TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-AM-71-12		

4. Title and Subtitle	5. Report Date
ACCEPTANCE TESTS OF VARIOUS UPPER TORSO RESTRAINTS	March 1971
	6. Performing Organization Code

7. Author(s)	8. Performing Organization Report No.
John J. Swearingen, D. Av. T.	

9. Performing Organization Name and Address	10. Work Unit No.
FAA Civil Aeromedical Institute P. O. Box 25082 Oklahoma City, Oklahoma 73125	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address Office of Aviation Medicine Federal Aviation Administration 800 Independence Avenue, S. W. Washington, D. C. 20590	OAM Report
	14. Sponsoring Agency Code

15. Supplementary Notes

This study was conducted under Tasks AM-A-69-PRS-37 and AM-A-70-PRS-37.

16. Abstract

This study demonstrates that people can be motivated to utilize and, in fact, eagerly accept the use of upper torso restraint equipment for the prevention of head and chest injuries induced by flailing during crash decelerations, provided that specific design criteria are followed by structural engineers. By giving attention in this study to design of specially constructed restraint equipment to incorporate the maximum in features for comfort, neatness of appearance, ease of stowage, and ease of donning and escape, it was found that over 90% of the test subjects utilized these upper torso restraint systems throughout the two-year test period. In contrast, only an estimated 3 to 5% utilization of the factory-installed torso restraint equipment in over 10,000,000 automobiles manufactured since 1 January 1968 has been attained to date. General aviation aircraft manufacturers should give careful consideration to these significant design criteria, along with incorporating inertia reels for ease of motion, before launching an extensive program for installation of upper torso restraint in light aircraft.

17. Key Words	18. Distribution Statement
Restraint equipment, Body flailing, Crash Injuries, Aviation safety, Human factors, Aircraft design.	Availability is unlimited. Document may be released to the National Technical Information Service, Springfield, Virginia 22151, for sale to the public.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	12	$3.00

Form DOT F 1700.7 (8-69)

ACCEPTANCE TESTS OF VARIOUS UPPER TORSO RESTRAINTS

Introduction.

For survival in transportation vehicle crash impacts, the occupants must participate in their environmental deceleration. While lap belts reduce the possibility of fatalities from occupant ejection[1-11] by a factor of approximately 75%[12], they represent only a partial participation of the occupant in the deceleration of his environment and allow the upper torso and appendages to flail about to produce serious or fatal injuries during the secondary impact.

An extensive educational program over a 10-year period utilizing all the news media and many other innovations has succeeded in raising lap belt usage by automotive occupants to about 30% in those vehicles equipped with lap belts.[13] On the other hand, in a recent study of seventy light aircraft accidents conducted by Swearingen,[14] it was found that better than 95% of the occupants involved were wearing their lap belts. In general, the light aircraft pilot has, for one reason or another, accepted the use of lap belts in the aircraft. For these reasons, the acceptance of upper torso restraint in general aviation aircraft would be expected to be higher than in automobiles.

Upper torso restraint is not generally provided in light aircraft, but the critical need for additional body restraint in crashes is clearly demonstrated in the study identified by Reference 14. It should be noted that this additional restraint equipment is required in general aviation aircraft conforming to the requirements of Part 23 of the Federal Aviation Regulations and manufactured under Approved Type Certificates issued on or after 14 September 1969.

Since 1 January 1968, all automobiles manufactured for sale in the United States have been required by law[15] to be equipped with a combination lap-upper torso belt system for the two outboard front seat positions. The author estimates that there are over 20 million automotive vehicles in use in this country at present that are equipped with both lap belts to prevent ejection and shoulder belts to prevent the head and upper torso from jackknifing forward and striking the steering wheel, instrument panel, or windshield. Unfortunately, only a very small percentage (3 to 5%)[16] of these upper torso belt devices are being utilized by the motoring public. Snyder[17] has discussed in detail the many variations of current automotive shoulder belt installations and the current problems involved in their use and acceptance. He states that "the major problem, from a protection standpoint, in the 1969 automotive vehicles appears to be that the restraint systems provided simply do not fit properly a large segment of the automotive occupant population. Too often the upper torso belt rides along the side of the neck or even off the shoulder."

It is the purpose of this study to evaluate the acceptance of various types of upper torso belt restraint equipment in terms of comfort, ease of donning, neatness of stowage, and freedom of movement which, along with Snyder's analysis of the problems of the system installed by the automotive industry, should serve as a guide for the general aviation manufacturers for the installation of restraint equipment that will be generally accepted by the flying public.

