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CHILDREN RETRAINT SYSTEMS FOR CIVIL AIRCRAFT

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16. Abstract

Child restraint systems have been developed to provide protection to children involved in automobile crashes. These systems are not yet approved for use in civil aircraft. Six typical systems were exposed to controlled impacts on a test sled to simulate aircraft crash conditions; these systems were inverted to simulate turbulence. A special test seat was developed to represent an aircraft passenger seat for these tests. The results of the tests and characteristics of the child restraint systems that are critical for civil aircraft applications are discussed.

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INTRODUCTION

The need to provide a special means of protecting infants and small children during a crash has been recognized for several years, but the first Federal regulatory specification for these devices was not adopted by the National Highway Traffic Safety Administration (NHTSA) until 1971. This document, Motor Vehicle Safety Standard (MVSS) Number 213, Child Seating Systems, established requirements and static testing procedures for infant and child restraint systems that could be used to provide crash protection in automobiles. Subsequently, many manufacturers marketed different versions of child restraints that were in compliance with that specification, and these were purchased by citizens throughout the nation.

Naturally, many of these citizens believed that their purchase, intended to provide crash protection for their children and approved by an administration of the Department of Transportation, would provide similar protection for their children in the event of a crash while traveling by air. However, as citizens tried to carry the child restraints on board the aircraft, they were often told that the restraints were considered "carry-on articles" and must be securely stowed as such during takeoffs and landings, and that the small child must be restrained by the adult seatbelt or held by an adult during takeoff and landing.[1] The resulting confusion and occasional conflict demonstrated the need for clarification of the situation.

The problem is made more difficult by several factors. If it is recognized that the use of infant or child restraint systems is made practical through their sales in the automotive-related marketplace,* then the importance of the MVSS regulating their performance will be obvious. Unfortunately, MVSS 213[2] is generally conceded to be an inadequate standard and it has been subjected to severe public and professional criticism. The NHTSA has issued a Notice of Proposed Rulemaking (NPRM) (Docket Number 74-9) designed to revise and upgrade the existing standard. The availability of restraints for use on aircraft would be greater if the performance required was compatible with the revised MVSS.

However, since the MVSS is not an adequate standard for the infant and child restraint systems to be used on aircraft the aviation needs could supplement the automotive requirements to provide for differences in the crash and operational environments. For example, automobile seat backs are now required to be either fixed or latched to remain upright during a crash, but the majority of aircraft seats will fold forward. The infant or child restraint in the aircraft should restrain the child <u>and</u> insure that the child is not injured by the folding seat back action. Turbulent flight and the possibility of emergency evacuation are other differences that occur in the aircraft application.

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*Although an industry standard (Aerospace Recommended Practice 766, Restraint Device for Small Children) has been available since 1967, there have been virtually no devices available for use that have been developed in accordance with these procedures.

Certain aspects of the use of infant and child restraint systems are beyond the scope of this report. The devices that will be discussed require installation in a seat by use of a seat (safety) belt. This stipulation requires the availability of an adult seat for the infant or child less than 2 yr of age, and it will be presumed that such a seat will be available without regard to the problem of who pays for the seat. The question of techniques that may not require an adult seat will not be discussed here because in actual practice their use is infrequent and, in some cases, may even contribute to injury. These alternatives usually consist of techniques that are dependent on the skill of the cabin attendant and/or passengers, such as containing the infant in the fold of a blanket while the edges of the blanket are sat upon by passengers in adjacent seats, or they require some modification to the aircraft structure, usually a bulkhead, for attachment of an infant crib.

It will also be a basic assumption that the restraint device will be properly used in accordance with the instructions of the manufacturer and that the infant or child will be given adequate attention during the flight to insure its comfort and prevent injury as a result of the child's falling or crawling from the device or becoming entangled in bedclothes or in straps that may be part of the device. Although these devices are usually designed so that the infant or child will not be injured when the device is properly used, it is unreasonable to expect the manufacturer to compensate for all modes of improper use or for basic lack of attention on the part of adults accompanying the infant or child.

CURRENT REGULATORY STATUS

The scope of regulations or standards that are presently in effect in the United States, or are under consideration, provided a basis for the test procedure of this study. Three basic documents were considered. Industry-recommended practices are voluntary standards that are not enforced by any regulatory body. Motor Vehicle Safety Standards outline performance requirements for automobile safety systems, and it is the responsibility of the manufacturer or distributor to certify compliance with the standard. Federal Aviation Regulations (FAR) pertain to operational and system safety requirements, and a manufacturer or operator is certified to be in compliance with these regulations after presentation of data or demonstration of compliance.

Aerospace Recommended Practice (ARP) 766, Restraint Devices for Small Children,[3] was prepared by the Cabin Safety Provisions Committee of the Society of Automotive Engineers (SAE) Aerospace Council in 1967. As such, it represents the primary voluntary standard available to the industry for child restraint systems for transport aircraft.

MVSS 213, Child Seating Systems,[2] is the standard to which all infant and child seating systems generally marketed are fabricated. This standard became effective April 1, 1971, after several amendments. It has been subjected to severe and frequent public criticism, typical of which was from the Consumers Union in February 1974[4] and March 1975.[5] This criticism recognizes that a major concern is that the required static test procedures are inadequate to determine effective crash protection. Consequently, several systems have been marketed that provide inadequate crash protection even though they complied with the requirements of MVSS 213.

The NHTSA NPRM Docket Number 74-9, issued in February 1974,[6] proposes revisions to MVSS 213 to provide dynamic test performance requirements for child restraint systems and includes requirements for the "car bed" type of restraint systems.

FAR Sections 91.14,[1] 121.311,[7] and 127.109[8] provide that a child who has not reached his second birthday may be held by an adult who is occupying a seat or a berth. A child more than 2 yr of age would require an "approved seat or berth." It would be feasible to consider an approved infant or child restraint system to be an "approved seat or berth" for a child and thus permissible for use on board the aircraft.

BIOMEDICAL CONSIDERATIONS OF CHILD RESTRAINT SYSTEMS

The infant or small child differs markedly from the adult in characteristics that are critical in designing effective protection from crash forces. These have been summarized by Burdi et al.[9] The relatively large head mass of the small child, together with the small, undeveloped muscular and skeletal structure of the neck, causes one of the more serious injury potentials. If the head is allowed to flail during the crash sequence, serious injury could occur to the neck vertebrae, the spinal cord, the arteries supplying blood to the head, or the brain. Providing correct support for both the small child's head and torso is a task that is essential for optimum protection.

In addition, the bone structure of the child is highly cartilaginous, so that there are no firm structural "anchor points" on the child's skeleton. Because of this elastic skeleton, the internal organs and soft tissues of the child's body do not have a protective "cage" to shield them from injury. It is incumbent on the restraint system designer to avoid high, localized forces that may act on the child. These forces may arise from webbing restraint belts, from adjustment or latch hardware on the belts, or from the structure of the frame of the restraint device. Distribution of impact forces over the child's body by large smooth areas provided by the restraint device is a characteristic of the better systems.

The age span of concern covers the period in which the infant develops the capability to sit unaided. Thus, restraint systems must provide protection for both the infant who is unable to sit upright and the small child who will probably "demand" to sit upright. Although some systems offer this protection in a single device, it is common to see one device in use for infants and another for small children.

Finally, although guidelines for the design of infant and child restraint systems can be stated, it must be recognized that there is no way to specify in a quantitative manner the protection provided by the system. The various injury criteria that have been developed are limited to mature adult applications. Even with that limitation, these injury criteria have not been validated on a statistical base and are considered only the best available within the state-of-the-art. Considering the tremendous expenditure of time, human talent, and resources that have been spent on developing these adult injury criteria, it is unlikely that valid child injury criteria will be available in the foreseeable future.

FACTORS IN EVALUATING INFANT AND CHILD RESTRAINT SYSTEMS

Considering the lack of quantitative measures to indicate crash injury in an infant or child, it is apparent that any approach to the evaluation of the adequacy of an infant or child restraint system must be arbitrary or subjective to some extent. Basically, such evaluations are made on three factors:

1. Does the restraint system keep the infant or child within a safe displacement envelope during the crash?

2. Are restraint loads evenly distributed over the infant's or child's body and head?

3. Is the head motion, relative to the body, limited to normal ranges while maintaining adequate load distribution?

Test specifications and procedures attempt to define these factors in a manner that can be consistently and fairly applied to all restraint systems that may be evaluated. The previously mentioned regulatory documents attempt to make such application. Reports by Feles,[10] Rogers and Silver,[11] Heap and Grenier,[12] Appoldt,[13] Aldman,[14] Appoldt,[15] Robbins et al.,[16] Roberts,[17] Stalnaker,[18] and others indicate various design and experimental approaches and test results in an attempt to achieve or evaluate these goals.

TEST DUMMIES

A continuing problem in all evaluations has been the lack of an adequate surrogate for the infant or child in performing tests. Infants have been represented by dolls bought at a local toy store and weighted according to the researcher's judgment or by "beanbags" made in the crude form of an infant. Such techniques do not lead to consistent or comparable evaluations. The simulation of the small child has most often been accomplished by commercially available 3-yr-old-child dummies. Unfortunately, these dummies retain the rigid construction of their adult counterparts and may provide misleading performance information.

To correct this situation, the Civil Aeromedical Institute (CAMI) developed a series of infant[19] and child dummies that can be easily manufactured and that provide a more realistic soft-flesh simulation and flexible-torso simulation.

SEAT CHARACTERISTICS

The performance of the infant or child restraint system, when installed in an adult seat, varies with the action of the seat under dynamic loads. For example, a child restraint system tested on a "soft" seat cushion may generate enough cushion deflection to allow the child to be "dumped" from the restraint. Conversely, a system tested on a "hard" seat cushion would show little tendency to "dump." Another factor is that most aircraft seat backs, unlike modern automobile seat backs, are not latched to remain upright during impact. The inertia loads of the seat back can be transmitted to the seat cushion through the restraint device and thus aggravate the cushion deflection problem and perhaps cause injury to the child unless he is protected from the seat back impact. If a restraint system is to be safely used in a variety of adult seat installations, it is obvious that the characteristics of the test seat must approximate those of the operational seats. The most important characteristics include cushion elasticity, deformation of the seat pan and back pan, weight of the seat back, location of the center of mass of the seat back relative to the pivot point, and mass moment of inertia of the seat back relative to the pivot point. Since these data are not generally available, a "typical" air carrier passenger seat was selected from the inventory of the Protection and Survival Laboratory, disassembled, and measured. A test seat was then designed and built to correspond to those measurements. This seat has a rigid steel frame for the seat pan and a pivoted seat back frame of composite steel and aluminum construction. The frames are covered with a 0.020-in-thick, 2024-T3 aluminum sheet to form the seat and back surfaces. These surfaces were then covered with a 2-in layer of polyurethane foam (1.5 lb/ft^3 density), which was held in place with a canvas cover. The center of mass and mass distribution of the seat back approximated those found in the air carrier seat.

IMPACT DYNAMICS

A primary concern in all impact tests involving aircraft systems is that data representing "real world" aircraft crash pulses (deceleration-time histories) are not available. Although many aircraft crashes have been staged by various experimental facilities, there is little evidence that these crashes are statistically representative of field experience. Likewise, estimates based on crash investigations involve numerous assumptions that may invalidate the results. Thus, any statement of an appropriate impact pulse for testing of seats and restraints is subject to question.

This problem can be circumvented in tests of child restraint systems if the tests are designed to stress the adult safety belt, which holds the child system in place, to a level approximating its design values. This condition can be achieved by a test that falls within the test limits of the revised MVSS 213 and, therefore, appears to be compatible with the proposed NHTSA requirements for the infant/child restraint system.

TURBULENT FLIGHT

The child restraint system must be useful for conditions of flight as well as for a crash or rough landing. In particular, the child must be provided adequate restraint during conditions of turbulent flight. Since equipment capable of replicating this environment is not normally available in a test laboratory, these conditions were simulated by simply inverting the system so that gravity acts to pull the child from the seat.

