FINAL REPORT ON NHTSA CONTRACT DOT-HS-013-1-180

CHILD RESTRAINT DEVELOPMENT

BY

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September 1972

1. Report No.	2. Government Accession No. PB 214 046/5	3. Recipient's Catalog No.

4. Title and Subtitle	5. Report Date
Child Restraint Development	29 September 1972
	6. Performing Organization Code
7. Author(s) Verne L. Roberts	8. Performing Organization Report No. UM-HSRI-BI-72-1
9. Performing Organization Name and Address Highway Safety Research Institute The University of Michigan Huron Parkway & Baxter Road Ann Arbor, Michigan 48105	10. Work Unit No. 11. Contract or Grant No. DOT-HS-013-1-180
12. Sponsoring Agency Name and Address National Highway Traffic Safety Administration U. S. Department of Transportation Nassif Building Washington, D. C.	13. Type of Report and Period Covered Final Report 1 July 1971 to 28 August 1972 14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract

This report documents the results of a program entitled, "Child Restraint Development". In the course of this program two child seats were designed and constructed which gave superior impact protection over those which are available commercially.

In addition to the development of the child seats, performance standards and a compliance test procedure for the evaluation of child seating systems were developed.

17. Key Words	18. Distribution Statement

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
			$ 5.45

Form DOT F 1700.7 (8-69)

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1.0 INTRODUCTION

Approximately 1,000 children per year under the age of four are killed in automotive accidents (1)* with an even greater number injured. Last year in the City of Detroit alone (2) over 70% of all children injured in traffic accidents of all forms including pedestrians, bicycles and mini-bike operators were passengers in motor vehicles at the time of their injury. Many of these deaths and injuries could have been prevented had the children been wearing a proper restraint system.

The research regarding effective child protection has been underway since the 1950's. Moore et al 3) reported the accident experience of child passengers in auto accidents studied in the ACIR program in 1959. In 1962, Dye (4) reported his experiences in the evaluation of a large series of then available child restraint devices and documented a number of criteria which should be applied in the evaluation of potential child seats or restraints systems. Subsequent to the Dye paper, Aldman (5) reported in 1966 on the development of a rearward facing child seat for use in Swedish automobiles, and Appoldt (6) discussed dynamic tests of child restraint devices manufactured by Rose Manufacturing Company. In addition, Siegel (7) and his coworkers in 1968 related the design of several types of child seats to the types and frequency of injury patterns as found in accident investigations. Based upon accident cases, Siegel recommended the use of lap belts for children over four years of age but recommended special devices for younger children.

Burdie (8) and his coworkers have discussed the anatomy of children with several guidelines for the design and selection of child restraint systems. They suggested that the child's braincase is relatively weaker than that of adults and therefore recommended that head impact tolerances for children be reduced accordingly. This paper by Burdie, as well as other works on the same

*Numbers in parentheses designate References at end of paper subject, points out the danger of a lap belt only restraint used in conjunction with the child due to the lack of development of the iliac crest on the child's pelvis. Because the child's pelvis is incompletely developed relative to the adult pelvis, the iliac crest does not provide the foundation for total body support as is generally given by the larger, more developed bone structure found in the adult. Burdie also suggested that restraint loads be distributed widely over the chest because of the extreme flexibility of the child's thorax and hence the vulnerability of the internal thoracic organs to nonpenetrating compression injuries.

King (9) in 1969 developed a reasonably thorough presentation of child anthropometry which included a set of design criteria. King suggested that for children under 50 pounds a stable support platform be provided for any child restraint device. He noted that extreme motion is undesirable due to the danger of contact with interior vehicle structures, and developed requirements for the distribution of load over wide areas of the body. He pointed out the importance of the location of the child's center of gravity as it would affect the dynamic design of a restraint system. For children weighing more than 50 pounds, it was suggested that a stiff booster cushion coupled with a stable mounting platform and an adult lap belt should provide an acceptable restraint system.

Two papers have resulted from the automotive industry's attempts to design appropriate restraint systems for children. Feles (10) in 1970 discussed the development of the General Motors Infant Carrier, a device which has been widely used and promoted and which was found in our previous study to provide, with current seating designs, the best protection available for infants. The other restraint system developed with the automotive industry, the Ford Tot Guard, was discussed and the basis for its design given in the paper by Head (11) in 1970. Both the General Motors Infant Carrier and the Ford Tot Guard reflect improvements which are possible in child restraints if a carefully conceived program is used to develop and dynamically test the child seating device.

In 1970, we presented the results of our first research series (12) in an SAE paper which documented the limitations and gross design inadequacies of the multitude of child restraint devices and seats which were offered the consumer. At that time performance criteria and design guidelines were proposed in the hope that industry innovation would follow. Subsequent to our paper and the following full report (13) the first motor vehicle safety standard for child seating systems (FMVSS 213) was promulgated by the NHTSA.

The child seating standard which currently exists had the effect of removing the "hook over" and hook under" seats from the marketplace and, in some instances, raising the performance of the seating systems to a 15 to 20 mph frontal barrier equivalent crash. Unfortunately in almost every instance, the intent of the standard, injury reduction at 30 mph was not achieved.

2.0 DESIGN OF CHILD RESTRAINT SYSTEMS

The design of child restraint systems or car seats, as they are commonly called, has not been directed toward crashworthiness but rather toward providing a means of keeping a child confined to a fixed seating position while riding in a motor vehicle. While confinement of the child to a given location is one of necessary requirements of safe seating, it is essential that the child restraint extend its' protection beyond the panic braking level of support provided with most current designs offered the consumer. Experience with a limited number of child seating systems has shown that it is possible to provide the same level of crash protection to the child as is offered his parents.

The restraint systems considered and developed in the course of this program have attempted to provide safe seating for children in the twelve-month to six-year age range. In addition to providing crashworthiness, the proposed designs are durable, easy to use by the child and his parents, comfortable for the child and yet capable of manufacture using currently available techniques and materials. While the cost of any new design is difficult to forecast with accuracy because of the various types of tooling available to produce the proposed designs as well as the projected quantity to be manufactured, it is believed that production versions of all of the designs can be made available to the consumer at prices which will be competitive with current and proposed seats capable of providing the same crashworthiness.

One of the more stringent requirements placed upon child seating designs arises from the constantly changing anatomical structure of the child as he progresses from the newborn to the seven-year-old who is capable of using the adult restraints with a properly designed booster cushion. For the purposes of this program three stages of development were chosen for consideration: infant, toddler and six-year-old child. For the purposes of this program the infant was defined as a child from birth to age twelve months. At twelve months most children can sit erect and are ready to ride in the normal seated position. A toddler is defined as a child from twelve to forty-eight months and is capable of using a child restraint which may incorporate webbing or a crash pad restraint. The six-year-old is chosen as the mean of the age range from five to seven.

2.1 Infant Restraint

Proper restraint of an infant from the time of birth to twelve months poses a significant challenge to the restraint designer who is accustomed to the adult skeleton with its' fixed anatomy and fully calcified tissues. The infant presents a picture of an enlarged head and abdomen in relationship to the rest of his torso with no effective means of grasping or otherwise restraining the child against the high accelerative loads imposed by a crash.

Because of the lack of a firm skeletal structure, the infant restraint must rely upon the use of broad flat surfaces which will not apply localized loads to the body during a crash. In the only device available to the consumer today which successfully incorporates this philosophy, the General Motors Corporation Infant Carrier, the child rides in a rearward facing position with a system of straps used to provide positioning and not restraint. The G.M. Infant Carrier or a device similar in construction provides adequate protection by providing:

(a) Rearward Facing Position

By distributing decelerative forces over the back of the infant for frontal impacts, an infant carrier of the G. M. type uses the least vulnerable body area to distribute the loads for over two-thirds of the potential accidents. This scheme does not require the use of a harness nor does it attempt to restrain the childs head or abdomen in a manner which will provide localized loading or utilize the neck to restrain the head directly.

(b) Broad Flat Sides

In our experience the flat sides of an infant carrier act in a similar manner to the back in terms of their ability to minimize localized loading during lateral impacts. In dynamic tests of the G.M. device the infant simulator is observed to move toward the side a short distance and then load up the carrier as it swings in the direction of impact.

(c) Minimal Harness or Restraint for Positioning Purposes Only

The infant because of his skeletal structure is not amenable to using a system of straps for total restraint. Therefore straps or a harness should only be used to properly position the child within the carrier and to allow some protection in the event of a roll-over. The existing commercial device by utilizing a simple vee set of straps in conjunction with the adult lap belt satisfies this requirement completely.

The G. M. infant carrier was tested with the impact sled during our previous contract FH-11-6962 and found to be totally acceptable in terms of its performance. For this reason we did not attempt during this contract to design an improved device but rather addressed ourselves to the development of an infant simulator fo dynamic testing purposes.

2.1.1 Infant Restraint Performance

Two infant carrier devices were dynamically tested, the G. M. Infant Carrier and the Five Filer Brothers, Inc. car bed. The G. M. Infant Carrier has been found to provide acceptable infant restraint and was chosen to document the comparison between its performance and that of another form of infant restraint, the car bed. Both devices were tested utilizing the infant simulator developed in conjunction with this program. Both were tested at 30 mph, 21.5 peak G in the frontal direction. The pulse shape was trapezoidal and similar in nature to all of the 30 mph frontal impact tests reported in the appendix to this report. The Infant Carrier performed as expected containing the dummy without allowing it to move from the confines of the restraint device.

The second child carrying device selected for testing was a car bed manufactured by the Five Filer Brothers, Inc. of Grove City, Pennsylvania. The car bed which was advertised as being acceptable for use in either the front or rear seat of a vehicle was restrained by means of two metal straps which were intended to hook over the adult seat. When tested in a manner identical to the infant carrier, the entire car bed and child disengaged and flew off the seat. It is obvious that a similar occurrence in a vehicle during an accident could seriously injure a child and possibly adult passengers. While car beds can offer some positive benefits for the consumer, their use should not be encouraged until an appropriate means of restraining both the car bed and its' occupant is devised.

2.2 Toddler Restraint

The largest share of the child seat use and hence potential child exposure occurs with children between the ages of twelve and forty-eight months. The preponderance of devices available to the consumer are intended for this age range and it has received extensive consideration under this contract.

During our previous contract, FH-11-6962, thirty-seven different devices were tested which employed a variety of different design philosophies including seats which hooked over and under the adult car seat. Our experience with the dynamic performance of child seating systems indicated that with the exception of the Ford Tot-Guard and the Sears Safety Harness, there were no seating systems available which came close to providing safe child seating during a crash. With this research program, therefore, the seat designs developed were intended to overcome the deficiencies found with past and current products.

2.2.1 Toddler Seat Design Criteria

The overriding criteria for the child seat designs developed under this program was their crashworthiness. Consistent with the desire for crash protection for the child-equal to or better than that afforded his parents with the current upper torso-lap belt systems now available-was the desire to provide the needed safety along with ease of use and comfort. These factors were combined into the following design criteria.

1. Structural Integrity

The child seat should not collapse in an uncontrolled manner,i.e. in such a manner as to allow excessive head motion in addition to the non-productive absorption of energy. Additionally fracture of the various seat components shall not occur if they allow the child to be exposed to potential injury by their failure.

2. Dynamic Interaction with the Adult Seat

The child seating system shall consider the important interface between its structure and the adult seat cushion and back. Past experience has demonstrated the dramatic and often disastrous consequences of localizing the forces between the child and adult seats leading to excessive deformation of the adult seat and increased motion by the child in the direction of impact.

3. Proper Use of the Adult Restraints to Secure the Child Seat

While the adult lap belt is the most substantial structural means available to restrain the child and his seat, care must be taken to insure that adult restraints are used to retain the child seat only and that they not wrap around the child and his seat in such a manner as to compress the child between his seat and the adult restraint system.

4. Load Distribution

Because of the decreased stiffness of the child's skeletal system and the underdeveloped nature of his pelvic structure proper load distribution is critical. Generally the statement can be made that the broader the area through which loads are applied the more acceptable the design. The use of broad surfaces however must be consistent with the child's size,i.e. a three-inch wide lap belt would be unsuitable.

5. Limitation of Body Motions

Our knowledge of child tolerance to impact forces is minimal, however an acceptable and conservative design criteria is the limitation of head motion to the point that it does not strike any vehicle interior structure.

6. Comfort

Comfort is a nondefinable term somewhat similar to beauty. However, certain factors such as the use of padding where appropriate to minimize localized ischemia under the ischia tuberosities is clearly indicated. Additionally the design of a seat to allow the child to sleep, or at least not to inhibit sleep, is also preferable. A design should also consider the element of parental use and attempt to provide for ease of inserting and extracating the child from the device at the beginning and end of each journey.

7. Useability

Any device intended for use by children should incorporate materials which will not be easily soiled and can be cleaned if necessary. Cracks and crevices which can contain food particles, spilled liquids etc. should be eliminated when possible to prevent bacterial growth and allow personal hygiene.

8. Cost

Since cost may be an unfortunate but significant factor to the consumer when selecting a child restraint, any design must attempt to provide the maximum safety consistent with a competitive price. The world's safest car seat design if it cannot be sold will not improve the overall safety picture for child passengers in motor vehicles. At the same time cost-cutting if carried to the extreme can strip a safe design of its benefits. Thus close interaction between the design engineer and the manufacturing engineer during the design phase is essential.

The above eight criteria could probably be restated in a similar manner for any product, however, in the above form they were an essential part of our design process for the various designs and ultimate seats which were developed under this program.

2.2.2 Preliminary Designs

Three child restraint concepts for toddlers were developed for presentation to the Contract Technical Monitor as indicated by the statement of work. The first concept, a child harness, is shown in Figure 1. The harness would use toggle strap attachments to the lap belt hardware, thus minimizing the need for supplemental straps and hardware associated with many harness designs. The harness when properly installed would not allow the child to stand erect but would provide for a reclining position for sleeping and resting.

The restraint loads were intended to be transferred to the child's torso by means of the vest and reinforcing straps. The adjustable straps which connected the harness to the lap belt were intended to be affixed at the center of gravity for the three-year-old child to minimize the possibility of the lower strap ropeing and pressing into the abdomen.

The second concept proposed involved a modification of the Tot-Guard. A concept drawing is shown in Figure 2. The primary difference is the elevation of the sides of the Tot-Guard to pick up the head and shoulders of the occupant. Our previous research indicated that the Tot-Guard concept, while being the most effective child restraint tested under conditions of frontal impact, was lacking in lateral protection. Our studies indicated that under conditions involving direct side impact that it would be possible for the child to bend over the low sides with possible injury. By raising the sides of the Tot-Guard it was hoped to minimize head lateral motion as well as eliminate the potential for flank injury.

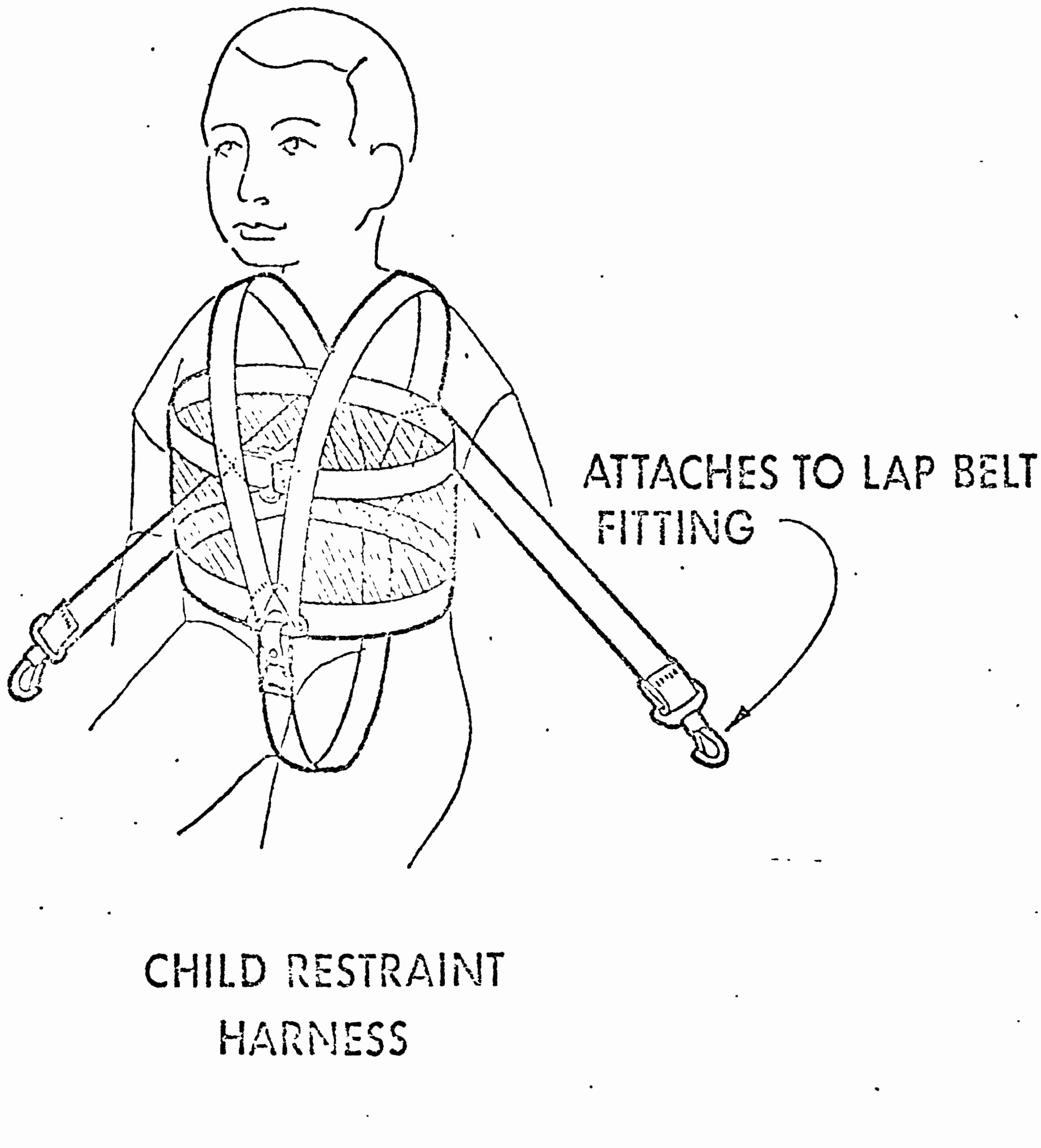

Fig. 1 Proposed Child Harness Concept

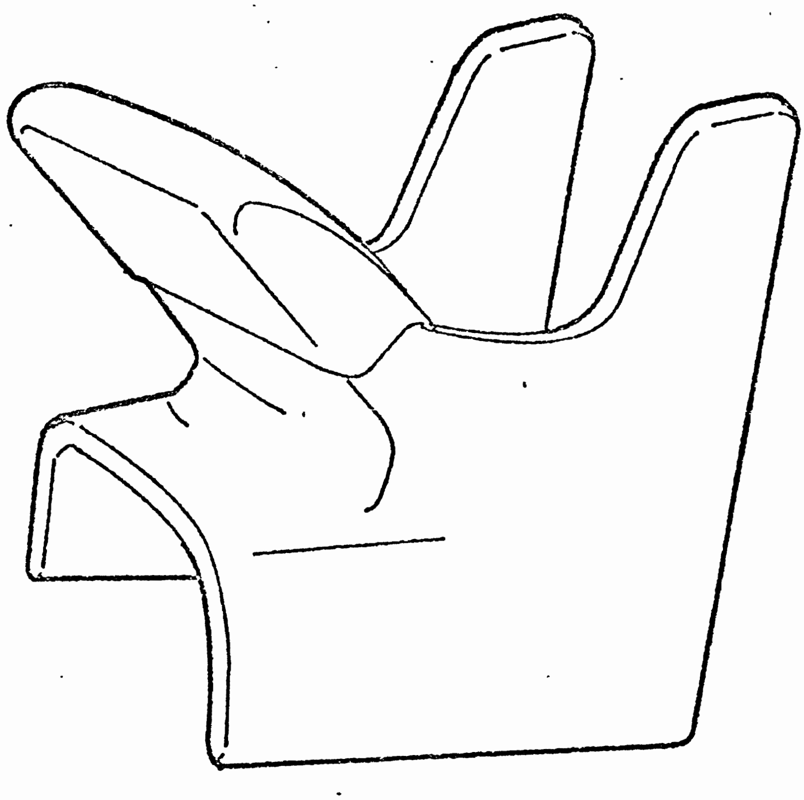

Fig. 2. Child Seat Concept Involving Modification of the Ford Tot Guard

The third concept proposed is shown in Figure 3. This design incorporated a bucket seat with a crash pad similar to the Tot-Guard. The platform area was intended to be rotated forward to allow easy access for the child. Upon the insertion of the child into the bucket area, the platform could be rotated back into position and latched. Subsequent to the latching action an active inflatable cushion could be inflated to provide proper fit and load distribution. The other feature of the seat which was believed to be critical to its performance was the positive mechanical attachment to the adult lap belt. This would be achieved by the use of the slide bar hardware shown in Figure 3. The design was intended to provide good load distribution in the frontal direction with some degree of versitility and fit allowed by the inflatable cushion to provide for different child sizes. The sides are built up and padded to contain the head and shoulders of the child during lateral impact. Additionally, the use of the slide for buckles and the mechanical attachment to the plate on the rear of the design is such that in frontal impact the two halves of the lap belt are placed in tension, while for lateral impact the lap belt half on the side away from the point of impact is placed in tension, thus restraining the entire assembly through its rear plate structure.

In developing these preliminary designs we attempted to provide crash protection for children up through four years of age which was consistent with the design criteria developed previously. The concepts were consistent with our previous research under FH-11-6962 as well as subsequent experience gained in the design and testing of other restrain systems in the interim between the previous and current contracts. These concepts were submitted to the Contract Technical Monitor and after serious discussion were modified to provide the final design configurations.

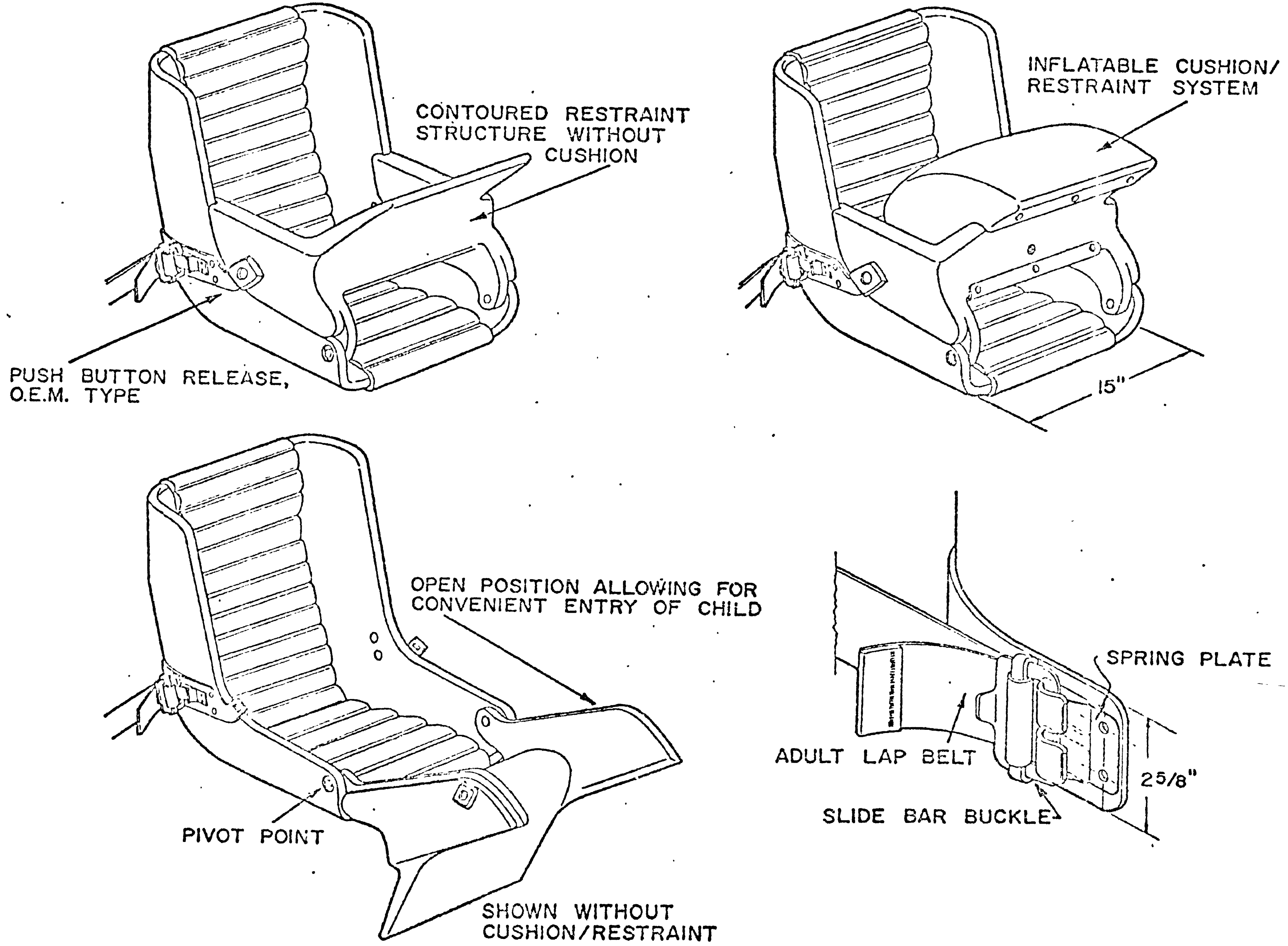

Fig. 3. Child Seat Concept Incorporating an Active Air Cushion Restraint

2.2.3 Final Design Concepts

Two designs were selected for prototype construction and testing, the modified Tot-Guard and the combined bucket-crash pad design (Toddler seat) shown previously in Figure 3. The Tot-Guard was modified by building up the sides and adding padding in the head contact area. Complete drawings of the seat as it was tested were furnished the Contract Technical Monitor with the progress report for June 1972. (Drawing HSRI 100-967-E) A line drawing of the seat and its overall geometry is shown in Figure 4. It is believed that the seat can be fabricated in a variety of means including the rotational casting process currently used for the Tot-Guard. Other possible means of fabrication include blow molding and the use of a two part assembly incorporating injection molding of the components.

The concept which showed the greatest potential for minimizing injury is the concept shown in Figure 5. Following the initial selection of the design, modifications were made in the overall concept to improve its' acceptability and reduce its' cost. These included lowering the crash pad to improve visibility and replacing the active airbag restraint with a multifoam pad to provide load distribution and energy attenuation.

Additionally, the means of securing the crash pad was modified by eliminating the double latching system and going to a belt and buckle combination which latches under the shield. A prototype seat was provided to two Institute employees for use with their children for one week periods. These preliminary field tests indicated that children could unlatch the shield themselves while riding thus negating its effectiveness. By placing the latch assembly under the shield the parent could insert and remove the child easily without the fear of the child letting himself out while riding. The final drawings for the seat were supplied to NHTSA through our progress report for May 1972. (HSRI Drawings 100-948-E, 100-954-E, 100-956-E, 100-962-E, 100-964-E)

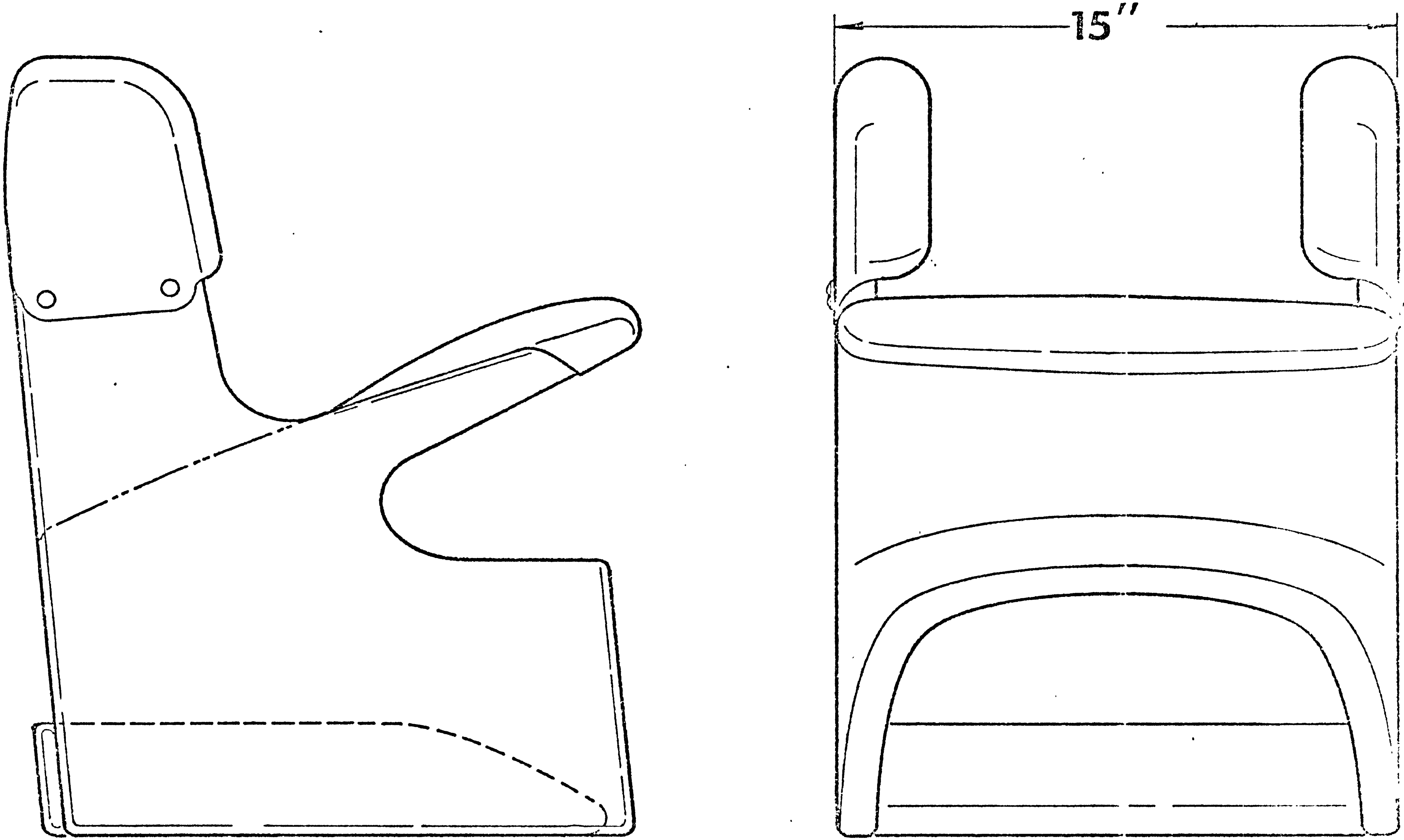

Fig. 4. H.S.R.I. MODIFIED FORD "TOT-GUARD"

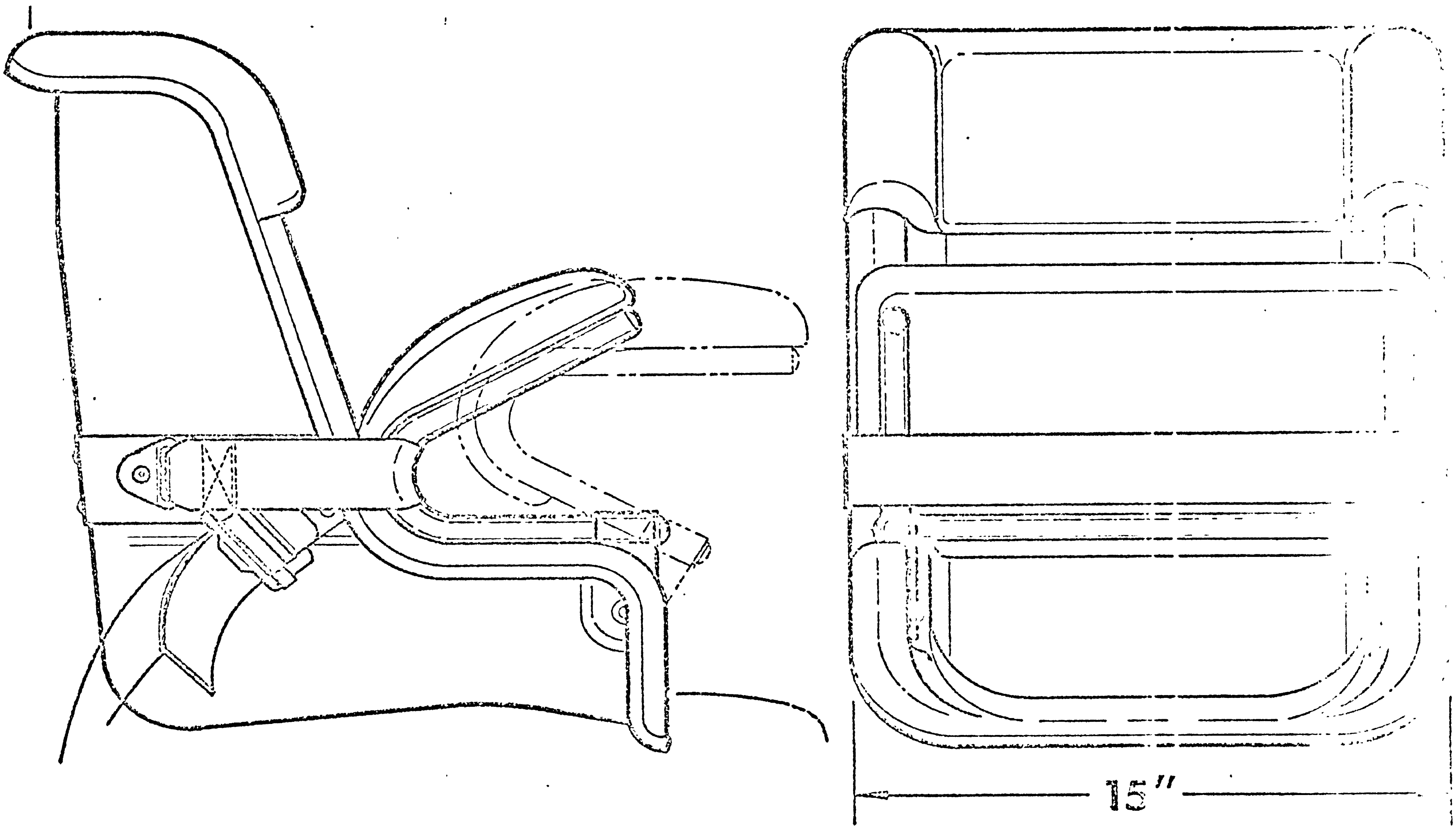

Fig. 5. Final Configuration of HSRI Toddler Seat

The seat does not require unusual manufacturing techniques for either its fabrication or assembly. The shell can be molded using either vacuum form or injection molding of plastic while the metal and foam components are standard stamping or bending procedures.

2.2.4 Dynamic Performance of the Prototype Seats

Both child seats were tested to determine their dynamic performance using the HSRI Impact Sled. Tests were conducted at impact velocities of 20 and 30 mph with impact directions from the front, side and rear. The test device used, a Sierra 3-year dummy, was instrumented with two triaxial accelerometer assemblies which were placed in the head and chest of the dummy. The seats were tested in conjunction with a bench seat taken from a full-size Chevrolet with the adult lap belts installed in their proper anchor locations. The electronic and photometric data recorded for each of the tests performed are listed in Table I. For comparative purposes, test results for the Ford Tot-Guard are also displayed.

When we examine the performance offered by the two prototypes, we see that the Toddler seat performs very well in terms of its' ability to limit the motion of the child's head and thus minimize the potential for head contact with the vehicle interior structure. In fact a study of available vehicle interior dimension data indicate that, for frontal impact, no head contact will occur with any vehicle interior. Laterally the seat does not meet our hoped-for design "bogey" of 12 inches, however the performance is significantly improved over any commercially available seat and the availability of the seat shell with its padding in the head impact zone provides and effective means of distributing any force produced by contact with door structures over a broad area. The variation in Head-Left Right values for the two lateral tests indicates the difference in the performance of the two energy absorbing foams which were tried, Ensolite and Scott Impact III. The Ensolite used in the seats was of

Table I. Dynamic Tests of the Prototype Child Seats

	Test No.	Impact Velocity (mph)	Direction	Accelerations*						Displ. (in.)
				Head			Chest			
				H-AP	H-SI	H-LR	C-AP	C-SI	C-LR	
HSRI Toddler	503	20.5	Fwd	75	25	5	27.5	22.7	2.7	10.2
	509	30.3	Fwd	90	30	10	38.8	30	5.1	10.9
	572	31.2	Fwd	60	32	10	32	28	15	14.1
	496	20.5	Side	12.5	30	44	21	16	36	17.7
	569	20.8	Side	12	37	77	15	18	46	18.6
	495	20.7	Rear	24	10	7.5	24	10	3.7	3.4
Modified Tot-Guard	511	30.0	Fwd	75	38.8	12.4	46.5	26.2	10	16.9
	499	19.7	Side	22.5	29	13.5	15	20	47.5	22.3
	516	20.1	Rear	23	12	18	18	14	2.5	4.1
Tot-Guard	483	20	Fwd	52.5	35	7.5	35	21	2.5	17.8
	484	30	Fwd	67.5	39	5	42.5	22.5	5	18.2
	498	20	Side	15	37.5	40	15	20	27.5	22.6
	494	20	Rear	30	20	2.5	30	10	5	4.5

*All accelerometer Data Filtered According to SAE J211 the type AH which a density of 8.5 lb/ft^3 and a maximum resistance of 8 p.s.i. at 25% compression. Scott Impact III is a newly developed foam having a density of 2.7 lb/ft^3 and a maximum resistance of 2.75 p.s.i. at 25% compression. The lower value of 44 g's was achieved with Ensolite and its use for the lateral padding in the head impact area is recommended. Under rear impact the child's weight is applied broadly against the back of the adult seat back and hence the unit pressure is lowered thus minimizing the depression of the seat back.

The effect of the design change in the crash pad is shown in the difference in the head A-P acceleration values for the 30.3 mph (original configuration) and the 31.2 mph (modified version) frontal impact tests. The change in the structure did allow additional head excursion, however, it was still found to be less than 50% of several commercially available child seats.