Procedure.

An invitation for volunteers to participate in an automobile shoulder belt research study was circulated in January 1968 in the Civil Aeromedical Institute and some other portions of the Aeronautical Center. Information was released that the Protection and Survival Laboratory would install, free of charge, two sets of combination lap-shoulder belt assemblies in the automobile of each of the first 100 volunteers. Actual installation was terminated in March of 1968. By this time 95 automobiles had been equipped with dual sets of combination lap-shoulder belt assemblies. Volunteers were assured that their cars would not be used in crash testing. In

general, they were allowed to choose from eight different configurations of restraint equipment. However, certain design models (e.g., convertibles) dictated a specific design of shoulder belt installation. In addition, volunteers were given a choice of 11 different colors of webbing to match the upholstery of the automobile.

Questionnaires, to determine complaints and favorable comments, degree of utilization, mobility, and whether or not they wish to have the shoulder belts removed, were sent out at intervals of two weeks, four months, one year, and two years after installation. Where possible, modifications were made on the installations between questionnaires to eliminate complaints.

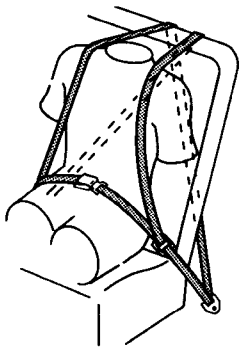
The Sample: Fifty-two of the volunteers worked in the Civil Aeromedical Institute and were familiar with some of the crash safety research conducted in the Protection and Survival Laboratory. The remaining 43 were employees of other Divisions at the Aeronautical Center.

Eighty-two of those requesting installation of shoulder belts were males and 13 females. However, since two sets of harnesses were installed in each front seat, female exposure to the use of the belts, as right seat passengers and alternate drivers, probably approached that for the male population.

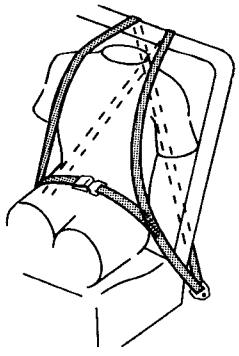
An occupational analysis of the sample group revealed the following distribution: Professional—20; Technicians—28; Clerical—9; Skilled Laborers—28, and Laborers—10.

In the selection of the type of shoulder belts desired, the subjects had a choice among four different double and four single strap designs (Figures 1, 2 and 3). Only ten chose from the double belt selection in the following order: 1 Type A, 3 Type B, 4 Type C, and 2 Type D. The distribution of those selecting the single strap belt was: 7 Type E, 11 Type F, 62 Type G, and 5 Type H.

It should be noted at this point that the eight types of belt restraint systems shown diagrammatically in Figures 1, 2, and 3 have one common feature—there is *only one buckle* to fasten in each of the systems. In Type A the shoulder straps are continuous with the lap belt with each half sliding through a fixed guide ring, while in Types B, C, and D the shoulder straps are sewn to the lap belt near the seat junction. The pro-

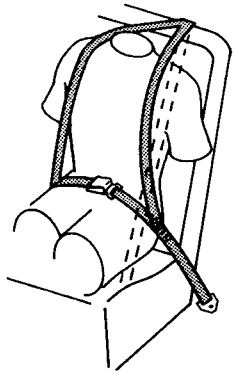


A Double shoulder straps over seat back to floor and continuous with lap belt through D rings.

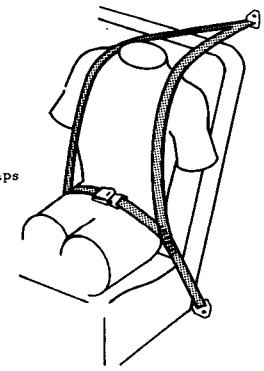


B Double shoulder straps over seat back to floor, sewn to lap belt at seat intersection.

FIGURE 1. Diagrammatic sketches of Types A and B shoulder belt installations.