ATTACHMENT OF INFANT OR CHILD RESTRAINT SYSTEM TO THE ADULT SEAT

The proposed NHTSA standards allow two attachment techniques for child restraint systems, either by the adult restraint system in the vehicle or by belt assemblies or extensions, supplied with the child restraint, that must be specially attached to the vehicle. This last alternative allows straps other than those installed by the vehicle manufacturer to be installed by the child restraint user. Since these straps require modification of the vehicle and could cause interference with other seating positions, it is apparent that this technique would be unsatisfactory for passengers using air carrier transport aircraft. This alternative might be suitable for general aviation aircraft installations, where one aircraft could be modified for one child restraint system, but the ready availability of child restraint systems that do not require this modification make it unnecessary.

EVACUATION

The final consideration pertaining to the use of infant or child restraint systems pertains not to the adequacy of the system, but to potential problems that may occur in the event of an emergency evacuation. Any device that physically restrains a child may delay the rapid evacuation of the child by the accompanying adult when compared to the child held in the arms of the adult. In addition, most of the devices will obstruct passage in front of a seat in which one is installed. Limitations on the location of these devices in air carrier aircraft should be anticipated.

TEST PROGRAM

To provide basic data on the performance of child restraint systems in a civil aircraft environment, the CAMI Protection and Survival Laboratory conducted tests on a selected variety of systems. All systems tested required only a seatbelt for installation so that the test would be applicable to operational civil aircraft without modifications. The systems were selected to provide data representative of several basic design approaches and included: (i) a vest-type restraint that attached directly to the seatbelt (Sears/Rose); (ii) "shield" devices without straps (Ford Tot-Guard, Mopar, Peterson Toddler); (iii) "infant carrier" devices (Peterson infant, General Motors Infant Safety Carrier); and (iv) plastic shell and webbing restraint (Peterson child, Bobby-Mac).

The vest-type restraint system could be used in conjunction with an occupied adult seat by passing the seatbelt through the vest loop and seating the child on or by the side of the adult. Although this arrangement violates the concept of one occupant per restraint and creates a definite potential for injury due to crushing of the child between the adult's legs and chest, it does represent a possible application. Tests were also conducted on that combination.

DYNAMIC TEST CONDITIONS

The test seat was attached to the sled so that the impact force vector was angled 10^{o} below and 10^{o} to the left of the normal longitudinal axis of the floor. Thus, the occupant would move forward, down, and to the left, simulating an oblique impact such as may occur during an aircraft crash. The impact pulse used for those tests involving only a child restraint system (i.e., without an adult) were based on the range proposed by NHTSA. The allowable range and the impact pulse used for these tests are shown in Figure 1. This impact produces loads in the lap belt that approximate the static test loads required for aircraft seatbelts and thus represents a maximum crash for which protection can be provided with existing seatbelts. Selection of this impact pulse would also allow tests of child restraint systems for aircraft to be accomplished at other test facilities that are set up to test child restraint systems for automobiles.

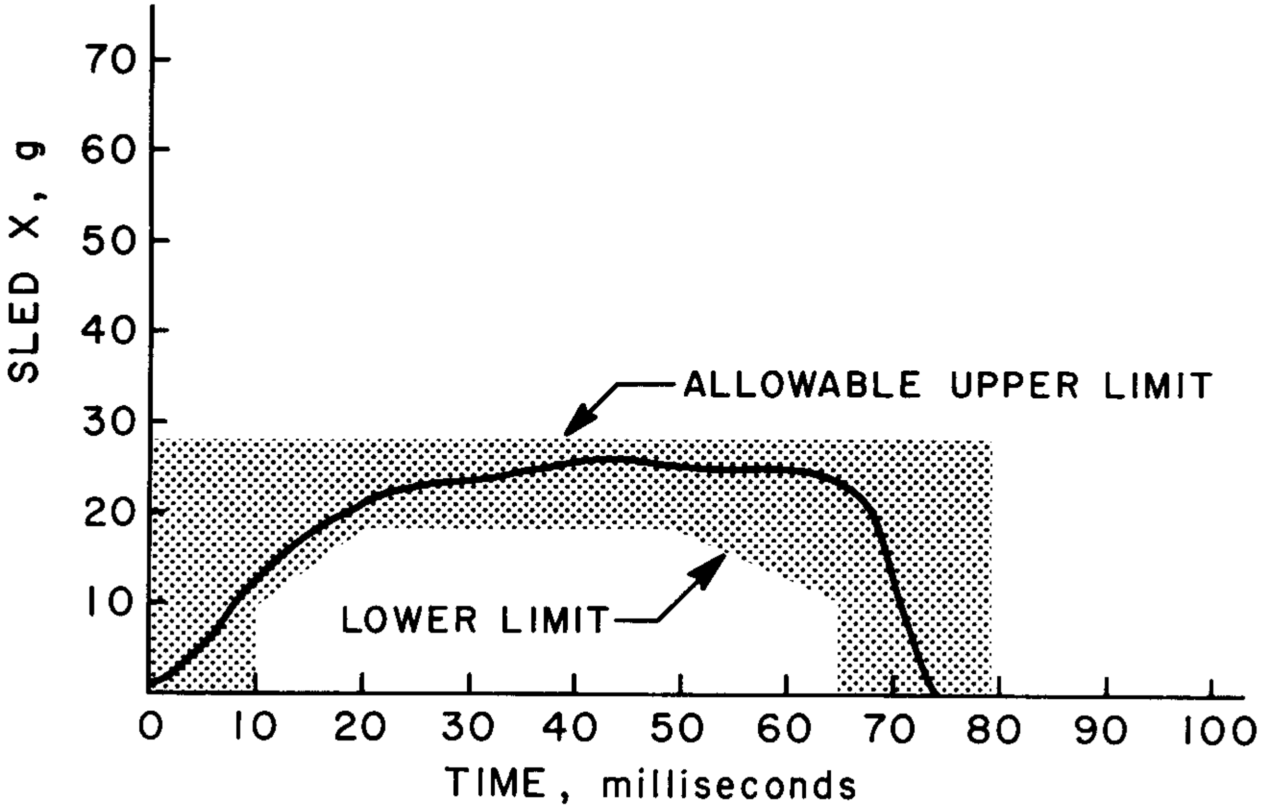

FIGURE 1. Acceleration pulse for sled tests of child restraint systems.

Two tests were accomplished using a fifth-percentile female dummy restrained by the lap belt with an infant dummy attached to the lap belt by a restraint harness. For these tests, the impact pulse, shown in Figure 2, was established at about 9 g.

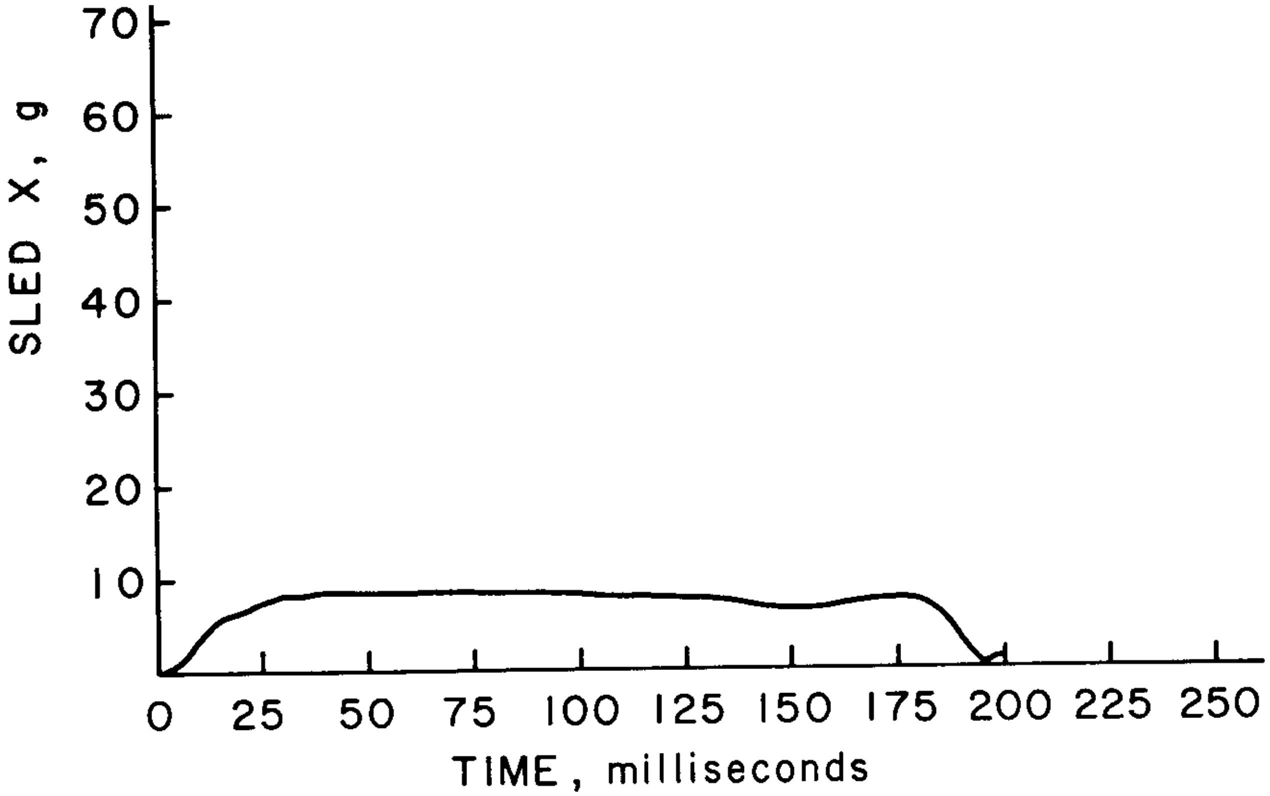

FIGURE 2. Acceleration pulse for tests of child restraint and adult seating combinations.

INSTRUMENTATION

All dynamic tests were recorded on film by using HyCam photoinstrumentation cameras operating at 1,000 frames/s. These films were reviewed to provide data on the displacement of the dummy's head and the general performance of the restraint system. Head displacement plots were made for all tests by tracing the position of the head relative to the sled at 5-ms intervals until maximum head displacement was accomplished. Angular deflection of the seat back was plotted in a similar manner. Sled acceleration was measured with a B&H/CEC 4-202-0001 accelerometer and loads in the lap belt were measured with a Lebow 3419 lap belt load cell in each segment of the belt. These transducers used Endevco 4470-4476-2A Universal Signal Conditioners for excitation and signal conditioning, and data were recorded on a B&H/CEC 5-133 oscillograph.

TURBULENCE SIMULATION

Turbulent flight was simulated by inverting the combination of the test seat, child restraint, and dummy. The combination was inverted by pitching the seat forward, pitching the seat backward, and rolling the seat to the right. Either 6-mo-old-infant dummies or 3-yr-old-child dummies were used as was most appropriate to the child restraint being evaluated.

RESULTS

The results of these tests are summarized in Tables 1 and 2. Because of the diversity of the child restraint concepts evaluated, it is appropriate to provide specific comments relative to that system. Detailed comments relative to each system tested are provided in Appendix A.

TABLE 1. Dynamic Test Results

Restraint: Dummy	Head Displacement Forward (in)	Seat Back Rotation (degrees)	Lap Belt Loop Load (lb)
Lap Belt: Infant	22.5	79	1,550
Tot-Guard: 3-yr-old-child	11.5	47	2,900
Bobby-Mac:			
Infant (1)	15.6	31	1,950
Infant (2)	16.7	62	850
Infant (3)	12.5	64	1,770
Mopar: 3-yr-old-child	13.6	48	3,175
GM: Infant	16.9	65	1,700
Sears (Small):			
Infant	25.7	85	1,950
3-yr-old-child	29.5	78	2,930
Infant (4)	25.3	77	3,080
Rose (Small):			
Infant (5)	19.8	89	1,730
Rose (Large):			
3-yr-old-child	29.6	79	2,250
Sears (Small):			
Adult and Infant (6)	22.7	57	2,800
Adult and Infant (7)	24.8	61	
Peterson Infant:			
Infant	17.5	72	1,200
Peterson Toddler:			
Infant	12.8	37	1,800
3-yr-old-child	17.0	42	2,350
Peterson Child:			
3-yr-old-child	20.3	62	1,900

NOTES: (1) Upright position, forward facing.
(2) Fully reclined, rearward facing.
(3) Fully reclined, forward facing.
(4) Tight seatbelt.
(5) Dummy lying on side on seat.
(6) Infant dummy on lap of female dummy.
(7) Infant dummy at side of female dummy.