The modified Tot-Guard performed as expected for the frontal impacts because it was structurally identical to its forebearer. Head displacement for lateral impact was still disappointingly high being identical to the Tot-Guard. The high lateral motion occurred because the entire assembly rotated under the lap belt. Positive benefit was obtained however in that the child can no longer rotate over the low side as with the Tot-Guard and the potential for flank injury was significantly reduced.

The performance of both seats indicates that crashworthy child seating is an achievable reality consistent with current materials and fabrication techniques. It is hoped that the continuing lack of performance evidenced in current child seating concepts can be modified and that these seats can provide by their existence, guidance for a rapid evolution in safe seat design.

2.3 Age Six Child Restraint

While the American public has had a variety of devices offered which have attempted to provide seating for children up to approximately age three, there has been little attempt to provide seating for the child in the size and age range between the car seat and the time that he may properly use the adult seat belt. This phase of this research program addressed itself to providing seating for the child in the three to six year age bracket.

2.3.1. Design Criteria

As with the other elements of this program, crashworthiness must be the primary element in the consideration of a seat's effectiveness. The primary difference between the seat intended only for use by toddlers and the seat for the older child is that of increased size along with the greater assurance for the older child that his skeleton is more completely developed and hence capable of resisting properly applied restraint system loads. As indicated in 2.2.1 the criteria for child restraints may be summarized as:

1. Structural Integrity
2. Proper Dynamic Interaction with the Adult Seat
3. Proper Use of the Adult Restraints to Secure the Child Seat
4. Proper Load Distribution
5. Limitation of Body Motions
6. Comfort
7. Useability
8. Cost

The above criteria were used to develop the restraint system design described in the following section.

2.3.2. Six Year Child Seat Design

A single concept evolved and was carried through to the construction of prototypes and their ultimate dynamic testing. The design, which is shown in Figure 6, was an individual bucket seat incorporating a five-point harness with center release. By age six the child's anatomy has progressed to the point that the one and one-half inch wide belts can provide him with adequate load distribution. Dual over the shoulder upper torso restraint was employed

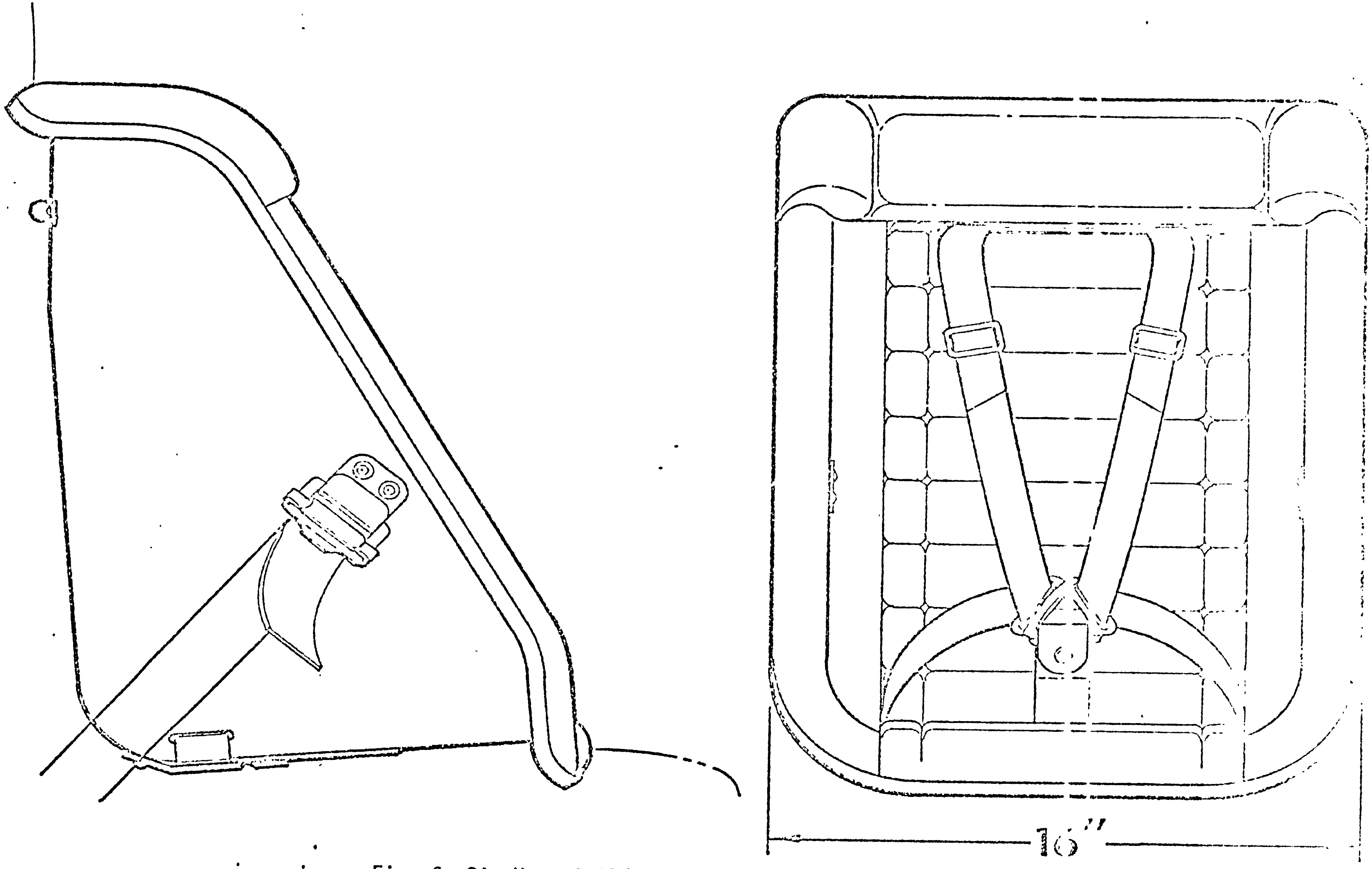

Fig. 6. Six Year Child Seat Prototype

with a crotch strap placed well forward and designed to position the lap belt. The position of the crotch strap was designed in such a manner as to not impinge upon the groin area but only to prevent the upper torso restraints from pulling the lap belt up and into the abdomen.

The seat essentially provides the intermediate age child with his own bucket seat which is to be placed on top of the adult seat. The seat shell incorporates a back plate for strength and positive attachment of the adult lap belt to provide a strong link to the vehicle structure.

This design as well as the others developed for this program does not elevate the child any further than necessary above the adult seat. Our experience has shown that any significant elevation of the child above the adult seat accentuates his motion during impact and degrades the systems crashworthiness. The drawings for this system were furnished with the report for May 1972. (HSRI Drawings 100-952-E, 100-965-E, 100-966-E)

2.3.3 Dynamic Performance of the Six Year Child Restraint

The prototype seats were tested in the same manner as the toddler seats discussed in 2.2.4 with the exception that the Sierra six year crash test dummy was used rather than the three year size dummy used in the other test series. All other test details including the accelerometers, sled pulse; optical instrumentation and electronic and optical data processing remained constant. The test results are shown in Table II. For comparative purposes a Ford Tot-Guard was also tested with the six year old dummy. While the Tot-Guard is not specifically recommended for a child of this size, the 50-pound weight of the test dummy only exceeded the upper limit for the Tot-Guard by five pounds, and thus it was felt would provide a reasonable comparison.

Table II. Dynamic Tests of the Prototype Six Year Seat

Seat	Test No.	Impact Velocity (mph)	Direction	Acceleration*						Displ. (in.)
				Head			Chest			
				H-AP	H-SI	H-LR	C-AP	C-SI	C-LR	
HSRI 6-Yr.	506	21.1	Fwd	32	37.5	2.5	27	19	2.5	13.9
	575	30.5	Fwd	49	70	27.5	37.5	26	7.5	18.7
	503	20.6	Side	10	37.5	10.5	6.2	15	25	21.4
	576	20.2	Side	15	34	90	19	7.5	16.4	21.6
Ford Tot-Guard	505	20	Fwd	20	53	2.5	23	20	2.5	22.8
	514	30	Fwd	35	71.5	5	32	20	4	26.6
	504	20	Side	15	40	14	12.5	12.5	17.5	28

*Filtered According to SAE J211

The performance of the six year child seat was found to be acceptable in terms of its ability to control the motions of the larger dummy in an impact. The only aspect of the design which required modification and re-testing was the high head lateral acceleration was reduced by adding an additional 1/2" of Scott III foam in the head impact area. It is believed that the values recorded would not be observed in tests of production versions of the seat because the rigid fiberglass shell used in the prototype would be replaced in production with a softer plastic shell more capable of deforming upon impact. Additionally the use of an aluminum casting for the dummy head tends to produce higher accelerometer values upon direct impact. This situation is not consistent with human dynamic response and may properly be judged to be a testing artifact. Comparison with the values recorded with the Tot-Guard indicates equal or superior performance particularly in terms of the limitation of head motion.

3.0 DEVELOPMENT OF DYNAMIC COMPLIANCE TEST

3.1 Development of Performance Criteria

One of the most severe tasks associated with the evaluation of a child restraint system is the definition of the performance requirements used in the evaluation. The problem is particularly vexing because a child seat may be used in any vehicle with lap belt restraints to secure it and within those vehicles in any seating position other than the driver's. Over the course of this contract a variety of criteria were conceived, evaluated and accepted or rejected. Acceptance or rejection for the criteria was based upon the ease of measurement, the availability of biomechanical criteria for comparison and the cost to the manufacturer and hence ultimately the consumer involved in providing the data. The first set of performance criteria evaluated consisted of acceleration limits. An approach which is consistent with past and current practices for adult restraint systems.

3.1.1 Discussion of Possible Criteria

3.1.1.1 Acceleration Criteria. Deceleration values sustained during sudden changes in velocity have historically been used to define human tolerance to impact. This practice has some considerable validity when describing adult tolerance because of the availability of volunteer and cadaver data achieved with adults. Only one paper exists in the literature which attempts to describe child tolerance to impact in acceleration values. Snyder (14) in his paper used fall data gathered from children's accidents to develop information for whole body deceleration tolerance. The procedure used however which involves estimation of the stopping distance allowed on impact and subsequent computation of the uniform deceleration values which are predicted to have occurred has not been widely accepted as a valid procedure not does the availability of whole body values provide significant assistance in the problem at hand.

There are two distinct schools of thought about how adult values might be used for the child case with no preponderance of evidence to suggest that one or the other, or for that matter either, is correct. One position taken is that the child is more flexible and hence less prone to injury than the adult with his fully calcified tissues. How much more flexible and thus how much additional acceleration the child can sustain is not known. Another position taken is precisely the opposite in that the increased flexibility of the child is believed to allow greater deformation of the skeleton and hence more damage to the internal organs.

Complicating the entire process of using acceleration values recorded with anthropometric dummies for performance criteria is the construction of the dummy used for the testing. Crash test dummies have been shown to be reasonable indicators of human motion during impact but their kinetic response i.e. acceleration tends to give higher readings than would be sustained by a human. The discrepancy comes about from the difference in construction between the human and dummy which provides a skeleton for the dummy stiffer than its human counterpart. The increased stiffness coupled with a lack of damping in the dummy provide higher peak accelerometer readings which may not be reproducible. Therefore, because of the lack of suitable human tolerance information for children as well as the lack of crash test dummies of the appropriate construction the use of acceleration as the performance criteria for child seats is not recommended at this time.

3.1.1.2 Pressure Criteria. Another mechanical variable which has been proposed as a potential criteria for restraint system performance is the pressure between the child and his restraint system during impact. While there is little doubt that the application of localized force to the human body will cause injury, the difficulty with accepting pressure as the index of performance is similar to that which acceleration namely, how much and how do we measure it?

There is little biomechanical data available regarding the relationship between pressure and injury. Some information does exist relating measure and abdominal injury, Beckman et al. (15). This information however is preliminary in nature and does not address itself to local pressure but rather the average pressure beneath a rigid impactor. The difference between average pressure and local pressure is intensified when one considers the pressures which exist between a flexible surface such as a belt and the abdomen. Merely measuring the area of a belt before a test and dividing the force acting in the belt system during impact by the area will not give any indication of the "true" pressure which exists at the belt-body interface during the test. This situation comes about because of the gradient of pressure which must occur across the belt from side to side and from end to end. It is complicated by the tendency of belts to "rope up" or fold during an impact thus decreasing even further the projected area. The problem is not any easier when a padded surface such as a crash pad is considered because of the constantly changing, and difficult to measure contact patch between the dummy and the device.

Accurate and repeatable measurement of local pressure has only been accomplished by means of a crushable metal foam developed by General Motors which has not been publicly available. Research is now underway to develop pressure measuring systems but until such become available, pressure is not recommended as an appropriate performance criteria.

3.1.1.3 Motion Criteria. A third possibility which has been proposed as a criteria for restraint system performance is that of motion limitaion. Studies of accident data for restrained adult, vehicle occupants suggest very conclusively that if the head does not contact the vehicle interior that head injury does not occur. The British Standards Institute standard (BSI-354 Amend.5) for child seating has incorporated the same philosophy since 1964 by describing the maximum excursion for a torso block during frontal impact. There is nothing in the Biomechanics literature to suggest that this approach is inconsistent with improved crashworthiness. It is believed that performance criteria for child restraints based upon the concept that the child's head shall not strike the vehicle interior can, with the addition of limitations on the area over which the restraining forces are applied, offer easily measured indications of the crashworthiness of a design. Such an approach also negates the need to discuss acceleration related criteria of head impact since presumably it will not be allowed to occur.

Motion limitation is also attractive as a criteria because it requires only a high speed motion picture camera placed perpendicular to the direction with a framing rate sufficient to capture the event.

3.1.1.4 Proposed Performance Criteria. Based upon the previous discussion of the three alternatives available as performance criteria, it is believed that criteria based upon the motion in the direction of impact should be selected as the criteria used to discriminate between crashworthy and non-crashworthy child car seats. The test device used would be the three and six year crash test dummies currently available (30 and 50 pounds) and the motion referred to should be of a photometric target affixed to the dummies head. For the child restraint intended for infant use, the motion of the head of the infant simulator developed under this contract, also in the direction of impact, should also be used as the measure of performance.

For frontal impact, it is proposed that the displacement of the head in the direction of impact be limited to twenty-two inches (22 in.). The twenty-two inch limitation is feasible as indicated by the results of the tests performed with the prototype seats developed under this contract (see results, pp. 11 and 17) and is less than the distance from the adult seat back to the instrument panel of all cars of current American Manufacture. (1972 Vehicle Data and Code Supplement, Auto. Mfg.Ass.)

For lateral impact, it is proposed that the displacement of the head in the direction of impact also be limited to twenty-two inches (22 in.). Our studies have shown that while lesser excursions are possible that we have not been able to keep the dummies head from moving past the edge of a bucket seat during a 20 mph, 16g impact. Thus, under the best of conditions, some impact of the child's head will occur with a door structure if he is seated immediately adjacent to the impact site. However, if the vehicle in which the child is riding is struck with sufficient force to cause the 20 mph lateral velocity change suggested, intrusion of the door structure into the passenger compartment will undoubtedly occur. Under the preceeding circumstances the child's head will be likely to strike the door structure as it moves toward him and compromises his seating space even if he is allowed minimal head motion. When we consider the reality of impact adjacent to the occupant and his subsequent head impact, the interests of child crashworthiness will probably best be served by limiting the lateral motion of a child seated in the rear center position so that he cannot strike either side structure when the vehicle is in a collision which does not provide for passenger compartment intrusion. The twenty-two inch limitation for lateral motion is such that this will not be possible for the narrowest American five passenger vehicle, the Plymouth Valiant. The Valiant allows 55.5 inches of shoulder room and hence the child occupant should have four to five inches clearance in a properly designed car seat.

For rear impact it is proposed that the motion of the child's head be limited to six inches to the rear under conditions of a 20 mph, 16g change in motion of the occupant compartment. Our results indicate that the motion limitation of six inches is completely feasible with proper seat design and will not allow enough rearward head motion to exceed 45 degrees.

The performance criteria may be summarized as follows:

Forward and Lateral Motion	22 inches
Rearward	6 inches

4.0 DEVELOPMENT OF COMPLIANCE PROCEDURES

As critical as the evaluation of proper, easy to understand and measurable performance criteria is the definition of the means by which child seating systems should be tested to determine whether or not they satisfy the performance criteria. There have been two approaches to compliance testing taken for child seats. One approach as embodied in the current American standard, FMVSS #213, employs a wooden torso block pulled statically with a one thousand pound force. The criteria of failure is the ability of the child restraint to retain the torso block so that it does not move more than twelve inches. This approach is consistent with the standard for child harnesses (Type 3 seat belt) established as SAE J4C in 1955. While the intent of the static standard, to provide a basic minimum level of structural strength and hence crashworthiness, is excellent, the intervening years since its' adoption have produced little in the way of improvement in seating and it has unfortunately resulted in establishing a maximum limit of performance rather than the intended minimum. One of the primary difficulties in the ability of a static force to properly simulate a dynamic event, i.e., a crash, is the steady pull in a constant direction rather than the constantly changing motion of a child in a seat during a crash. An additional problem common to most of the current child seats which the static test does not completely expose is the dynamic interaction which occurs between the child and adult seats which leads to the extreme motion and flailing of the entire assembly as the child seat digs deeply into the adult seat cushion during impact.

Dynamic testing of child seating systems to determine their crashworthiness has been a part of the British Standard since 1964 and has also been adopted by Australia and several other European countries. The dynamic test while not reproducing completely the actual crash of a motor vehicle, such reproduction can only be accomplished through actual crash conditions, does provide a generally more severe testing environment which exposes the seating system to the stresses imposed by impact loading. Dynamic testing throughout the course of our research both in the previous contract and in this program has consistently exposed the lack of safety provided by child seats which appear on the basis of static tests and visual inspection to be adequate to their task. Thus it is our belief that if the true protective nature of a child seating system is to be identified, a dynamic compliance procedure must be adopted.

4.1 General Discussion

Our research indicates that the crashworthiness of a child seat can be determined by three tests with an impact sled. To determine the frontal impact protection offered by a child restraint, a 30 mph impact with a minimum deceleration level of 22g using a crash test dummy as the test subject must be performed. The 30 mph impact level provides the same velocity change at which adult restraint systems are being tested and thus provides a similar test for children as we are providing for their parents.

Lateral impact protection can be demonstrated by a 20 mph velocity impact with a minimum deceleration level of 16g using a crash test dummy as the test subject. While a pure lateral impact test is an approximation of all crashes which involve a motor vehicle struck from the side, it is the potentially most dangerous and has been an adequate indicator a child restraints lateral performance. Tests conducted under contract FH-11-6962 where 45° oblique impacts were performed indicated that those seats which did not offer protection under condition of oblique impact also did not offer protection when tested laterally.

Rear impact protection is potentially the easiest to provide with a child restraint system. Rear impact crashworthiness is effectively demonstrated by examining the performance of child seating systems under conditions of 20 mph velocity impact with a minimum deceleration level of 16g with a crash test dummy as the test subject. Rear impact is not believed to be a serious problem with those seating systems which do not raise the child's head above the level of the adult seat back. For those child seating systems which do elevate the child however, structure must be provided to limit the rearward motion of the head to the point that hyperextention of the child's neck does not occur.

The three tests proposed to define the crashworthiness of a child seating system would be accomplished using an impact sled of either the forward impact, rear impact or rebound type. The compliance rig which is discussed in 5.0 will be used with either a bench or bucket seat from a late model vehicle. The seat mounting and lap belt anchor locations would be at the same geometrical locations as occur within the body of the vehicle whose seat is being used.

The seat tracks should be welded in the midposition to establish the seat and lap belt geometry and the entire assembly bolted to the impact sled moving assembly. When the seat has been installed in accordance with the manufacturers instructions, the child dummy,whose joints are tightened to resist 2g, should be placed in the seat and any harness or restraint straps adjusted.

During the actual test the only electronic montoring necessary would be that of sled velocity. The motion of the child's head should be monitored by the use of a high speed camera placed at a right angle to the test direction with the camera placed at least twenty feet from the impact sled. Data analysis to determine compliance will consist of the establishment of the test velocity and the maximum head excurision of the dummy as defined in 3.1.1.4.

4.2 Definition of the Test Environment

The test environment for a child is determined by the deceleration levels selected for the impact sled. Based upon our previous experience and the measured acceleration levels from full-scale vehicle crash tests, deceleration values of 17g peak for 20 mph side and rear impact combined with a 22g peak for frontal impacts have been selected as appropriate environmental levels for child seat tests. Two basic questions must be answered when defining sled decelerations: What is the best pulse shape? and What is the method of defining the acceptable pulse variation?

While a few impact sleds have a variety of pulse shapes available, two pulses predominate in current practice, the square and the sinusoidal pulse. Neither pulse totally describes a car crash. The sine wave has been generally conceded to be softer than an actual vehicle pulse because of the absence of the spike caused by sheet metal loading and buckling produced by the front end prior to frame collapse,a phenomenon which is associated with 0° Barrier impact. The square wave however,while being the most efficient means of deceleration,is more severe than a car crash with current vehicles. The proposed bumper standards however,in addition to having the effect of minimizing vehicle damage,are also producing stiffer vehicle front end structures and moving crash pulses toward a square or trapezoidal pulse. Thus with the exception of a vehicle manufacturer who choose to develop or market a child restraint device tailored to their vehicles, most child restraints must be used with a variety of vehicle makes and models. For the typical case therefore an impact sled pulse tailored to a more severe case will provide a greater margin of safety for child than that which will understate the intensity of impact.

The parellel problem which was stated previously involves the difficulty of many facilities to modify their deceleration pulse shape at will. In our facility for example the level of the deceleration pulse is accurately controlled and highly variable but the shape is fixed without a significant capital expenditure. The same statement is true to a greater or lessor extent at other comparible facilities. With this thought in mind,it is proposed that the test environment for compliance tests of child restraints be specified in terms of the maximum stopping distance required to decelerate the moving sled through the proposed velocity changes of 20 and 30 mph. This approach is consistent with the B.S.I. standard. The British standard only specifies the stopping distance for the sled and does not attempt to define a pulse. By specifying these limited variables of velocity and stopping distance, each manufacturer is free to use any mechanism or deceleration pulse to decelerate the impact sled, test fixture and child restraint. The B.S.I. standard, which specifies a maximum distance which is allowed to bring the sled to rest, is in effect specifying a minimum deceleration level. The minimum level is the level required to decelerate at a constant rate. For the British standard the minimum level is 15g.

Because of the inherent simplicity of the above approach and the lack of instrumentation required it is proposed that the test environment for a dynamic test of child seat performance be described in terms of a velocity, a stopping distance and an interior geometry. Therefore it is recommended that the environment be:

(1)	30 mph frontal impact-stopping distance.	18 inches maximum
(2)	20 mph side impact-stopping distance.	10 inches maximum
(3)	20 mph rear impact-stopping distance.	10 inches maximum

The stopping distances of eighteen inches is that which is required to decelerate a body at a constant rate of 20g from 30 mph to zero in the case of frontal impact. The stopping distances of ten inches specified for the side and rear impacts is the distance required to decelerate a body at a constant rate of 16g from 20 mph to zero.

4.2.1 Discussion of Test Devices (Dummies)

It is proposed that three different test devices be used to evaluate child seat performance. For infant carriers performance tests a simple test device was developed in conjunction with this program. The device (See Figure 7) is constructed of a soil cloth outer skin filled with a ABS plastic pellets and lead shot mixture to provide the proper weight. (A drawing of the simulator was provided with our progress report for May 1972, HSRI drawing 100-966-D) The dimensions used to construct the device are given in Table III. These dimensions were furnished to the program by NHTSA and represent a compilation of their best available sources.

Table III. 50th Percentile Six Month Child Dimensions

Weight	17.42 lb.
Stature (recumbent crown - sole length)	26.42 in.
Shoulder breadth	7.44 in.
Chest girth (xiphoid)	17.38 in.
Chest breadth	5.42 in.
Waist height (from level of iliac crest)	12.62 in.
Hip breadth (at iliac crest)	4.59 in.
Arm length	11.20 in.
Head circumference	16.98 in.
Sitting height (recumbent crown-rump length)	17.72 in.

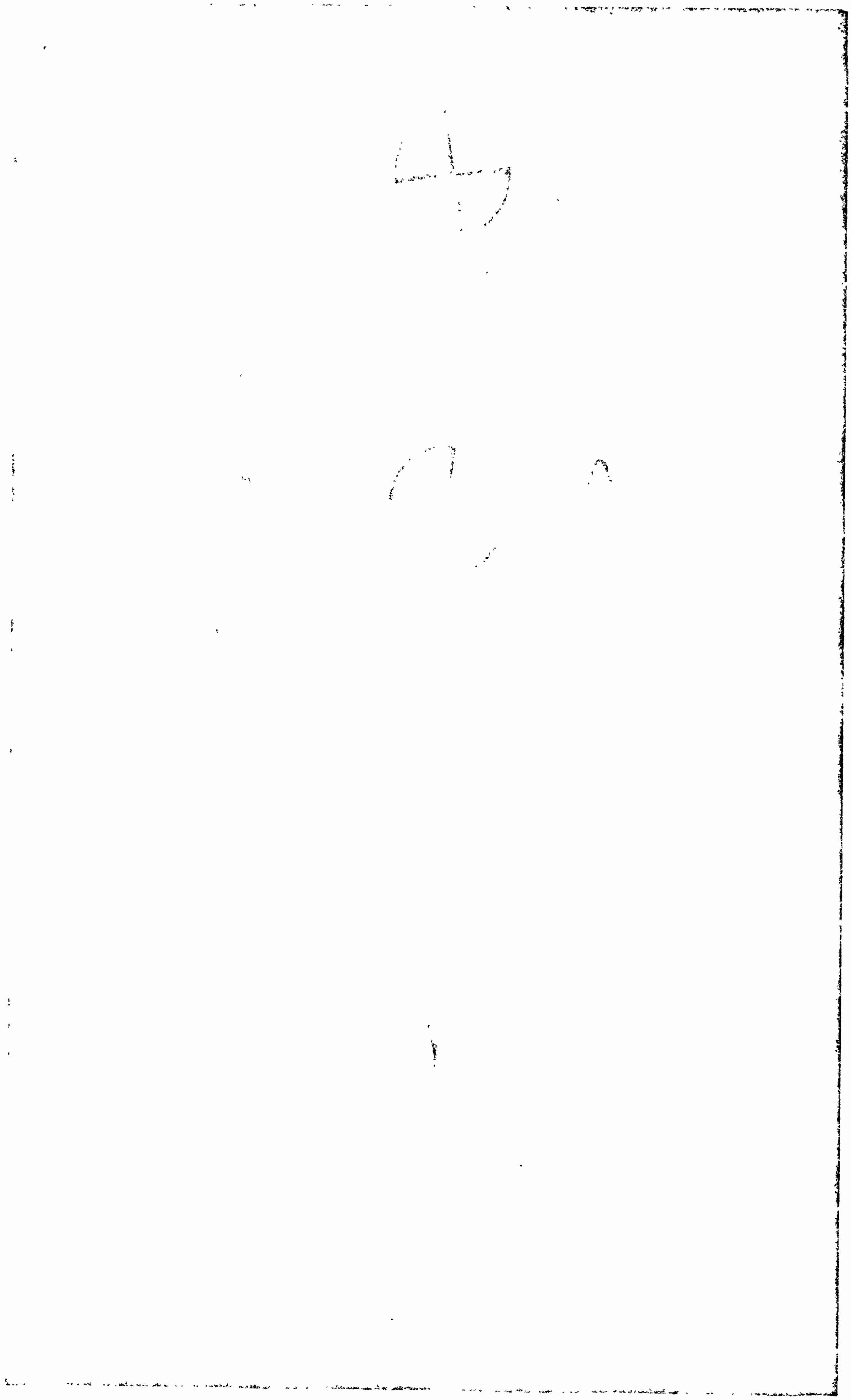

Fig. 7 Six Month Infant Simulator

The simulator has been found to be useful as a means of loading an infant simulator during impact. Because of some lack of fidelity in terms of "joint" placement and construction, it will assume a slightly unnatural seating position under some circumstances however,considering its simplicity and low cost ($50),it is a useful device.

For child seats for larger children, we recommend the use of the thirty and fifty pound Sierra Engineering crash test dummies. These devices are commercially available, rugged in construction and are reasonably accurate representations of the children in these weight ranges. The ongoing research programs funded by NATSA and others will undoubtedly produce in the coming months a more representative set of child size data. As this data becomes available, it is recommended that the NHTSA fund a development program to upgrade the child dummies to make them consistent in construction with the currently available adult crash test devices.

4.2.2 Discussion of Adult Seat

Two compliance fixtures have been proposed as being suitable for providing an easily fabricated and portable test set up. A G. M. bench seat was acquired and the associated body drawings to allow the establishment of the seat and lap belt attachment points in the same position as in a full sized Chevrolet. The choice of the G. M. bench seat was based upon the fact that Chevrolet is the largest selling American automobile and hence its seat would be more widely used. Additionally, the construction of the seat, cast Urethane foam is also used throughout much of the G. M. line of vehicles. The foam seat construction is softer than the spring construction commonly used in the past and as a result provides a more severe case for dynamic testing. This situation arises because of the increased interaction between the child seat and the adult seat during impact particularly for those seats which have a limited bearing area between the child seat assembly and the adult seat. A schematic of the test rig is shown in Figure 8. The drawing of the proposed assembly was furnished with the progress report for December 1971. (HSRI Drawing. 100-959-E)

The bench seat tracks were welded three inches rearward of the most forward position. The test rig was assembled by bolting the bucket seat to the welded framework and attaching the production lap belts to their respective anchors. Additional bracing was added to maintain the seat back positon. The bracing does not affect the performance of the test but does add to the sturdiness of the assembly and allows for repeated use. Child seats were tested in the center and outboard seating positions to determine the effect of seat construction on their performance. The outboard position was found to allow greater motion on the part of the dummy when a Strollee Model 590 was used for comparison. (See Table IV) The outboard position allowed the dummies head to move 29.7 inches in the direction of impact while the middle position only allowed 27.2 inches of motion. The ten percent difference is attributed to the edge effect produced on the outboard position where the volume of the material beneath the child seat is reduced and hence is able to absorb less energy.

The other approach considered for the test rig utilized a similar weldment to that proposed for the bench seat to provide seat track anchor points and lap belt attachments for a bucket seat. While the bucket seat is somewhat stiffer than the bench seat it is a desireable compromise for a test rig because of its smaller size. The use of a bucket seat will allow the moving element 22 x 22 inches while the bench seat will require a moving element 54 x 54 inches. A drawing of the bucket seat compliance fixture was provided with our progress report for May 1972. (HSRI Drawing 100-963) In order to document the effect of the adult seat type on child seat performance, a limited number of seats were tested with both adult seating configurations.

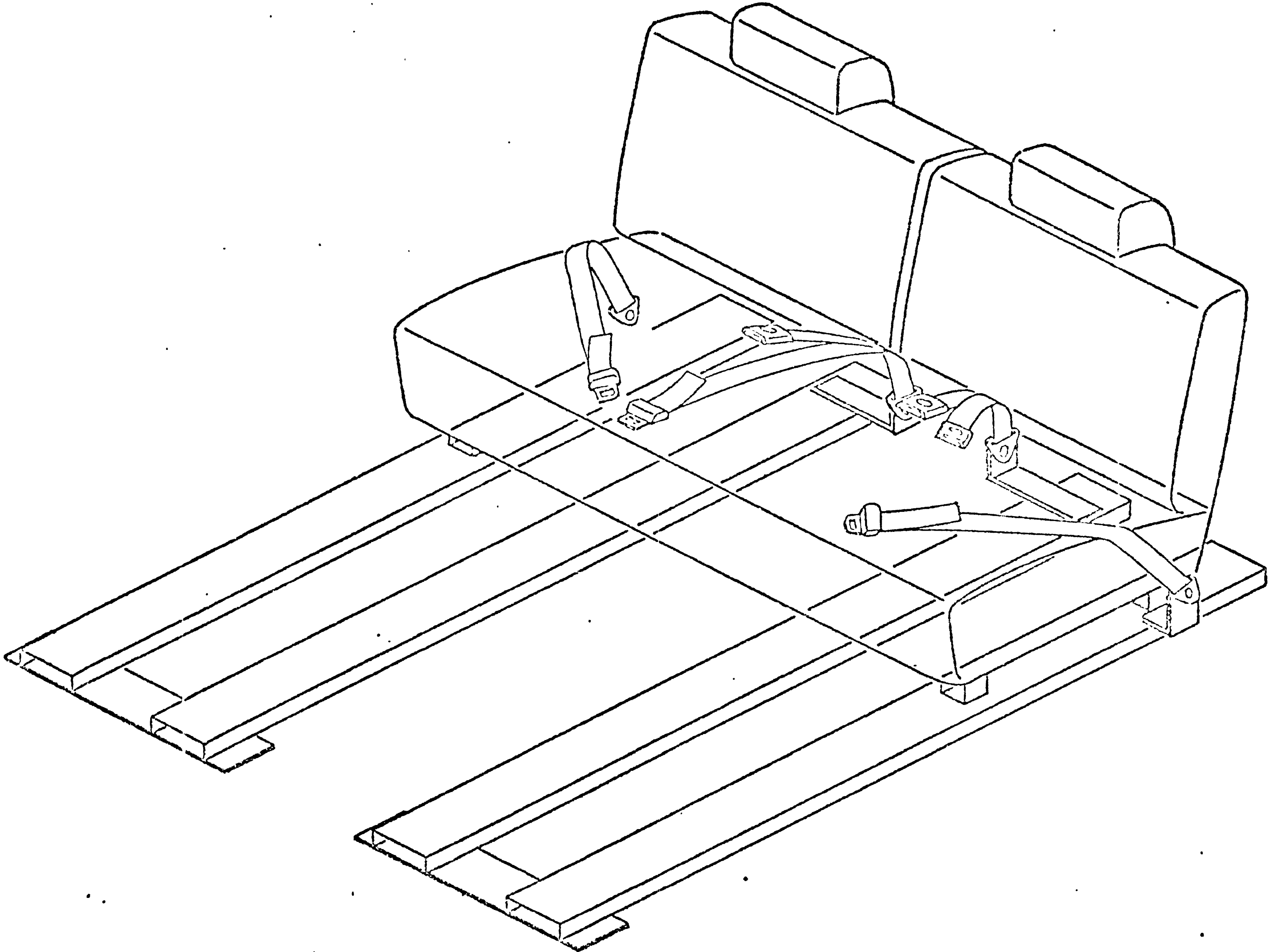

Fig. 7. Schematic of Proposed Compliance Test Fixture for a Bench Seat

In order to provide a comparison a Strolee child seat model #590 and the Peterson Model #68 were tested with the bucket seat under the same test conditions as they had previously been tested with the bench seat. The test results are shown below.

Table IV. Child Seat Performance - Bench vs. Bucket Seats

Child Seat	Test No.	Direction	Velocity	Adult Seat	Head Displacement
Strolee 590	486	Front	30 mph	Bench-Center	27.2
Strolee 590	513	Front	30 mph	Bench-Outboard	29.7
Strolee 590	600	Front	30 mph	Bucket	24.8
Strolee 590	500	Side	20 mph	Bench	25.7
Strolee 590	601	Side	20 mph	Bucket	N.A.
Peterson 68	487	Front	30 mph	Bench-Center	28.7
Peterson 68	607	Front	30 mph	Bucket	26.0
Peterson 68	501	Side	20 mph	Bench	25
Peterson 68	606	Side	20 mph	Bucket	19.0

The results indicate that the stiffer construction of the bucket seat as well as the builtup sides on the seat cushion contribute to decreased displacement of the crash test dummy and the child seat assembly. One of the interesting sidelights of the bucket seat test of the Strollee seat was the release during the test of the child's harness assembly by the dummy during the lateral impact test with the bucket seat. As the child test and test dummy moved in the direction of impact, the motion of the test dummy within the restraint was sufficient to unlatch the buckle assembly fastening the lap belt and allow the dummy to swing free. Retention of the dummy was only accomplished by the steel-plastic bar placed around the front of the harness assembly. The buckle was manufactured by Fruhling Products Inc. of Pasendena, Ca. and is found on several other child seat models. While this disengagement has only been found in one of our two tests of the child seat, we believe that it could occur in many left side lateral impacts and thus should either be redesigned or not allowed with child restraints. This defect could only have been discovered through a dynamic sled test.

4.2.3 Discussion of Instrumentation

The compliance test procedure as proposed was selected in part on the basis of the limited instrumentation required for test performance. The only electronics instrumentation required will be the devices necessary to determine the sled velocity. Velocity may be determined by means of two magnetic proximity probes a known distance apart along the track of the sled and an electronic counter to measure the time elapsed from one probe to the other. Digital counter with fixed neon display and magnetic proximity probes are amongthe two simplest items of electronic gear possible to perform the compliance tests. The only other form of sophisticated equipment necessary is a high speed camera.

An analysis has been performed in Appendix B which documents the camera speed necessary to adequately monitor the test. On the basis of our analysis it is apparant that a camera with a top speed of 500 frames per second is adequate to the task. By limiting the required camera speed the cost of the optical instrumentation is approximately one half that had 1,000 frames per second been necessary.

4.3 Proposed Compliance Fixture

To summarize our research regarding compliance tests, it is recommended that a welded steel framework (HSRI Drawing 100-959-E) to which a bench seat and lap belt anchor points may be attached in the proper geometrical relationship be used as the compliance test rig. Child restraints should be installed on the rig in accordance with the manufacturers directions and child test dummies of the infant, three-year-child and the six-year-child be used to determine the ability of child seating systems to contain the child during impact. The criteria of compliance should be dummy head displacement in the direction of impact.

5.0 USING PROPOSED DYNAMIC COMPLIANCE TEST

In the course of determining the suitability of the compliance test fixtures developed under this program, several models of currently available child seat designs were dynamically tested. The test conditions were those described in 4.1 and 4.2. Because these seats were tested prior to the complete definition of the performance criteria acceleration values recorded for the head and chest triaxial accelerometers are also recorded. The results are listed in Table V.

The results consistently confirm the belief that while the static test requirements will demonstrate the ability of a child seat's structure to resist fracture that all of the currently available devices fail to adequately retart a child's motion in the direction of impact. It is believed that this situation has occurred because of the lack of understanding of crashworthy design by the manufacturers. It is hoped that a new test requirement as specified in this report will help to provide safe seating for children consistent with the protection available to their parents.