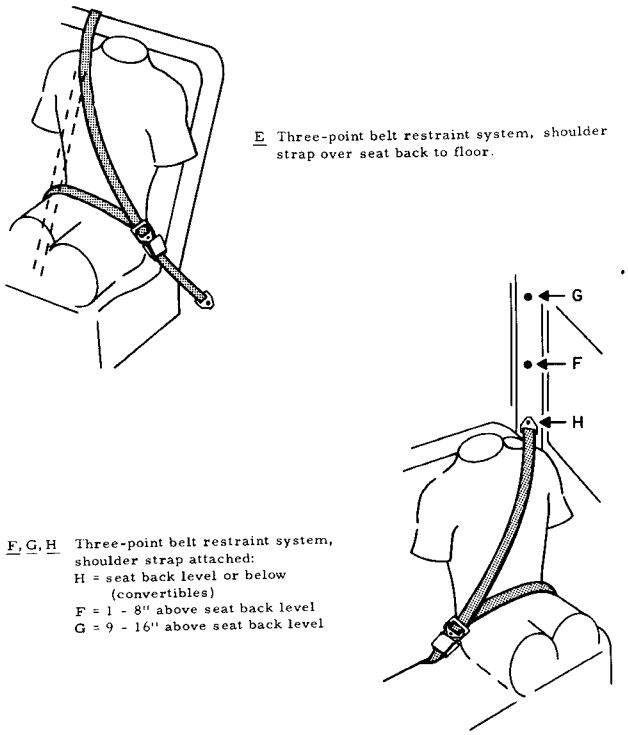


C Double shoulder straps to single strap over seat back and to floor. Double straps sewn to lap belt at seat intersection.



D Double shoulder straps to single strap fastened to body behind seat at seat top level (pick-up trucks only). Double straps sewn to lap belt at seat intersection.

FIGURE 2. Diagrammatic sketches of Types C and D shoulder belt installations.



E Three-point belt restraint system, shoulder strap over seat back to floor.

F, G, H Three-point belt restraint system, shoulder strap attached:
H = seat back level or below (convertibles)
F = 1 - 8" above seat back level
G = 9 - 16" above seat back level

FIGURE 3. Diagrammatic sketches of Types E, F, G, and H shoulder belt installations.

cedure for donning these four types of restraint consists of slipping the shoulder straps on like a pair of suspenders and fastening the lap belt buckle (See Figure 6). In the three-point belt restraint systems (Types E, F, G and H, Figure 3), the single shoulder strap is continuous through the tongue of the buckle to form half of the lap belt and cannot be detached from the belt. This type of restraint system is simply donned as shown in Figure 7.

A distribution of the experimental vehicle date of manufacture is shown in Figure 4. It will be noted that a large percentage of these vehicles were late-model cars at the time of shoulder belt installation. Since it was necessary to drill holes through the body, door post, or roof channel (including upholstery or headliner) in 80 of these automobiles, the author feels that the volunteers must have had a significant interest in impact protection through the use of torso restraint.

Results.

Ninety-five of Questionnaire #1 (Figure 5) were sent out two weeks after all restraints were installed and 93 were returned. Answers to the questions are indicated in terms of per cent in Figure 5.

Comments on Shoulder Belt Questionnaire #1 (after 2 weeks of use):

NOTE: Representative comments are presented from the questionnaires demonstrating satisfaction with the installation, donning ease, wearing comfort, and protection provided. The comments were far too numerous to be published in total.

"I have always felt that lap belts were a necessity for my safety as well as my passenger's, but since using the shoulder belt, I realize that lap belts alone afford only partial safety. They will always be standard equipment in any vehicle I own in the future."

"A very neat installation was made."

"Very well pleased with how fast and easy shoulder belt is to connect."

"I find that belts are very comfortable and are used by my wife and whole family."

"With the increased stability of the body during curves, decelerations, and accelerations, the arms are free for steering only. Driving is a greater pleasure than ever."

"The shoulder strap combination is much better than regular lap belts. I feel much more secure."

"I find the belt restraint system easy to fasten and adjust."

"The shoulder belt is very comfortable while driving and I would not like to drive without them any more."

"In a pick-up shoulder belts let the passengers relax to the extent they do not have to brace themselves as much on cornering or stopping."

"I find on a long run or trip I get less tired and my back does not ache near as much after the trip. I wear my restraint equipment snug so it keeps me sitting in an erect position. Thus less tiring. Plus a feeling of more security."

"I feel lost without it now and I've become accustomed to wearing it."

"It is far more comfortable than I thought it would be! I find it reminds me to sit up straight and I am not as tired after driving a long ways. I really am pleased!"