TABLE 2. Turbulence Simulation Results

Restraint: Dummy	Restrained Dummy Pitch Forward	Pitch Rearward	Roll Right
Lap Belt:			
Infant	Yes	No	No
3-yr-old-child	Yes	Yes	Yes
Ford Tot-Guard:			
Infant	Yes	No	No
3-yr-old-child	Yes	Yes	Yes
Bobby-Mac:			
Infant	Yes	Yes	Yes
Mopar:			
Infant	No	No	No
3-yr-old-child	Yes	Yes	Yes
GM Infant	Yes	Yes	Yes
Sears/Rose:			
Infant and 3-yr-old-child	Yes	Yes	Yes
Peterson Infant:	Yes	Yes	Yes
Peterson Toddler:			
Infant	No	No	No
3-yr-old-child	Yes	Yes	Yes
Peterson Child:			
3-yr-old-child	Yes	Yes	Yes

DISCUSSION

The performance of the child restraint systems in these tests must be considered relative to their intended design goals but with full regard for the practical use of the system in the field. For example, the child size limitations specified by the manufacturer for their system are compared with the size of the dummy in Table 3. In several cases, the available dummies did not fall within the specified limits. However, these limits have little practical utility in the field. For example, the infant dummy appears to "fit" the Bobby-Mac Baby Chair in the reclined position, even though it exceeds the 15-lb weight limit by 2.4 lb. The failure of that system to properly restrain the dummy could be attributed to the wrong-size dummy, but it is unreasonable to expect parents or crewmembers to know or make such a distinction between sizes. Similar problems exist relative to the instructions for installation of the system. Instructions for the Mopar system require that the open space between the smaller child and the restraint be filled with blankets; the Bobby-Mac Baby Chair requires an unusual placement of the seatbelt when the restraint is used in the reclining position, and the Peterson infant system requires different seatbelt placement from that required for the General Motors (GM) Infant Safety Carrier even though the two systems are similar. It is unreasonable to expect that a cabin attendant can be familiar with these variations and others that may exist.

Likewise, fitting a strap system to an infant or child is a burden to place on the cabin attendant. Proper fitting of the Sears/Rose system, even to a passive dummy, required several minutes of careful adjustment. Other restraint harnesses, though not as complex, required painstaking and "intimate" fitting. Systems without some form of harness, the "shield" restraints, did not require fitting but also did not provide adequate restraint for the smaller dummy during the turbulence simulation tests.

TABLE 3. Limitations of Child Size

Restraint System	Age (yr)	Seated Height (in)	Max. Stature (in)	Weight (lb)
Ford Tot-Guard	1-5	19-25		
Bobby-Mac			40	7-35
Rearward, Infant				15
Mopar			45	21-50
GM Infant				20
Sears/Rose: Small			48	20-50
Large				45-70
Peterson: Infant			25	6-18
Toddler			35	18-30
Child			40	25-40
Dummy: Infant	1/2	18	27	17.4
Child	3	22	39	32.7

The "shield" type of restraint, characterized by the Mopar Child's Car Seat and the Ford Tot-Guard, presents an additional problem during emergency evacuation. These systems effectively block passage in front of the seat and are so large that they cannot easily be moved out of the way. The rearward-facing infant restraints, such as the GM Infant Safety Carrier and the Peterson infant system, also block passage but can be moved more easily out of the way. The only location in which these devices could be used without blocking passage is in a nonexit window seat. Only the vest-type restraint system did not present an interference problem, but this system presents some difficulty in removing the seatbelt that could impede evacuation of the child and adult companion from the aircraft in an emergency.

Forward rotation of the seat back, while the seat was occupied by an adult dummy, was approximately 60^{o}. This motion is normally provided in an attempt to reduce crash injury to the occupant seated behind. No child restraint tested in this program was designed to retain the seat back, and most systems were labeled to restrict their use to latched or fixed-back seats. Nevertheless, the shield-type restraint systems restricted seat back rotation to about 45^{o}. The effect this would have on injuries to a passenger seated behind the seat holding the restraint system is unknown. Impact of the passenger on the seat back could also increase the likelihood of failure of the child restraint or of the seat assembly.

The child must be protected from seat back loads that could cause injury. Ideally, this protection would be provided while still allowing the seat back to fold as if the seat were occupied by an adult, so as not to compromise the safety of the passenger seated behind. The vest-type restraint system allowed full rotation of the seat back but provided no protection for the child from the seat back. The GM and Peterson infant restraints allowed the seat back to rotate forward properly and provided protection for the child, but the Peterson restraint failed in a manner that could result in injury. The Peterson child system also allowed the seat back to fold, but only because the combined load of the seat back and restraint harness, acting on the shell of the child restraint, caused the shell to fail.

Forward head motion is an indicator of the relative performance of the restraint, inasmuch as a greater displacement indicates less control of the occupant. Only the lap belt, the vest-type restraints, and the Peterson child system (which failed structurally) exceeded 18 in forward head displacement.

A final concern is the labeling provided on the seats by the manufacturers and the necessity of identifying such seats as may be acceptable for civil aviation applications. Most systems contain labels that prohibit their use with unlatched seat backs, in accordance with automotive practice. This would prohibit their use in most aircraft seats if the wording were taken literally. At the other extreme, the Sears/Rose vest systems carry only a label that states they meet all Federal specifications. Obviously, the existing labels cannot be used as an acceptance criteria for application to civil aircraft. If automotive systems are also certified for aircraft applications prior to distribution, they could be placarded to that effect prior to distribution to the public. If systems already in private ownership are to be allowed, a means of notifying the public and the aircraft operators of the acceptable systems should be devised.

CONCLUSIONS

The test program provided a reasonably severe evaluation of child restraint systems. The basic concepts leading to this test program can be incorporated into a test specification to establish a repetitive test method. A uniform test procedure must be established, guidance must be provided regarding allowable locations for child restraint seats in the aircraft, and a means of notifying the public and aircraft operators of the acceptable seats must be devised.

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APPENDIX A

DETAILED TEST RESULTS

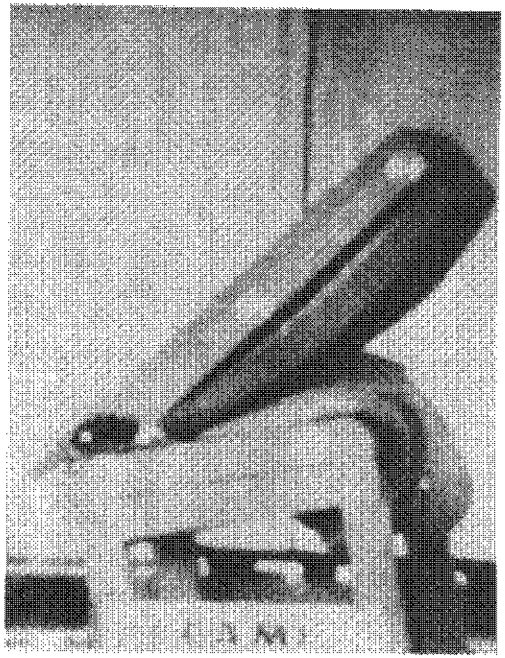


FIGURE A-1. Response to impact.

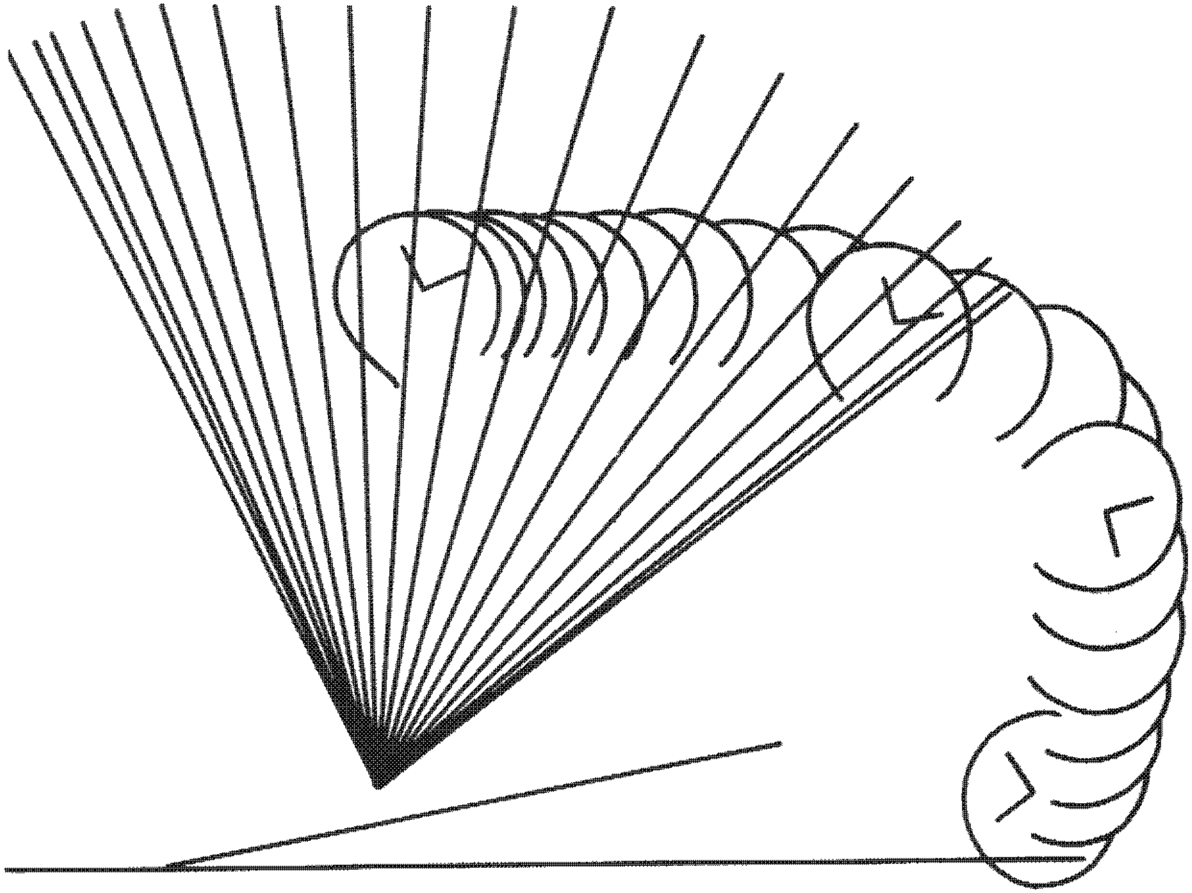


FIGURE A-2. Head displacement of dummy over front of seat cushion.

SYSTEM DESCRIPTION	SYSTEM PERFORMANCE	GENERAL COMMENTS
An infant dummy was restrained by an adult lap belt.	Dynamic test. A lap belt loaded the pelvic area of the dummy. The dummy's body was compressed between the seat back and seat and its head was flexed over the forward edge of the seat cushion. Serious injuries to the system occupant's head or neck could occur, particularly if the front of the bottom edge of the seat was not properly padded. Turbulence test. Failures to restrain the infant dummy were experienced in roll and in rearward pitch tests. The 3-yr-old-child dummy was restrained in all cases.	None.