Table V. Child Seat Impact Test Data

Seat	Test No.	Direction	Velocity mph	Sled	H-AP	H-SI	H-LR	Head Displace-ment (in.)	C-AP	C-SI	C-LR
Hamill	479	Front	20 mph	16.5	37.5	57.5	7.5	25.4	32.5	15	5
Protecta-	489	Front	30 mph	23	94	85	12.5	28.4	45	21	8
Tot	497	Side	20 mph	17	20	35	22.5	24.4	10	15	22.5
	490	Rear	20 mph	17	25	20	2.5	4.9	29	19	7.5
	482	Front	20 mph	18	17.5	22.5	2.5	24	20	12.5	2.5
Kantwet	488	Front	30 mph	22	55	47.5	7.5	25.8	25	20	7.5
#78	502	Side	20 mph	17.5	30	42.5	45	23.2	7.5	25	27.5
	493	Rear	20 mph	17	31	24	5	9.5	27.5	25	7
	480	Front	20 mph	16	32.5	40	2.5	19.6	24	12.5	5
Strolee	486	Front	30 mph	23	22.5	57.5	5	27.2	30	25	3
#590	513	Front	30 mph	23.5	29	54	9	29.7	37.5	27.5	9
	500	Side	20 mph	17.5	22.5	24	52.5	25.7	12.5	21	20
	491	Rear	20 mph	17	21	25	2.5	12.7	25	26	4
	481	Front	20 mph	17	19	35	5	27.5	20	12.5	2.5
Peterson	487	Front	30 mph	22	95	102.5	15	28.7	26	25	10
#68	501	Side	20 mph	17	22.5	39	62.5	25	6.5	21	15
	492	Rear	20 mph	17	32.5	27.5	5	10.1	29	17.5	5
	483	Front	20 mph	17.5	52.5	35	7.5	17.8	35	21	2.5
Ford	484	Front	30 mph	22	67.5	39	5	18.2	42.5	22.5	5
Tot-Guard	498	Side	20 mph	17	15	37.5	40	22.6	15	20	27.5
	494	Rear	20 mph	17	30	20	2.5	4.5	30	10	5

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APPENDIX A TEST RESULTS

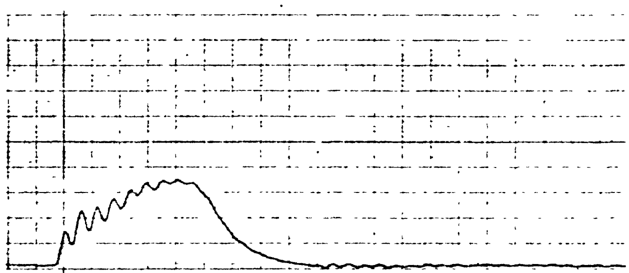
SUMMARY DATA HEAD ACCELERATIONS

Test Number A-479 Test Type HAMILL

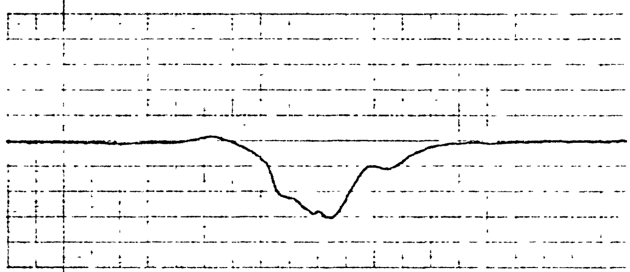
Dummy 3-YEAR PROTECTA-TOT

Sled Velocity 32.0 ft/sec FRONTAL IMPACT

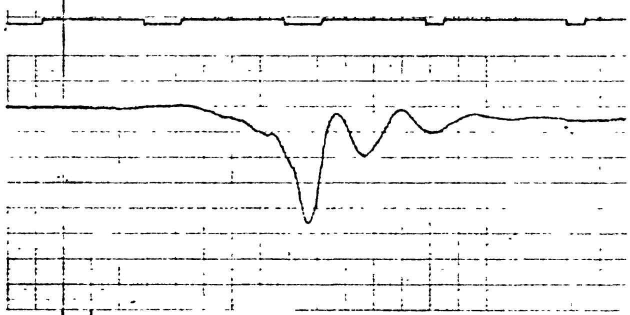
Sled Pulse
5 g's/division
Filtered
Class 60



Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

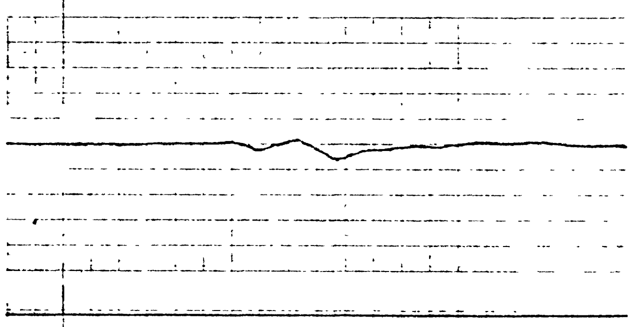


Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

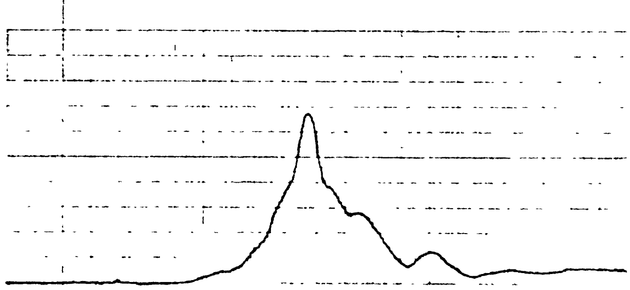


12.5 msec.

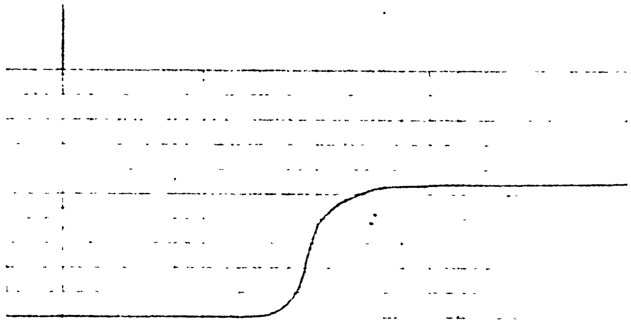
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 $g^{2.5}$ sec/div.



SUMMARY DATA CHEST ACCELERATIONS

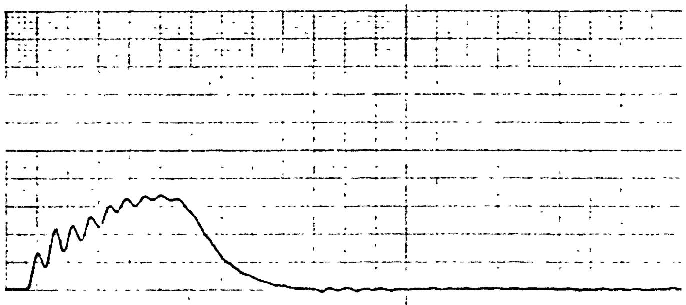
Test Number A-479

Dummy 3-YEAR

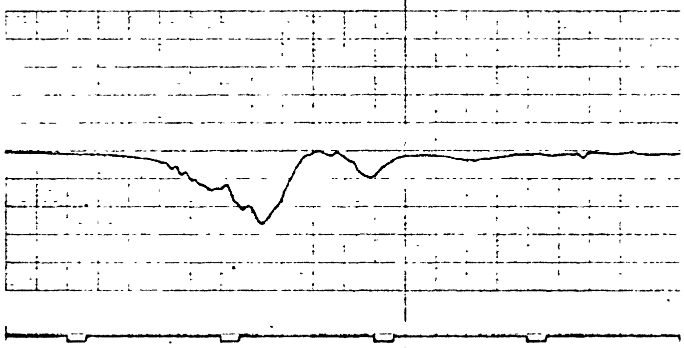
Sled Velocity 32.0 ft/sec

Test Type HAMILL PROTECTA-TOT FRONTAL IMPACT

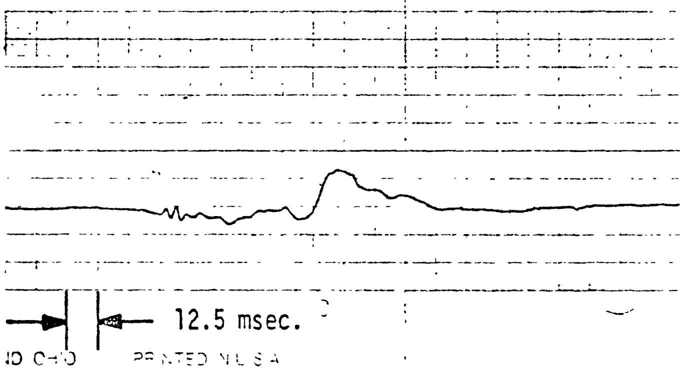
Sled Pulse
5 g's/division
Filtered
Class 60



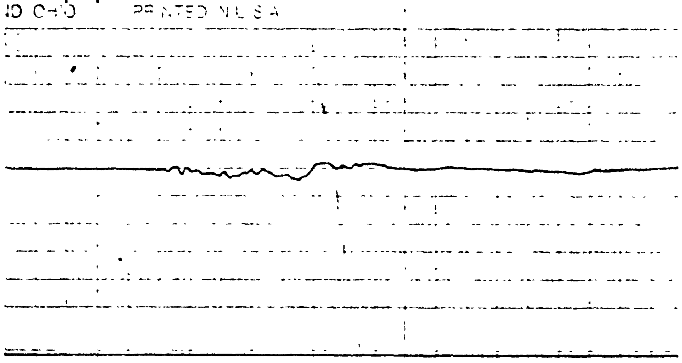
Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



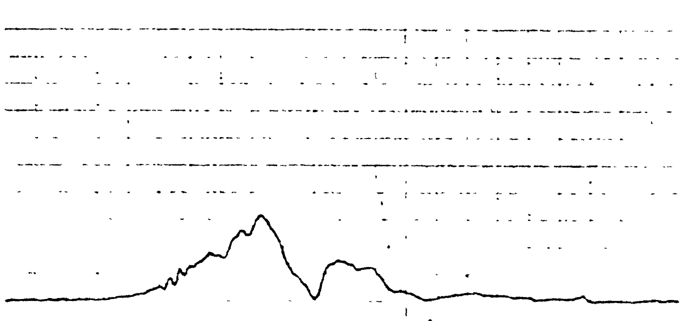
Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



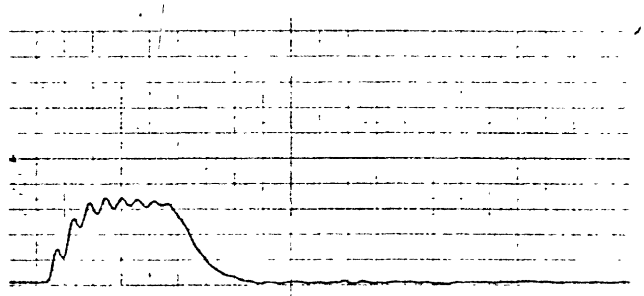
SUMMARY DATA HEAD ACCELERATIONS

Test Number A-480 Test Type STROLEE #590

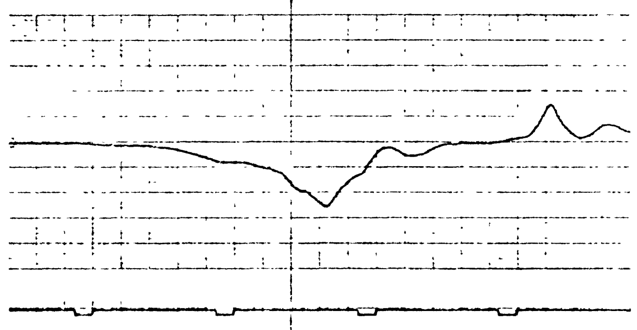
Dummy 3-YEAR

Sled Velocity 28.9 ft/sec FRONTAL IMPACT

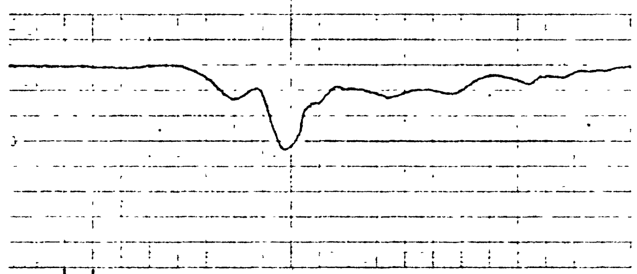
Sled Pulse
5 g's/division
Filtered
Class 60



Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

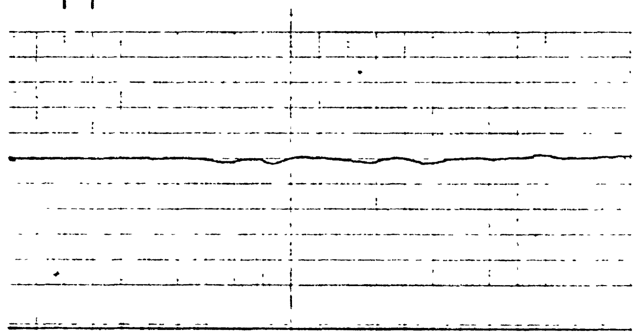


Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

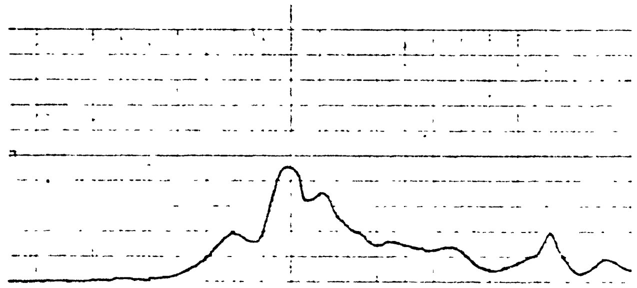


12.5 msec.

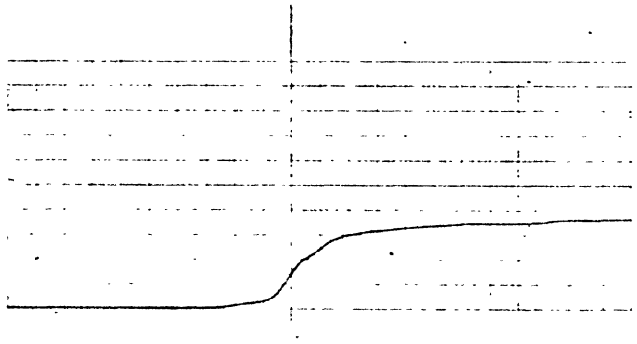
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 g-- sec/div.



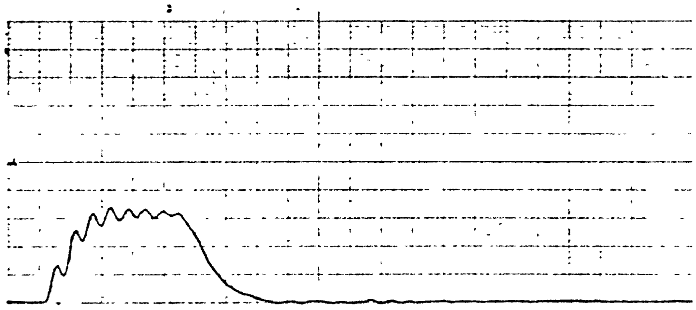
SUMMARY DATA CHEST ACCELERATIONS

Test Number A-480 Test Type STROLEE #590

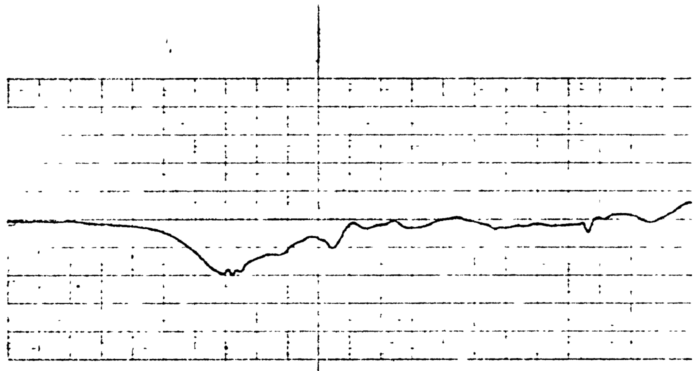
Dummy 3-YEAR

Sled Velocity 23.9 ft/sec FRONTAL IMPACT

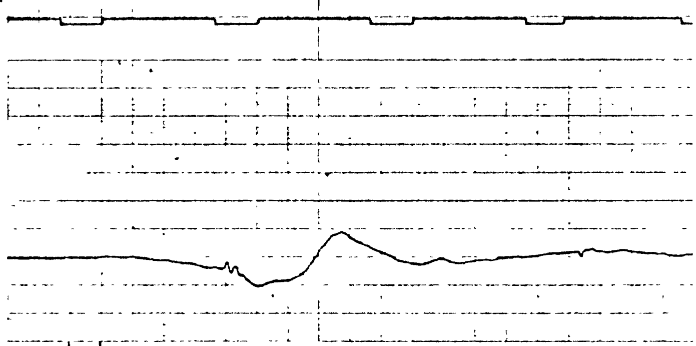
Sled Pulse
5 g's/division
Filtered
Class 60



Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

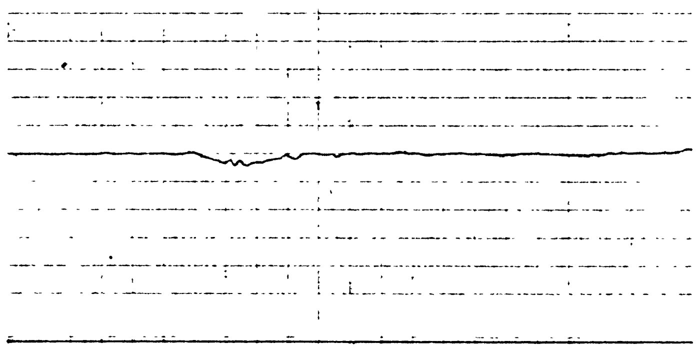


Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

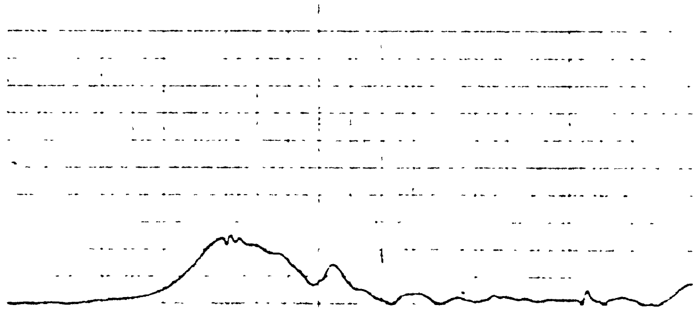


12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



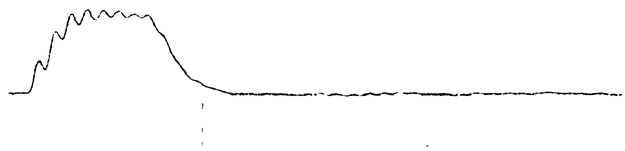
SUMMARY DATA HEAD ACCELERATIONS

Test Number A-481 Test Type PETERSON #6B

Dummy 3-YEAR

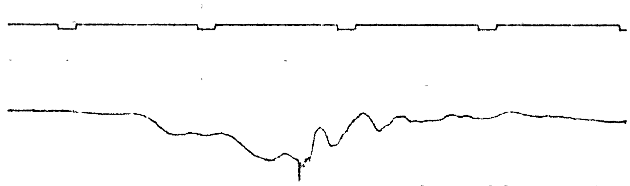
Sled Velocity 28.2 ft/sec FRONTAL IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60



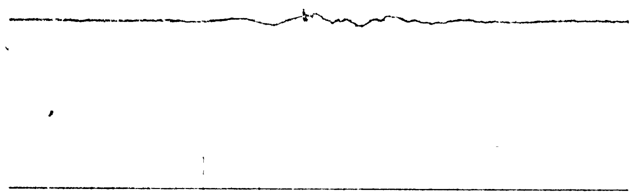
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

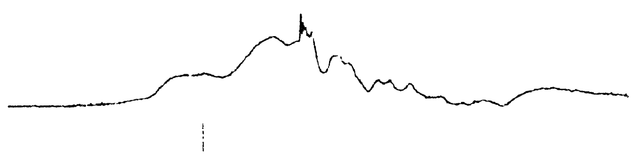


12.5 msec.

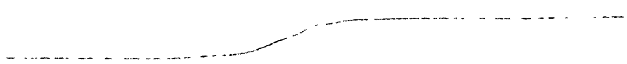
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 g sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-[illegible] Test Type [illegible]RSON [illegible]

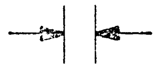
Dummy [illegible]

Sled Velocity [illegible] ft/sec FRONTAL IMPACT

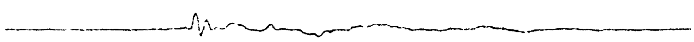
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

SUMMARY DATA HEAD ACCELERATIONS

Test Number A-482

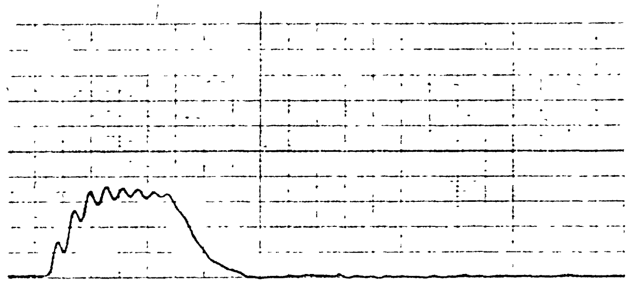
Test Type KANTWET #78

Dummy 3-YEAR

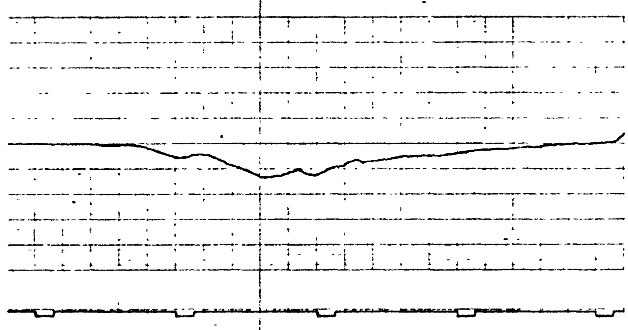
Sled Velocity 29.5 ft/sec

FRONTAL IMPACT

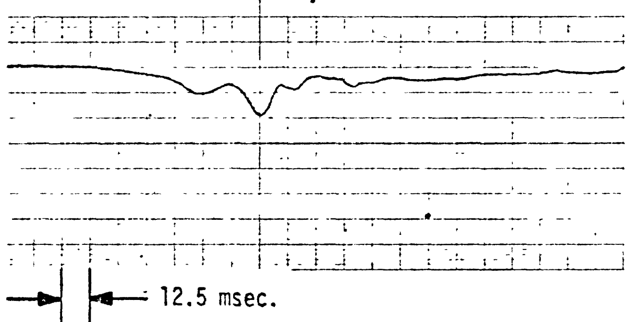
Sled Pulse
5 g's/division
Filtered
Class 60



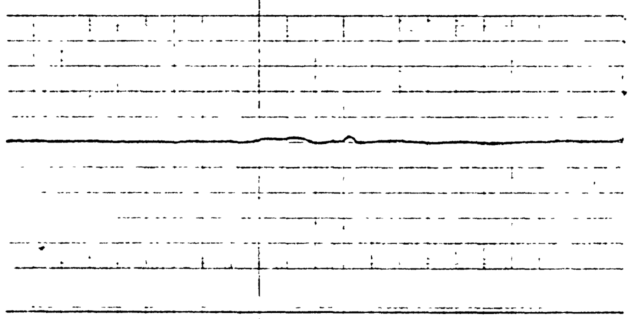
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



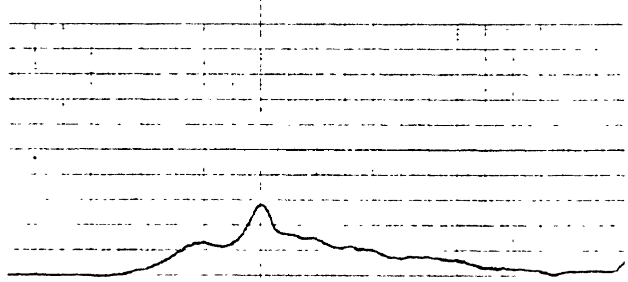
Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



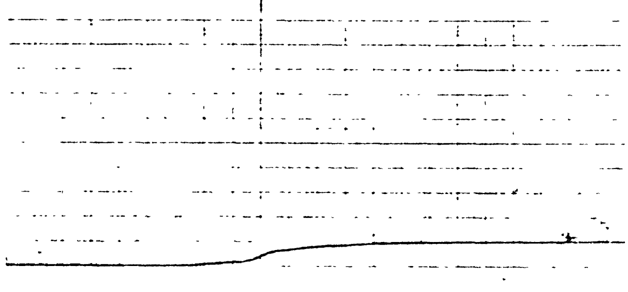
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 g$^{2.5}$ sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-482 Test Type KANTWET #78

Dummy 3-YEAR

Sled Velocity 29.5 ft/sec FRONTAL IMPACT

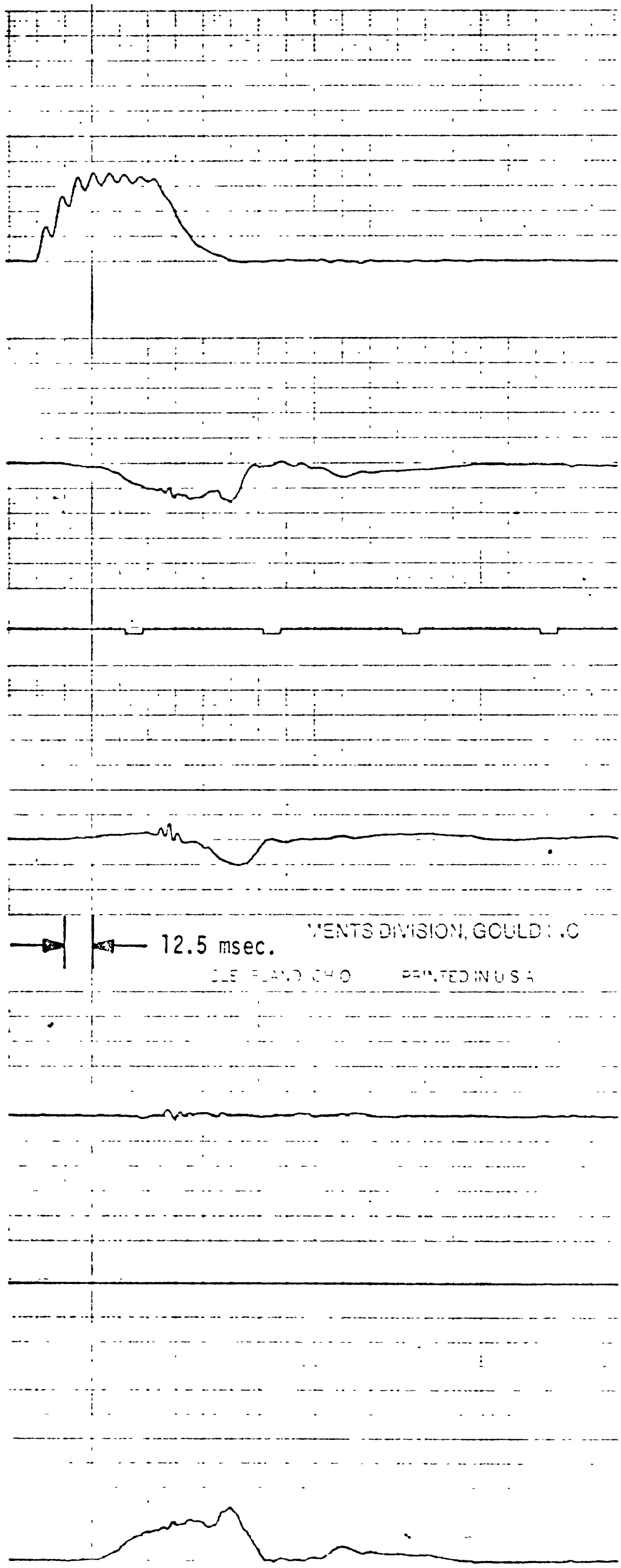
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



SUMMARY DATA HEAD ACCELERATIONS

Test Number A-483 Test Type TOT-GUARD

Dummy 3-YEAR

Sled Velocity 29.4 ft/sec FRONTAL IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

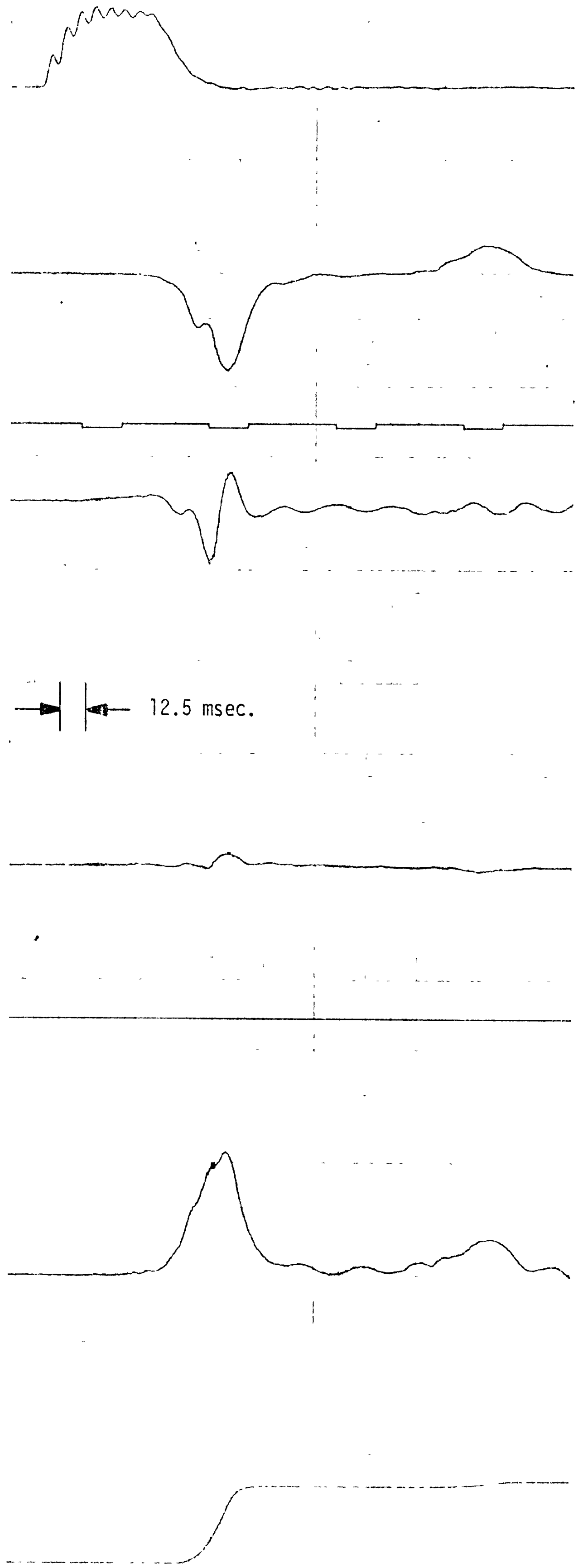
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
100 g ·· sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number 4-223

Dummy 3-Y[illegible]

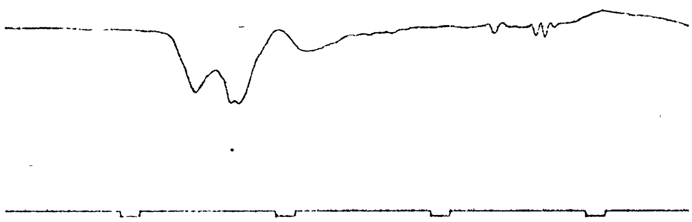
Sled Velocity [illegible]4 ft/sec

Test Type TOT-GUARD

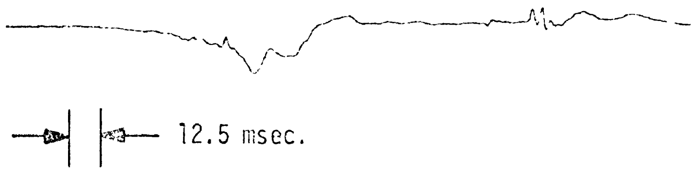
FRONTAL IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

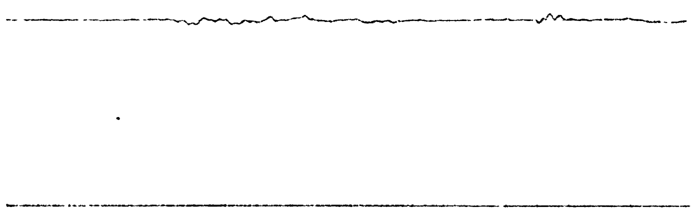
Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

SUMMARY DATA HEAD ACCELERATIONS

Test Number A-484 Test Type TOT-GUARD

Dummy 3-YEAR

Sled Velocity 48.1 ft/sec FRONTAL IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

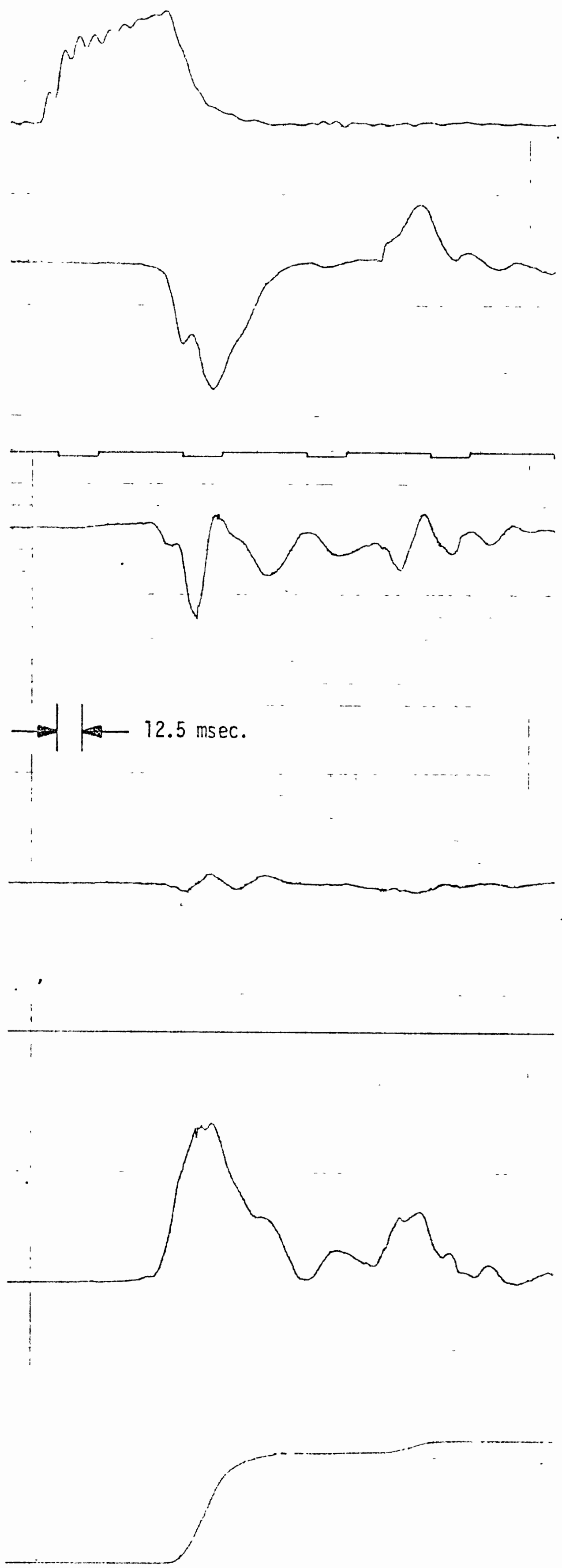
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
200 $g^{2.5}$ sec/div.



