UM-HSRI-78-52 Final Report

IMPACT TESTING OF RESTRAINT DEVICES USED WITH HANDICAPPED CHILDREN IN BUS SEATS AND WHEELCHAIRS

By:

Lawrence W. Schneider

and

John W. Melvin

Prepared for:

Bureau of Crippled Children
Department of Public Instruction
126 Langdon Street
Madison, Wisconsin 53702

November 1978

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
UM-HSRI-78-52		

4. Title and Subtitle
Impact Testing of Restraint Devices Used With Handicapped Children in Bus Seats and Wheelchairs

5. Report Date
November 8, 1978

6. Performing Organization Code
HSRI

7. Author(s)
L.W. Schneider and J.W. Melvin

8. Performing Organization Report No.
UM-HSRI-78-52

9. Performing Organization Name and Address
Highway Safety Research Institute
The University of Michigan
Ann Arbor, Michigan 48109

10. Work Unit No. (TRAIS)

11. Contract or Grant No.
DRDA-78-1659-J1

12. Sponsoring Agency Name and Address
Bureau of Crippled Children
Department of Public Instruction
State of Wisconsin

13. Type of Report and Period Covered
Final
June 23,1978-Sept.30,1978

14. Sponsoring Agency Code

15. Supplementary Notes

16. Abstract
A series of 16 sled impact tests were conducted at the Highway Safety Research Institute sled facility in order to evaluate the effectiveness of restraint devices and systems currently being used for the transport of school bus and wheelchair-seated handicapped children in the State of Wisconsin. A sled impact pulse of 20 m.p.h. and 16 G's was used for all tests. Eight tests involved wheelchairs in forward-facing and side-facing orientations for head-on and 33 degree oblique impacts. Another eight tests involved forward-facing bus seats for head-on and 33-degree oblique impacts. The results generally point out the ineffectiveness of many currently used devices and systems for protecting the child in the event of a bus collision. In six of the eight bus seat tests the dummy's head struck the back of the bus seat in front. The practice of placing wheelchairs in a side-facing orientation is shown to be a poor one for the protection of the child.

17. Key Words	18. Distribution Statement
Sled impact test School bus Handicapped children Restraint	Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None	80	

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The authors would like to express their appreciation to Joe Benson, Jean Brindamour, and Marv Dunlap who operate the HSRI sled facility and to Stan Schneider and Don Erb who were primarily responsible for the individual sled set-ups. Acknowledgement is also given to C. Ernest Cooney, Prevention Specialist in the Bureau of Crippled Children, Madison, Wisconsin who initiated and designed this series of tests and who assisted with the set-up of the initial sled runs.

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

The safe transport of handicapped children to and from school involves special problems in restraint design. In recent years a number of different techniques and devices have been developed and used for restraining the handicapped child either in school bus seats or in wheelchairs. Most of these devices and techniques have never been subjected to impact testing to determine their performance under dynamic loading. In this study a number of different restraint techniques and devices currently being used in the transportation of handicapped children in the State of Wisconsin were subjected to sled impact testing and their performance evaluated.

II. PROCEDURES

A. Impact Facility and Sled Deceleration Pulse

Impact tests were performed at the Highway Safety Research Institute Impact Sled Laboratory. This facility consists of an impact sled (Figure 1) that moves on a 45-foot track into a pneumatic decelerator and can simulate crashes up to 75 m.p.h. and 75 times the force of gravity. The sled itself is a 975-lb. test platform, 6.5-ft. square and is driven by a compressed-gas-powered ram. The sled operates on the principle of rebound, stopping and reversing direction abruptly by impacting the adjustable pneumatic decelerator. In this study, all pressures were set to achieve a 20 m.p.h. velocity differential and 16 G (i.e., 16 times the acceleration of gravity) deceleration pulse. Figure 2 shows a typical sled deceleration pulse for the tests in this study.

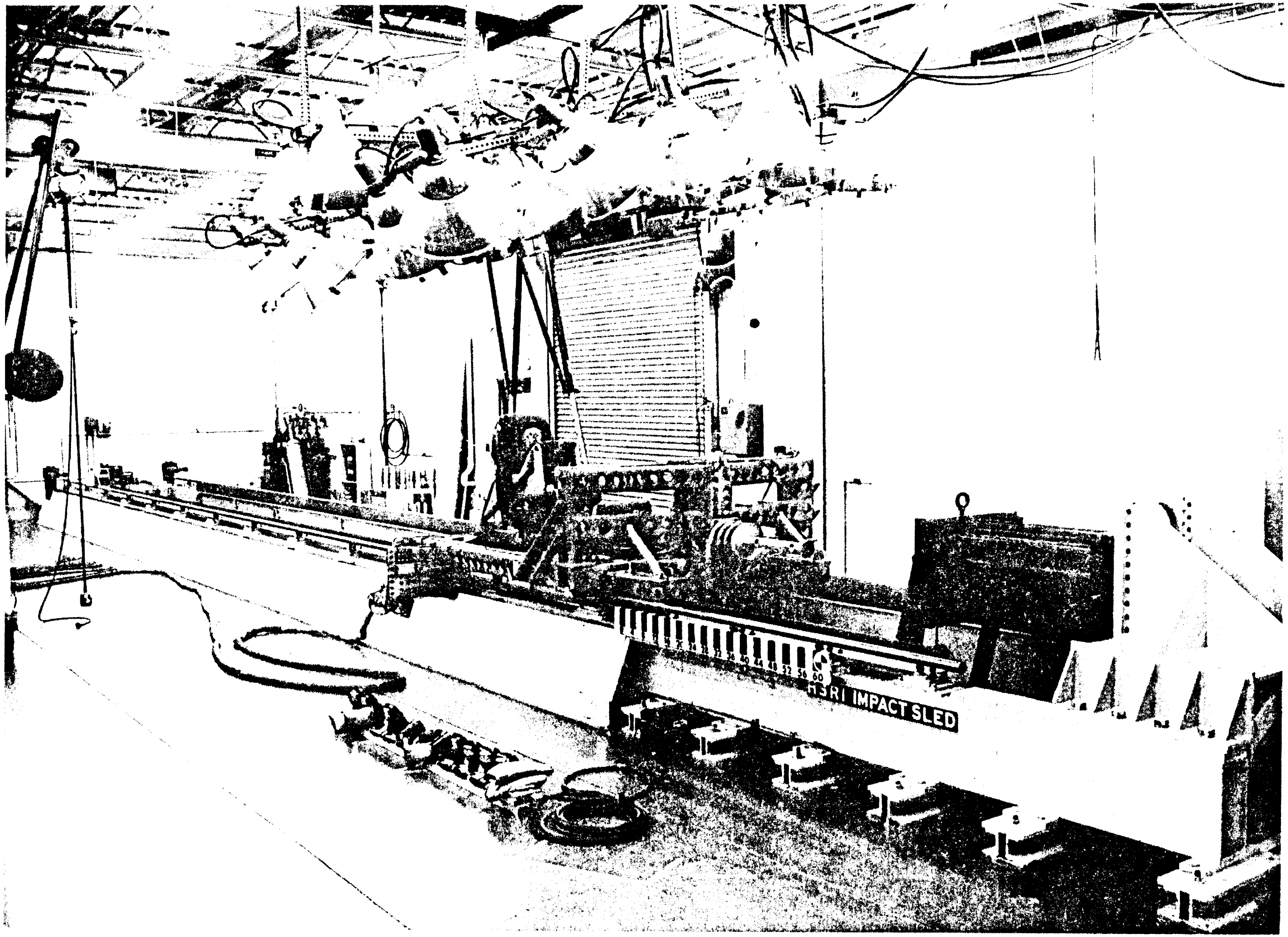


Figure 1. HSRI's Impact Sled Facility

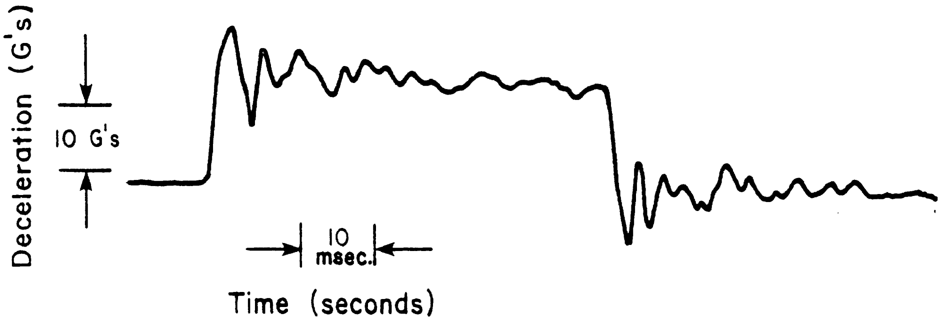


Figure 2. Sled Test Deceleration Pulse

B. Matrix of Test Conditions and Restraint Systems

A total of sixteen impact tests were performed for a variety of restraint systems and test conditions. These tests can be divided into two basic categories - those with wheelchairs and wheelchair restraints, and those with bus seats and bus seat restraints.

1. <u>Wheelchair Tests</u>

Eight wheelchair tests were performed using two sizes of wheelchairs purchased from Everest and Jennings, Inc. The Tiny-Tot Universal model was used in four tests with a 6 year dummy weighing 49 pounds, and the Junior Premier model was used in four tests with a 5th percentile female dummy weighing 105 pounds. In all wheelchair tests, the dummy was restrained to the chair by a Collins Saf-T-Straint (Collins Industries, Inc. Hutchinson, Kansas) padded belt illustrated in Figure 3. This device consists of a pad and safety belt sewn together. In this study, the belt was wrapped aroung the chair back just above the armrests, buckled in front and pulled tight.

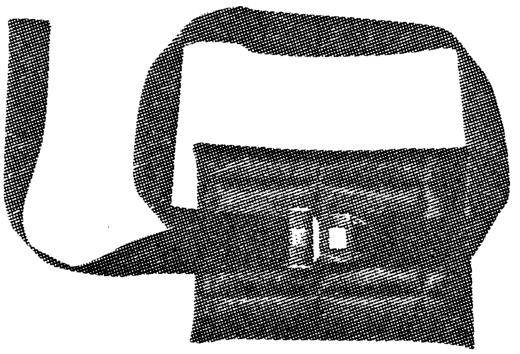


Figure 3. Collins Saf-T-Straint used to restrain dummy in wheelchair.

Two methods of restraining the wheelchairs to the bus were tested. The Collins Saf-T-Lock (manual model) devices shown in Figure 4 are bolted to the bus floor and hold the wheelchair by gripping the rear wheel rims between the steel structures by two steel pins. This restraint was tested in both the forward facing and side facing (wheelchair backed up to bus sidewall) directions for head-on impacts.

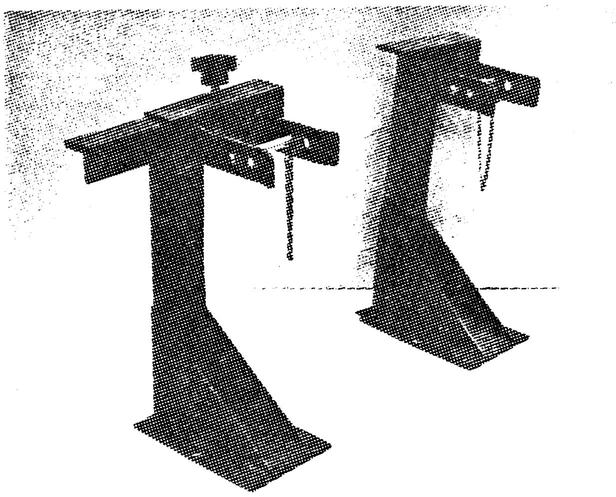


Figure 4. Collins Saf-T-Lock devices used to restrain wheelchairs.

The second wheelchair restraint system tested was that of using safety belts (Ruppert Industries) anchored to the bus wall and wrapped around the front of the wheelchair. This method was tested using both one and two belt systems for head-on and 33 degree oblique impacts (i.e., 33 degrees to front of bus), the latter condition achieved by orienting the wheelchairs at 33 degrees to the sled motion. Table 1 summarizes this matrix of eight wheelchair tests.

TABLE 1

WHEELCHAIR IMPACT TEST MATRIX
ALL TESTS AT 20 M.P.H. AND 16 G'S

Wheelchair	Dummy	Orientation in Bus	Impact Direction	Restraint
E&J Tiny Tot	6 yr.	Forward	Head-on	Collins Saf-T-Lock
E&J Junior	5th%ile female	Forward	Head-on	Collins Saf-T-Lock
E&J Tiny Tot	6 yr.	Side	Head-on	Collins Saf-T-Lock
E&J Junior	5th%ile female	Side	Head-on	Collins Saf-T-Lock
E&J Tiny Tot	6 yr.	Side	Head-on	One belt to bus wall Collins Saf-T-Straint
E&J Junior	5th%ile female	Side	Head-on	Two belts to bus wall Collins Saf-T-Straint
E&J Tiny Tot	6 yr.	Side	33° oblique	Two belts to bus wall Collins Saf-T-Straint
E&J Junior	5th%ile female	Side	33° oblique	One belt to bus wall Collins Saf-T-Straint

2. <u>Bus Seat Tests</u>

Another eight impact tests were performed using devices designed to restrain children in bus seats. Since most school bus seats in use today do not yet conform to the new standards set forth in FMVSS 222 (i.e., closer spacing, padded seat backs, etc.), the older style bus seats were considered most appropriate for this study. For these tests, two seats were bolted to the sled with a distance of 27 inches from the back of the rear seat to the back of the front seat. The dummy was placed in the rear seat for all tests.

Four types of restraint situations were tested for forward facing seats in both head-on and 33 degree impacts for a total of eight tests. Two tests each were performed for the following restraint/dummy situations:

1) Rupert (Rupert Industries, Inc. Wheeling, Illinois) E-Z-On Harness with 6 year dummy.

2) Easy Way Dubl-Life Saver Restraint Vest (Easy Way Products, Co., Cincinnati, Ohio) with 6 year dummy.

3) Ford Tot Guard with 5th percentile female dummy.

4) Ortho-Kinetics Travel Chair (Ortho-Kinetics, Inc. Waukesha, Wisconsin) with 6 year dummy.

Figure 5 shows the Rupert E-Z-On Harness and accompaning restraining belts. The harness is worn by the child (zipper in back) and the restraining belts are permanently installed in the bus. These belts are fastened to two heavy duty eye bolts secured to the bus floor just behind the seat. The two long belts go over the top of the seat

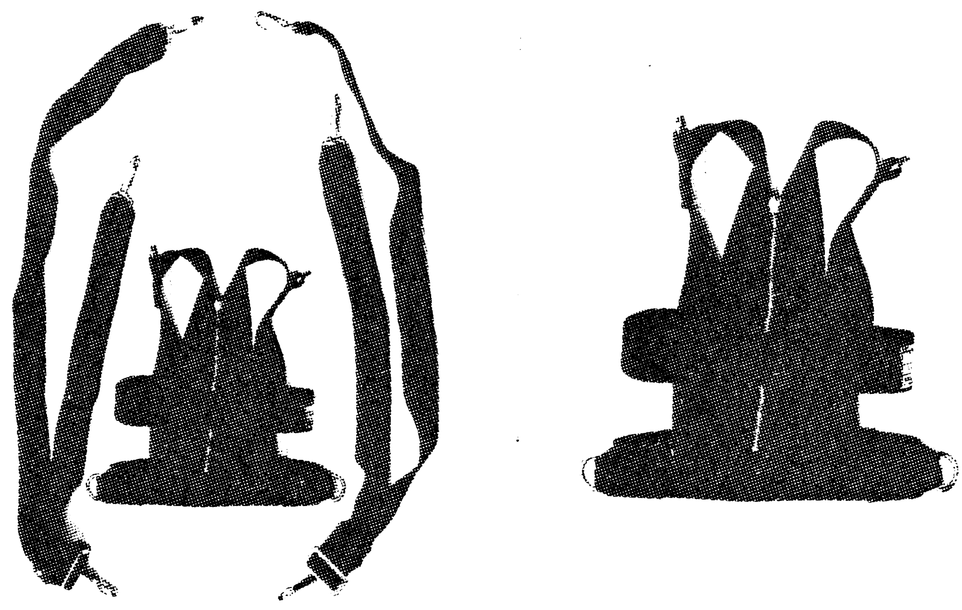


Figure 5. Rupert E-Z-On Restraining Harness. Left-with belt restraints. Right-harness only.

and fasten to the upper "D" rings on the harness while the two belts go through the bus seat under and behind the seat cushion and fasten to the lower "D" rings on the harness.

Figure 6 shows the Easy Way Dubl-Life Saver Restraint Vest. This device consists of a light weight pad to which a standard lap belt has been sewn. A second belt is strung crosswise through a double section in the back of the pad. This belt is strapped around the bus seat back by putting one end through the bus seat behind the seat cushion and the other end over the top of the seat and is secured and tightened in back of the seat. The pad is wrapped around the child's lower torso and abdomen and the lap belt tightened.

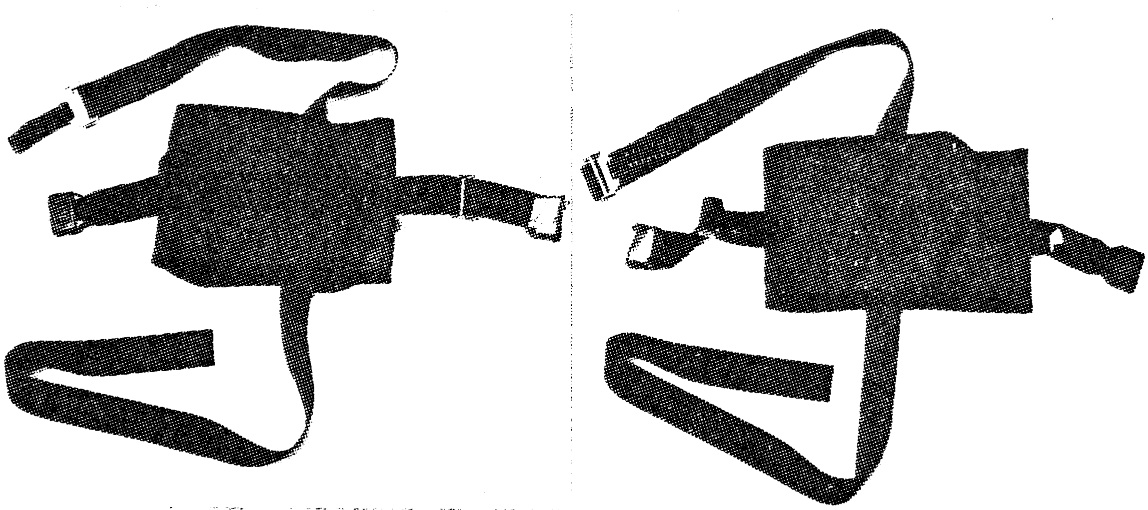


Figure 6. Easy Way Dubl-Life Saver Restraining Vest.
Left-back view. Right-front view.

Figure 7 shows the Ford Tot Guard and 5th percentile female dummy in position on the bus seat. The Tot Guard is used without the booster seat and the seat belt (Rupert Industries) tightened in the usual manner around the front of the Tot Guard. In one test the seat belt was anchored to the bus floor and put through the bus seat behind the seat cushion while in a second test the belt was belted to the bus seat structure behind and under the seat cushion.

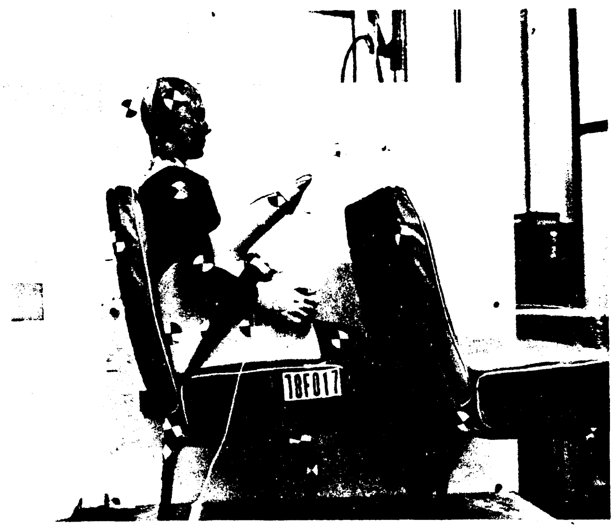


Figure 7. Ford Tot Guard and 5th percentile female dummy on bus seat.

Figure 8 shows the Ortho-Kinetics Travel Chair which of itself is not a restraint but rather a version of a wheelchair which can be placed on the seats of automobiles or buses. Upon pulling a lever in back, the rear wheels and lower frame collapse up allowing the chair to fit on a seat. Two procedures for restraining this chair and 6 year dummy occupant were tested. The first involved simply using a standard seat belt (Rupert Industries) which was bolted to the bus seat frame. The belt was wrapped around the lower portion of the chair near the dummy's waist. In a second test, a Rupert E-Z-On Harness was modified with belt loops replacing the "D" rings and placed on the 6 year dummy. A lap belt was placed through the lower loops and a second belt secured to the floor behind the seat was inserted through the upper loops behind the dummy's neck.

Figure 8. Ortho-Kinetics Travel Chair

Table 2 summarizes these eight bus seat impact tests and the restraint and test conditions.

TABLE 2

MATRIX OF SCHOOL BUS SEAT TESTS
ALL TESTS AT 20 M.P.H. AND 16 G'S, FOR FORWARD FACING SEATS

Dummy	Restraints	Impact Direction
6 yr.	Rupert E-Z-On Harness	Head-on
6 yr.	Easy Way Dubl-Life Saver Restraint Vest	Head-on
5th%ile female	Ford Tot Guard with Lap Belt thru bus seat to floor	Head-on
6 yr.	Ortho-Kinetics Travel Chair with lap belt anchored to bus seat.	Head-on
6 yr.	Rupert E-Z-On Harness	33^o oblique
6 yr.	Easy Way Dubl-Life Saver Restraint Vest	33^o oblique
5th%ile female	Ford Tot Guard with Lap Belt anchored to seat structure.	33^o oblique
6 yr.	Ortho-Kinetic Travel Chair with modified Rupert harness and two belts.	33^o oblique

Table 3 summarizes the matrix of 16 tests performed. It should be noted that no attempt was made in this study to evaluate the manner in which belts, seats, or other hardware are fastened to the school bus interior. While an evaluation of this aspect of the system is certainly important, all hardware in this study were fastened securely so that the performance of the restraint device alone could be evaluated.