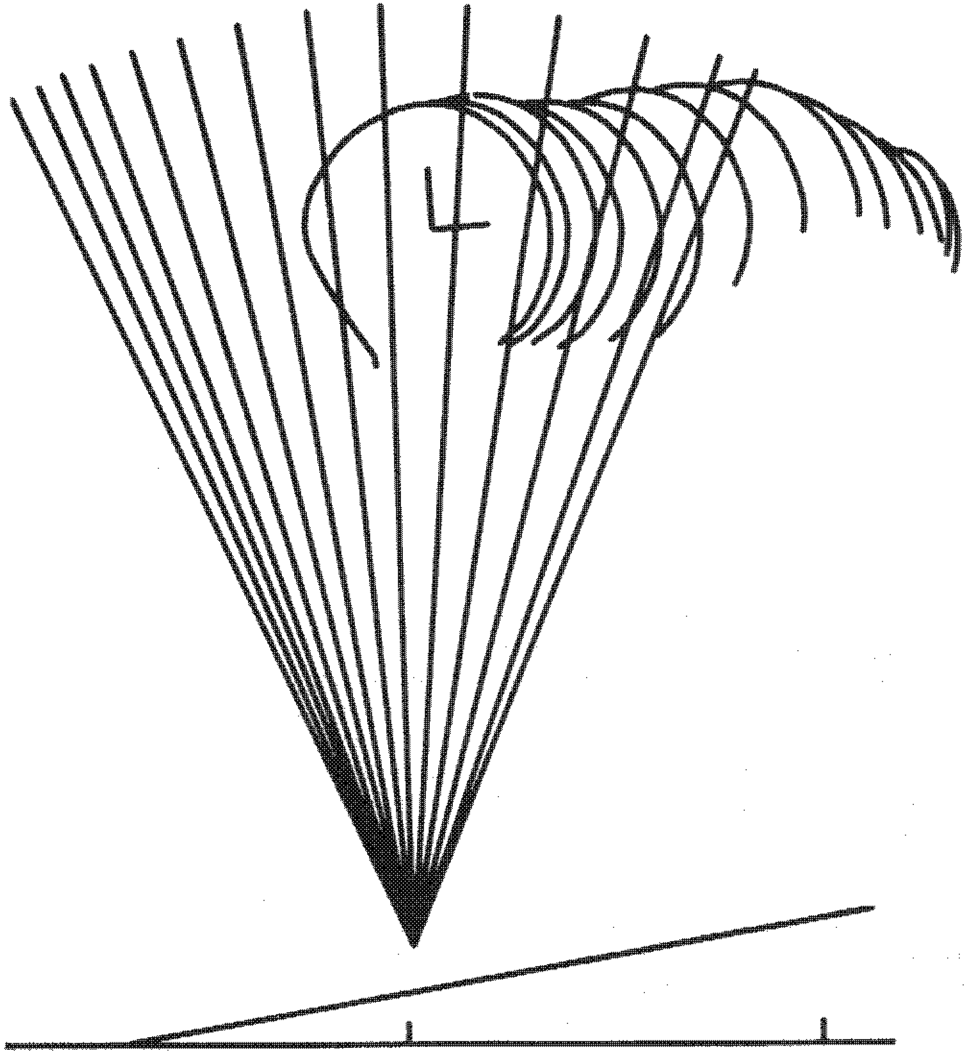


FIGURE A-3. Head displacement and seat back displacement during dynamic test.

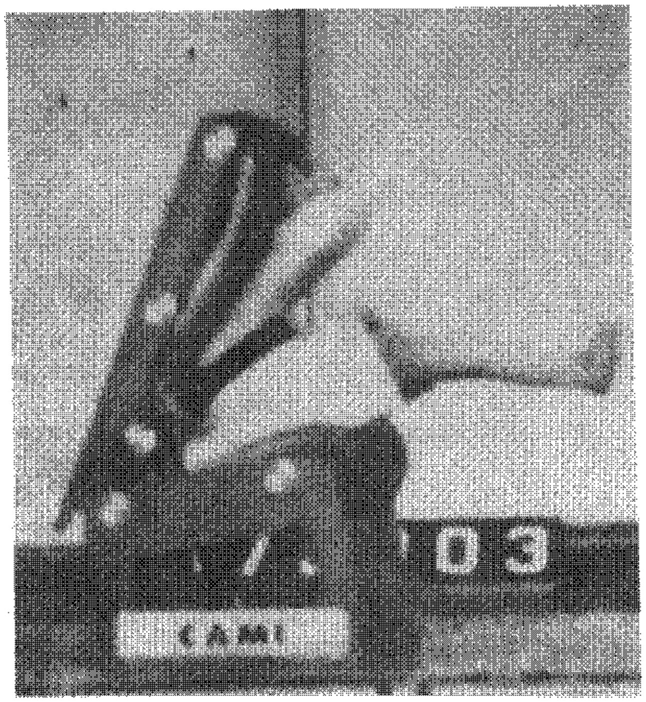


FIGURE A-4. Impact of seat back on child dummy's head during dynamic test.

FORD TOT-GUARD (continued)

SYSTEM DESCRIPTION	SYSTEM PERFORMANCE	GENERAL COMMENTS
The shield device was held in place by the lap belt. The child is seated on a separate plastic spacer behind the shield. No straps are used to hold the child in place. The space behind the shield allows the child some activity. During impact the child contacts the shield and the impact force is distributed over the child's torso and head; support is provided to the head to prevent excessive flexion of the neck.	Dynamic test. The restraint held the child dummy in position with 11.5 in relative head motion. Load distribution over the dummy's body was provided by the shield. The seat back impacted on the dummy's head after the head contacted the shield, so that the seat back inertia load was transmitted through the dummy's head. Lower limbs and torso extended from the restraint. Turbulence test. Failures to restrain the infant dummy were experienced in roll and pitch rearward tests. The separate plastic seat spacer fell out of position.	The restraint could hinder evacuation of other passengers if it were located between them and the aisle.

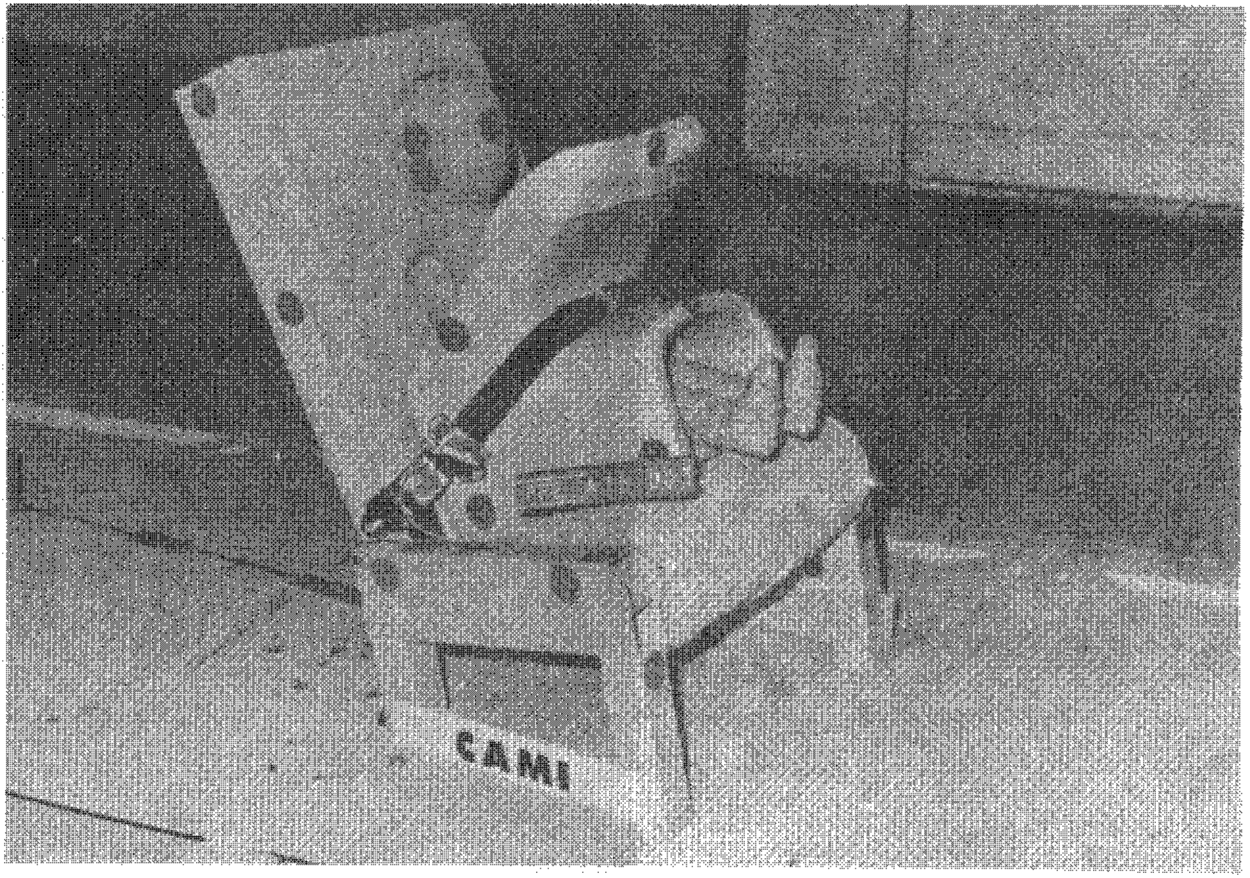


FIGURE A-5. Seat and restraint installation.

FORD TOT-GUARD (continued)

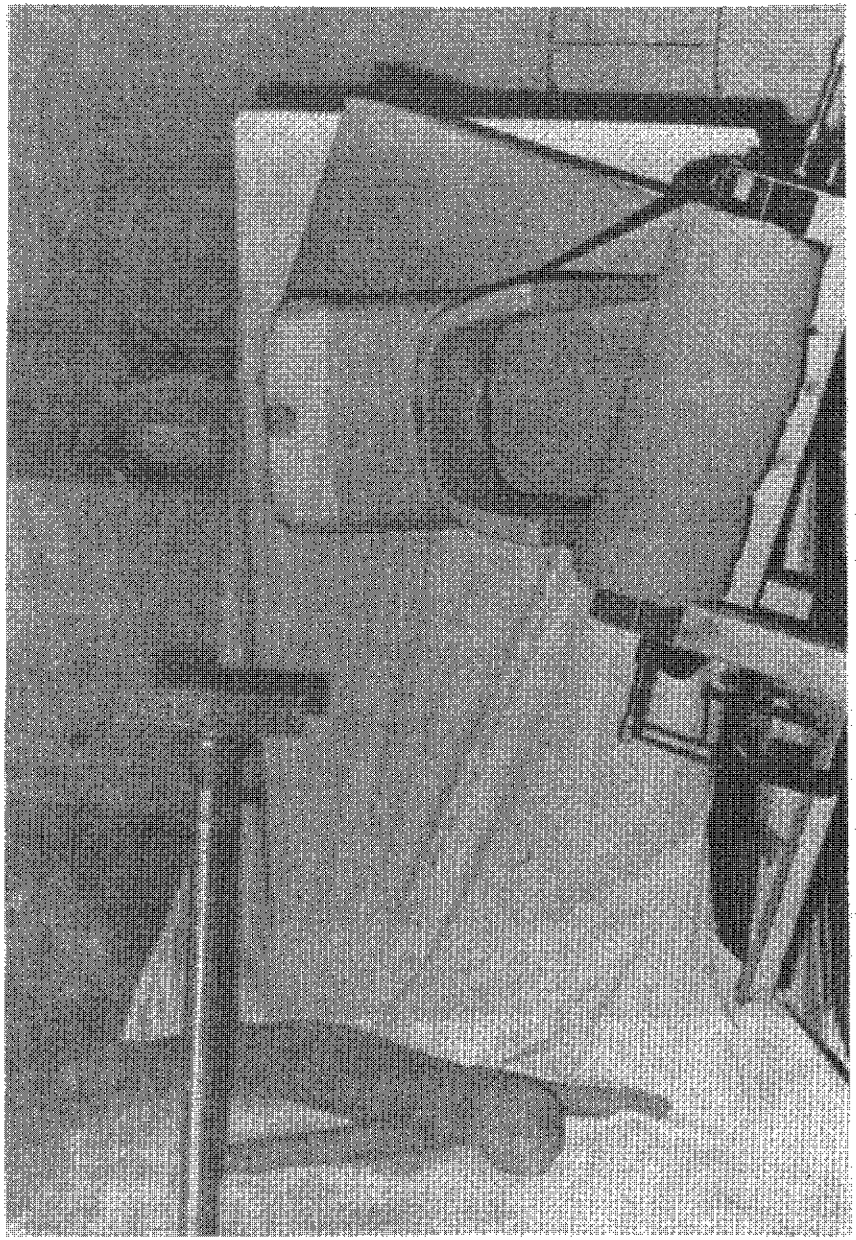


FIGURE A-6. Retention failure in lateral load turbulence simulation.