SUMMARY DATA CHEST ACCELERATIONS

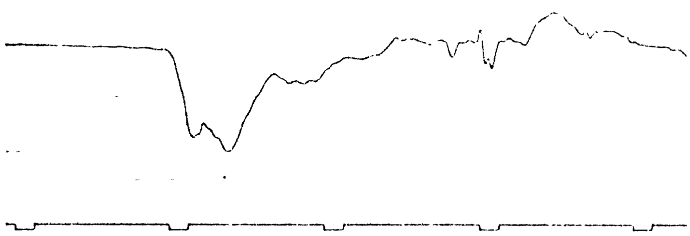
Test Number A-484 Test Type TOT-GUARD

Dummy 3-YEAR

Sled Velocity 22.1 ft/sec FRONTAL IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

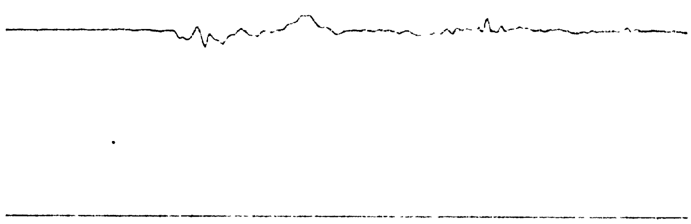
Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



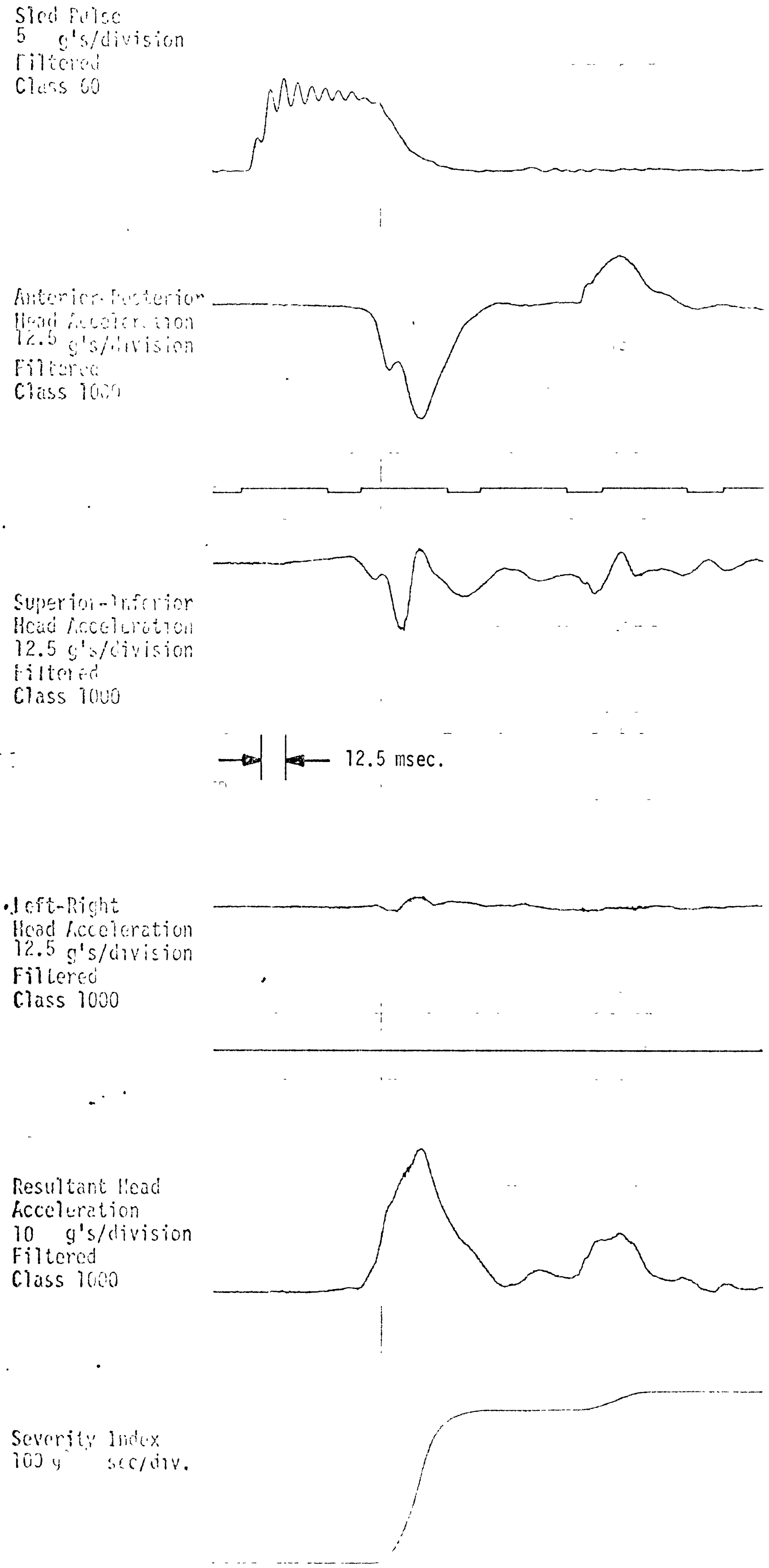
Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

SUMMARY DATA HEAD ACCELERATIONS

Test Number A-485 Test Type TOT-GUARD

Dummy 3-YEAR

Sled Velocity 41.4 ft/sec FRONTAL IMPACT



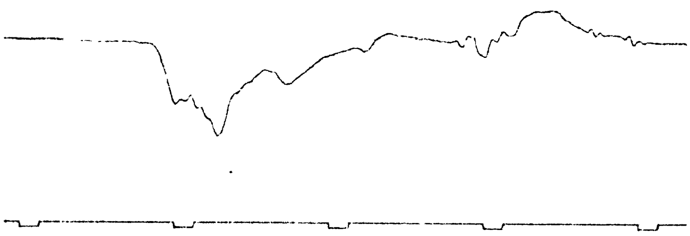
L

SUMMARY DATA CHEST ACCELERATIONS

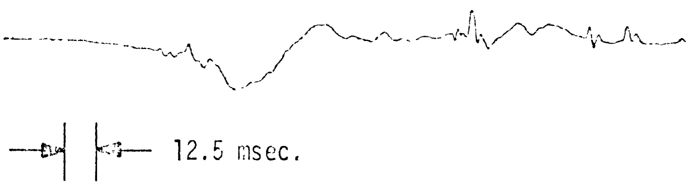
Test Number A-425 Test Type TCT-GUARD
Dummy [illegible]
Sled Velocity [illegible] ft/sec FRONTAL IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

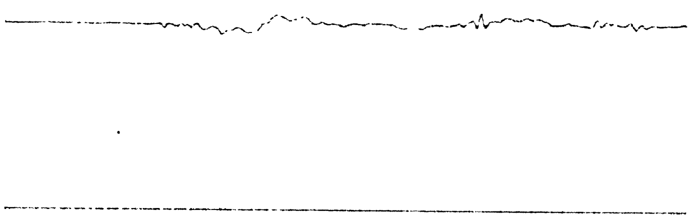


Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

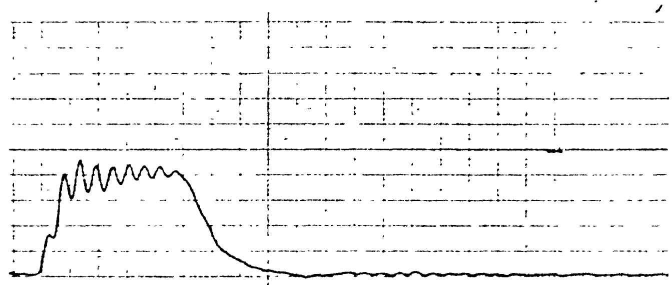
SUMMARY DATA HEAD ACCELERATIONS

Test Number A-486 Test Type STROLEE #590

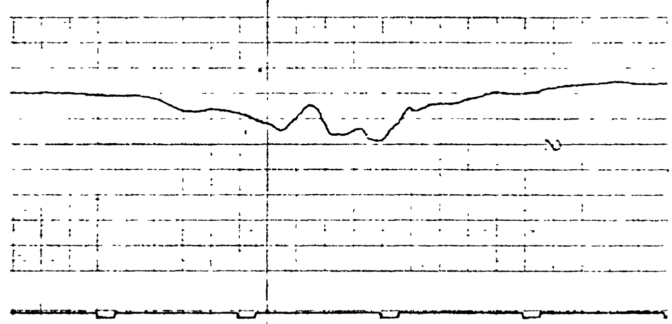
Dummy 3-YEAR

Sled Velocity 43.5 ft/sec FRONTAL IMPACT

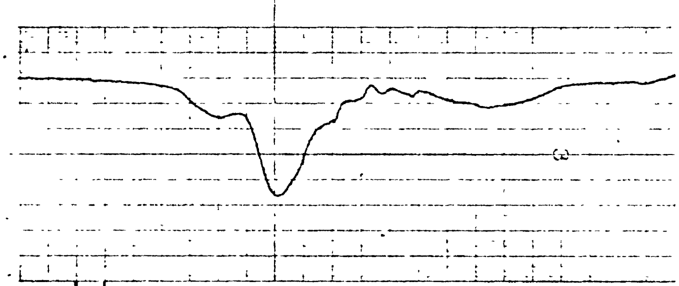
Sled Pulse
5 g's/division
Filtered
Class 60



Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

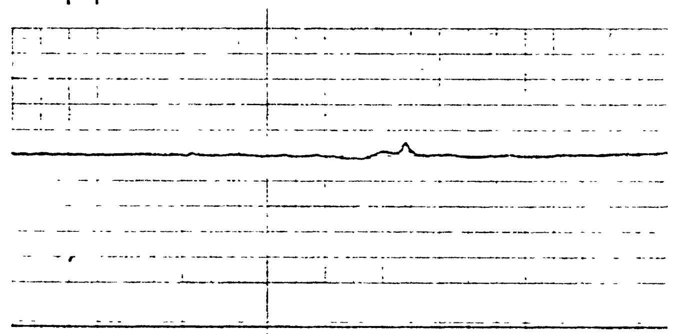


Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

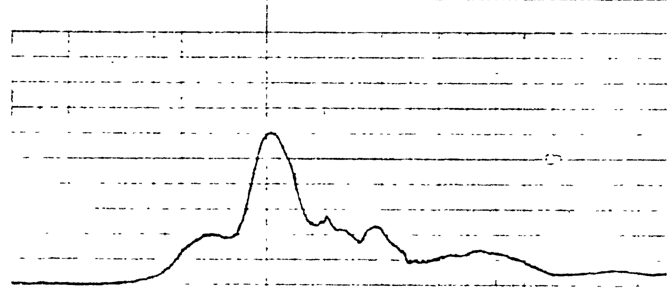


12.5 msec.

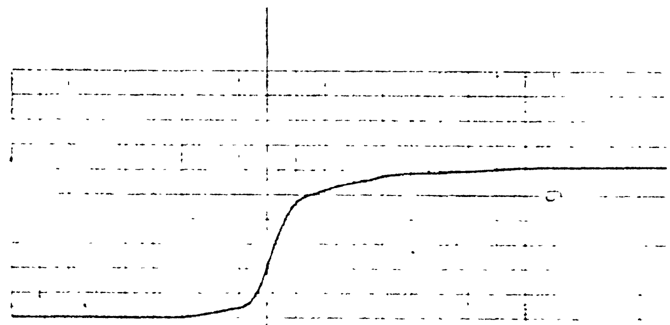
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 g[illegible] sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-496 | Test Type STROLEE #590
Dummy 3-YEAR |
Sled Velocity 43.5 ft/sec | FRONTAL IMPACT

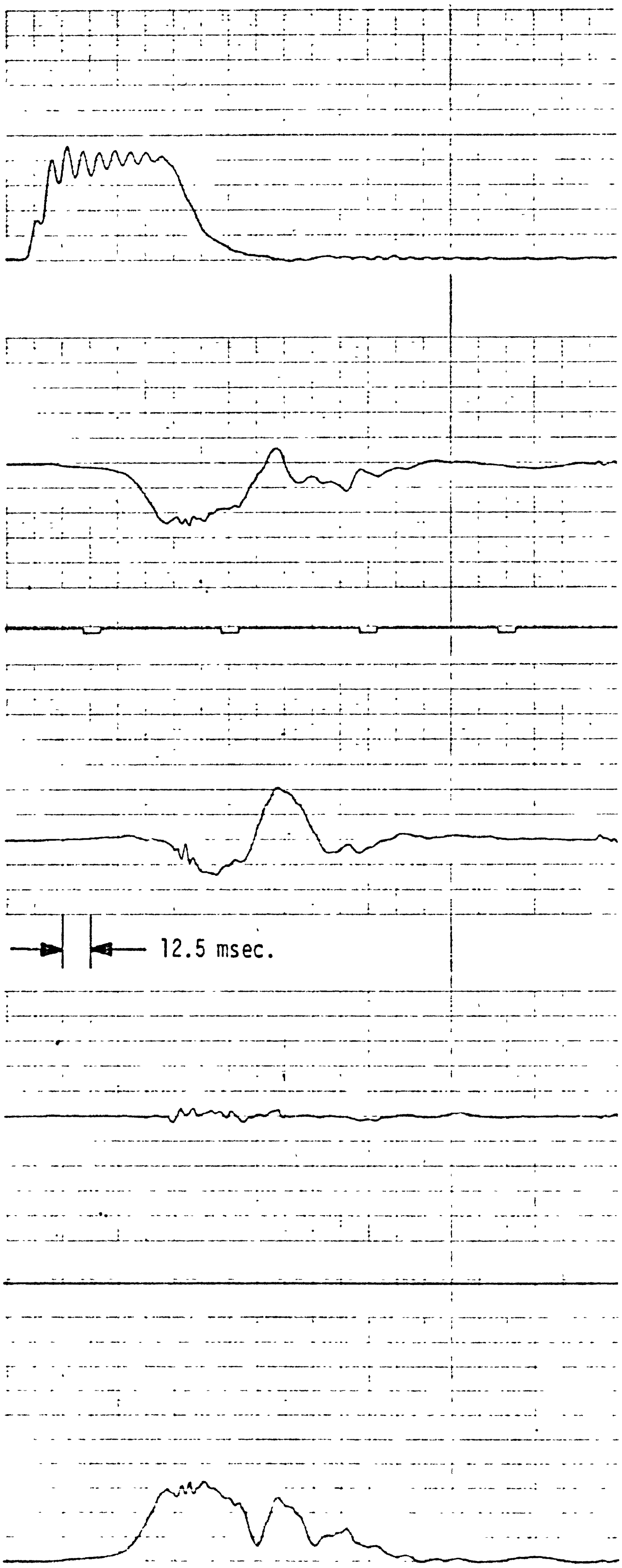
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



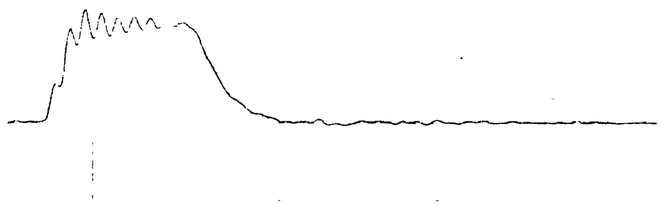
SUMMARY DATA HEAD ACCELERATIONS

Test Number A-497 Test Type PETERSON #68

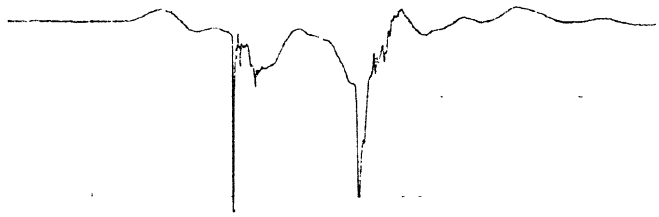
Dummy 3-YEAR

Sled Velocity [illegible] ft/sec FRONTAL IMPACT

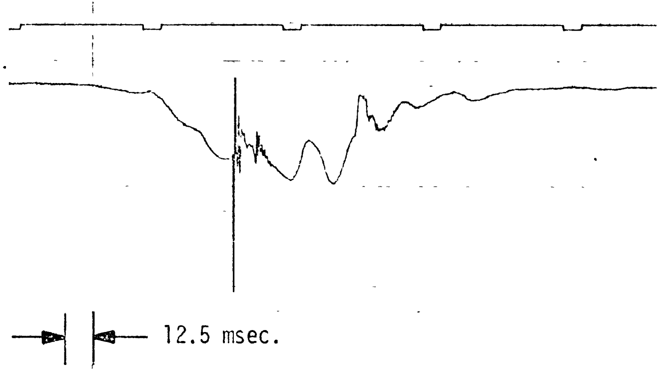
Sled Pulse
5 g's/division
Filtered
Class 60



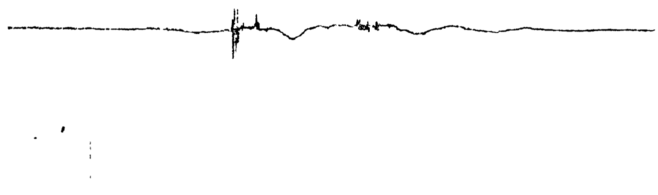
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



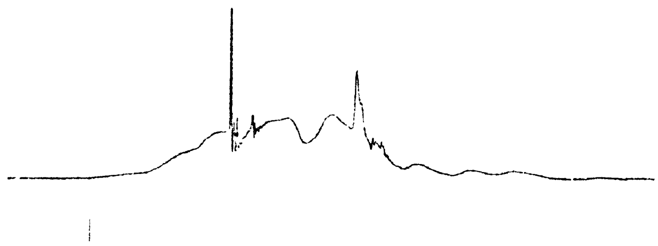
Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



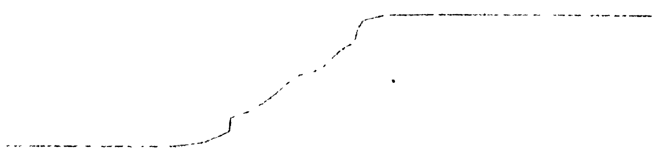
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
20 g's/division
Filtered
Class 1000



Severity Index
200 $g^{2.5}$ sec/div.



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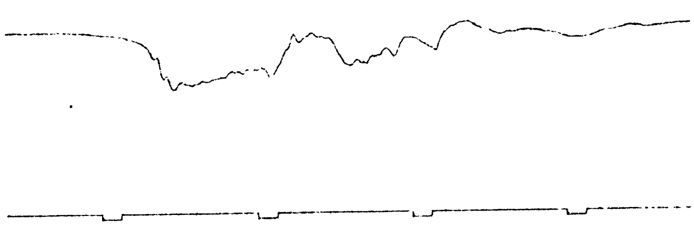
SUMMARY DATA CHEST ACCELERATIONS

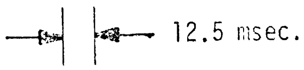
Test Number A-487 Test Type PETERSON #68
Dummy [illegible]
Sled Velocity [illegible] ft/sec FRONTAL IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

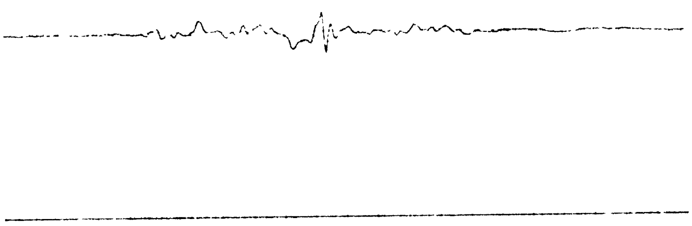
Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



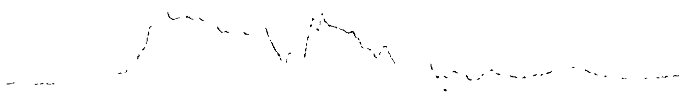
Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

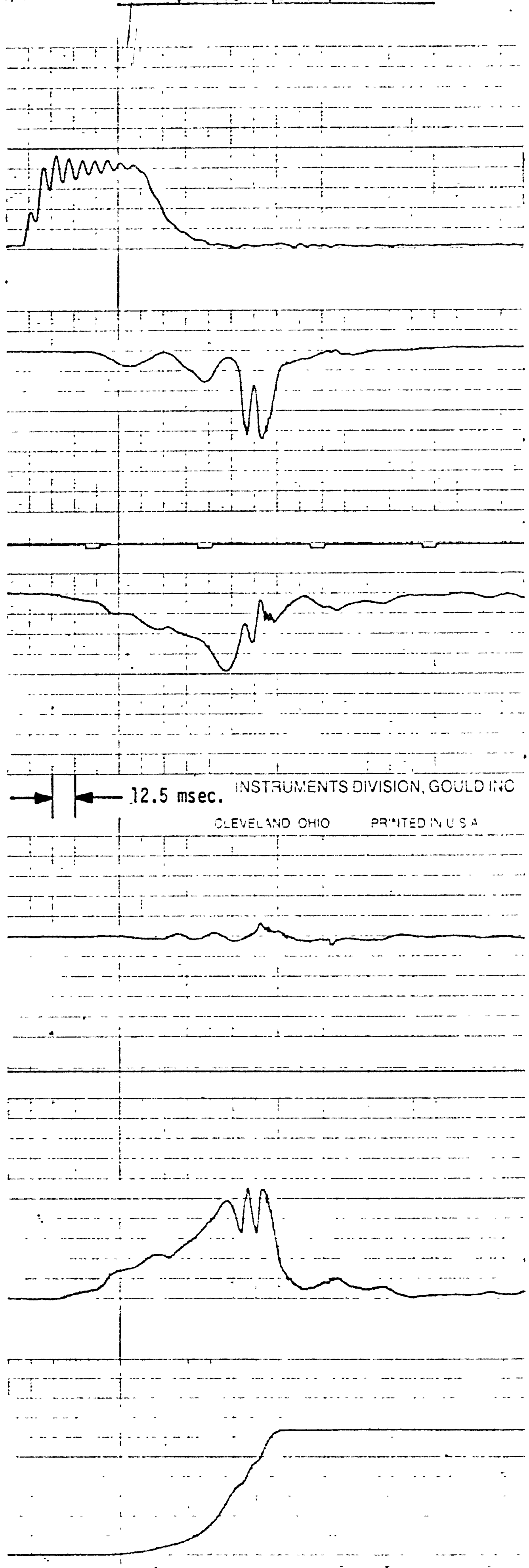


SUMMARY DATA HEAD ACCELERATIONS

Test Number A-488 Test Type KANTWET #78

Dummy 3-YEAR

Sled Velocity 43.9 ft/sec FRONTAL IMPACT



Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

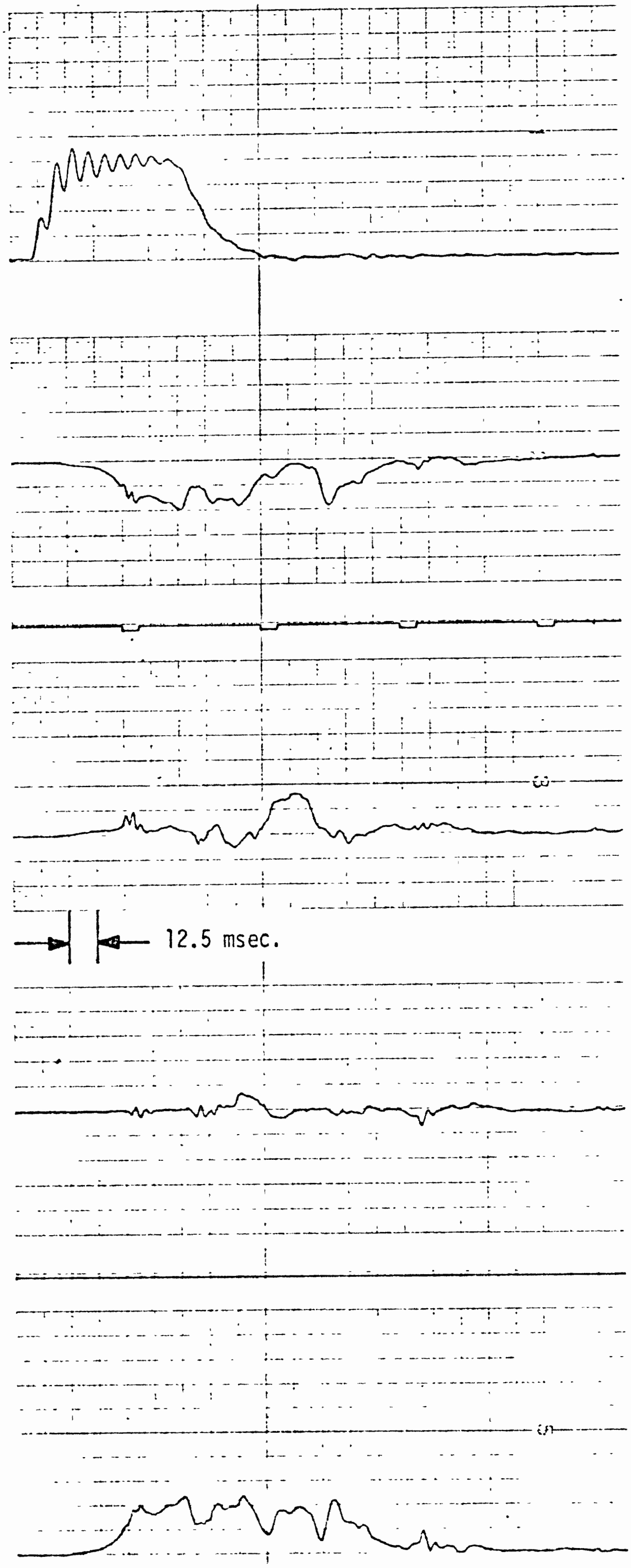
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
100 g⁻ ⁻ sec/div.

SUMMARY DATA CHEST ACCELERATIONS

Test Number A-488 | Test Type KANTWET #78
Dummy 3-YEAR
Sled Velocity 43.9 ft/sec | FRONTAL IMPACT



Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

SUMMARY DATA HEAD ACCELERATIONS

Test Number A-489 Test Type HAMILL PROTECTA-TOT FRONTAL IMPACT

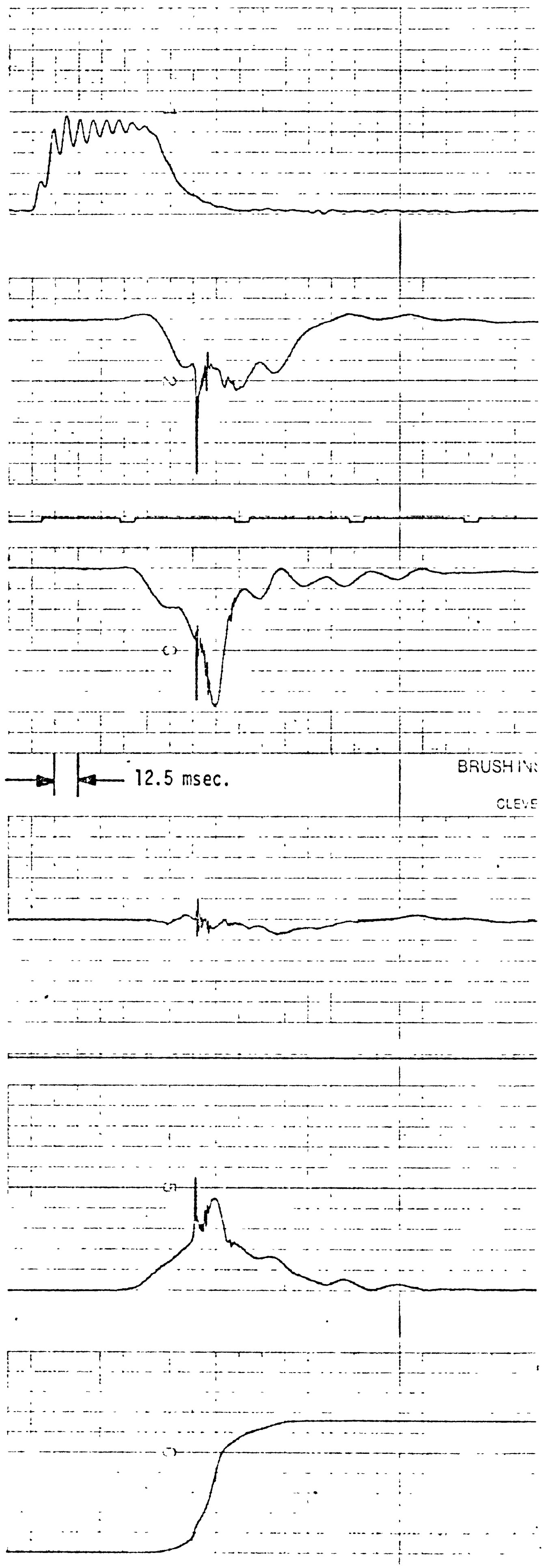
Dummy 3-YEAR

Sled Velocity 44.3 ft/sec

Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000

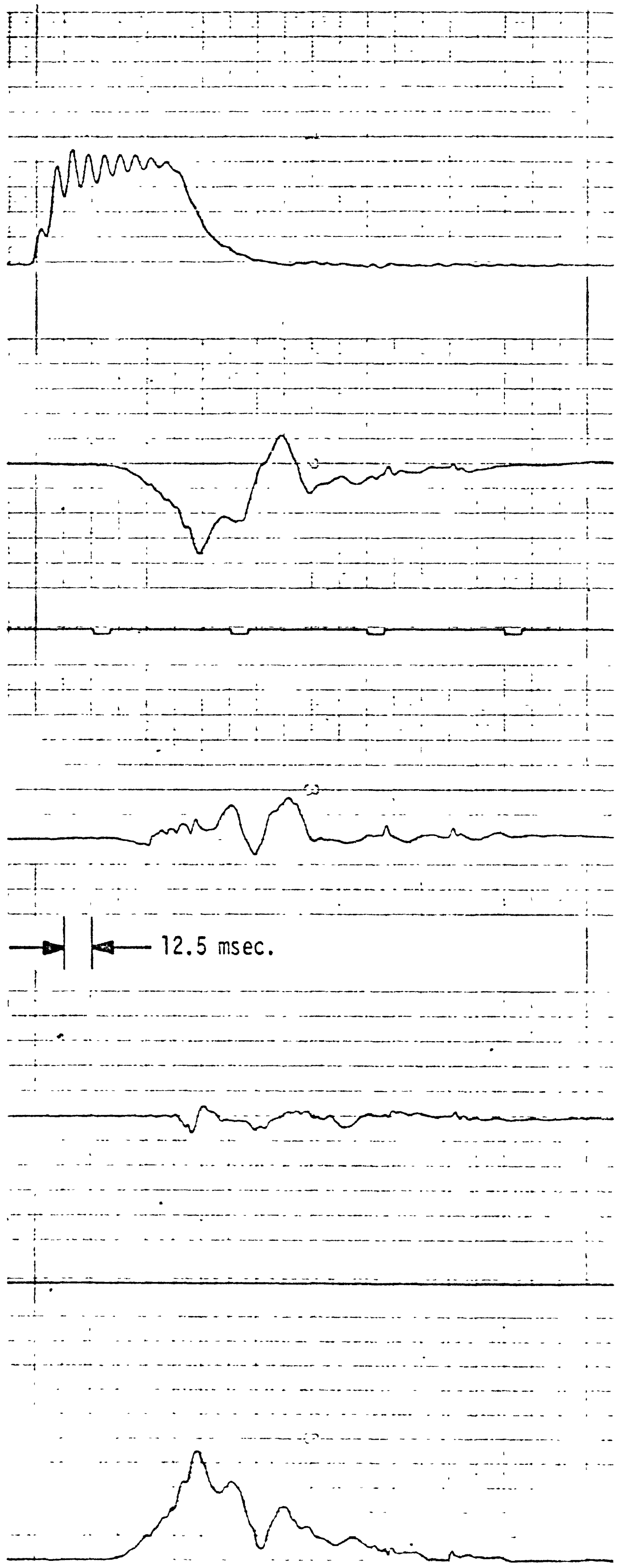
Resultant Head
Acceleration
20 g's/division
Filtered
Class 1000

Severity Index
200 $g^{2.5}$ sec/div.

SUMMARY DATA CHEST ACCELERATIONS

Test Number A-489
Dummy 3-YEAR
Sled Velocity 44.3 ft/sec

Test Type HAMILL
PROTECTA-TOT
FRONTAL IMPACT



Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

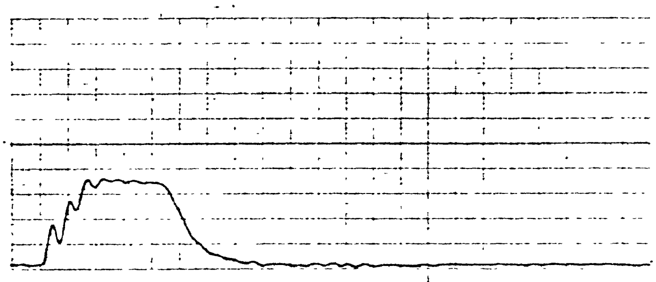
SUMMARY DATA HEAD ACCELERATIONS

Test Number A-490 | Test Type HAMILL PROTECTA-TOT REAR IMPACT

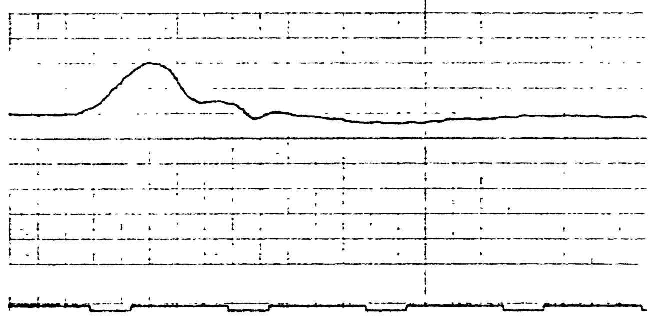
Dummy 3-YEAR

Sled Velocity 30.5 ft/sec

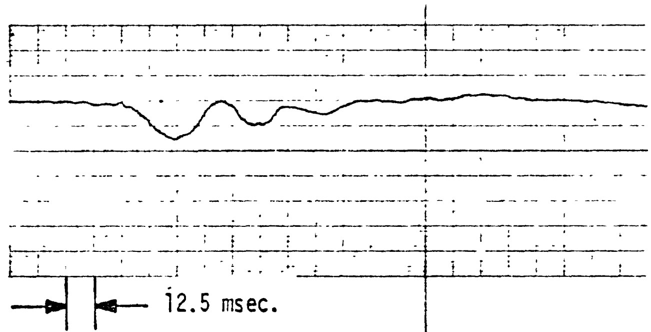
Sled Pulse
5 g's/division
Filtered
Class 60



Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

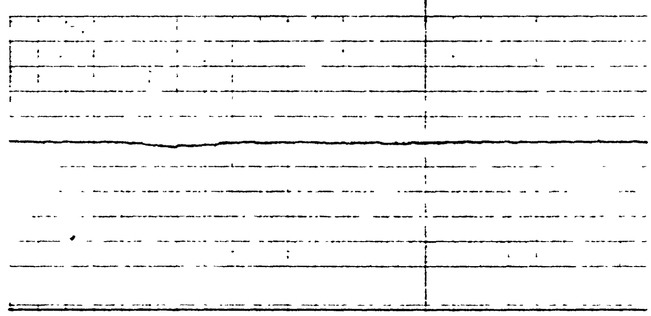


Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

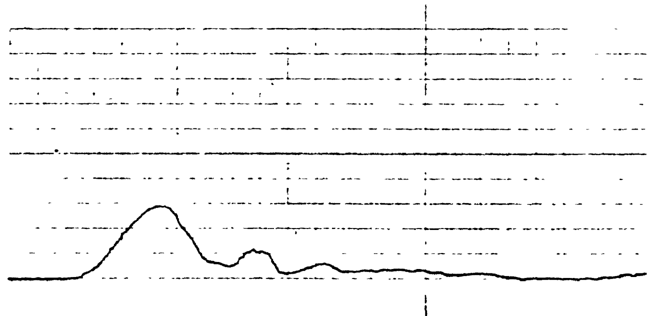


12.5 msec.

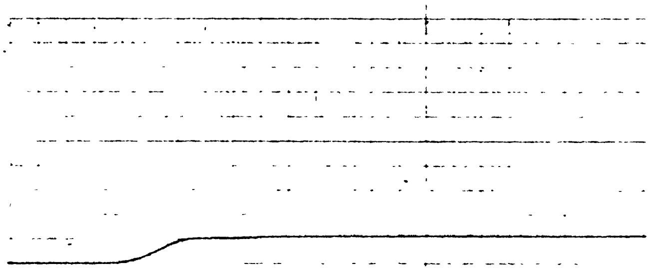
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 $g^{2.5}$ sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-490 Test Type HAMILL
Dummy 3-YEAR PROTECTA-TOT
Sled Velocity 30.5 ft/sec REAR IMPACT

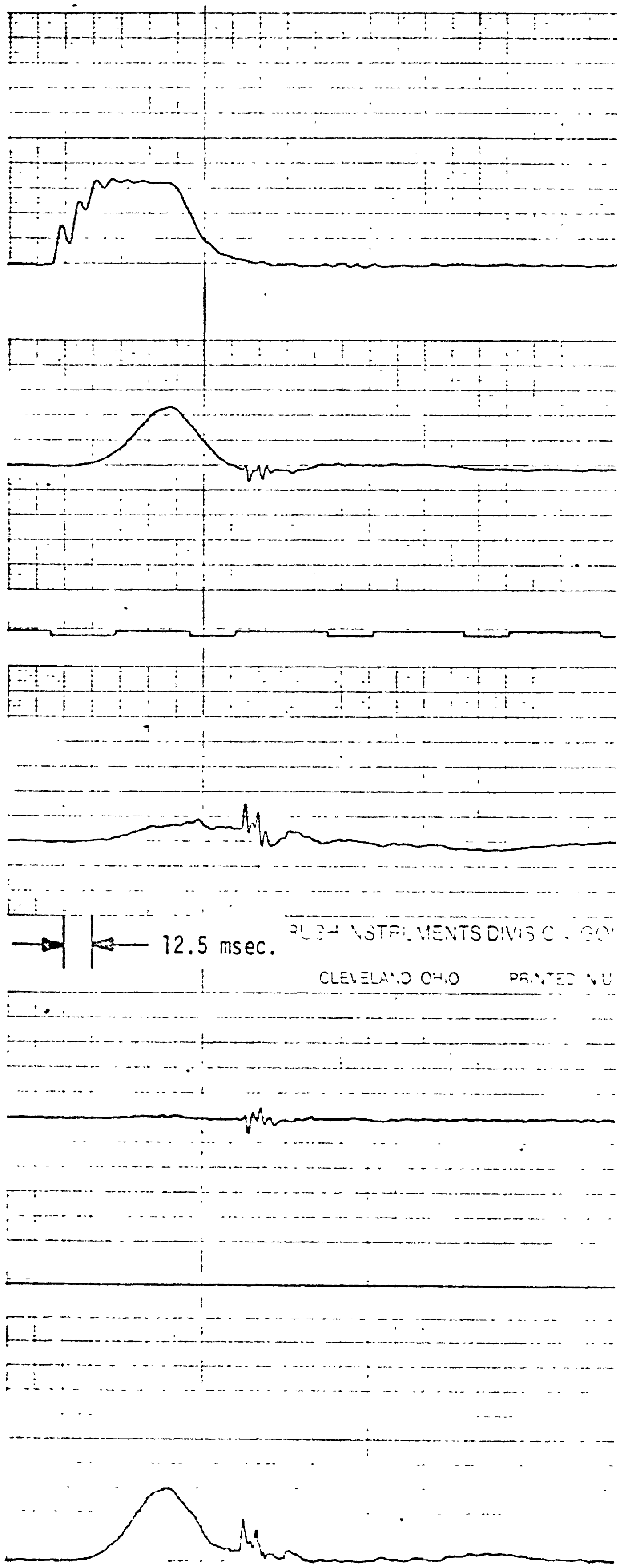
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



SUMMARY DATA HEAD ACCELERATIONS

Test Number A-491 Test Type STROLEE #590

Dummy 3-YEAR

Sled Velocity 30.0 ft/sec REAR IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

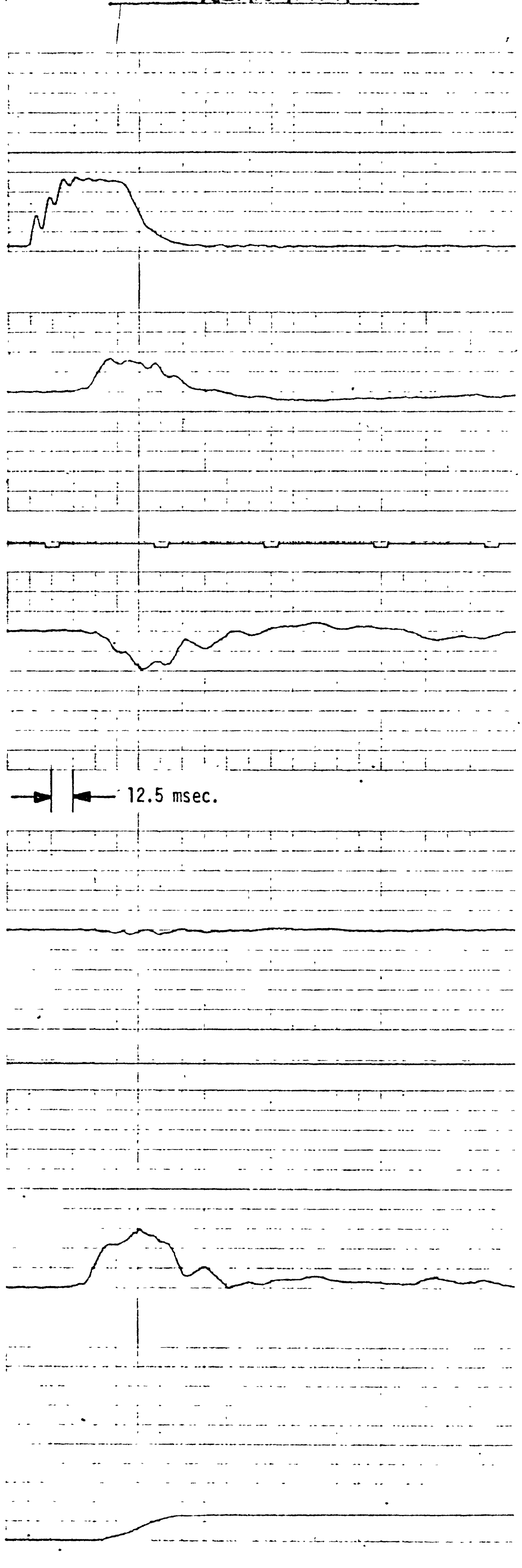
Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

12.5 msec.

Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
100 $g^{2.5}$ sec/div.

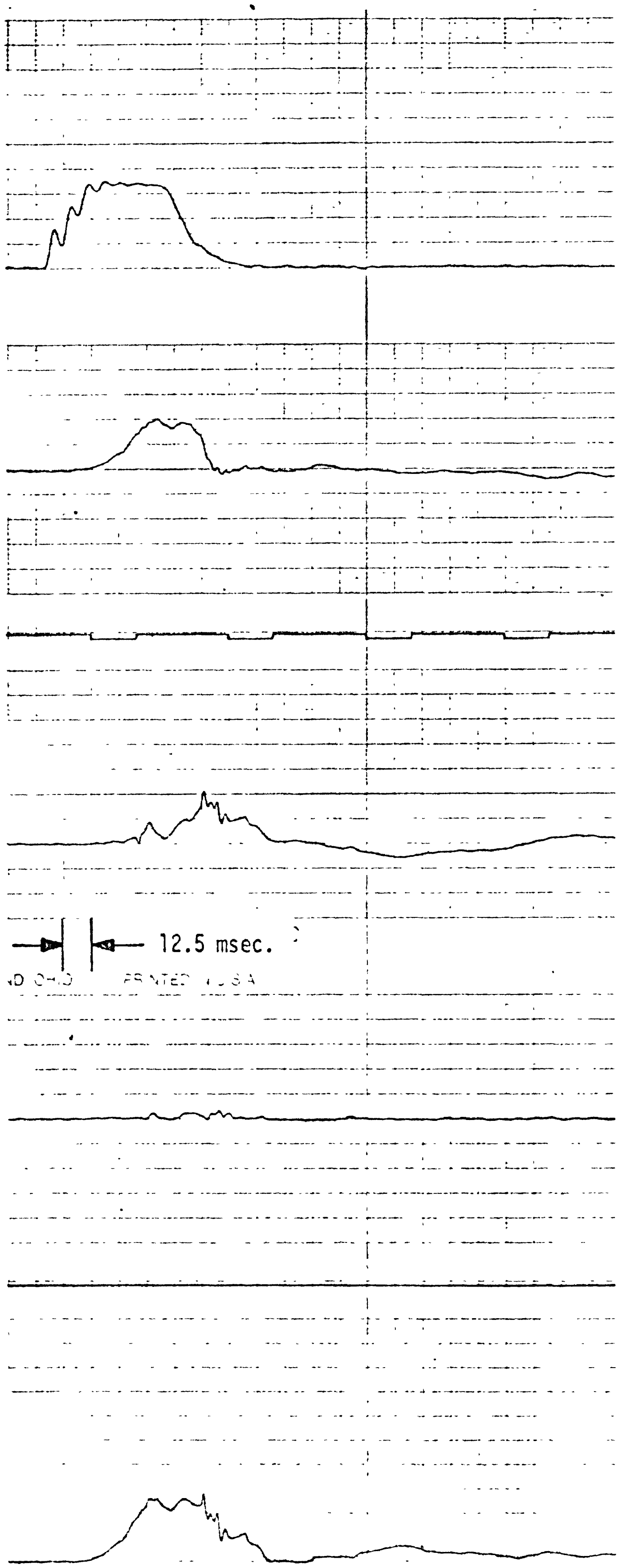


SUMMARY DATA CHEST ACCELERATIONS

Test Number A-491 Test Type STROLEE #590

Dummy 3-YEAR

Sled Velocity 20.0 ft/sec REAR IMPACT



Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

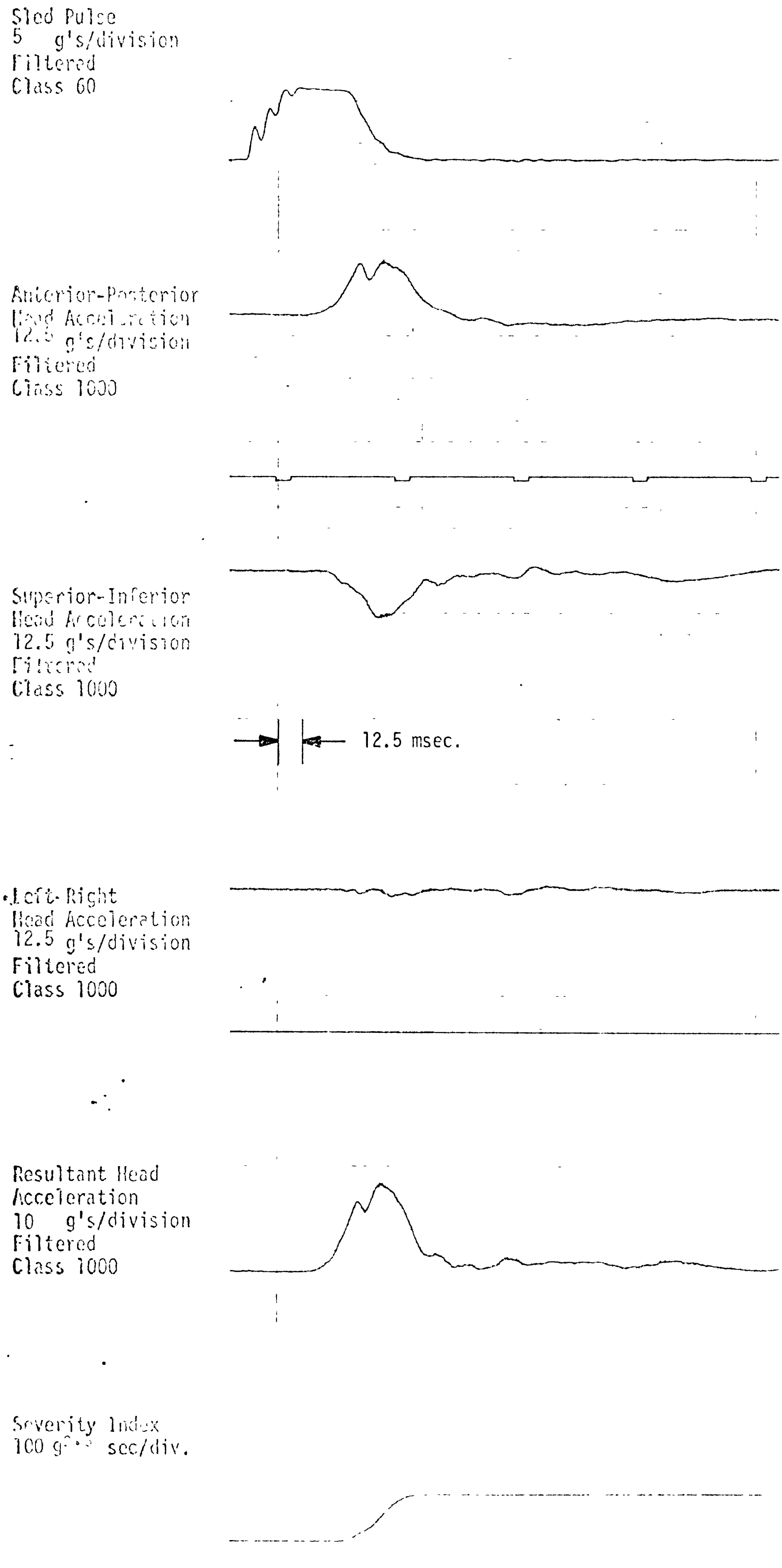
Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

SUMMARY DATA HEAD ACCELERATIONS

Test Number A-492 Test Type PETERSON #68

Dummy 3-YEAR

Sled Velocity 29.6 ft/sec REAR IMPACT



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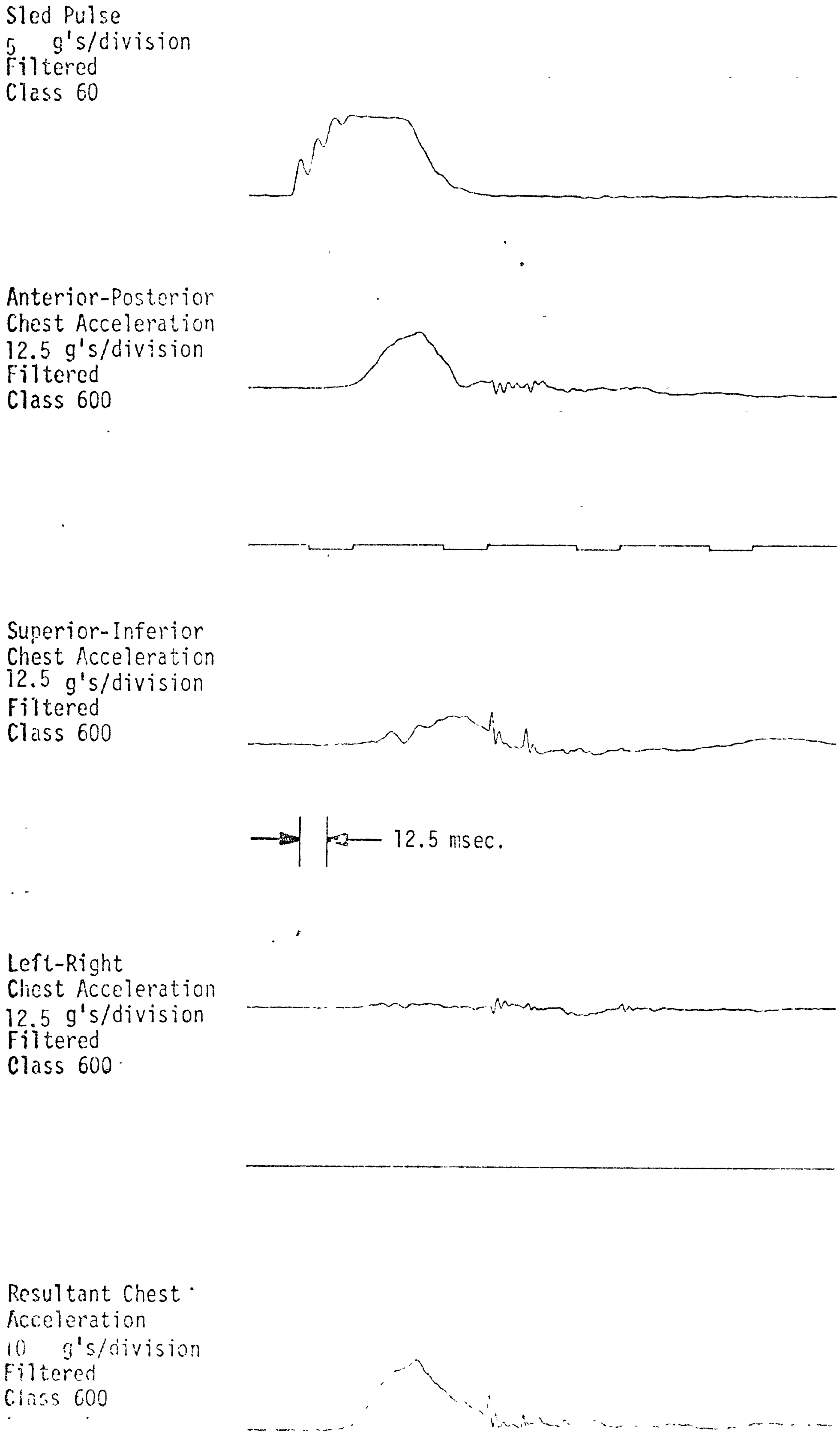
SUMMARY DATA CHEST ACCELERATIONS

Test Number A-492 Test Type PETERSON #6B

Dummy B-Y[illegible]

Sled Velocity [illegible] ft/sec REAR IMPACT



SUMMARY DATA HEAD ACCELERATIONS

Test Number A-493 Test Type KANTWET #78

Dummy 3-YEAR

Sled Velocity 29.9 ft/sec REAR IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

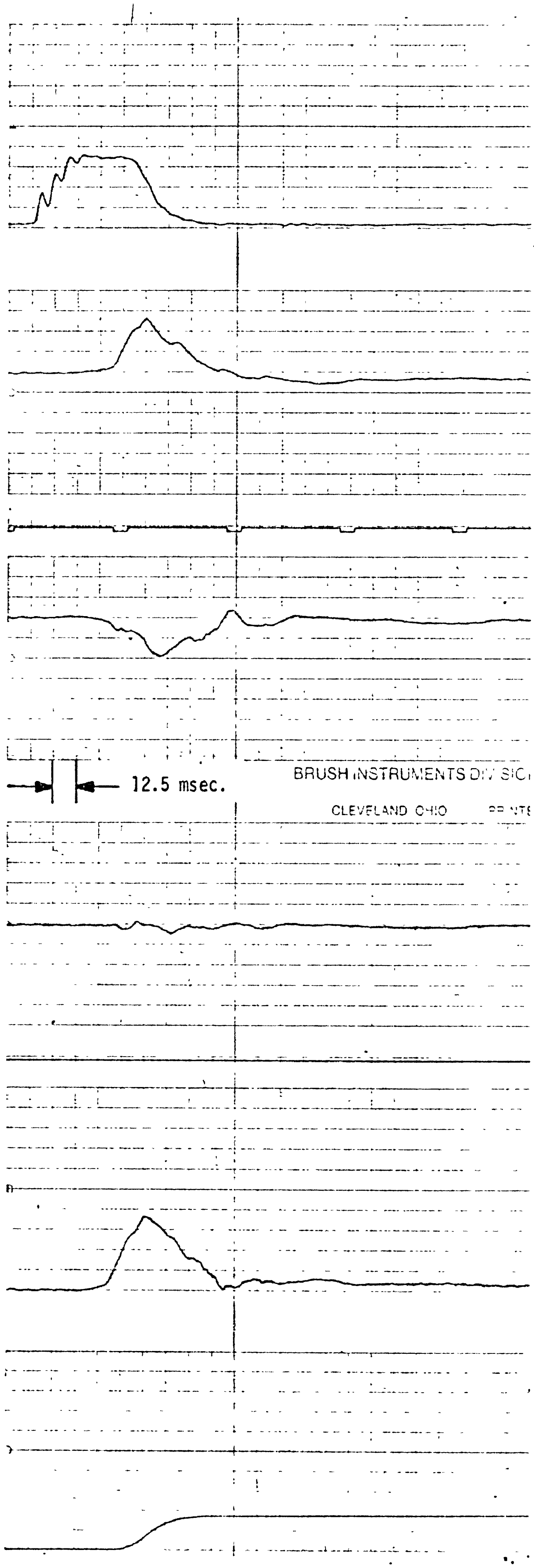
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
100 g^2.5 sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number *A-493* Test Type *KANTWET #78*

Dummy *3-YEAR* *REAR IMPACT*

Sled Velocity *29.9* ft/sec

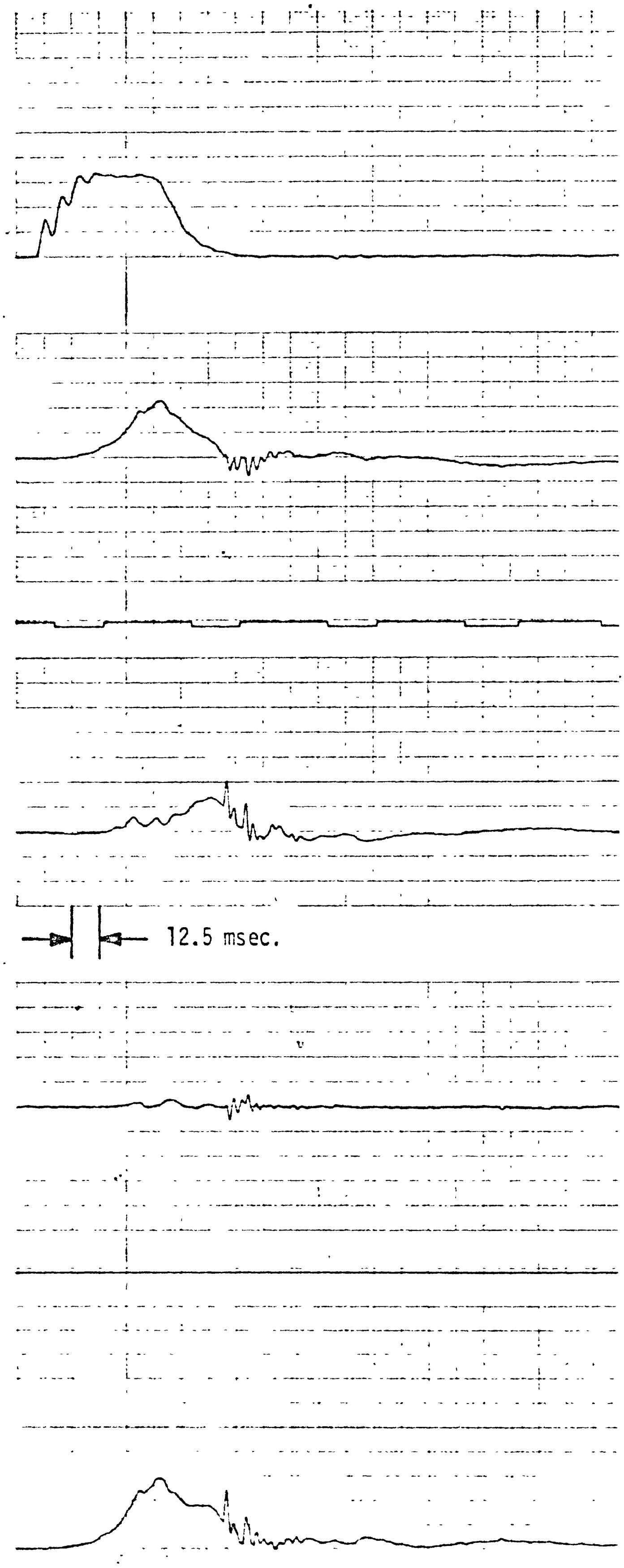
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



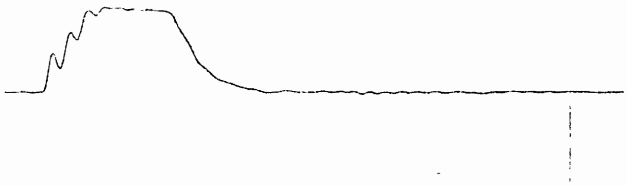
SUMMARY DATA HEAD ACCELERATIONS

Test Number A-494 Test Type TOT-GUARD

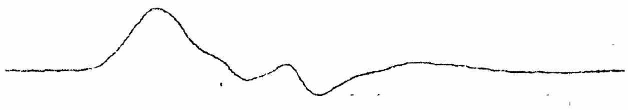
Dummy 3-YEAR

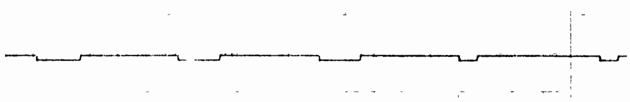
Sled Velocity 20.6 ft/sec REAR IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60



Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

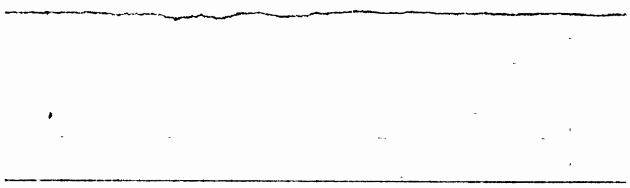




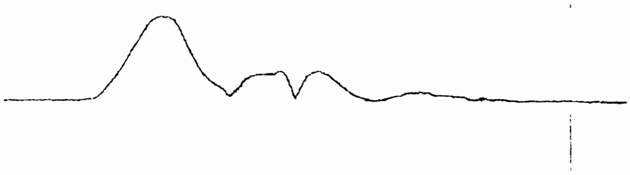
Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

12.5 msec.

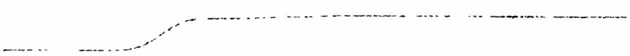
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 g· sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-[illegible]

Dummy [illegible]

Sled Velocity [illegible] ft/sec

Test Type TOT-GUARD

REAR IMPACT

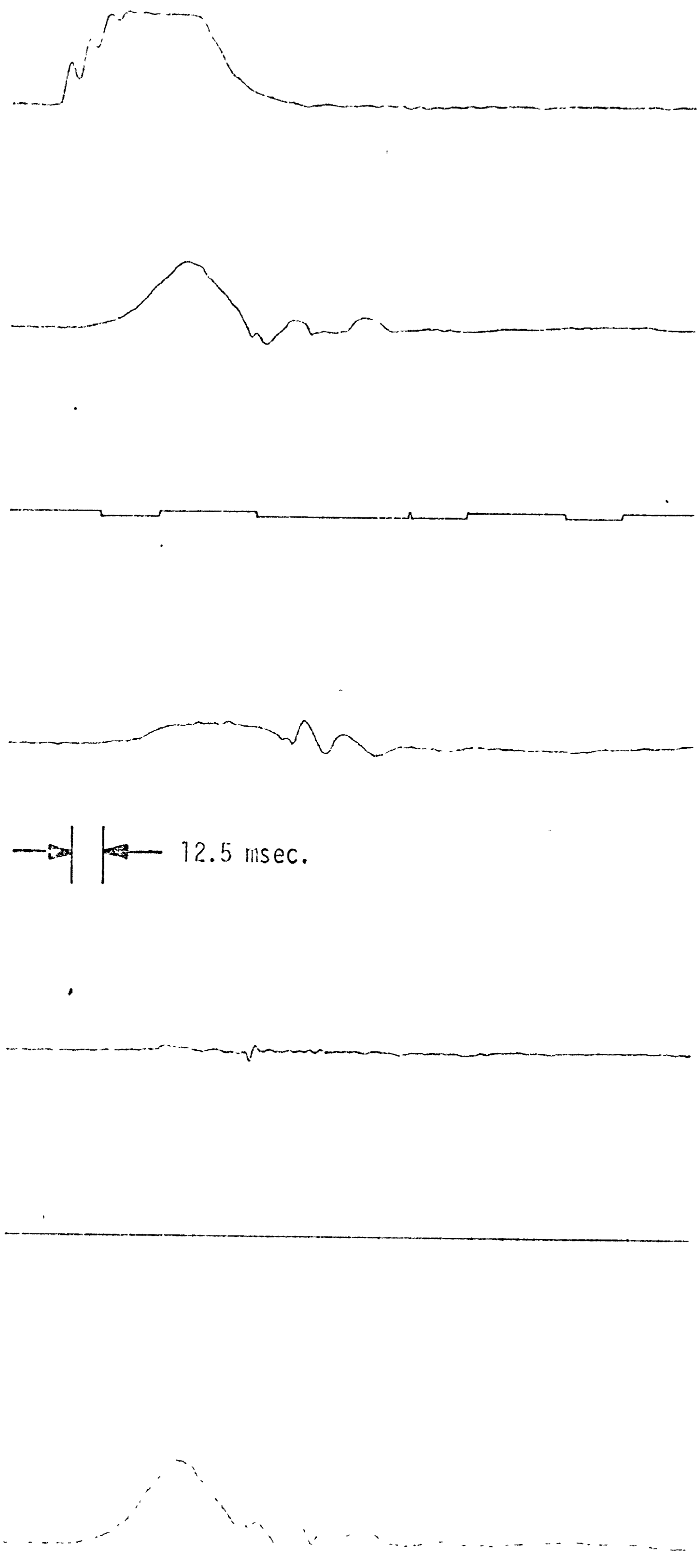
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



SUMMARY DATA HEAD ACCELERATIONS

Test Number A-1145 Test Type HSRI 3-YEAR

Dummy 3-YEAR

Sled Velocity 20.7 ft/sec REAR IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

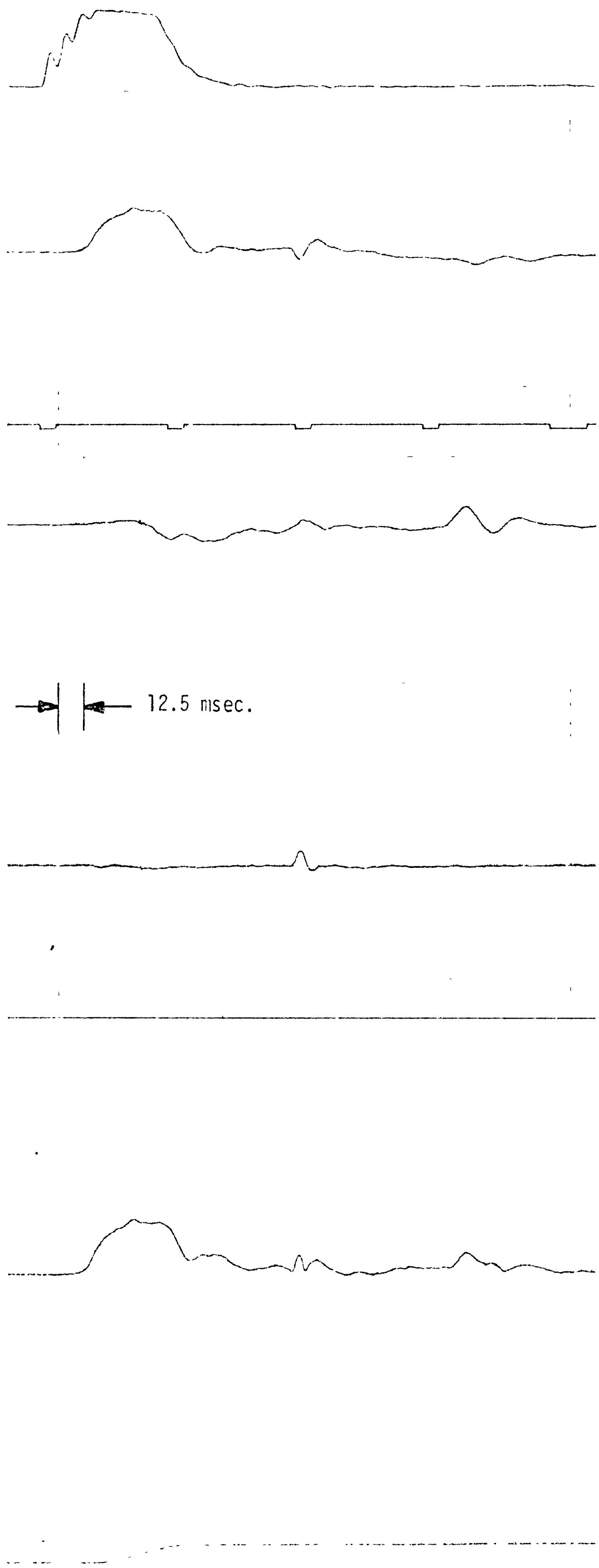
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
100 g sec/div.



SUMMARY DATA CHEST ACCELLRATIONS

Test Number A-475

Dummy [illegible]

Sled Velocity [illegible].7 ft/sec

Test Type H S R T 4-YEAR

REAR IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

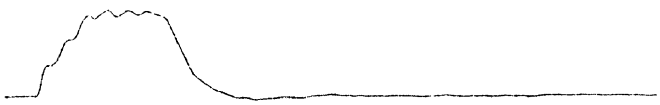
SUMMARY DATA HEAD ACCELERATIONS

Test Num. A-496 | Test Type HSRI 4-YEAR

Dummy 3-YEAR

Sled Velocity 20.0 ft/sec | SIDE IMPACT

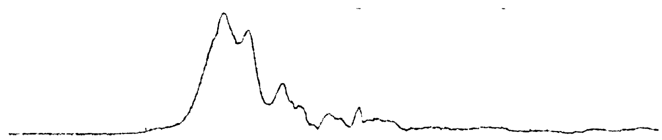
Sled Pulse
5 g's/division
Filtered
Class 60



Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
100 g^ sec/div.

SUMMARY DATA CHEST ACCELERATIONS

Test Number A-496
Dummy [illegible]
Sled Velocity [illegible] ft/sec

Test Type HSRI 4-YEAR
SIDE IMPACT

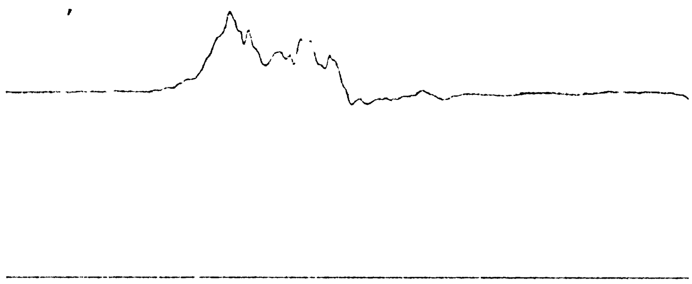
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

SUMMARY DATA HEAD ACCELERATIONS

Test Number A-497 Test Type HAMILL

Dummy 3-YEAR PROTECTA-TOT

Sled Velocity 29.4 ft/sec SIDE IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

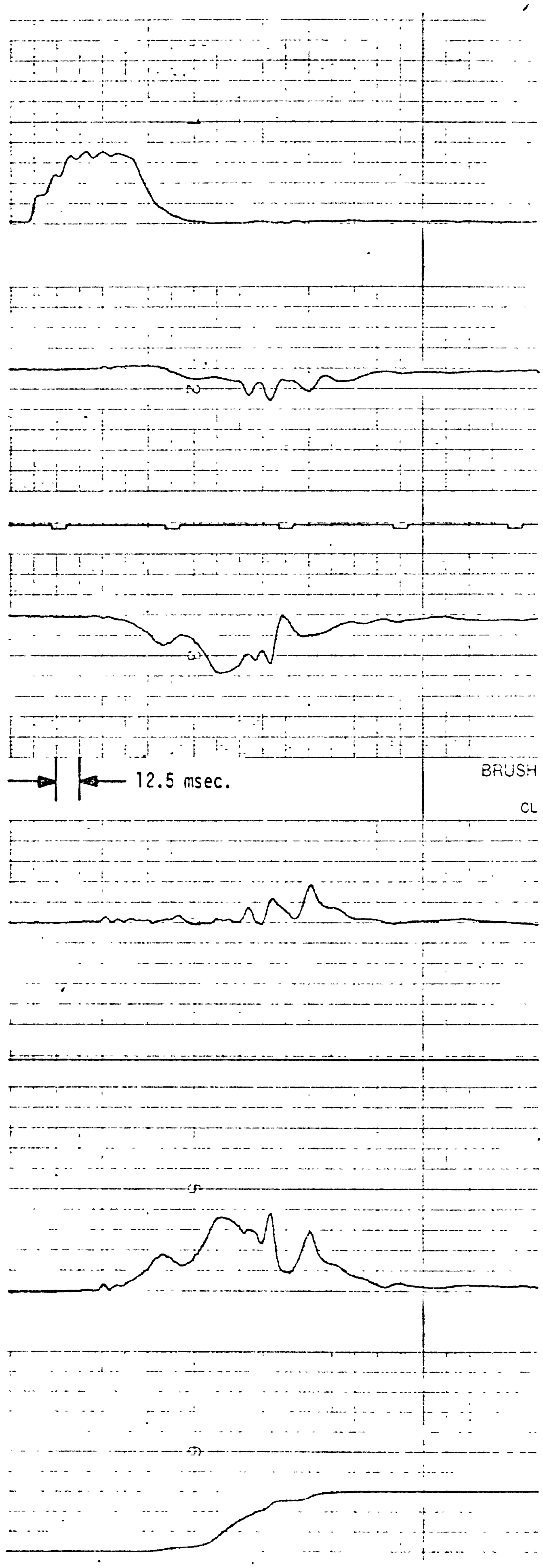
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
100 g[illegible] sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-497
Dummy 3-YEAR
Sled Velocity 29.4 ft/sec

Test Type HAMILL
PROTECTA-TOT
SIDE IMPACT

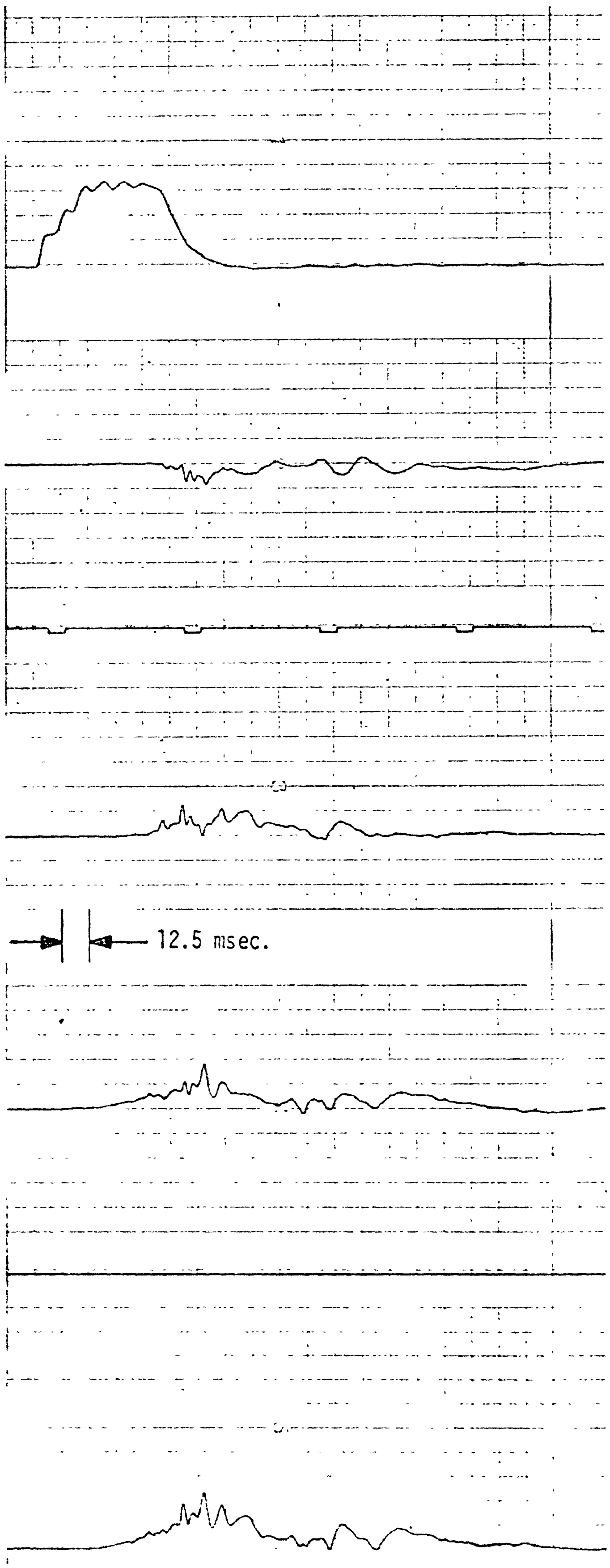
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



SUMMARY DATA HEAD ACCELERATIONS

Test Number A-498 Test Type TOT-GUARD

Dummy 3-YEAR

Sled Velocity 29.5 ft/sec SIDE IMPACT

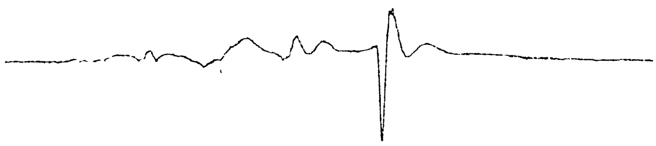
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

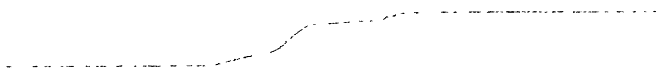
12.5 msec.

Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
100 sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-4?3
Dummy 2-YEAR
Sled Velocity [illegible] ft/sec

Test Type TOT-GUARD

SIDE IMPACT

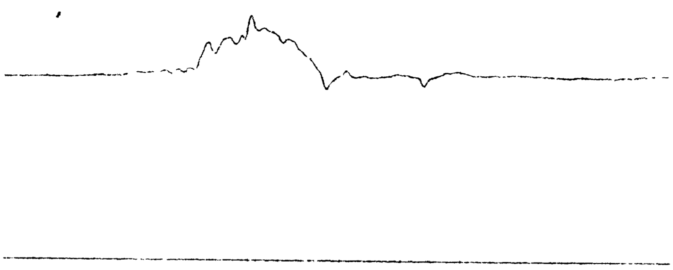
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

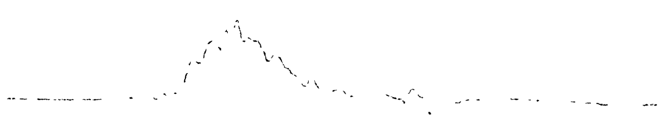
Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

 12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



SUMMARY DATA HEAD ACCELERATIONS

Test Number A-499 Test Type

Dummy 3-YEAR MODIFIED TOT-GUARD

Sled Velocity 26.9 ft/sec SIDE IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

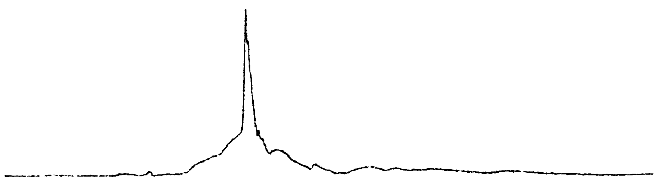
Anterior-Posterior
Head Acceleration
25.0 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
25.0 g's/division
Filtered
Class 1000

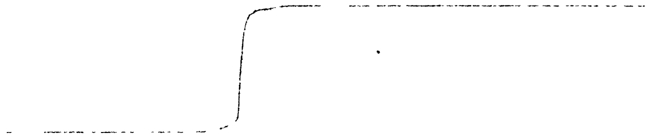
12.5 msec.