TABLE 3

MATRIX OF TESTS

Test No.	Type of Test: Bus Seat (BS) or Wheelchair(WC)	Dummy	Orientation in Bus	Impact Angle (degrees) RE Front of Bus	Restraints Used
78F002	WC-Tiny Tot	6 yr.	Forward facing	0	Collins Saf-T-Lock Collins Saf-T-Straint
78F003	WC-Junior	5th%ile female	Forward facing	0	Collins Saf-T-Lock Collins Saf-T-Straint
78F004	WC-Junior	5th%ile female	Side facing	0	Collins Saf-T-Lock Collins Saf-T-Straint
78F005	WC-Tiny Tot	6 yr.	Side facing	0	Collins Saf-T-Lock Collins Saf-T-Straint
78F006	WC-Tiny Tot	6 yr.	Side facing	0	Single belt to bus wall Collins Saf-T-Straint
78F007	WC-Junior	5th%ile female	Side facing	0	Two belts to bus wall Collins Saf-T-Straint
78F008	BS	6 yr.	Forward facing	0	Rupert E-Z-On Harness
78F009	BS	6 yr.	Forward facing	0	Easy Way Dubl-Life Saver Restraint Vest
78F010	BS	5th%ile female	Forward facing	0	Ford Tot Guard without booster - lap belt thru bus seat to floor
78F011	BS	6 yr.	Forward facing	0	Ortho-Kinetics travel chair with lap belt attached to bus seat
78F012	WC-Tiny Tot	6 yr.	Side facing	33	Two belts to bus wall Collins Saf-T-Straint
78F013	WC-Junior	5th%ile female	Side facing	33	One belt to bus wall Collins Saf-T-Straint
78F014	BS	6 yr.	Forward facing	33	Rupert E-Z-On Harness with heavy duty "D" rings
78F015	BS	6 yr.	Forward facing	33	Easy Way Dubl-Life Saver Restraint Vest
78F016	BS	6 yr.	Forward facing	33	Ortho-Kinetics Travel chair with modified Rupert harness & two belts
78F017	BS	5th%ile female	Forward facing	33	Ford Tot Guard without booster Safety belt to seat frame

C. Test Measurements and Data

In each test, GSE seat belt force sensors measured the tensions in the various belts and these signals along with the sled deceleration pulse were recorded on analog tape. High contrast markers were placed on the dummys, wheelchairs, bus seats, and sled structure and high speed movies at 1,000 frames per second were taken from side and overhead cameras. Pre and post photographs were taken with 35 mm film to document the test set-up and results and a polaroid sequence camera was used to obtain an immediate record of the impact event.

III. SUMMARY OF RESULTS

The Appendix to this report contains a description of the test conditions and set-up along with a detailed description of the results for each of the sixteen impact tests. Included in this documentation are pre and post test photographs and the graph check sequence photographs of the impact response. In this section a summary of these results and measurements and an evaluation of the performance of each device is given. Peak belt loads were measured from chart paper recordings of the load cell signals and maximum dummy head excursions[1] in the direction of sled impact were obtained from analysis of the high speed films. These results are summarized in Tables 4 and 5 for the wheelchair and bus seat tests respectively.

A. Wheelchair Tests

1. Saf-T-Straint

The Collins Saf-T-Straint was used to restrain the dummy to the wheelchair in all wheelchair tests. While this device succeeded in keeping the dummy "in the seat" in all tests, it is clear that this restraint alone is not adequate for protecting wheelchair occupants. Because of the size of the pad and the manner in which the belt must be wrapped around the chair back, the belt load is

---

[1] It should be noted that head excursions reported in this study are computed relative to the initial position of the head in each run. Because the initial position of the dummy relative to other bus structures (e.g., a seat back) may vary for different restraints, these measures of head excursion do not by themselves give an absolute measure of probable head contact.

TABLE 4

APPROXIMATE HEAD EXCURSIONS IN DIRECTION OF IMPACT AND PEAK BELT LOADS FOR WHEELCHAIR TESTS

Test No.	Restraint System	Orientation in Bus	Impact Direction	Dummy	Head Excursion cm.	Head Excursion in.	Peak Belt Loads (lbf.) Saf-T-Straint	Peak Belt Loads (lbf.) Upper Chair Belt	Peak Belt Loads (lbf.) Lower Chair Belt
78F002	Collins Saf-T-Lock	forward	head-on	6 yr.	76.5	30.1	300	-	-
78F003	Collins Saf-T-Lock	forward	head-on	female	74.7	29.4	660	-	-
78F004	Collins Saf-T-Lock	side	head-on	female	96.8	38.1	370	-	-
78F005	Collins Saf-T-Lock	side	head-on	6 yr.	99.3	39.1	255	-	-
78F006	One belt to bus wall	side	head-on	6 yr.	86.6	34.1	120	1600	-
78F007	Two belts to bus wall	side	head-on	female	97.0	38.2	260	1250	850
78F012	Two belts to bus wall	side	33°	6 yr.	67.6	26.6	100	not measured	1200
78F013	One belt to bus wall	side	33°	female	80.3	31.6	210	-	1350

TABLE 5

APPROXIMATE HEAD EXCURSIONS IN DIRECTION OF IMPACT AND PEAK BELT LOADS FOR BUS SEAT TESTS

Test No.	Restraint System	Impact Direction	Head Excursion cm.	Head Excursion in.	Head Contact With Front Seat Back	Peak Belt Loads (lbf.) Dummy Belt*	Peak Belt Loads (lbf.) Restraint Belts Upper	Peak Belt Loads (lbf.) Restraint Belts Lower
78F008	Rupert E-Z-On Harness	head-on	46.7	18.4	no	-	300/170	170/150
78F009	Easy Way Double Life Saver	head-on	71.4	28.1	yes	240	540	-
78F010	Ford Tot Guard	head-on	82.0	32.3	yes	-	-	600
78F011	Orthokinetics Chair with Lap Belt	head-on	59.9	23.6	yes	520	-	-
78F014	Rupert E-Z-On Harness	33^{o}	47.5	18.7	no	-	290/350	240/290
78F015	Easy Way Double Life Saver	33^{o}	69.9	27.5	yes	260	400	-
78F016	Orthokinetics Chair with Modified Rupert Harness	33^{o}	53.1	20.9	yes	560	270	-
78F017	Ford Tot Guard	33^{o}	65.3	25.7	yes	-	-	950

*The belt is called a dummy belt if it makes contact with the dummy. Otherwise it is called a restraint belt.

applied up on the abdomen of the occupant rather than on the pelvic bone. While the pad will certainly help to distribute the load, the belt loads of 300 lbf. and 660 lbf. (see Table 4) obtained for the two forward facing tests are approaching magnitudes likely to cause injury to abdominal organs (1, 2). In the side facing tests the belt loads are smaller but this is because the dummy is being partially restrained by the wheelchair side frame. In the two forward facing tests, the maximum forward head excursion relative to the head initial position was 30.1 and 29.4 inches respectively and this is primarily due to the hip and torso flexion allowed because there is no upper torso restraint. Such large excursions are likely to result in head injury due to contact with other vehicle structures and in spinal trauma due to hyperflexion of the neck and torso, and should be prevented by restraining the upper torso if at all possible. Because the wheelchair is neither tall enough nor strong enough, upper torso restraints would be most effective if anchored to the bus structure itself.

2. Collins Saf-T-Lock

For the forward facing wheelchair tests (78F002 and 78F003), the Saf-T-Lock tie-downs were effective in holding the chair although a mechanism to prevent forward pitch of the wheelchairs would be an improvement. In this regard, it should be noted that the wheelchair brakes had been applied prior to the test and were working well. Had the brakes not been applied or not been grabbing as well, the pitching would probably have been even worse. In a preliminary test with the

Tiny Tot wheelchair and 6 year dummy, failure to apply the brakes prior to the run resulted in the chair pitching backward during the sled acceleration of about .5 G.

For the side facing tests (78F004 and 78F005), the Saf-T-Lock devices proved to be less effective. While they held onto the wheelchair, the inertial forces produced considerable rotation and twisting about the tie-down points and the dummies flailed sideways into and over the armrests with peak head excursions of 38.1 and 39.1 inches in the two cases. Damage to the chairs in these test was substantial and in the test with the female dummy the rearward Saf-T-Lock was badly bent.

3. Safety Belts to Bus Wall

From the outset it was clear that this was an ineffective procedure for restraining wheelchair occupants since the wheelchair by itself has no lateral strength other than that provided by the occupant. In all four belt restrained wheelchair tests (78F007, 78F008, 78F012, 78F013) the dummy was squeezed in the wheelchair as it twisted around inside the restraining belt(s). While two belts may be somewhat more effective than one belt, none of the test results were encouraging for this method of restraint. In performing these tests the belts were placed around the wheelchair structure in ways that seemed optimum and which would probably not be done by most bus drivers. Less care in the placement or in tightening the belts, however, would make the restraints even less effective and perhaps render the belts completely useless (since they could slip off the chair completely).

B. Bus Seat Tests

1. Rupert E-Z-On Harness

The Rupert E-Z-On Harness performed effectively in both the head-on and 33 degree oblique impact tests (78F008 and 78F014) in that it prevented the dummy's head from contacting the front bus seat. In the first test, however, (78F008) three of the four "D" rings sprung open and became hazardous flying objects in addition to allowing unrestrained lower torso motion and knee contact with the front seat back. In both tests, head excursion was limited to about 18.5 inches. The design of the harness also distributes the load over the chest and shoulders as well as the lap region thereby preventing excessive loading of the abdominal organs.

2. Easy Way Dubl-Life Saver Restraint Vest

The performance of this restraint device (tests 78F009 and 78F015) was completely ineffective for protecting children in school bus seats. The padded vest does not adequately distribute belt loads over the torso and only succeeds in causing the loads to be placed over the vulnerable organs of the abdomen rather than on the pelvic bone. The single belt wrapped about the seat back and through the vest provides little restraint for about 16 inches of dummy travel and no upper torso restraint. In both tests the head struck the top of the seat back of the front seat with head excursions of about 28 inches.

3. Ford Tot Guard

The 5th percentile female dummy was used in the two Ford Tot Guard tests (78F010 and 78F017) and in both cases the dummy's head struck the top of seat back of the front seat. In the first test (78F010) of a head-on impact, the belt restraining the Tot Guard was bolted to the floor and put through the seat between the seat cushion and seat back. Because of the thickness of the seat cushion and the "S" shaped path of the belt around the seat frame and cushion as shown in Figure 9, the belt did not immediately restrain the Tot Guard upon impact even through it was pulled tight. As the impact proceeded, the inertial forces pulling on the belt caused the belt to squeeze

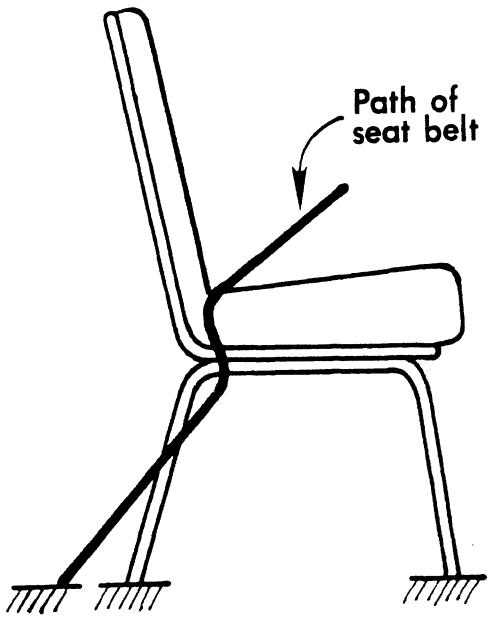


Figure 9. Side view of school bus seat illustrating "S" shaped path of seat belt when anchored to the floor.

the seat cushion, straightening out the "S" shaped portion resulting in belt slack and the dummy's knees smashing violently through the front seat back. In the second test (78F017) the belt was bolted to the seat frame thereby eliminating this slack and reducing torso motion.

The head excursions relative to the head initial position for the two tests were 32.3 and 25.7 inches in the first and second tests respectively, although in both cases the head struck the front seat back. It could be said that in the second test the Tot Guard performed well but that the dummy was too large for the restraint. If, however, the Tot Guard had gone over the front seat back (which would have happened with either a lower seat back or firmer seat cushion), the restraint would have been more effective since the dummy would have contacted the top of the Tot Guard rather than the seat structure.

4. Ortho-Kinetics Travel Chair

As previously mentioned, this device is not a restraint, but rather a type of wheelchair which has been designed to fit on automobile or bus seats and thereby allow transport of handicapped children without removing them from their chair. Typically, the chair and child are restrained to a seat by a standard lap belt which is wrapped about the child's waist. The chair is equipped with a vinyl lap belt and vinyl shoulder straps with velcro fastenings for securing the child under normal conditions but these were not intended for impact protection.

In test 78F011, the Ortho-Kinetics chair with 6 year dummy was tested using this standard lap belt restraint anchored to the bus seat structure. As expected, the chair and dummy pitched forward so that the dummy's chin struck the top of the front seat back. This occurred even though the total head excursion in the direction of impact was only 23.6 inches, since the child's head started from a position several inches forward of the seat back.

In the second test (78F016) of the Ortho-Kinetics chair at an oblique impact, a modified Rupert Harness was used in an attempt to provide upper torso restraing and thereby prevent head impact. This design involved replacint the "D" rings with loops through which belts could be placed. The lap belt, as before, was placed around the dummy and chair, through the lower loops, while a belt anchored to the floor behind the seat was placed through the upper loops from behind and over the seat back and behind the dummy's neck. While it is believed that this design has potential for improving the protection of children traveling in Ortho-Kinetic chairs, the results of this test were little better than the test with lap belt only. This was primarily a result of improper placement of the upper loops which caused considerable slack and virtually no upper torso restraint for several inches. The maximum head excursion relative to the initial head position in the direction of impact was 20.9 inches and again the head (forehead) struck the top of the front seat back.

It is of interest also to look at the peak lap belt tensions for these runs which were 520 lbf. and 560 lbf respectively. These are considerably higher than those of the Easy Way Dubl-Life Saver Restraint Vest, for example, due to the fact that the chair and the dummy are being restrained by the same belt. The child therefore must bear the added inertial load resulting from the mass of the chair as well as his own mass. In recent studies using baboons and Rhesus monkeys (1, 2), it was found that pressures of 30-45 psi resulted in ESI (estimated severity of injury) injury ratings of 3 (reversible trauma). Thus one must consider that these belt loads are approaching serious injurious levels.

A procedure for lowering these loads, of course, is to separately restrain the chair so that the child does not bear the load of its inertial forces.

IV. DISCUSSION AND CONCLUSIONS

A large percentage of all injuries in school bus collisions are to the head due to contact with hard interior bus structures such as seat backs, sidewalls, and windows. In terms of protecting against this type and mechanism of injury the results of this study point out the ineffectiveness of many of the restraint systems being used today for transporting handicapped children.

When transporting children in wheelchairs, consideration must be given not only to simply holding down the wheelchair but also to effectively restraining and protecting the wheelchair occupant. The Collins Saf-T-Straint does a good job of keeping the child "in the chair" but alone does not prevent excessive head excursion and torso flexion which can result in head and spinal injury. The need to supplement this device with an upper torso restraint anchored to the bus structure is clear.

The Collins Saf-T-Lock device does an adequate job for forward facing wheelchairs and head-on impacts but is clearly inadequate for placing wheelchairs sideways in buses. In fact, the results of this study suggest that the practice of placing wheelchairs sideways in school buses is a poor one likely to result in injury during impact from almost any direction except the very rare case of a direct lateral impact to the opposite side. Wheelchairs have not been designed with vehicle transportation in mind and until appropriate structural modifications are made, one must consider their structural weaknesses in providing for restraint and occupant protection. The majority of school bus accidents involve frontal and rearend collisions (3) which, for the side facing wheelchair, result in forces causing structural collapse and consequent occupant flailing and injury. While the Saf-T-Straint belt may keep the child in the seat, the forces are largely absorbed by the hard structure of the wheelchair side-frame rather than the restraint pad. A recent federal motor vehicle safety standard (FMVSS 222) requires that all school buses manufactured after April, 1978 shall have forward facing seats only. This principle should also be applied to the transport of the handicapped whether or not school bus seats are used.

For school bus seat restraints, the Rupert E-Z-On Harness was an effective restraint when heavy duty "D" rings were used. The process of installing the restraint belts properly with appropriate belt lengths was somewhat tedious, and while this must only be done once, it should be done with care so that minimum slack is available.

The Easy Way Dubl-Life Saver Restraint Vest was an ineffective restraint. It did not adequately restrain the dummy and it's use causes the belt loads to be placed more directly over the vulnerable organs of the abdomen. A child would probably be protected more by a simple lap belt which would tend to keep the forces lower on the pelvis and less on the abdomen.

While the Ford Tot Guard did not effectively provide protection from head contact in these tests, it is felt that this can be an excellent restraint if it is secured by a belt fastened to the bus seat structure and if the child is not too large so as to override the padded surface. In newer bus seats with lower seat backs and harder cushions, this restraint should also perform better.

Use of the Ortho-Kinetics Travel Chair with a lap belt only does not provide complete protection on impact since the chair top and upper torso of the child are essentially unrestrained. The use of the Rupert harness in some modified form has potential for improving the protection with this chair but proper harness fit is essential. In no case should one rely on the vinyl-velcro straps provided with the chair for upper torso restraint in vehicle impact. Neither the strap material nor the velcro fastenings are sufficient to carry the inertial loads of even a modest impact.

With regard to the use of seat belts on school bus seats, this study indicates that the procedure of bolting the belt to the floor and putting the belt through the seat behind and around the frame and seat cushion can result in considerable potential slack (at least for the older style school bus seat) due to the "S" shaped path of the belt and the softness of the cushion. Where this type of situation exists, it is recommended that the belts be anchored to the seat frame (assuming that the frame is securely fixed to the bus floor) using large washers to distribute the load and in such a manner that no slack is present when the belt is pulled tight.

In most school buses (except those manufactured after April, 1978), bus seat cushions are usually fastened to the seat frame with simple metal clips which easily break loose on impact. In this study, the seat cushions were also secured using conduit clamps after seat cushions breaking loose proved to be a problem and hazard in initial tests. It is recommended that in school buses where the seat cushions are easily pulled up, additional measures be taken to secure the seat cushions in place.

FINAL COMMENTS

In this study we have attempted to evaluate the performance of several commonly used devices and techniques for restraining handicapped children in school buses. It has not been the intent to test all devices used or to test for all possible impact conditions. The results indicate, however, the ineffectiveness of many of the currently used restraint systems for protecting children in the event of school bus collisions. It is quite apparent that most devices and procedures have not been adequately impact tested and that the designers of these restraints have little understanding of basic crashworthiness design concepts. The protection of handicapped children certainly involves special problems and considerations not encountered in designing to protect the non-handicapped, but some basic guidelines such as preventing head contact with hard surfaces by upper torso restraint, distributing the loads over the skeletal structures as much as possible, and seating occupants in forward facing positions, still apply. The recent school bus seat standard, FMVSS 222, which requires seats to be padded with energy absorbing materials will no doubt provide increased protection in the event of head or knee impact, but this ruling should not be used as an excuse to allow unreasonable body excursions and joint flexion to take place. Since this standard does not require replacement of old seats, it will be many years before the majority of school bus seats conform to these requirements.

There is a need, then, for designers and installers of these protective systems and devices, whether they are school personnel or manufacturers, to obtain assistance from engineers and researchers with the necessary experience in impact protection, and for any device or system to be dynamically tested under realistic impact conditions prior to marketing and/or use. Substantial improvements in protection for the handicapped child can be made by adherance to a relatively few and simple design principles. Finally, the concern of emergency egress of the handicapped children in accidents involving fire or the threat of fire is an important one which has not been addressed in this study, but which should be a consideration in the design of handicapped restraint systems.

REFERENCES

1. Melvin, J.W., Stalnaker, R.L., Roberts, V.L., and Trollope, M.L. Impact Injury Mechanisms in Abdominal Organs. Proceedings Seventheenth Stapp Car Crash Conference. November, 1973 Society of Automotive Engineers, Inc. New York. SAE # 730968

2. Stalnaker, R.L., Roberts, V.L., and McElhaney, J.H. Side Impact Tolerance to Blunt Trauma. Proceedings Seventeenth Stapp Car Crash Conference, November, 1973. Society of Automotive Engineers, Inc. New York. SAE # 730979

3. Siegel, A.W., Nahum, A.M., and Runge, D.E. Bus Collision Causation and Injury Patterns. Proceedings Fifteenth Stapp Car Crash Conference, November, 1971. Society of Automotive Engineers, Inc. New York. SAE # 710860

4. 49 CFR Part 571.222

APPENDIX

SLED TEST SET-UPS AND RESULTS

Test No. and Type: 78F002 TINY TOT WHEELCHAIR

Restraint: Collins Saf-T-Lock; Collins Saf-T-Straint

Dummy: 6 year child (49 lbs.)