FORD TOT-GUARD (continued)

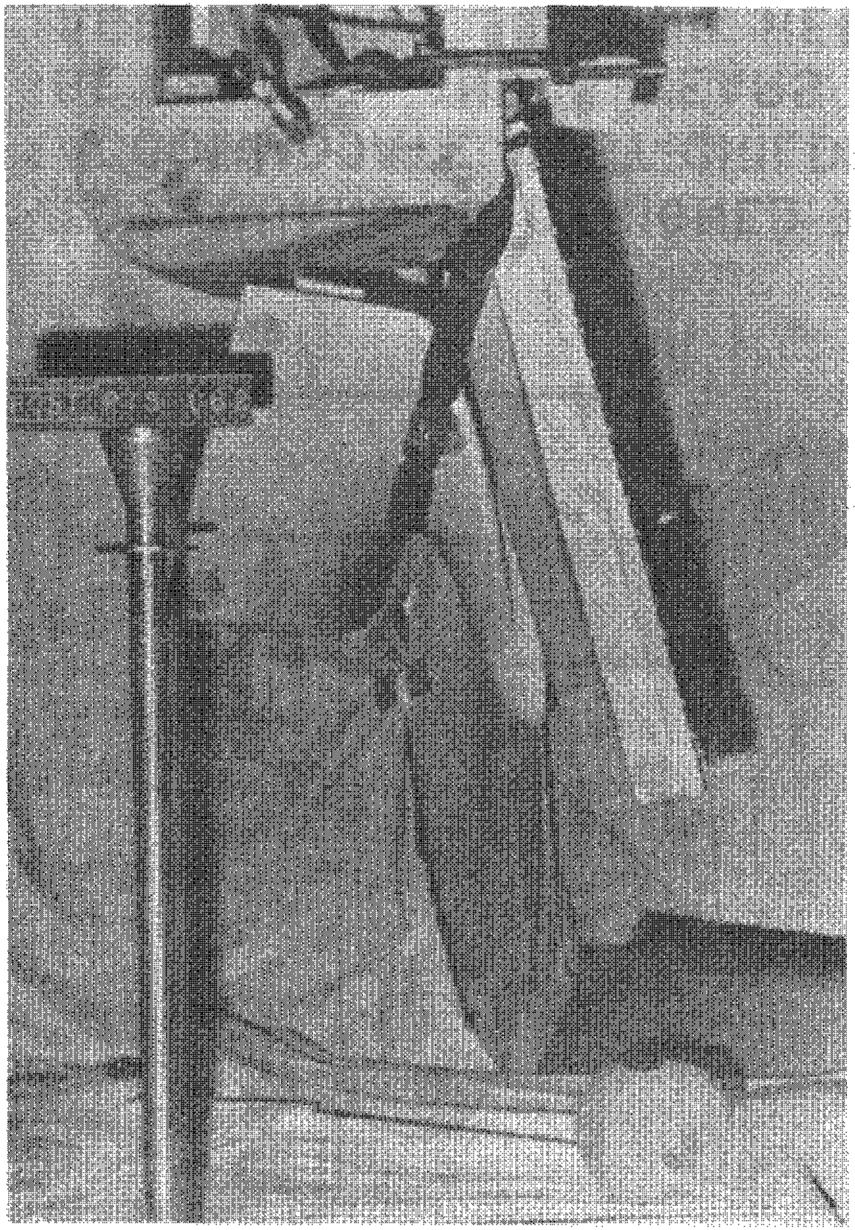
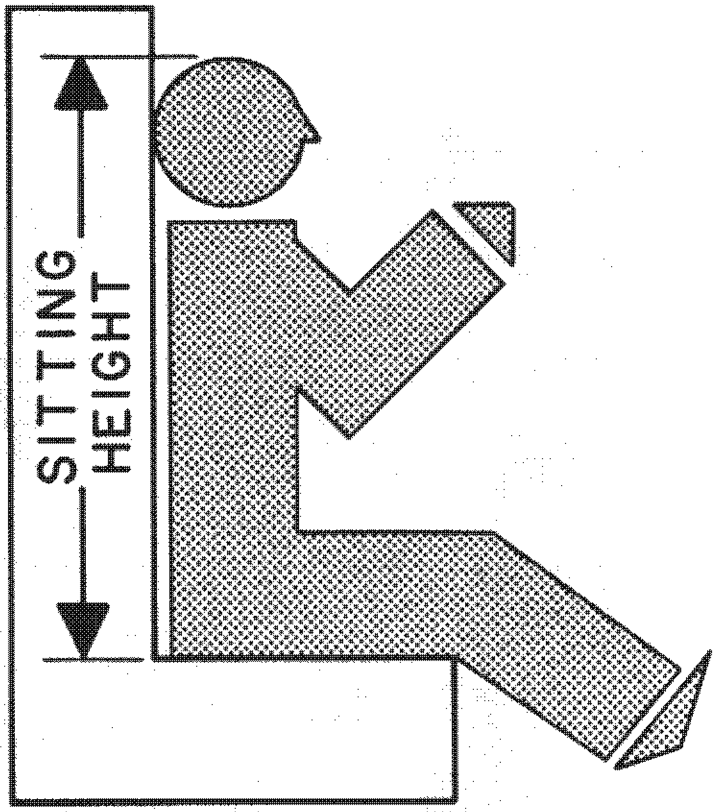


FIGURE A-7. Retention failure in rearward pitch turbulence simulation.



TOT-GUARD IS DESIGNED TO ACCOMMODATE MOST CHILDREN BETWEEN 1 AND 5 YEARS OF AGE, HAVING SEATING HEIGHTS BETWEEN 19 AND 25 INCHES.

FIGURE A-8. Manufacturer's instructions on the restraint system.

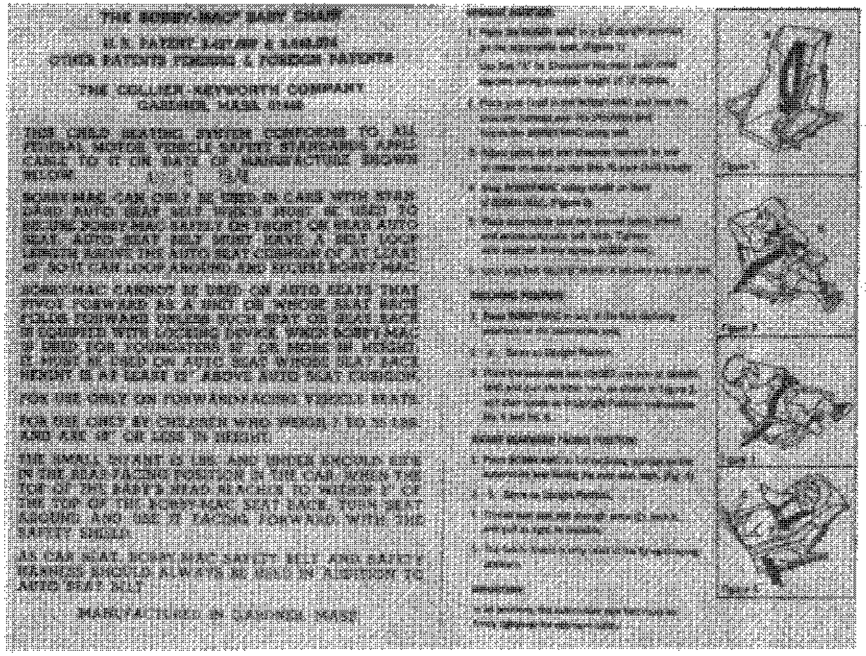


FIGURE A-9. Manufacturer's instructions on the restraint system.

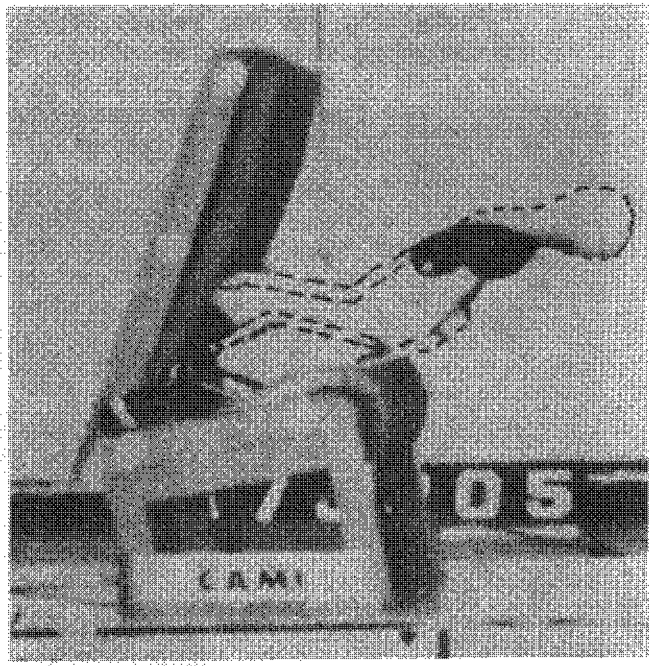


FIGURE A-10. Extension of infant dummy head and neck over the restraint system.

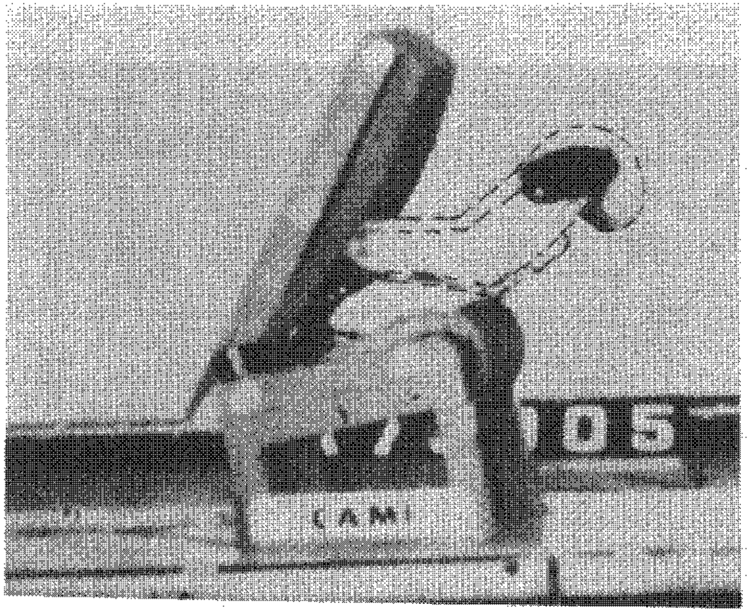


FIGURE A-11. Rotation of the infant dummy head and neck over the restraint system.

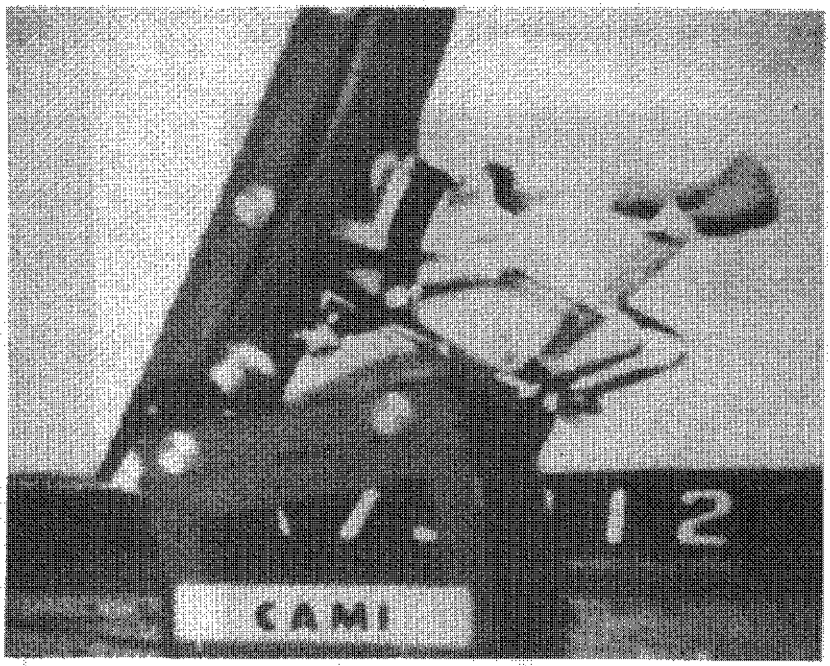


FIGURE A-12. Compression of the head between the restraint system and the seat back.