As a result of Question #8, to which 73% of the subjects said they would like to see improved

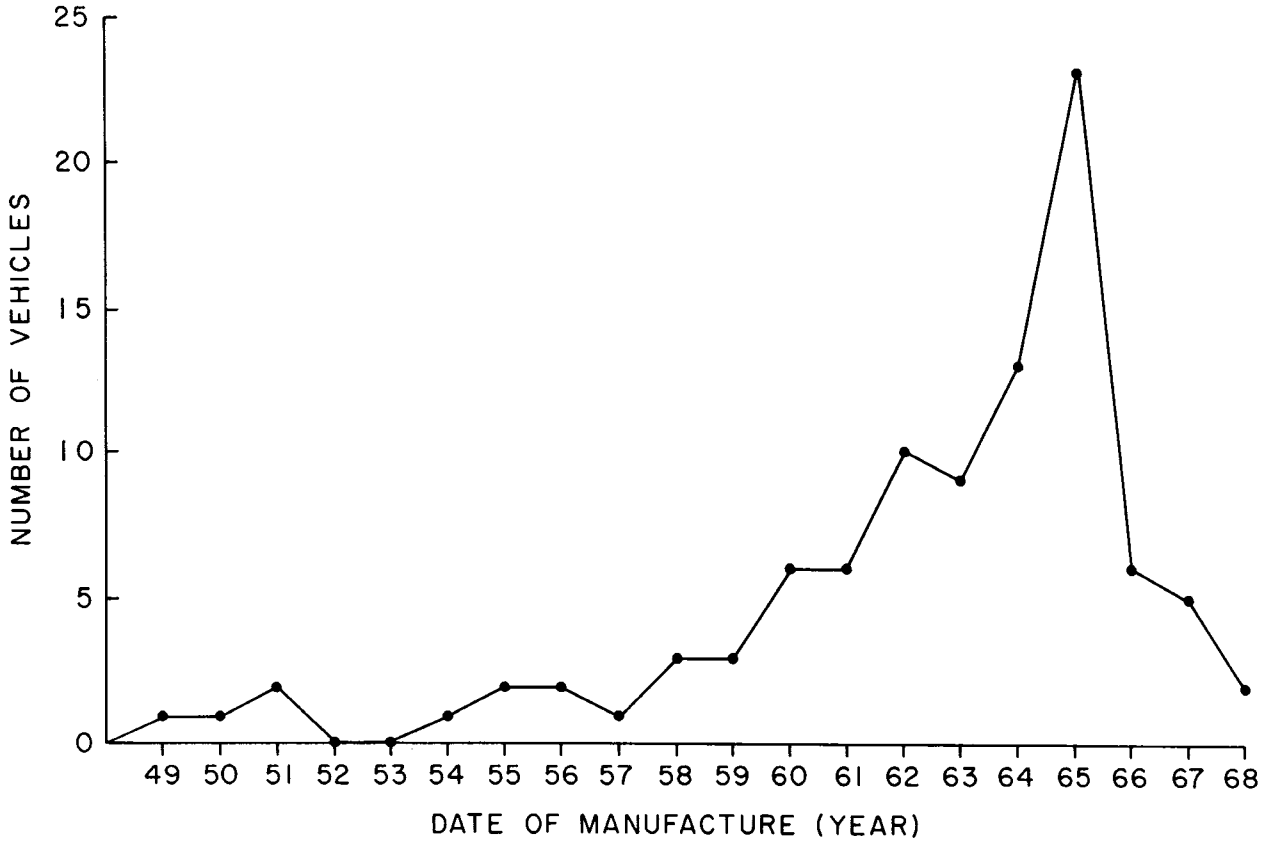


FIGURE 4. Distribution chart of dates of manufacture of test vehicles.

stowage, spring-wound belt retractors were purchased and inserted on the various straps to take up the slack webbing when occupants removed them.

To illustrate neat stowage by the addition of retractors, a Type B restraint system representing the double shoulder strap equipment with straps held snugly against the seat is shown in Figure 6, and a Type G single shoulder strap restraint held neatly vertical along the inner side of the door post by one retractor enclosed in a boot at the bottom and a second floating retractor at the top is illustrated in Figure 7.

The discomforts of the 10% noted in Question Number 1 were studied and it was found that the complaints were founded by errors in installation; e.g., one strap too short or adjustments located such that they rested on a bony structure. Types B, D, E, F and G were represented in the nine complaints. Corrections were made as necessary.