Orientation in Bus: Forward facing

Impact Pulse: 20 m.p.h., 16 G, head-on impact

Set-Up Description:

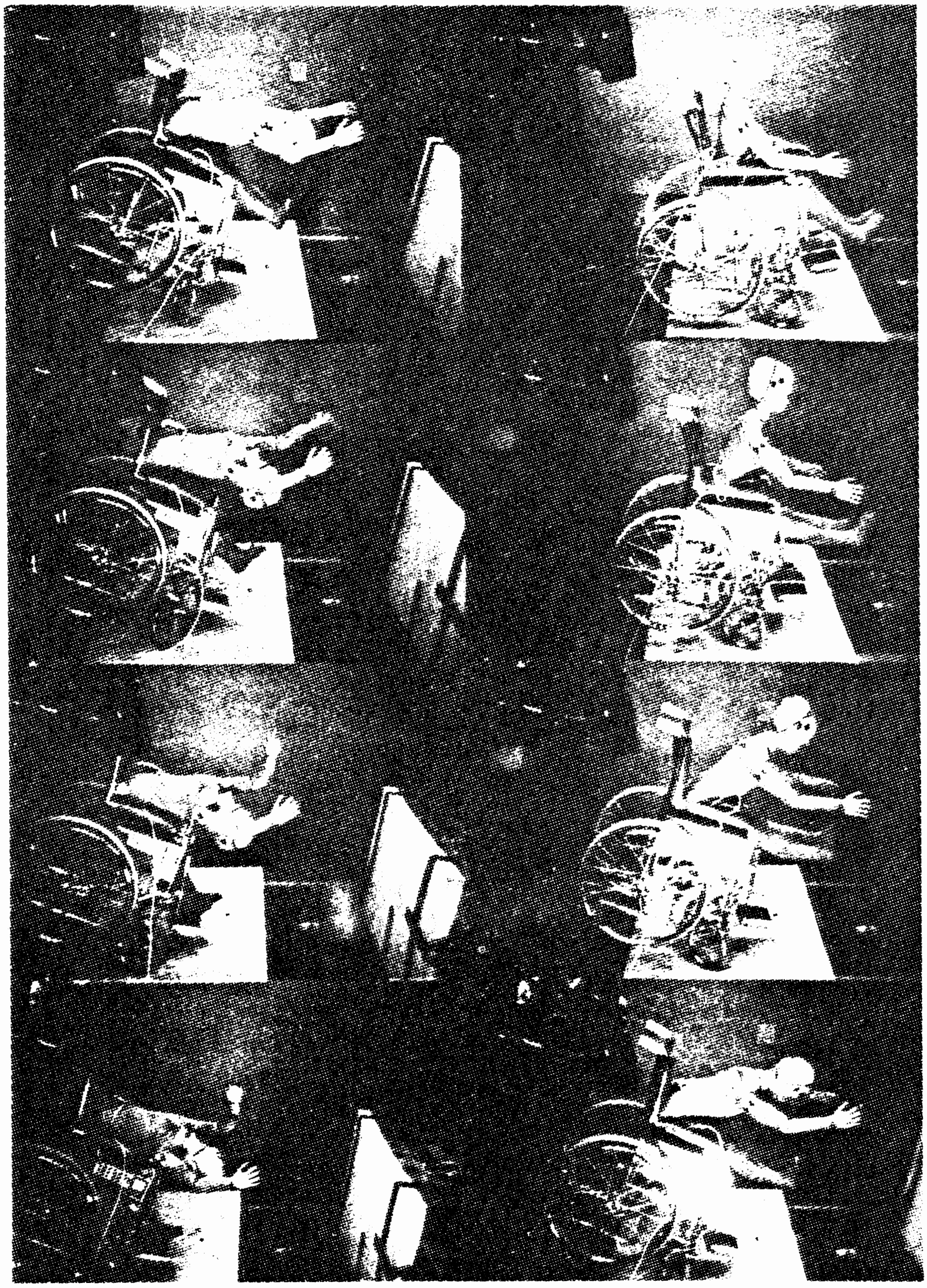
The Collins Saf-T-Lock wheelchair tie-downs were bolted rigidly to the sled rails facing forward and the large wheels on the Tiny Tot wheelchair were secured in place by means of the steel pins. The 6 year child dummy was placed in the wheelchair and strapped to the chair back by means of the Collins Saf-T-Straint padded belt. The wheelchair friction brakes on both sides were applied and a load cell was installed to measure the tension in the Saf-T-Straint belt.

Photograph of Set-Up:

Test No. and Type: 78F002 TINY TOT WHEELCHAIR

Graph Check Sequence Photograph:

5 6 7 8



1 2 3 4

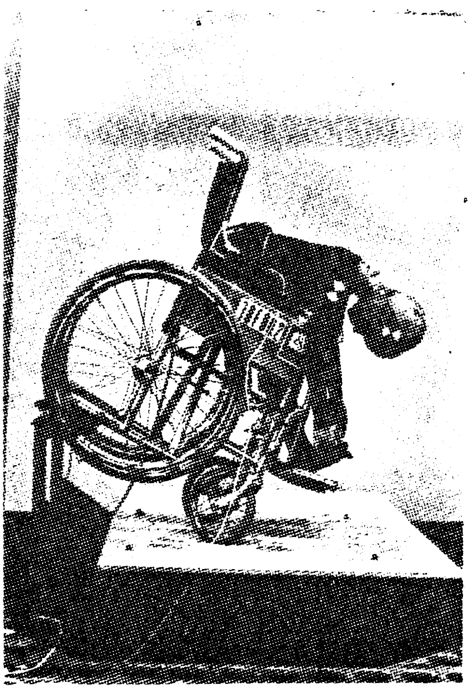
78F002

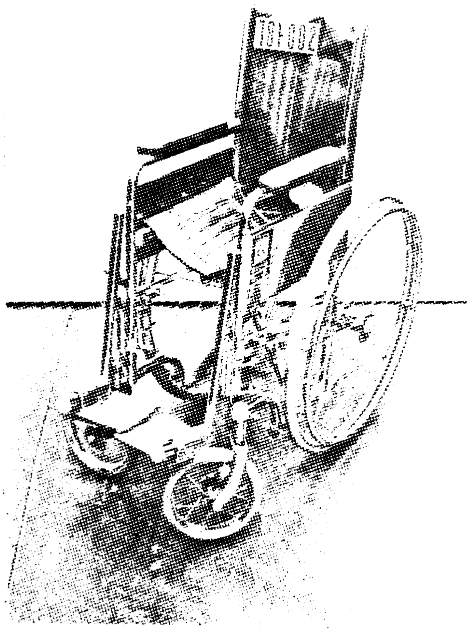
Test No. and Type: 78F002 TINY TOT WHEELCHAIR

Description of Test Results:

The Collins Saf-T- Lock device restrained the wheelchair and the Saf-T-Straint kept the dummy in the seat although the chair pitched forward about 30 degrees during impact and remained in that position at the end of the test. The head and torso of the child dummy pitched forward extensively with the dummy jackknifing at the hip joint. The maximum head excursion was 76.5 centimeters (30.1 inches) in the direction of impact. Peak tension in the Collins Saf-T-Straint was about 300 lbs. Damage to the wheelchair was minor with small dents in the wheel rims where the steel pins exerted force and slight frame and wheel axle bending.

Photographs of Results:





Test No. and Type: 78F003 JUNIOR WHEELCHAIR

Restraint: Collins Saf-T-Lock; Collins Saf-T-Straint

Dummy: 5th percentile female (105 lbs.)

Orientation in Bus: Forward facing

Impact Pulse: 20 m.p.h., 16 G, head-on impact

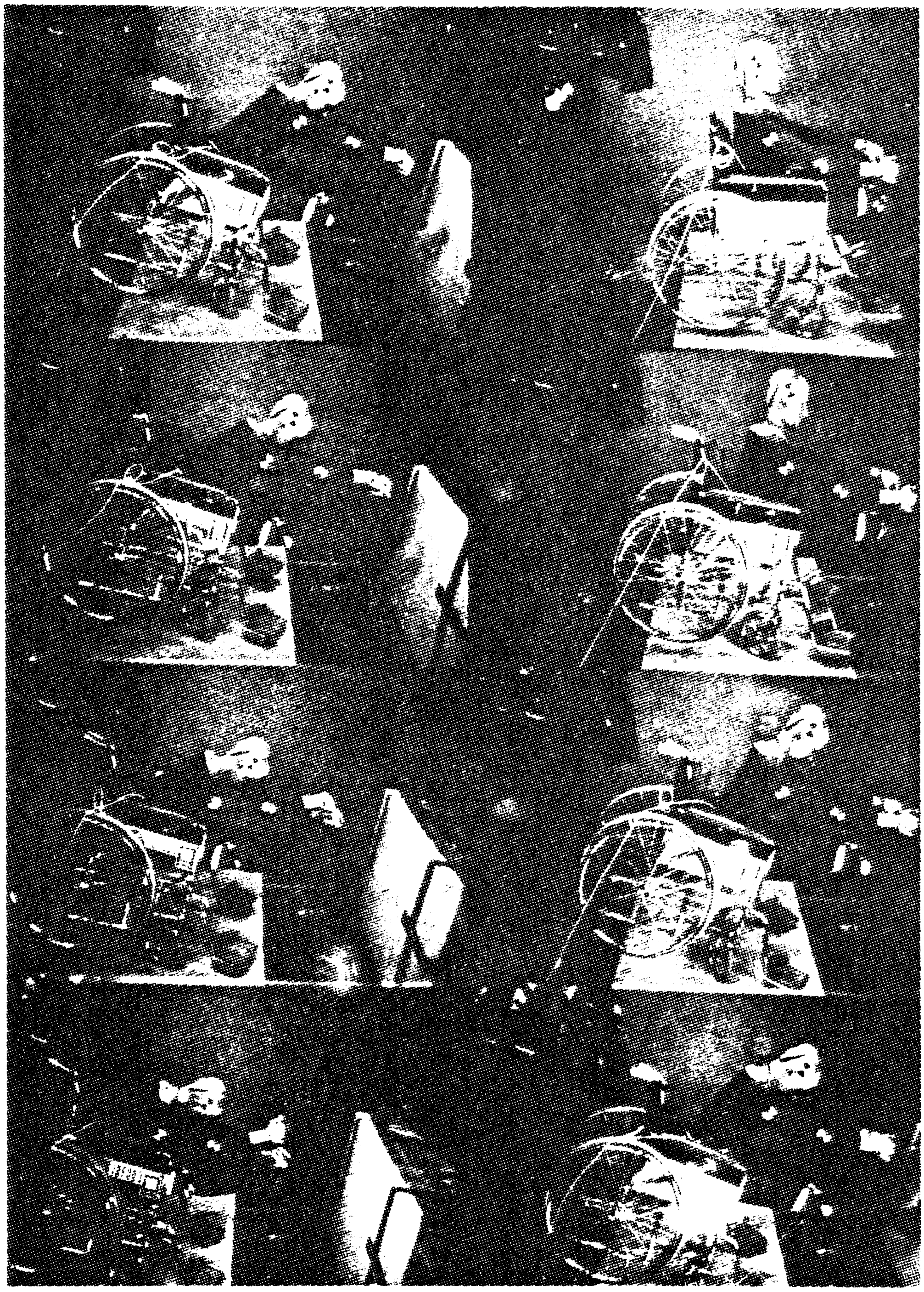
Set-Up Description:

The Collins Saf-T-Lock wheelchair restraints were bolted rigidly to the sled rails facing forward and the large wheels of the Junior wheelchair were secured in place by means of the steel pins. The 5th percentile female dummy was placed in the wheelchair and strapped to the chair back by means of the Collins Saf-T-Straint padded belt. The wheelchair friction brakes on both sides were applied and a load cell was installed to measure the tension in the Saf-T-Straint belt.

Photo of Set-Up:

Test No. and Type: 78F003 JUNIOR WHEELCHAIR

Graph Check Sequence Photograph:



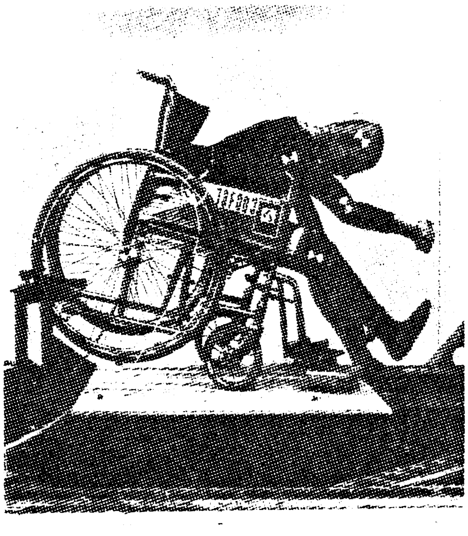
78F003

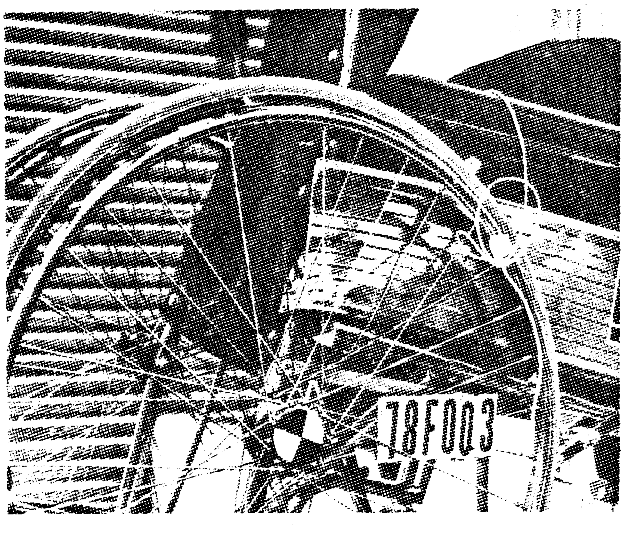
Test No. and Type: 78F003 JUNIOR WHEELCHAIR

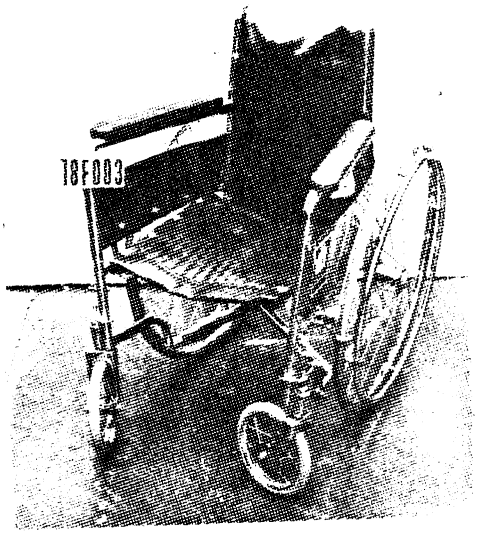
Description of Test Results:

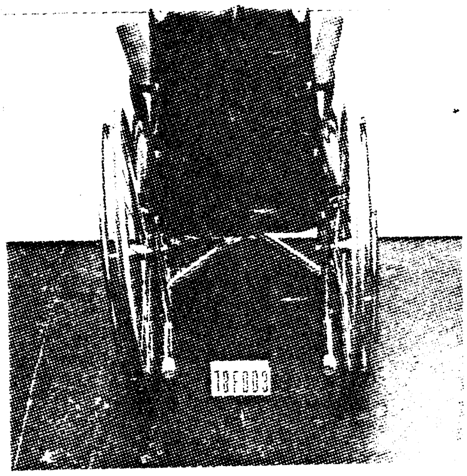
The Collins Saf-T-Lock device restrained the wheelchair and the Saf-T-Straint kept the dummy in the seat although the chair pitched forward about 10 degrees and remained in that position at the end of the test. The head and torso of the dummy pitched forward extensively with the dummy jackknifing at the hip joint. The maximum head excursion was 74.7 centimeters (29.4 inches) in the direction of impact. Peak tension in the Collins Saf-T-Straint belt was 660 lbf. During the test the wheelchair collapsed in back so that the rear handles touched. The plastic tube inserts which fix the horizontal seat bars to the vertical frame on the front of the chair popped out resulting in separation of the wheelchair frame. There was moderate damage to the wheelchair including bent frame tubing and axles.

Photographs of Results:









Test No. and Type: 78F004 JUNIOR WHEELCHAIR

Restraint: Collins Saf-T-Lock; Collins Saf-T-Straint

Dummy: 5th percentile female (105 lbs.)

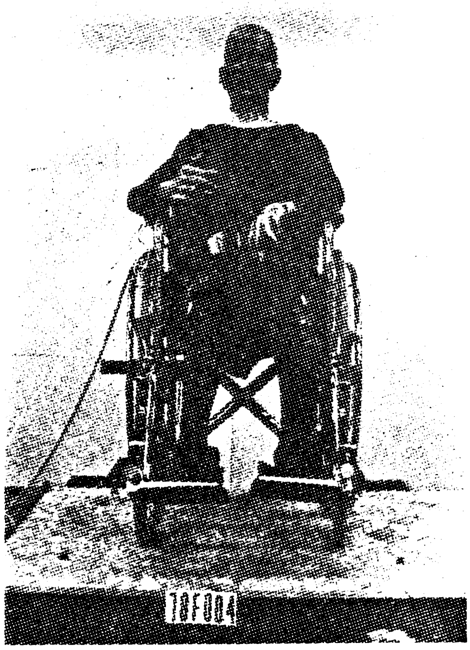
Orientation in Bus: Side facing

Impact Pulse: 20 m.p.h., 16 G, head-on impact

Set-Up Description:

The Collins Saf-T-Lock wheelchair restraints were bolted to the sled rails an appropriate distance apart along the left side of the sled and facing to the right. The Junior wheelchair was secured in position using the steel pins and the 5th percentile female dummy was strapped in the chair by means of the Collins Saf-T-Straint padded belt. The wheelchair friction brakes on both sides were applied and a load cell was installed to measure the tension in the Saf-T-Straint belt.

Photograph of Set-Up:



Test No. and Type: 78F004 JUNIOR WHEELCHAIR

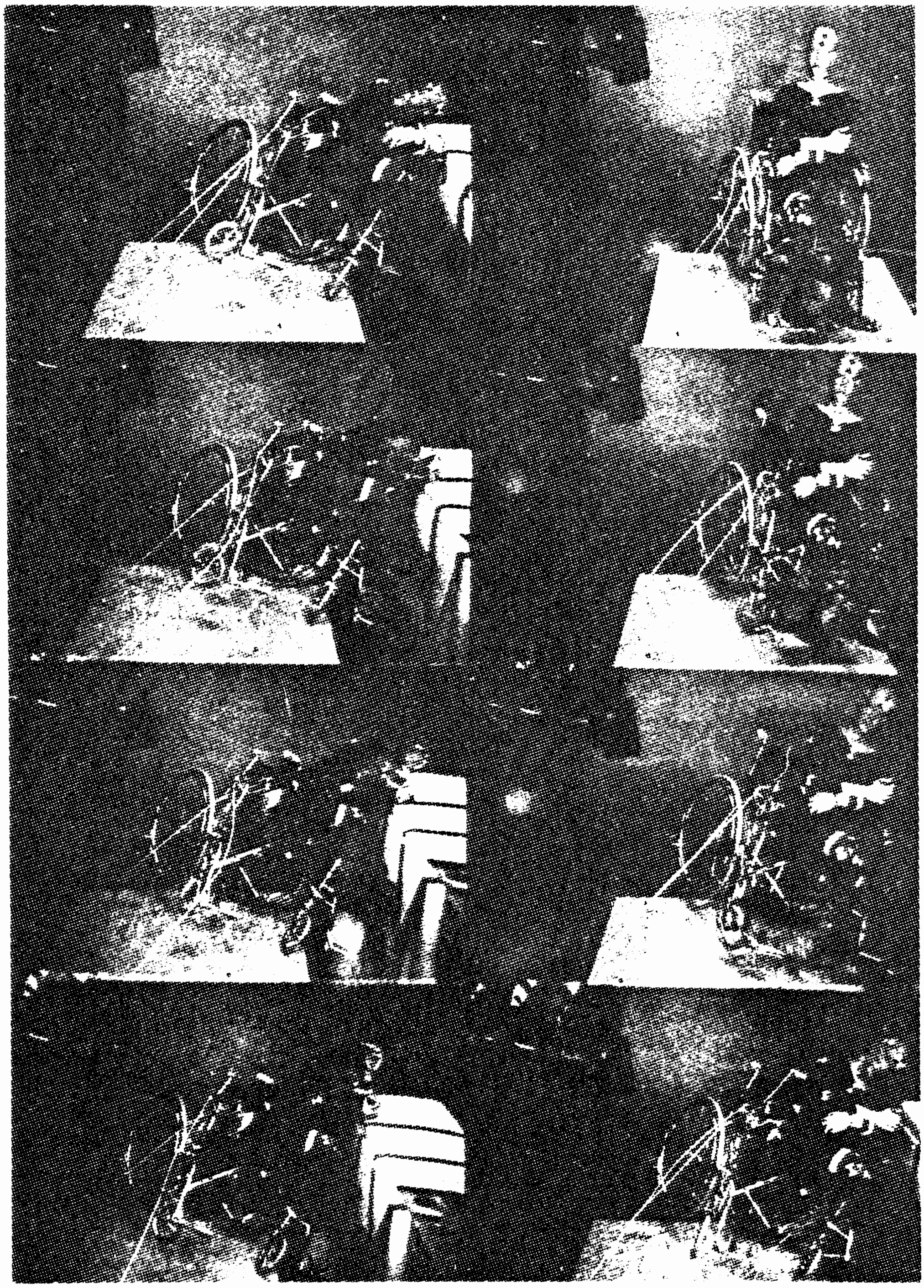
Graph Check Sequence Photograph:

5 1

6 2

7 3

8 4



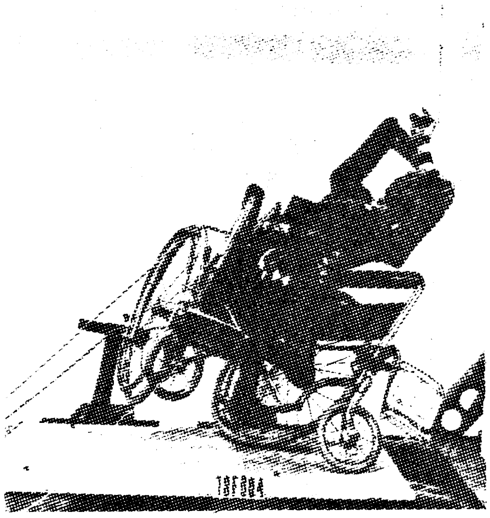
78F004

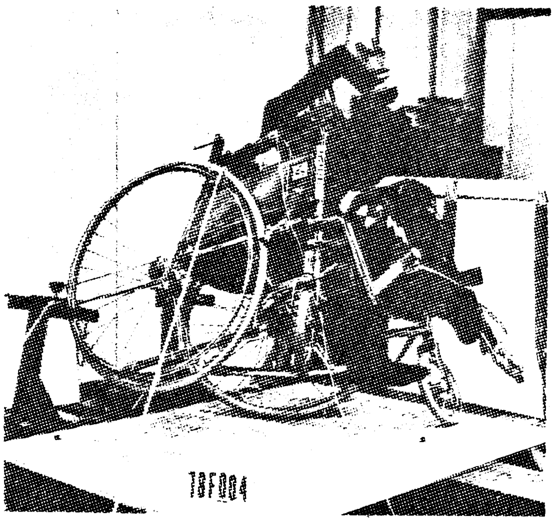
Test No. and Type: 78F004 JUNIOR WHEELCHAIR

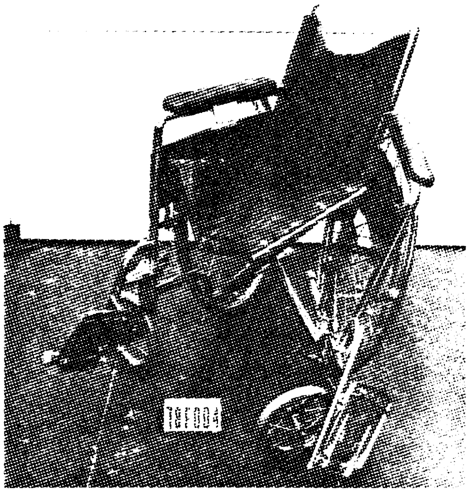
Description of Test Results:

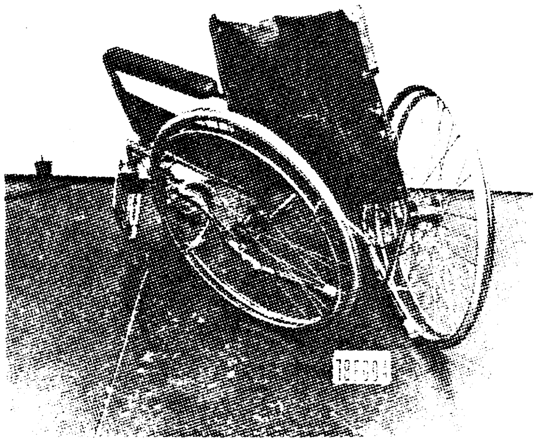
The Collins Saf-T-Locks held on to the wheelchair and the Saf-T-Straint held on to the dummy but the wheelchair and dummy underwent severe torquing and twisting during impact. The bottom plate on the rearward Saf-T-Lock was bent out of shape around the floor bolts and the restraint itself was bent over at about a 15 degree angle to the vertical. The dummy flexed sideways into the left side of the chair breaking the side frame away at the front. The maximum head excursion of the dummy was 96.8 centimeters (38.1 inches) in the direction of impact. Damage to the wheelchair was extensive including frame separation and bending and bending of the left wheel axle. The peak force in the Saf-T-Straint belt was 370 lbf.