BOBBY-MAC BABY CHAIR (continued)

SYSTEM DESCRIPTION	SYSTEM PERFORMANCE	GENERAL COMMENTS
The Bobby-Mac Baby Chair consists of an adjustable shell on which the child sits, a removable shield placed in front of the child, and a system of straps that holds the child in position in the shell. This system can be used in a variety of positions and configurations as indicated on the instruction sheet. It was tested in an upright forward-facing configuration, a reclined forward-facing configuration, and a reclined rearward-facing configuration. The rearward-facing position is intended by the manufacturer for children who weigh less than 15 lb and whose heads do not come within 2 in of the top of the seat. An overall limitation of weights between 7 and 35 lb and height of 40 in or less is specified.	Dynamic test. The 6-mo infant dummy exceeded the size indicated for the rearward-facing configuration. The head and neck extended over and around the top of the restraint back during this test (Figures A-10 and A-11). This arrangement would cause serious injury to an occupant. The test of the upright forward-facing configuration resulted in flattening of the dummy's head as it contacted the shield, compressing the thin layer of non-energy-absorbing padding. In the reclined forward-facing configuration, the dummy's head was compressed between the seat back and the shield as the seat back moved forward (Figure A-12). Turbulence test. The system retained the dummy in all tests with proper system installation. Failures occurred when the reclining position was tested with the seatbelt NOT passed under one arm of the system. Although this is an improper installation, it represents an obvious, and therefore probable, installation that can occur in the field.	The limitation for rearward-facing use of this system will severely limit use of that configuration. Seat back height of the restraint is about 15 in, limiting sitting height of the child to about 13 in to provide the recommended clearance. Since an average 1-mo-old infant has a sitting height of about 14 in, the rearward-facing configuration is obviously limited to very small, very young infants. Installation of the restraint system in the reclined configuration is critical relative to passing the lap belt under one arm and over the other arm of the restraint. Since this installation is "unnatural" compared to the obvious installation with the lap belt over both arms, improper installation is expected to be a common occurrence in the field. Adjustment of the lap belt with the restraint in the rearward-facing position was difficult because the centrally located adjustment slide was hidden under the restraint. This arrangement would be expected to result in improper installations in the field.

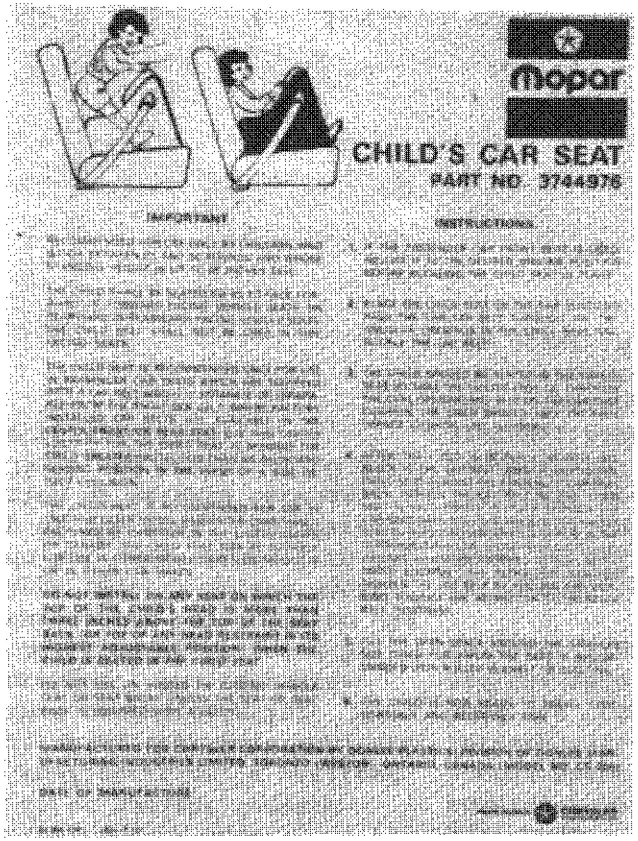


FIGURE A-13. Manufacturer's instructions on the restraint system.

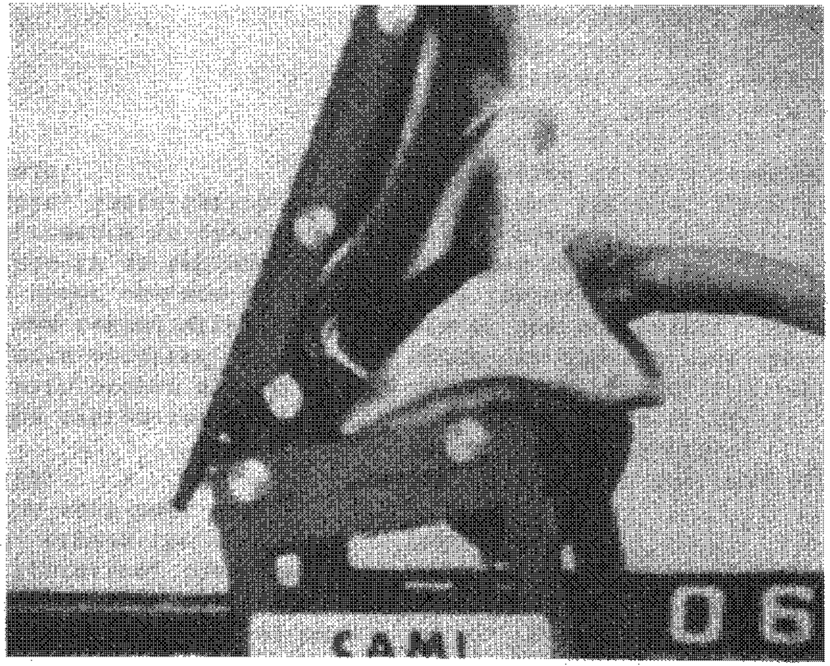


FIGURE A-14. Impact of seat back on dummy's head.

SYSTEM DESCRIPTION	SYSTEM PERFORMANCE	GENERAL COMMENTS
This system is functionally similar to the Ford Tot-Guard except that the seat spacer is integral with the shield.	Dynamic test. Dynamic testing was similar to that used for the Ford Tot-Guard. Head displacement of 13.6 in was experienced. The seat back impacted on the dummy's head. Turbulence test. Failures to restrain the infant dummy were experienced in roll, forward pitch, and rearward pitch tests.	The restraint could hinder evacuation of other passengers if it were located in a center or an aisle seat.

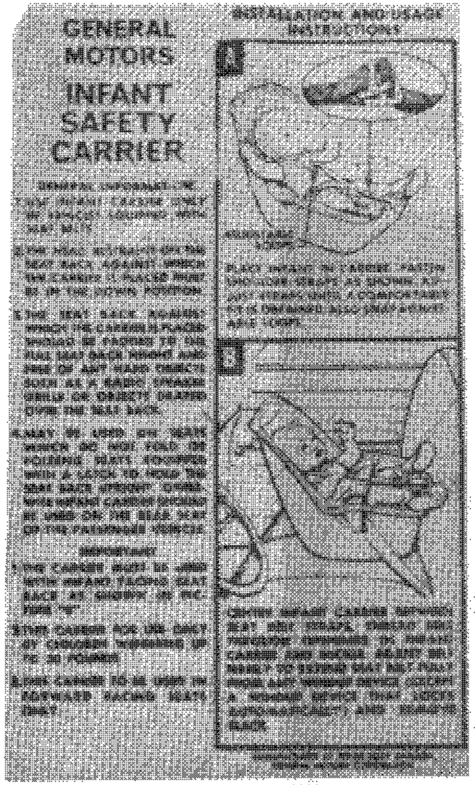


FIGURE A-15. Manufacturer's instructions on the restraint system.

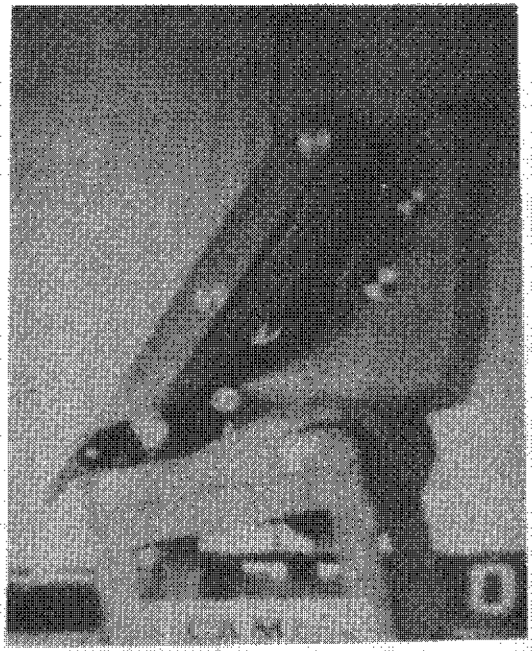


FIGURE A-16. Maximum response during impact.

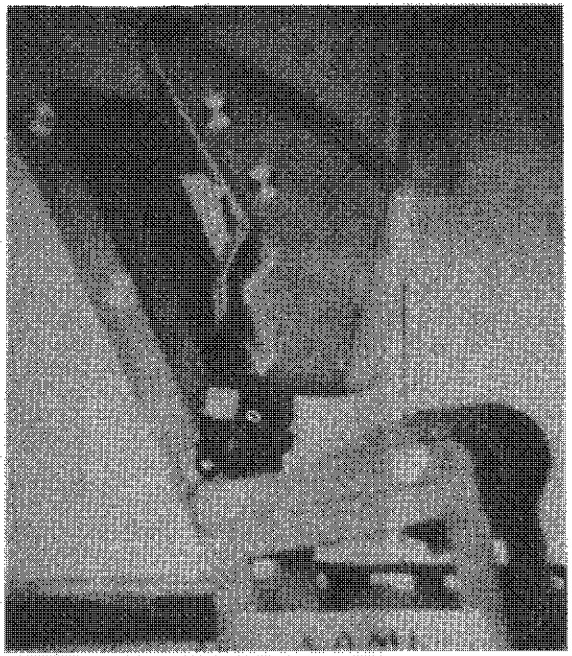


FIGURE A-17. Rebound of restraint after impact.

SYSTEM DESCRIPTION	SYSTEM PERFORMANCE	GENERAL COMMENTS
This system consists of a rearward-facing seat for infants, held in place by an adult lap belt. The infant is positioned in the restraint by web belts that pass over both shoulders and go forward, between the legs.	Dynamic test. The restraint seat, carrying the infant dummy, moved forward during the impact until snubbed by the lap belt. The seat back then moved forward, contacting the sides of the restraint seat and then lightly contacting the infant dummy's head. After the primary impact, the restraint seat rebounded into the adult seat back. Turbulence test. The infant dummy was restrained in all tests.	The restraint system was damaged by the impact forces but remained intact.

SEARS LITTLE RIDER CHILD'S AUTO SAFETY VEST
ROSE MANUFACTURING COMPANY CHILD'S AUTO SAFETY VEST

FIGURE A-18. Manufacturer's instructions on the restraint system.

SEARS LITTLE RIDER
ROSE CHILD'S AUTO SAFETY VEST (continued)

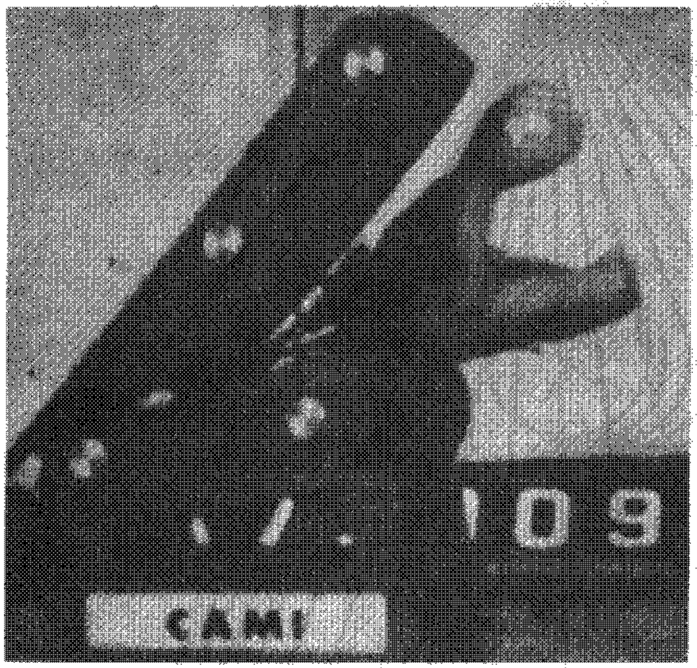


FIGURE A-19. Response of dummy prior to impact by the seatbelt.

