mr. Woodson has worked actively in the area of human factors engineering, research and development for more than twenty years. He is principal author of the standard work, "Human Engineering Guide for Equipment Designers," former Head, Human Engineering Group, Human Factors Division, U.S. Navy Electronics Laboratory, San Diego, and former Chief of Human Factors Engineering, Life Sciences Laboratory, General Dynamics' Convair Division.

Peter H. Selby - Responsible for the development of driver interface priorities and requirements. Mr. Selby's twenty years' experience in the areas of functional analysis, task analysis, training and training equipment design make him eminently well qualified to analyze driver tasks and to derive training requirements and appropriate methodology. As Flight Training Supervisor for General Dynamics/Convair for nearly fifteen years, Mr. Selby directed the transition training of more than 2,000 pilots and flight engineers, both military and civilian, in the USA and abroad. He is a specialist in the area of instructional technology, the development of behavioral objectives, and is the author of six books in the programmed instruction format. As Senior Research Engineer with the Life Sciences Laboratory, General Dynamics/Convair, Mr. Selby was responsible for research and development in the areas of training methodology and training equipment technology as they relate to aerospace systems.

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U.S. DEPARTMENT OF TRANSPORTATION

PUBLIC OPINION SURVEY QUESTIONNAIRE

We are trying to learn what you think about the seat belt and shoulder belt in the car you use most. Your opinion is very important since you are the user of such equipment, and for designers to know how to correct problems that annoy users, or discourage regular use of safety belts, they must learn how users feel about seat belts and shoulder belts.

Some seat belts and shoulder belts have features that make them unpleasant and/or difficult to use. We are interested in learning about your experience with the seat belt and/or shoulder belt system in the car that you most frequently use as a driver or a passenger.

We are concerned about only three types of difficulties or unpleasantness associated with the use of seat belts and shoulder belts, and we would like you to comment on how these systems cause you:

1. Confusion, e.g., difficult to understand what connects to where, etc.

2. Inconvenience, e.g., difficult to reach, to connect, etc.

3. Discomfort, e.g., rubbing, pressing, hurting, etc.

In order for us to be able to benefit most from your opinions, we must know something about you and the car you are referring to. So would you please give the following information about yourself.

Height__________ Weight__________ Age__________ Sex__________

Occupation____________________ Education_______________

Describe any physical handicaps:_________________________

____

____

____

Are you usually the driver or the passenger of the car you are referring to? Driver_____________; Passenger____________.

What type of car are you referring to?

Make____________________Model_______________Year_____________.

What type of seats (in front)? Bench Seat_____Bucket Seat_____

How long have you been using this car?_________________________

Now, would you please tell us what makes the seat belt and shoulder belt seem confusing to you by putting a check in the "yes" column if you have experienced the problem described, or by putting a check in the "no" column if you have not experienced the problem described, and by providing us with any additional information concerning your experience with the problem in the "explain" column.

Problem	Yes	No	Explain
Cannot tell which belts go together.			
Belts get tangled with other belts.			
Cannot tell where to insert belt into the buckle.			
Cannot see the belt or buckle in the dark.			

Problem	Yes	No	Explain
Belt blends into the upholstry because they are the same color.			
When the shoulder belt is fastened to the lap belt and becomes twisted, I cannot figure how to untangle the belts.			
Cannot be sure how to pull lap belt so the retractor will not lock too soon.			

In what other ways are the belts in the car to which you are referring too complicated or difficult to understand?

Now, please tell us what makes the seat belt and shoulder belt <u>inconvenient</u> to you.

Problem	Yes	No	Explain
Belts are hard to reach because of where they are installed.			
It takes time getting belts properly arranged for connecting.			
I cannot reach dashboard controls when shoulder belt is secured.			
Belt adjustment devices are awkward to manipulate.			

In what other ways are the belts in the car you are now using difficult to use, or connect, or reach, and in what other ways does the use of the belts interfere with your driving or any other activities while riding in the car?

____

____

____

____

Now, please tell us what makes the seat belt and shoulder belt <u>uncomfortable</u> to you.

Problem	Yes	No	Explain
Shoulder belt rides across my face.			
Shoulder belt cuts across my neck.			
Shoulder belt falls off my shoulder.			
Lap belt rides up on my stomach.			
Shoulder belt crosses the breast area so it is annoying.			
The shoulder belt rests too heavily on my shoulder.			

Problem	Yes	No	Explain
The buckle or adjusting hardware seems too heavy.			
The lap belt tends to tighten up too much as I drive along.			
The shoulder belt webbing seems to be too stiff.			
The shoulder belt seems to have a rough surface.			
Manipulation of buckle hurts my fingers and/or takes too much force to operate.			

In what other ways do the belts in the car you are now using bind, press or rub against you too hard, or hurt you, or otherwise cause you any other discomfort?

____

____

____

In any cars other than the one you've been referring to, what other problems have you encountered with seat belts and shoulder belts in terms of confusion, inconvenience, or discomfort. Please tell us what kind of car was involved.