Left-Right
Head Acceleration
25.0 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
20 g's/division
Filtered
Class 1000



Severity Index
100 g²·⁵ sec/div.



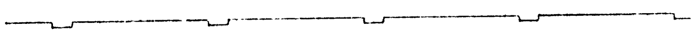
SUMMARY DATA CHEST ACCELERATIONS

Test Number A-499
Dummy 3-YEAR
Sled Velocity [illegible] ft/sec

Test Type
MODIFIED TOT-GUARD
SIDE IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

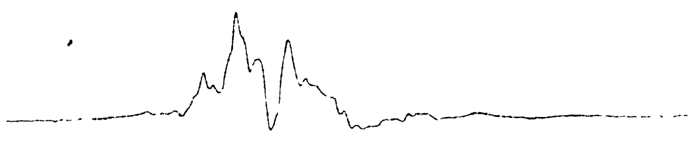
Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



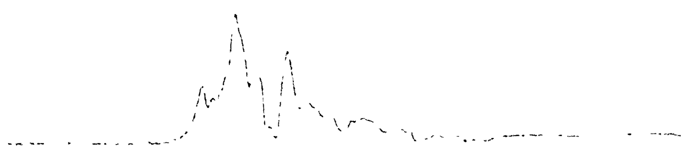
Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



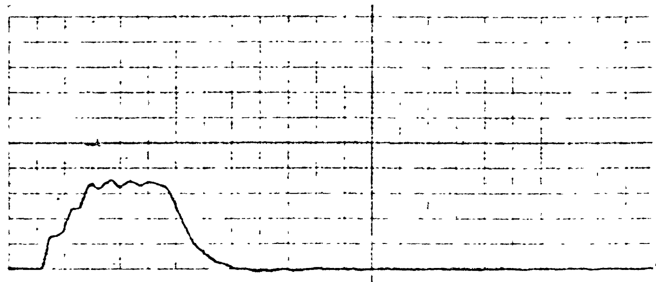
SUMMARY DATA HEAD ACCELERATIONS

Test Number A-500 Test Type STROLEE #590

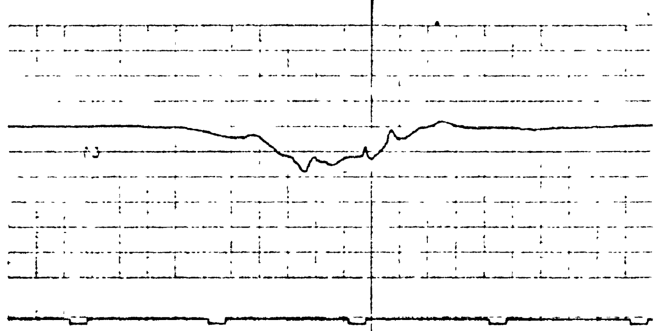
Dummy 3-YEAR

Sled Velocity 29.6 ft/sec SIDE IMPACT

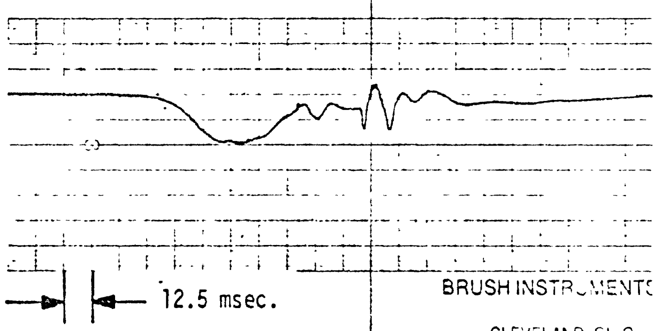
Sled Pulse
5 g's/division
Filtered
Class 60



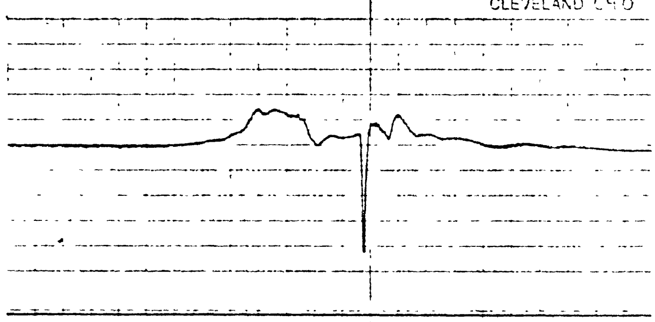
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



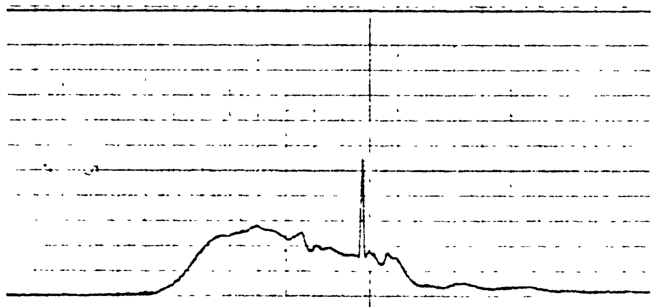
Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



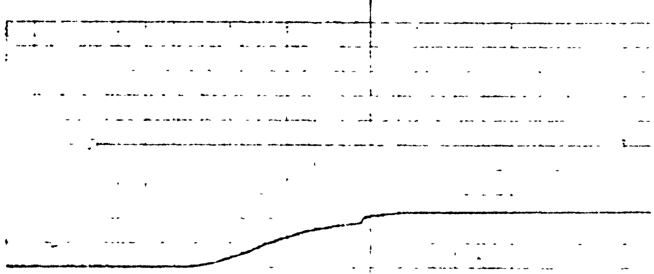
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 $g^{2.5}$ sec/div.



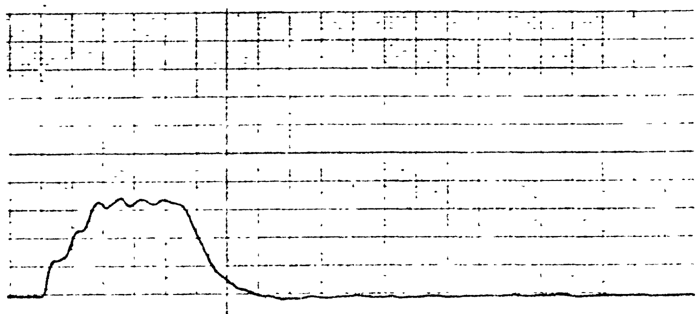
SUMMARY DATA CHEST ACCELERATIONS

Test Number A-500 Test Type STROLEE #590

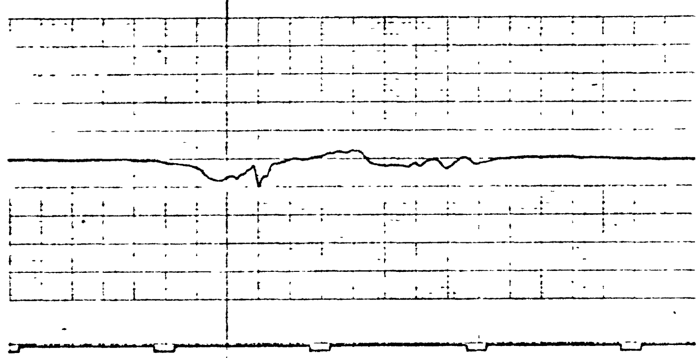
Dummy 3-YEAR

Sled Velocity 29.6 ft/sec SIDE IMPACT

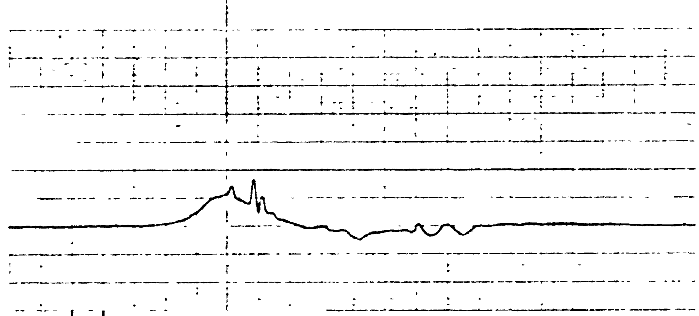
Sled Pulse
5 g's/division
Filtered
Class 60



Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

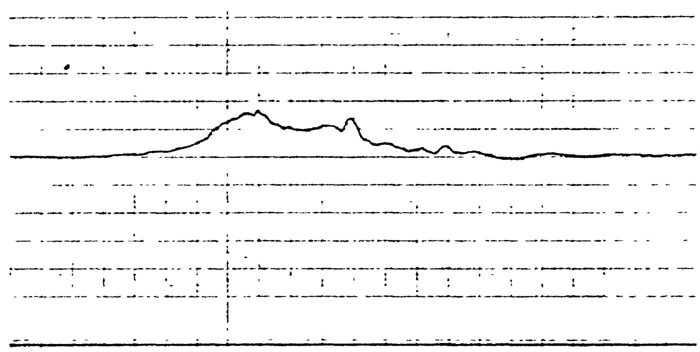


Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

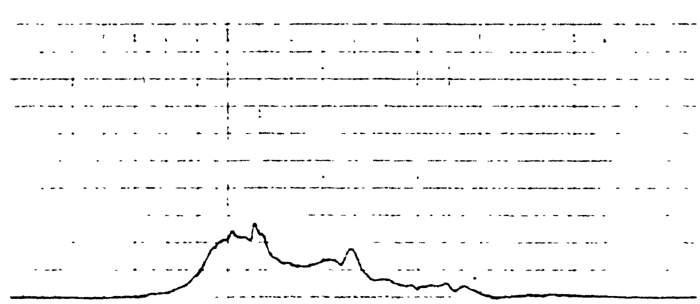


12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



SUMMARY DATA HEAD ACCELERATIONS

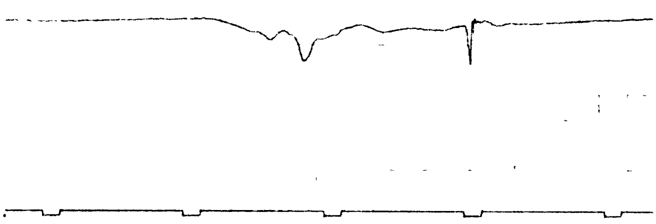
Test Number A-501 Test Type PETERSON #69

Dummy 3-YEAR

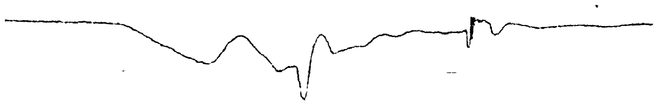
Sled Velocity [illegible] ft/sec SIDE IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

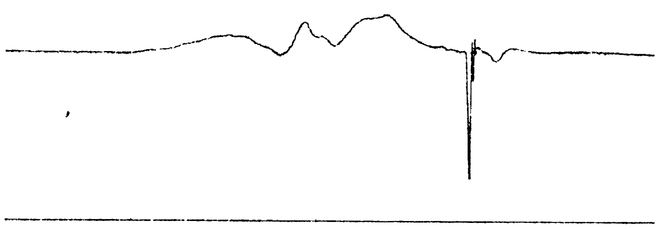


Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

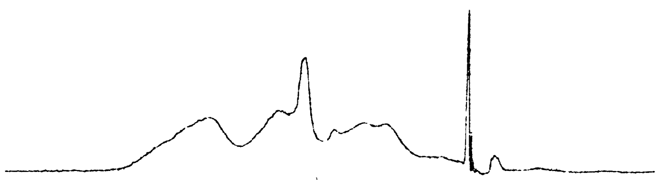


12.5 msec.

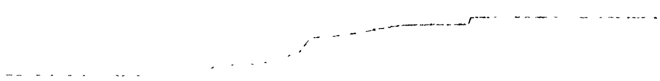
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 g sec/div.



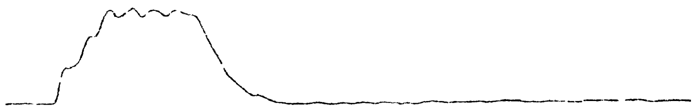
SUMMARY DATA CHEST ACCELERATIONS

Test Number A-501
Dummy 3-YEAR
Sled Velocity 30.4 ft/sec

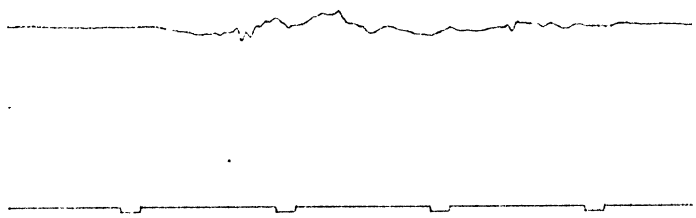
Test Type PETERSON '68

SIDE IMPACT

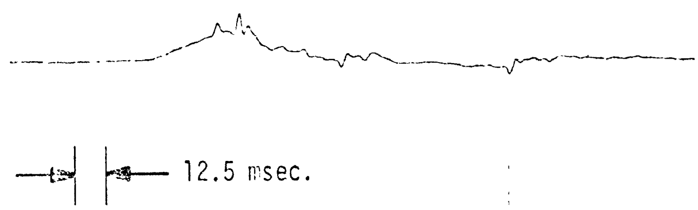
Sled Pulse
5 g's/division
Filtered
Class 60



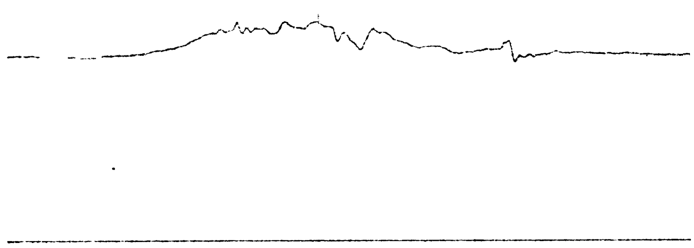
Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

SUMMARY DATA HEAD ACCELERATIONS

Test Number A-502 Test Type KANTWET #78

Dummy 3-YEAR

Sled Velocity 30.4 ft/sec SIDE IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

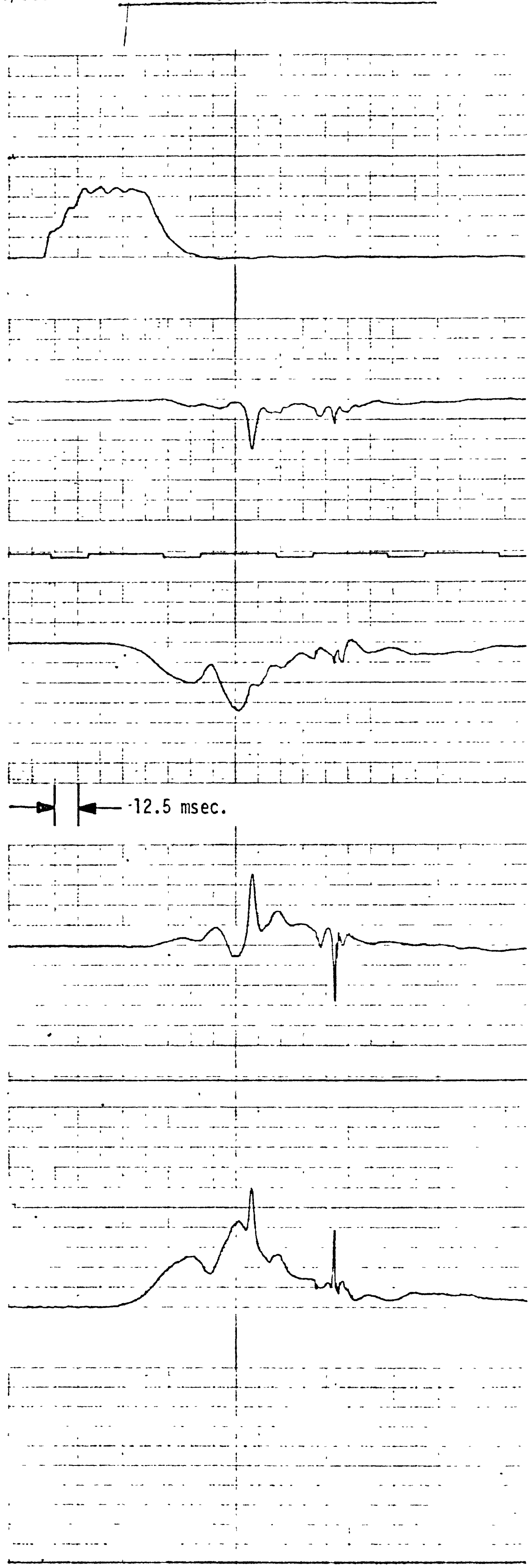
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
100 $g^{2.5}$ sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-502
Dummy 3-YEAR
Sled Velocity 30.4 ft/sec

Test Type KANTWET #78
SIDE IMPACT

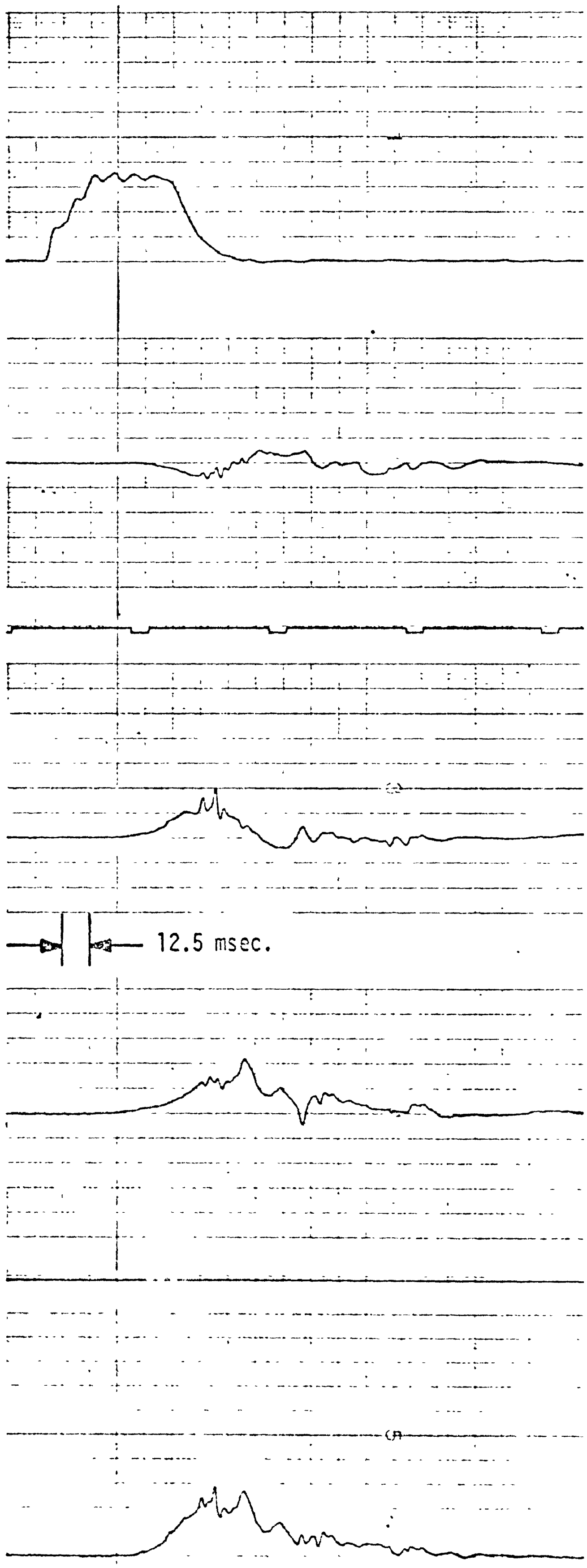
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



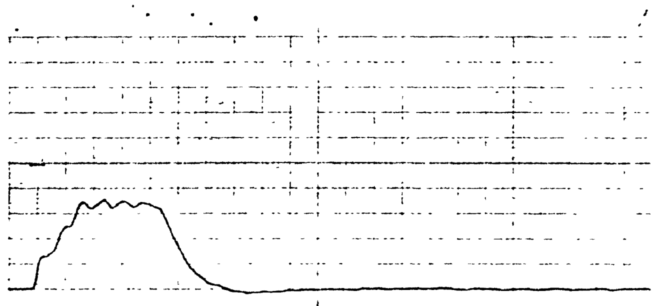
SUMMARY DATA HEAD ACCELERATIONS

Test Number A-503 | Test Type HSRI 6-YEAR

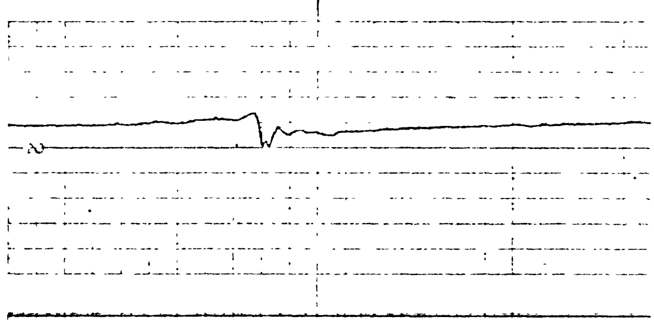
Dummy 6-YEAR

Sled Velocity 30.2 ft/sec | SIDE IMPACT

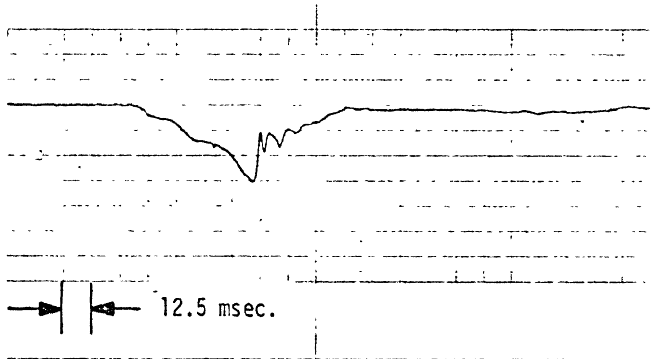
Sled Pulse
5 g's/division
Filtered
Class 60



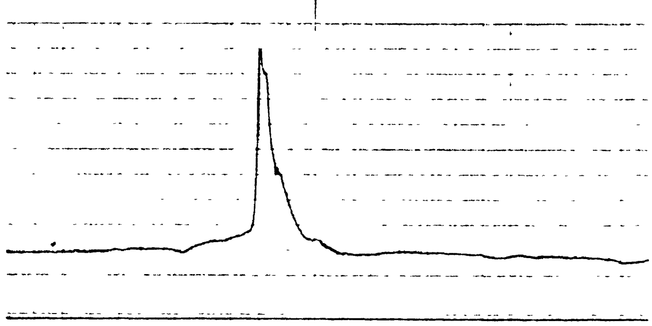
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



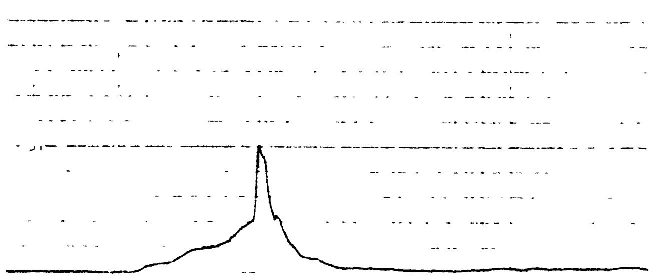
Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



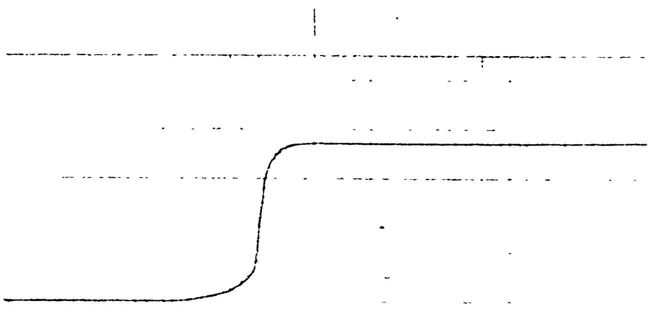
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
20 g's/division
Filtered
Class 1000



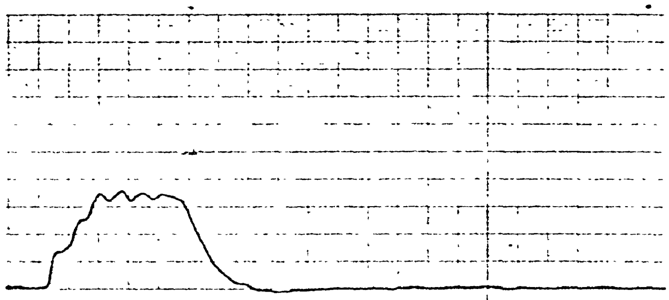
Severity Index
100 g[illegible] sec/div.



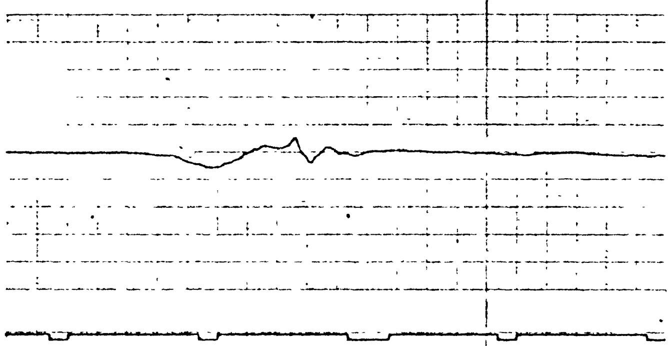
SUMMARY DATA CHEST ACCELERATIONS

Test Number *A-503* Test Type *HSRI 6-YEAR*
Dummy *6-YEAR*
Sled Velocity *30.2* ft/sec *SIDE IMPACT*

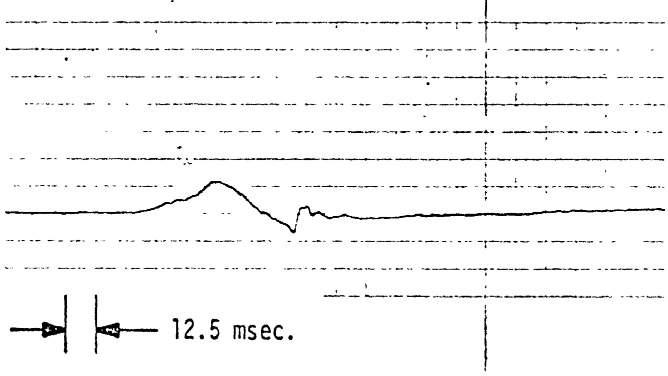
Sled Pulse
5 g's/division
Filtered
Class 60



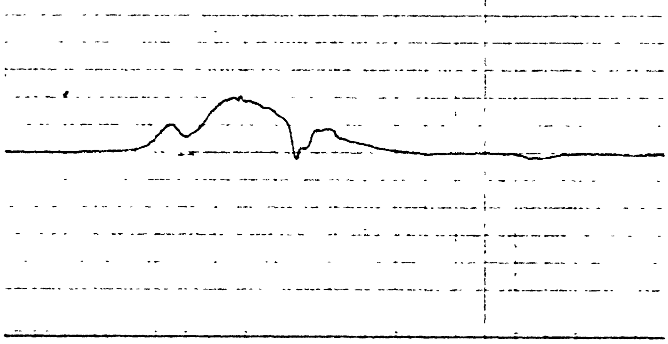
Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



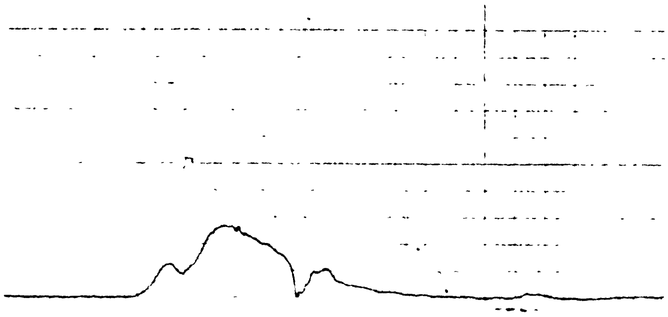
Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



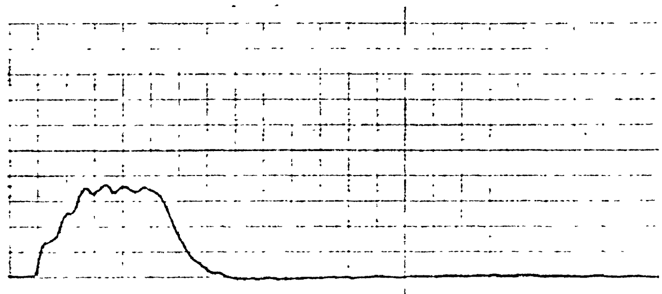
SUMMARY DATA HEAD ACCELERATIONS

Test Number A-504 Test Type TOT-GUARD

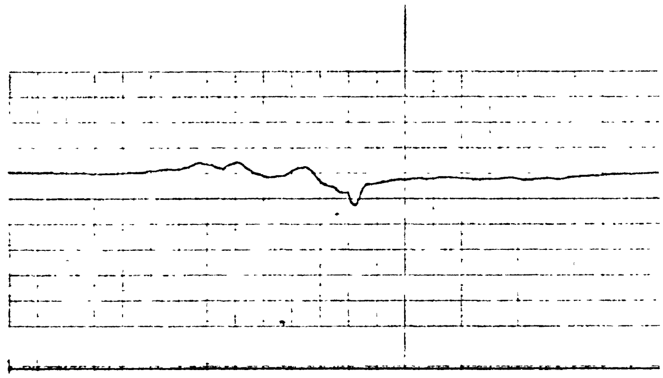
Dummy 6-YEAR

Sled Velocity 29.9 ft/sec SIDE IMPACT

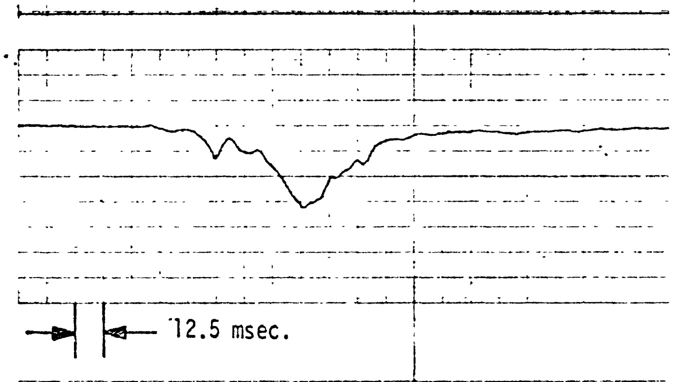
Sled Pulse
5 g's/division
Filtered
Class 60



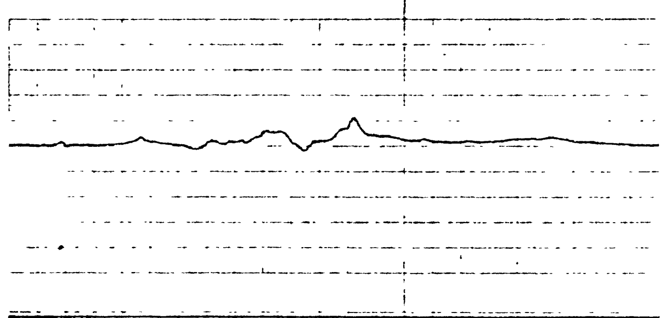
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



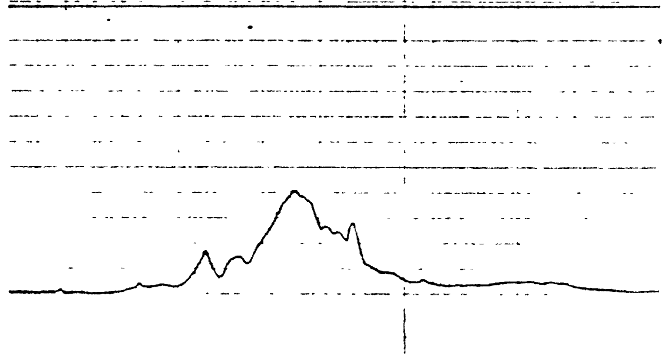
Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



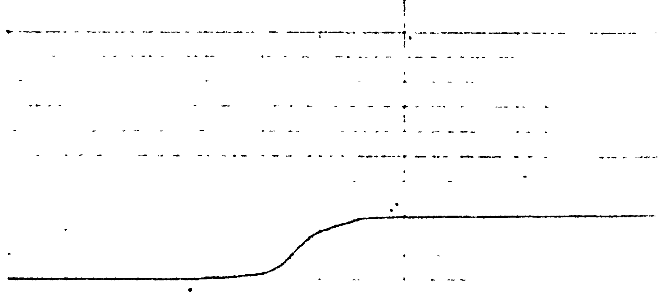
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 $g^{2.5}$ sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-504 Test Type TOT-GUARD

Dummy 6-YEAR

Sled Velocity 29.9 ft/sec SIDE IMPACT

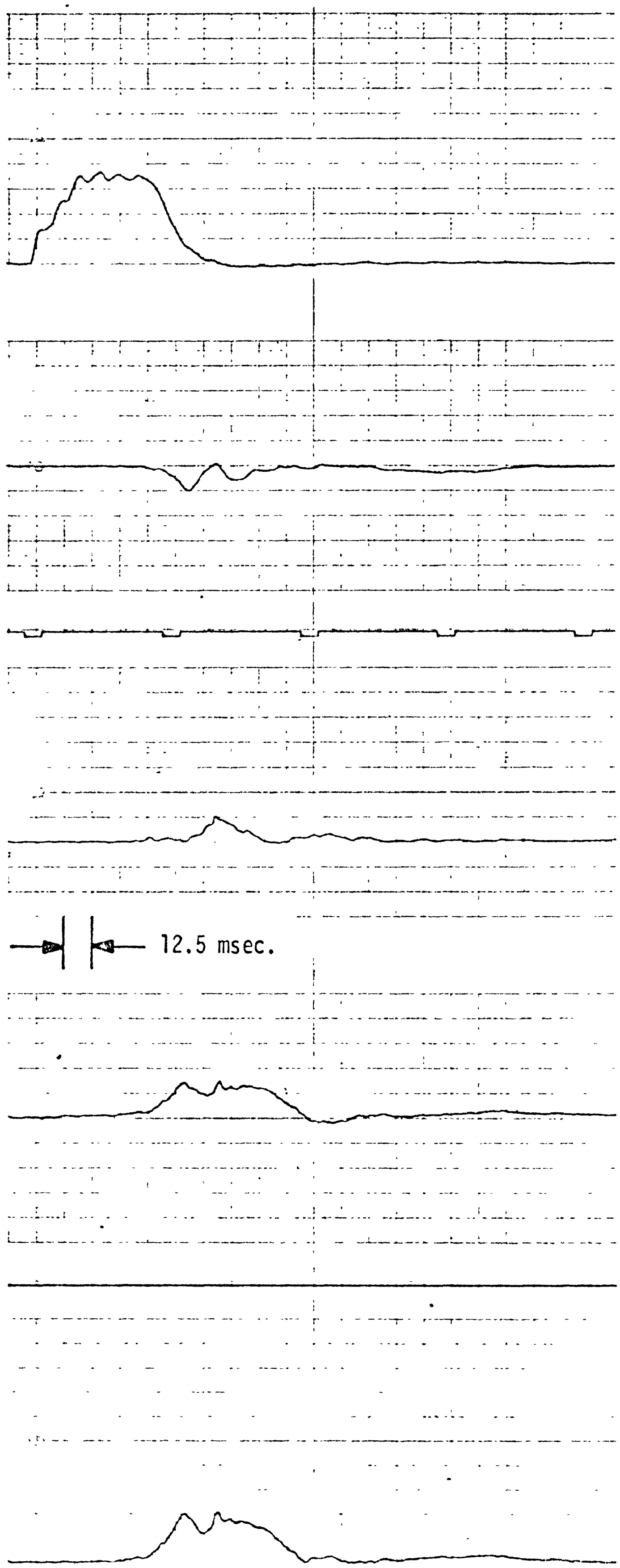
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



SUMMARY DATA HEAD ACCELERATIONS

Test Number A-505 Test Type TOT-GUARD

Dummy 6-YEAR

Sled Velocity 30.5 ft/sec FRONTAL IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

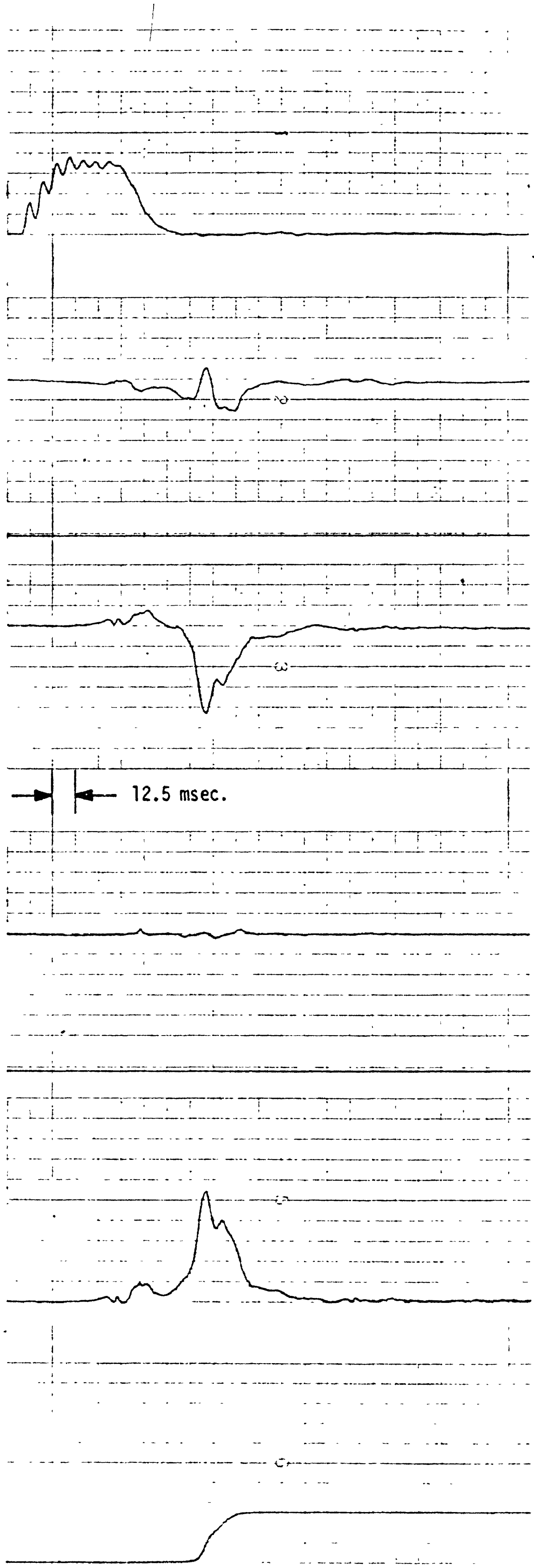
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
100 g-·· sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number *A-505* Test Type *TOT-GUARD*