In regard to Question #4, most of the 18 persons complaining of not being able to reach all the controls were referring to the brake release lever. They were advised to release the emergency brake with the vehicle in park before donning the harness.

Of 95 copies of Questionnaire #2 (Figure 8) that were mailed out, after four months, 83 were returned. Twelve subjects had traded cars or moved and could not be contacted. Answers to the eight questions ranged as follows:

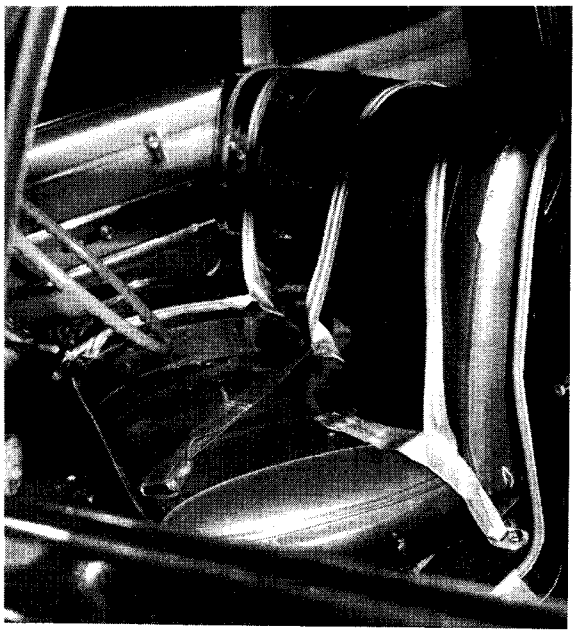
Question	*% Yes*	*% No*
1. (Still wear faithfully)	94	6
2. (Were retractors installed?)	78	22
3. (Are retractors satisfactory?)	91	9
4. (Near misses or accidents)	7	93
5. (See comments that follow)	N/A	N/A
6. (Secure feeling)	94	6
7. (Remove restraint system)	1	99
8. (Comments—follow)	N/A	N/A

RESTRAINT SYSTEM QUESTIONNAIRE #1
(Two Weeks)

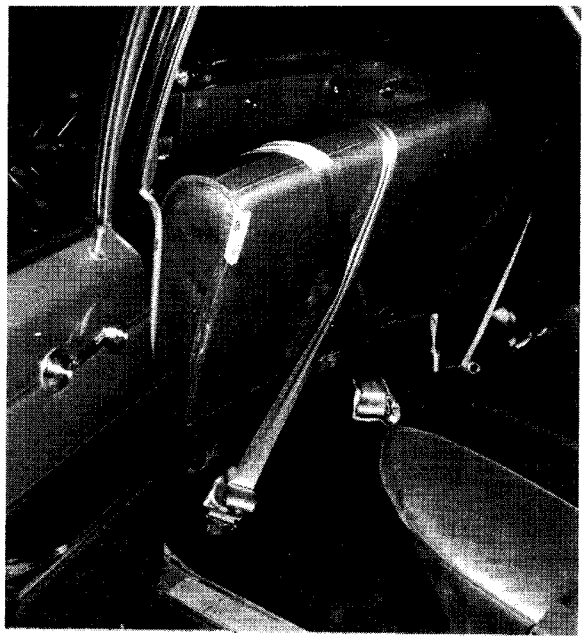
	% Yes	% No
1. Do you find your belt restraint system comfortable? If no, please state discomfort. _____	90	10
2. Do you wear your restraint equipment every day to and from work?	92	8
3. Do you don it for short trips--2-3 blocks or less?	82	18
4. Can you reach all necessary controls with the equipment worn comfortably?	80	20
5. How many times have you forgotten to don your restraint equipment until after starting to drive? Never 38 Seldom 62		
6. Does wearing it make you feel more secure?	97	3
7. Do you feel that the restraint equipment detracts from the appearance of your car?	19	81
8. Would you be more pleased if stowage was improved to eliminate loose webbing?	73	27
9. Does your front seat passenger usually wear this protective equipment?	90	10
10. Would you like for us to remove the belt restraint system from your car?	1	99

11. Any comments you would like to make. _____

FIGURE 5. Copy of questionnaire distributed two weeks after harness installation.