Photographs of Results:









Test No. and Type: 78F005 TINY TOT WHEELCHAIR

Restraint: Collins Saf-T-Lock; Collins Saf-T-Straint

Dummy: 6 year child dummy (49 lbs.)

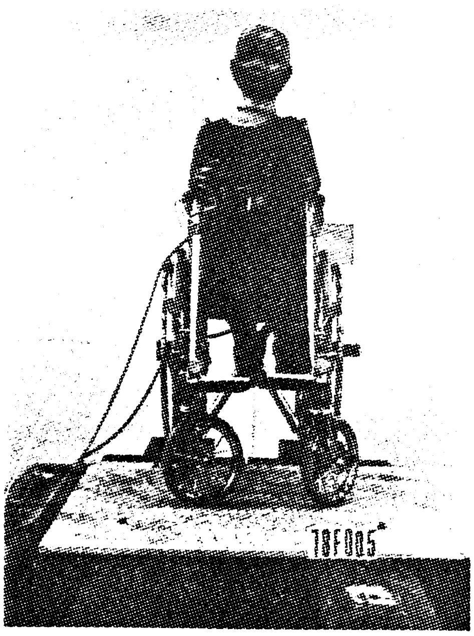
Orientation in Bus: Side facing

Impact Pulse: 20 m.p.h., 16 G, head-on impact

Set-Up Description:

The Collins Saf-T-Lock wheelchair restraints were bolted to the sled rails an appropriate distance apart along the left side of the sled and facing to the right. The Tiny Tot wheelchair was secured in position using the steel pins and the 6 year dummy was strapped in the chair by means of the Collins Saf-T-Straint padded belt. The wheelchair friction brakes on both sides were applied and a load cell was installed to measure the tension in the Saf-T-Straint belt.

Photograph of Set-Up:



Test No. and Type: 78F005 TINY TOT WHEELCHAIR

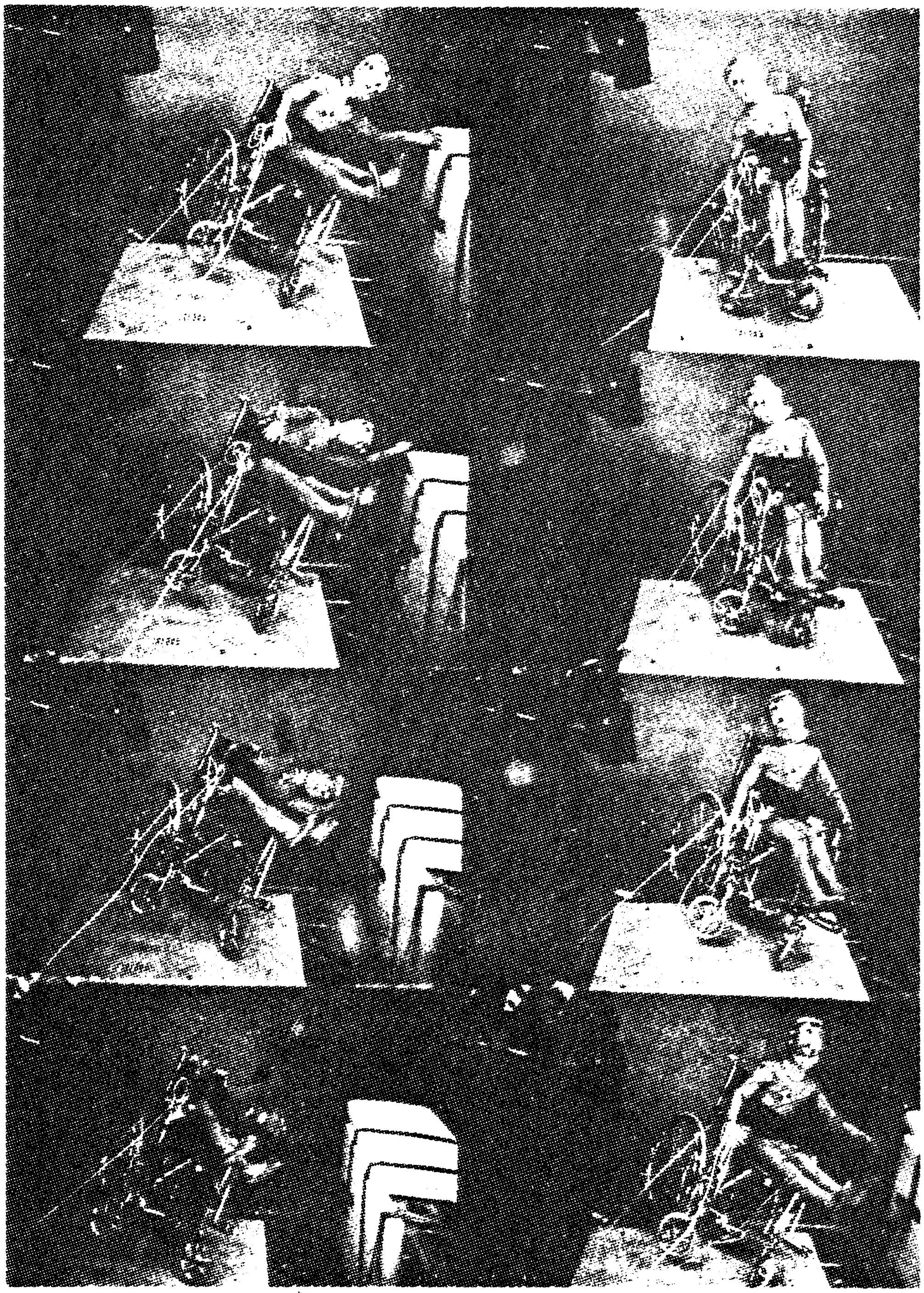
Graph Check Sequence Photograph:

5 1

6 2

7 3

8 4



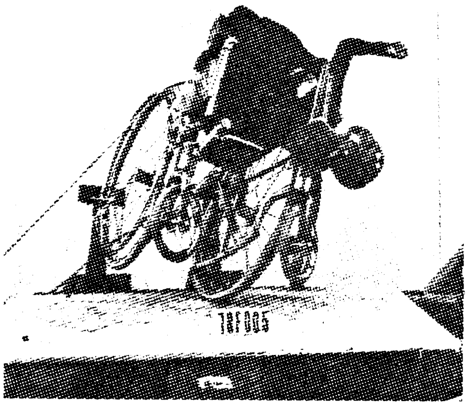
78F005

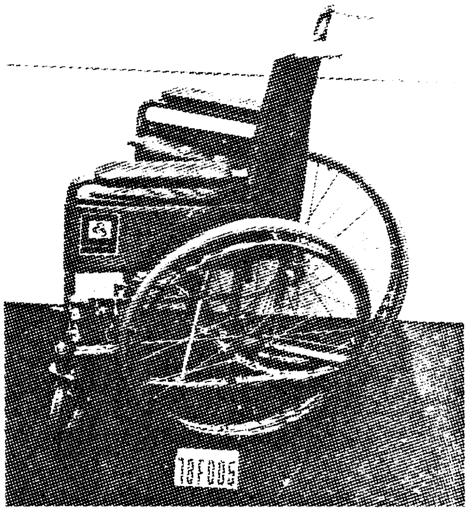
Test No. and Type: 78F005 TINY TOT WHEELCHAIR

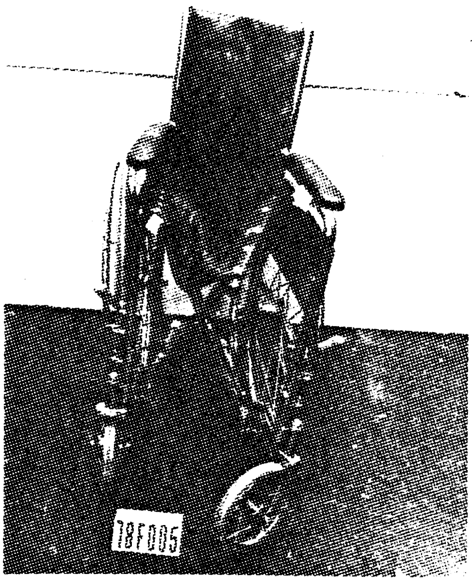
Description of Test Results:

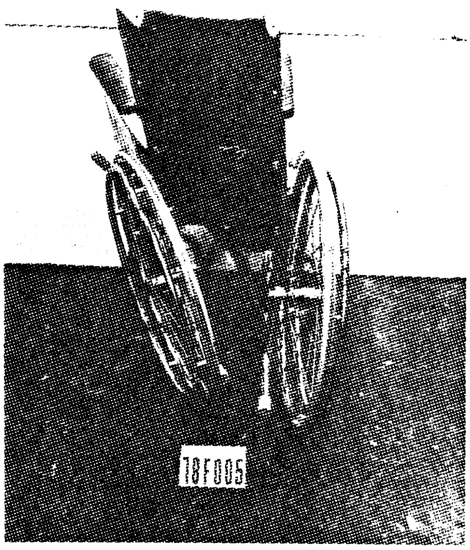
The Collins Saf-T-Lock devices held on to the wheelchair and the Saf-T-Straint held on to the dummy but the wheelchair and dummy underwent severe torquing and twisting sidewards as the impact proceded. The dummy flexed extensively over the wheelchair arm with the dummy's head moving 99.3 centimeters (39.1 inches) in the direction of impact. The maximum belt load in the Saf-T-Straint belt was about 255 lbf. Wheelchair damage was moderate with considerable frame and axle bending on the left side. The plastic insert on the horizontal tubing of the seat frame popped in the front resulting in separation of the chair frame.

Photographs of Results:









Test No. and Type: 78F006 TINY TOT WHEELCHAIR

Restraint: Safety belt to bus wall; Collins Saf-T-Straint

Dummy: 6 year child (49 lbs.)

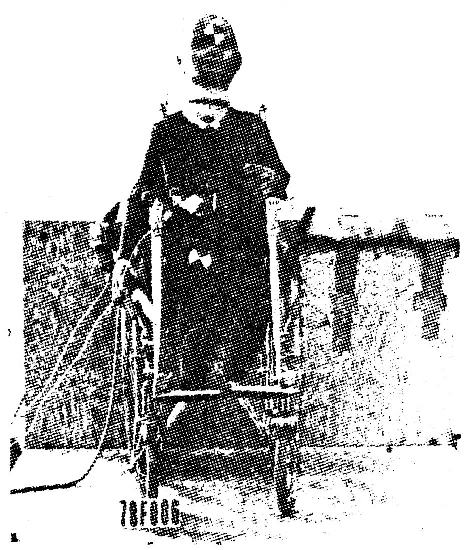
Orientation in Bus: Side facing

Impact Pulse: 20 mph, 16 G, head-on impact

Set-Up Description:

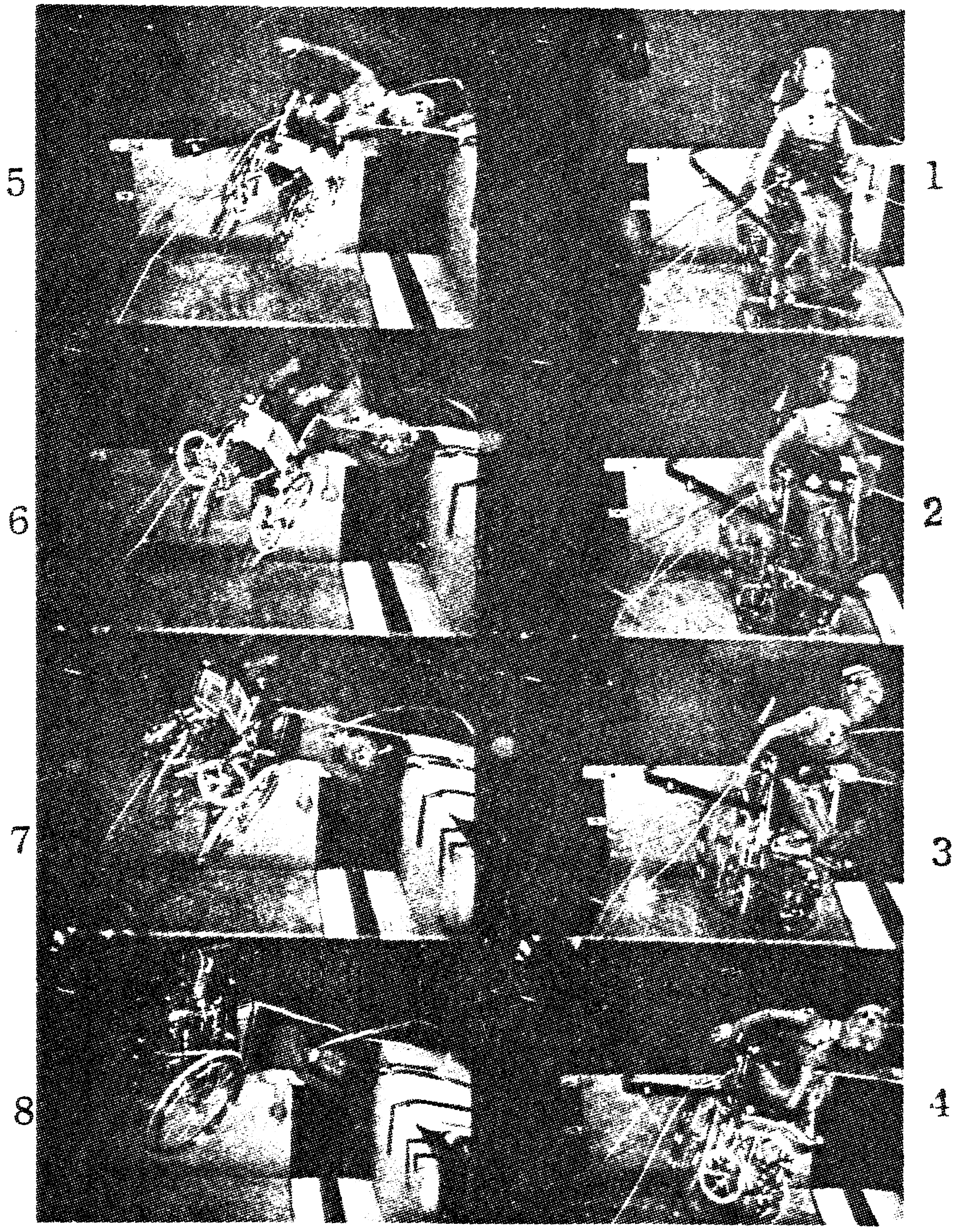
A pseudo-bus wall about two feet high was constructed using angle iron and a sheet of 3/4 inch plywood and bolted to the left side of the sled. Rupert safety belt anchors were bolted to this structure approximately 24 inches from the floor. The Tiny Tot Wheelchair with six year dummy secured by means of the Collins Saf-T-Straint was backed up to this wall midway between the belt anchors. A Rubert belt was installed and wrapped about the front of the wheelchair. Each half of the belt was wrapped around the front vertical frame on its side just beneath the sheet metal sides before buckling in front of the chair behind the dummy's legs. The belt was tightened by hand and the wheelchair brakes were applied. A piece of masking tape was used to keep the dummy's head from moving during sled acceleration. Two load cells were used to measure the belt tensions in the Saf-T-Straint and the belt holding the wheelchair.

Photograph of Set-Up:



Test No. and Type: 78F006 TINY TOT WHEELCHAIR

Graph Check Sequence Photograph:



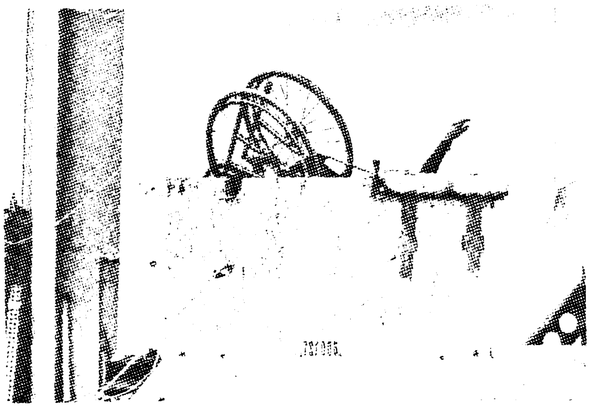
78F006

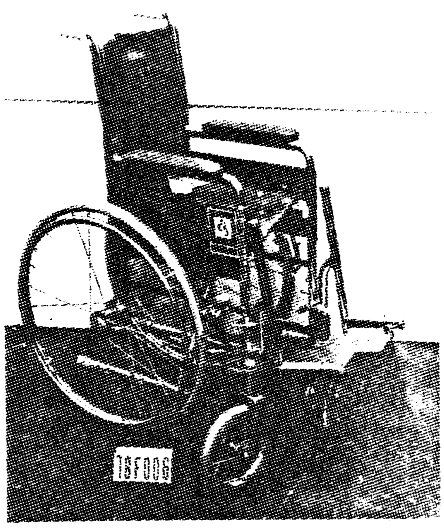
Test No. and Type: 78F006 TINY TOT WHEELCHAIR

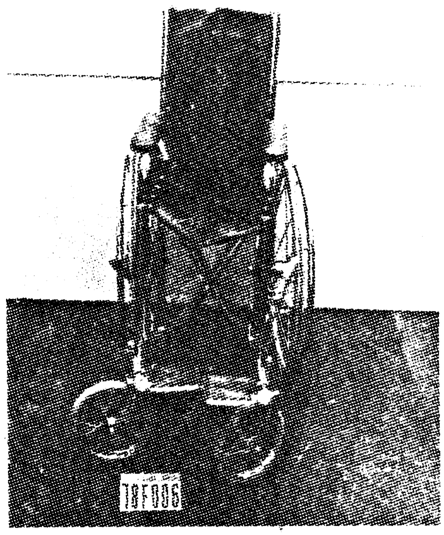
Description of Test Results:

Upon impact, the wheelchair and dummy moved forward on the sled, the dummy flexing sidewards and rotating and the chair rotating and collapsing together on the dummy. The tension in the wheelchair restraining belt and the slight downward direction of the belt from the wall anchors to the wheelchair resulted in an upward and rearward force on the wheelchair pulling the chair with the dummy up and over the two foot bus wall. The test ended with the wheelchair with dummy hanging over the wall on the opposite side. The maximum head excursion was 86.6 centimeters (24.1 inches) in the direction of impact. Damage to the chair was relatively minor.

Photographs of Results:







Test No. and Type: 78F007 JUNIOR WHEELCHAIR

Restraint: Two safety belts to bus wall; Collins Saf-T-Straint

Dummy: 5th percentile female (105 lbs.)

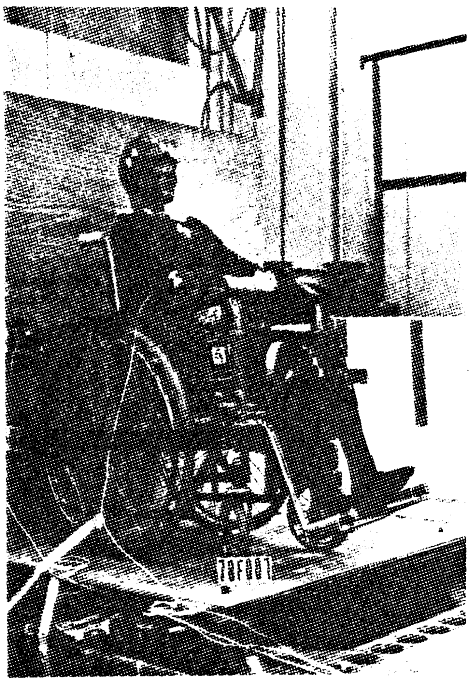
Orientation in Bus: Side facing

Impact Pulse: 20 m.p.h., 16 G, head-on impact

Set-Up Description:

A pseudo-bus wall about four feet high was constructed out of angle iron and 3/4 inch plywood and bolted to the left side of the sled. Two sets of Rupert Safety belt anchors were bolted to this structure at about 12 and 24 inches from the bus floor. The Junior wheelchair with the 5th percentile female dummy restrained to the wheelchair back by means of the Collins Saf-T-Straint was backed up to the wall between the belt anchors. Two Rupert Safety belts were installed. The upper belt was wrapped around the front of the wheelchair and pulled taunt in the groove between the armrests and the arm frame tubing. The lower belt was wrapped around the front of the wheelchair inside the footrest fixtures and behind the dummy's legs. Both belts were buckled in front. The wheelchair brakes were applied prior to testing. Three load cells were used to measure the belt tensions in the Saf-T- Straint belt and upper and lower wheelchair restraining belts.