Dummy *6-YEAR*

Sled Velocity *30.5* ft/sec *FRONTAL IMPACT*

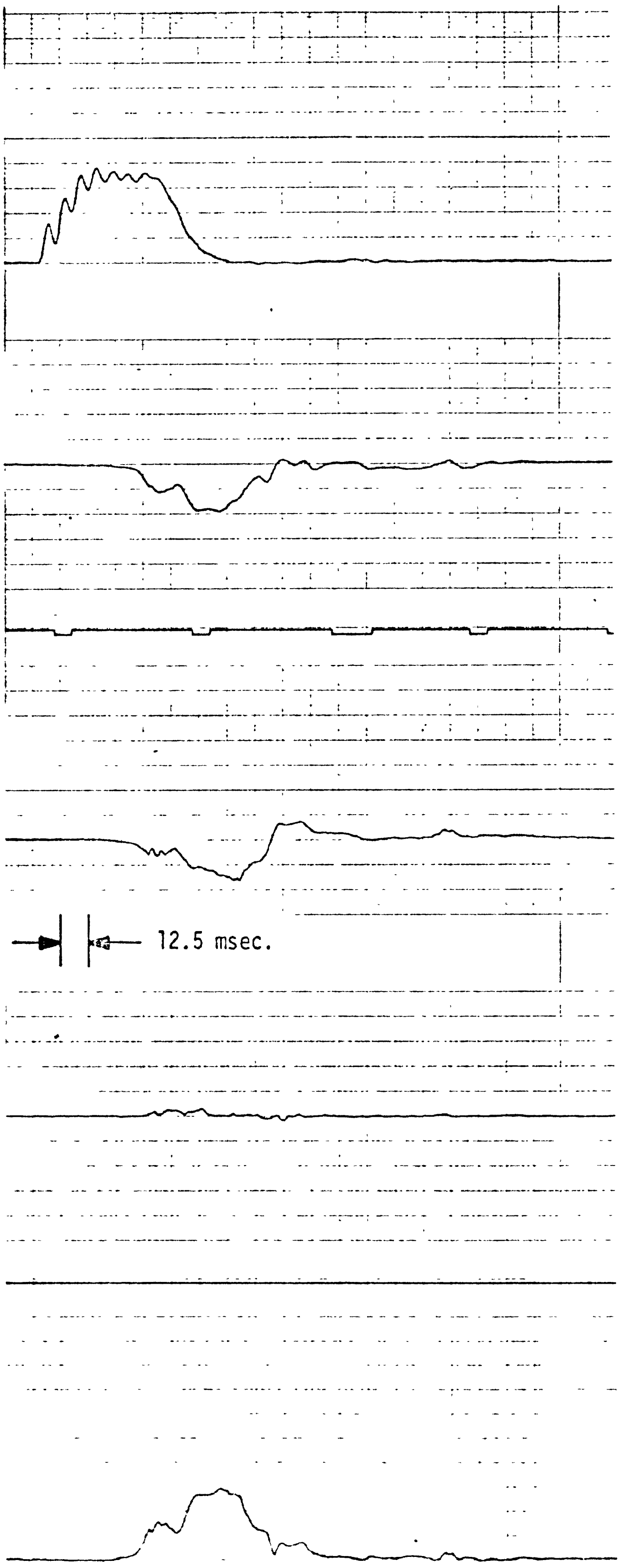
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

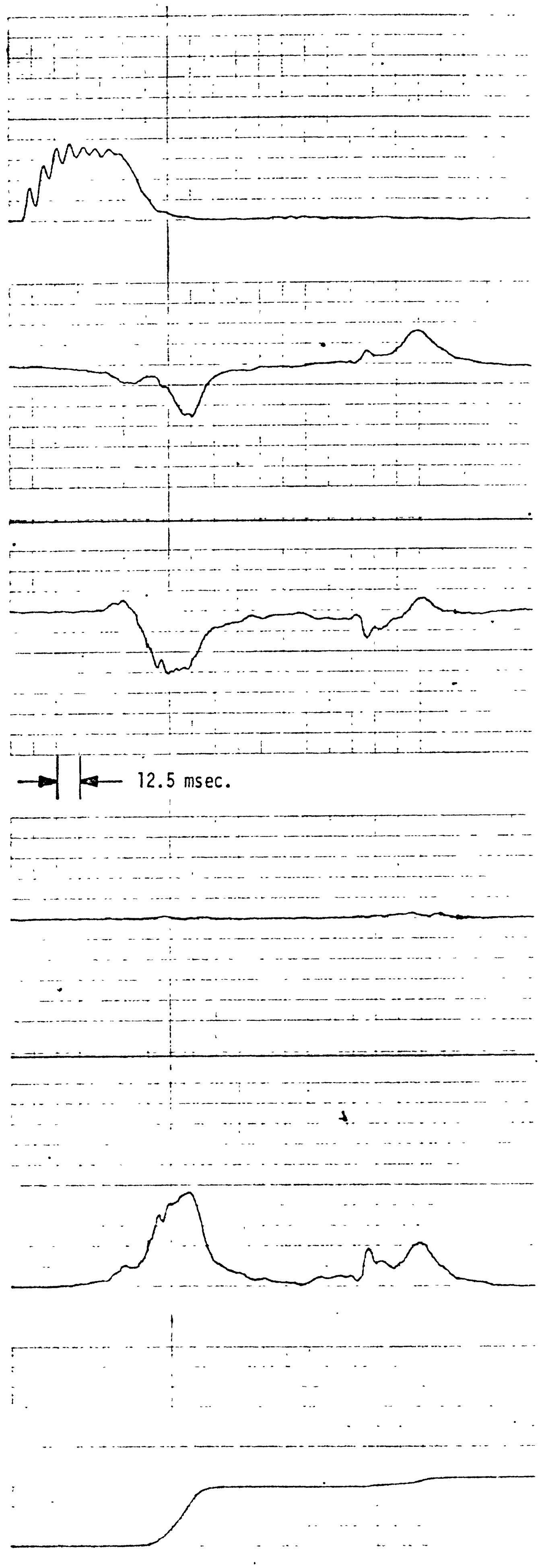


SUMMARY DATA HEAD ACCELERATIONS

Test Number 1-506 Test Type HSRI 6-YEAR

Dummy 6-YEAR

Sled Velocity 30.9 ft/sec FRONTAL IMPACT



Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

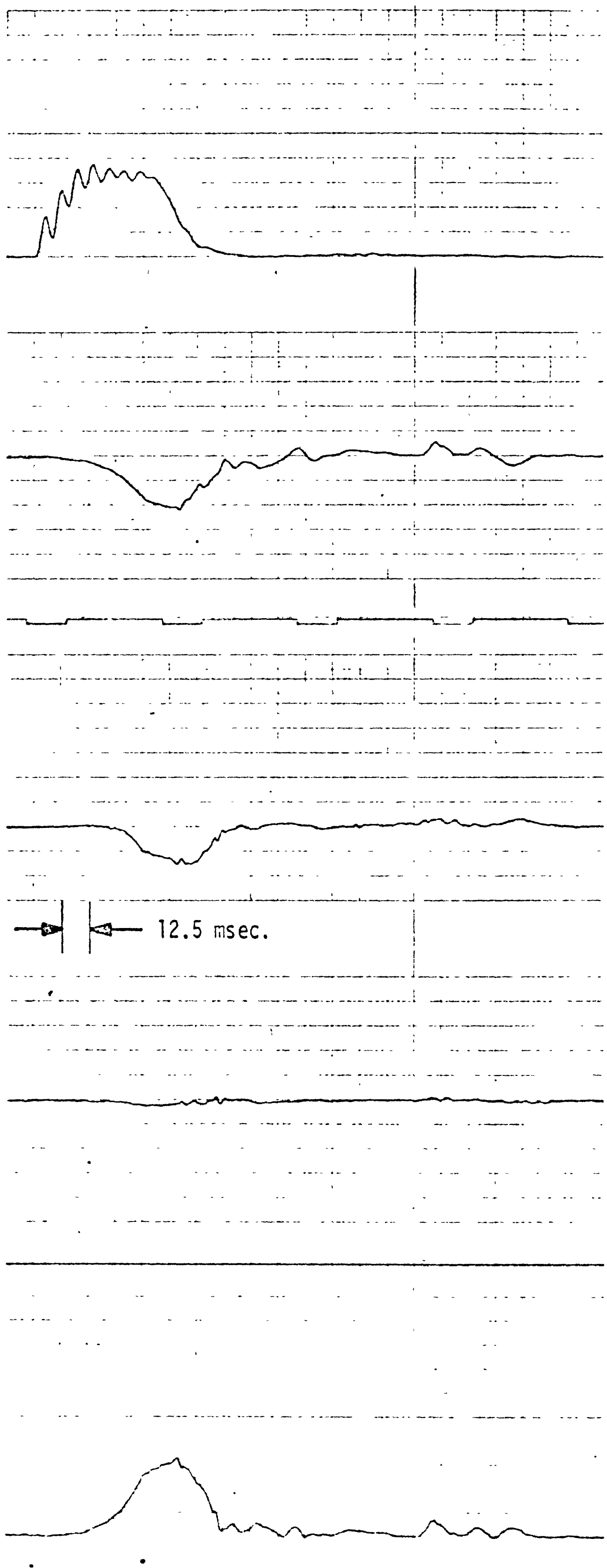
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
100 $g^{2.5}$ sec/div.

SUMMARY DATA CHEST ACCELERATIONS

Test Number A-506 Test Type HSRI 6-YEAR
Dummy 6-YEAR FRONTAL IMPACT
Sled Velocity 30.7 ft/sec



Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

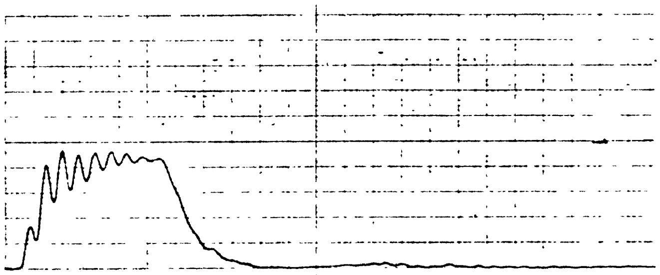
SUMMARY DATA HEAD ACCELERATIONS

Test Number A-507 Test Type HSRI 6-YEAR

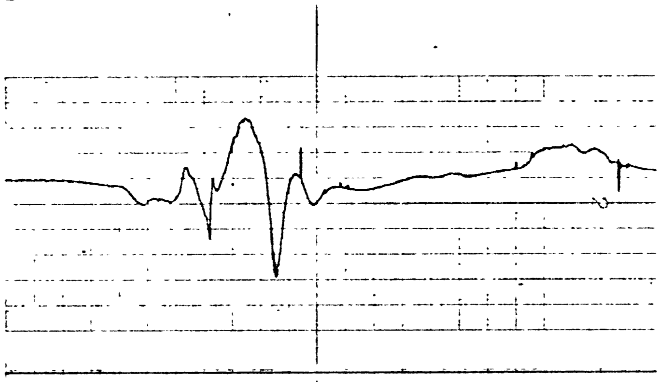
Dummy 6-YEAR

Sled Velocity 45.7 ft/sec FRONTAL IMPACT

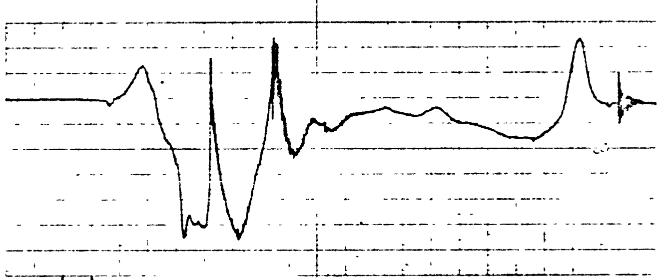
Sled Pulse
5 g's/division
Filtered
Class 60



Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

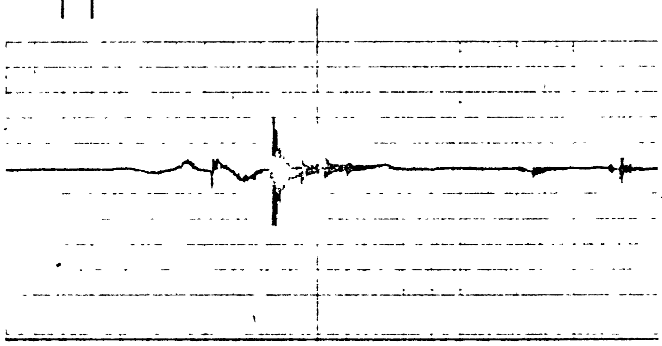


Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

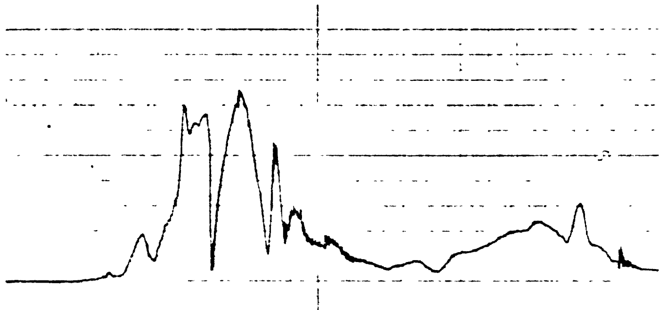


12.5 msec.

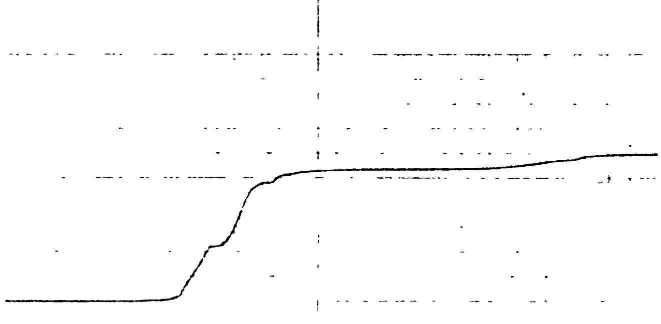
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
200 $g^{2.5}$ sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number *A-507*
Dummy *6-YEAR*
Sled Velocity *4[illegible].7* ft/sec

Test Type *HSRI 6-YEAR*
FRONTAL IMPACT

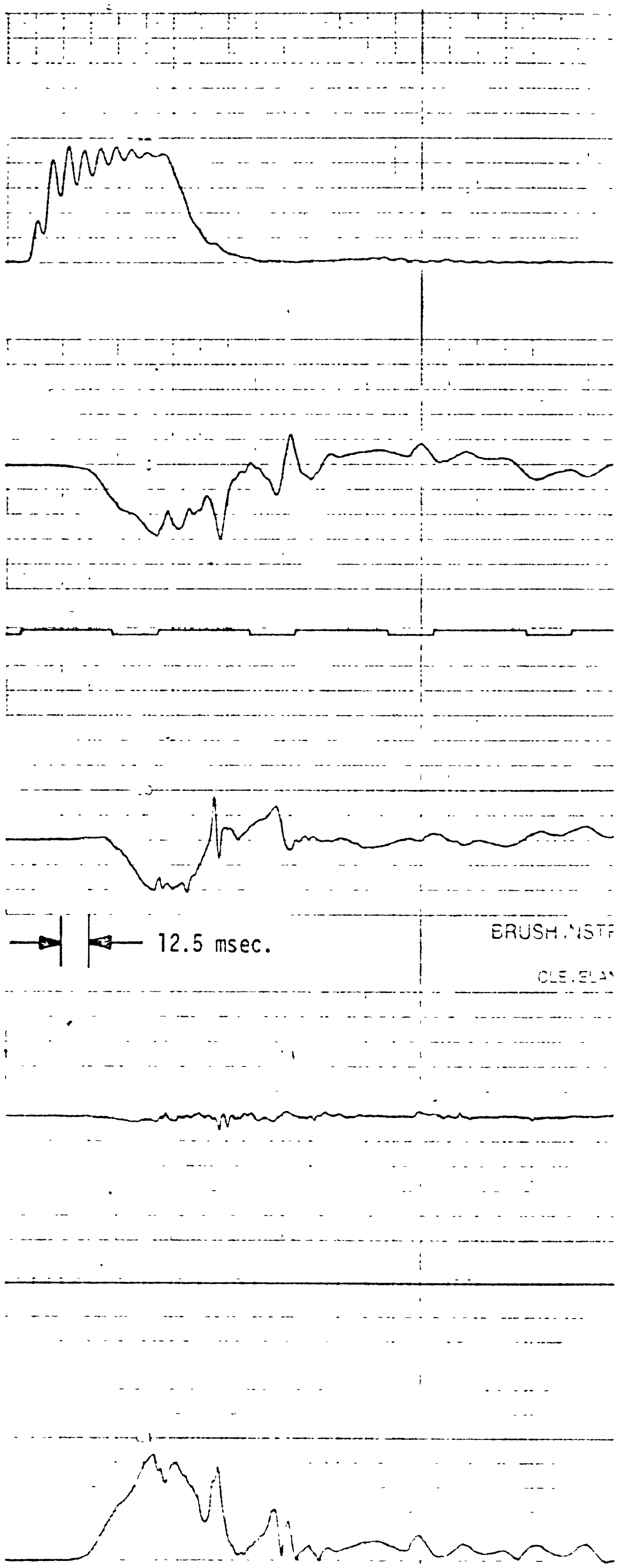
Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



SUMMARY DATA HEAD ACCELERATIONS

Test No. A-008 Test Type HSRI 4-YEAR

Dummy 3-YEAR

Sled Velocity 30.0 ft/sec FRONTAL IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

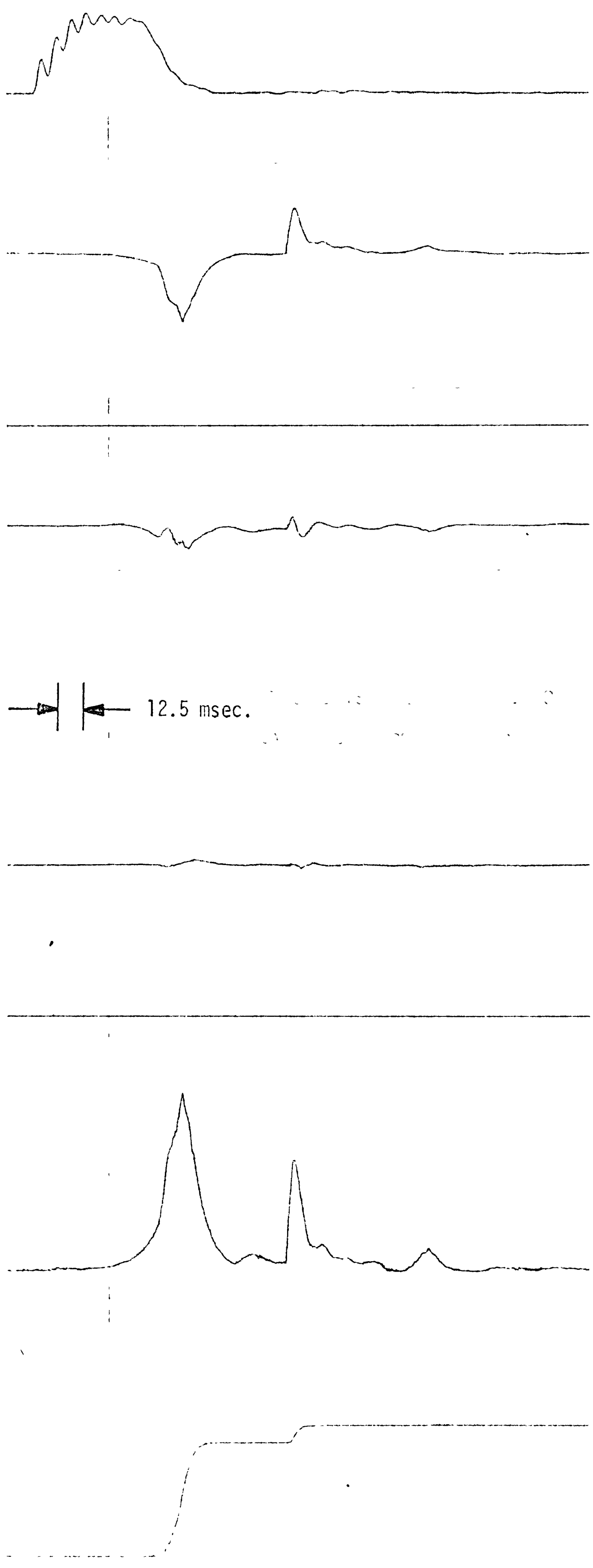
Anterior-Posterior
Head Acceleration
25.0 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
25.0 g's/division
Filtered
Class 1000

Left-Right
Head Acceleration
25.0 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

Severity Index
100 g [illegible] sec/div.



L.

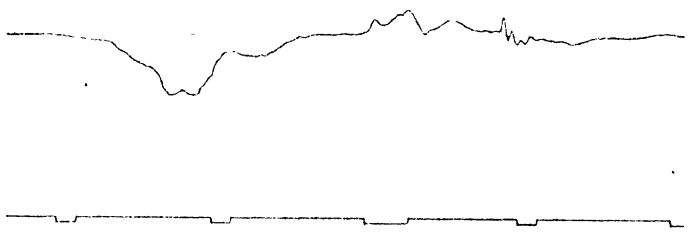
SUMMARY DATA CHEST ACCELERATIONS

Test Number A-500
Dummy [illegible]
Sled Velocity [illegible] ft/sec

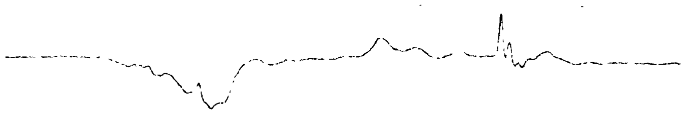
Test Type [illegible] 4-YEAR
FRONTAL IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

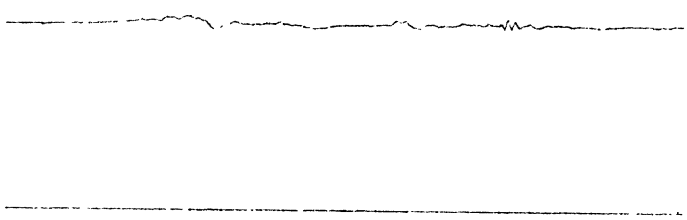


Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



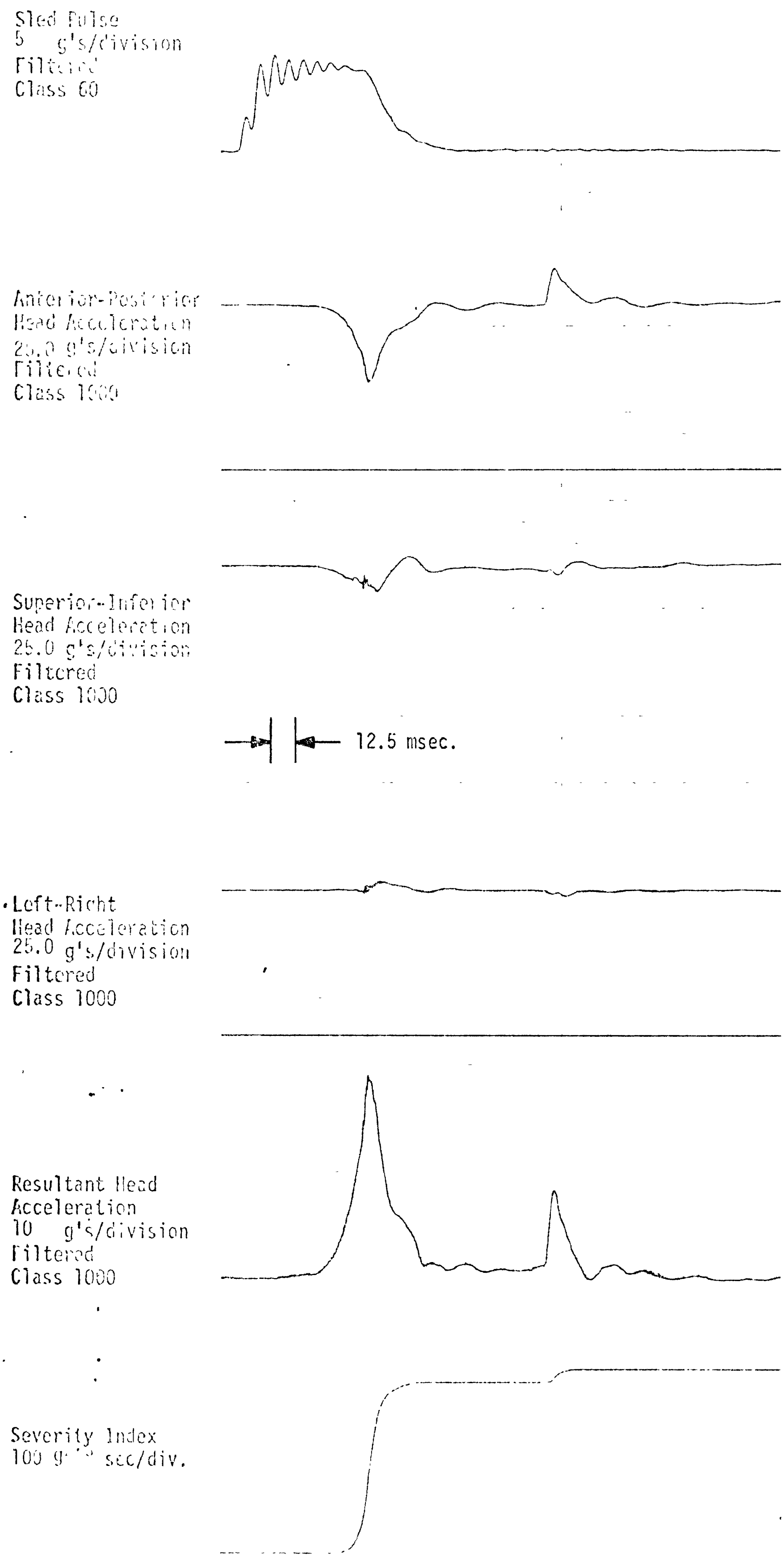
Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

SUMMARY DATA HEAD ACCELERATIONS

Test Number A-509 Test Type HSRI 4-YEAR

Dummy 3-YEAR

Sled Velocity 44.5 ft/sec FRONTAL IMPACT



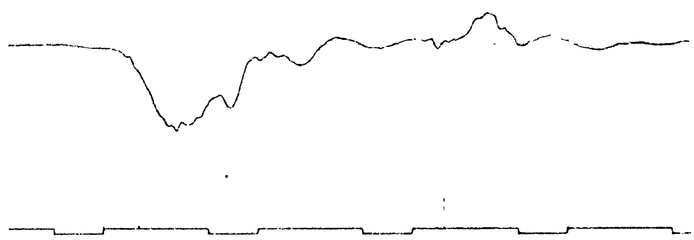
SUMMARY DATA CHEST ACCELERATIONS

Test Number [illegible]
Dummy [illegible]
Sled Velocity [illegible] ft/sec

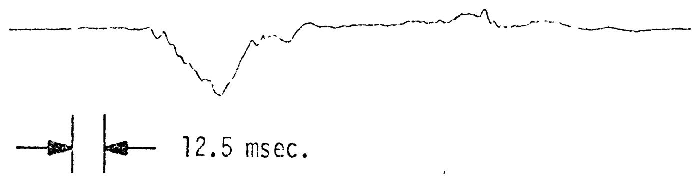
Test Type MSCI 4-YEAR
FRONTAL IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

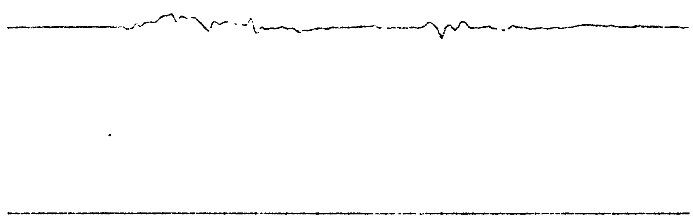


Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

SUMMARY DATA HEAD ACCELERATIONS

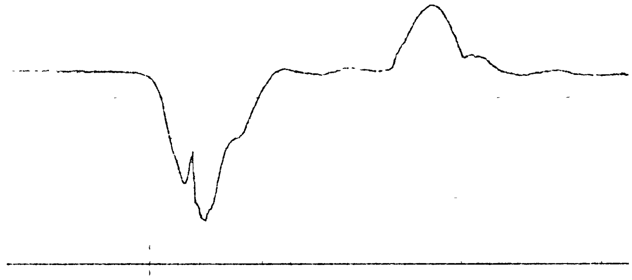
Test Number A-511 | Test Type MODIFIED TOT-GUARD FRONTAL IMPACT

Dummy 3-YEAR

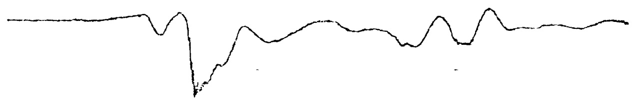
Sled Velocity 44.0 ft/sec

Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

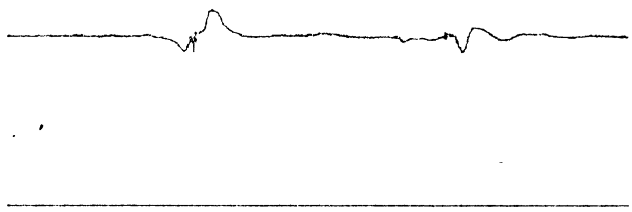


Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

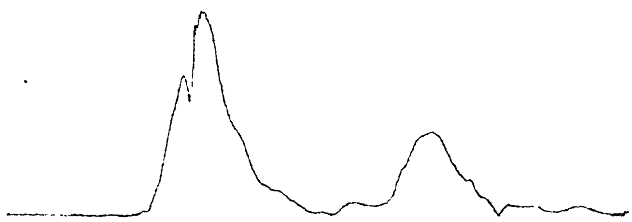


12.5 msec.

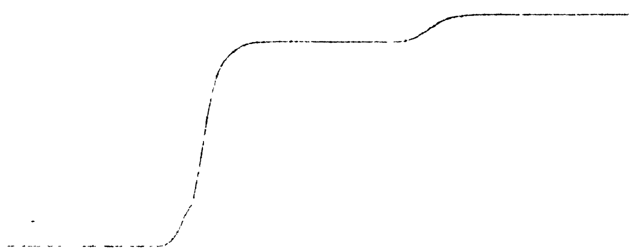
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 g [illegible] sec/div.



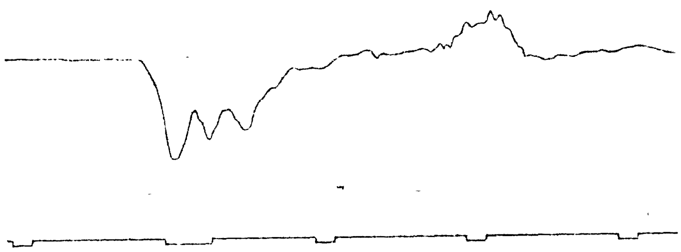
SUMMARY DATA CHEST ACCELERATIONS

Test Number [illegible]-511
Dummy [illegible]
Sled Velocity 44.0 ft/sec

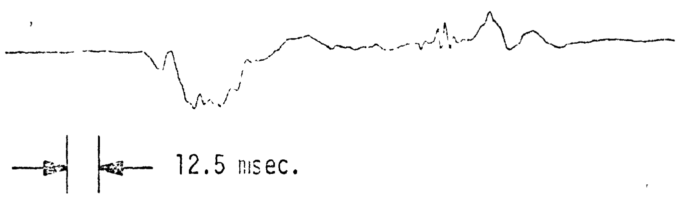
Test Type
MODIFIED [illegible]
FRONTAL IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

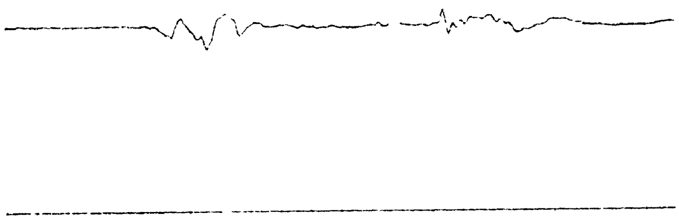


Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

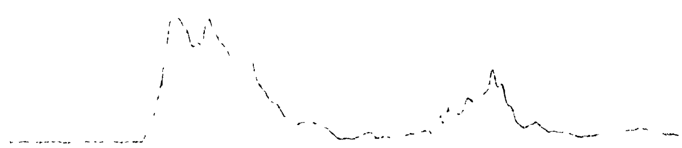


12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

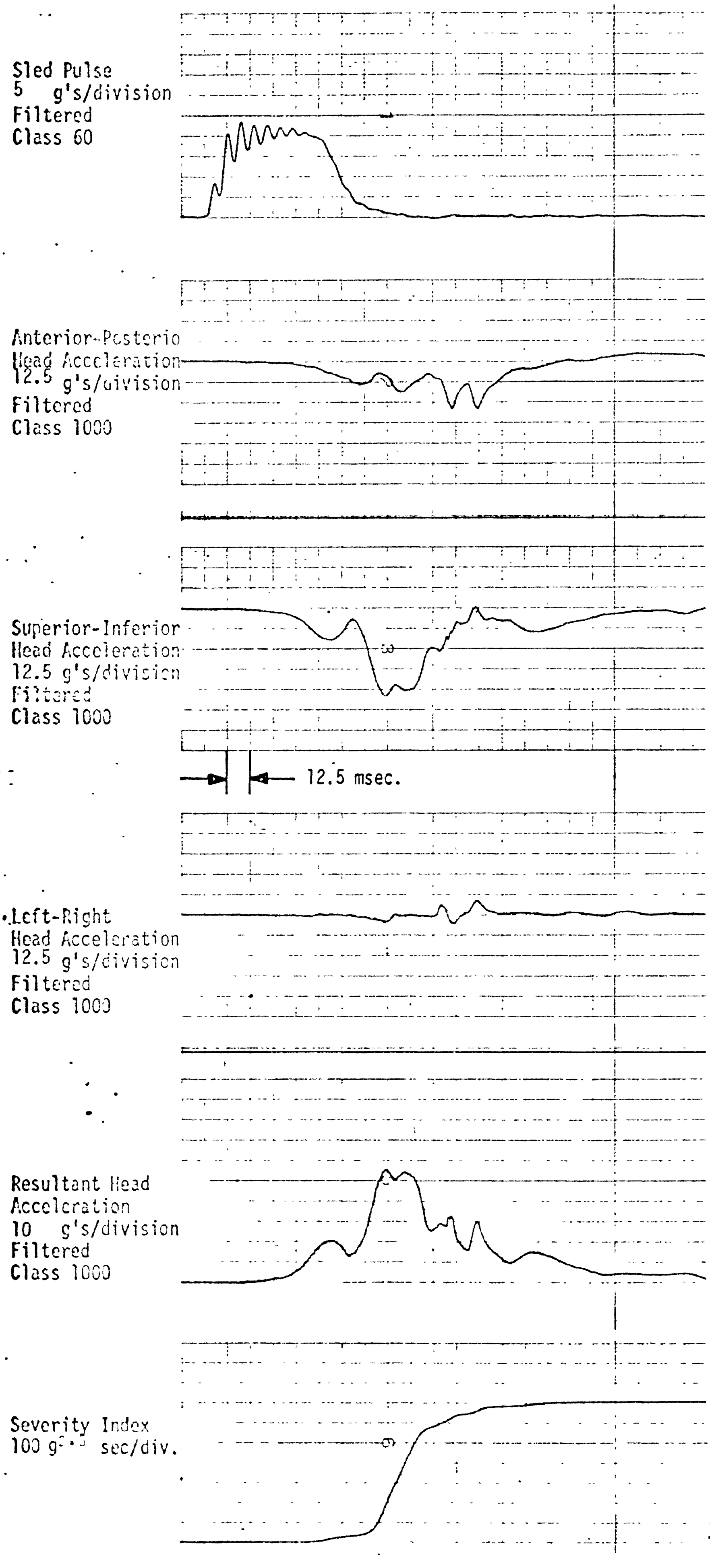


SUMMARY DATA HEAD ACCELERATIONS

Test Number A-5/3 | Test Type STROLEE #590

Dummy 3-YEAR

Sled Velocity 43.5 ft/sec | FRONTAL IMPACT (0/3 POSITION)



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-5/13

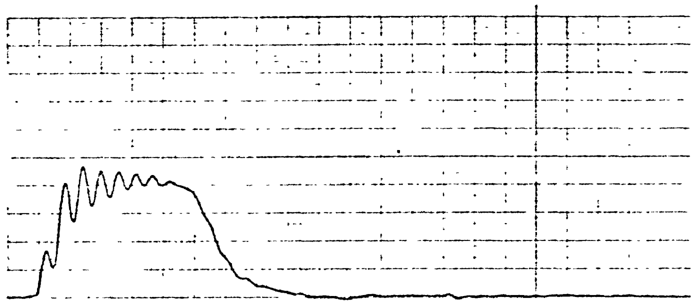
Dummy 3-YEAR

Sled Velocity 43.5 ft/sec

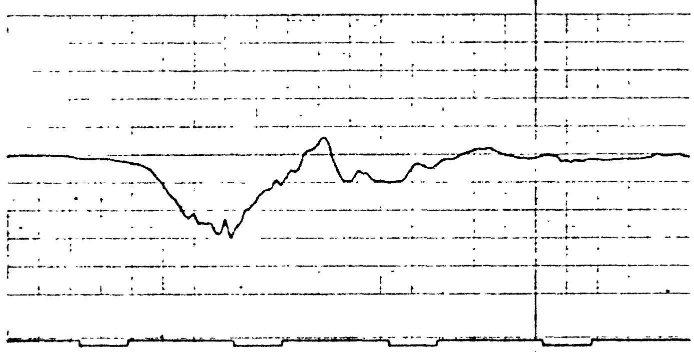
Test Type STROLEE #590

FRONTAL IMPACT (O/B) POSITION)