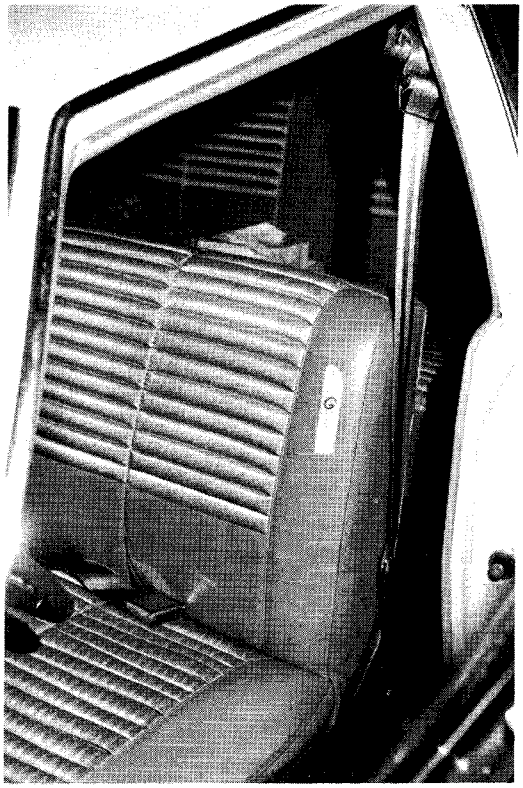
A Shoulder straps sewn to lap belt close to seat intersection to prevent submarining.



B Retractors hold straps smoothly against seat back when not in use.

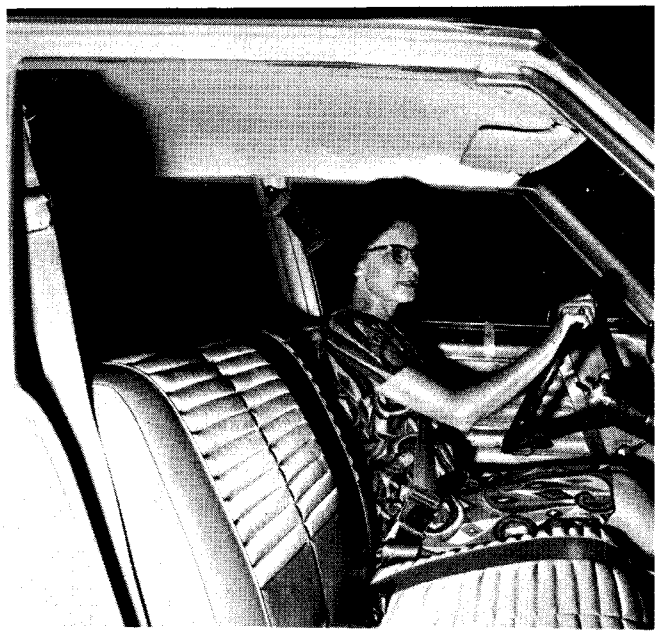
C Shoulder belts slipped on like suspenders and only lap belt buckle to fasten.

FIGURE 6. Type B double shoulder belt installation.



A Shoulder strap and half of lap belt held neatly vertical along B post by two retractors. Only one buckle in seat.

B Subject dons restraint equipment by grasping tongue of buckle with right hand and pulling over left arm and shoulder.



C Subject wearing three-point belt restraint system.

FIGURE 7. Type G combination shoulder belt installation.

RESTRAINT SYSTEM QUESTIONNAIRE # 2

It has now been four months or longer since belt restraint systems were installed in your car and we would like to have your present evaluation after wearing them for this period of time. Will you please answer the following questions and return the questionnaire to AC-119?

	Yes	No
1. Do you still wear this equipment faithfully?	☐	☐
2. Were seat belt retractors installed on your shoulder straps to improve the stowage of loose webbing when not in use?	☐	☐
3. If yes, are they working satisfactorily?	☐	☐
4. Have you had any near misses or accidents while wearing the restraint system?	☐	☐

5. If yes, please describe in detail. _____

_____

_____

_____

6. Do you feel insecure and unprotected when riding in a car not equipped with this safety equipment?	☐	☐
7. Would you like for us to remove it from your car?	☐	☐

8. Other comments you would like to make. _____

_____

_____

_____

FIGURE 8. Copy of Questionnaire Number 2, distributed four months after installation.