Photograph of Set-Up:



Test No. and Type: 78F007 JUNIOR WHEELCHAIR

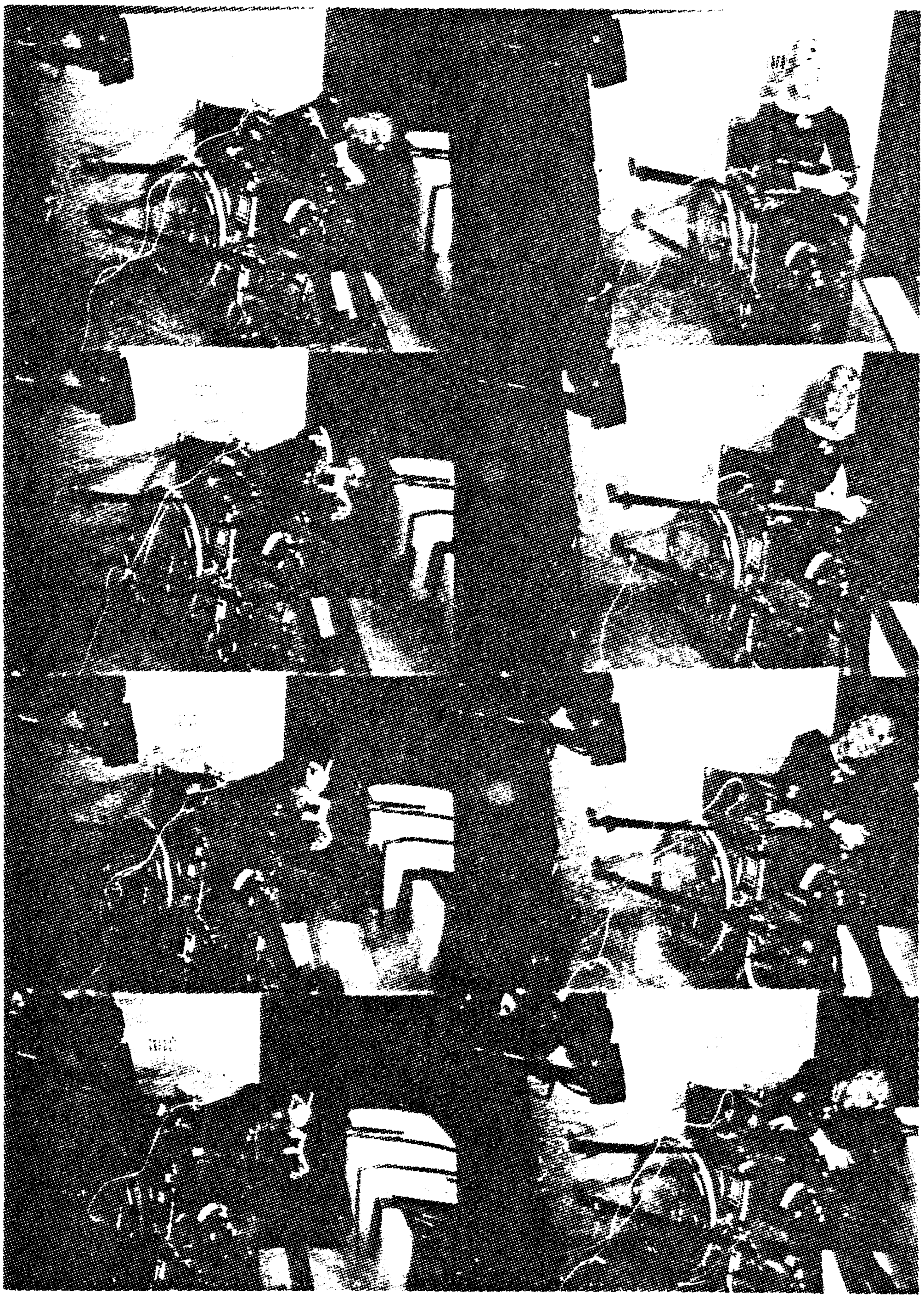
Graph Check Sequence Photograph:

5 1

6 2

7 3

8 4



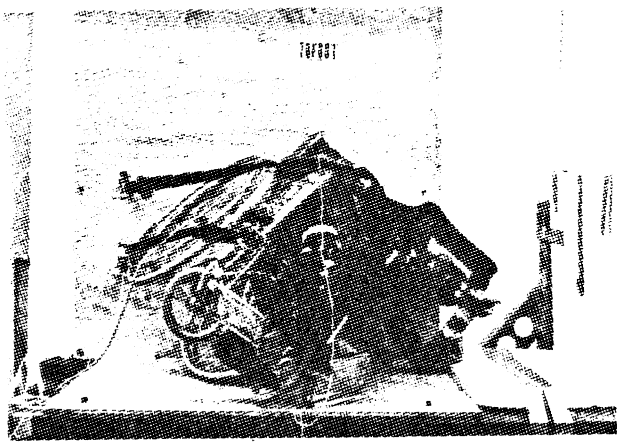
78F007

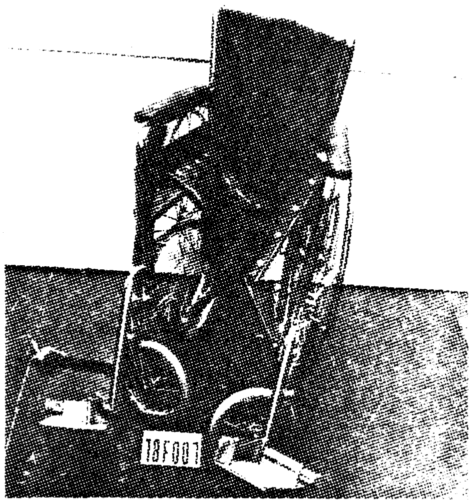
Test No. and Type: 78F007 JUNIOR WHEELCHAIR

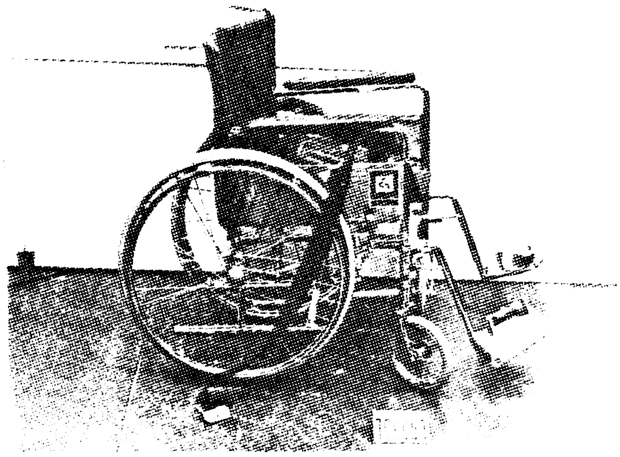
Description of Test Results:

Upon impact, the wheelchair rotated forward pivoting about the left rear wheel and the dummy rotated and flexed sidways into the wheelchair structure with the dummy's head crossing the plane of the pseudo-bus wall forward of the wall. At the end of the test the wheelchair had tipped nearly completely over and the dummy's arms were resting on the floor forward of the starting position, the dummy hanging sideways over the arm of the wheelchair. Damage to the wheelchair was substantial including frame separation and bending, and extensive bending of the left axle. The upper belt became wedged between the armrest and arm frame tubing. The maximum excursion of the dummy's head was 97.0 centimeters (38.2 inches) in the direction of impact. The peak belt tensions were 260 lbf in the Saf-T-Straint, 1,250 lbf in the upper wheelchair belt and 850 lbf in the lower wheelchair belt.

Photographs of Results:







Test No. and Type: 78F008 BUS SEAT WITH RUPERT E-Z-ON HARNESS

Restraint: Rupert E-Z-On Harness

Dummy: 6 year child dummy (49 lbs)

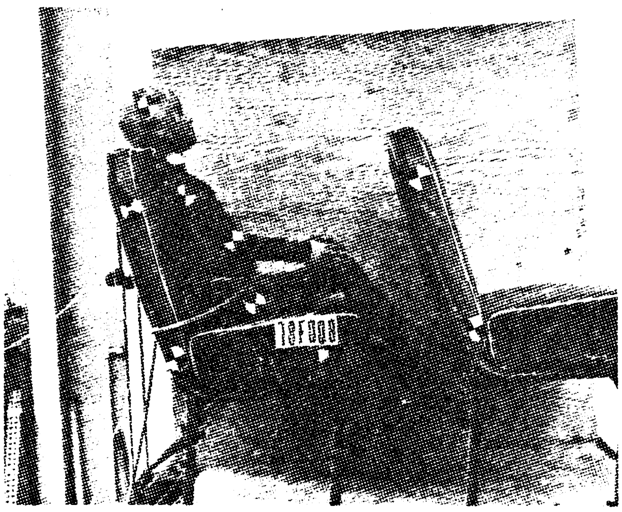
Orientation in Bus: Forward facing

Impact Pulse: 20 m.p.h., 16 G, head-on impact

Set-Up Description:

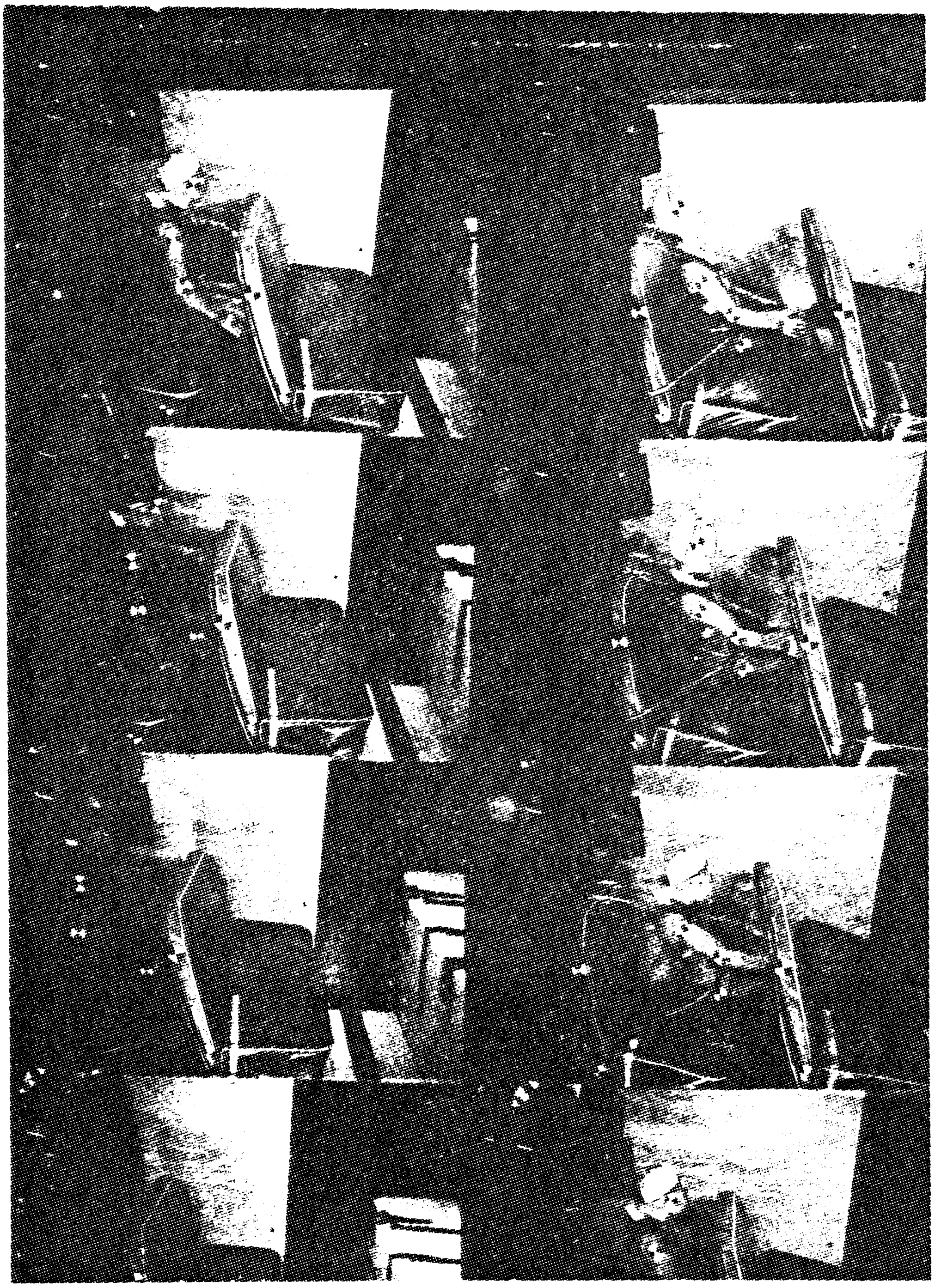
Two school bus seats and a pseudo bus wall and floor were bolted to the sled facing forward with a horizontal distance of 27 inches from the back of the rear seat to the back of the front seat. The Rupert harness eye bolts were bolted to the sled just behind the rear seat and about 14 inches apart. The two upper belts and two lower belts were placed over and through the seat as described in the Rupert instructions. The six year old child dummy, wearing the Rupert harness, was seated in the center of the rear seat, the four belt clips fastened to the four "D" rings provided on the harness, and adjsuted for reasonable tension. Four load cells were used to measure the tensions in these four restraint belts.

Photograph of Set-Up:



Test No. and Type: 78F008 BUS SEAT WITH RUPERT E-Z-ON HARNESS

Graph Check Sequence Photograph:



5 1

6 2

7 3

8 4

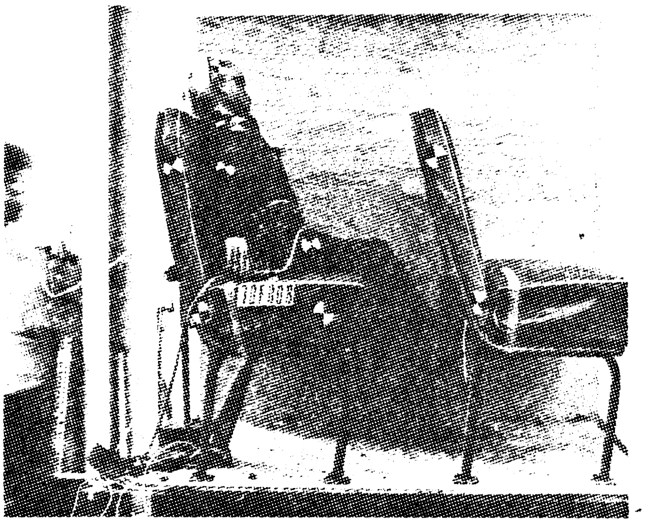
78F008

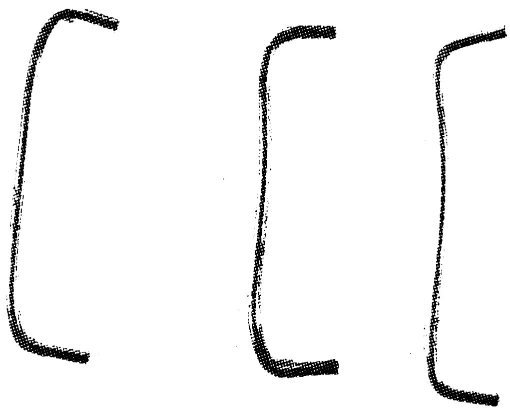
Test No. and Type: 78F008 BUS SEAT WITH RUPERT E-Z-ON HARNESS

Description of Test Results:

Upon impact the dummy began to slide forward on the bus seat increasing the tension in the restraint belts. After a few inches travel, three of the four "D" rings opened and flew free of the sled, one landing over 25 feet away. Only the upper left "D" ring held, thereby providing continued restraint to the upper torso. The lower torso continued to move forward with the knees and lower legs striking the back of the front seat. The head did not contact with the front seat. Maximum head excursion was 46.7 centimeters (18.4 inches) in the direction of impact. Peak belt loads were 300 and 170 lbf in the left and right upper belts and 170 and 150 lbf in the left and right lower belts respectively.

Photographs of Results:





Three of the four "D" rings which sprung open during impact.

Test No. and Test Type: 78F009 BUS SEAT WITH EASY WAY DUBL-LIFE SAVER

Restraint: Easy Way Dubl-Life Saver Restraint Vest

Dummy: 6 year child dummy (49 lbs.)

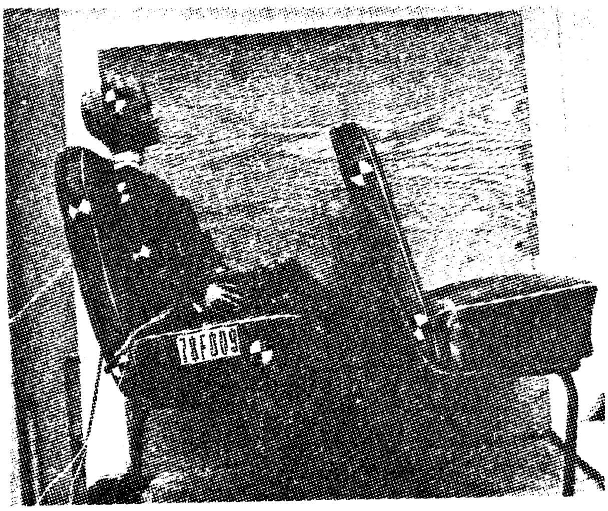
Orientation in Bus: Forward facing

Impact Pulse: 20 m.p.h., 16 G, head-on impact

Set-Up Description:

Two bus seats and a pseudo bus wall and floor were bolted to the sled facing forward with a horizontal distance of 27 inches from the back of the rear seat to the back of the front seat. The Easy Way Dubl-Life Saver Restraint Vest was placed on the rear seat with the vertical belt wrapped around the seat back by placing it between the seat back and seat cushion and was pulled tight. The 6 year child dummy was placed on the rear seat and the belt and pad wrapped around his waist and abdomen and pulled tight. Two load cells were used to measure the tension in the seat back and dummy belts.

Photograph of Set-Up:



Test No. and Test Type: 78F009 BUS SEAT WITH EASY WAY DUBL-LIFE SAVER

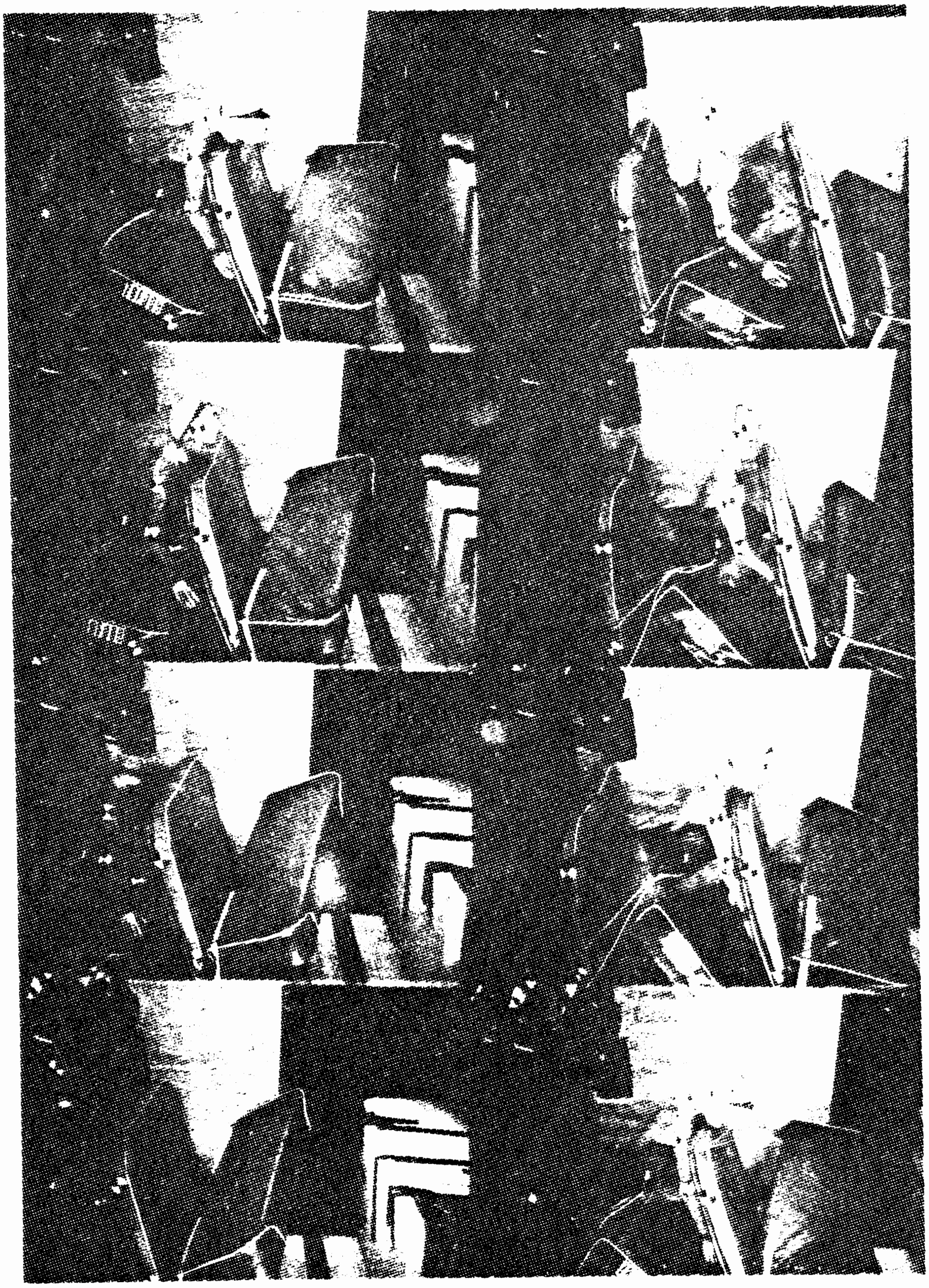
Graph Check Sequence Photograph:

5 1

6 2

7 3

8 4



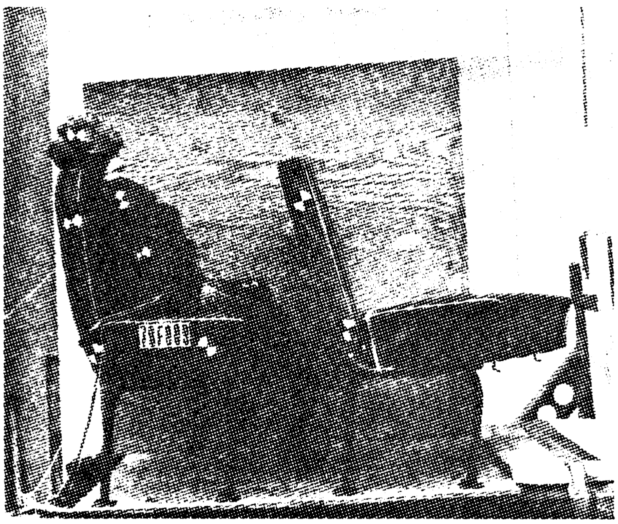
78F009

Test No. and Test Type: 78F009 BUS SEAT WITH EASY WAY DUBL-LIFE SAVER

Description of Test Results:

Upon impact, the dummy moved forward on the seat, the belt and harness system appearing to stretch and give and provide little initial restraint. Excursion of the torso was 40.6 centimeters (16 inches) before head rotation began. The head flexed forward as the torso reached its maximum excursion, the chin striking the top of the front seat back. The maximum head excursion was 71.4 centimeters (28.1 inches) in the direction of impact. The rear seat back was bent forward to a nearly vertical position. Peak belt loads were 540 lbf. in the belt over the seat back and 240 lbf. in the belt around the dummy.