____

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Please give us your name, address and phone number.

Name____

Address____

Phone_______________________________

Finally, please enclose this form in the stamped, self addressed envelope we sent you, and mail it back to us.

Thank you very much for your cooperation.

Man Factors, Inc.
Program Managers
4433 Convoy Street
San Diego, CA 92111

APPENDIX B

SELECTED PHOTOS OF SEAT RESTRAINT PROBLEMS

The following photographs represent only a few of the several hundred photos taken during the study. It should be pointed out that, although a particular vehicle/system is shown, this does not necessarily mean that this was the only instance of the particular problem illustrated. Rather, the particular photo happened to provide an especially good view of the particular problem.

APPENDIX B

BUICK APOLLO

With headrest raised to proper position, harness rides across subject's neck and inboard breast

IMPALA

IMPALA

Even the better systems strangle some users, and it made no difference in this case whether the headrest/harness guide was up or down

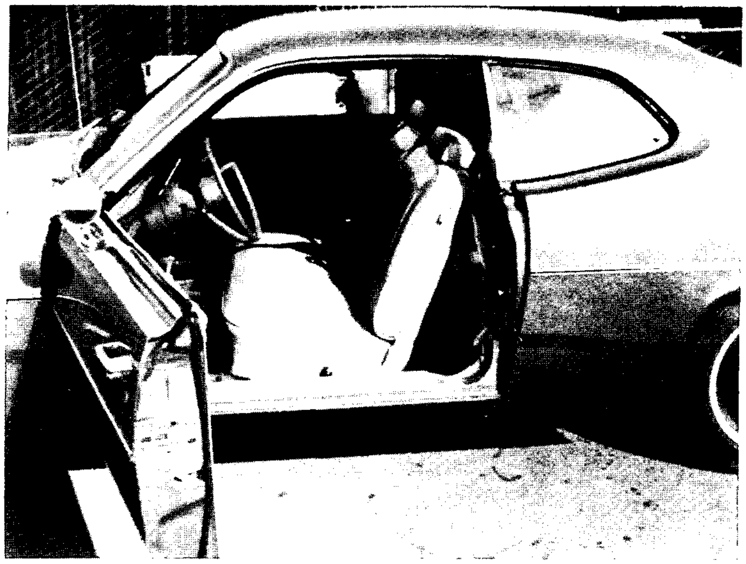
Duster 2

Harness falls off shoulder

Buick Regal

If subject forgets to raise head-
rest, harness pulls down on the
shoulder

APPENDIX B



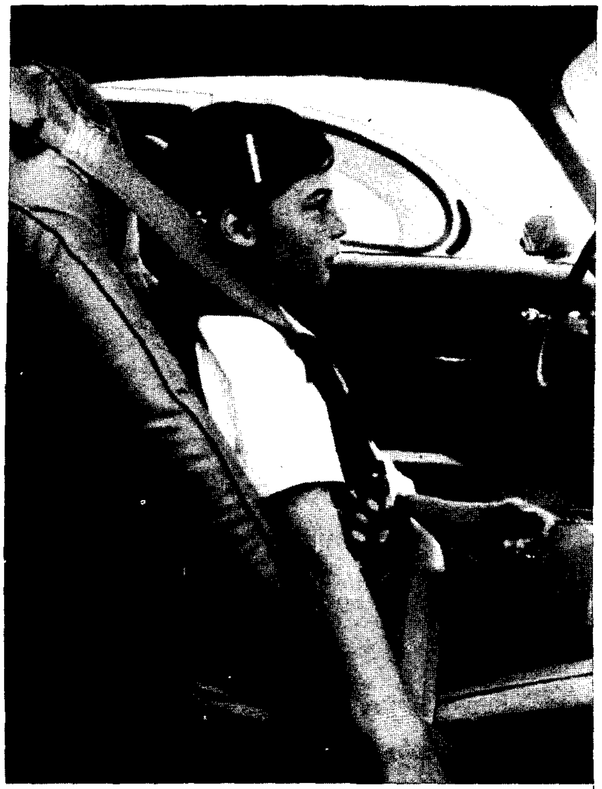
Duster #1

Webbing does not fully retract

Console conflicts with access and manipulation of buckle

Capri

Arm rest interferes with access to latch plate



CAMARO

CAMARO

Many systems obviously create problems for youngsters such as this 10 year old

Some systems made it almost impossible to get into the back seat

DODGE CORONET

In this particular model Officers invariably catch their arm in exiting or some other object that is mounted on their belt (in this case the MACE)

The current 3-point system invariably interferes with weapon retrieval

Harness restricts reach

TEST SUBJECT__________ VEHICLE____________

QUESTIONS FOR EVALUATION OF SEAT BELT SYSTEMS

(0=No Problem; 3=Serious Problem)

Set #1

Questions to be asked of subject upon completion of belt-system donning.