RESTRAINT SYSTEM QUESTIONNAIRE #3
(After One Year and After Two Years)

	Yes	No
1. Do you still have the car in which we installed a belt restraint system?	☐	☐
2. If the answer to #1 is yes:		
(a) Do you still wear it on long trips (25 mi. & over)?	☐	☐
(b) Do you still wear it on trips of 2 - 25 miles?	☐	☐
(c) Do you still wear it on trips of 1 block to 2 miles?	☐	☐
3. If the answer to #1 is no:		
(a) State Make _____ Model _____ and Year _____ of your new car.		
(b) Is it equipped with shoulder belt?	☐	☐
(c) If it has a shoulder belt, do you wear it?	☐	☐
Please describe and discuss. _____		
4. Have you had any near misses or accidents since the last questionnaire? If yes, please describe: _____	☐	☐
5. Have you noticed any fraying or signs of wear?	☐	☐
6. Are your shoulder and seat belts becoming soiled?	☐	☐

7. Other comments: _____

8. NOTE: If you have an accident in the future, will you please notify us before you repair your car? We would like to get pictures of it to tie in with our accident study.

FIGURE 9. Copy of questionnaire distributed after one year and again after a two-year period.

Near Misses and Accident Comments (Questions 4 and 5):

From the comments received in answer to these questions and based on speeds and forces involved, the author estimates that at least one death and probably 20 serious injuries were prevented in eight separate accidents or incidents by the use of the combination lap-shoulder belt restraint system during a four-month period.

Favorable Comments were very similar to those received on Questionnaire Number 1 and will not be repeated here.

Questionnaires 3 and 4 were identical (Figure 9) and were distributed at the end of one and two years respectively. After one year, 75 of the original 95 volunteers still owned the vehicles in which test restraint equipment had been installed. Two of the 75 had removed the test equipment, reducing the test sample to 73. Of the remaining 18 of the original sample, 8 had resigned and could not be contacted and 10 had traded cars. Only three of those that had traded owned late-model cars with factory-installed shoulder belts.

After two years 13 of the original sample had moved; 27 had traded automobiles and only 55 still had the original vehicles. Of the 27 that had traded, 14 had new automobiles with factory-installed shoulder belts. Answers to the two questionnaires were tabulated as follows:

	One Year		*Two Years*	
Question	*Yes*	*No*	*Yes*	*No*
1. (Still have car)	75	10	55	27
2. (a) Wear on long trips (25 mi. or more)	95%	5%	98%	2%
(b) 2–25 mi.	92%	8%	92%	8%
(c) 1 block—2 mi.	73%	27%	71%	29%

Question 3 was designed to try and determine whether or not those that traded for new cars equipped with factory-installed shoulder belts were utilizing them. As stated above, only three individuals, after the one-year test period, owned late-model automobiles with factory-installed shoulder belts. One indicated that he was wearing his shoulder belt and two were not. However, after two years of the test period, 14 had late-model cars with factory-installed upper torso restraint equipment. Three indicated they were using the new safety belts; one said sometimes and ten said no. Of the ten answering in the negative, as determined by an individual check of previous questionnaires, nine were enthusiastic users of the CAMI-installed equipment. Representative comments for not wearing shoulder belts were:

"Shoulder belt crosses across the neck; I'm afraid of them. We always wear seat belts."

"Would prefer double shoulder belts as present shoulder belt cuts and abrades neck. Very uncomfortable, improperly installed, and of a poor and potentially hazardous design. Separate from seat belt."

"Cuts into neck—will make a loose fit for comfort."

"Would like shoulder belt to come from post—it is too far back for comfort and easy accessibility."

"Roof-mounted diagonal belt. Dislike position across base of neck. Inability and nuisance of stowage are also negative factors not present with the experimental belt system in the 'old' cars."

"Regular . . . installation (new car) uncomfortable; bundlesome, difficult to keep up with all the straps—a pain to keep stored. Wear mine occasionally."

Question Number 4: No serious accidents were reported on these two questionnaires.

In the two final questions—5 in regard to fraying and 6 as to soiling—7% reported fraying after one year and 20% after two years. Sixteen per cent reported their restraint equipment becoming soiled after one year and 56% after two years.

Consideration should be given to replacing webbing after two or three years of use since fraying induced by constant usage will have weakened the webbing to an unsafe level. Perhaps the manufacturers could also offer the purchaser some instructions for cleaning restraint webbing as it becomes soiled.

Summary and Conclusions.