Photograph of Results:



Test No. and Test Type: 78F010 BUS SEAT WITH FORD TOT GUARD

Restraint: Ford Tot Guard without booster seat; lap belted bolted to floor

Dummy: 5th percentile female (105 lbs.)

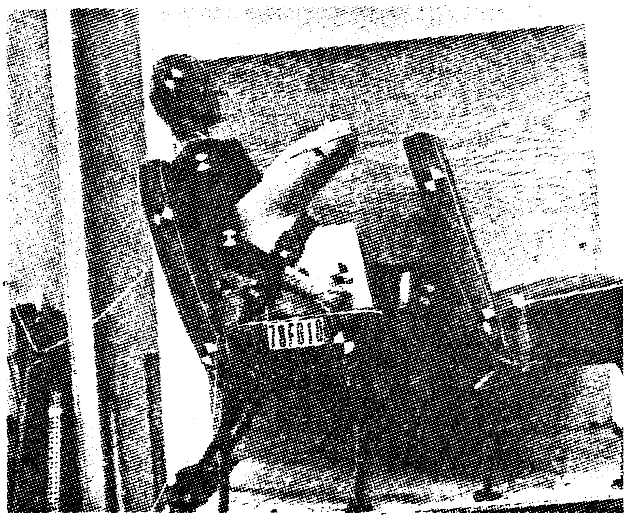
Orientation in Bus: Forward facing

Impact Pulse: 20 m.p.h., 16 G, head-on impact

Set-Up Description:

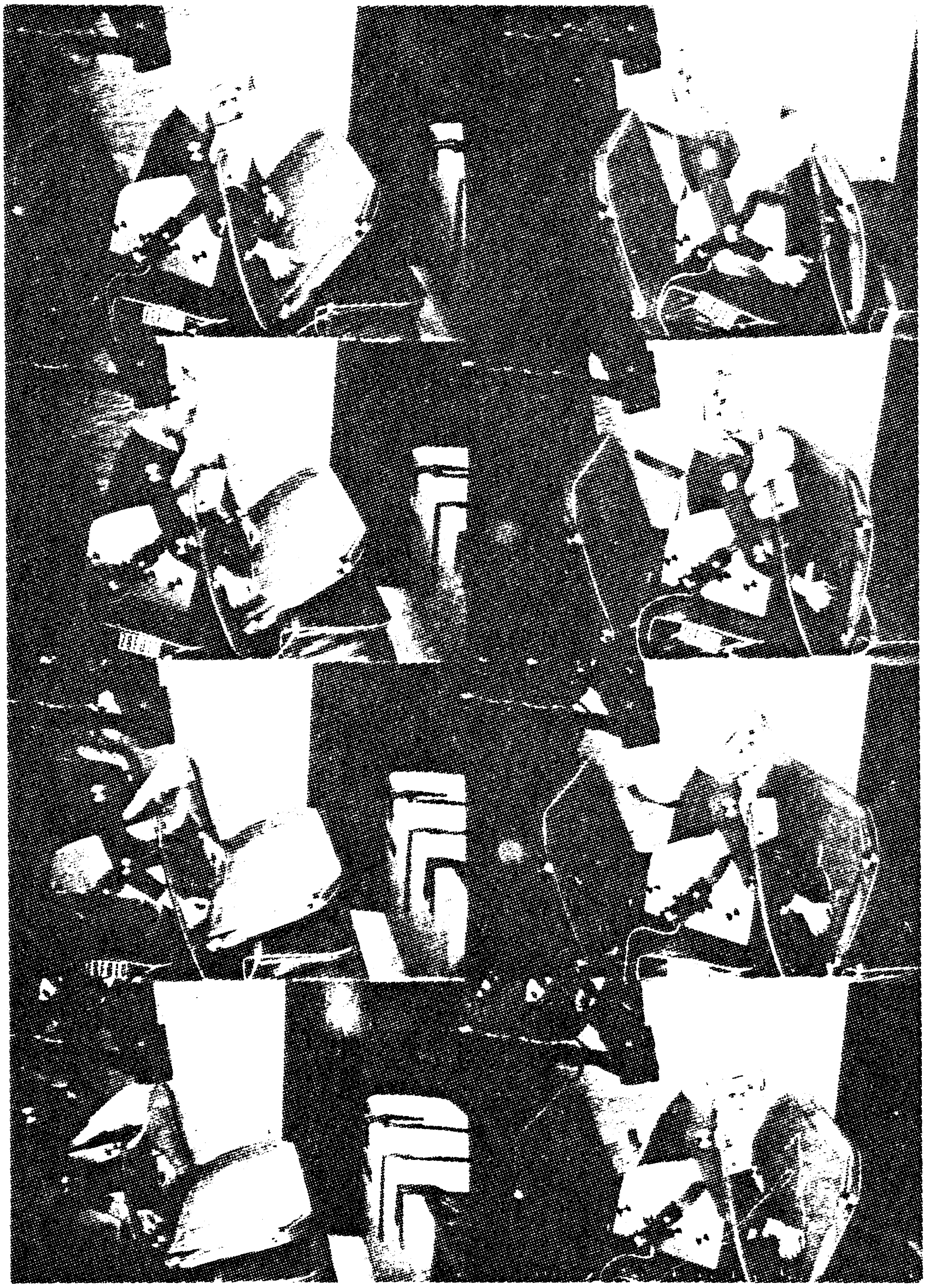
Two school bus seats and a pseudo bus wall and floor were bolted to the sled facing forward with a horizontal distance of 27 inches from the back of the rear seat to the back of the front seat. A Rupert seat belt was bolted to the sled under and just behind the rear seat and inserted through the seat between and around the seat cushion and seat frame. The 5th percentile female dummy was seated in the center of the rear seat and the Ford Tot Guard (without booster) put in place. The seat belt was wrapped around the Tot Guard and pulled tight. A load cell was used to measure the tension in the belt near the Tot Guard.

Photograph of Set-Up:



Test No. and Test Type: 78F010 BUS SEAT WITH FORD TOT GUARD

Graph Check Sequence Photograph:



5 6 7 8 1 2 3 4

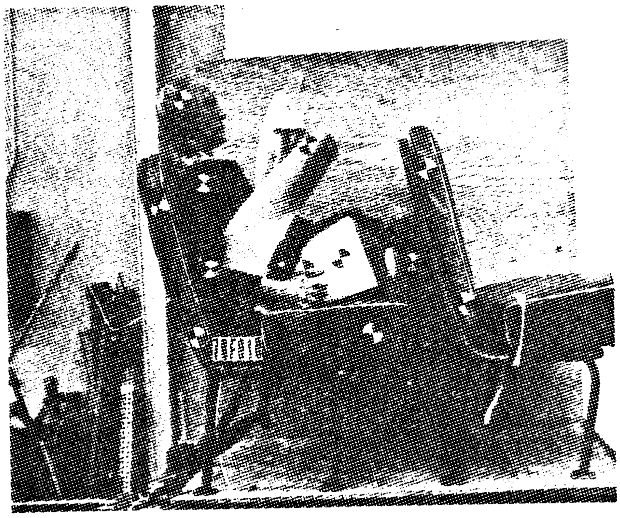
78F010

Test No. and Test Type: 78F010 BUS SEAT WITH FORD TOT GUARD

Description of Test Results:

Upon impact the dummy and Tot Guard moved forward and then downward on the seat cushion while the seat cushion itself attempted to break free pushing up and forward on the dummy seat. The dummy's knees impacted violently into the back of the front seat knocking it completely out and the dummy's lower face struck the seat back frame. The maximum excursion of the dummy's head was 82.0 centimeters (32.3 inches) in the direction of impact. Peak tension in the belt was 600 lbf.

Photograph of Results:



Test No. and Test Type: 78F011 BUS SEAT WITH ORTHO-KINETICS TRAVEL CHAIR

Restraint: Ortho-Kinetics Travel Chair with lap belt

Dummy: 6 year old dummy (49 lbs.)

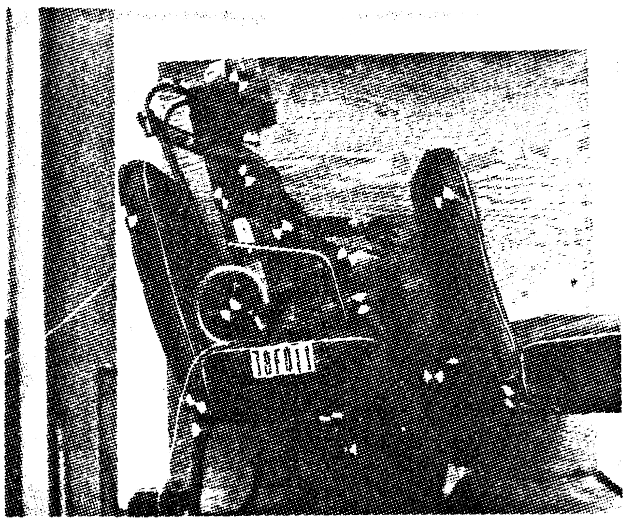
Orientation in Bus: Forward Facing

Impact Pulse: 20 m.p.h., 16 G, head-on impact

Set-Up Description:

Two bus seats and a pseudo bus wall and floor were bolted to the sled facing forward with a horizontal distance of 27 inches from the back of the rear seat to the back of the front seat. A Rupert seat belt was anchored to the seat structure at the junction of the seat and seat back. The Ortho-Kinetics travel chair was placed in the center of the seat and the 6 year dummy placed in the chair. Head rest and side supports were adjusted for optimum restraint and the vinyl straps and lap belt tightened. The seat belt was then placed around the dummy lap and pulled tight. A load cell was used to measure the tension in this lap belt.

Photograph of Set-Up:



Test No. and Test Type: 78F011 BUS SEAT WITH ORTHO-KINETICS TRAVEL CHAIR

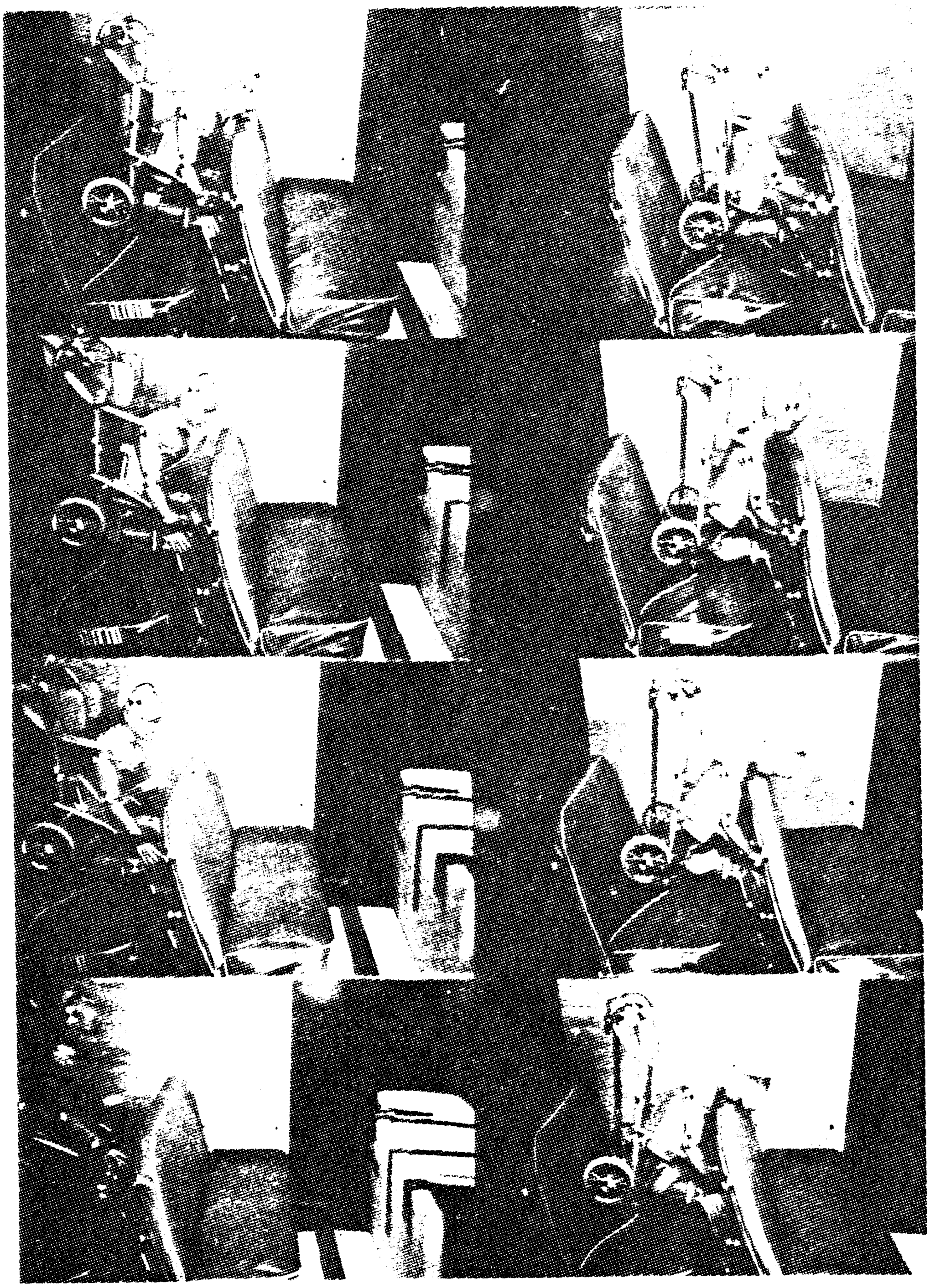
Graph Check Sequence Photograph:

5 1

6 2

7 3

8 4



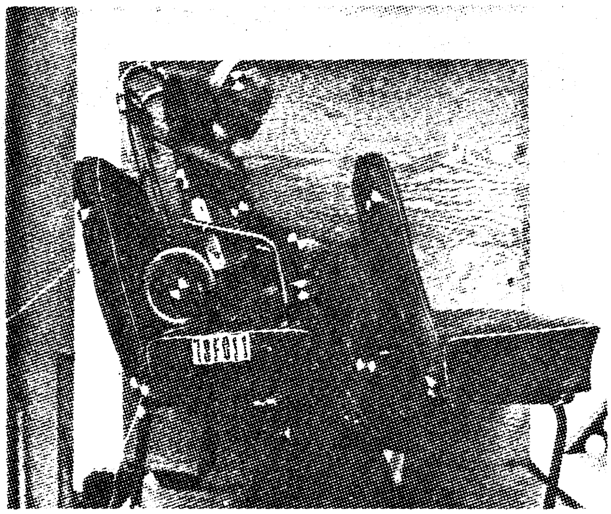
78F011

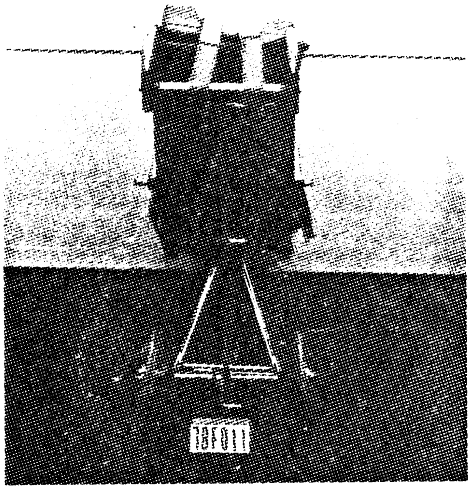
Test No. and Test Type: 78F011 BUS SEAT WITH ORTHO-KINETICS TRAVEL CHAIR

Description of Test Results:

Upon impact, the lap belt held the chair close to the bus seat but the upper portion of the chair and dummy rotated forward, the dummy breaking a vinyl strap, and the dummy's chin striking the top of the front seat back. Maximum head excursion was 59.9 centimeters (23.6 inches) in the direction of impact. Peak belt tension was 520 lbf. Damage to the Ortho-Kinetics chair was minor with one broken strap and slightly bent rear wheel axles.

Photographs of Results:





Test No. and Test Type: 78F012 TINY TOT WHEELCHAIR

Restraint: Two Rupert safety belts to bus wall; Collins Saf-T-Straint

Dummy: 6 year dummy (49 lbs.)

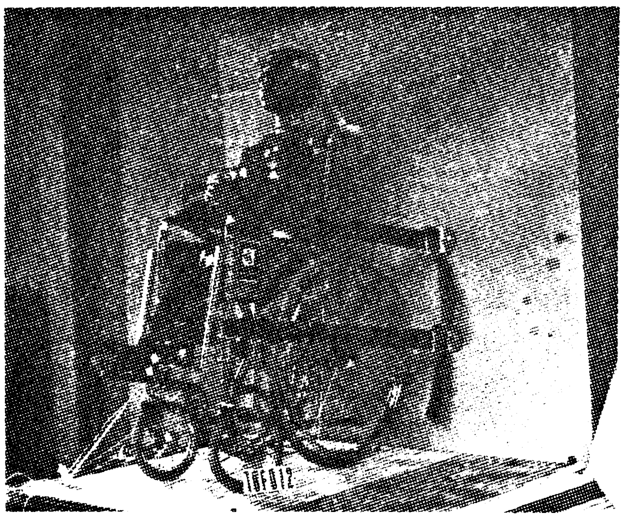
Orientation in Bus: Side facing

Impact Pulse: 20 m.p.h., 16 G, 33 degrees to bus front

Set-Up Description:

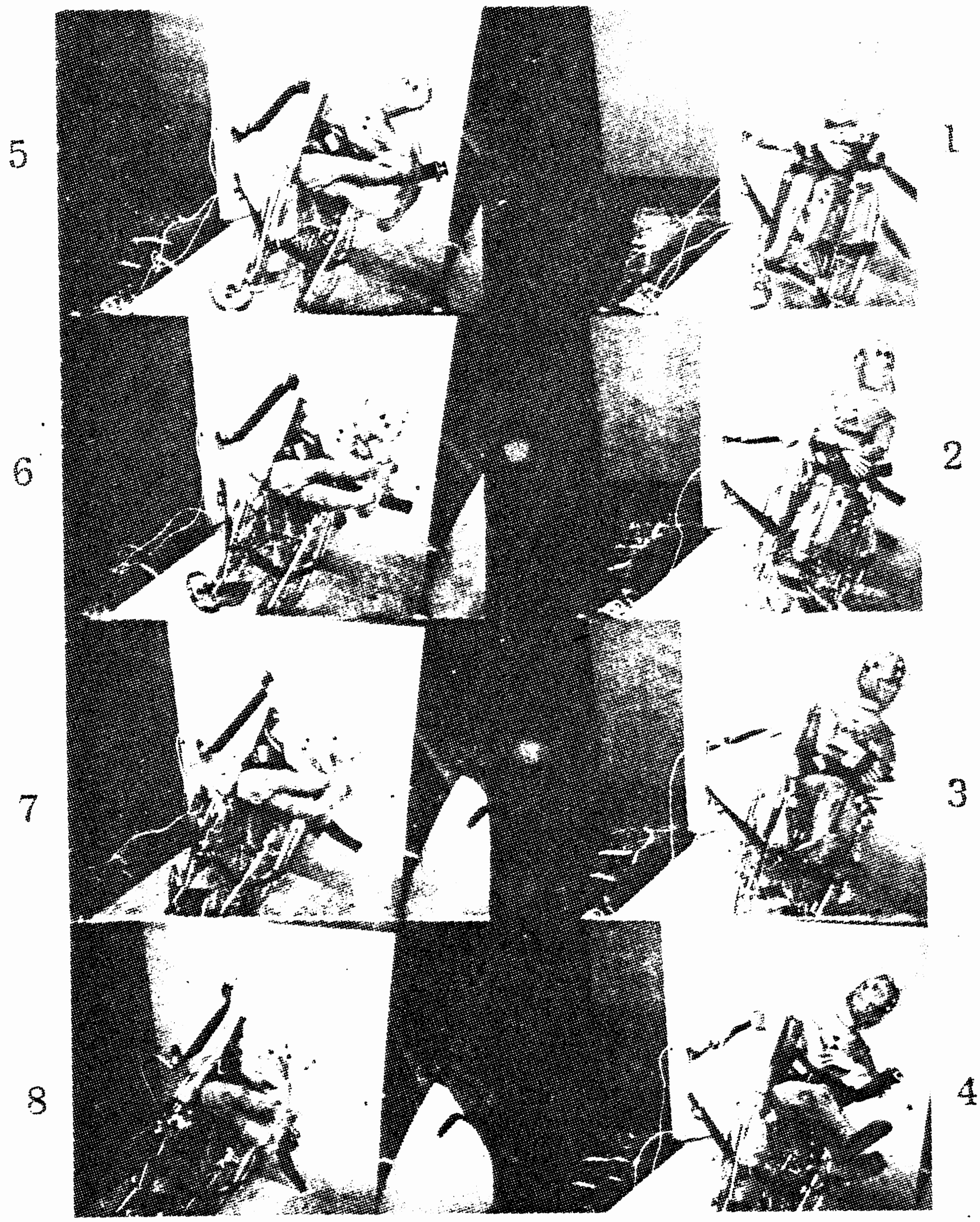
A pseudo bus wall and floor were bolted to the sled rails at an angle of 33 degrees to the side of the sled. Two Rupert blets were anchored to the wall at heights of 12 and 24 inches. The Tiny Tot wheelchair with 6 year dummy restrained to the chair back by the Collins Saf-T-Straint padded belt was backed up to the wall between the belt anchors. The upper belt was wrapped about the front of the wheelchair in the armrest grooves and tightened. The lower belt was wrapped around the front of the wheelchair just above the leg support fixtures and behind the dummy's legs and tightened. The wheelchair brakes were applied and two load cells were used to measure the tension in the lower chair belt and Saf-T-Straint belt.