(For Standard System)

1. Did you have any difficulty in locating the latchplate?	0 1 2 3
2. Did you have any difficulty in retrieving the latchplate?	0 1 2 3
3. Did you have any difficulty in extending the webbing?	0 1 2 3
4. Did you have any difficulty in finding the buckle?	0 1 2 3
5. Did you have any difficulty in securing the buckle?	0 1 2 3
6. Did you have to straighten the webbing?	0 1 2 3

(For Passive System)

1. Did you experience confusion on how to get past the webbing upon entering the vehicle?	0 1 2 3
2. Did the belt system interfere with your entry into the vehicle or closing the door?	0 1 2 3
3. Did you have any difficulty in unhooking the webbing?	0 1 2 3

4.	Did the harness drag across your chest (breast)/clothing?	0	1	2	3
5.	Did the harness miss your shoulder?	0	1	2	3
6.	Did you have to straighten the webbing?	0	1	2	3

Set #2

Questions to be asked after subject has: adjusted seat to rearmost, forward, and preferred positions; reaches for glove compartment and left vent handle; and turns to look toward left rear and out of rear window. (For Standard and Passive Systems)

1.	Did the belt system interfere with the seat adjustment?	0	1	2	3
2.	Did the belt system interfere with your reach to the glove compartment, or with any controls?	0	1	2	3
3.	Did the shoulder harness obstruct your left rear view?	0	1	2	3
4.	Did the shoulder harness limit your turning to the right to look out the rear window?	0	1	2	3
5.	Did the webbing fail to achieve or retain a snug fit?	0	1	2	3
6.	Did the webbing lay on or rub against your neck or face?	0	1	2	3
7.	Did the webbing fall off your shoulder?	0	1	2	3
8.	Did the shoulder harness lay across your breast (or on the inboard side of your chest)?	0	1	2	3
9.	Did the webbing exert pressure on your shoulder?	0	1	2	3

10.	Did the webbing chafe across your shoulder?	0	1	2	3
11.	Did the lap belt ride up on your stomach?	0	1	2	3

Set #3

Questions to be asked of subject upon completion of belt-system doffing.

(For Standard System)

1.	Did you have any difficulty in locating the buckle release?	0	1	2	3
2.	Did you have any difficulty in operating the buckle release?	0	1	2	3
3.	Did the webbing hang up on you, your clothes, or parts of the vehicle during retraction?	0	1	2	3
4.	Was retraction and stowage complete?	0	1	2	3

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(For Passive System)

1.	Did you experience confusion on how to doff the belt system?	0	1	2	3
2.	Did you have any difficulty in stowing (i.e., hooking) the belt system?	0	1	2	3
3.	Did the belt drag across your chest (breast)/clothing?	0	1	2	3

Set #4

Questions to be asked after subject has exited from vehicle.

(For Standard System)

1.	Did the belt system interfere with your exit?	0	1	2	3

2. Were all parts of the belt system clear of the door? 0 1 2 3

(For Passive System)

1. Did the belt system interfere with opening the door or exiting from the vehicle? 0 1 2 3

2. Did you have to hold the door against the tension of the belt? 0 1 2 3

Time required to make emergency exit: ____________ seconds

Set #5

Questions to be asked after subject has completed emergency exit from adjacent door and begun emergency exit toward opposite door.

(For Standard and Passive Systems)

1. Did you experience any difficulties in making an emergency exit from the door on the driver's side? 0 1 2 3

2. Did you experience or can you imagine any difficulties in making an emergency exit from the opposite door? 0 1 2 3

Compared with

The Criterion Car (____________________)

The Comparison Car (____________________)

is:

Much Worse	Somewhat Worse	Slightly Worse	Same	Slightly Better	Somewhat Better	Much Better
3	2	1	0	1	2	3

Purpose Of Test

(To Be Read To Test Subjects)

The seat belt system installed in vehicles manufactured in 1974 has a number of new design features. Some of these features, such as the manner in which the belt is buckled and the way it retracts, were designed to reduce the confusion, inconvenience, and discomfort that was associated with the use of seat belts in older model cars.

The purpose of this research project is to determine the extent to which these design objectives have or have not been achieved. Seat belts must be designed to accommodate the requirements of all sizes of people, large, medium, or small. We want to learn what you, a potential user of this system, think about it.

So, as you put on the seat belt, as you are wearing it, and as you take it off, please be thinking about any problems of confusion, inconvenience, and discomfort you encounter.

This study is not concerned with any problems involving the ignition lockout part of the system which prevents you from starting the engine until you have put on the seat belt. We are interested only in any problems you may experience while putting the seat belt on, while wearing it, and while taking it off.

Immediately following the test we will ask you some questions, and you will be able to tell us about your observations.

APPENDIX E - Summary of Analysis of Variance

Source	Degrees of Freedom	Mean Square	F	p
Subjects (S)	23	35.85		
Cars (C)	5	434.33	55.83	$<.001$
C x S	115	7.78		
Questions (Q)	24	66.13	11.77	$<.001$
Q x S	552	5.62		
C x Q	120	42.89	20.33	$<.001$
C x Q x S	2760	2.11		