Eight types of combination lap-shoulder belt assemblies were evaluated by a group of nearly 100 informed individuals over a period of two years. Every effort was made to make the restraint installations comfortable, neat in appearance, easily stowed, and easy to use. Response to questionnaires at intervals of 2 weeks, 4 months, one year, and 2 years revealed that over

90% of the participants were utilizing the restraint equipment on long trips throughout the entire test period. Usage on short trips dropped from 82% during the initial portion of the test to 71% after two years, indicating that a few people were tiring of donning the protective equipment for very short drives. This high rate of usage compared to the extremely low rate for factory-installed shoulder belts may be attributed to the fact that most of the test group in this study were aware of the need for additional crash protection and were pleased with the comfort, appearance, ease of donning and stowage.

An educational program along with good human engineering design will be necessary if the majority of the general public can be expected to utilize shoulder belt/seat belt restraint equipment.

It is suggested that the general aviation aircraft manufacturers take heed to current designs and installations in late model automobiles that discourage acceptance and use of upper torso restraints and the results of this study before embarking on an extended program of installation of shoulder belts in light aircraft. Since reach is much more critical in the operation of aircraft, inertia reels or similar devices to allow freedom of motion must be incorporated in the installation design of upper torso restraint systems in general aviation aircraft.

It is considered feasible by the author that a selection of shoulder belt assemblies could be offered at the same time an aircraft purchaser selects exterior and interior color and pattern designs.

REFERENCES

1. Schwimmer, S. and R. A. Wolf: Leading Causes of Injury in Automobile Accidents, Automotive Crash Injury Research of Cornell Univ., Ithaca, N. Y., 1962.
2. Tourin, B. and J. W. Garrett: Safety Belt Effectiveness in Rural California Automotive Accidents, Automotive Crash Research of Cornell Univ., N. Y., 1960.
3. Huelke, D. F. and P. W. Gikas: Ejection—The Leading Cause of Death in Automobile Accidents, CONF. PROC., TENTH STAPP CAR CRASH CONF., Holloman AFB, 1966, pp. 156–181.
4. Vulcan, A. P.: Review of the Relative Merits of Various Types of Motor Vehicle Seat Belts, J. AUSTRALIAN ROAD BOARD 2:33–40, June 1966.
5. Wolf, R. A.: Control of Ejection in Automobile Accidents, J. AMER. MED. ASSN. 158:220–224, April 1962.
6. Campbell, H. E.: Role of the Safety Belt in 19 Auto Crashes, BUL. AMER. COL. OF SURG. 50:155, 1955.
7. Frazier, R. G.: Effectiveness of Seat Belts in Preventing Motor Vehicle Injuries, NEW ENGLAND MED. J. 264:1254–1256, June 15, 1961.
8. Gikas, P. W. and D. F. Huelke: Causes of Death in Automobile Accidents, Can Seat Belts Really Save Lives? J. MICH. STATE MED. SOC. 63:351–354, May 1954.
9. Lindgren, S. and E. Warg: Seat Belts and Accident Prevention, THE PRACTITIONER 188:467–473, April 1962.
10. Tourin, B.: Ejection and Automobile Fatalities, PUBLIC HEALTH REPORT 73:381–391, May 1958.
11. Huelke, D. F. and P. W. Gikas: Determination of Seat Belt Effectiveness for Survival in Highway Collisions, CONF. PROC., SEVENTH STAPP CAR CRASH CONF., C. C. Thomas, Springfield, Ill., 1965, pp. 403–431.
12. Huelke, Donald F. and William A. Chewning: Comparison of Occupant Injuries With and Without Seat Belts, SAE Report No. 690244.
13. Louton, J. C. and T. W. Ruster: Restraint Systems, Design and Performance Parameters, PROC. GENERAL MOTORS CORP, AUTOMOTIVE SAFETY SEMINAR, July 1968, Safety Research & Development Lab., Milford, Mich.
14. Swearingen, John J.: General Aviation Structures Directly Responsible for Trauma in Crash Decelerations, DOT/FAA Aeronautical Center, Civil Aeromedical Institute, Office of Aviation Medicine, Report AM 71–3.
15. Department of Transportation, National Traffic Safety Agency, Federal Motor Vehicle Safety Standards No. 209, Title 23, P 255 (FMV 209-seat belt assembly. FMV 210—seat belt anchorage). Jan. 1967.
16. Roberts, V. L.: Motor Vehicle Restraints, 1970 INTERNATIONAL AUTOMOBILE SAFETY CONFERENCE COMPENDIUM, 978–993.
17. Snyder, R. G.: A Survey of Automotive Occupant Restraint Systems: Where We've Been, Where We Are and Our Current Problems, SAE Report 690243, Jan. 1969.