Photograph of Set-Up:



Test No. and Test Type: 78F012 TINY TOT WHEELCHAIR

Graph Check Sequence Photograph:



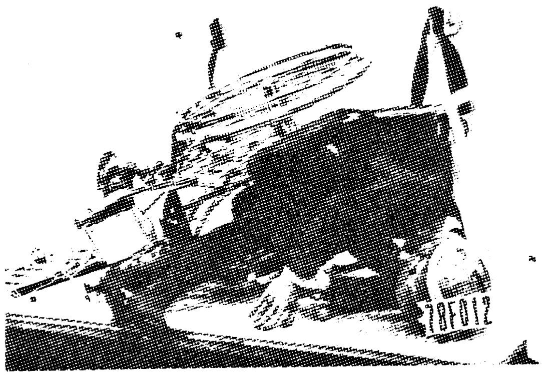
78F012

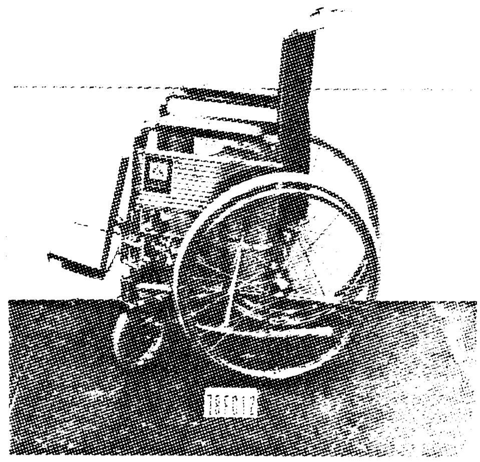
Test No. and Test Type: 78F012 TINY TOT WHEELCHAIR

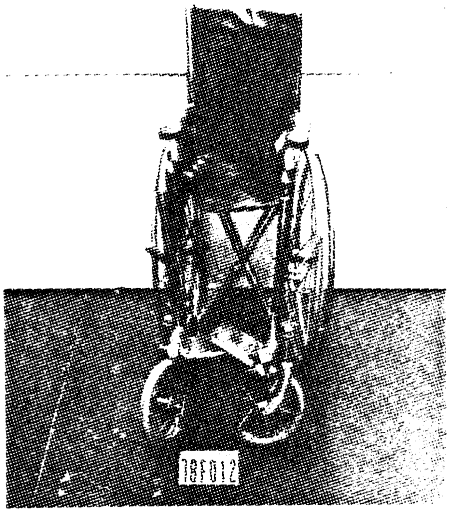
Description of Test Results:

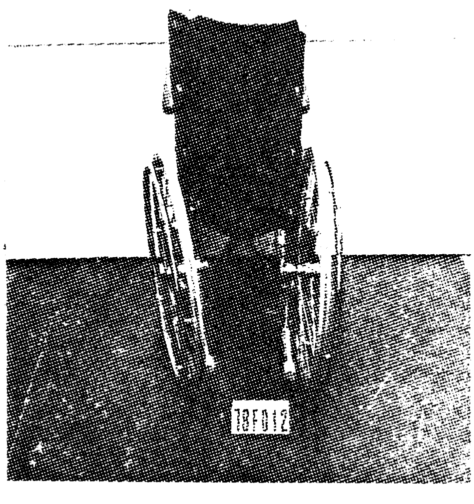
Upon impact the wheelchair and dummy rotated and fell sidewards toward the front of the sled with the back of the dummy's head striking the bus wall. Shortly after impact the upper chair belt broke loose at the buckle allowing the chair and dummy to fall completely over landing on the floor. The maximum head excursion of the dummy was about 67.6 centimeters (26.6 inches) in the direction of impact. Damage to the wheelchair was moderate including frame separation and badly bent left axle.

Photographs of Results:









Test No. and Test Type: 78F013 JUNIOR WHEELCHAIR

Restraint: One Rupert belt to bus wall; Collins Saf-T-Straint

Dummy: 5th percentile female (105 lbs)

Orientation in Bus: Side facing

Impact Pulse: 20 m.p.h., 16 G, 33 degrees to bus front

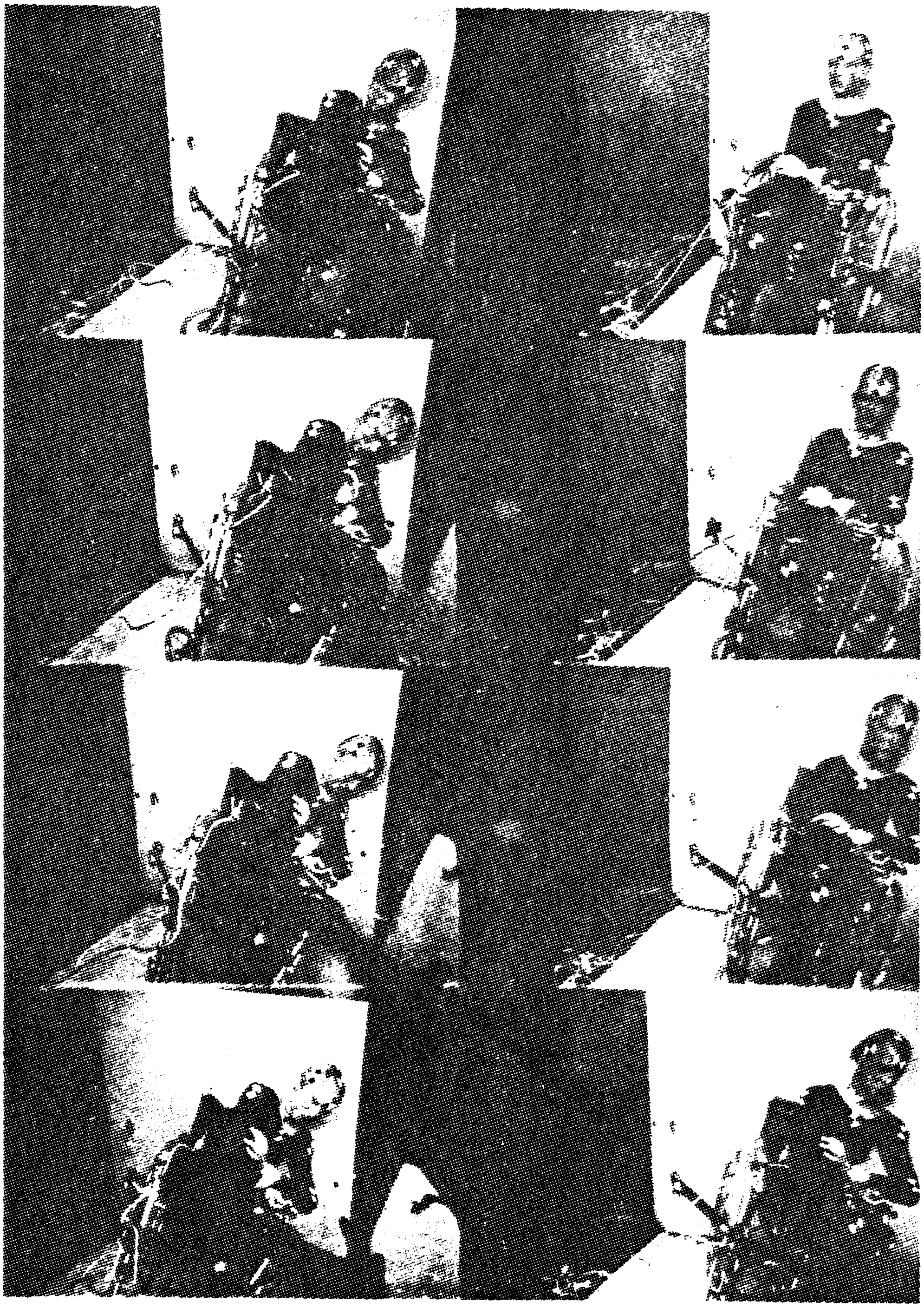
Set-Up Description:

A pseudo bus wall and floor were bolted to the sled at an angle of 33 degrees to the side of the sled. A Rupert belt was anchored to the wall at about 12 inches from the floor. The Junior wheelchair with female dummy restrained to the chair back by the Collins Saf-T-Straint padded belt was backed up to the wall between the belt anchors. The safety belt was wrapped around the front of the chair just above the foot rest fixtures behind the dummy's legs and inside of the brake levers. The belt was buckled in front and pulled tight. The wheelchair brakes were applied and two load cells were used to measure the tension in the Saf-T-Straint and chair belt.

Photographs of Set-Up:

Test No. and Test Type: 78F013 JUNIOR WHEELCHAIR

Graph Check Sequence Photograph:



5 1
6 2
7 3
8 4

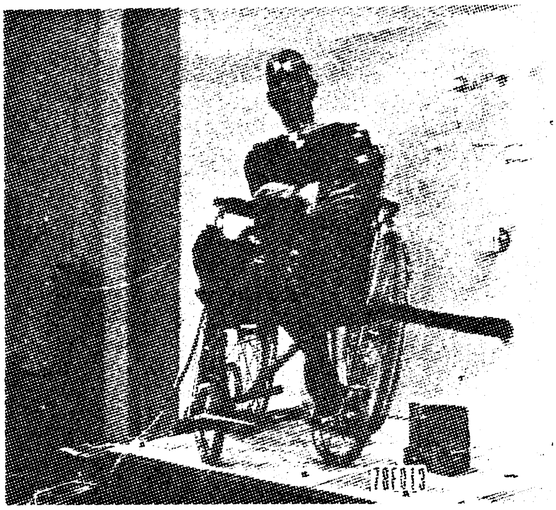
78F013

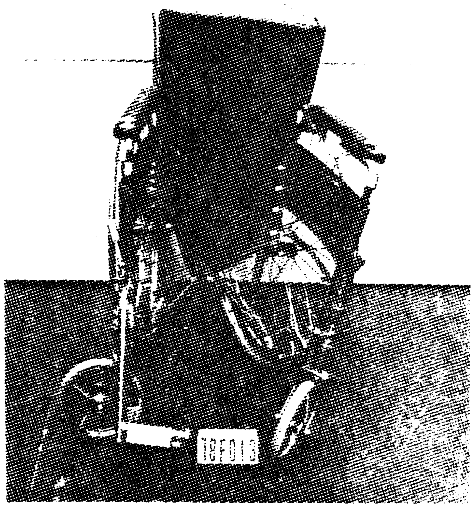
Test No. and Test Type: 78F013 JUNIOR WHEELCHAIR

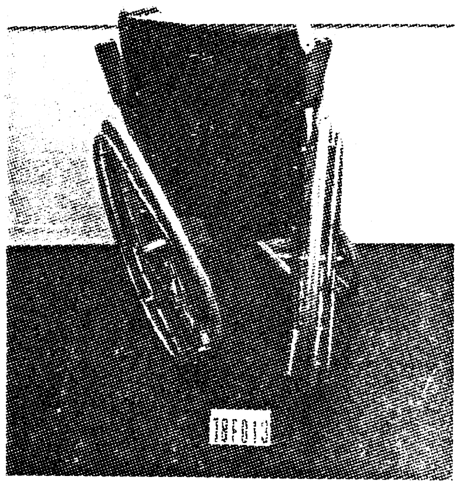
Description of Test Results:

Upon impact, the chair and dummy began pivoting together toward the direction of impact about the left rear wheel. Rotation of the chair was stopped by the tension in the chair belt while the dummy continued to rotate lifting up and into the left side of the chair, the dummy's head impacting the pseudo bus wall. The dummy then rotated back with the chair to end up near the original position. The maximum head excursion was about 80.3 centimeters (31.6 inches) in the direction of impact. Damage to the chair consisted of substantial bending of the left side steel tubing and wheel axle, and separation of the seat frame from the front vertical tubing (i.e., plastic guides popped out). During the impact, the left wheelchair foot-rest broke loose and flew off the sled. The peak belt tensions were 210 lbf. in the Saf-T-Straint and 1350 lbf. in the chair belt.

Photographs of Results:

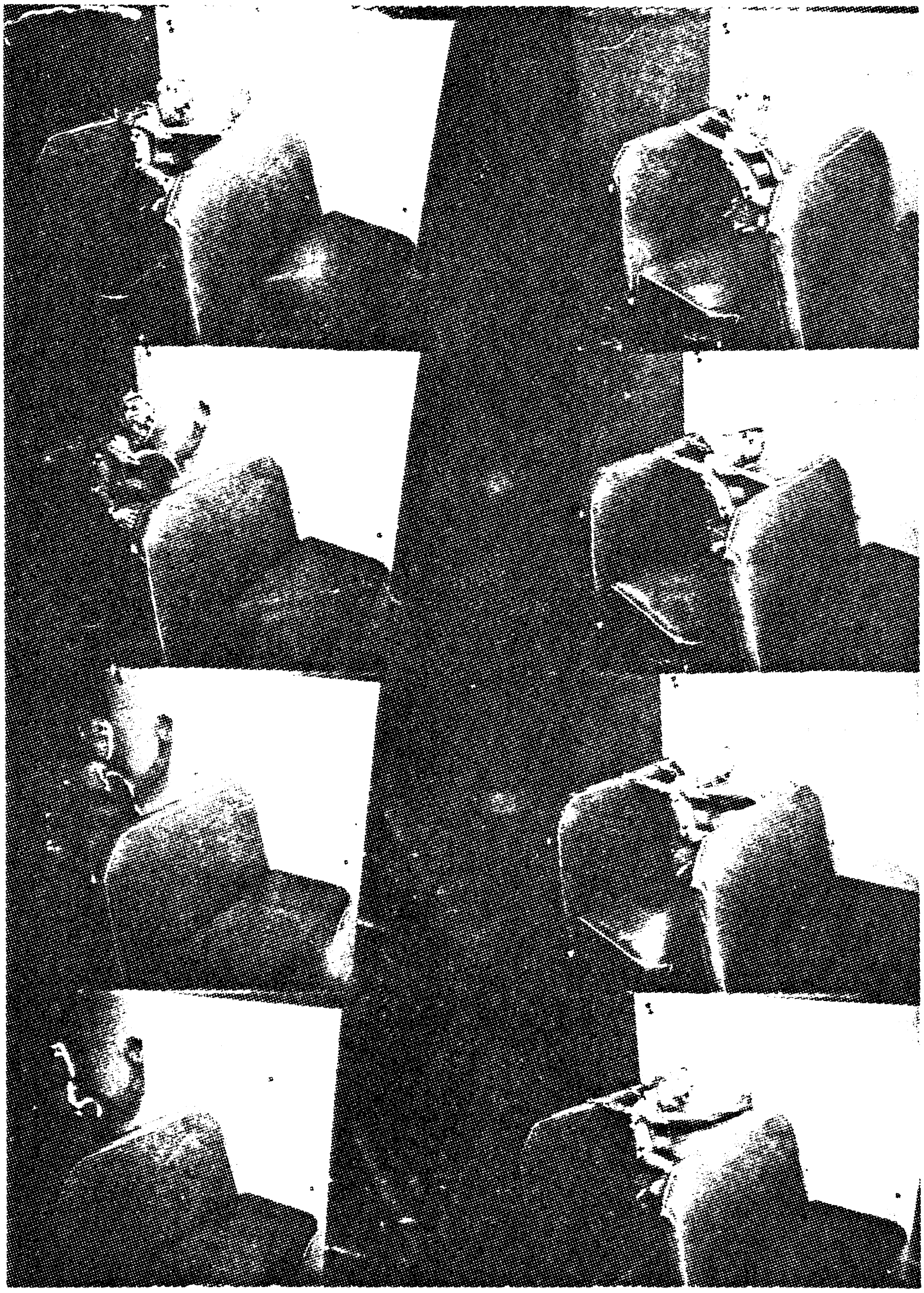






Test No. and Test Type: 78F014 BUS SEAT WITH RUPERT E-Z-ON SAFETY HARNESS

Graph Check Sequence Photograph:



5 1

6 2

7 3

8 4

78F014

Test No. and Test Type: 78F014 BUS SEAT WITH RUPERT E-Z-ON SAFETY HARNESS

Restraint: Rupert E-Z-On Safety Harness and restraint belts

Dummy: 6 year dummy (49 lbs.)

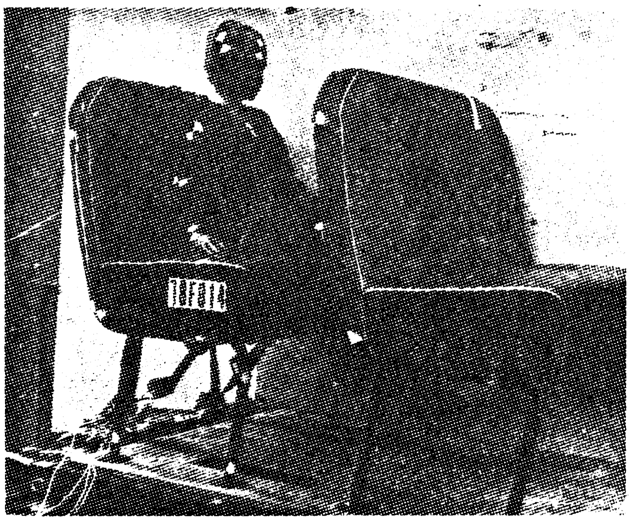
Orientation in Bus: Forward facing

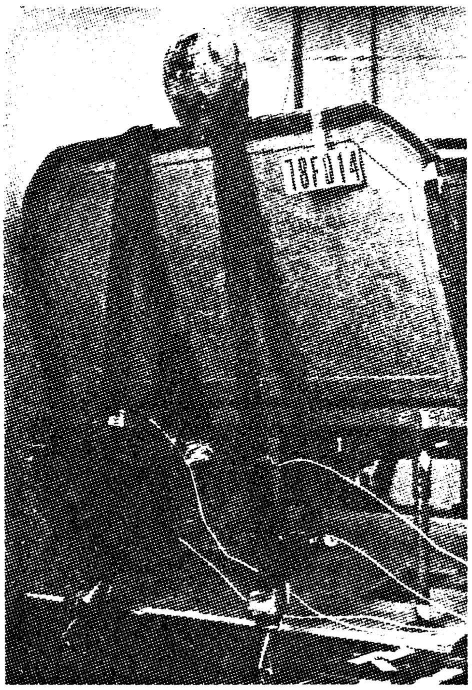
Impact Pulse: 20 m.p.h., 16 G, 33 degrees to bus front

Description of Test Set-Up:

Two school bus seats and pseudo bus wall and floor were bolted to the sled at an angle of 33 degrees to the side of the sled with the horizontal distance from the back of the rear seat to the back of the front seat equal to 27 inches. The Rupert eye bolts were bolted to the sled just behind the rear seat as per the Rupert instructions. The 6 year dummy wearing the Rupert harness with heavy duty "D" rings replacing the original rings was placed in the center of the seat and the belt clips attached to the "D" rings. Belts were adjusted to take up any slack. Four load cells were used to measure the belt tensions in the two upper belts and two lower belts near the belt anchor points.

Photographs of Set-Up:





Test No. and Test Type: 78F014 BUS SEAT WITH RUPERT E-Z-ON SAFETY HARNESS

Description of Test Results:

Upon impact the dummy torso moved toward the front of the sled but was quickly restrained by the tension in the four belts. The head flexed forward but did not come close to striking the front seat. The maximum head excursion was 47.5 centimeters (18.7 inches) in the direction of impact. Peak tensions in the belts were 240 and 290 lbf. in the left and right lower belts and 290 and 350 lbf. in the left and right upper belts respectively. At the end of the test the dummy was very near its starting position.

Photograph of Results:

Test No. and Test Type: 78F015 BUS SEAT WITH EASY WAY DUBL-LIFE SAVER

Restraint: Easy Way Dubl-Life Saver

Dummy: 6 year child (49 lbs.)

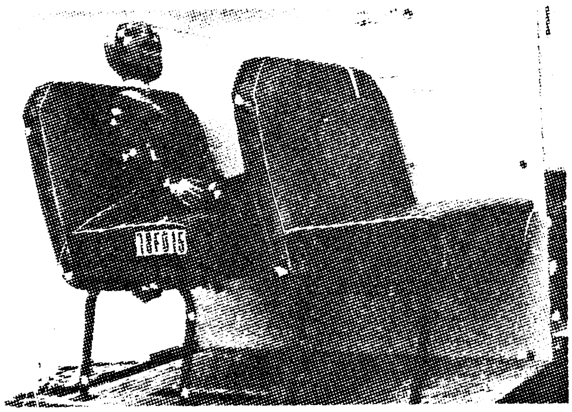
Orientation in Bus: Forward facing

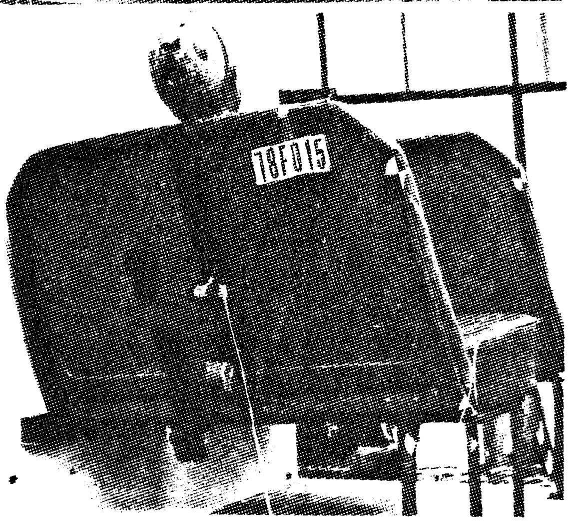
Impact Pulse: 20 m.p.h., 16 G, 33 degrees to bus front

Description of Test Set-Up:

The two bus seats and a pseudo bus wall and floor were bolted to the sled at an angle of 33 degrees to the side of the sled with the horizontal distance from the back of the rear seat to the back of the front seat equal to 27 inches. The Easy Way Dubl-Life Saver Vest was placed on the bus seat and the vertical belt was wrapped around the rear seat back by putting it through the seat behind the seat cushion. The dummy was placed on the seat and the padded vest placed around the lower torso and the belt buckled. Both belts were pulled as taught as manually possible. Two load cells were used to measure the tension in these belts.