FIGURE A-20. Response of dummy after impact by the seatbelt.

SEARS LITTLE RIDER
ROSE CHILD'S AUTO SAFETY VEST (continued)

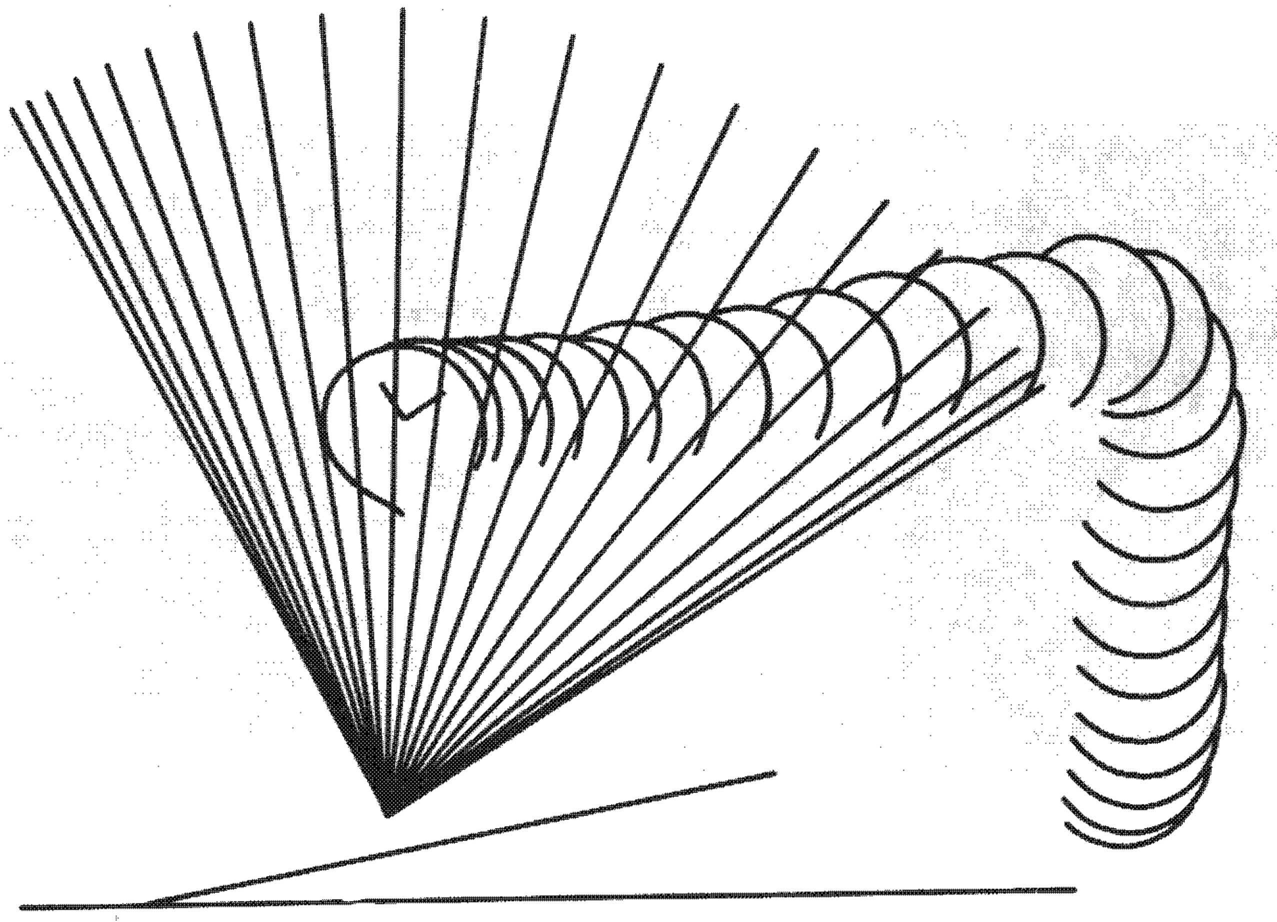


FIGURE A-21. Tracing of head movement showing displacement over the seat cushion.

SEARS LITTLE RIDER
ROSE CHILD'S AUTO SAFETY VEST (continued)

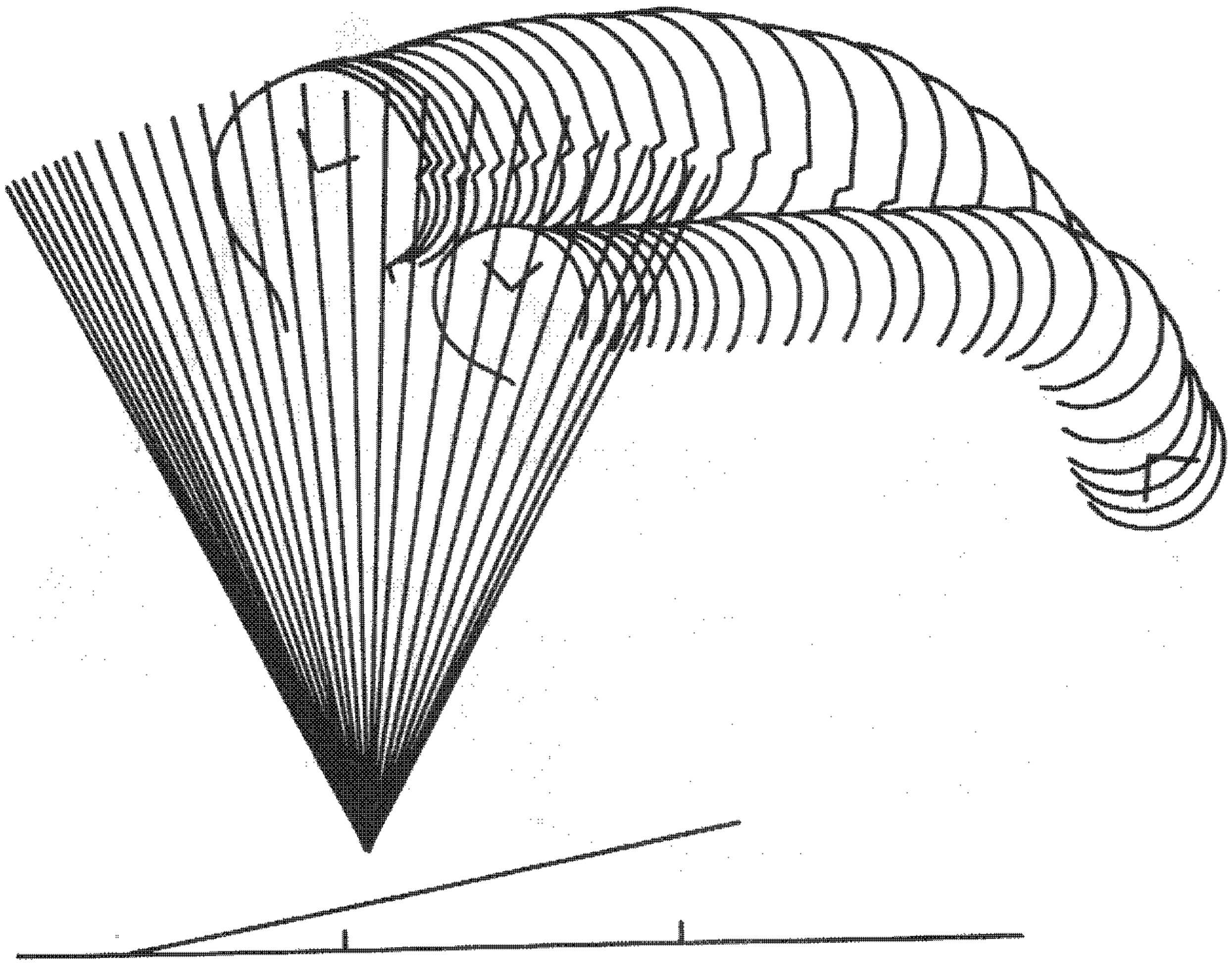


FIGURE A-22. Tracing of head movement of adult dummy holding infant dummy in lap.

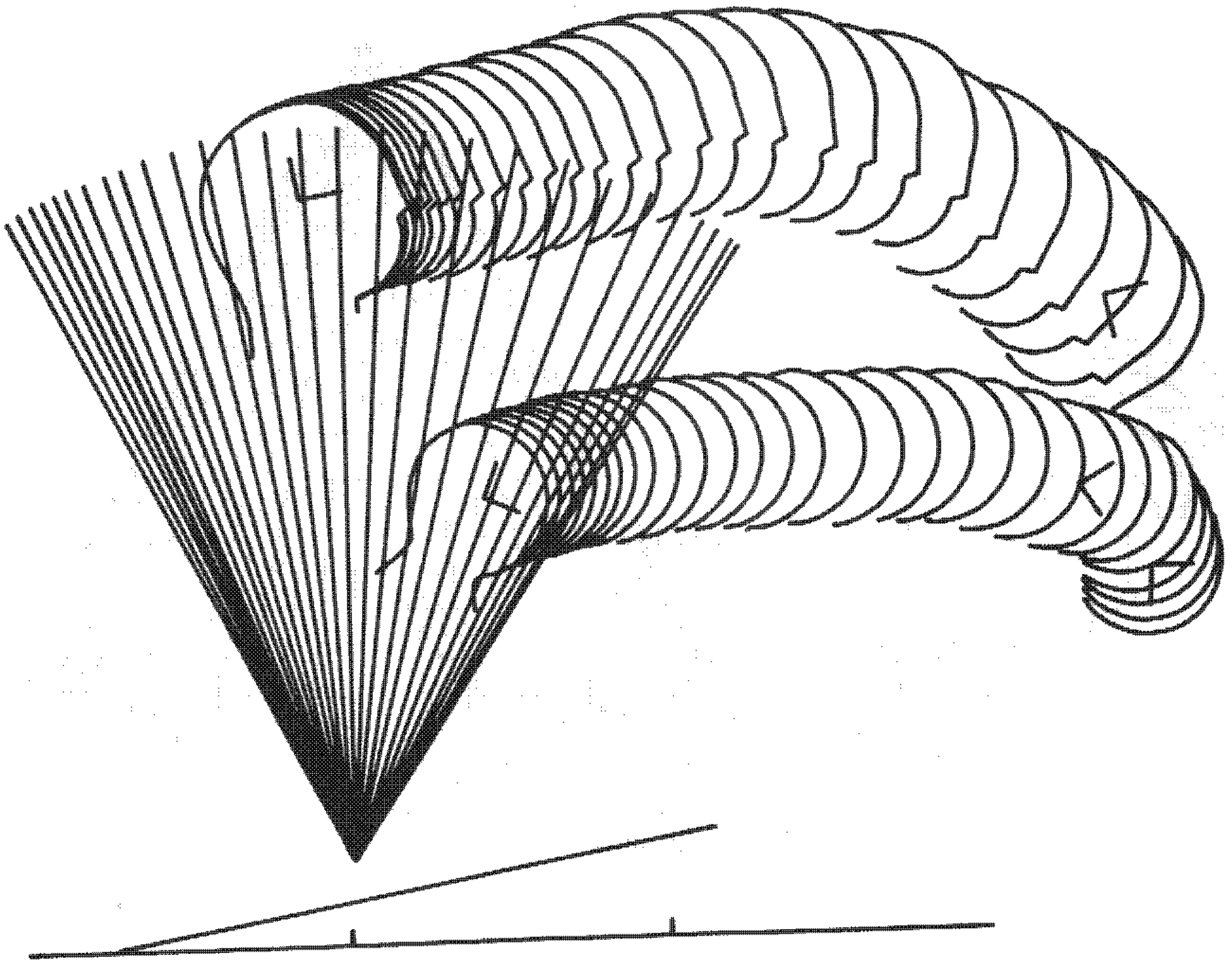


FIGURE A-23. Tracing of head movement of adult dummy with infant dummy seated at side.

SEARS LITTLE RIDER
ROSE CHILD'S AUTO SAFETY VEST (continued)

SYSTEM DESCRIPTION	SYSTEM PERFORMANCE	GENERAL COMMENTS
These restraint systems are of similar configuration, except the Rose system uses 1-in webbing around the body while the Sears system uses 1½-in webbing. The restraint consists of a chest belt and a pelvic belt, separated by a mesh spacer in front and a double-thickness, 2-in vertical strap in back. The chest belt is held in place by 1-in-wide straps over each shoulder. The pelvic belt is located by a 1-in-wide crotch strap. The child is restrained in the vehicle by passing the lap belt around the back strap. Two sizes of restraint systems are available: small for children weighing 20 to 50 lb and large for children weighing 45 to 70 lb. The large size provides approximately 9 in between chest belt and pelvic belt; the small size provides about 7 in (center-line measurements). Although the system should be adjusted to prevent the child from standing, it is possible for the child to lie on the seat while the restraint is applied.	<u>Dynamic test</u>. This system was tested with both the infant and 3-yr-old-child dummies seated upright, with the infant lying on the seat, and with the infant held on the lap of an adult dummy or seated at the side of the adult dummy. Although these last conditions violate the rule of one restraint belt per occupant, they represent a possible field application. In tests using the child or infant dummy alone, the typical response was for the occupant to move forward until snubbed by the restraint, then be impacted on by the seat back, and finally be driven down into the seat with the head flexing forward. This presents a potential for serious head or neck injury, either from impact with the seat back or from flexing and impact with the seat bottom. The exception to this sequence was the case in which the infant dummy was laid on its side on the seat cushion. In this case, the dummy moved in a horizontal arc until caught between the seat back and seat bottom. During the test with the infant dummy seated on the lap of the adult dummy, the adult flexed about the lap belt, over the infant. With the infant dummy seated beside the adult dummy, the infant was generally protected from the seat back by the adult. Additional side loads beyond those present in this test could alter those results. <u>Turbulence test</u>. The system restrained the dummy in all tests.	It was noted during these tests that the mesh front piece flexed away from the dummy torso and thus was not capable of aiding load distribution over the torso. Adjustment of the restraint to the child was difficult and considerable excess strap resulted when the system was fitted to the infant dummy.

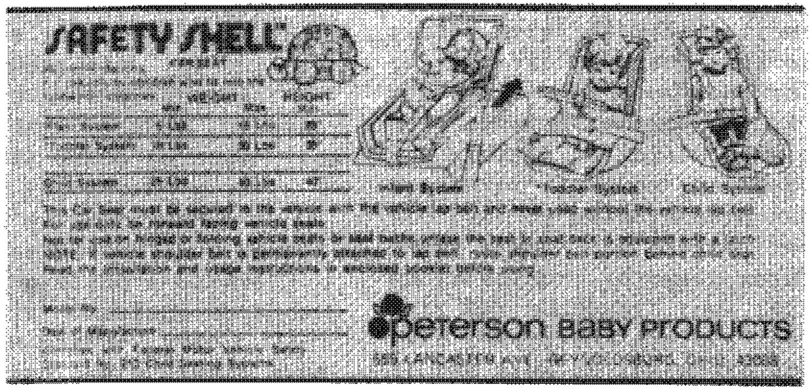


FIGURE A-24. Manufacturer's instructions on the restraint system.

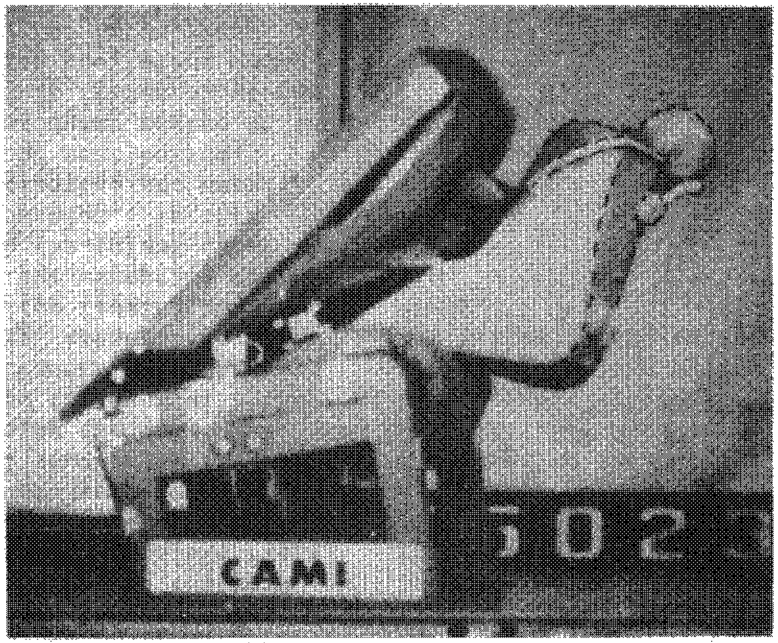


FIGURE A-25. Response of infant restraint configuration to the impact. Dashed lines show an outline of the dummy and restraint system.

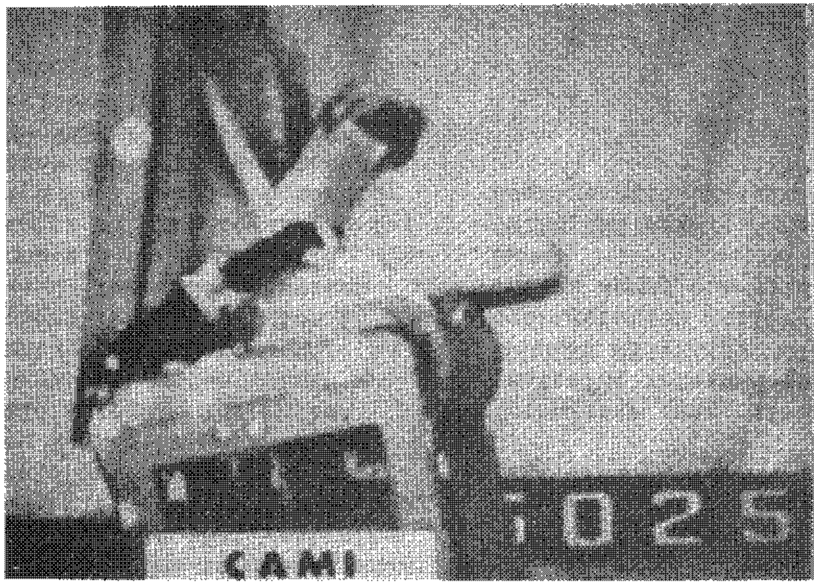


FIGURE A-26. Response of toddler restraint with infant dummy (17.4 lb).

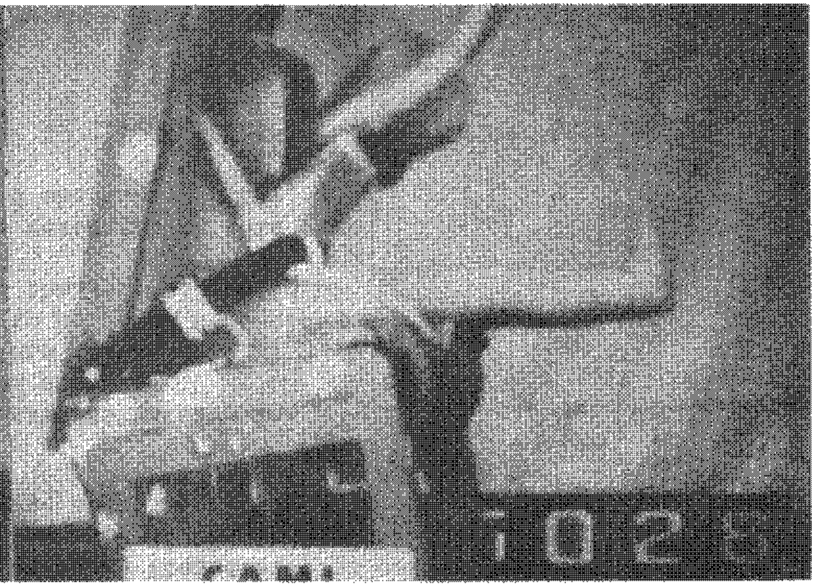


FIGURE A-27. Response of toddler restraint with 3-yr-old-child dummy (32.7 lb).

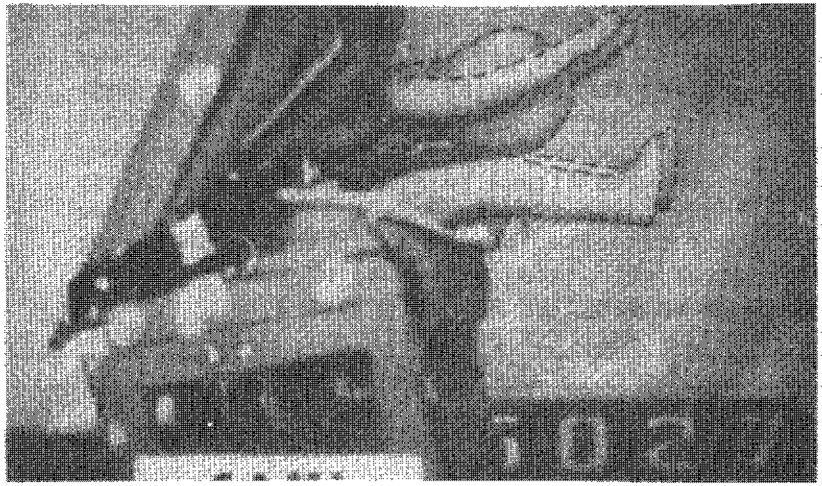


FIGURE A-28. Response of child restraint system.

PETERSON SAFETY SHELL (continued)

SYSTEM DESCRIPTION	SYSTEM PERFORMANCE	GENERAL COMMENTS
This system consists of a basic shell that can be converted by the owner into three restraint configurations: infant, toddler, and child. A "Side Restraint Strap"--provided "to be used only if shell is to be placed next to the side of car"--was not used in these tests. The infant restraint is a rearward-facing shell with a strap system that passes over the shoulders of the supine infant and provides a loop for positioning the adult seatbelt. The toddler system uses a shield that restrains the child and provides a shield retention strap that also passes between the child's legs. The child system uses a restraint harness to hold the child in an upright seated position in the shell. The toddler system accepts a range of child weights between 18 and 30 lb, which fell between 6-mo-old-infant (17.4-lb) and the 3-yr-old-child (32.7-lb) dummy available for test.	Dynamic test. INFANT RESTRAINT: The infant dummy's legs folded over the belt and were trapped by the folding seat back. The shell failed under the dummy's head, allowing its head to move back. The inner plastic liner, the side of the structural shell, and the foot of the structural shell cracked. The loop positioning the seatbelt failed. TODDLER RESTRAINT: The infant dummy loaded the shield with both head and torso. The 3-yr-old-child dummy loaded the shield with torso and lower head/neck. The shield was loose after testing. CHILD RESTRAINT: The restraint back collapsed under loads from the child harness and the seat back. The dummy flexed over the adult seatbelt. Fracture of the back of the restraint system was noted after the test. Turbulence test. INFANT RESTRAINT: The restraint retained the dummy. TODDLER RESTRAINT: This restraint configuration failed to hold the 6-mo-old-infant dummy but held the 3-yr-old-child dummy. CHILD RESTRAINT: The restraint in this configuration retained the dummy.	Assembly of the system into the three basic configurations is relatively complicated and required frequent and careful reference to the 26-page instruction book provided by the manufacturer, even when assembly was done by an experienced technician. Quality control also varied among the seats obtained for testing; missing snaps were noted on the loop for the infant restraint on one occasion.

*U.S.GPO:1992-661-063/40074