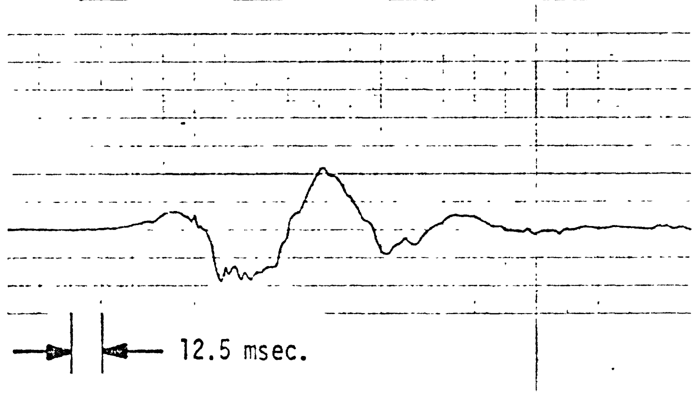
Sled Pulse
5 g's/division
Filtered
Class 60



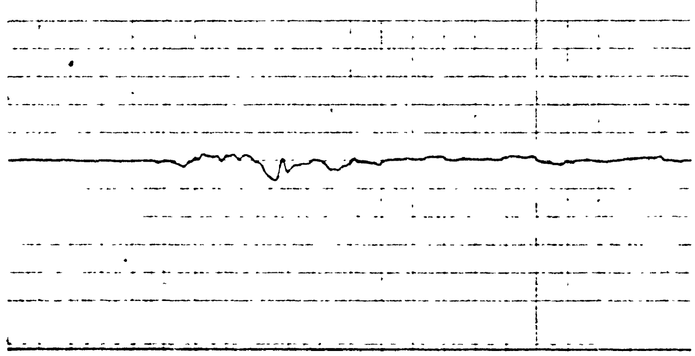
Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



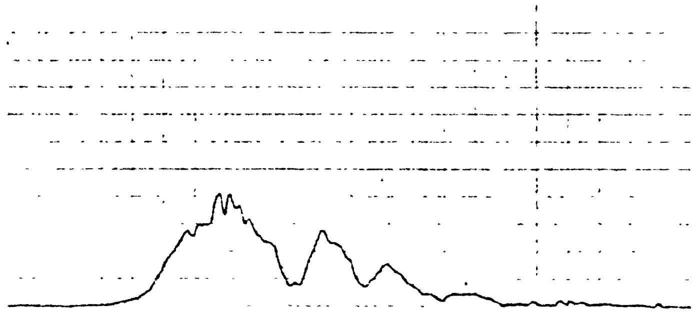
Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



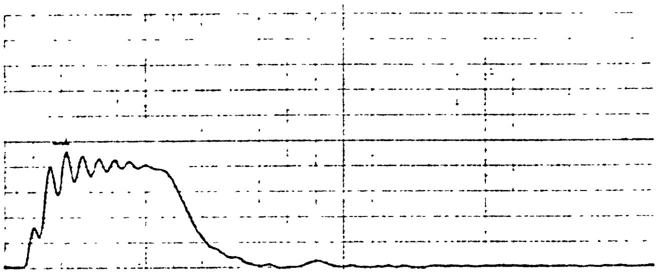
SUMMARY DATA HEAD ACCELERATIONS

Test Number A-514 Test Type TOT-GUARD

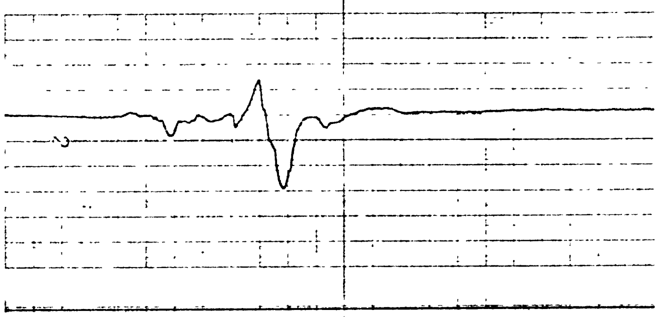
Dummy 6-YEAR

Sled Velocity 43.9 ft/sec FRONTAL IMPACT

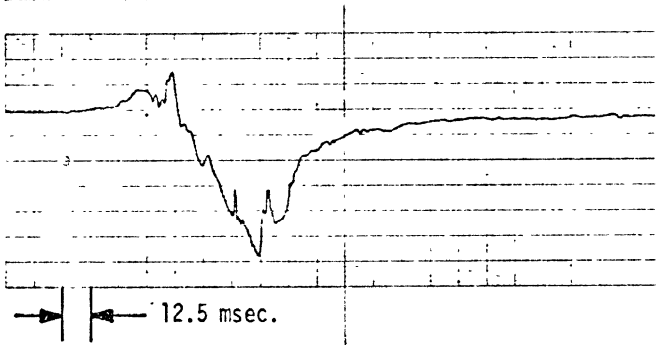
Sled Pulse
5 g's/division
Filtered
Class 60



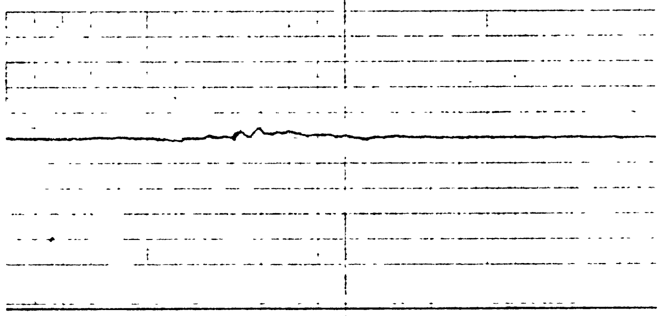
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



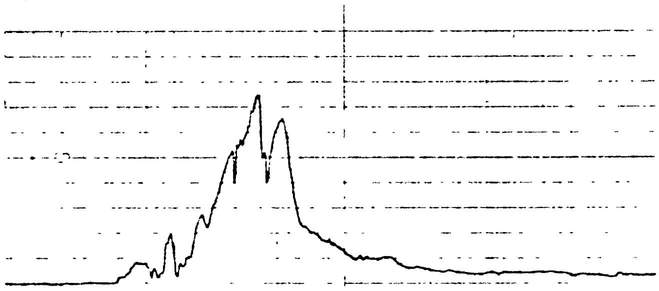
Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



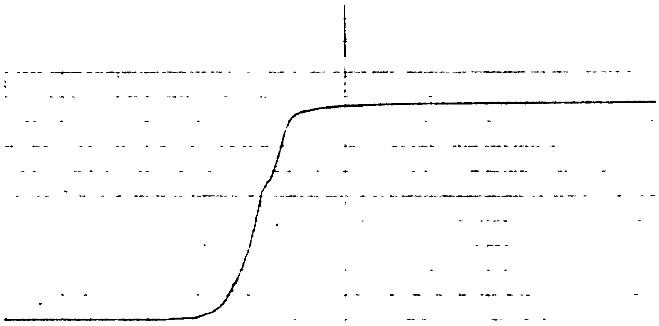
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 g ²·⁵ sec/div.



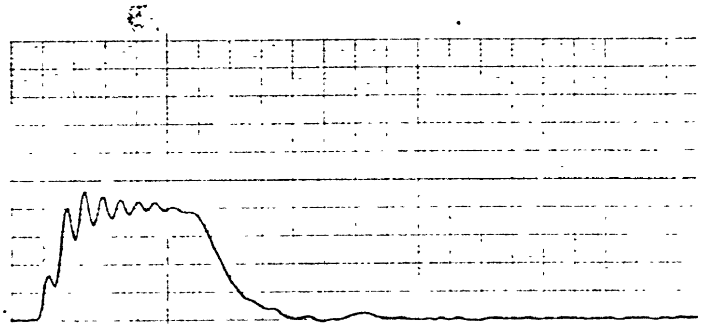
SUMMARY DATA CHEST ACCELERATIONS

Test Number A-514 | Test Type TOT-GUARD FRONTAL IMPACT

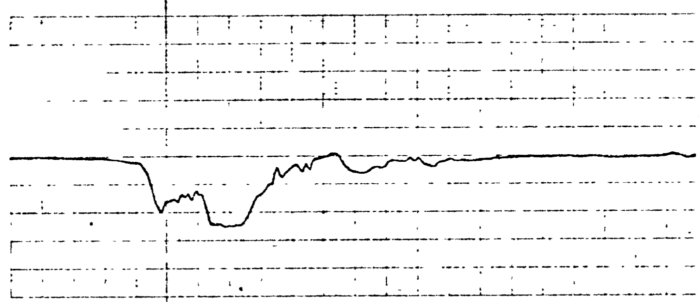
Dummy 6-YEAR

Sled Velocity 43.9 ft/sec

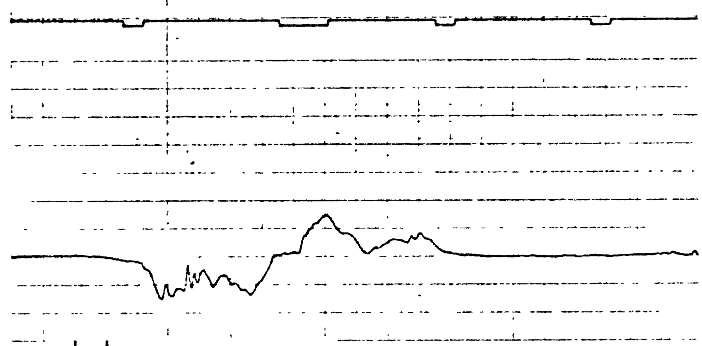
Sled Pulse
5 g's/division
Filtered
Class 60



Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

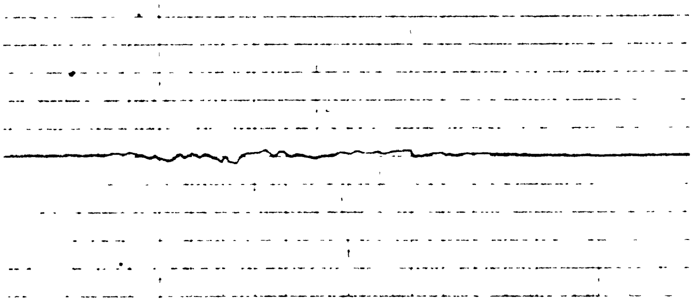


Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

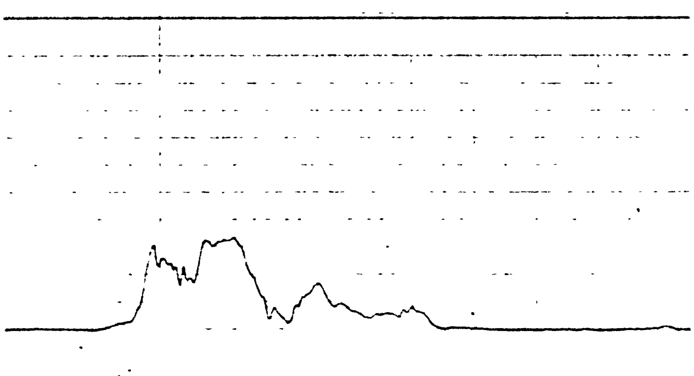


12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

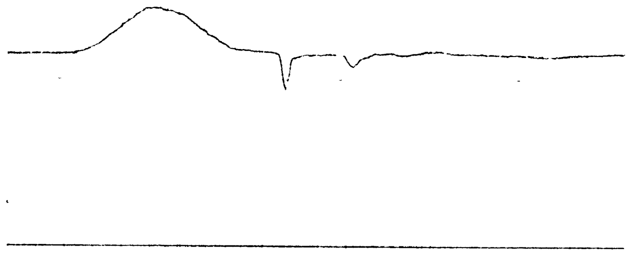


SUMMARY DATA HEAD ACCELERATIONS

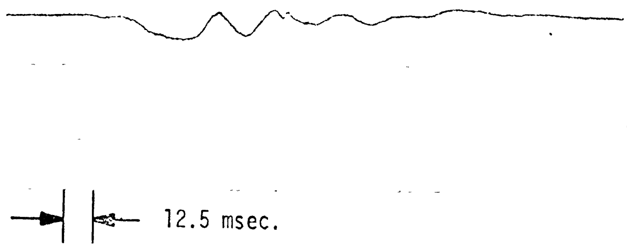
Test Number A-516 Test Type
Dummy 3-YEAR MODIFIED TOT-GUARD
Sled Velocity 29.6 ft/sec REAR IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

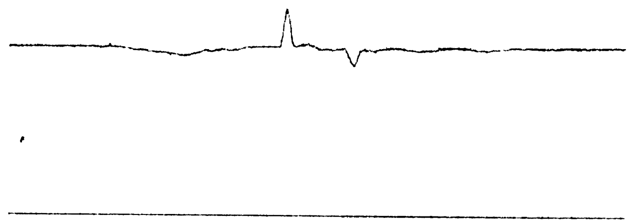
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



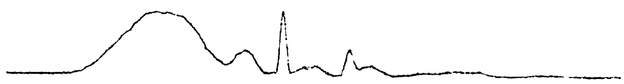
Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000



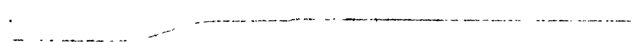
Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000



Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000



Severity Index
100 g - sec/div.



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-516

Dummy [illegible]

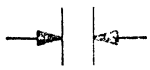
Sled Velocity [illegible] ft/sec

Test Type MODIFIED T[illegible] GUARD [illegible] IMPACT

Sled Pulse
5 g's/division
Filtered
Class 60

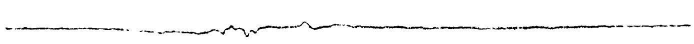
Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

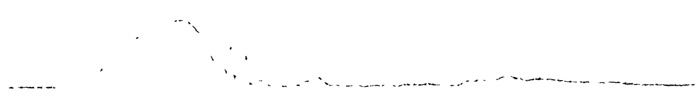


12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



SUMMARY DATA HEAD ACCELERATIONS

Test Number A-600 Test Type STROLEE 590

Dummy SIERRA 3 YEAR FRONT IMPACT

Sled Velocity 44.0 ft/sec

Sled Pulse
10 g's/division
Filtered
Class 60

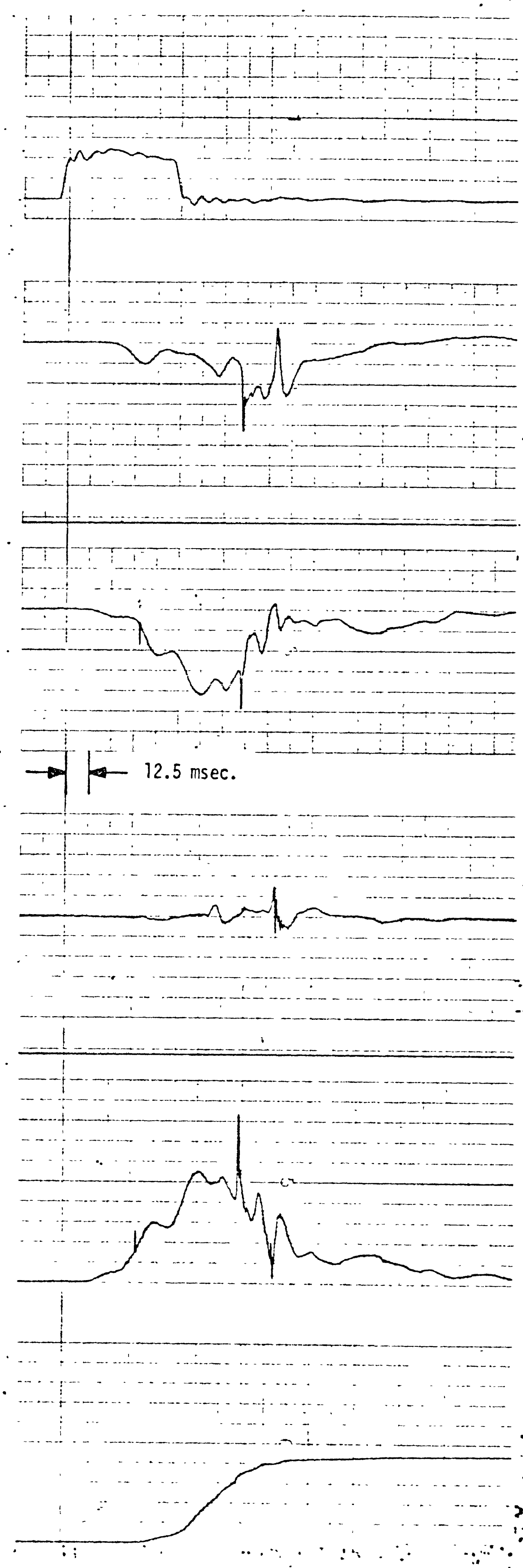
Anterior-Posterior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Superior-Inferior
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Left-Right
Head Acceleration
12.5 g's/division
Filtered
Class 1000

Resultant Head
Acceleration
10 g's/division
Filtered
Class 1000

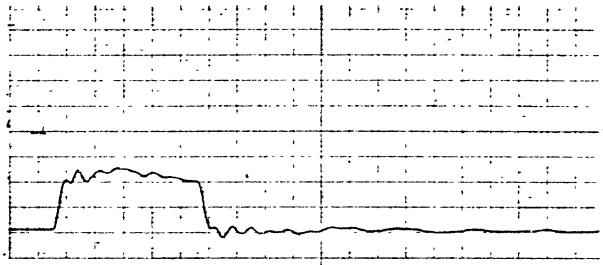
Severity Index
200 $g^{2.5}$ sec/div.



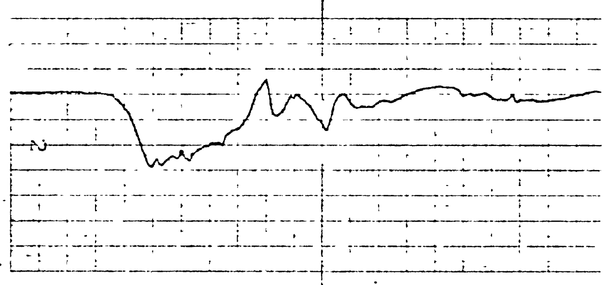
SUMMARY DATA CHEST ACCELERATIONS

Test Number A-600 | Test Type STROLLER 590
Dummy SIERRA 3 YEAR | FRONT IMPACT
Sled Velocity 44.0 ft/sec

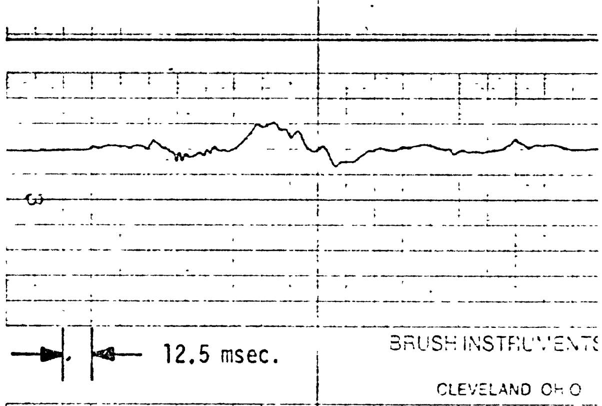
Sled Pulse
10 g's/division
Filtered
Class 60



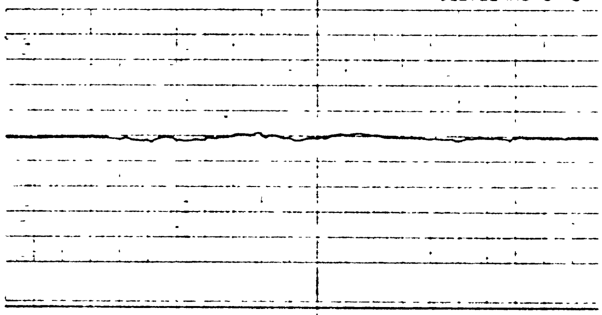
Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



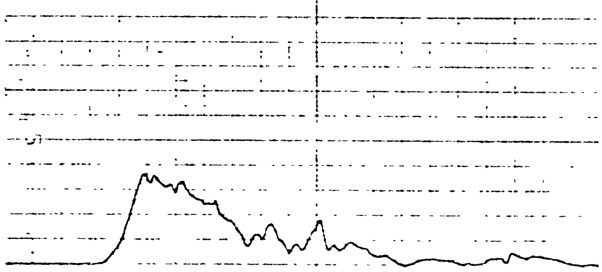
Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600

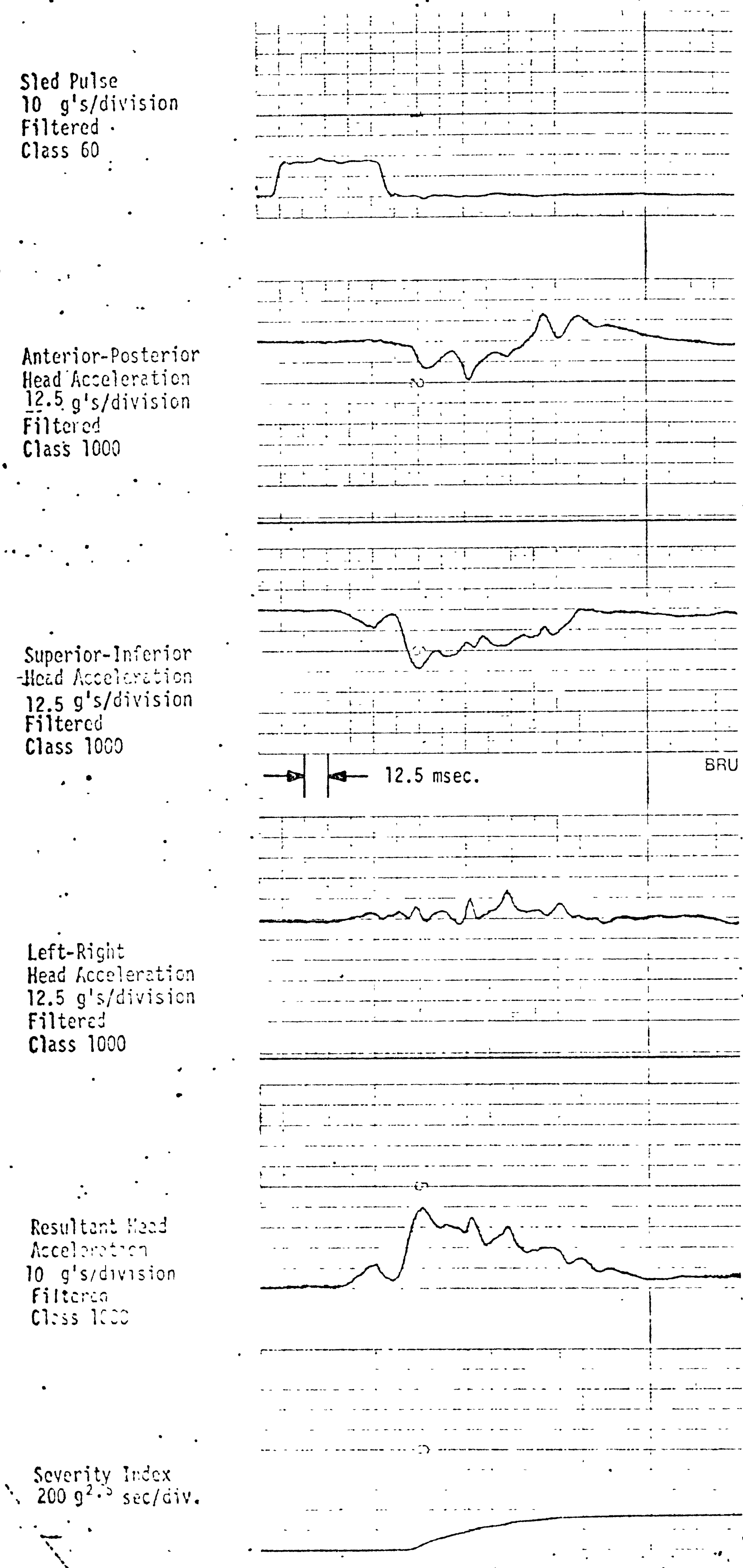


SUMMARY DATA HEAD ACCELERATIONS

Test Number A-601 Test Type STROLEE 590

Dummy SIERRA 3 YEAR SIDE IMPACT

Sled Velocity 30.5 ft/sec



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-601

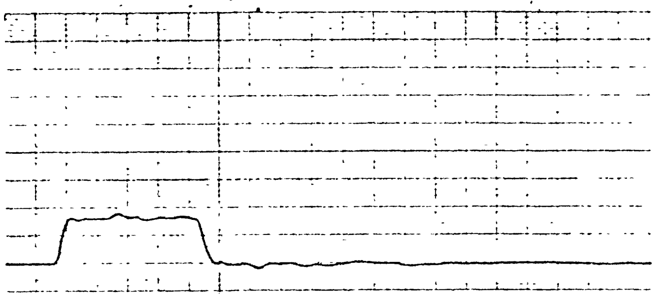
Dummy [illegible] YEAR

Sled Velocity [illegible] ft/sec

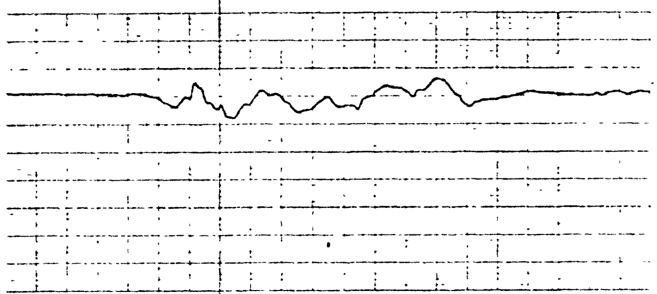
Test Type [illegible] 590

SIDE IMPACT

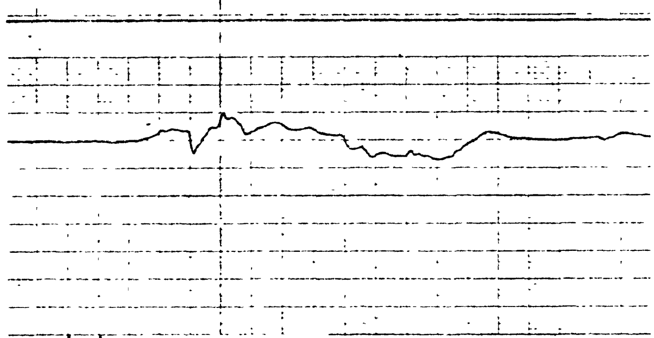
Sled Pulse
10 g's/division
Filtered
Class 60



Anterior-Posterior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

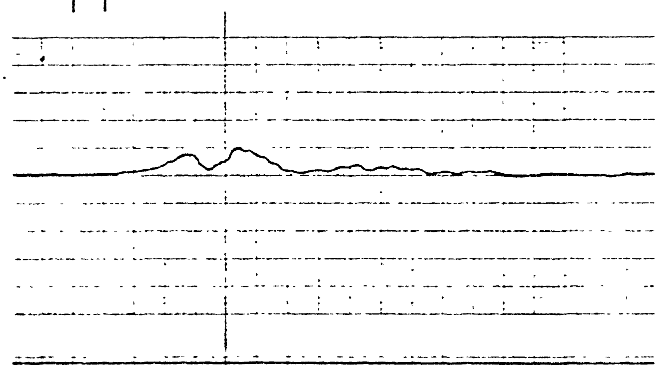


Superior-Inferior
Chest Acceleration
12.5 g's/division
Filtered
Class 600

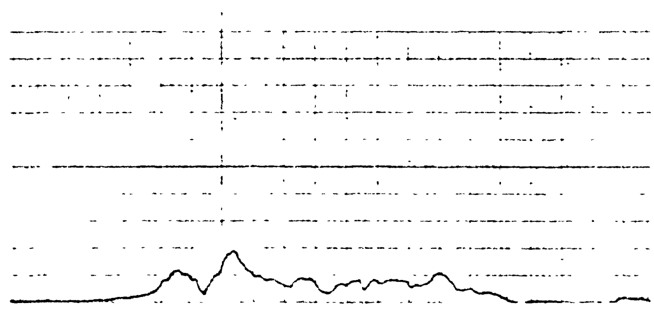


12.5 msec.

Left-Right
Chest Acceleration
12.5 g's/division
Filtered
Class 600



Resultant Chest
Acceleration
10 g's/division
Filtered
Class 600



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-606 Test Type PETERSON CHILD SEAT
Dummy SIERRA 3 YR SIDE IMPACT
Sled Velocity 29.1 ft/sec

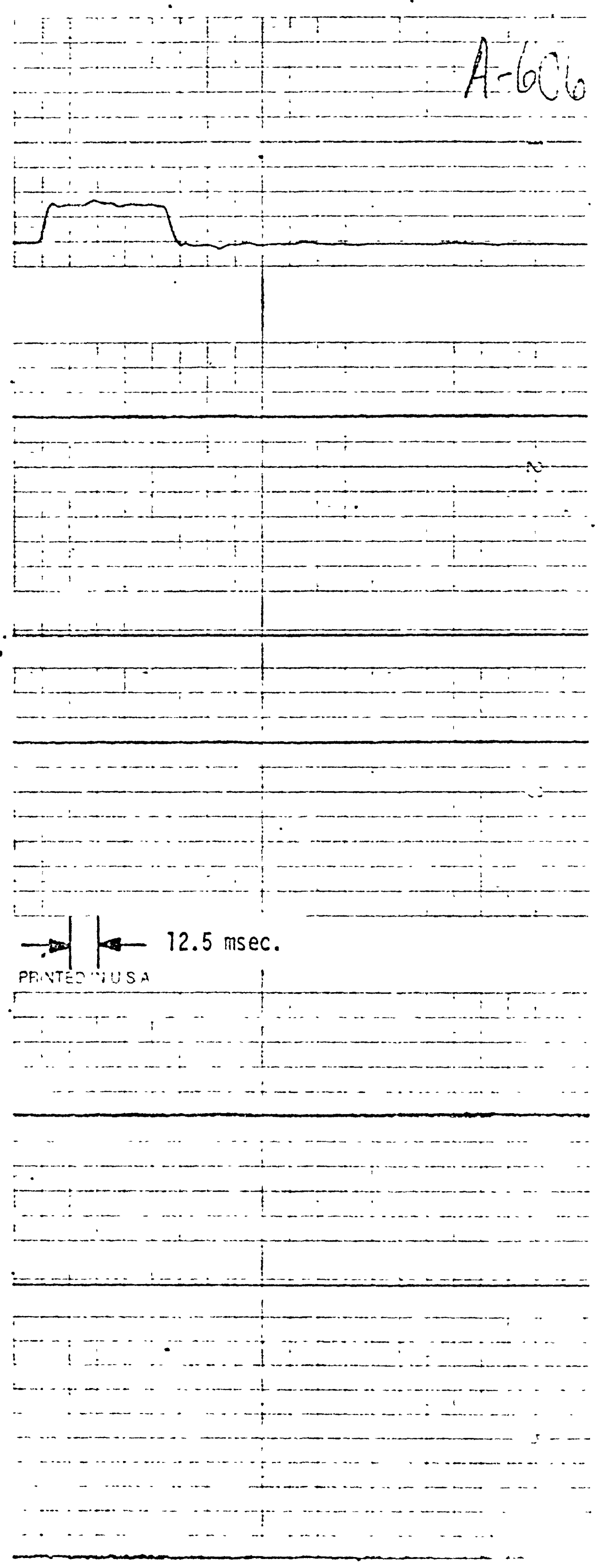
Sled Pulse
10 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
g's/division
Filtered
Class 600

Resultant Chest
Acceleration
g's/division
Filtered
Class 600



SUMMARY DATA CHEST ACCELERATIONS

Test Number A-607 Test Type PETERSON CHILD SEAT
Dummy SIERRA 3 YEAR FRONT IMPACT
Sled Velocity 43.8 ft/sec

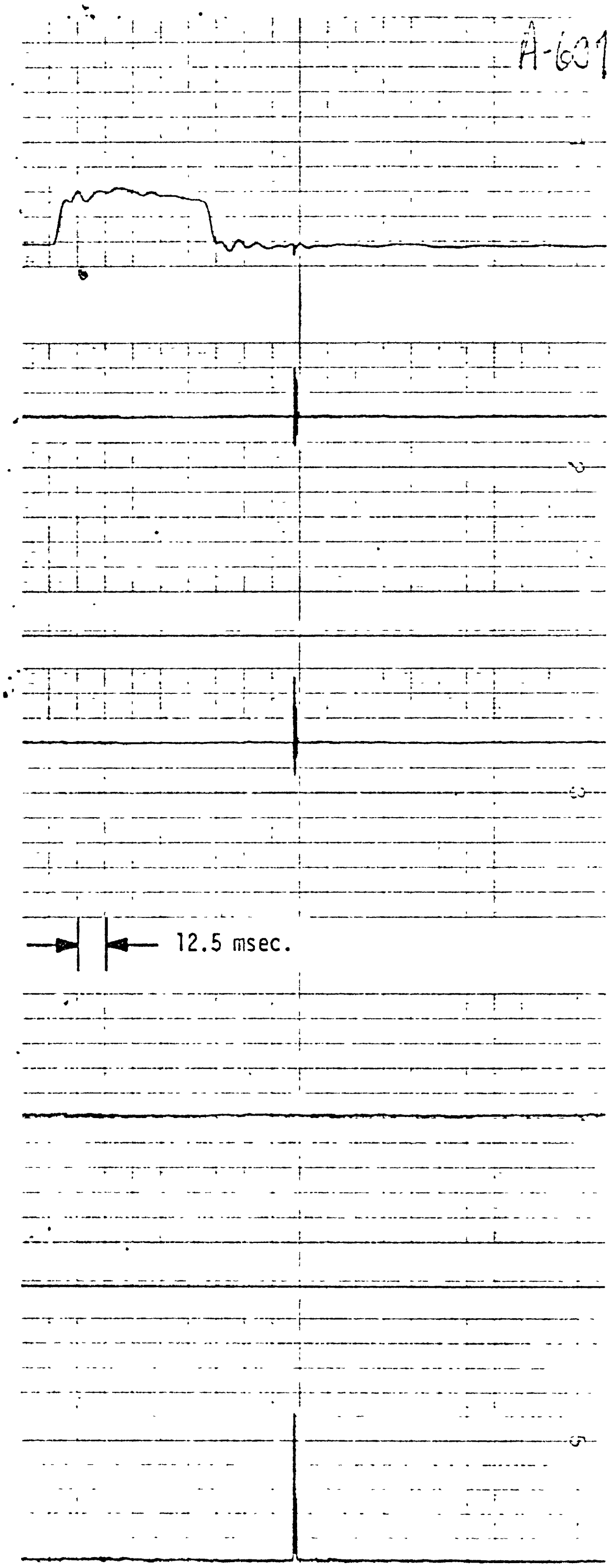
Sled Pulse
10 g's/division
Filtered
Class 60

Anterior-Posterior
Chest Acceleration
g's/division
Filtered
Class 600

Superior-Inferior
Chest Acceleration
g's/division
Filtered
Class 600

Left-Right
Chest Acceleration
g's/division
Filtered
Class 600

Resultant Chest
Acceleration
g's/division
Filtered
Class 600



APPENDIX B ANALYSIS OF FRAMING REQUIREMENTS

APPENDIX B. ANALYSIS OF FRAMING REQUIREMENTS

The photographic film coverage since it will be the means used to establish performance must use the proper framing rate to insure that an adequate number of frames are available to properly document the event. In photographing a object, blurring of the image will occur depending upon film exposure duration, velocity of the object and the image magnification. Blur or minimum definable motion is determined by the equation:

(1) $$b = TMV \cos \alpha$$

when

b = image blur, inches

T = exposure duration, sec.

M = optical magnification (image size)

V = object velocity, inches/sec

α = angle between the direction of motion and the film plane, deg.

The magnification, M, in practical terms is the ratio of the film frame width, in to the field width, W, covered by the lens. For 16 mm film the frame width is 0.4 in. Exposure duration, T, is determined by

(2) $$T = \frac{\Theta_{aper}}{360°} \times \frac{1}{F} = \frac{\rho}{F}$$

where Θ_{aper} is the angle of the open sector in a disc shutter and F is the frame rate in frames per sec. The ration $\Theta_{aper}/360°$ is known as the shutter duration ratio, ρ. The determination of the appropriate frame rate in terms of acceptable image blur, geometry, object velocity and the camera construction may be determined from equations 1 and 2 above:

(3) $$b = \frac{\rho}{F} \frac{\omega}{W} V \cos \alpha,$$

(4) or $$F = \frac{\rho W V \cos \alpha}{bW}$$

for linear motion.

Vibration or cyclic motion presents a slightly different problem in frame rate determination because of the variable velocity. If we assume harmonic motion, then the object velocity, V, becomes:

(5) $V = \pi AF$

where

A = amplitude of motion

F = frequency of motion

Thus for harmonic motion of the dummy head, the frame rate requirement is:

(6) $F = \frac{\Pi \rho WFA \cos \alpha}{bW}$

We may apply equations (4) and (6) to a child seat test A-601 which used a Strollee Model 590 child seat with the three-year dummy installed on a Ford bucket seat. For the linear position:

$V = 30 \text{ mph} = 528 \text{ in/sec}$

$W/W = 0.4 \text{ in}/84 \text{ in} = 4.8 \times 10^{-3}$

$\alpha = 0; \cos \alpha = 1$

$\rho = 1/2.5 = .4$(Hycam)

$b = 0.5\%$ of film frame width $= 0.002$ in.

then F = 506 frames/sec.

for the oscillatory motion the pulse was 0.1 sec in duration which has a fundamental frequency of 5 hz., and an amplitude of 20 inches. Therefore

F = 302 frames/sec.

thus if we allow a measurement induced error of 1/2 of 1 percent we can utilize a camera capable of 500 fps. By requiring only 500 fps, the type of camea required is simplified and the cost of developing a compliance facility significantly reduced.