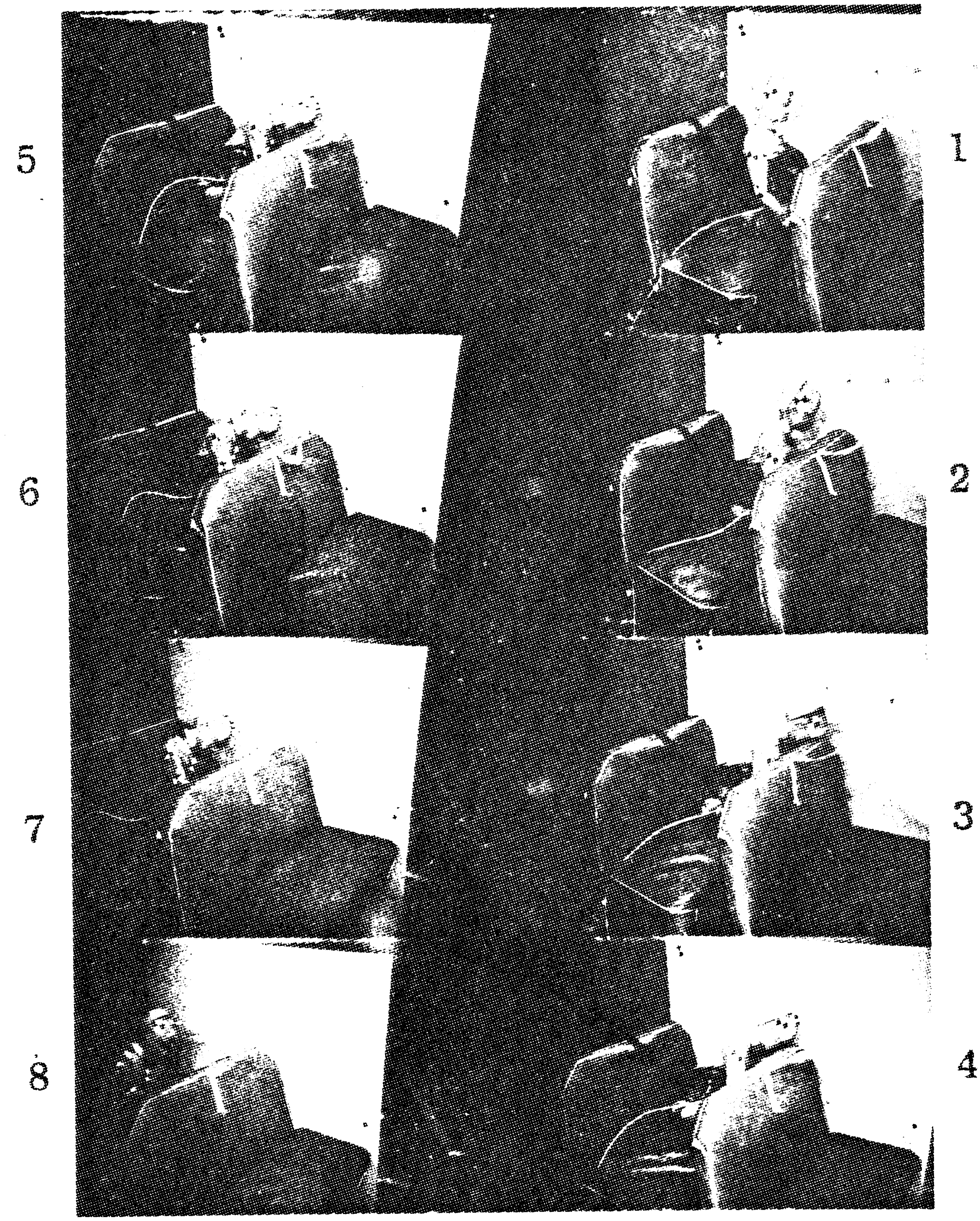
Photographs of Set-Up:





Test No. and Test Type: 78F015 BUS SEAT WITH EASY WAY DUBL-LIFE SAVER

Graph Check Sequence Photograph:



78F015

Test No. and Test Type: 78F015 BUS SEAT WITH EASY WAY DUBL-LIFE SAVER

Description of Test Results:

Upon impact, the dummy moved forward on the seat toward the front of the sled with very little torso or neck flexion and with little apparent restraint. Considerable slack was provided by both the belt pad folding in back and by the straightening of the belt as the seat cushion was pulled out. The torso moved about 37.3 centimeters (14.7 inches) before head rotation began. As the torso approached its maximum excursion the head began to flex forward and the forehead struck the top bar of the front seat back near the wall. The dummy then rebounded to near its original position at the end of the test. During the test, the rear seat back was bent forward to a nearly vertical position by the force in the restraining belt. The maximum head excursion was about 69.9 centimeters (27.5 inches) in the direction of impact. Peak belt loads were 260 lbf. in the belt around the dummy and 400 lbf. in the belt around the seat back.

Photograph of Results:

Test No. and Test Type: 78F016 BUS SEAT WITH ORTHO-KINETICS TRAVEL CHAIR

Restraint: Modified Rupert E-Z-On Harness with upper and lower safety belts

Dummy: 6 year old dummy (49 lbs.)

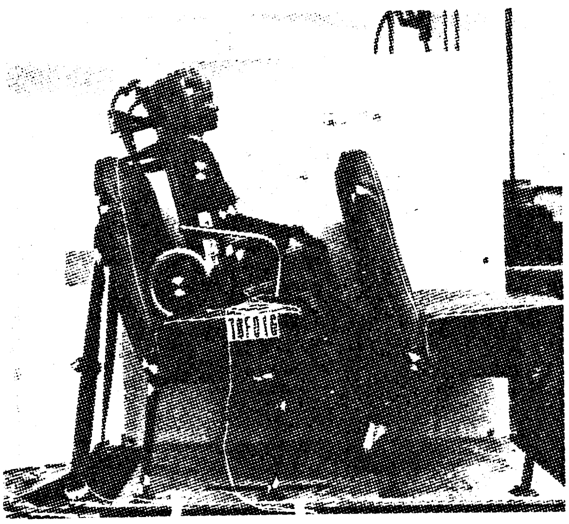
Orientation in Bus: Forward facing

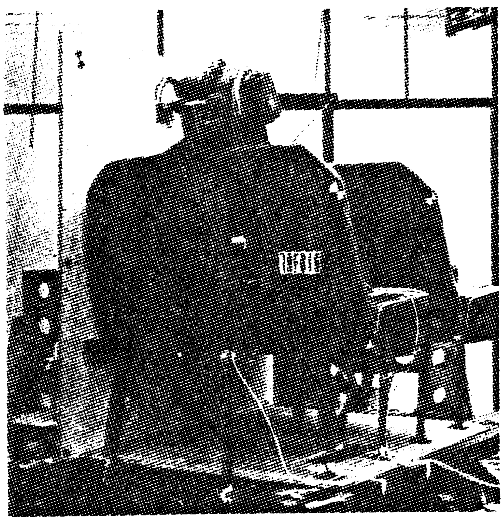
Impact Pulse: 20 m.p.h., 16 G, 33 degrees to bus front

Description of Test Set-Up:

Two bus seats and a pseudo bus wall and floor were bolted to the sled at 33 degrees to the side of the sled so that the horizontal distance from the back of the rear bus seat to the back of the front bus seat was 27 inches. A Rupert E-Z-On Harness was modified to have belt loops in place of the "D" rings and was put on the 6 year dummy. The Ortho-Kinetics travel chair with dummy was placed in position in the center of the rear bus seat and the chair straps and side supports adjusted for maximum restraint. A Rupert belt was anchored to the bus seat frame just behind and under the seat cushion and was inserted through the lower belt loops in the E-Z-On harness and buckled. A second Rupert belt was bolted to the sled behind the bus seat and placed through the upper loops in the E-Z-On harness behind the dummy's neck. Both belts were manually tightened but it was apparent that the upper loops in the harness were placed so as to allow considerable slack in the upper torso restraint. Two load cells were used to measure the tension in these upper and lower belts.

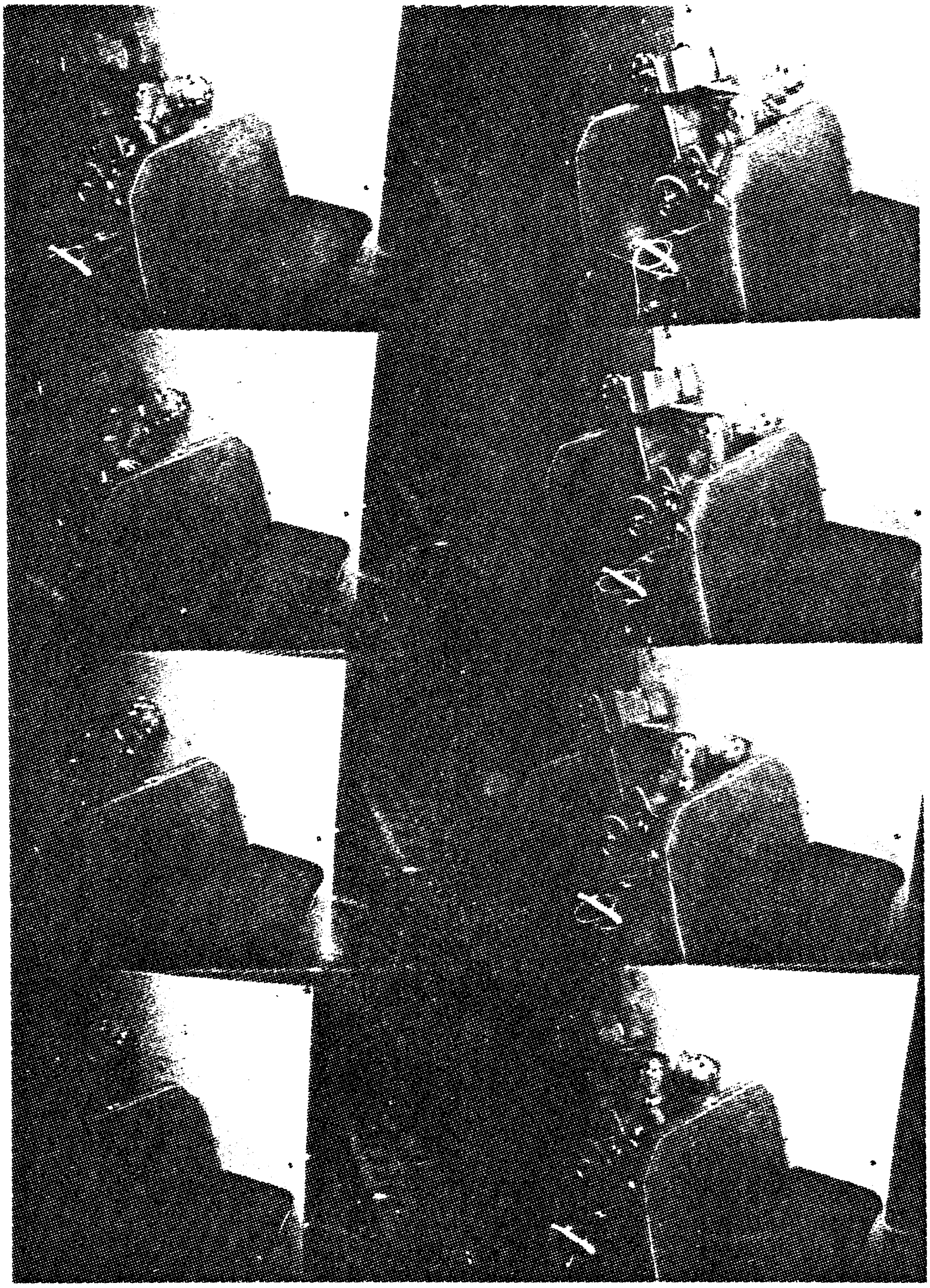
Photographs of Set-Up:





Test No. and Test Type: 78F016 BUS SEAT WITH ORTHO-KINETICS TRAVEL CHAIR

Graph Check Sequence Photograph:



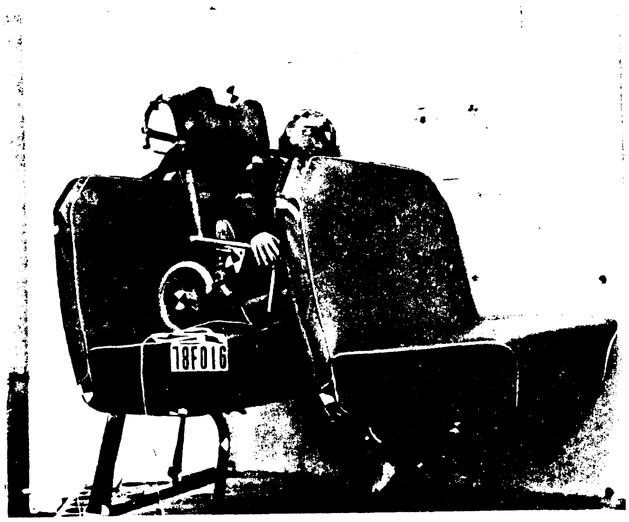
78F016

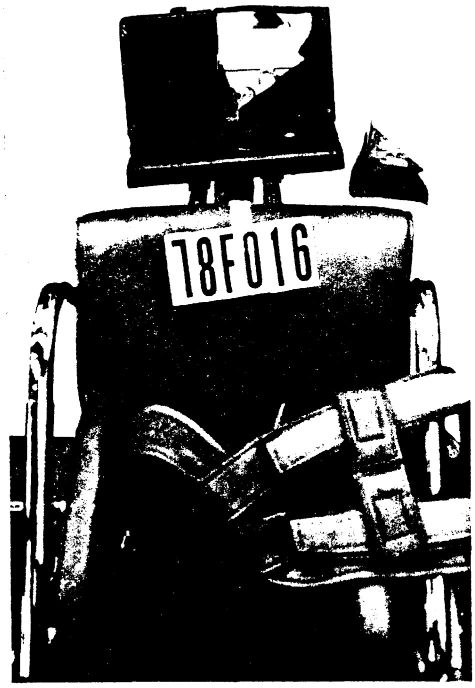
Test No. and Test Type: 78F016 BUS SEAT WITH ORTHO-KINETICS TRAVEL CHAIR

Description of Test Results:

Upon impact the chair was restrained close to the seat back but the torso and head of the dummy began to rotate forward. Eventually the upper torso motion was limited by the upper belt and the head flexed forward, the forehead striking the bar on the top of the front seat back near the wall. The head then continued on around rubbing against the wall and the dummy returned to a tilted seated position near its starting position. The maximum head excursion was about 53.1 centimeters (20.9 inches) in the direction of impact. Peak tensions in the belts were about 560 lbf. and 270 lbf. in the lap and top belts respectively. During the impact, both of the vinyl straps across the dummy's shoulders broke loose at the velcro fastening. Damage to the Ortho-Kinetics chair was minor with only slight bending of the rear wheel axles and breaking of the plastic foot rest.

Photographs of Results:





Test No. and Test Type: 78F017 BUS SEAT WITH FORD TOT GUARD

Restraint: Ford Tot Guard without booster seat and Rubert seat belt

Dummy: 5th percentile female (105 lbs.)

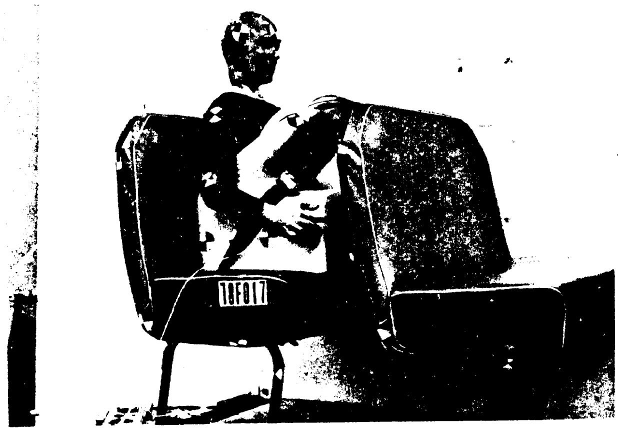
Orientation in Bus: Forward facing

Impact Pulse: 20 m.p.h., 16 G, 33 degrees to bus front

Description of Test Set-Up:

Two bus seats with a pseudo bus wall and floor were bolted to the sled at an angle of 33 degrees to the side of the sled and so that the horizontal distance from the back of the rear seat to the back of the front seat was 27 inches. A Rupert seat belt was bolted to the rear bus seat frame just below and behind the seat cushion and the 5th percentile female dummy was placed on the seat between the two belt anchor points. The Ford Tot Guard without booster seat was placed over the dummy's legs and the belt tightened in position. A load cell was used to measure the tension in the belt.

Photograph of Set-Up:



Test No. and Test Type: 78F017 BUS SEAT WITH FORD TOT GUARD

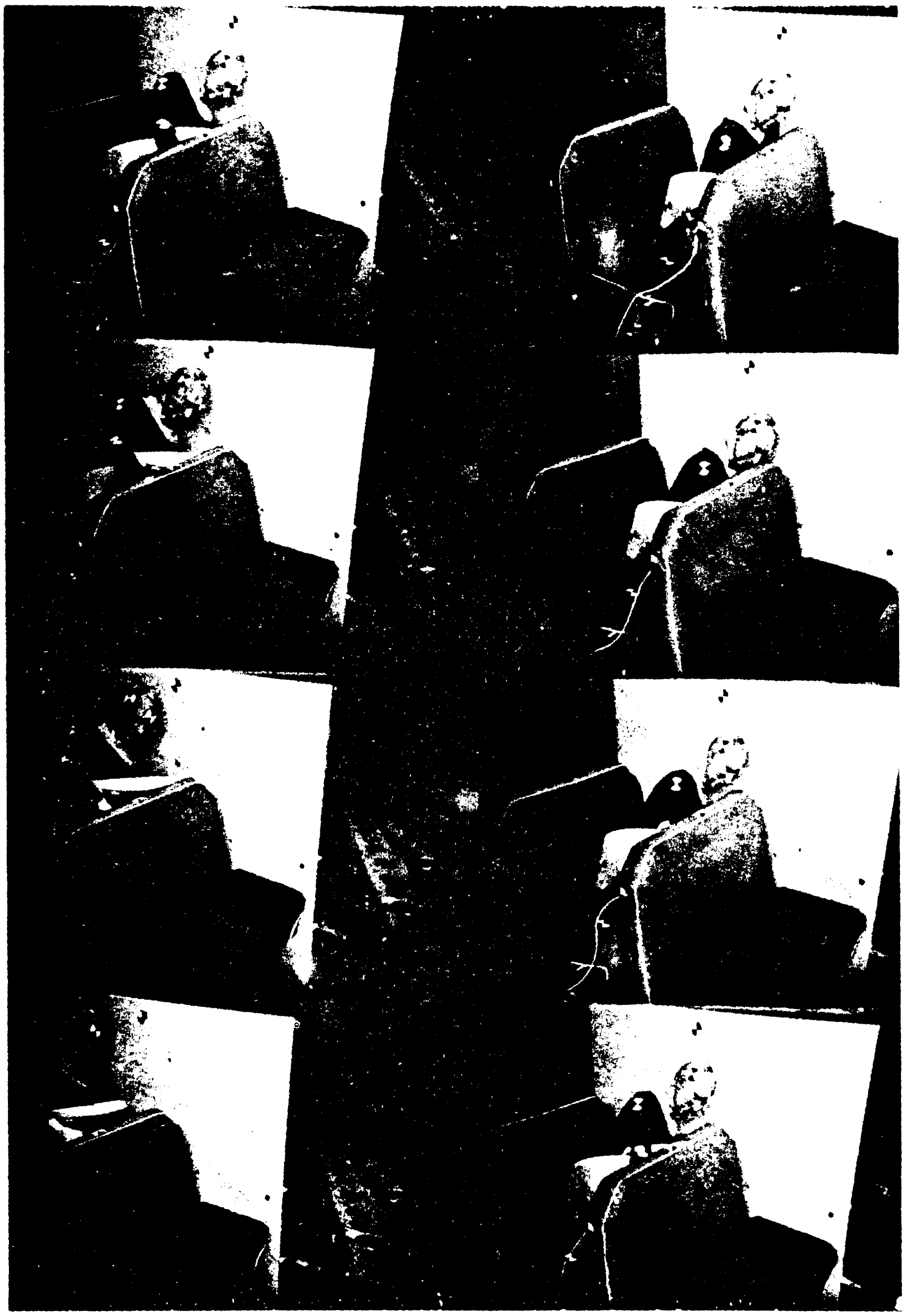
Graph Check Sequence Photograph:

5 1

6 2

7 3

8 4



78F017

Test No. and Test Type: 78F017 BUS SEAT WITH FORD TOT GUARD

Description of Test Results:

Upon impact, the dummy rotated forward in the Tot Guard pushing the Tot Guard toward the front of the sled and down on the seat cushion. The padded front of the Tot Guard struck into the front seat back below the top of the seat and the dummy's head rotated into the top bar of the seat back impacting just above the eyes near the wall. The dummy's head and torso then rebounded back up and returned to near the original position. The maximum head excursion was 65.3 centimeters (25.7 inches) in the direction of impact. The peak belt load was approximately 950 lbf.

Photograph of Results: